

# IIGCC

## Addressing methane emissions from fossil fuel operations

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# Glossary and acronyms

<b>CMM</b>	Coal mine methane
<b>EDF</b>	Environmental Defense Fund
<b>GEM</b>	Global Energy Monitor
<b>GFMR</b>	The World Bank's Global Flaring and Methane Reduction Partnership
<b>GHG</b>	Greenhouse gas
<b>GMP</b>	Global Methane Pledge
<b>GMT</b>	IEA's Global Methane Tracker
<b>IEA</b>	International Energy Agency
<b>IEA NZE</b>	IEA's Net Zero Emissions by 2050 scenario
<b>IGO</b>	Intergovernmental organisation
<b>IMEO</b>	UNEP's International Methane Emissions Observatory
<b>IOC</b>	International Oil Companies: publicly traded and broadly owned oil and gas corporations with multinational operations
<b>LDAR</b>	Leak detection and repair
<b>MRV</b>	Measurement, reporting and verification
<b>NOC</b>	National Oil Companies: majority state-owned oil and gas corporations
<b>NOJV</b>	Non-operated joint venture
<b>OGCI</b>	Oil and Gas Climate Initiative
<b>OGDC</b>	Oil and Gas Decarbonisation Charter
<b>OGMP 2.0</b>	The Oil and Gas Methane Partnership 2.0
<b>ppb</b>	Parts per billion (a measure of the concentration of a substance)
<b>SMP</b>	Steel Methane Programme
<b>UNEP</b>	United Nations Environment Programme
<b>UNFCCC</b>	United Nations Framework Convention on Climate Change
<b>US IRA</b>	US Inflation Reduction Act
<b>VAM</b>	Ventilation air methane
<b>WEO</b>	IEA's World Energy Outlook
<b>ZRF</b>	The World Bank's Zero Routine Flaring (ZRF) Initiative



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# Investor Foreword

Methane emissions present a major risk to companies in the oil and gas and coal industries, and to their investors. Unabated methane is exacerbating global warming, and compounding physical risks and transition risks to the global economy. There is no version of a credible energy transition plan that does not drastically reduce methane emissions from fossil fuel operations by 2030.

Methane emerged as a key topic at COP28, and the past 12 months have seen a proliferation of methane commitments from nations and corporates alike. New regulations that will increase the cost of emitting have been outlined in both producer and importer jurisdictions, and new technologies are revolutionising our ability to independently examine corporate methane emissions.

This progress represents an opportunity for companies to demonstrate leadership, prepare for potential regulatory change, and maintain their social license to operate amid growing scrutiny on the fossil fuel sector. But it also presents risks given many companies are in the dark as to the true nature of their methane emissions, relying upon elementary estimation methods.

For us as investors and engagers, methane engagement raises the challenge of holding multiple objectives in mind at once. Companies need to better integrate direct measurement with verification in order to understand their emissions and to comply with tightening regulations, but they also need to take proven abatement actions now that are independent of their measurement baseline. Similarly, taking a systematic risk perspective requires us to ensure that a focus on methane emissions does not obscure the urgent need for carbon dioxide emissions reductions.

This paper aims to help investors to deepen their engagements on this critical topic. It provides a comprehensive technical background and synthesises key messages to equip engagers with the understanding they need. The engagement frameworks provide an ambitious but credible basis by which to undertake and monitor company engagement. Linkages to the Net Zero Standards for Oil and Gas and Diversified Mining provide helpful data and harmonisation.

Not only will it help to upskill investors for their existing engagements, it can also support them to open new engagement avenues on this topic. This guidance is useful for investors thinking of engaging national oil companies, banks, sovereigns, midstream companies, and downstream entities such as utilities, airlines, cement or steel companies.

The need for action on methane is clear: cutting emissions this decade can significantly reduce the rate of near-term warming and ultimately the level of peak warming reached. There is both investment and climate opportunity in swiftly tackling this challenge.

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# Executive Summary

## Methane emissions represent investment risk

### **Rapid cuts in methane emissions are needed to keep climate goals in sight.**

The fossil fuel sector is responsible for a significant fraction (c. 37%) of anthropogenic methane emissions and offers the greatest abatement potential. In the IEA's Net Zero Emissions by 2050 scenario (NZE), methane emissions from fossil fuels decline by 75% by 2030, relative to 2022.

**This raises the prospect of tightening legislation and rising costs of emitting methane,** both in producer and importer jurisdictions. The past year alone has seen the introduction of an emissions tax on oil and gas methane emissions in the US, and new methane regulation in the EU which targets fossil fuel methane emissions both within and beyond its borders.

**While the picture is variable, most producers still have a weak understanding of their methane emissions,** relying on factor-based estimates rather than incorporating direct measurement. Not only does this inhibit their ability to design optimal, cost-effective abatement strategies, it leaves them exposed to reputational and legal risks associated with inaccurate reporting. These risks are accentuated by the revolution in independent measurement capacity, particularly from satellite instruments such as the recently launched MethaneSAT. The financial sector, regulators and civil society will increasingly have access to the data needed to challenge inaccurate reporting.

**These risks extend beyond operators of fossil fuel production assets.** They will also materialise through JV relationships and non-operated assets, and a related set of risks and opportunities exist for companies downstream in value chains. For instance, coal mine methane emissions may add as much as 27% to the CO<sub>2</sub>e footprint of steelmaking<sup>1</sup>. There is an opportunity for the steel sector to cut its upstream scope 3 emissions dramatically at relatively low cost through partnership with metallurgical coal miners on abatement efforts. Similar opportunities exist for other hard-to-abate sectors reliant on oil or its derivatives, gas, or coal.

**This paper aims to support investor engagement on methane.** It synthesises the contextual information needed to support investors to deepen engagements and hone engagement asks. It provides guidance on how investors may wish to consider tackling idiosyncratic and systemic methane-related risks across portfolios, with notes on engaging with national oil companies (NOCs), banks, sovereigns, and value chain companies.

<sup>1</sup> Figure from Ember [269], CO<sub>2</sub>e calculated using methane's 20-yr GWP



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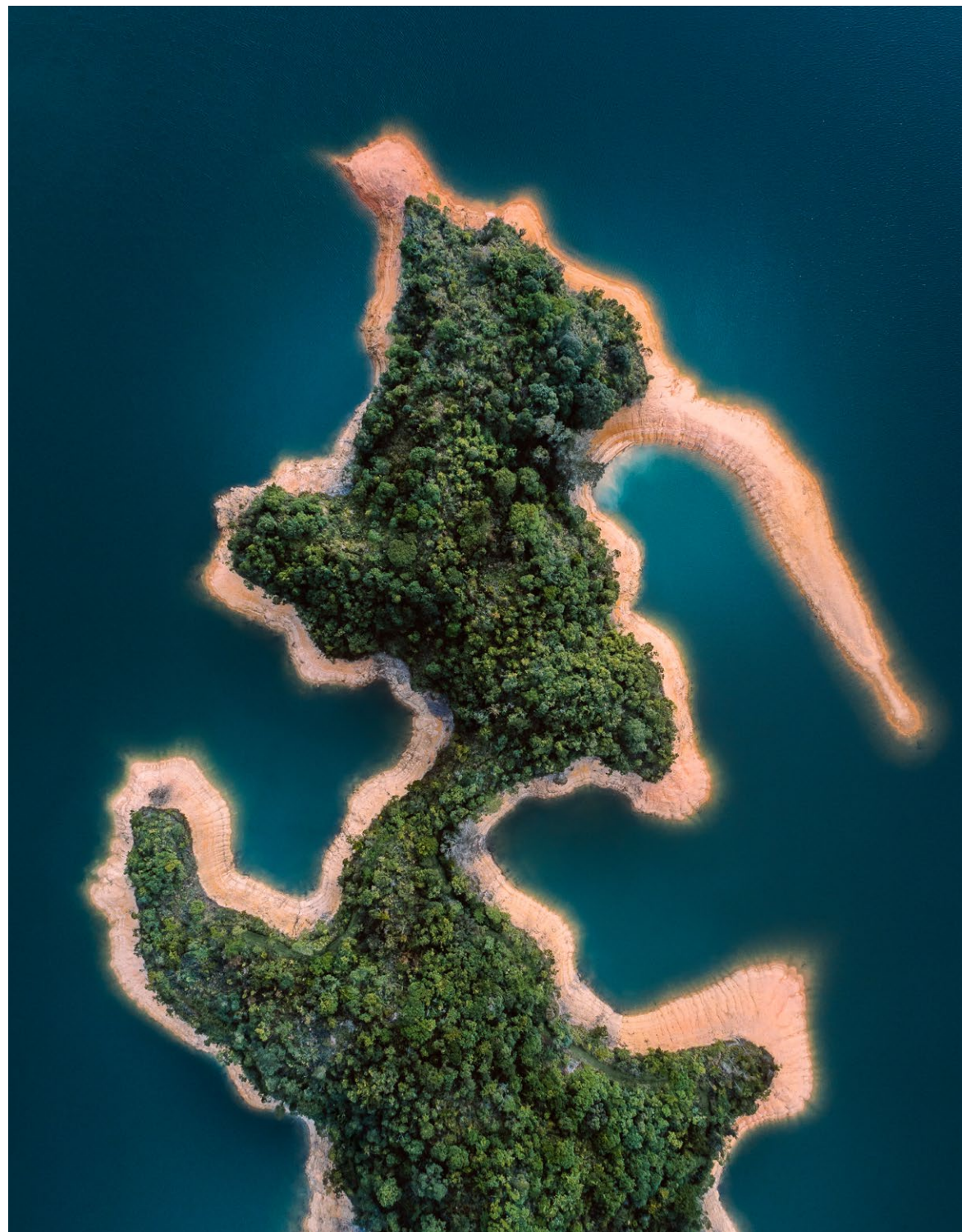


## Momentum on methane is building.

Methane has become a focus of the COP process, with COP28 yielding a number of steps forwards. The Oil and Gas Decarbonisation Charter (OGDC) was established, with 52 companies aiming to achieve near-zero upstream methane emissions by 2030. The first Global Stocktake recognised the need to substantially reduce methane emissions by 2030. More countries joined the Global Methane Pledge, and new financing was announced for methane abatement. In addition, the UNEP's Oil and Gas Methane Partnership (OGMP) 2.0 is working with a growing number of companies to report asset-level methane emissions and improve measurement and abatement practices. Meanwhile, UNEP has a similar initiative in development for metallurgical coal with the Steel Methane Programme (SMP). The importance of methane in the transition is also highlighted by the IEA, which cites methane reductions as one of its four 2030 decarbonisation pillars, and provides pertinent analysis in annual Global Methane Tracker reports.

## Action on methane and carbon dioxide must go together.

In an environment where methane momentum is growing, but progress on securing declining production and demand for fossil fuels is lagging behind global climate ambitions, investors and governments would be wise to connect these challenges rather than focus on methane at the expense of carbon dioxide. Methane – though more potent as a greenhouse gas – has a lifetime of about a decade, whereas much of the carbon dioxide we emit today will remain in the atmosphere for millennia. Delaying action on carbon dioxide will have near permanent consequences for the climate, and carbon dioxide emissions from use of fossil fuels remain the largest long-term source of climate-related risk in investor portfolios. But the two gases can and must be tackled together. Indeed, declining production is an obvious way to reduce methane emissions and will be critical in meeting the IEA's key pillar for meeting the Paris Agreement goals of 75% fossil methane emissions reduction by 2030.



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# Engagement frameworks for addressing methane emissions

**We have developed engagement frameworks for addressing methane emissions from oil and gas and coal operations.** These frameworks flow from the content of this paper, which in turn synthesises literature from expert organisations, practitioners and academia. The frameworks are designed to support investor engagement on methane emissions.

The frameworks begin with high-quality measurement, reporting and verification (MRV) as a foundational feature. However, this is not to suggest that this must be exhaustively completed before action is taken. Rather, the framing is that companies should take action *while* they build their understanding of their emissions and *before* they have a perfect measurement baseline.

High quality measurement-based reporting involves the integration and reconciliation of both source-level and site-level measurements, the use of multiple measurement systems, and sufficient density of sampling in time and space. The OGMP 2.0 and forthcoming SMP set out *gold standard* pathways towards high-quality MRV.

Properly characterising methane emissions and their variability across assets and over time will enable more efficient and cost-effective abatement efforts. It can also help companies prepare for advancing stakeholder expectations and regulatory requirements.

Setting methane emission targets is an important step for a company to take and can help focus resource and effort on abatement. However, targets must be coupled with ever-improving measurement efforts in order to provide assurance to their credibility. Very few companies, if any, currently have comprehensive high quality disclosure practices; performance against targets should be treated with some scepticism until such reporting is in place.

Beyond their own operational efforts, companies can contribute to wider progress through active membership of the OGMP 2.0 or SMP, and through knowledge sharing via these platforms. Companies can also engage with their partners in non-operated joint ventures or assets to improve standards of methane reporting and mitigation. This is essential for comprehensively addressing the methane-related risks that a company is exposed to.

As companies make progress, investors will expect to see this transparently and accurately reported. As MRV progresses over time, reported methane emissions are likely to change by virtue of changes in methodology. Companies can offer transparency to investors by attempting to re-baseline emissions on the basis of these methodological changes and improved understanding of methane sources. This is especially pertinent for companies whose methane emissions target is stated in terms of a percentage reduction in emissions against a baseline. For these entities, re-baselining can help remove perverse incentives against expanding MRV.

Investors can also address methane-related risks and opportunities by engaging a broader ecosystem of actors, including value chains, capital providers and governments. We include high level guidance on engaging the ecosystem underneath the sectoral engagement frameworks.

In [Section 7](#), we discuss how the engagement frameworks can leverage the assessments of companies against the Net Zero Standards for Oil and Gas and Diversified Mining.



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# Oil and gas methane engagement framework

## Measurement, reporting and verification

### Does the company provide comprehensive methane disclosures?

- In both units of absolute emissions (tCH<sub>4</sub>) and methane intensity (tCH<sub>4</sub>/GJ)?
- Disaggregated by business segment, basin, product/throughput type?
- Using the same boundary for numerator and denominator in intensity figures?
- With full disclosure of the calculation methodology, including measurement units and conversion factors used?
- Providing the % breakdown of emissions sources by type (non-routine flaring, routine flaring, venting, fugitive) across all segments, including non-operated and abandoned/unused assets, with clear definitions of each source?

### Does the company have high-quality MRV in place or a commitment to do so?

- Using multiple, complementary monitoring systems?
- Across all segments, including non-operated and abandoned/unused assets?
- Providing the % breakdown of emissions/production covered by different measurement technologies, including details on frequency, duration, detection thresholds, and quantification uncertainty?
- Achieving OGMP 2.0 Gold Standard pathway, with published target dates to reach OGMP 2.0 Level 5 reporting for all operated and non-operated assets?
- Providing the % breakdown of emissions/production covered by different OGMP 2.0 reporting levels?
- With external verification? If so, data inspections or independent measurement?

## Targets

### Has the company set a sufficiently ambitious target to reduce methane emissions, by 2030 at the latest?

- Covering all business segments and assets, or with a timeline to cover all?
- In terms of both absolute and intensity, using methodology described above?
- By business segment, basin, product?
- If indexed, providing a base year and value?
- Specifying role of production (incl. field depletion), intensity declines and divestments/acquisitions?
- Aligned with IEA NZE benchmark? (See [Section 5.5](#))

## Strategy

### Has the company set out a comprehensive, effective and adequately resourced strategy for methane mitigation?

- With a comprehensive LDAR programme covering all segments and assets, including abandoned/inactive wells?
- With zero routine flaring and minimising non-routine flaring?
- With systems to recover associated/excess gas to reduce venting and flaring, and new production contingent on adequate gas takeaway capacity?
- With steps to improve flare performance, including zero tolerance for unlit flares?
- With plans to replace/retrofit/adapt high-emitting equipment and processes?
- Prioritising heaviest-emitting sources?
- Stating current- and forward-looking capex and opex figures? Including plugging/decommissioning costs and liability?
- Providing timeline and milestones?
- Linking milestones to expected emissions reductions?
- Referencing a methane marginal abatement cost curve (MACC)?

## Industry engagement

### Has the company joined major initiatives on methane?

- OGMP 2.0?
- OGDC?
- GFMR?
- MGP?

### Has the company engaged its NOAs and NOJVs on methane?

- On MRV practices?
- Frequent sharing of emissions data?
- Alignment with its strategy and targets?
- In contract terms?
- Sharing best practice?
- Providing technical or financial support?

## Progress

### Does the company disclose progress against its targets?

- Emissions performance consistent with the form of the targets?
- On track to achieve or exceed targets?
- Is there critical evaluation of the reliability of stated performance against intensity targets?
- Is any re-baselining of emissions and targets transparently stated and justified, with clear disclosure of methodology changes?
- Separating out the role of production (including field depletion), intensity declines and divestments/acquisitions?

### Does the company disclose progress against its strategy?

- Providing details on milestones achieved, e.g. % of relevant equipment replaced/retrofitted and % of identified leaks repaired
- Stating capital spend on methane abatement in the last reporting year



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# Coal methane engagement framework

## Measurement, reporting and verification

### Does the company provide comprehensive methane disclosures?

- In both units of absolute emissions (tCH<sub>4</sub>) and methane intensity (tCH<sub>4</sub>/kt)?
- On a mine-by-mine basis?
- Setting out the methodology for methane emissions reporting by mine-type (or individual mine)?
- Evaluating the reliability of the methodology and stating the rationale for using it?
- Additionally reporting coal mine methane emissions from coal that the company trades?

### Does the company have high-quality MRV in place or a commitment to do so?

- Integrating direct measurement? Providing details on a mine-by-mine basis?
- Using multiple, complementary monitoring systems?
- With details on sampling frequency, duration, detection thresholds and quantification uncertainty?
- Reconciling source-level and facility-level observations?
- Covering all coal mines, including non-operated assets?
- With external verification? If so, data inspections or independent measurement?
- Including continued MRV after mine closures?

## Targets

### Has the company set sufficiently ambitious targets to reduce methane emissions?

- Has the company set a specific target to reduce its coal mine methane emissions?

- Covering all assets, including non-operated assets, or a timeline to do so?
- In terms of both absolute emissions and methane intensity?
- If indexed to a base year, providing base year value?
- Aligned with the IEA NZE? (see [Section 6.5](#))
- With an interim milestone?
- With separate targets on metallurgical and thermal coal assets, or quantifying respective contributions to an overall target?
- Quantifying contributions to an absolute reduction target from production and intensity declines?
- Coupled with a commitment to achieve high-quality MRV across all assets?

## Strategy

### Has the company set out a comprehensive, effective, and adequately resourced strategy for methane mitigation?

- Including degasification and capture/ utilisation prior to and during excavation? [Underground and surface mines]
- Including ventilation air methane destruction or utilisation? If so, which technologies: RTO, catalytic combustion, concentration, or other? [Underground mines]
- Including post-closure abatement measures? [Underground mines]
- Including targeting low-methane coal seams and minimising disturbance?
- Prioritising heaviest emitting mines?
- Setting out technologies involved and their maturity?
- Stating current and forward-looking opex and capex required?
- Providing timeline and milestones for delivery of strategy?
- Linking milestones to expected emissions reductions?

- Referencing a methane marginal abatement cost curve (MACC)?

## Industry engagement

### Has the company joined major initiatives on methane?

- Actively engaging with the Steel Methane Programme (SMP)? Once launched, member of SMP?

### Has the company engaged its partners in JVs and non-operated assets on methane?

- On MRV practices?
- Requiring frequent sharing of emissions data?
- Seeking alignment with the company's methane strategy and targets?
- In contract terms?
- Sharing best practices?
- Providing technical or financial support?

### Similarly, has the company engaged producers providing coal that the company trades?

- On MRV, strategy, and targets?

## Progress

### Does the company disclose progress against emissions targets?

- Consistent with the form of the targets?
- With progress on track to achieve targets?
- With critical evaluation of the reliability of stated performance against targets?
- With any re-baselining of emissions transparently stated and justified?
- Separating out the role of production and intensity changes in overall methane reductions?

### Does the company disclose progress against its strategy?

- Providing details of milestones achieved
- Stating capital spend on methane abatement in the last reporting year



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# Engaging the ecosystem

Investors can also engage a range of other actors to address risks arising from fossil methane in their portfolios. These include:

## Banks

- Are banks engaging producers on methane emissions through client relationships, across all of their products and services?
- Are banks requesting high-quality methane disclosures and scrutinising performance as part of due diligence questionnaires?
- Are they providing financing for methane solutions?
- Do banks have conditions on corporate-level or project-level financing, or underwriting, related to methane management?

## Governments

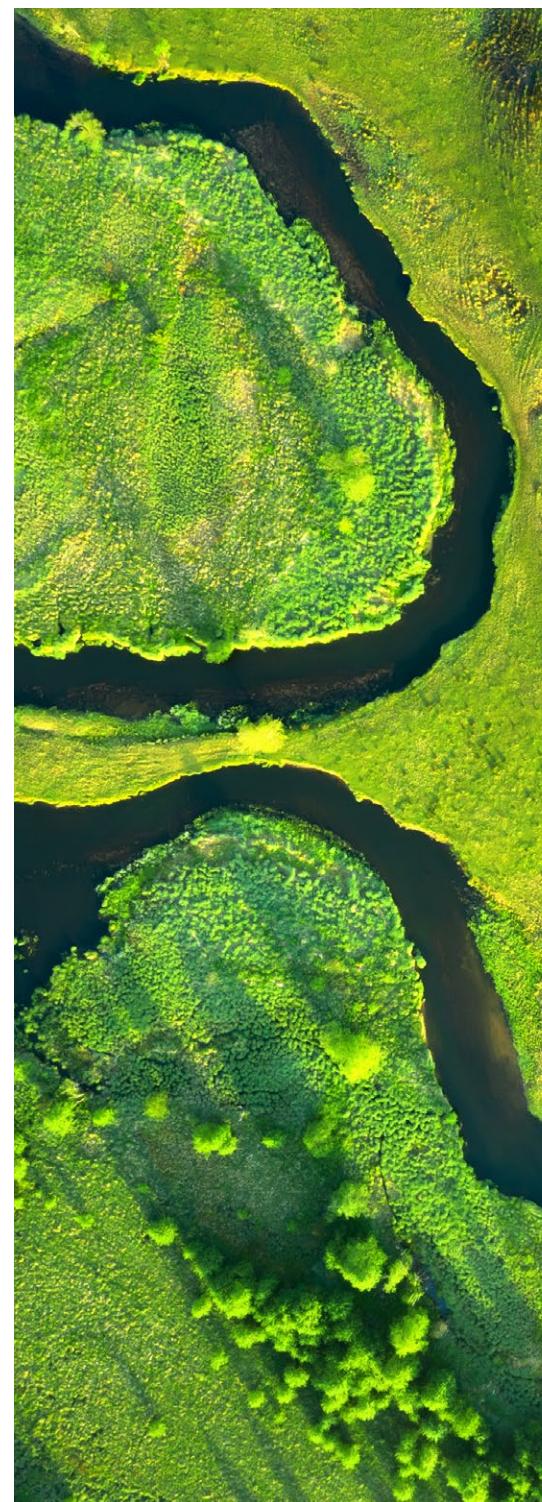
Governments can be engaged either through sovereign debt relationships or policy engagement. Investors may wish to ask if the government is:

- Improving the standards of mandatory emissions reporting in producing nations?
- Tightening requirements for mandatory abatement actions in producing nations?
- Increasing financial incentives for abatement action in producing nations (e.g. through cost of carbon or methane fees)?
- Putting in place methane MRV and abatement requirements on imported fossil fuels?

## Value chains

Corporates across value chains can be engaged on their exposure to fossil fuel methane emissions and potential role in abatement. Relevant corporates involved in oil and gas value chains include **service providers** to upstream operators, **midstream partners** involved in oil and gas gathering, boosting, processing, transmission and storage, **utilities** supplying gas-fired power and residential gas, **airlines** using aviation fuel, **shipping** companies using bunker fuels, **chemical and petrochemical** companies using oil and/or gas as feedstock, and **heavy industries** relying on oil and gas for high-heat processes. Relevant entities for coal mine methane include **utilities companies** with coal-fired power stations, **steelmakers** with blast furnaces, and **cement makers** using coal in kilns.

- Is the company seeking high-quality methane data from their supply chain as part of procurement? And actively requesting improvement e.g. by encouraging their partners to join OGMP 2.0?
- Do they require a certain standard of methane management from suppliers? How is this implemented?
- Do they provide upstream methane emissions disclosures in their own reporting, as part of their scope 3 disclosures? Do they state this in terms of tCH<sub>4</sub> and a relevant intensity figure?
- Are they engaging their suppliers on methane emissions reporting and abatement?
- Are they providing financial or technical support on abatement projects?
- Are steelmakers engaging with, or members of, the SMP?



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# Scope and structure of this paper

This paper deals with methane emissions from fossil fuel operations (or ‘fossil methane’). Both investor-owned and state-owned companies<sup>2</sup> are considered. While institutional investors are more likely to be able to engage directly with the former, we also discuss potential levers for engaging state-owned enterprises, which produce more than half of the world’s fossil fuels [1; 2] and very likely the majority of methane emissions [3].

In terms of corporate scope by sector and segment, the focus is on companies operating in upstream and midstream oil and gas, and coal producers. However, the guidance is also relevant for engaging with downstream entities, financial services providers and sovereigns.

A broad introduction to methane places fossil methane in the context of overall anthropogenic emissions. This is followed by a deep dive into the climate science behind why methane is such a significant greenhouse gas and how it differs from carbon dioxide. The intent of this section is to help investors discuss the methane challenge in the same confidence they can with carbon dioxide and to avoid prevalent misconceptions.

<sup>2</sup> Here investor-owned companies are defined as broadly owned, publicly listed entities that operate in the private sector. State-owned companies are majority owned by governments and operate within the constraints of a government mandate, however they may also be publicly listed and part-owned by investors, and may also have an international presence. Usually considered public sector companies, they operate in a commercial environment in competition with private sector companies.

An overview of reporting and measurement techniques explores the common methods of constructing methane inventories, the difference between bottom-up and top-down approaches, and what is required for high quality direct measurement. This is followed by a review of policy context, in which we examine both the global picture of methane policy coverage, by type, as well as some of the more significant recent developments in detail. This section aims to equip investors with knowledge of advancing regulations and related regulatory risks to companies.

The paper then provides sectoral deep dives into methane abatement in oil and gas and coal mining, respectively. These sections begin by examining the origin of methane emissions, both by country, type of company, and where and how they arise within operations. This is followed by an overview of the status of methane emissions reporting within that sector, an exploration of technical abatement solutions and a discussion on assessing the credibility and ambition of methane targets in these sectors.

The paper concludes by linking the engagement frameworks to the metrics of the Net Zero Standards on Oil and Gas and Diversified Mining. Public assessments against these standards can be used in the frameworks.



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# Key points to support engagement on methane emissions

Key points for investors to consider are drawn out throughout the paper and are consolidated below. Evidence, references and explanation supporting each point can be found in the relevant section of the paper.

## Climate Science

- 1. The temperature of peak warming will be determined by a combination of factors:** a) cumulative emissions of CO<sub>2</sub> (which is long-lived) up to that point, and b) annual emissions rates of methane (and other short-lived climate forcers) at that time and in the decade or so prior.
- 2. In IPCC 1.5°C scenarios with low/no overshoot, total anthropogenic methane emissions fall by 34% by 2030 relative to 2019.** Emissions reductions can drive a reversal of some of the warming experienced from methane to date, and thus help slow the rate of overall warming.
- 3. GHG metrics like CO<sub>2</sub>e that aggregate CO<sub>2</sub> and CH<sub>4</sub> can be ambiguous with respect to climate outcomes, and obscure methane emitters within portfolios.** For this reason, it is best to keep methane and carbon dioxide separate in reporting and targets.
- 4. Deep methane emissions cuts are essential for maximising the chance of meeting Paris climate goals and limiting near-term warming.** However, they must not come *at the expense of* efforts to mitigate CO<sub>2</sub> emissions. CO<sub>2</sub> emissions lock the world into higher temperatures in the long term.

## Reporting and measurement

- 5. National inventories compiled and submitted to the UNFCCC likely underestimate methane emissions by a significant margin.** Insofar as these inventories reflect underlying corporate reporting, they are also indicative of the scale of likely understatement in company reports.
- 6. Joining OGMP 2.0, or engaging with the developing SMP, as relevant, is an excellent early objective for a company engagement.** These IMEO initiatives provide platforms for asset-level methane disclosure and best-practice sharing among fossil fuel producers, with a clear goal to progress to direct measurement-based reporting.
- 7. Both bottom-up and top-down measurements are needed to build reliable estimates of corporate methane emissions.** With a host of measurement technologies available, each with its own strengths and weaknesses, a sophisticated approach employs multiple systems simultaneously, and involves sufficient sampling in space and time.
- 8. Independent measurements will increasingly expose corporate underreporting and poor practice with respect to methane emissions.** New satellite instruments coming online in the next few years will support efforts to hold companies to account and alert them to large emission sources.



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## Global policy context

9. **Methane regulations for the fossil fuel industry are rapidly gaining momentum and will need to tighten further over the next decade to align with GMP commitments.** This could pose significant transition risks for companies without robust methane reduction and monitoring plans.
10. **Governments are employing various approaches to reduce fossil methane, including measures to improve emissions data, mandate specific abatement measures, set performance-based targets or put a price on emissions.** Maintaining competitiveness will require companies to adopt best practices with urgency and transparently communicate such efforts to investors.
11. **Regulatory effort to tackle fossil methane is most effective when backed by a robust data infrastructure and verification system. However, imperfect data should not delay action.** Proven methane abatement measures are available and should be implemented immediately, even as efforts to improve emissions data continue.

## Tackling methane emissions from oil and gas

12. **Global oil and gas production and methane emissions are dominated by NOCs.** Although engagement with these companies is less straightforward than with IOCs, a range of levers exist for investors, including: engagement via IOCs and upstream service providers, banks, importing country governments, and direct engagements with NOCs and NOC governments.
13. **Globally, methane emissions from oil and gas are concentrated in upstream operations and in natural gas transmission and distribution networks.** However, depending on a company's asset locations and operational context, the nature of emission sources under their scope (and suitable mitigation strategies) will vary.
14. **Until companies establish credible, measurement-based reporting methods (i.e. OGMP 2.0 level 5) across operated and non-operated assets, emission disclosures and reported performance against targets should be treated with scepticism.** This is perhaps most important with respect to intensity targets, which can obscure the effects of production changes.
15. **To enable fairer and more accurate comparisons, companies could disclose both aggregated (corporate-level) and disaggregated (segment-, basin- and product-level) methane emissions intensities, aligning with financial reporting.** This should be accompanied by full transparency on the calculation method, including the numerator, denominator, measurement units, and conversion factors used.

16. **A comprehensive methane mitigation plan in oil and gas tackles vented, flared, and fugitive emissions, clearly differentiating between them.** It commits to zero-routine flaring and minimising routine flaring, incorporates advanced LDAR programmes covering all assets, and continuously improves process and equipment efficiency.
17. **Cost-effective methane abatement depends on factors like regulatory and financial capacity, infrastructure development, global market integration and local know-how.** This highlights the need for focused project support and funding in low- and lower-middle income economies, from both private and public entities.
18. **Oil and gas intensity targets should be stated with a consistent boundary for numerator and denominator, to enable fair comparisons across companies and be physically most meaningful.** While the OGCI and OGDC target of "near-zero" or below 0.2% methane intensity by 2030 uses inconsistent calculation boundaries, it can nonetheless be considered aligned with methane intensity in the NZE, providing it is simultaneously supported by a progression towards high-quality measurement and reporting (OGMP 2.0 level 5).
19. **In the NZE, methane emissions decline by 81% and 61% by 2030 in oil and gas, respectively, against 2022 levels.** Companies stating their methane targets in terms of indexed % reductions can be compared against these benchmarks. Investors should be cognisant of the different starting points of companies, and the possible need for re-baselining of emissions as measurement and reporting practices improve.



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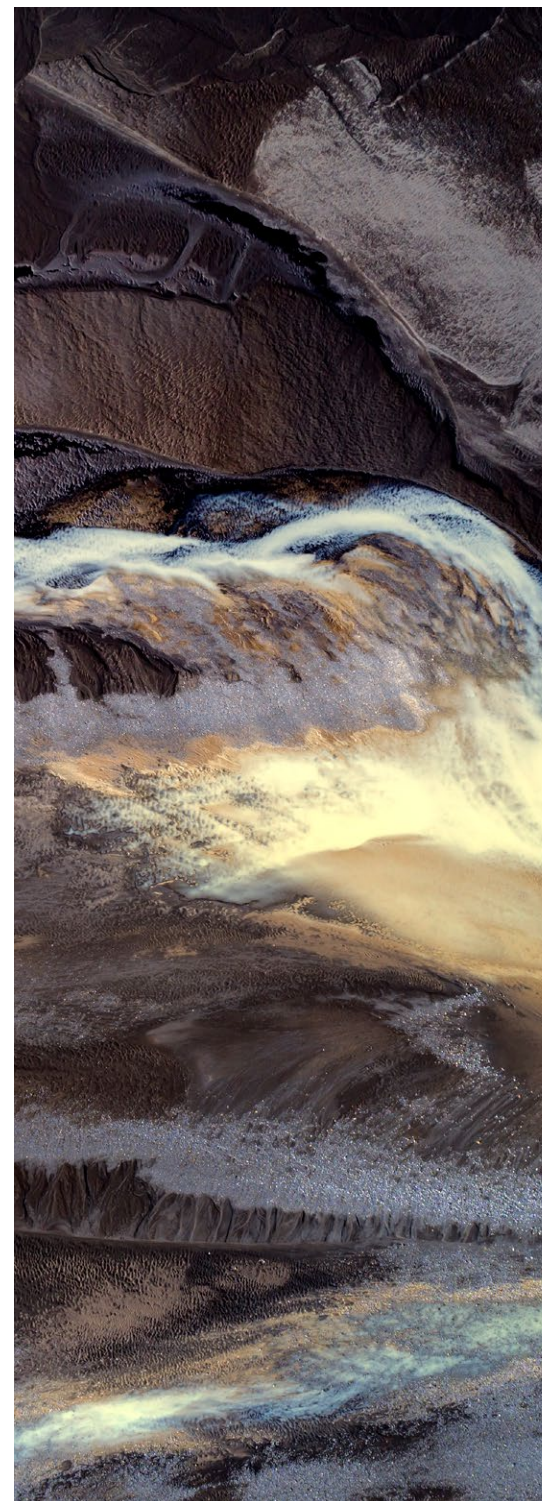
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## Tackling methane emissions from coal mining

- 20. Coal mine methane emissions are highly variable between mines and depend on coal grade, depth of extraction, mining techniques and production output, as well as any mitigation employed.** Companies have very different methane emissions and intensities according to their mine portfolio.
- 21. Globally, it is the exception rather than the rule that methane emissions reporting is based on high quality direct measurement.** Coupled with high variability in coal mine methane emissions, this renders corporate reporting highly uncertain.
- 22. UNEP's Steel Methane Programme, still in development, promises to help improve corporate reporting standards and encourage the uptake of direct measurement.** Miners can play an active role in driving industry progress through this initiative.
- 23. A comprehensive methane mitigation plan in coal mining involves actions taken throughout the mine life cycle.** Drainage of coal seams prior to and during excavation yields rich gas that can be utilised, while even low concentration ventilation air methane from underground mines can be addressed by techniques such as regenerative thermal oxidation. Underground mines can be sealed or flooded (where environmentally appropriate) to limit post-closure emissions.
- 24. While underground coal mines are typically higher-emitting than surface mines, they also present greater methane abatement potential.** Similarly, while metallurgical coal is usually more methane intensive than thermal coal, it offers greater potential for intensity reductions due to its more frequent underground origin.
- 25. While methane intensity metrics are not commonly used by coal miners, aiming for below 3 tCH<sub>4</sub>/kt by 2030 globally could be considered aligned with climate goals.** This average conceals a lot of variability and will not be an appropriate target for all companies. Companies may claim to be below this benchmark already, however without high-quality MRV (i.e. SMP level 5), such claims should be treated with scepticism.
- 26. In the NZE, methane emissions from thermal coal and metallurgical coal decline by c. 74% and c. 66%, respectively, by 2030 against 2022 levels.** In thermal coal, the majority of the reductions come from declining production, whereas intensity declines make up the larger share for metallurgical coal. Despite limitations, indexed pathways are unambiguous about what is required from corporates in sum. Re-baselining as MRV improves should be allowable if transparently stated and justified.



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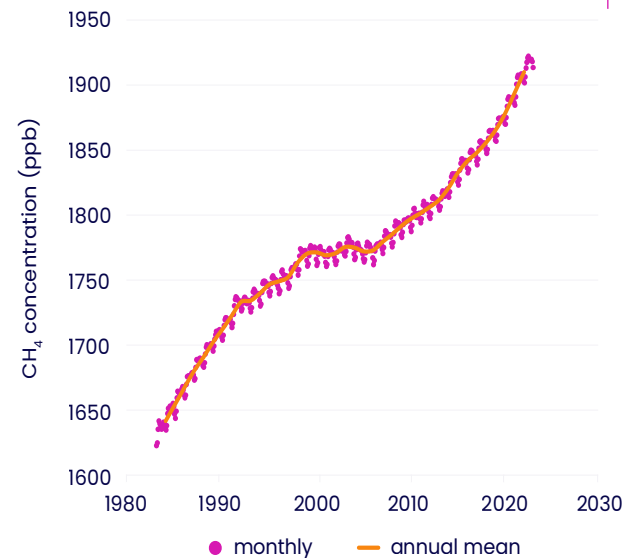
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# 1. Introduction to methane emissions

For the majority of the last two millennia, methane concentrations in the atmosphere have been relatively stable between **600** and **700 parts per billion (ppb)**, as revealed by ice core records from Greenland and Antarctica [4]. In 2023, that figure averaged **1,922 ppb**, which is 2.6x the levels in 1750, marked roughly as the time when methane concentrations began to climb [5; 6].

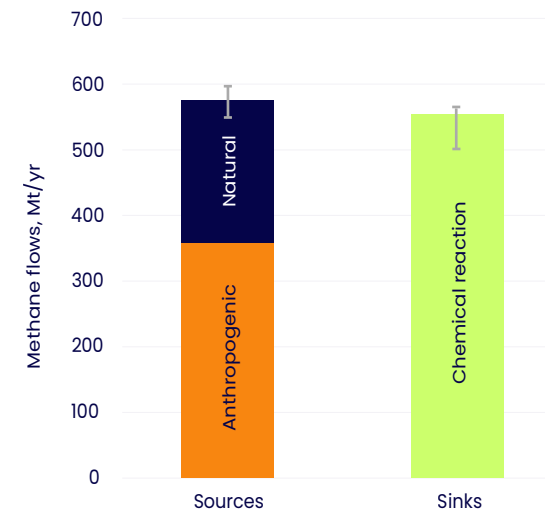
**Figure 1a**



**Figure 1:** Methane concentrations and anthropogenic emissions. a) Global-mean surface methane concentrations from NOAA's Global Monitoring Laboratory [216]. b) Total anthropogenic and natural methane emissions ('sources') and total sinks of methane. Data are top-down estimates averaged over 2008–2017 from Saunio et al. [12]. Uncertainty bars shown.

The rise in atmospheric methane – which has been observed in detail over recent decades (**Figure 1a**) – is driven by an imbalance between sources and sinks of the gas. This imbalance has arisen from the addition of anthropogenic emissions to existing natural sources of methane, which were previously balanced by sinks (**Figure 1b**). Because methane is a short-lived gas, methane sinks have also risen, lagging behind the rise in methane sources.

**Figure 1b**



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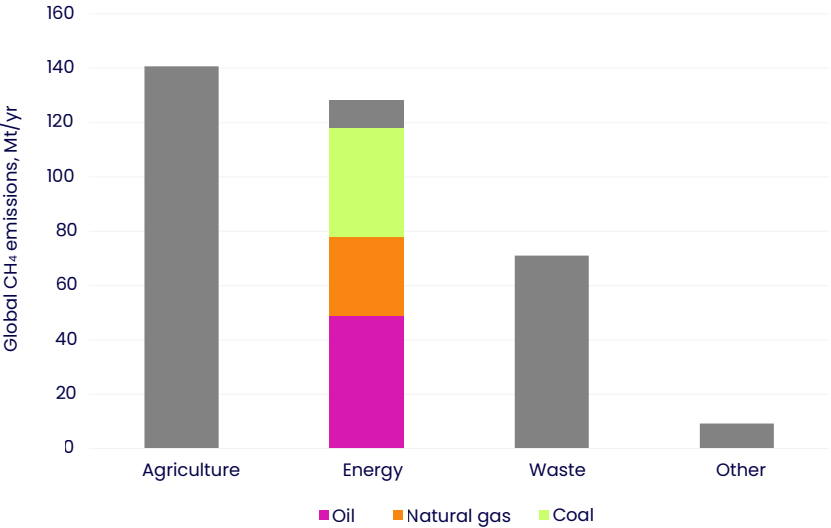
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The energy sector comprises c. 37% of anthropogenic emissions and offers the greatest abatement potential [7; 8]. This paper focuses on methane emissions from oil and gas and coal mining, which together dominate the energy sector's methane emissions (**Figure 2**), and are a substantial fraction of its overall operational emissions (**Figure 3**).

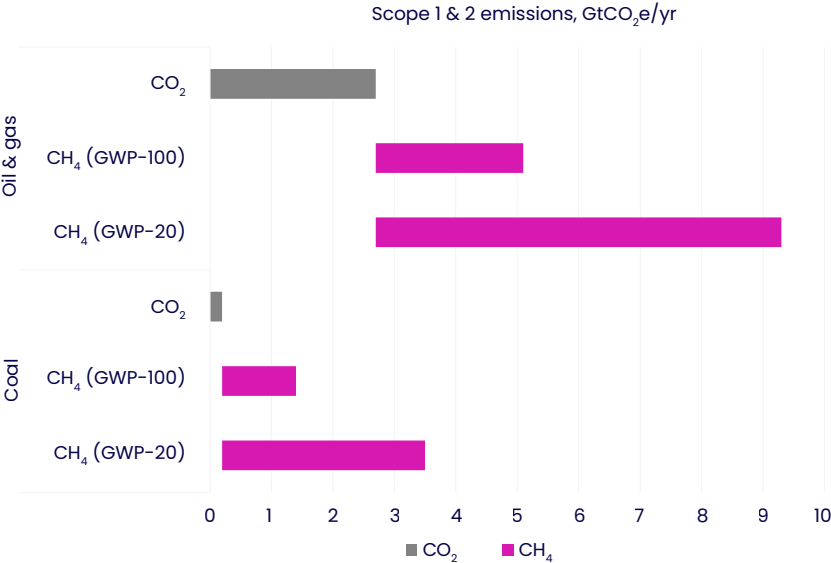
In the IEA's Net Zero Emissions by 2050 scenario (NZE), in which global warming is limited to 1.5°C, methane emissions from fossil fuels fall 75% by 2030 vs. 2022 (**Figure 4**). In this paper, we will explore the ways in which methane emissions reductions of this nature could be achieved, and the role of corporates in this. The aim is to support investors to conduct effective engagements with their companies on this topic.

**Figure 2**



**Figure 2.** Breakdown of global anthropogenic methane emissions in 2023, from IEA's Global Methane Tracker 2024 [8]. This report focusses on methane emissions from oil, natural gas and coal. The remainder of methane emissions from the energy sector come from bioenergy.

**Figure 3**



**Figure 3.** Scope 1 & 2 emissions from fossil fuel production, processing, transport and refining for 2022. Modified from ETC, Fossil Fuels in Transition [168]. Methane is expressed in CO<sub>2</sub>e using GWP-100 = 30 and GWP-20 = 82.5. As we explore later, CO<sub>2</sub>e is not well-suited to target-setting or understanding climate outcomes.



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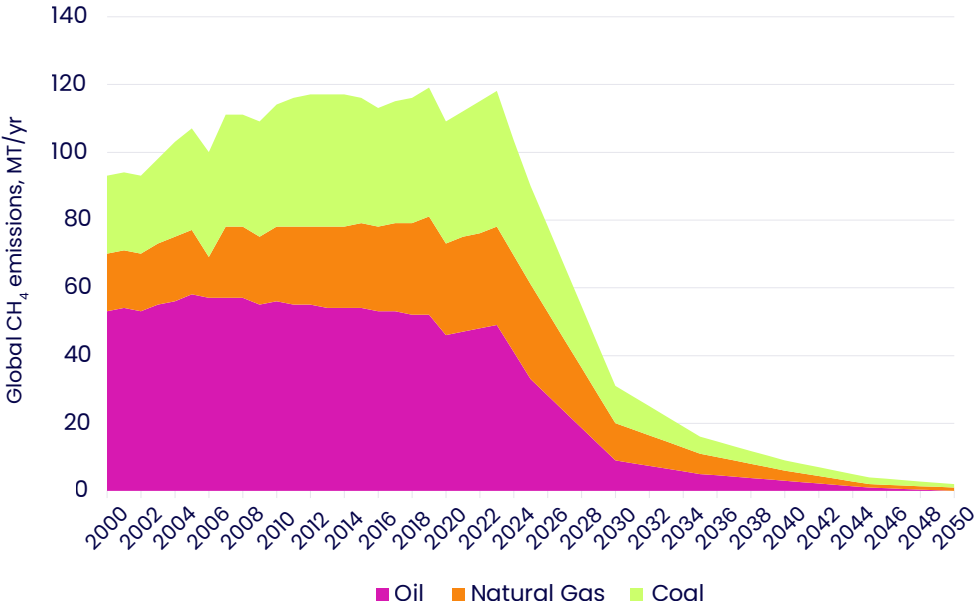
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Methane emissions more broadly consist of three types. **Biogenic** methane is produced from microbial decomposition in oxygen-poor environments; **thermogenic** methane is produced as part of the geological formation of oil, gas and coal; and **pyrogenic** methane results from incomplete combustion [9]. There can be both natural and anthropogenic sources of emissions from these categories, as shown in Table 1 below.

In this paper we focus on thermogenic methane from anthropogenic sources: methane emissions from fossil fuel operations.

Figure 4



**Figure 4.** Historical methane emission estimates from fossil fuels (2000–2023) from the IEA and projections to 2030 from the IEA NZE scenario. Steep declines in emissions are required from each fuel to achieve a 75% reduction in 2030 vs. 2022. Data from the IEA Global Methane Tracker 2024 [7].

Table 1

Methane emissions categories	Natural	Anthropogenic
Biogenic	Wetlands, freshwater systems, permafrost soils, termites, other wild animals.	<b>Agriculture:</b> rice paddies, ruminants. <b>Waste:</b> landfills, sewage.
Thermogenic	Natural venting of fossil methane	<b>Fossil fuels:</b> extraction, processing, distribution and consumption
Pyrogenic	Wildfires	<b>Energy:</b> biofuel and fossil fuel combustion

**Table 1.** Categorisation of methane emissions. In this paper we focus on methane emissions from fossil fuel operations (in bold outline).



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## 2. The climate science context

Investors are now largely familiar with carbon dioxide (CO<sub>2</sub>); they understand that there is an approximately linear relationship between cumulative emissions of CO<sub>2</sub> and warming, and this means that: **a)** net zero is essential for warming to stop, at any level, and **b)** warming outcomes are determined by carbon budgets up to net zero.

As a short-lived gas, methane behaves differently, but as a potent greenhouse gas (GHG), it is nonetheless highly influential on the global climate. Here we provide a brief review of the climate science on methane, to highlight key messages investors may wish to use when framing engagement on methane emissions and to help them discuss this gas with the same confidence as CO<sub>2</sub>.

### 2.1 In brief

Climate forcers are substances that drive warming or cooling by influencing the Earth's energy balance: they cause radiative forcing<sup>3</sup>. They can be separated into two categories with respect to their impact on global climate:

1. **Long-lived GHGs like CO<sub>2</sub>**. The warming impact of these gases depends primarily on their cumulative emissions over centuries or more.
2. **Short-lived climate forcers, including methane (CH<sub>4</sub>)**. For these substances, their warming (or cooling) impact depends primarily on current and recent annual emissions rates.

A consequence of these properties is that peak warming will be determined by cumulative CO<sub>2</sub> emissions **and** the annual emissions of CH<sub>4</sub> and other short-lived climate forcers at that time.

Keeping warming to 1.5°C requires urgent reductions in methane emissions; IPCC scenarios compatible with 1.5°C show an average decline in total anthropogenic methane emissions of 34% by 2030 on 2019 levels [10]. It also requires that we stay within a limited CO<sub>2</sub> budget, which demands a rapid fall toward near zero CO<sub>2</sub> emissions over the next few decades.

Tackling methane is one key part of climate action; it is not an alternative to cutting CO<sub>2</sub> emissions. Indeed, the two gases can be tackled simultaneously in relation to fossil fuel production.

<sup>3</sup> Radiative forcing is the change in the net energy balance (in Wm<sup>-2</sup>) at the top of the atmosphere between incoming energy (from the sun) and outgoing energy (from the Earth system).



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## 2.2 Methane: a short-lived gas

Methane has a short lifetime in the atmosphere of c. 9 years<sup>4</sup> [11]. It is primarily removed by chemical reaction with the hydroxyl radical<sup>5</sup>, OH. The hydroxyl radical is naturally occurring and replenished through the reaction of ozone with sunlight in the presence of water vapour [12].

As with other GHGs, it is the concentration of methane in the atmosphere that determines its contribution to warming<sup>6</sup>, as well as how it interacts with other climate pollutants. Changes in atmospheric concentrations of methane are driven by imbalances between sources and sinks of the gas. When sources exceed sinks, concentrations will increase, and vice versa.

Owing to the relatively fast removal of methane from the atmosphere, its concentrations are largely controlled by the rate of current and recent annual emissions (over the last decade or so).

There are two important corollaries of this. First, the contribution of methane to peak warming is controlled by annual emissions over a relatively short period of time leading up to that point [13; 14]. Second, reducing methane emissions can quickly lead to falling concentrations, reversing the recent warming it has caused [15; 16; 17].

**Key point 1: The temperature of peak warming will be determined by a combination of factors: a) cumulative emissions of CO<sub>2</sub> (which is long-lived) up to that point, and b) annual emissions rates of methane (and other short-lived climate forcers) at that time and in the decade or so prior.**

Indeed, in a scenario in which anthropogenic methane emissions immediately cease, methane concentrations may return to near pre-industrial levels in as little as 15 years [17].

When methane breaks down in the atmosphere, a complex sequence of chemical reactions takes place, largely (but not entirely) leading to the production of atmospheric CO<sub>2</sub><sup>7</sup>. In the case of fossil methane, this is new carbon in the climate system<sup>8</sup>, and explains why fossil CH<sub>4</sub> has a marginally higher global warming impact than biogenic or pyrogenic CH<sub>4</sub> [18].

It is true, then, that even after the 'removal' of fossil methane, some climate impact remains through the production of CO<sub>2</sub>. But, in practice, the total CO<sub>2</sub> yield from methane emissions is relatively insignificant.<sup>9</sup>

The lifetime of methane is short and one chemical process dominates its removal from the atmosphere. CO<sub>2</sub> is very different in this respect. Nearly half of annual emissions are relatively quickly partitioned into the upper ocean<sup>10</sup> and the biosphere on land<sup>11</sup> but the remaining added CO<sub>2</sub> can persist in the atmosphere for centuries to millennia, only gradually removed by several different geochemical processes [15]. These different properties have important implications for the climate effects of these two gases.

## 2.3 Warming from methane

By mass, methane is a much more potent GHG than CO<sub>2</sub>, meaning that it absorbs more outgoing radiation from the Earth which it then reradiates as heat in all directions. This absorption happens when particular frequencies of outgoing radiation provoke vibrations and rotations of the molecule in question. Geometrically, CH<sub>4</sub> is a more complex molecule than CO<sub>2</sub> and offers more vibrational and rotational modes. It therefore can absorb more outgoing radiation [19].

- 4 The lifetime of methane is not entirely independent of its concentration in the atmosphere. As the atmospheric burden of methane increases, the oxidising capacity of the atmosphere decreases, and the lifetime of methane increases: the so-called perturbation lifetime of an additional methane pulse is c. 12 years. [17]
- 5 A radical is a highly reactive atom, molecule, or ion that has at least one unpaired electron. The OH radical is naturally generated by photolysis in the atmosphere.
- 6 Altitude of emissions is also relevant, but this is generally only a consideration in the aviation sector and with respect to CO<sub>2</sub>.

- 7 The yield of CO<sub>2</sub> is c. 75% molecule-to-molecule, and, given the difference in the mass of each molecule, on average 1 kg of CH<sub>4</sub> generates c. 2.1 kg of CO<sub>2</sub> [20]
- 8 Whereas methane from decomposition or incomplete combustion of organic matter would yield CO<sub>2</sub> that may only recently have been removed from the atmosphere via photosynthesis.
- 9 How significant is this new CO<sub>2</sub>? As fossil methane emissions are currently around 120 Mt/yr, this would equate to c. 250 Mt/yr CO<sub>2</sub> emissions (see footnote 7), on the order of half a percent of total CO<sub>2</sub> emissions. This is relatively insignificant.

- 10 There is a dynamic equilibrium in the surface ocean between atmospheric CO<sub>2</sub> and aqueous CO<sub>2</sub> in the ocean. Higher atmospheric concentrations drive CO<sub>2</sub> into the ocean, where it then participates in chemical reactions that reduce seawater pH (ocean acidification). However, CO<sub>2</sub> is less soluble in warmer waters; the capacity of the ocean to take up additional CO<sub>2</sub> declines in a warming climate.
- 11 Due to the CO<sub>2</sub> fertilisation effect, higher CO<sub>2</sub> concentrations generally increase the biological uptake of carbon. However, this carbon—while stored in plant matter—is sensitive to wildfires or economic exploitation and may re-enter the atmosphere.



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The absorption of outgoing radiation by elevated GHGs affects the balance of incoming and outgoing radiation, leading to warming. The rate of energy gained by the Earth’s climate system is called the *radiative forcing*, a quantity that is in theory attributable to contributions from individual climate forcers. Despite being present at far lower concentrations than CO<sub>2</sub> in the atmosphere (**Table 2**), growth in methane concentrations have contributed significant radiative forcing since 1750, equal to one quarter of the radiative forcing from the growth in CO<sub>2</sub> [20].

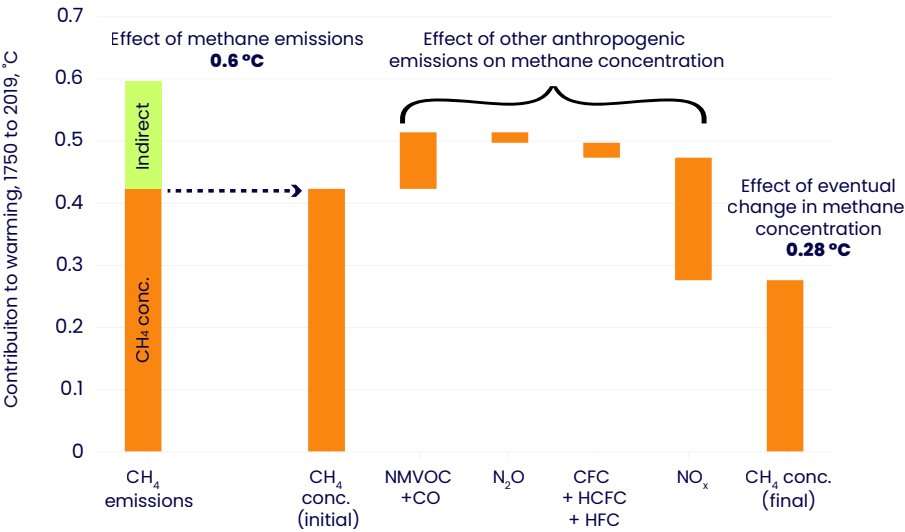
However, it is not just through the ultimate increase in methane concentrations that methane emissions cause warming. Methane participates in a complex array of chemical reactions, some of which lead to further warming. Methane promotes the production of tropospheric ozone<sup>12</sup> (O<sub>3</sub>), another short-lived climate pollutant with a lifetime of weeks in the atmosphere. Tropospheric ozone additionally has detrimental effects on respiratory health and plant productivity [21; 22; 17]. More minor warming effects from methane emissions come from the production of CO<sub>2</sub>, the enhancement of stratospheric water vapour and influences on aerosols. These indirect effects add to the warming attributable to methane emissions, as shown in the left-hand column in Figure 5.

**Table 2**

	Concentrations (ppm)		Effective radiative forcing (W/m <sup>2</sup> )
	1750	2019	
Methane	0.729	1.866	0.54 ±0.11
Carbon dioxide	278	410	2.16 ±0.26

**Table 2.** Changes in concentration and corresponding effective radiative forcings (the rate of energy gained by the Earth system from 1750 to 2019). Data from IPCC AR6, WGI, Chapter 7 [20].

**Figure 5**



**Figure 5.** Warming due to methane emissions (left-hand column) is comprised of both increasing CH<sub>4</sub> concentrations and indirect warming, due to the production of other climate forcers formed because of it, most notably tropospheric ozone. Other anthropogenic gases affect the lifetime of methane in the atmosphere, modifying the eventual change in methane concentration. These gases include non-methane volatile organic compounds (NMVOCs), carbon monoxide (CO), nitrous oxide (N<sub>2</sub>O), chloroflourocarbons (CFCs), hydrochloroflourocarbons (HCFCs), hydroflourocarbons (HFCs) and nitrogen oxides (NO<sub>x</sub>). Data from IPCC AR6, WGI, Chapter 6 [11].

12 The troposphere is the lowest layer of the atmosphere and is the layer in which we live and experience weather. The “ozone layer” that protects Earth from ultraviolet radiation resides in the stratosphere, at higher altitudes.

Meanwhile, other gases emitted by human activity also affect methane concentrations, and therefore its warming effect, as shown in Figure 5. The strongest effect is from nitrogen oxides (NO<sub>x</sub>), which decrease methane lifetimes and have affected warming from methane by **-0.2°C** since 1750.

Examining Figure 5, we can see that the warming attributable to

- methane *emissions*, **0.6°C**,
- is significantly higher than the warming attributable to
- the rise in methane *concentrations*, **0.28°C** [11; 20].

As described above, this difference is due to i) indirect warming due to methane emissions, and ii) the erosion of methane abundance by other emitted gases [11; 20].

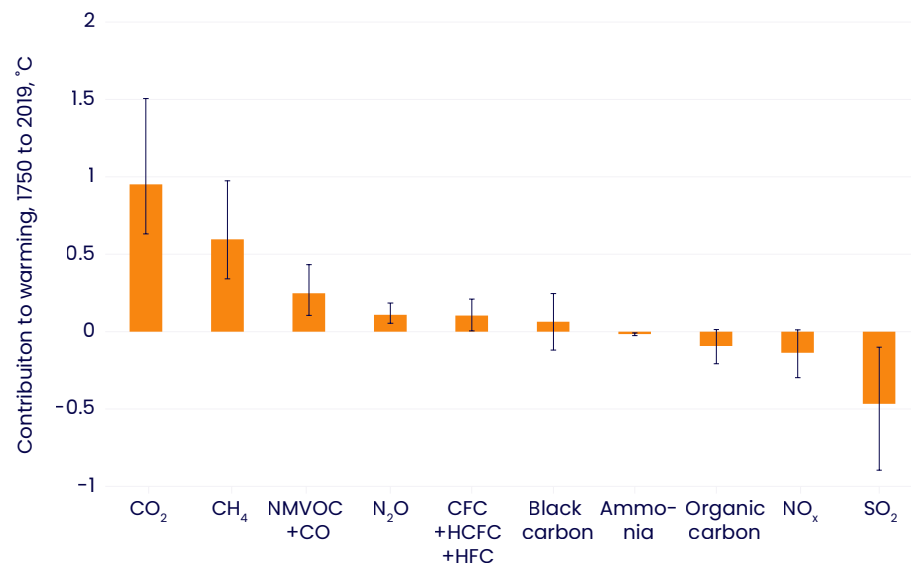
This is a notable point because these two different figures can lead to different statements about the role of methane in climate change, while both being true. In the context of discussing methane *emissions*, we must focus on the larger number, 0.6°C.

Methane emissions are the second leading contributor to global warming after CO<sub>2</sub>. **Figure 6** shows the contributions of emissions of major climate forcers to global warming as compiled by the IPCC in its Sixth Assessment Report [20]. Methane emissions are responsible for about 30% of gross warming since 1750.

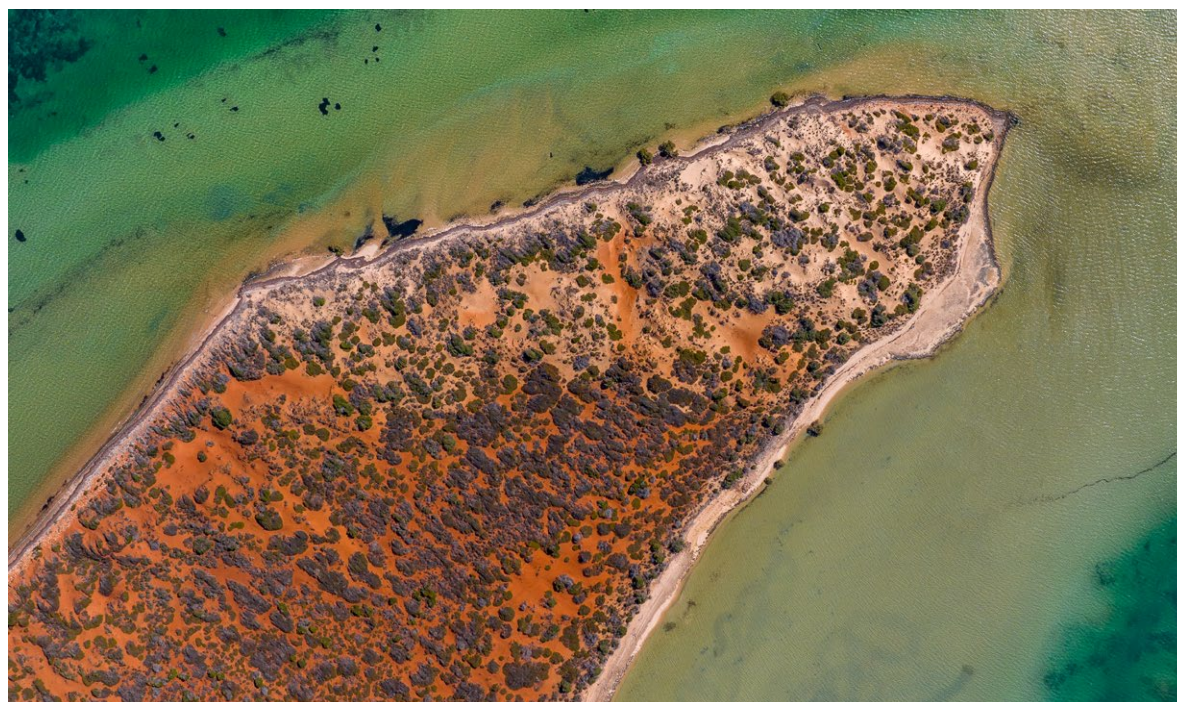
Though they are responsible for a cooling effect, emissions of NO<sub>x</sub> and sulphur dioxide (SO<sub>2</sub>) are not desirable due to the range of harmful health and environmental effects these gases cause [23]<sup>13</sup>.

<sup>13</sup> There is a vibrant debate about the risks of intentionally altering climate through 'solar radiation management, one method for which is the high-altitude release of light-scattering aerosols (the climate impact of SO<sub>2</sub> is due to the aerosol effect, as SO<sub>2</sub> reacts in the presence of water to form sulphate aerosols) [257]

**Figure 6**



**Figure 6.** Warming contributions 1750 to 2019 due to emissions of major climate forcers. Emissions of these climate forcers cause warming or cooling due to direct and indirect contributions. Error bars shown. Data from IPCC AR6, WGI, Chapter 6 [11].



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## 2.4 Role of methane in emissions scenarios

Because the rate of methane emissions near the time of peak warming contributes to the temperature reached, it also affects the remaining carbon budget (the cumulative CO<sub>2</sub> emissions allowable) for 1.5°C or any level [4; 22]. Indeed, the chance of limiting warming to 1.5°C is strongly influenced by future pathways of methane emissions, and changes in methane emissions can rapidly impact climate [24].

**Key point 2: In IPCC 1.5 °C scenarios with low/no overshoot, total anthropogenic methane emissions fall by 34% by 2030 relative to 2019.** Emissions reductions can drive a reversal of some of the warming experienced from methane to date, and thus help slow the rate of overall warming.

As noted above, the effect of methane on global temperatures is driven by the rate of recent emissions, whereas CO<sub>2</sub> warming effect depends on cumulative emissions. A consequence of this is that warming due to CO<sub>2</sub> only stops when net emissions cease [25], whereas methane's warming effect will stop if emissions remain constant (to be precise, decline by less than 1% per year) [26; 27]. This behaviour is illustrated in [Figure 7b](#) and [7c](#).

In line with this, while net zero anthropogenic CO<sub>2</sub> emissions will stabilise warming, net zero GHG emissions will lead to gradually declining temperatures ([Figure 7c](#)), due to the inclusion of short-lived gases. Net zero GHG emissions occurs decades later than net zero CO<sub>2</sub> in most climate scenarios [28].

Meeting the Paris Agreement goals requires more than simply stabilising the contribution of methane emissions to global temperatures; it must be partially reversed. In the IPCC's Sixth Assessment Report, in pathways that limit warming to 1.5°C with limited or no overshoot, total anthropogenic (i.e. not just fossil) methane emissions are reduced by a mean of:

- **34%** below 2019 levels by 2030, and
- **44%** below 2019 levels by 2040 [28].

The effect of these reductions is to reverse some of the warming already experienced due to methane. In some 1.5°C scenarios, methane mitigation contributes **-0.1°C** by 2050, relative to 2020 [26].

Without targeted policies and abatement efforts, methane emissions could continue to rise. Some studies present *avoided warming* figures, which compare a mitigation scenario to another scenario in which emissions rise. For example, the Global Methane Assessment [29], suggests that methane mitigation can avoid **0.3°C** of further warming by the 2040s, while Ocko et al. [30] state that pursuing all mitigation measures now could slow near-term decadal warming by around 30%, avoiding **0.25°C** of additional warming by mid-century.

It is important to remember that these avoided warming figures depend on an assumed counterfactual scenario, which may or may not be a useful comparison. There is no such ambiguity involved in describing the reversal of methane-induced warming relative to historical levels (as shown above).

Methane is not the only short-lived climate pollutant that will affect climate over the next few decades. Emissions of SO<sub>2</sub> (shown in [Figure 6](#)) and other aerosol precursors are likely to diminish (as fossil fuel combustion both declines and becomes cleaner). These aerosols have harmful environmental and health effects, and so their mitigation is desirable, though it will lead to a partial reversal of the **-0.51°C** cooling effect we have hitherto experienced from aerosols [11]. This foreseeable contribution to warming re-emphasises the importance of methane emission reductions, which are well-placed to combat short-term warming by virtue of their rapid impact.

## 2.5 Methane and climate metrics

Several metrics are used by scientists to compare the impacts of different climate forcers. The most widely known of these is the global warming potential (GWP) metric. Despite its name, it does not compare gases on their effect on global temperature. Rather, it compares the cumulative effect that different gases have on the Earth's radiative forcing [31]. It quantifies the radiative forcing due to a one-off (pulse) emission of a tonne of gas relative to an equivalent tonne of CO<sub>2</sub>, integrated over a fixed time period, and includes indirect warming effects.

GWP is not the ratio of radiative forcing in the year cited but the value averaged over the *entire period* from time of emission to that year. A metric that compares the expected temperature change in a given year after the one-off emission of these gases is the global temperature-change potential (GTP). It is worth highlighting the difference as statements about methane's role in climate are not always supported by the right metric for the purpose.

GWP and GTP metrics for fossil methane are shown in [Table 3](#). Both show how, relative to CO<sub>2</sub>, methane's ability to warm the climate is more potent but decays over time.



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Annual emissions of greenhouse gases in the so-called Kyoto-basket ( $\text{CO}_2$ ,  $\text{CH}_4$ ,  $\text{N}_2\text{O}$ , HFCs and others) are generally aggregated and disclosed on a  $\text{CO}_2$ -equivalent ( $\text{CO}_2\text{e}$ ) basis by weighting by a GWP metric [13; 32; 33]. Methane emissions are often reported in this manner.

While ubiquitous, this approach is limited in its usefulness for understanding climate change, primarily because of how it lumps together short-lived and long-lived climate pollutants [14; 16; 15; 13]. A defined pathway of  $\text{CO}_2\text{e}$  emissions can lead to very different climate outcomes over time depending on the contributions of different gases, most importantly  $\text{CO}_2$  and  $\text{CH}_4$  [33]. A high- $\text{CO}_2$ /low- $\text{CH}_4$  pathway leads to lower near-term but higher warming indefinitely thereafter, versus a low- $\text{CO}_2$ /high- $\text{CH}_4$  pathway [33].

To see this in action, examine the emissions profiles in **Figure 7**; if these are aggregated  $\text{CO}_2\text{e}$  pathways, very different climate outcomes would occur depending on the mix of  $\text{CO}_2$  and  $\text{CH}_4$  in annual emissions. A similar diagram is presented in an Oxford Martin School briefing [34].

**Key point 3: GHG metrics like  $\text{CO}_2\text{e}$  that aggregate  $\text{CO}_2$  and  $\text{CH}_4$  can be ambiguous with respect to climate outcomes, and obscure methane emitters within portfolios.** For this reason, it is best to keep methane and carbon dioxide separate in reporting and targets.

Aggregating emissions of  $\text{CH}_4$  and  $\text{CO}_2$  as  $\text{CO}_2\text{e}$  can make it hard for investors to identify methane emissions in their portfolios. It also implies a fungibility between the gases which does not accurately reflect climate outcomes, as described above and illustrated in **Figure 7**.

**Table 3**

	Global warming potential		Global temperature-change potential	
	How much more energy is trapped from year 0 to the year cited		How much warmer the climate would be at the year cited	
	GWP-20	GWP-100	GTP-50	GTP-100
<b><math>\text{CH}_4</math> (fossil)</b>	82.5 $\pm$ 25.8	29.8 $\pm$ 11	13.2 $\pm$ 6.1	7.5 $\pm$ 2.9

**Table 3.** GWP and GTP metrics for methane. Both metrics are defined relative to  $\text{CO}_2$ . GWP averages the radiative forcing due to a one-off pulse emission over a fixed time period—in this case year 0 to year 20, and year 0 to year 100—compared against a pulse of the same mass of  $\text{CO}_2$  [20]. GTP is a measure of the ratio of temperature change due to  $\text{CH}_4$  vs  $\text{CO}_2$  a given number of years after these pulse emission, in this case 50 and 100 years [20]. Values for these metrics are stated within an uncertainty window. Data from IPCC AR6, WGI, Chapter 7 [20].

A key cautionary point is that achieving  $\text{CO}_2\text{e}$  reductions by tackling methane *at the expense of addressing  $\text{CO}_2$  emissions* commits the world to higher temperatures in the long term [15; 33; 14]. Reporting gases on a disaggregated basis, or at least in ‘baskets’ grouped by lifetime (the approach taken under the Montreal Protocol), removes the climate ambiguity associated with  $\text{CO}_2\text{e}$  [33; 35].

In terms of meeting specific climate goals, the emphasis is best placed on limiting *cumulative emissions* of  $\text{CO}_2$ , i.e. keeping to a carbon budget, while limiting future emissions of  $\text{CH}_4$  to *specific rates* [13].

**Key point 4: Deep methane emissions cuts are essential for maximising the chance of meeting Paris climate goals and limiting near-term warming.** However, they must not come at the expense of efforts to mitigate  $\text{CO}_2$  emissions.  $\text{CO}_2$  emissions lock the world into higher temperatures in the long term.



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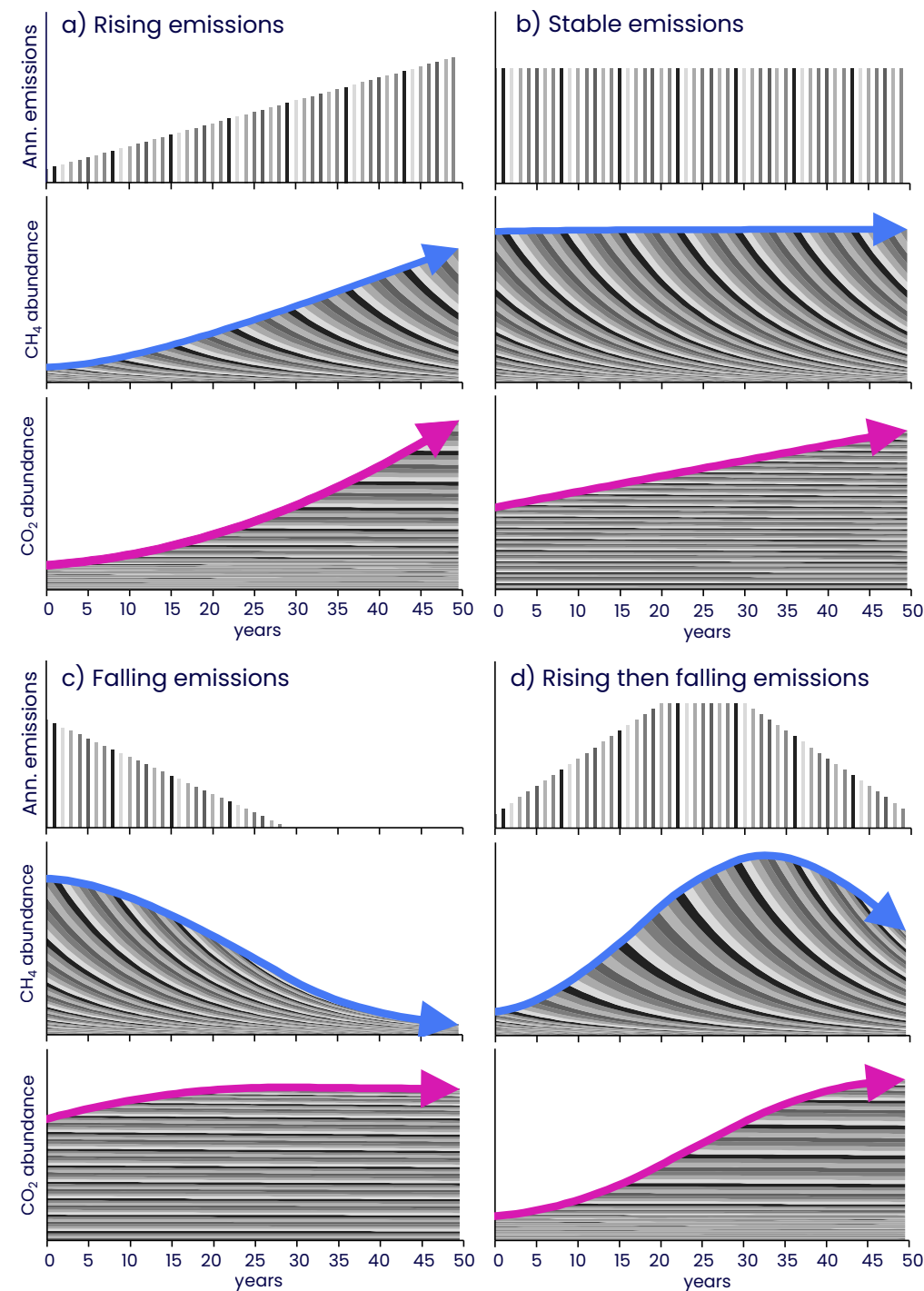
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**Figure 7.** Illustrative annual emissions profiles (top; greyscale bars) and resulting atmospheric abundance changes in CH<sub>4</sub> (middle; blue line) and CO<sub>2</sub> (bottom; pink line). Four scenarios shown in subplots **a–d**. GHG abundances correspond relatively linearly to global warming. Stacked greyscale curves illustrate the decay of annual emission contributions in the atmosphere. The abundance is the sum of these decaying contributions through time. We calculate the curves using convolution of respective emissions profiles and representative decay functions, with a 12-yr timescale for CH<sub>4</sub> and a 2,000-yr timescale for CO<sub>2</sub> (with a 50% atmospheric partitioning factor). We use a 50-yr spin-up period with constant emissions of the same value as shown in the first year of the subplot. Charts are not to any particular scale and are illustrative of trends only. Note that methane’s decay timescale is not entirely independent of its abundance, however this would have little effect on these illustrations. The annual emissions profiles in each subplot are the inputs for both CH<sub>4</sub> and CO<sub>2</sub> abundance curves. Note that, if this profile was in terms of CO<sub>2</sub>e, it could be comprised of variable amounts of CH<sub>4</sub> and CO<sub>2</sub>. A CO<sub>2</sub>e profile could be entirely CH<sub>4</sub> or entirely CO<sub>2</sub>. But the climate outcome would differ markedly depending on the choice, as illustrated.

**Figure 7: Response of CH<sub>4</sub> and CO<sub>2</sub> abundance to idealised emissions scenarios**



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# 3. Reporting and measurement: How well do we know methane emissions?

## 3.1 Construction of methane inventories

Methane emissions cause changes to atmospheric concentrations of methane and other gases. These changing concentrations can be measured and are increasingly well-documented. Year-on-year changes give a clear indication of the *difference* between the total magnitudes of sources and sinks of methane. However, they do not constrain the *absolute magnitude* of either, much less the different constituent emission sources.

There are two approaches to determining methane emission inventories (collections of individual emission sources), at corporate, regional, or global levels [12]:

- **Bottom-up** approaches aggregate emissions from multiple individual sources, whether measured directly or estimated with emission factors.
- **Top-down** approaches couple overarching observations of changing methane concentrations with inverse modelling to attribute these changes to sources.

A limitation of bottom-up approaches is that some emission sources may be missed, leading to underestimation. While top-down approaches can in principle capture these, they may suffer from significant uncertainty due to, e.g., weather conditions that hinder measurement, or the difficulty of source attribution when multiple emitting sites are close together. At the global level, these two approaches yield quite different numbers for different categories of methane emissions [12].

Countries report national emission inventories to the United Nations Framework Convention on Climate Change (UNFCCC)<sup>14</sup>. The IPCC provides guidance for the construction of these inventories, which covers methane from fossil fuel operations [36; 37; 38]. The IPCC guidance sets out a tiered structure for reporting, which can be summarised as follows:

- **Tier 1:** Calculation using generic, global emission factors.
- **Tier 2:** Calculation using country or region-specific emission factors.
- **Tier 3:** Calculation incorporating direct measurements at facilities.

Tiers 1 and 2 estimate emissions using equations that combine production and activity data with emission factors for specific facilities, types of equipment or processes. In its guidance, the IPCC provides factors and equations for an array of processing stages and operations. These schemes can be complex, however – crucially – they are based on what emissions could reasonably be expected to be, rather than any contemporaneous measurement. This means that, in the context of oil and gas, accidental leaks will be missed. Tier 3 methods, by contrast, do involve direct measurement, and use multi-input models to handle a variety of measurements and produce a final estimate of emissions.

In accordance with national regulations – where these exist – corporates report their methane emissions to governments; these regulations set a floor for corporate data handling on methane and influence the methodologies that feed into their public reporting.

Beyond regulation, industry-led methodologies, such as the Natural Gas Sustainability Initiative (NGSI) or the IGO-led Oil and Gas Methane Partnership 2.0, also inform data-handling and reporting practices [39].

<sup>14</sup> Annex I countries report national inventories annually, whereas non-annex I countries report less frequently via national communications and biennial update reports.



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In **Figure 8** we compare independent estimates of global methane emissions from the fossil fuel sector against UNFCCC inventories. Of the 17 global estimates compiled, UNFCCC inventories are substantially the lowest. It is therefore fair to suppose that the UNFCCC inventories are, in sum, underestimates. This likely reflects corporate reporting more broadly, insofar as these UNFCCC inventories aggregate corporate contributions. Indeed, corporate reporting via OGMP 2.0 (discussed further in **Section 3.3**), when extrapolated to the global level, falls further below the independent estimates.

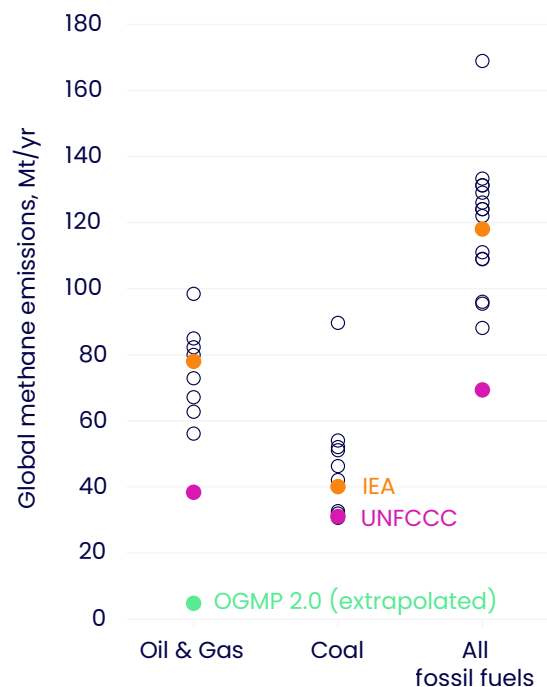
The IPCC notes that Tier 1 approaches in oil and gas may “easily be in error by an order of magnitude or more” [36 p. 39], while in surface mining and underground mining, it states that Tier 1 approaches have an uncertainty of a factor of 3 and a factor of 2, respectively [36].

In the oil and gas sector, large, accidental leaks make a considerable contribution to overall emissions. These events are not captured by emission factors and are one of a number of possible reasons for frequent underestimation [40; 41; 42; 43; 44].

**Key point 5: National inventories compiled and submitted to the UNFCCC likely underestimate methane emissions by a significant margin.**

Insofar as these inventories reflect underlying corporate reporting, they are also indicative of the scale of likely understatement in company reports.

**Figure 8**



**Figure 8.** Comparison of global fossil fuel methane emissions estimates. Key UNFCCC and IEA estimates highlighted. Other estimates shown include both top-down and bottom-up approaches. Sources: UNFCCC [101], US-EPA [259], Hoglund-Isaksson [260], Global Energy Monitor [188], Schwietzke et al. [261], Kholod et al. [189], Shen et al. [62], Saunio et al. [12], O'Rourke et al. [262], Maasakkers et al. [263], IEA [8], Hoglund-Isaksson [264], Crippa et al. [102], Climatewatch [265].

## 3.2 Importance of direct measurement

When done well, integrating direct measurement (Tier 3 reporting) reduces uncertainty in establishing methane inventories and allows for the temporal and spatial variability in emissions sources to be characterised with greater confidence.

In doing so, direct measurement supports:

- The understanding of fossil methane emissions at both local and global scales
- The design of effective mitigation strategies, both over the long-term and in rapid response to large leaks [45]
- Companies to set and track progress against ambitious targets
- Investors and civil society to hold companies accountable to these goals
- The implementation of effective policy tools, market-based instruments, and regulatory standards [7]

Further, while emissions factors are based on parameters such as equipment type and location, they do not factor in *how well* such equipment is operated. Switching to measurement-based reporting incentivises not only updating equipment but also operating existing equipment at a higher standard of methane performance.



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### 3.3 IMEO initiatives

The International Methane Emissions Observatory (IMEO), established by the UN Environment Programme (UNEP) with European Union support, is working to address the measurement gap in several ways. UNEP is commissioning measurement studies [46; 45] to independently assess emissions on a variety of scales. It recently launched its Methane Alert and Response System (MARS) to inform authorities of large methane plumes and track their mitigation.

IMEO coordinates the Oil and Gas Methane Partnership (OGMP) 2.0, a platform for asset-level company reporting on methane emission, best-practice sharing, and evaluation of company performance [46; 43]. IMEO is also preparing the Steel Methane Programme (SMP), which will fulfil a similar role as the OGMP 2.0 as a reporting and target-setting vehicle for companies on methane from metallurgical coal mines.

IMEO gathers asset-level information from its OGMP 2.0 participants and publishes summaries of their total emissions, aggregated by reporting level (see below) and distinguishing between operated and non-operated assets. It also cites any targets on methane reductions that participating companies have.

- **Level 1:** Emissions reported by aggregated source categories at country level only.
- **Level 2:** Emissions reported by aggregated source categories using source-specific activity data and regional/country-specific emission factors.
- **Level 3:** Emissions reported by detailed source type using generic emission factors and activity data.
- **Level 4:** Emissions reported by detailed source type using source-specific activity factors and source-specific emission factors established with empirical measurements.

- **Level 5:** Emissions reported similarly to Level 4, but with the addition of reconciliation with site-level measurements.

We will discuss corporate performance against these reporting levels, and the nature of targets set, in [Section 5.3](#) and [Section 6.3](#).

Investors see joining OGMP 2.0 as a highly valuable, if not essential, part of an oil and gas company's journey on tackling methane emissions. The key attributes that distinguish it from other initiatives of its kind are: its global and standardised coverage; the fact that all of a corporate's assets are covered, including non-operated assets; and the clear performance scale towards high quality measurement based reporting.

**Key point 6: Joining OGMP 2.0, or engaging with the developing SMP, as relevant, is an excellent early objective for a company engagement.** These IMEO initiatives provide platforms for asset-level methane disclosure and best-practice sharing among fossil fuel producers, with a clear goal to progress to direct measurement-based reporting.

### 3.4 Measurement techniques

Fossil fuel companies can employ an array of techniques to build their measurement capacity and gather more reliable methane emissions data. The type of equipment and techniques that are appropriate will vary according to the nature of the site/facility and its emissions.

Corporates and nation states are also increasingly under scrutiny from independent measurement efforts. A range of observation technologies are being used to characterise and attribute methane emissions from regional to point-source scales, including ground-based networks [47], ship-based sampling [48], aircraft-based sampling [49; 50], and satellite remote sensing [42; 51].

The exercise of accurately characterising corporate methane emissions is challenging, especially in oil and gas operations where there are a large number of potential emission points, and where these points can be remote and geographically dispersed. In addition, emission rates can be highly variable in time, and the frequency of sampling must be sufficient to capture this variability. A significant fraction of emissions can occur from accidental leaks that are difficult to predict. At operational coal mines, measurement is simpler at underground mines, where methane emissions largely result from point sources (ventilation air), rather than at surface mines, where methane is emitted over a large area.



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Due to these factors, a sophisticated approach is required for measurement that combines and reconciles measurements across different levels, using component or local-level measurements in a bottom-up scheme, alongside top-down facility-level measurement [52]. The array of measurement approaches, by technology and monitoring system, are summarised in **Table 4**. While these technologies can detect and measure methane concentrations, models and weather data are required to convert these into an emissions estimate.

Each type of technology and monitoring system has its own strengths, weaknesses, and use cases. As such, a sophisticated approach will utilise multiple systems and technologies, reconciling bottom-up with top-down information.

Methane can be detected and measured through its interactions with infrared light<sup>15</sup> (laser analyses, cameras, satellite instruments), its participation in chemical or photochemical reactions, or its effect on the thermal conductivity of air. Measurement techniques rely on at least one of these effects.

**In situ sampling** techniques measure methane concentrations in air samples or intake air. Example systems include:

- **Tunable diode laser absorption spectroscopy (TDLAS).** A diode laser is tuned over the characteristic absorption wavelengths of methane in a sample cell. The methane concentration is calculated as a function of the absorption of light [53].
- **Cavity-enhanced absorption spectrometry (CEAS).** A form of TDLAS in which the interaction between laser and gas is enhanced by reflection within a cavity.
- **Cavity ring-down spectroscopy (CRDS).** A highly sensitive form of CEAS using a high-finesse optical cavity [54].

<sup>15</sup> Methane absorbs infrared light with an absorption peak in the shortwave infrared. This makes it detectable and is the source of its greenhouse effect; it absorbs outgoing radiation from Earth's surface.

- **Gas chromatography with flame-ionisation detector (GC-FID).** Gas chromatography separates methane from ambient air in a sample, and the flame-ionisation detector measures methane concentration by detecting ions formed by combustion in a hydrogen flame [47; 55].
- **HiFlow sampling.** A portable or handheld vacuum-sampling system, using either a TDLAS system or a combination of a thermal conductivity sensor and a catalytic oxidation sensor [56; 57].

Laser-based techniques for direct sampling (including TDLAS, CEAS and CRDS) are also sometimes referred to under *active* optical gas imaging, as opposed to *passive* approaches such as infrared cameras (see below) [58].

In situ sampling can be done at fixed installations or as part of ground-based [47] or airborne surveys [49; 54]. Ground-based networks can be site-level or international in scale [47]. They must be combined with flow or wind data, and dispersion or mass-balance models, to interpret emissions.

**Imaging** in **Table 4** refers to passive optical gas imaging, using infrared cameras or satellite instruments, that detect methane's absorption peak in infrared light, and generate multi-pixel images. Infrared cameras can resolve methane leakage points and approximate concentration distributions. They can be handheld, fixed, or used as part of ground-based or aerial survey systems (e.g. the Methane Airborne Mapper instrument, MAMAP) [59]. They are relatively easy to operate but in general are better-suited to detection than quantification of emissions, and their effectiveness is also weather-dependent [60; 58; 61].

**Satellites** offer particular promise given their capacity to provide regular repeat measurements and cover a near-global range of locations. New satellites are due to come online in the near future that will add observational capacity.

Satellite instruments can be divided into two main categories, as below, with launch dates shown in parentheses:

- **Area-flux mappers.** With wide swath areas and coarse spatial resolution (0.1–10 km), but high detection precision, these instruments can be used for characterising emissions at **regional to global scales** [51].
  - Current: GOSAT (2009); TROPOMI (2017); MethaneSAT<sup>16</sup> (2024)
  - Planned missions: GOSAT-GW (2024); Sentinel-5; GeoCarb; CO<sub>2</sub>M; MERLIN
- **Point-source imagers.** With fine pixel resolution (<60 m), these instruments are used to image and quantify **individual plumes of methane** [51].
  - Current: Sentinel-2 (2015); GHGSat (2016); PRISMA (2019); EnMAP (2022); Carbon Mapper (2023)

Synergies exist between these two instrument types: area-flux mappers have high spatial coverage and can detect large leaks. Through communication between the satellite instruments, these detections can then be used to “tip and cue” point source imagers to attribute emissions to individual assets or facilities [46]. Tackling these accidental large leaks identified by area-flux mappers could make a significant contribution to overall CH<sub>4</sub> emissions as they comprise roughly 10% of oil and gas CH<sub>4</sub> emissions [42].

<sup>16</sup> MethaneSAT launched in March 2024. Note that MethaneSAT is sometimes considered a hybrid instrument in that it can both quantify area emissions and detect high emission points [64].



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Limitations of satellite instruments include difficulty of retrieving readings when there is cloud cover, or in the following environments: offshore areas, snowy or ice-covered regions, and high latitudes. In particular, this renders oil and gas operations in the frequently cloud-covered tropics and offshore regions poorly covered by satellites and often excluded from global measurement efforts [42; 62].

Detection of methane over water is challenging due to the low diffuse reflection of shortwave infrared radiation by water. However, a relatively new innovation that overcomes this limitation is the *sunglint* mode, in which the sensor exploits the direct specular reflection of sunlight from the water surface [51; 63]. This mode can be achieved by agile instruments able to modify their view angle (PRISMA, Worldview-3, GHGSat, Carbon Mapper), or capture a sufficiently wide field-of-view that part of the swath captures the sunglint area (TROPOMI, Sentinel-2, LandSat) [51]. MethaneSAT is not currently set up to capture in sunglint mode, but its technical team aims to develop this capacity in the future [64].

Satellites are also limited in their sensitivity. Even point-source instruments can only detect emission events larger than about 100 kg/hr [51]. This means they are generally not suitable for attributing yearly emissions to individual facilities. Instead, they can detect and quantify large emission events—or confirm their absence.

Attribution of facility-level emissions is also more difficult when multiple facilities are located near to one another, and either occupying the same pixel or with overlapping methane plumes.

**Table 4**

	Component level				Regional level						
					Facility level						
	Enclosed volume	Gas stream	Handheld	Targeted instruments	Ground surveys	Sensor network: site level	Drone surveys	Satellite: point-source	Aircraft surveys	Satellite: area-flux	Sensor network: large-scale
<b>In situ sampling</b> <ul style="list-style-type: none"> <li>• Laser spectroscopy</li> <li>• Gas chromatography</li> <li>• HiFlow sampling</li> </ul>	●	●	●	●	●	●	●		●		●
<b>Imaging</b> <ul style="list-style-type: none"> <li>• Infrared cameras</li> <li>• Satellite instruments</li> </ul>			●	●	●		●		●	●	
<b>Atmospheric LiDAR</b> <ul style="list-style-type: none"> <li>• Ground-based</li> <li>• Airborne</li> </ul>					●				●		

'Remote sensing'

**Table 4:** Grouped measurement technologies and their use in different types of monitoring systems. Pink dots indicate where a particular technology (left) has application. We do not distinguish between in situ sampling approaches, but height of dots indicates which technology is used for imaging and LiDAR in different monitoring systems. Table constructed based on literature review including citations in text—may be incomplete.



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IMEO's MARS aims to connect satellite detection of methane plumes with a notification process to promote on-the-ground mitigation [45]. In 2023 (1 January–15 November), IMEO detected nearly 1,500 methane plumes globally from the fossil fuel sector, of which 600 were attributable to facilities using point-source imagers. The MARS initiative alerted governments and relevant OGMP 2.0 member companies to 127 of these plumes – all in the oil and gas sector.

Planned satellite launches will boost observational capacity, particularly over selected high-priority areas, and offer higher detection and quantification precision [42]. While an individual satellite is inherently limited in temporal and spatial coverage, a constellation of satellites makes for a more formidable measurement system.

Some companies are now using satellite data to improve their own measurement capacity [43]. For instance, the Oil and Gas Climate Initiative (OGCI) has a partnership with GHGSat to identify and address large leaks [65].

**Atmospheric LiDAR** (light detection and ranging) technologies involve emitting and receiving reflected pulses of light to measure the concentration of atmospheric gases and pollutants. Methane can be measured through a technique called differential absorption LiDAR (DIAL), which works by emitting two closely spaced wavelengths of light, one of which is absorbed strongly by methane, and another which is unaffected. The difference in return signals provides a measure of the methane abundance. Surveys can be either:

- **Ground-based**, exploiting the backscatter of the signal by aerosols at different levels in the atmosphere. This technique is known as range-resolved DIAL (RR-DIAL) [66; 52].
- **Airborne**, exploiting the reflection of the signal from the ground surface. This technique resolves total air column methane and is known as integrated path DIAL (IP-DIAL) [67; 68; 69].

DIAL instruments can scan across a range of angles, as well as from a range of positions, which allows for the spatial resolution of methane plumes [70]. They can be highly accurate but require technical expertise to operate and interpret [52]. They are able to work in conditions where satellite imaging is low in accuracy or not possible (e.g. due to cloud cover, over ocean, and at night-time) [66].

**Modelling** is required to combine diverse inputs – including observations that are limited in time and space – and reach an estimate of emissions. For instance, point-source measurements of methane concentration across a broad spatial area can be translated back to an estimate of methane emissions from a point source by inverse modelling of the emission plume, with knowledge of the meteorology.

**Key point 7: Both bottom-up and top-down measurements are needed to build reliable estimates of corporate methane emissions.** With

a host of measurement technologies available, each with its own strengths and weaknesses, a sophisticated approach employs multiple systems simultaneously, and involves sufficient sampling in space and time.

When component-level observations are aggregated with no other inputs, total emissions will be systematically underestimated, as not all sources are likely to be captured. Accurate estimates therefore require a multi-input approach, including top-down as well as bottom-up information.

As methane measurement capacity and data availability increases, the ability of investors, regulators and civil society to hold corporates to account for their methane emissions will rise accordingly: both through corporates' own measurement and reporting and through independent measurement campaigns.

**Key point 8: Independent measurements will increasingly expose corporate underreporting and poor practice with respect to methane emissions.** New satellite instruments coming online in the next few years will support efforts to hold companies to account and alert them to large emission sources.



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# 4. Policy context

## 4.1 A changing policy landscape

Policymakers globally are increasingly acknowledging the need to address methane emissions, highlighted by the prominence of the topic at COP28. The outcome of the Global Stocktake now clearly recognises the necessity for substantial methane reductions by 2030, and new grant funding announced for methane abatement has exceeded US\$1 billion – tripling previous annual grant levels [71; 72].

Additionally, the Global Methane Pledge (GMP) has welcomed several new participants, encompassing a total of 158 nations as of May 2024, collectively responsible for over half of global fossil fuel methane emissions [73; 74]. Led by the US, EU and others, participants commit to *“take voluntary actions to contribute to a collective effort to reduce global [anthropogenic] methane emissions at least 30% from 2020 levels by 2030”* [75].

In line with these pledges, the body of national regulations targeting methane emissions is growing, demonstrating a push for improved management and accountability from major methane emitting sectors.

The number of methane regulations has risen 70% since 2015 to approximately 255 active policies in 2023 [76]. Around half of the policies target fossil fuel methane emissions exclusively, with 8% addressing both fossil fuel and biogenic methane [76]. The oil and gas sector is the primary focus of these policies, making up 76% of this total.

The fewer coal mine methane policies may be due to the relative concentration of coal production among a few major players, and the perception that imposing new requirements in countries with planned coal phase-outs is an excessive burden on operators, even though abandoned mine emissions are significant and growing in importance [76; 77; 78].

The IEA’s 2024 Methane Tracker highlights another critical gap: high-level commitments under the GMP would reduce methane emissions from oil and gas by 55% and from coal by 40% by 2030, but existing regulations are only expected to reduce emissions by around 20% and less than 10%, respectively [79]. The gap hints at growing regulatory risk in the coming decade, as meeting the GMP target would require the rollout of more stringent regulations around the world. Furthermore, the observed pushback from the oil and gas industry against recent regulatory efforts in the EU and US suggests a misalignment that could pose significant challenges for companies as they adapt to new mandates [80].

**Key point 9: Methane regulations for the fossil fuel industry are rapidly gaining momentum and will need to tighten further over the next decade to align with GMP commitments.** This could pose significant transition risks for companies without robust methane reduction or monitoring plans.



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## 4.2 Regulatory approaches for managing fossil fuel methane emissions

The table below presents different regulatory approaches for managing fossil fuel methane emissions, along with concrete examples. It follows the classification of policy approaches in the IEA's Regulatory Roadmap and Toolkit [77].

It is important to highlight that policies often blend several approaches. China's National Methane Action Plan, for instance, also includes information-based and prescriptive measures such as enhancing MRV systems and promoting LDAR technologies and flaring reduction measures [85].

The financial implications of new methane regulations could be profound. Companies lacking advanced methane reporting procedures and mitigation plans may see steep rises in operating and capital expenditures from compliance costs, upgrades to infrastructure and equipment, and penalties for non-compliance. Rising methane taxes and increased public scrutiny could shift demand towards lower-emissions competitors – in the US for instance, nearly half of natural gas supply is seeking low-methane certification [89]. Falling behind could erode profit margins, weaken balance sheets and constrain access to finance.

Approach	Description	Policy example
<b>Information-based</b>	Policies that aim to improve emissions data, for instance by requiring companies to measure, report and verify (MRV) their emissions.	<b>EU Methane Regulation, 2024:</b> Requires fossil fuel operators to periodically report source-level methane emissions. Initially, generic emissions factors are permitted, but site-level measurements and source-level quantification are required within 48 months for both operated and non-operated assets. Importers must comply with EU-equivalent MRV measures by January 2027 for new contracts unless regulatory equivalence with the producing country is established [81]. Emissions data will be made available in a public methane transparency database [82]. Non-compliant importers will face fines and/or loss of market access. For further details, see <b>Box 1</b> .
<b>Prescriptive</b>	Policies that mandate the adoption of recognised best practices, such as restrictions on venting and flaring.	<b>Nigerian Guidelines for management of fugitive methane and greenhouse gas emissions in upstream oil and gas operations, 2022:</b> Mandates the submission of detailed GHG management plans, frequent Leak Detection and Repair (LDR) inspections and timely flare repairs with a minimum flare efficiency of 98%. Cold venting is prohibited and certain equipment such as pneumatic controllers, pumps and compressor seals must be replaced or upgraded to reduce leaks. Non-compliance may lead to fines, temporary or permanent withdrawal or non-approval of License and/or permit, and other penalties [83; 84].
<b>Performance-based</b>	Policies that establish specific standards, such as emission reduction targets, but do not prescribe methods for compliance, unlike prescriptive policies.	<b>China National Methane Action Plan, 2023:</b> While this new regulatory framework lacks any methane emissions reduction targets, it does establish an annual utilisation target of 6 billion cubic metres of coal mine gas beginning in 2025 [85].
<b>Economic</b>	Policies providing financial incentives (positive and negative) for compliance, making methane abatement more cost-effective.	<b>US IRA Waste Emissions Charge for Petroleum and Natural Gas Systems, 2024:</b> Tax on methane emissions, charging \$900 per tonne of methane (\$36 per tCO <sub>2</sub> e, by 100-yr GWP) released above a certain threshold, rising to \$1,200 (\$48 per tCO <sub>2</sub> e) and \$1,500 per tonne (\$60 per tCO <sub>2</sub> e) from 2025 and 2026, respectively [86; 87]. A 2022 congressional analysis found that the law should effectively penalise a third of all methane emissions from oil and gas infrastructure in the US [88].



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A case in point is Diversified Energy Co. (DEC), the largest oil and gas well owner in the US. In December 2023, four Democratic Committee leaders scrutinised the company for allegedly underestimating its environmental liabilities, including “unsustainable” methane emissions and well remediation costs [90; 91]. The inquiry was followed by a short-seller attack which contended that DEC was unprepared for new US methane regulations [91; 92]. The short seller cited an independent satellite study predicting annual methane fees up to \$325 million, far above DEC’s estimates and free cash flow forecasts, with implications for the company’s financial stability [93]. DEC’s share price experienced significant volatility following the report’s release [91].

**Key point 10: Governments are employing various approaches to reduce fossil methane, including measures to improve emissions data, mandate specific abatement measures, set performance-based targets or put a price on emissions.**

Maintaining competitiveness will require companies to adopt best practices with urgency and transparently communicate such efforts to investors.

## 4.3 Regulatory development in top methane emitting countries

**Figure 9** shows the coverage of fossil methane emissions by national regulations (per the policy classification above) across the 25 highest-emitting fossil fuel producing countries globally, by IEA data.<sup>17</sup>

Over half of these emissions come from countries that have not committed to the GMP’s 2030 emissions reduction target. However, this does not always correspond with a lack of regulatory progress.

China, for instance, has been criticised for not committing to the GMP or setting an explicit methane emissions reduction target. However, experts attribute this to a weak data foundation, which the country is now addressing through its National Methane Strategy [94; 95].

Research has highlighted the lack of monitoring obligations requiring emissions measurement as an important gap in current regulatory practice [75]. Indeed, the effectiveness of emissions standards depends greatly on reliable reporting systems to establish baselines and quantify progress [77; 96]. In a similar vein, emissions taxes require a robust data infrastructure to price emissions accurately and prevent underreporting by companies seeking to avoid financial penalties.

<sup>17</sup> Note that the IEA policy database provides more detailed policy coverage for IEA member countries compared to non-IEA members, which may impact the accuracy of the data presented in this chart.

Countries with weaker knowledge of their emissions – often non-Annex I countries under the UNFCCC with less stringent reporting requirements [97] – may therefore be better placed to pursue strict MRV measures and technology requirements, which mandate tried-and-tested methods that do not rely on having a strong data baseline [95; 77].

**Key point 11: Regulatory effort to tackle fossil methane is most effective when backed by a robust data infrastructure and verification system. However, imperfect data should not delay action.**

Proven methane abatement measures are available and should be implemented immediately, even as efforts to improve emissions data continue.

Despite the lack of domestic MRV requirements in non-Annex I countries such as India, Indonesia, Saudi Arabia, Libya, Qatar and Uzbekistan, there are some signs of progress as NOCs in these countries have joined the OGMP 2.0 and/or the Oil and Gas Decarbonisation Charter (OGDC). The latter commits signatories to reach net zero operational emissions by 2050, with “near-zero methane emissions” (below 0.2% intensity) and a halt to routine flaring by 2030 [98]. Given the close ties between NOCs and their respective governments, this could indicate a growing level of governmental ambition to tackle oil and gas methane emissions.

Finally, it is important to note that the data in Figure 9 cannot fully reflect the level of regulatory advancement in each country, as it misses key factors such as policy robustness, scope, implementation, and enforcement strength. For example, China’s CMM recovery policy has faced numerous implementation challenges over the past decades, including technical difficulties, inadequate infrastructure, and administrative barriers, resulting in unmet targets [100]. Additionally, issues such as manipulation of monitoring devices by coal mine owners to evade penalties have been found to be common [100].



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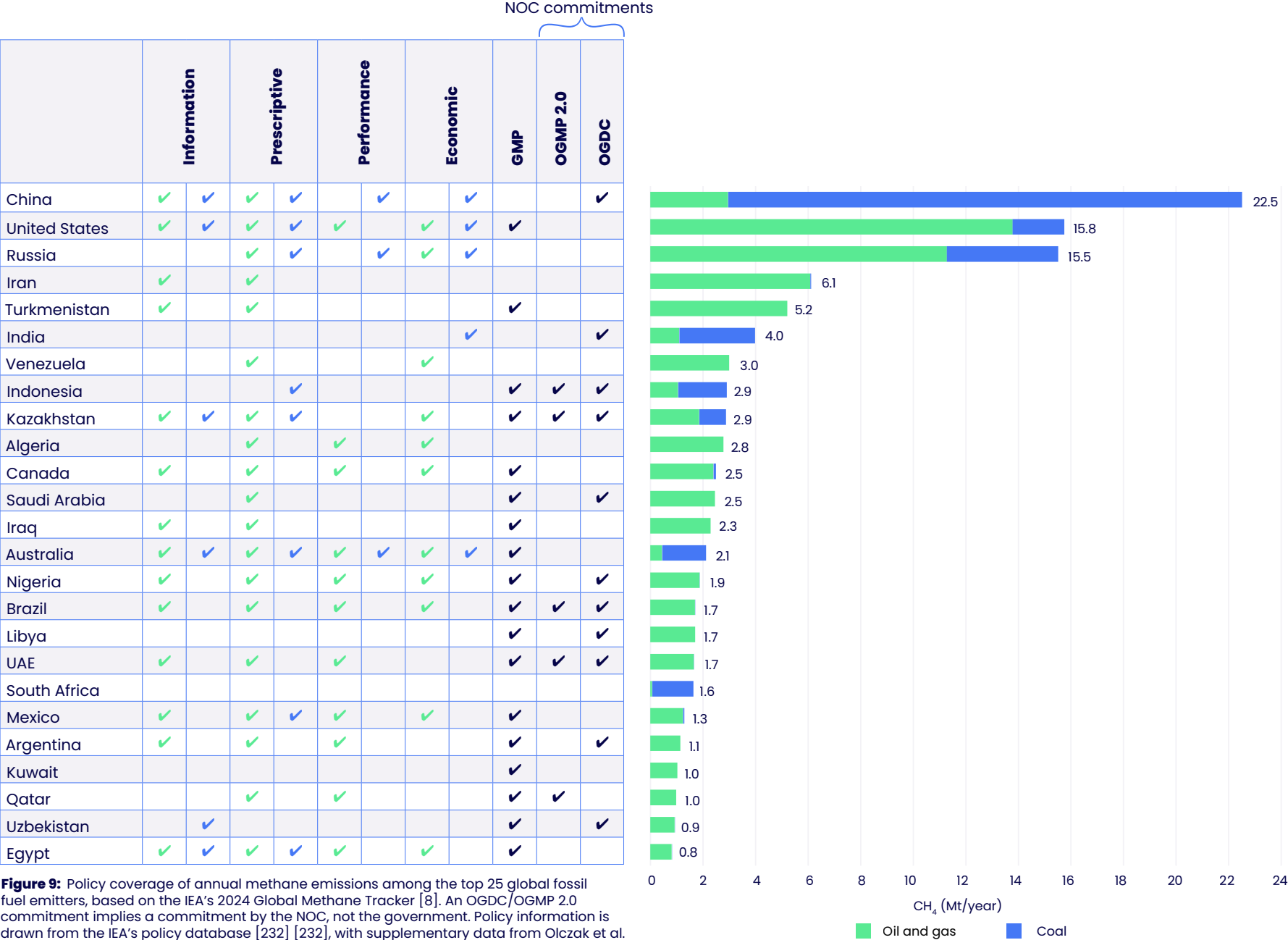
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Figure 9



**Figure 9:** Policy coverage of annual methane emissions among the top 25 global fossil fuel emitters, based on the IEA's 2024 Global Methane Tracker [8]. An OGDC/OGMP 2.0 commitment implies a commitment by the NOC, not the government. Policy information is drawn from the IEA's policy database [232] [232], with supplementary data from Olczak et al. [76] and the Global Methane Pledge [235].



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Satellite retrievals, in conjunction with measurement-based estimates of emissions, could offer a powerful oversight tool for governments to track compliance and policy effectiveness. An example is the EU's ambition to develop a satellite-backed global emissions monitoring tool, as part of its recent Methane Regulation Proposal (**Box 1**).

### Box 1: EU Methane Regulation

On 27 May 2024, the Council of the European Union granted final approval to the EU Methane Regulation, as part of the "Fit for 55" legislative package that seeks to cut the EU's GHG emissions by 55% by 2030 compared to 1990 levels [252; 267; 266].

Expected to take effect later in 2024, the law imposes source-level MRV requirements for the oil, gas and coal sectors, covering operating as well as closed, inactive, plugged and abandoned assets [253; 81]. Proof of no emissions will be necessary for inactive, plugged and abandoned oil and gas wells. While the European Commission prepares its official reporting methodology, it requests that operators use OGMP 2.0 technical guidance and reporting templates [268].

Technology requirements for oil and gas operators include regular LDAR inspections and an immediate halt to venting and flaring, except in the case of emergencies or equipment malfunctions [252; 268]. For coal, the regulation will ban routine venting and flaring from drainage stations by 2025 and from ventilation shafts by 2027, enforce venting thresholds for thermal coal mines starting in 2027, and prohibit all venting and flaring from closed and abandoned mines by 2030 [268]. A venting threshold for coking coal will be determined within three years of the regulation's entry into force.

The regulation also tackles emissions beyond the EU's borders. Beginning in January 2027, importers will be required to comply with the regulation's MRV criteria and meet specific methane intensity requirements by 2030.

Emissions data and information on methane measurement and reduction efforts will be publicly accessible through a transparency database, country- and company-specific methane performance profiles, and a global monitoring tool and rapid reaction mechanism for super-emitting events. Altogether, the European Commission suggests these tools will help buyers in the EU to make more informed purchasing decisions [280].

Given the potential reputational risks and, in cases of non-compliance, financial penalties and possible loss of market access, the regulation is expected to have far-reaching consequences worldwide. The EU is a key player in global energy markets, importing over 80% of its oil and gas needs and roughly 17% of the world's natural gas production<sup>18</sup> [77; 224]. Additionally, the upstream methane intensity of the EU's imported gas is estimated to be three to eight times higher than that of its domestically produced gas [225]. This underscores the significant leverage of the block in the global methane mitigation effort, an aspect that is not captured by **Figure 9**, which displays territorial methane emissions.



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<sup>18</sup> Calculation based on Eurostat EU natural gas import data [250] and Our World in Data production statistics [234].



# 5. Tackling methane emissions from oil and gas operations

## 5.1 Introduction

Estimates of global methane emissions from oil and gas operations vary significantly. As shown in **Figure 8**, the UNFCCC national inventories sum to 38 Mt CH<sub>4</sub> [101], substantially lower than independent estimates using both bottom-up and top-down approaches [7; 12; 102; 103], which vary between 57–98 Mt CH<sub>4</sub>.

We mostly rely here on the IEA's Global Methane Tracker, which offers independent and publicly available methane emissions data. The IEA employs country- and production type-specific emissions factors, adjusted according to local governance and industry characteristics, alongside data from scientific measurement studies and satellite imagery [104]. Given the prevalent lack of measurement-based data at source and facility level, no single database can provide a fully accurate account of all emissions. Therefore, it is crucial to note that the emissions data referenced in this section carry considerable uncertainty.

The IEA estimates total sectoral methane emissions for the year 2023 at around 77 Mt, excluding end-use emissions [7]. When converted to CO<sub>2</sub>e using GWP-100, this represents about half of the oil and gas sector's scope 1 and 2 emissions (**Figure 3**), or three-quarters if using GWP-20. Tackling methane is thus a key lever for the sector to reduce its operational footprint [105].

**Figure 10** illustrates the estimated breakdown of methane emissions in the oil and gas sector among the world's 25 highest-emitting countries according to the IEA. In 2022 and 2023, these nations collectively emitted c. 90% of the sector's global total, with the six highest emitters – the US, Russia, Iran, Turkmenistan, China and Venezuela – accounting for more than half. The figure also reveals substantial variation in methane intensities among these nations (the highest belonging to Turkmenistan) [106].

Emissions also appear to differ substantially between IOCs and NOCs. **Figure 11** shows bottom-up estimates of corporate methane emissions by Global Energy Monitor (GEM), based on emissions factors derived from the IEA Methane Tracker and company-specific production data from the Natural Resource Governance Institute. According to GEM's analysis, the top ten IOCs were responsible for just 13% of global O&G methane emissions in 2021, while their top ten NOC counterparts contributed around one-third (32%) [3].

The outsized proportion of methane emissions from NOCs underscores a hurdle in global methane reduction efforts. Controlling 51% of gas and 58% of oil production globally, these corporations exert substantial influence over industry emission trends [107].

However, their relative isolation from shareholder engagement and stakeholder scrutiny often leads to lower accountability on environmental performance. Additionally, many of these state-owned companies have not joined the OGDC and are based in nations that are not part of the GMP, such as Russia, Iran, Venezuela, and Algeria [107; 108]. We address barriers to investor engagement with NOCs in **Box 2: Strategies for Engaging with NOCs**.

**Key point 12: Global oil and gas production and methane emissions are dominated by NOCs.** Although engagement with these companies is less straightforward than with IOCs, a range of levers exist for investors, including: engagement via IOCs and upstream service providers, banks, importing country governments, and direct engagements with NOCs and NOC governments.



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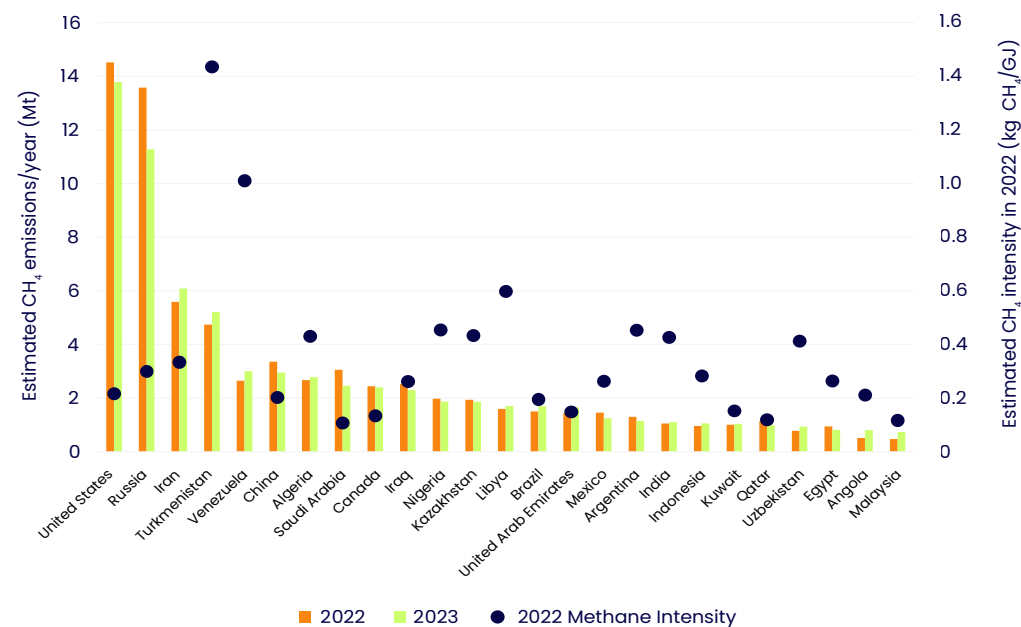
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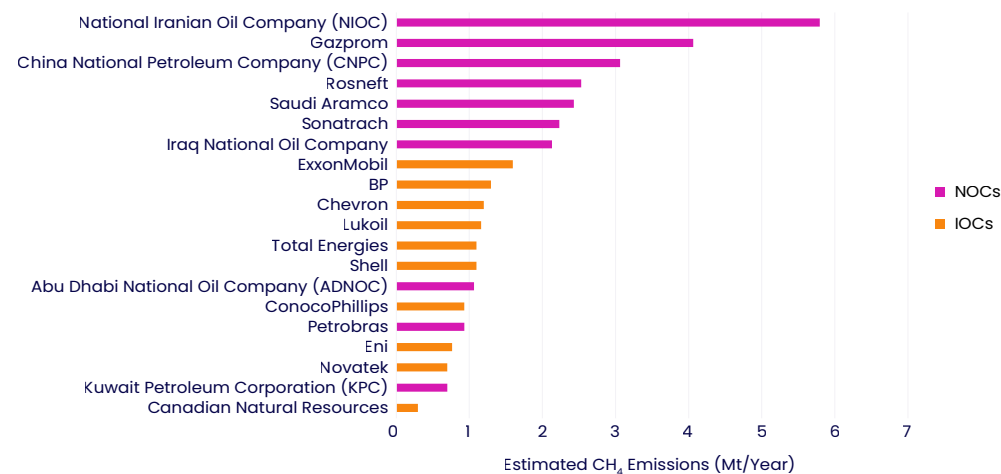
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**Figure 10**



**Figure 10:** Top 25 global methane emitters in the oil and gas sector for the years 2022 and 2023 (figures are estimates and subject to uncertainty). Intensity figures are calculated by dividing total oil and gas emissions over total oil and gas production for the year 2022, the most recent year for which production data is available. Sources: The IEA's 2023 and 2024 Global Methane Trackers [7; 8] for country emissions, and Our World in Data [233; 234] for production statistics [233; 234].

**Figure 11**



**Figure 11:** Estimated methane emissions by the top 10 IOCs and NOCs in 2021, according to Global Energy Monitor data [3]. Note that this is subject to considerable uncertainty.



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## Box 2: Strategies for Engaging with NOCs

Investors have various levers at their disposal to influence methane management by NOCs. These can range from indirect engagement through intermediaries to direct contact with NOCs or their governments.

### A) Direct engagement with NOCs and NOC governments

Investors can directly engage with NOCs where they hold equity stakes or bonds. Over twenty NOCs have publicly traded shares (some are even part of the Climate Action 100+ company focus list) and many more borrow on international debt markets, offering investors a pathway for influence [109]. For example, collaborative engagement under Climate Action 100+ led Petrobras, Brazil's NOC, to join the OGMP 2.0 and OGC's "Aiming for Zero Methane Emissions" flaring monitoring initiative [110]. Sovereign debtholders can also engage directly with NOC governments, who provide a mandate for NOC activities [109; 111]. The possibility of rising borrowing costs for nations with weak climate action make these conversations more pressing [111].

Moreover, investors could utilise innovative financing instruments, such as use-of-proceeds, sustainability-linked, or transition debt to link funding to methane reduction projects or objectives at NOCs [112]. These instruments offer NOCs, often constrained in financing options, access to more affordable capital while addressing transition risks for investors. Though the market for these instruments is nascent, investors can lead by establishing clear guidelines and promoting their adoption.

### B) Engagement via IOCs and other upstream actors

Another means for investors to influence NOCs is via the joint venture relationships between NOCs and IOCs [113; 114; 115]. These are partnerships characterised by shared ownership, governance, and the distribution of risks and profits [113]. IOCs frequently assume the role of "non-operating partners" in joint ventures, holding financial stakes but delegating operational responsibility, including environmental practices, to other partners. According to the Environmental Defense Fund (EDF), non-operated joint ventures (NOJVs) account for roughly **50%** of supermajor equity production, of which **60%** comes from partnerships with NOCs [114].

Just as IOCs derive revenue from these assets, they hold responsibility to manage associated transition risks. As such, shareholders can encourage IOCs to enshrine safeguards and obligations on environmental policies and practices in joint ventures [113; 114]. For a more comprehensive understanding of these pathways of influence, EDF has published several guidelines on the subject, including:

[Emission Omission \(2020\)](#); [Methane Action at National Oil Companies \(2021\)](#); [Catalyzing Methane Emission Reduction at Oil and Gas Joint Ventures \(2022\)](#); [Shared Duty: National, International Oil Companies Bound Together by Methane Obligations \(2024\)](#).

Investors can also engage other upstream actors such as service providers, who deliver consultative advice and technology solutions for upstream operations globally. Given their expertise and pivotal industry role, these providers are well-positioned to influence methane management at NOCs. Investors could ask for transparency on the methane emissions performance of the assets they provide services for and how they support methane emissions reduction efforts. Companies like Schlumberger have taken first steps by joining the "Aiming for Zero Methane Emissions" initiative and launching a new business division to address methane and flare emissions [116].

### C) Engagement with international banks

Banks, an important source of finance for NOCs, can also support improvements in practice [117], including by placing conditions on financing, and using credit and other client relationships to engage on methane management. Mexico's oil-driller, Pemex, released its first sustainability plan in March 2024 after sustained pressure from creditor banks alarmed by a series of accidents, toxic spills and escalating methane emissions [118].

Banks could also facilitate the issuance of KPI-linked or ring-fenced debt to support methane mitigation at NOCs [108]. Investors can engage with banks to encourage them to manage these methane-related risks on their balance sheets and/or business relationships [117].

### D) Engagement with policymakers in importer jurisdictions

Finally, investors could indirectly influence methane management in NOCs by advocating for domestic policies that raise the floor on methane action from importers. Potential policies could be methane border adjustments or methane procurement standards [119]. Investors can draw from previous policy engagement efforts, such as a 2021 letter to the Biden Administration by investors representing \$6.23 trillion AUM, which provided a platform for investor input into the administration's revision of federal methane regulations [120].



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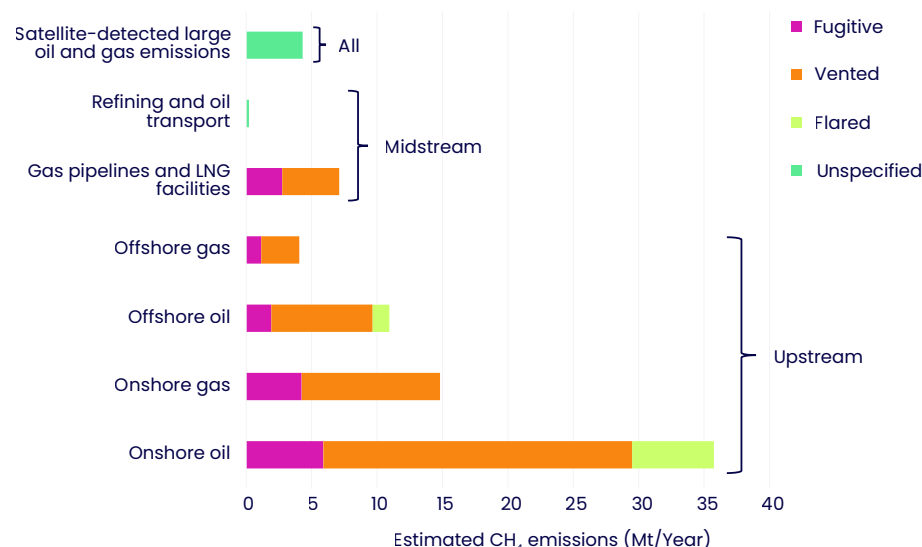
## 5.2 Origin of oil and gas methane emissions

Since methane makes up around 70–95% of natural gas – the remainder being ethane, propane and other heavier hydrocarbons – emissions can occur throughout the entirety of its value chain [121; 122; 123; 124]. In crude oil value chains, methane emissions occur during oil extraction and processing due to the frequent association of gas deposits with oil reserves [125; 126].

**Figure 12** displays the IEA’s estimates of the breakdown of methane emissions across segments of the oil and gas sector globally [8]. The upstream segment appears to be the sector’s primary origin of methane emissions, responsible for above 80% of the total. The majority of these emissions are linked to oil production, while midstream emissions seem to be almost exclusively associated with natural gas and LNG infrastructure.

Across segments, current satellite detection of individual large leak events, or “super-emitters”, is relatively low (6%), although this proportion may rise with advancements in satellite data acquisition and processing [127; 77]. Instead, emissions are largely related to venting (approximately 64% of the sector’s total) – this refers to the deliberate release of waste gas streams for design or safety reasons [37; 7]. Around 20% of emissions are fugitive, arising from unintentional leaks caused by leaky or malfunctioning equipment.

**Figure 12**



**Figure 12:** Oil and gas methane sources per segment. Using data from the IEA 2024 Global Methane Tracker [8] but excluding end-use emissions (approximately 3% of total emissions). Chart adheres to SBTi’s segment categorisation of the O&G value chain (upstream, midstream, downstream) [236].

An additional 9% of the sector’s total emissions is estimated to come from incomplete flaring during oil production, where gas is burned off and releases CO<sub>2</sub> rather than CH<sub>4</sub>. However, this combustion to CO<sub>2</sub> is rarely complete, allowing some methane to escape. Worse, flares are sometimes active but unlit, resulting in venting. Recent research indicates a significant underestimation of methane emissions from flaring, with actual emissions in major US gas-producing areas being five times higher than government estimates, and flaring efficiency recalculated to around 91%, markedly lower than the previously widely assumed 98% [128; 129].

A few caveats to **Figure 12** are worth highlighting. The IEA Methane Tracker does not include emissions from inactive and abandoned wells, which are understudied but could be significant in areas with a long history of energy development [130; 77]. One study estimated such wells contribute to 5–8% of total anthropogenic methane emissions in Pennsylvania [131].

Additionally, the chart’s global breakdown of emissions by segment and type does not show regional and basin-level variations. Recent research highlights significant variability in emissions sources depending on these factors [132; 133].

Lack of harmony and clarity in emissions classification protocols add to the confusion. Several studies highlight that conflicting definitions and difficulties in differentiating between fugitive and vented emissions from components like storage tanks and pneumatic equipment can skew inventory results [67; 134; 135].



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Similarly, it is difficult to distinguish routine flaring, which occurs during normal operations due to inadequate gas reinjection, offtake, or on-site utilisation facilities, from non-routine flaring caused by unusual conditions like maintenance or emergencies [136; 137]. The IEA estimates that ending non-emergency flaring by 2030 would cut flaring volumes by 95%, yet only 30% of flaring reported to the World Bank's Zero Routine Flaring (ZRF) Initiative is labelled as routine, with substantial inter-company variations [138].

Misclassification could hamper abatement efforts, as the distinct emission sources have distinct solutions (see [Section 5.4 Mitigation approaches](#)) [67; 135].

**Key point 13: Globally, methane emissions from oil and gas are concentrated in upstream operations and in natural gas transmission and distribution networks.** However, depending on a company's asset locations and operational context, the nature of emission sources under their scope (and suitable mitigation strategies) will vary.

## 5.3 Status of methane emissions reporting and target setting

The rise of regulatory advancements globally has made the accurate monitoring and disclosure of methane emissions essential for investors, as part of understanding company exposure to methane emissions-related transition risks [139].

As of May 2024, membership of the leading oil and gas methane reporting framework, the IMEO's Oil and Gas Methane Partnership (OGMP 2.0) stands at 140, up from 62 in 2020 [140] [45; 141]. Its "Gold Standard" rating approves oil and gas companies that have robust implementation plans to reconcile source- and site-level measurements (Level 5) on:

- **Operated assets** within 3 years from sign-on
- **Non-operated assets** within 5 years from sign-on [46]

As of 2023 reporting based on 2022 data, 84 of these members, including industry majors such as Shell, TotalEnergies, and bp, were on track to meet the "Gold Standard" in reporting as per OGMP 2.0's timeline.

However, despite representing about **34%** in global oil and gas production in 2023, OGMP 2.0 members reported only **2%** of the IEA's estimated total sectoral emissions that year. While it is plausible that OGMP 2.0 members operate at lower methane intensities than their non-member counterparts, the magnitude of this discrepancy could suggest significant underreporting, as acknowledged by IMEO in its 2023 OGMP 2.0 report [45].

This underestimation of methane emissions is not surprising, given that the average emissions-weighted reporting levels (see [Section 3.3](#) for definitions) by companies in the OGMP 2.0 are 3.1 and 2.5 for operated and non-operated assets, respectively [45]. A reliance on generic emission factors remains the norm. These figures include new members, partially obscuring the progress made by longer-standing participants. For instance, according to the initiative, the share of upstream emissions from operated assets at level 4 rose from 3% in the first year to 45% in the second year [46].

As companies progress into measurement-based reporting, disclosed methane emissions are likely to rise. One OGMP 2.0 member recently indicated that reported methane emissions rose 2.3 times when it moved to level 4 from level 3 [45]. The profile of its reported emissions also changed, with incomplete combustion from flaring going from being one of the smallest contributions to the largest.

This likely widespread underreporting is important to bear in mind when considering corporates' disclosures and targets.

Methane intensity has become a preferred method for communicating emissions performance [142]. Among OGMP 2.0 upstream oil and gas companies, 76% have set intensity targets, usually aiming for the **0.2%** by 2025 intensity target set by OGCI, an alliance of eight IOCs and four NOCs [45]. This target has become a benchmark for upstream companies, with initiatives like OGMP 2.0, OGDC and the World Bank's GMFR promoting "near zero" or "well below 0.2%" methane intensity targets by 2030 [73; 143; 144; 145].

As [Figure 13](#) shows, numerous companies report having already passed their intensity performance targets. A notable example is the OGCI alliance, which reported having achieved a collective average methane intensity of **0.17%** in 2022, exceeding the 0.2% target well in advance of the 2025 deadline [143] [143].



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Given the absence of comprehensive measurement-based reporting and the exclusion of non-operated assets from such targets – sometimes exempting up to 65% of production [113] – such disclosures should be treated with caution. For comparison, the IEA’s estimate of global mean methane intensity is **2.5%**, using the same calculation methodology as OGCI [105].

Disclosures from individual companies also reveal uncertainty in their reported figures. bp reported a methane intensity of 0.05% in 2023, well below its 0.20% target [146]. However, the company conceded this will be revised as measurement accuracy improves, planning a new baseline for a 50% intensity reduction target post-2025 [147]. Similarly, Shell described its 2022 methane intensity figure as an “estimate only”, citing ongoing measurement challenges [148].

Intensity reduction targets also offer significant room for manoeuvre, concealing effects from acquisitions or production changes. Companies with growing production will be less likely to reduce total methane emissions, even if their intensity drops. Notably, of the industry majors assessed in this section, only TotalEnergies has absolute methane emissions reduction targets, aiming for cuts of 50% and 80% by 2025 and 2030, respectively, based on 2020 levels [149].

**Key point 14: Until companies establish credible, measurement-based reporting methods (i.e. OGMP 2.0 level 5) across operated and non-operated assets, emission disclosures and reported performance against targets should be treated with scepticism.** This is perhaps most important with respect to intensity targets, which can obscure the effects of acquisitions or production changes.

**Figure 13**



**Figure 13:** Methane intensity targets for selected O&G majors and most recent reported emissions intensities. “Near-zero by 2030” targets (Shell, TotalEnergies, Equinor, Eni) are shown here as 0.2%. Sources: Shell [270], TotalEnergies [271], bp [272]; Equinor [273]; Chevron [274]; ConocoPhillips [275; 176]; Repsol [276]; Occidental Petroleum [277]; OMV [278]; Eni [279].

The variety of methods for calculating methane intensity, some of which are shown in **Table 5**, complicates the interpretation of intensity targets [142]. For example, Occidental reported an intensity of 0.26% using OGCI’s methodology, but 0.13% when applying NGSI guidelines [150]. The OGCI method excludes oil production from its calculation, despite including methane emissions from oil. While this approach encourages the marketing of associated gas and offers insights about the extent of gas wasted through flaring or venting, it can distort the perceived intensity of oil-focused companies.

Company disclosures frequently suffer from a lack of clarity regarding the choice of calculation method, conversion factors and measurement units. Additionally, reporting company-wide intensity figures alone can obscure variations in performance across different segments, basins, and products. This could hinder investors’ ability to meaningfully compare the methane performance of similar operators.

Along with company-wide intensity figures using the same boundary for numerator and denominator, we recommend disaggregating disclosures of methane emissions by segment, basin and product, in alignment with financial reporting. Additionally, all aspects of the calculation methodology should be transparently disclosed.

**Key point 15: To enable fairer and more accurate comparisons, companies could disclose both aggregate (corporate-level) and disaggregate (segment-, basin- and product-level) methane emissions intensities, aligning with financial segmentation.** This should be accompanied by full transparency on the calculation method, including the numerator, denominator, measurement units, and conversion factors used.



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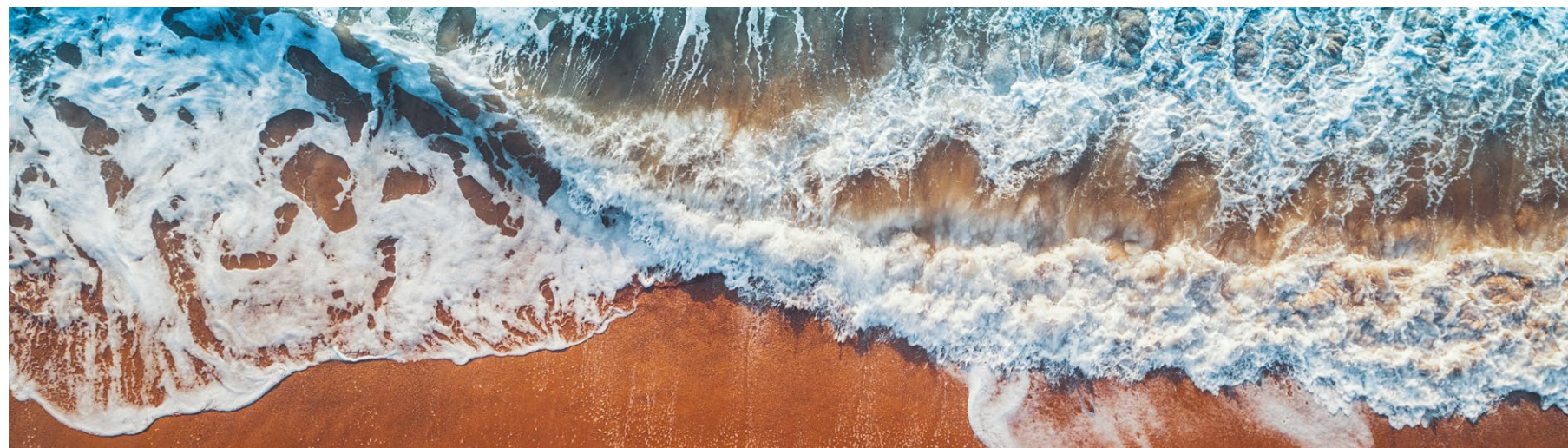
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**Table 5**

Organisation	Intensity target	Scope	Intensity calculation methodology
OGCI/OGDC	≤0.20% by 2025/2030	Operated upstream oil and gas assets	$\frac{\text{Upstream oil and gas emissions (Sm}^3\text{)}}{\text{Marketed natural gas (Sm}^3\text{)}}$
Natural Gas Sustainability Initiative (NGSI)	Methodology only	U.S. up- and midstream natural gas assets (incl. oil wells producing gas)	$\frac{\text{Total segment/facility emissions from natural gas (t)} * \text{Gas Ratio}}{\text{Natural gas throughput (Mcf)} * \text{CH}_4 \text{ content (\%)} * \text{CH}_4 \text{ density}(\frac{\text{t}}{\text{Mcf}})}$
One Future Gas Coalition	Value chain segment-specific intensity goals, with a collective target of ≤1% by 2025	Operated U.S. up- and midstream natural gas assets (incl. oil wells producing gas)	
MiQ	≤2.00% to ≤0.05%	Global up- and midstream natural gas assets (incl. oil wells producing gas)	
IEA (NZE)	0.5% by 2030 for natural gas; 0.3% by 2030 for oil	Global oil and natural gas supply chains	$\frac{\text{Total natural gas or oil emissions (kg)} * \text{CH}_4 \text{ energy density}(\frac{\text{EJ}}{\text{kg}})}{\text{Global marketed natural gas or oil production (EJ)}}$

**Table 5:** Methane Intensity Targets and Calculation Methodologies According to Industry Guidelines. One Future, MiQ and NGSI methodologies include the use of company-specific gas ratios for co-produced gas volumes. Note that Sm<sup>3</sup> represents a Standard Cubic Meter, denoting the amount of natural gas occupying one cubic meter under standardised temperature and pressure conditions [151]. Sources: IEA, 2023 [105]; OGCI, 2023 [151]; NGSI, 2021 [152]; M.J. Bradley & Associates, 2018 [153]; One Future, 2017 [154]; One Future, 2023 [155].



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## 5.4 Mitigation approaches

Oil and gas methane emissions reductions will be achieved through a combination of:

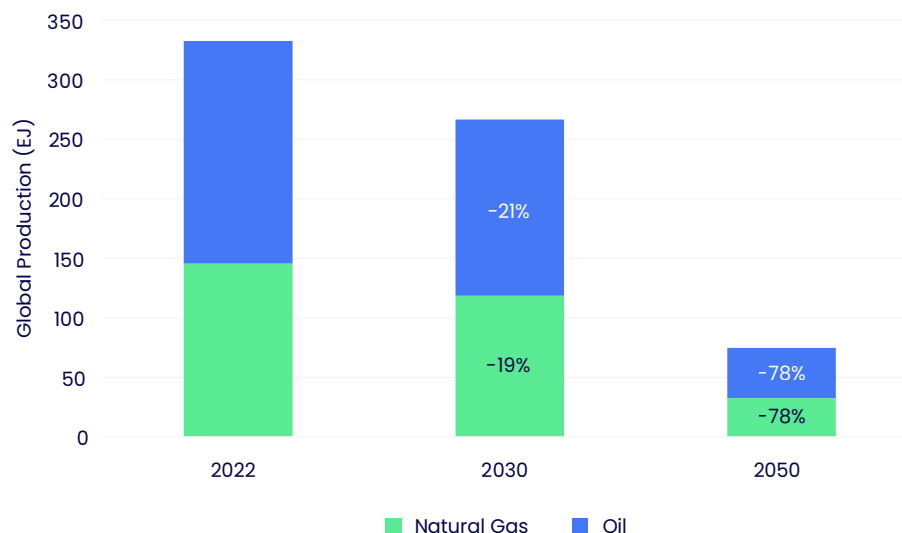
- **Decreasing production** of oil and gas
- **Reducing methane intensity** of oil and gas operations

In the IEA's NZE scenario, methane emissions from natural gas and oil drop by approximately 61% and 81% by 2030, respectively [156]. Production declines (**Figure 14**) account for approximately one-third of the overall reduction, with the remaining 70% achieved through the implementation of established and cost-effective mitigation technologies [157].

From 2024 to 2030, the required annual investment for these abatement efforts is projected to be \$14.4 billion, with an 80–20% split between capex and opex respectively [8]. For context, this figure represents 5% of the combined 2023 net income of the world's ten largest oil and gas companies [158–167].<sup>19</sup>

Comparing abatement costs to the value of the captured methane using average gas prices in 2023 suggests that up to 50% of methane emissions could have been mitigated at no net cost [8]. Even without a market for the captured gas, an emissions price of \$20 per tonne CO<sub>2</sub>-equivalent would make nearly all mitigation measures financially viable [156] – this is markedly below the US's methane fee of \$900–1,500 per tonne of methane (\$36–60/tCO<sub>2</sub>e) for facilities emitting over 25 ktCO<sub>2</sub>e a year [168; 86; 87].

**Figure 14**



**Figure 14:** Oil and gas production in the NZE [156]. Percentage declines are relative to 2022.

Effective methane mitigation starts with clearly defined emissions sources, requiring protocols that differentiate between unintended (fugitive) emissions and engineered emissions from flaring and venting, as well as routine and non-routine events. This can be supported by detailed inventories of flaring- and venting-related equipment [127]. For fugitive emissions, leak thresholds should be set below regulatory requirements to ensure a margin of safety [169].

As shown previously in **Figure 12**, the IEA estimates that the majority of oil and gas methane emissions occur due to venting [7]. Some key strategies and examples to reduce venting-related methane emissions are:

1. **Replacing high-emission devices**, such as natural gas driven pneumatic equipment, with zero emissions equipment that runs on clean power sources instead of natural gas pressure or uses closed loop systems [170; 127; 171]. Similarly, wet seals in centrifugal compressors are known to heavily absorb and vent methane but can be easily replaced by dry seals [170; 172].

2. **Process alterations:** Replacing traditional methane venting during oil extraction with efficient plunger lifts, which extract petroleum without releasing methane [65]. In the natural gas sector, mitigating emissions from dehydrator venting, a process crucial for maintaining pipeline integrity, can involve installing flash tank separators and optimising glycol circulation in dehydration systems [170; 173].
3. **Excess gas recovery and utilisation:** Utilising “vapour recovery units” (VRUs) to capture and pressurise hydrocarbon vapours can enable their redirection into pipelines for commercial or onsite use, reducing emissions while maximising resource utilisation [172; 170]. Where immediate market distribution is not possible, capturing and transporting gas for storage is another viable option [174; 157]. Effective communication between producers and midstream partners is crucial to prevent mismatches between production and takeaway capacity caused by infrastructure delays or operational disruptions [136; 139].

<sup>19</sup> The 10 largest oil and gas companies as of May 2024, based on market capitalisation: Saudi Aramco, ExxonMobil, Chevron, PetroChina, Shell, TotalEnergies, CNOOC, BP, Sinopec, and Petrobras.



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**Flaring**, which partially converts CH<sub>4</sub> into CO<sub>2</sub> through combustion, is another alternative to venting [175; 172; 125]. However, in addition to incomplete combustion, flaring is a significant source of CO<sub>2</sub> and pollutants that are harmful to human health [157; 170; 128]. Flares are also energy intensive to keep lit, especially at times of low flow. Therefore, committing to the World Bank's ZRF by 2030 pledge is a crucial early measure to take. Many may get there sooner, with companies like Shell, ConocoPhillips and Eni targeting ZRF by 2025 [148; 176; 177].

Like venting, flaring can be avoided by increasing the capture of excess or associated gas for onsite utilisation, market distribution or storage [174; 157]. Where flaring cannot be avoided, operators should ensure that flares remain lit and are equipped with automatic re-ignition mechanisms [129; 178]. Additionally, operators should balance flare capacity with gas production levels to avoid overload.

**Fugitive emissions** can be managed through LDAR programmes [179; 175]. These involve identifying and fixing leaks throughout the supply chain, employing a variety of techniques detailed in [Section 3.4 Measurement techniques](#) [69]. Frequent inspections are crucial for the early identification and repair of major and unpredictable emission sources, especially super-emitters [172; 127].

A credible LDAR programme sets explicit requirements for repair actions and timelines and covers all segments and assets, including inactive or abandoned wells, with regular inspections of known high risk sources like venting equipment and flares [139].

**Key point 16: A comprehensive methane mitigation plan in oil and gas tackles vented, flared, and fugitive emissions, clearly differentiating between them.**

It commits to zero-routine flaring and minimising routine flaring, incorporates advanced LDAR programmes covering all assets, and continuously improves process and equipment efficiency.

Mitigation options for abandoned and unused wells include gas recovery and usage, flaring, and plugging without vents [180].

Effective methane abatement relies on multiple conditions being met. Investment decisions that will reduce flaring or venting, for example, often rely on policies promoting the productive use of associated gas or the availability of export infrastructure [174; 77]. Additionally, lack of human resources and capital may hinder companies from pursuing abatement projects, despite the potential positive returns from selling captured gas [127].

Differences in these situational factors contribute to the high regional diversity in methane emission intensities, shown in **Figure 10**. For instance, research has attributed the high methane intensity in Turkmenistan to obsolete equipment causing leaks and excessive venting, while Algeria's high flaring volumes are linked to inefficient gas transport and processing infrastructure [106].

Addressing such barriers requires targeted support, particularly in economies where financial and technical resources are more constrained [108]. The World Bank's GFMR Partnership, which has obtained a \$250 million grant for methane reduction in low- and lower-middle-income regions, marks a notable milestone [181]. Nonetheless, substantial additional efforts will be needed to meet the estimated \$15–20 billion investment gap in these geographies through to 2030 [178; 182].

As well as financial resources, assistance can be delivered as technical support, such as the collaboration between US technical experts and Turkmenistan's state-owned company officials to improve the country's methane management practices [183]. Well-resourced sector peers can also contribute, as seen in TotalEnergies' memorandum with Nigerian National Petroleum Corporation (NNPC) to enhance the company's methane detection and measurement capabilities [98]. Additionally, voluntary industry initiatives such as the Methane Guiding Principles (MGP) and OGMP 2.0 enable members to pool resources and expertise to tackle shared challenges [114].

**Key point 17: Cost-effective methane abatement depends on factors like regulatory and financial capacity, infrastructure development, global market integration and local know-how.** This highlights the need for focused project support and funding in low- and lower-middle income economies, from both private and public entities.



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## 5.5 Assessing methane targets

Setting a target on methane emissions signals an intent to take action. Investors want to understand the level of ambition of company targets with respect to climate goals, and if these targets are credible. There are therefore two key considerations:

- Can the company set an ambitious target on methane emissions?
- Can the company commit to high-quality measurement and reporting (i.e. OGMP 2.0 level 5) to support the credibility of its target?

Here we consider two types of targets, and their relationship to the IEA's headline figure of **-75%** methane emissions from all fossil fuels by 2030.

Beyond these methane targets, investors will also want to consider a company's scope 3 targets and production guidance for a fuller sense of the transition risks associated with an oil and gas company.

### Intensity targets

As noted in **Section 5.3**, aiming for a specific methane intensity of production is a common formulation for targets within the oil and gas sector, with 76% of upstream oil and gas companies in the OGMP 2.0 setting their targets in this form [45].

In recent years, a "near-zero" methane emissions target, popularised by OGCI and OGDC, has gained traction. The target is generally defined as oil and gas methane emissions over marketed gas equalling less than 0.2%. One important issue with this formulation is the inconsistency between the boundaries used in numerator and denominator.

Some companies target 0.2% by 2025, and others by 2030. The question then arises: are these targets sufficiently ambitious to be considered aligned with the IEA's NZE?

The IEA's NZE methane intensity pathways<sup>20</sup>, using global production and methane emissions estimates, are as follows [105]:

- **Gas:** 1.4% in 2022, falling to 0.5% in 2030 (tCH<sub>4</sub> from gas / tCH<sub>4</sub> marketed gas)
- **Oil:** 1.3% in 2022, falling to 0.3% in 2030 (tCH<sub>4</sub> from oil / TJ marketed oil)

The OGCI/OGDC "near-zero" formulation, combining gas and oil emissions in the numerator and dividing by only marketed gas, is not directly comparable to these percentage figures. The formulation favours producers with large gas business, and disadvantages predominantly oil producers. Nonetheless, by comparison with the gas pathway above, and recognising that including oil methane emissions in the numerator would increase the value of the intensity figure, we can conclude that a near-zero/0.2% by 2025 or 2030 target is aligned with the global NZE pathway. Crucially, performance against this is only as credible as the supporting MRV practices.

Greater comparability is offered by using intensity figures with the same boundaries in numerator and denominator. The IEA definitions above could be used for separated oil and gas targets. Alternatively, intensity targets could be stated in kgCH<sub>4</sub> per TJ product.

For targets of this form, global pathways from the IEA NZE are as follows<sup>21</sup>:

- **Gas:** 257 kgCH<sub>4</sub>/TJ in 2022, falling to **61 kgCH<sub>4</sub>/TJ** in 2030
- **Oil:** 193 kgCH<sub>4</sub>/TJ in 2022, falling to **93 kgCH<sub>4</sub>/TJ** in 2030

20 Here natural gas methane intensity is total methane emissions from gas supply divided by global marketed gas production. Methane intensity of oil is the energy content of methane emissions from oil supply divided by the energy content of oil production.

21 Using oil and gas production data in 2022 and NZE figures for 2030 from WEO 2023 [222], and 2022 methane emissions and NZE figures for 2030 from GMT 2024 [8].

As these figures represent global pathways, leaders should be expected to pursue significantly lower trajectories. Similarly, where companies are already reporting lower methane intensities than stated in the NZE pathways, they are rendered of little use in galvanising further action.

One important consideration in comparing companies on an intensity basis is that different companies have different volumes of activities in upstream and midstream operations, as well as between oil and gas as separate products. This can be important for the initial magnitude of emissions and methane intensity, as well as the abatement potential (**Figure 12**).

The credibility of a company's performance against stated targets depends on the quality of MRV they are employing. However, even where companies are not currently reporting to a high standard, an intensity target provides a goal that is robust to the annual changes in measurement and emissions that will occur while companies simultaneously pursue abatement actions and measurement-based reporting.

It should be noted that a methane intensity target puts no constraint on production—a vital indicator for alignment with climate goals more broadly.

**Key point 18: Oil and gas intensity targets should be stated with a consistent boundary for numerator and denominator, to enable fair comparisons across companies and be physically most meaningful.** While the OGCI and OGDC target of "near-zero" or below 0.2% methane intensity by 2030 uses inconsistent calculation boundaries, it can nonetheless be considered aligned with methane intensity in the NZE, providing it is simultaneously supported by a progression towards high-quality measurement and reporting (OGMP 2.0 level 5).



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## Indexed absolute emissions targets

Companies may also target a particular % reduction in absolute methane emissions against a particular baseline. Such targets can be met through contributions from both methane abatement (which reduces methane intensity) and reduced production.

In considering whether or not such targets are aligned with climate goals, we can derive benchmarks from the IEA's NZE scenario.

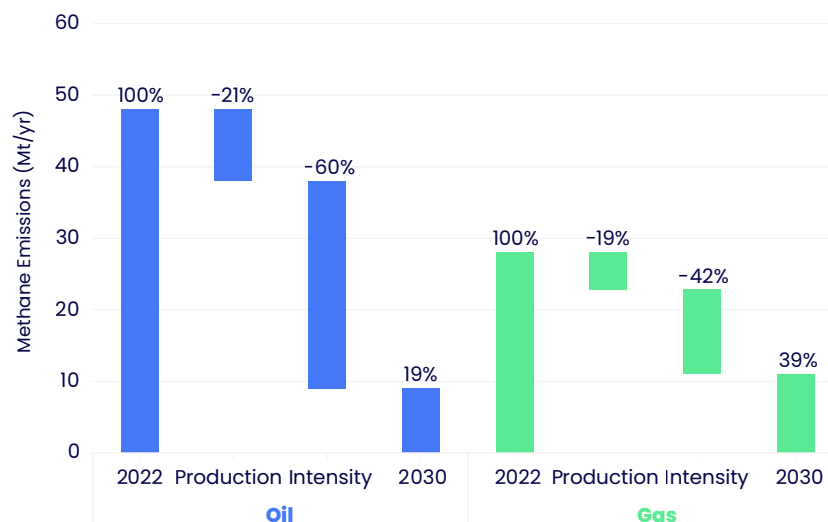
In the IEA's NZE, the headline figure of **-75%** methane emissions from all fossil fuels by 2030 versus 2022 involves declines in methane emissions of **81%** from oil and **61%** from gas, per the GMT 2024. In the NZE, these contributions are delivered by declines in both production and methane intensity of production, as shown in **Figure 15**.

Companies that commit to production declines in line with the NZE pathway (**Figure 15**) would need to target methane intensity reductions of **76%** and **52%** in oil and gas respectively, by 2030, in order to meet the NZE's methane reductions. Companies pursuing higher production levels than this would need correspondingly steeper intensity declines to meet the NZE benchmark (though these companies may still be considered misaligned on a scope 3 CO<sub>2</sub> basis).

While these global benchmarks can help investors understand what is required of companies as a whole, their usefulness for assessing company targets is limited by several factors.

Firstly, the approach neglects the extent to which corporates have already pursued emissions reduction efforts prior to the base year, and how their starting methane performance compares. In short, laggards who have taken very little action thus far may find it easier than leaders to meet the same percentage reduction, as they have more remaining levers at their disposal.

**Figure 15**



**Figure 15:** Declines in methane emissions between 2022 and 2030 from oil and gas operations in the NZE. In this scenario, total reductions are driven by a combination of declines in production and methane intensity. Based on Global Methane Tracker 2024 [8] and WEO 2023 [156].

In addition, due to interannual variability in methane emissions, a base year might be unusually high or low. Further, indexed reductions allocate greater emissions rights to higher historical emitters – this is known as the ‘grandfathering’ of emissions rights, a pragmatic approach but also one that raises fairness issues [185; 186]. Finally, reporting methane emissions against an indexed target does not give investors a good sense of current performance against peers, whereas intensity metrics can offer that parity when supported by high-quality reporting.

A potential complication in using indexed targets is that, until a company has high-quality reporting in place, it may struggle to establish a credible methane emissions baseline. As a company should be encouraged to take abatement action *while* improving measurement practices, re-baselining might be necessary – on the basis of improved calculations – to track progress as accurately as possible, and remove the perverse incentive against expanding direct measurement efforts once an indexed target is in place.

**Key point 19: In the NZE, methane emissions decline by 81% and 61% by 2030 in oil and gas, respectively, against 2022 levels.** Companies stating their methane targets in terms of indexed % reductions can be compared against these benchmarks. Investors should be cognisant of the different starting points of companies, and the possible need for re-baselining of emissions as measurement and reporting practices improve.



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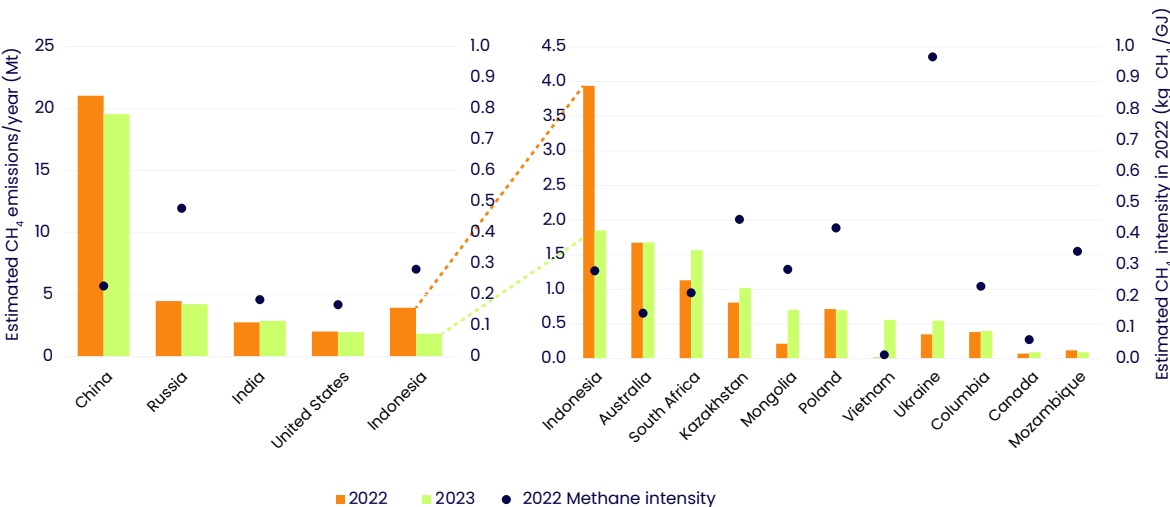
## 6.1 Introduction

Coal mine methane emissions comprise roughly one third of methane emissions from fossil fuel operations (**Figure 2**) and dominate coal miners' overall operational emissions (**Figure 3**). Methane emissions can also make up a significant fraction of the operational emissions of diversified miners that hold coal assets [187].

Estimates of global coal mine methane emissions vary. Countries report methane emissions to the UNFCCC; these national inventories sum to a global figure of **30.5 Mt**. As shown in **Figure 8**, other estimates yield higher numbers: recent top-down/hybrid studies put annual global emissions at 33 Mt, Shen et al. [62]; 40 Mt, IEA [8]; while an independent bottom-up assessment from GEM yields 52 Mt (though this does not include mitigation efforts) [188].

**Figure 16** shows the IEA's country-level methane emissions estimates for the 15 highest emitting coal producers (representing 94% of global coal methane emissions). These exclude emissions from abandoned mines, which may become increasingly significant in relative and absolute terms as mines are retired [189]. Ember estimates that abandoned mine methane emissions add 7 Mt to the IEA's total [190].

**Figure 16**



**Figure 16:** Estimated coal mine methane emissions in highest emitting 15 nations for the years 2022 and 2023. Top five on left; top 5–15 on right. Note that methane emission axis is rescaled, whereas intensity axis (black dots) is the same across both panels. Intensity figures are calculated by dividing total coal emissions by total coal production for the year 2022, the most recent year for which production data is available. Sources include the IEA's 2023 and 2024 Global Methane Tracker [7; 8] for emissions and Our World in Data [239] for production statistics.



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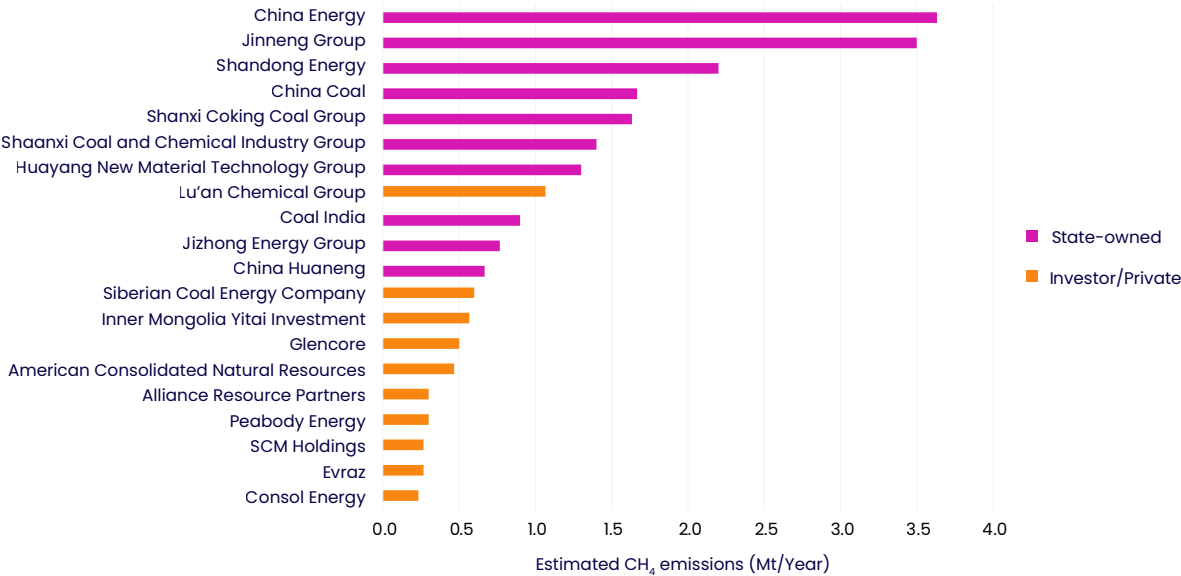


China accounts for roughly half of global coal mine methane emissions, similar to its share of global coal production [191; 62; 192; 188]. Its Shanxi province is the leading regional emitter by a significant margin [191]. According to GEM estimates [188], at the subnational level, the top 15 emitting regions are all Chinese with the exception of: Kemerovo, Russia; Australia's Bowen Basin in Queensland; Mpumalanga, South Africa; New South Wales, Australia; and the Appalachian region of West Virginia, USA.

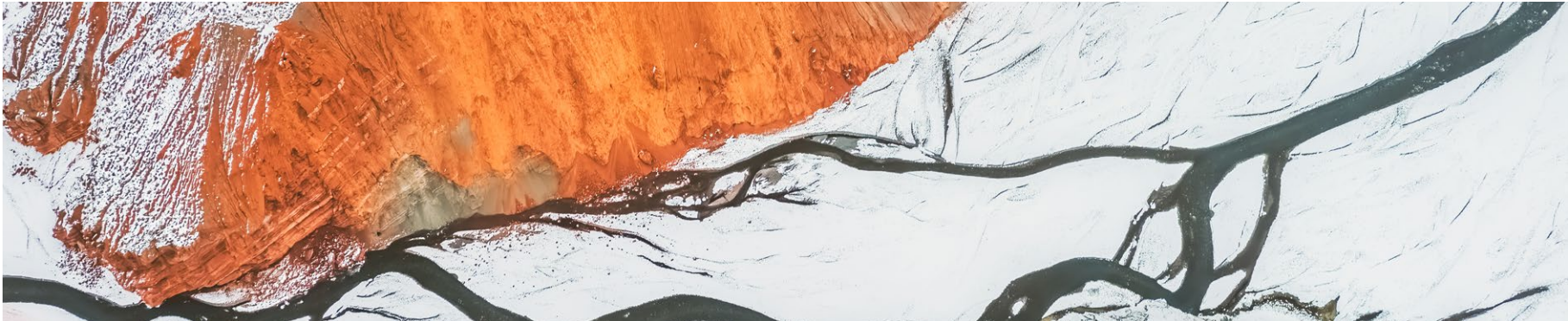
Mirroring this concentration of emissions, GEM reports that the top seven corporate coal mine methane emitters are Chinese state-owned enterprises, as shown in **Figure 17** [3]. Of these, all appear to be majority or entirely owned by national or regional state-owned assets supervision and administration commissions (SASACs), or the Chinese central government. However, some of them (e.g. China Coal, Inner Mongolia Yitai) have listed coal-producing subsidiaries, albeit with limited institutional shareholdings, while Shanxi Coking Coal Group is listed (c. 13% institutional ownership) [193]. Another large state-owned coal company, Coal India, is majority-owned by the Indian government, and c. 27% owned by institutional investors [193].

In contrast, the top ten investor- and privately-owned entities are more geographically distributed in terms of the locations of their headquarters and operations [3].

**Figure 17**



**Figure 17:** Coal mine methane emissions by top ten SOEs and top ten investor-owned companies in 2021, as classified and estimated by GEM [3]. GEM use a bottom-up approach with emission factors based on the MC2M methodology outlined in Kholod et al. [189]. Note that FactSet data suggests Lu'an Chemical Group is state-owned, contrary to classification here.



## 6.2 Origin of methane emissions in coal mining

Methane is produced during coalification, the geological formation of coal from sedimentary rocks rich in plant remains. This process is driven by heating during geological burial, and involves chemical and physical changes.

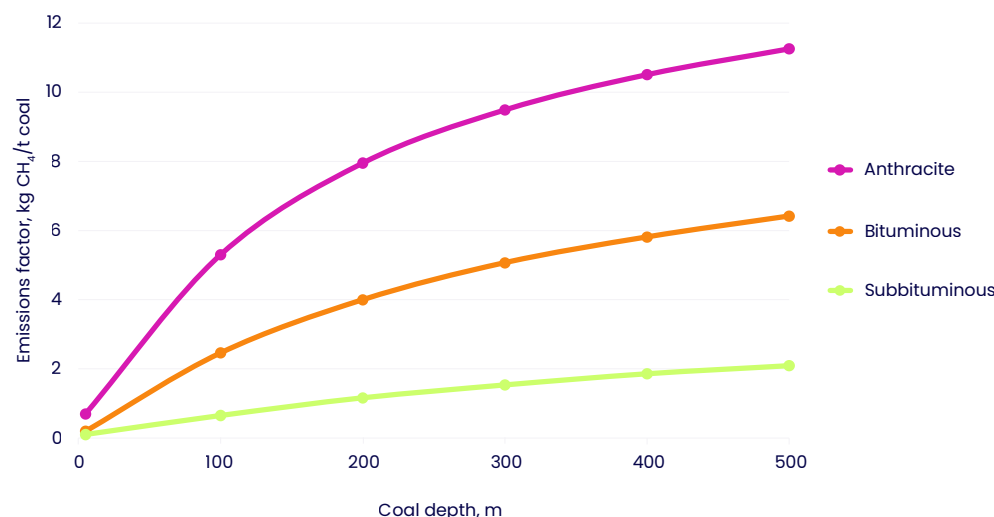
As the buried rock heats up, coalification produces progressively higher grades (or ranks) of coal, and methane is produced as the constituent organic matter undergoes a process called dehydrogenation. Much of this methane is trapped, however, through adsorption<sup>22</sup> to coal grains.

As illustrated in **Figure 18**, two factors are pivotal for the potential methane emissions from a coal mine [189; 194]:

- **Coal rank.** Generally, the higher the rank of coal, the more methane has been produced during burial, and the greater the adsorption capacity of the coal. There is usually therefore more methane available to leak to the surface when the rock is disturbed upon mining [194; 195].
- **Coal depth.** The adsorption capacity of coal also increases with increasing pressure and therefore deeper seams have a higher gas content and yield higher methane emissions upon mining. A near-surface seam can also gradually release methane to the atmosphere through natural fractures in the overlying rock, and therefore have less methane remaining at the point of mining. For these reasons, underground mines are more potent methane emitters than surface mines [38].

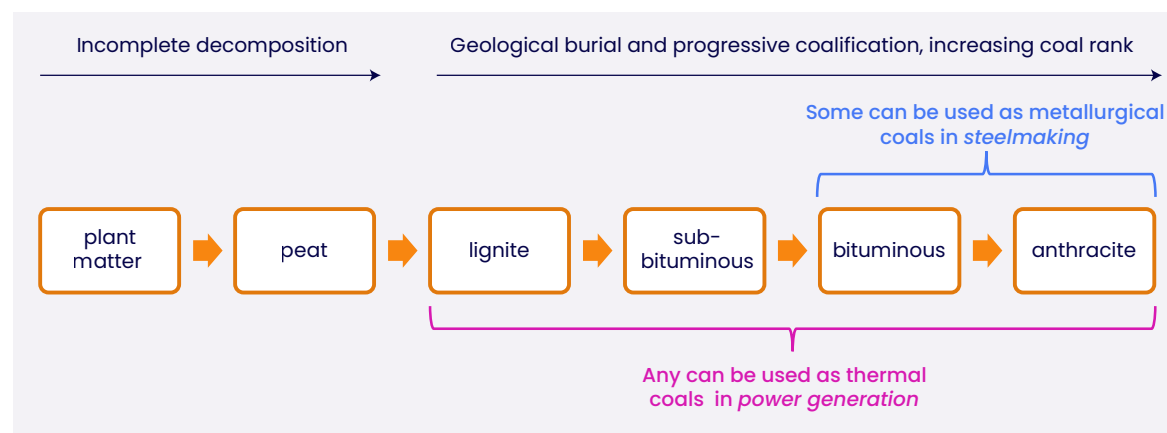
On top of these two factors, methane emissions are determined by the method of mining employed and the quantity of coal mined [194].

**Figure 18**



**Figure 18:** Factors used to predict methane emissions from the MC2M methodology [189; 188]. Methane emissions increase with rank of coal and depth of mining.

**Figure 19**



**Figure 19:** Transition of plant matter to coal grades of increasing rank, from lignite to anthracite [195]. Methane emissions increase with increasing coal rank. Carbon content of coal increases and moisture content decreases with increasing rank.

<sup>22</sup> Adsorption is the process by which molecules of a gas (or liquid) adhere to a solid surface.

When coal is mined, the methane-bearing rocks are depressurised and the gas can escape to the surface. This leakage to the atmosphere can be:

- uncontrolled, through voids and fractures, or direct exposure to the atmosphere in open-cut mines
- controlled, through ventilation air and degasification systems

Metallurgical coals possess particular qualities that make them appropriate for use as a fuel and reducing agent in blast furnace steelmaking. Relative to thermal coals, they are typically higher in carbon, and lower in moisture, ash and sulphur [196; 197]. As there is a correspondence between the rank of a coal and its carbon content, metallurgical coals are typically relatively high in rank, mostly bituminous.

However, not all bituminous coals qualify. Anthracite, a hard, high-carbon coal, is now relatively rare in steelmaking but is still used in specialist applications [197]. In contrast, all coals can be used as thermal coal—though coals suitable for steelmaking usually trade at higher prices (this pattern was disrupted in the 2022 energy crisis following Russia's invasion of Ukraine) [198].

**Key point 20: Coal mine methane emissions are highly variable between mines and depend on coal grade, depth of extraction, mining techniques and production output, as well as any mitigation employed.** Companies have very different methane emissions and intensities according to their mine portfolio.

## 6.3 Status of reporting

Countries report coal mine methane emissions to the UNFCCC using a menu of approaches outlined by the IPCC [37]. In many jurisdictions, corporates report to national governments in line with national regulations informed by these IPCC guidelines. However, the mine-level data that feeds into regional and national inventories is often not disclosed publicly.

According to Ember, 97% of reported coal mine methane emissions are calculated using emission factors (tiers 1 and 2) rather than through direct measurement at mines (tier 3) [190]. In Ember's analysis, Ukraine and Poland are the only two countries to have directly measured the methane emissions from the majority of their coal production. This points to an overwhelming reliance, globally, on highly uncertain emission factors to quantify methane emissions from coal mines.

**Key point 21: Globally, it is the exception rather than the rule that methane emissions reporting is based on high quality direct measurement.**

Coupled with high variability in coal mine methane emissions, this renders corporate reporting highly uncertain.

At underground mines, methane emissions can be measured directly in ventilation air and drainage streams. Measurement at surface mines is more challenging, as the emissions occur over a large area, and are comparatively diffuse [37].

As an example, Australia's National Greenhouse and Energy Reporting (NGER) regulations stipulate a measurement-based approach for underground mines, but accept an emission factor methodology for surface mines (c. 80% of its coal production) [199; 200]. This approach has recently come under criticism [200; 201], after independent satellite-based studies concluded that methane emissions from surface mines in Australia's Bowen Basin in Queensland were being significantly underestimated [202; 203].

In its 2023 review of the NGER legislation, Australia's Climate Change Authority recommended that the government urgently phase out its Method 1 estimation methodologies (use of generic emissions factors) for open-cut coal mining and urgently review its Method 2 (use of emissions factors based on a minimum of three borehole samples) [204]. In this recommendation, it highlighted the fact that a reliance on generic emissions factors provides little incentive for abatement action, as reductions would not be captured in these purely activity-based calculations [204]. The authority's report also detailed the gap from Australia's current NGER scheme to Gold Standard reporting under OGMP 2.0 and SMP, indicating the potential for greater alignment in the future.

Instead of a reliance on emission factors, more reliable quantification of methane emissions from surface mines can be achieved through multi-input models, involving both bottom-up and top-down measurement approaches, coupled with atmospheric data, geotechnical core data (measuring gas concentrations in discrete strata prior to mining), and production data [201]. Specific measurement technologies and monitoring systems that could be used are outlined in [Section 3.4 Measurement techniques](#). Detailed guidance also comes from a UNECE report on the monitoring, reporting, verification and mitigation of coal mine methane [205].



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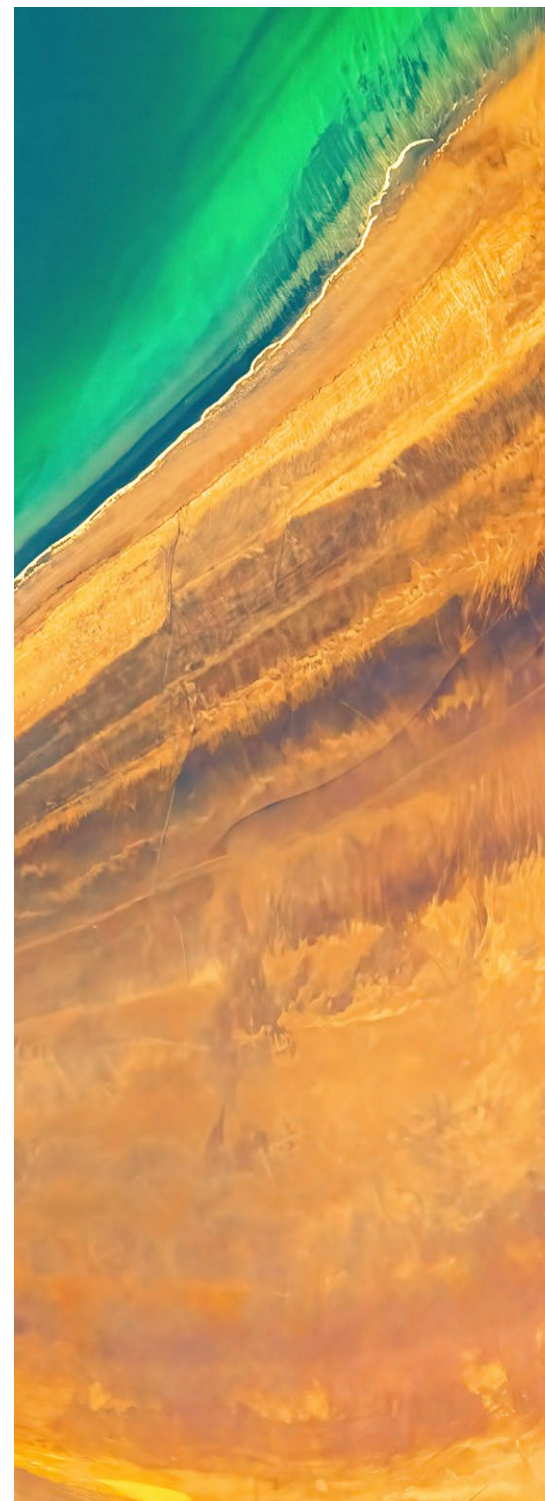
Verification of methane emissions data, providing quality control and assurance, can take several forms. At the most elementary level, verifiers (such as government agencies or relevant third-parties) can perform aggregated data comparisons to sense check overall data. A more granular verification includes data and calculation inspection, while the most robust approach also includes an independent measurement-based check on reported data, using remote sensing and/or measurements at individual facilities. The UNECE guidance provides further detail against each of these three techniques [205].

As described in **Section 3.3**, UNEP is developing a Steel Methane Programme (SMP), which will serve as an asset-level reporting initiative and provide a framework for companies to advance their measurement, reporting and verification (MRV) standards. The initiative will only cover metallurgical coal, but lessons will be applicable to thermal coal assets too. We expect the levels to follow the structure outlined in Section 3.3. The highest level of reporting (level 5) in a recent SMP draft includes the following elements [206; 200]:

- Total site and source-specific measurements taken with appropriate sampling frequency, and reconciliation between top-down and bottom-up approaches
- Use of a multi-input model for site-level measurements
- Use of sensors mounted on mobile platforms (e.g. drones)
- Independent verification with satellite imagery

Target setting on methane is at a much more nascent stage in coal mining than in oil and gas. Where miners do have targets on methane, these tend to be as indicative pathways as part of an overall CO<sub>2</sub>e operational emissions target [207; 187] rather than as a standalone CH<sub>4</sub> target.

**Key point 22: UNEP's Steel Methane Programme, still in development, promises to help improve corporate reporting standards and encourage the uptake of direct measurement.** Miners can play an active role in driving industry progress through this initiative.



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## 6.4 Mitigation approaches

Coal mine methane emissions will be reduced through a combination of:

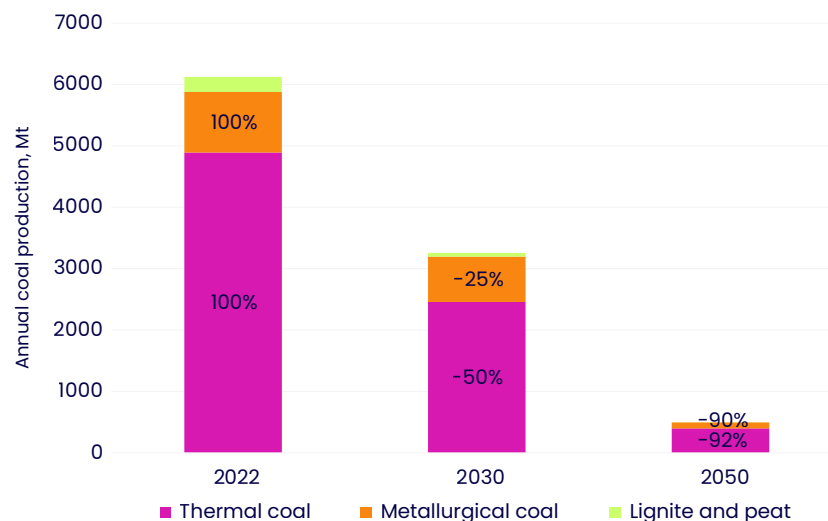
- **Decreasing production** of coal
- **Methane abatement** at operational and abandoned mines.

In the IEA's NZE, coal mine methane falls by approximately 70% by 2030 vs. 2022 [7]. The 47% fall in overall global coal production in the NZE by 2030 (**Figure 20**) nearly halves methane emissions, while the remaining reduction comes from decreasing the methane intensity of production (**Figure 23**).

In underground mines, miners already manage methane for safety reasons; mineshaft air can be explosive at methane concentrations of over 5% [208]. Methane emissions arise from degasification systems from pre-mining drainage of methane, from ventilation air systems during operations, and from mineshafts post closure. These are point sources that are amenable to mitigation [209].

Degasification systems offer good potential for capture and utilisation of methane as natural gas. Utilisation of drainage methane can largely be achieved at net negative cost [210; 8].

**Figure 20**



**Figure 20:** Coal production in the NZE, split out by thermal coal, metallurgical coal, and lignite and peat. Percentage declines are relative to 2022. Data from WEO 2023 [222].

Methane concentrations are lower in ventilation air, typically below 1% and fluctuate with time. Even at these relatively low concentrations (c. 0.3-1%), VAM can be destroyed via regenerative thermal oxidation (RTO) [208; 211]. This technology involves passing the ventilation air over a ceramic medium preheated to c. 1000°C. At these temperatures, the VAM oxidises and releases heat, which is transferred to a second heat exchange material. The reaction can be sustained without additional fuel input, and when VAM concentrations are sufficiently high, excess heat energy can be used for purposes such as electricity generation or shaft heating [208]. A significant fraction of methane abatement can be achieved using RTO at a modest cost of c. \$10/tCO<sub>2</sub>e (using 100-yr GWP) [210; 8].

Ventilation air methane can also feed lean-fuel gas turbines for electricity generation, however this often requires blending with a higher concentration source such as drained gas [208]. New catalytic combustors, such as CSIRO's VAMCAT, enable lean-fuel turbines to run on VAM concentrations [211]. VAM can also be concentrated using capture and enrichment units, expanding end-use options.

A comprehensive methane abatement strategy includes measures taken throughout the mine life cycle [209; 157]. For underground mines, these include:

- Before mining:** Draining and capturing methane via degasification boreholes for utilisation.
- During mining:** Destroying, utilising or concentrating VAM; using techniques that minimise coal seam and rock disturbance; further drainage of coal seams; and focusing mining operations on low-methane seams.



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**III. After mine closure:** Sealing abandoned mines, installing methane extraction boreholes and flooding (if environmentally appropriate) to reduce seepage.

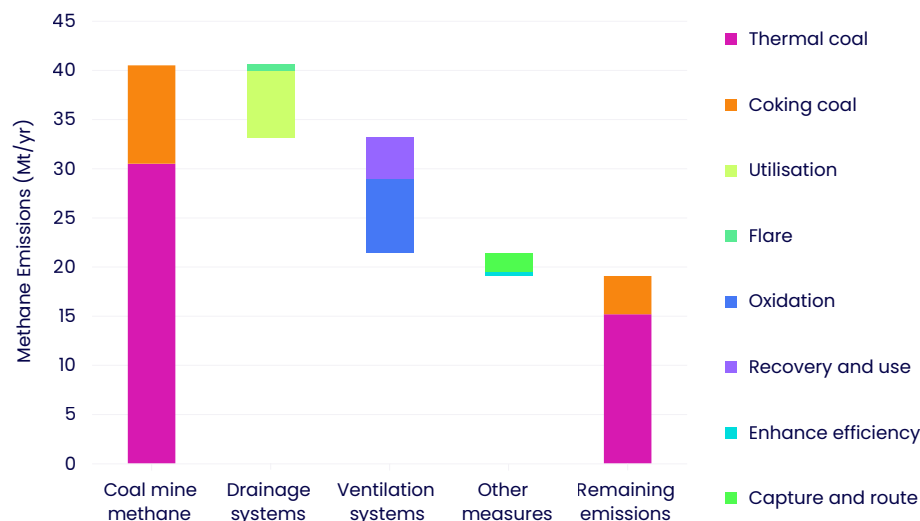
For surface mines, mitigation is most effective at the pre-mining stage. Directional drilling of degasification boreholes may help to capture the most methane depending on mine design [209]. In common with underground mines, the same principles of minimising coal seam disturbance, and progressive draining where possible prior to expansion of mining apply.

For surface mines, mitigation is most effective at the pre-mining stage. Directional drilling of degasification boreholes may help to capture the most methane depending on mine design [209]. In common with underground mines, the same principles of minimising coal seam disturbance, and progressive draining where possible prior to expansion of mining apply.

As shown in **Figure 21**, existing abatement techniques could cut current coal mine methane emissions by 55%, according to the IEA [7]. This corresponds to intensity reductions of 70% at underground mines and 20% at surface mines, as can be seen in **Figure 22**. The IEA also suggests that, in 2023, measures to mitigate 15% of global coal mine methane mitigation would have been actionable at net negative cost [8].

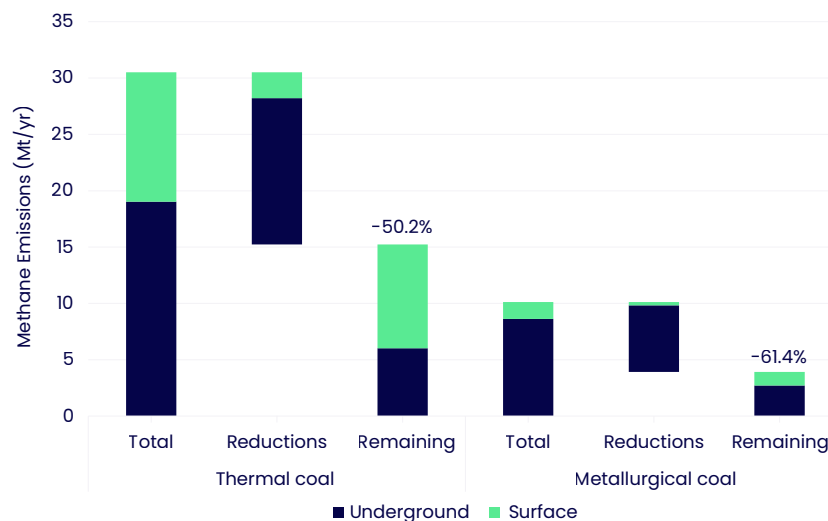
**Key point 23: A comprehensive methane mitigation plan in coal mining involves actions taken throughout the mine life cycle.** Drainage of coal seams prior to and during excavation yields rich gas that can be utilised, while even low concentration ventilation air methane from underground mines can be addressed by techniques such as regenerative thermal oxidation. Underground mines can be sealed or flooded (where environmentally appropriate) to limit post-closure emissions.

**Figure 21**



**Figure 21:** Coal mine methane mitigation approaches. Plot shows the feasible contributions different technologies could make to mitigating 2022 coal methane emissions. Figure from IEA Global Methane Tracker 2023 [7]. (Note that 2022 emissions were recalculated in GMT 2024.)

**Figure 22**



**Figure 22:** Coal mine methane abatement potential in 2022, broken down by thermal coal and metallurgical coal. Data from IEA Global Methane Tracker 2023 [7]. (Note that 2022 emissions were recalculated in GMT 2024.)



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According to these differences in available reductions, different companies and countries may be able to deliver different levels of methane mitigation depending on their portfolio of mines and the proportion of which are underground vs. surface [157]. For example, more than 87% of China's coal production is underground [212], whereas Indonesia's is almost entirely surface [188]. Because relatively more metallurgical coal mines are underground than thermal coal, there is also a difference in the feasible intensity reductions between these types of coal, as shown in Figure 22 [157].

**Key point 24: While underground coal mines are typically higher-emitting than surface mines, they also present greater methane abatement potential.**

Similarly, while metallurgical coal is usually more methane intensive than thermal coal, it offers greater potential for intensity reductions due to its more frequent underground origin.

## 6.5 Assessing methane targets

Explicit targets on coal mine methane emissions are currently rare; it is more common to see miners disclose indicative pathways factored into overall operational emissions targets, set in CO<sub>2</sub>e [187; 207]. However, recognising the importance of the issue, and the fact that methane emissions have a unique pathway, investors want to see miners disclose targets specific to methane emissions. Importantly, these must be supported by progress to high quality measurement and reporting (i.e. SMP level 5) to be considered credible.

### Intensity targets

Unlike in oil and gas, there is little precedent for methane intensity targets. However, based on global production and global methane emissions, we can provide an estimate<sup>23</sup> of what could be considered globally aligned in the IEA NZE, much as the IEA have done for oil and gas, separately (see Section 5.5).

- Thermal coal: 6.0 tCH<sub>4</sub>/kt coal in 2022, falling to **3.2 tCH<sub>4</sub>/kt** in 2030
- Metallurgical coal: 9.6 tCH<sub>4</sub>/kt coal in 2022, falling to **4.4 tCH<sub>4</sub>/kt** in 2030

As these are global pathways, leaders could be expected to pursue lower intensities, well below 3 tCH<sub>4</sub>/kt by 2030 at the latest. Note also that these pathways include declining production as per the NZE (Figure 20); with static production, much greater intensity reductions would be required for the same methane emissions reduction.

<sup>23</sup> Estimate is based on: production figures for 2022 and 2030 in the NZE from WEO 2023 [222]; breakdown of 2022 met coal and thermal coal methane emissions in GMT 2023 [7]; overall 2022 coal methane recalculation in GMT 2024 and restatement of 2030 overall coal mine methane emissions in GMT 2024 [8]; informed by thermal and met coal intensity reductions in Curtailing Methane Emissions from Fossil Fuel Operations [157].

As with oil and gas, the credibility of performance against targets such as these depends on simultaneous progress towards high quality measurement-based reporting.

The characteristics of a miner's portfolio will influence the methane intensity (see Section 6.4), namely the proportion of underground to surface mines, and the depth of mining, as well as the rank of coal (not just the breakdown of metallurgical to thermal coal).

Some corporates appear to be operating at below these intensity levels already, given their disclosed emissions and production (e.g. BHP [207], Glencore [213]). This may render global intensity benchmarks ineffective as target-setting tools for driving reductions at such companies. Reported low methane intensities may be partially driven by pre-existing abatement actions and a portfolio of mines that is naturally not particularly 'gassy'. But they may also be the result of understatement resulting from a reliance on emission factor-based reporting. Absent high-quality MRV (i.e. SMP level 5), reported methane performance should be treated with scepticism.

It should be noted that intensity targets alone do not address production declines, which will be a major source of emissions reductions from coal mine methane. Coal production remains an important source of transition risk in investor portfolios; a risk that is more immediate for thermal than metallurgical coal.

**Key point 25: While methane intensity metrics are not commonly used by coal miners, aiming for below 3 tCH<sub>4</sub>/kt by 2030 globally could be considered aligned with climate goals.** This average conceals a lot of variability and will not be an appropriate target for all companies. Companies may claim to be below this benchmark already, however without high-quality MRV (i.e. SMP level 5), such claims should be treated with scepticism.



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## Indexed absolute targets

As noted above, miners often include indicative pathways of absolute methane emissions in their strategy to reduce operational emissions. Investors would like to see these formalised as specific targets. This raises the question: what % reductions can be considered sufficiently ambitious?

In **Figure 23** we show the overall indexed declines in methane emissions from thermal and metallurgical coal implied by the IEA NZE, as updated in the GMT 2024 report. The overall methane emissions from coal decrease from 39 MtCH<sub>4</sub> in 2022 to 11 MtCH<sub>4</sub> in 2030, a decrease of **72%**. We estimate that this reduction is comprised of c. 74% and c. 66% reductions from thermal and metallurgical coal, respectively.

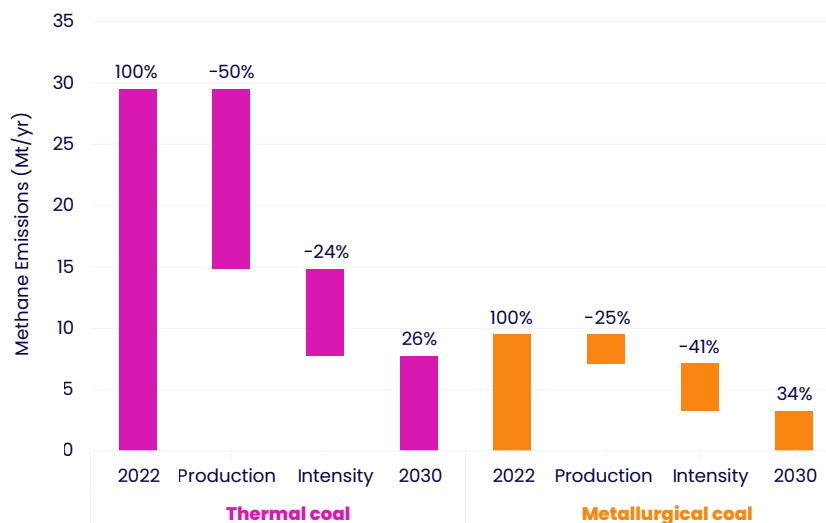
These overall reductions involve both intensity and production declines, as shown in **Figure 23**. In thermal coal, the majority of reductions come from production declines, whereas intensity reductions are more important in metallurgical coal. A company that discloses both intensity and absolute targets provides a good level of visibility on how they intend to tackle methane emissions.

Reflecting the fact that metallurgical coal production is skewed towards underground mines, which have greater abatement potential, expected methane intensity declines in the NZE are slightly higher for metallurgical coal than thermal coal; we estimate 54% and 48% reductions by 2030 versus 2022, respectively.

As with oil and gas, there are some nuances to consider when assessing indexed targets.

- Abatement effort prior to the base year is not considered, potentially leaving future % reductions more difficult for leaders than laggards.

**Figure 23**



**Figure 23:** Declines in methane emissions between 2022 and 2030 from thermal and metallurgical coal mining in the IEA NZE. In this scenario, total reductions are driven by a combination of declines in production and methane intensity. This figure, and the figures cited in the main text, are based on global production data from WEO 2023 [222] and overall global coal methane estimates in 2022 and 2030 in the NZE from GMT 2024 [8]. The breakdown of contributions is informed by GMT 2023 [7] and Curtailing Emissions from Fossil Fuel operations [157] but fitted to constraints from GMT 2024 and WEO 2023.

- A company that relies on emission factor-based reporting may struggle to establish an accurate baseline, potentially providing a perverse incentive against improving MRV over time, and complicating the calculation of year-on-year performance. To counter this, rebaselining on the basis of improved calculations should be allowable, if clearly justified and stated.
- The ease of abatement will depend on the breakdown of surface and underground mines in a miner's portfolio, though this is reflected (on the basis of global average) in the figures provided for metallurgical and thermal coal declines.
- Choosing a representative base year is important (given interannual variability)
- Emissions 'rights' are allocated on the basis of historical emissions, known as grandfathering, raising fairness questions [185; 186]

**Key point 26: In the NZE, methane emissions from thermal coal and metallurgical coal decline by c. 74% and c. 66%, respectively, by 2030 against 2022 levels.** In thermal coal, the majority of the reductions come from declining production, whereas intensity declines make up the larger share for metallurgical coal. Despite limitations, indexed pathways are unambiguous about what is required from corporates in sum. Re-baselining as MRV improves should be allowable if transparently stated and justified.



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# 7. Methane engagement frameworks and the Net Zero Standards

In the **Executive Summary**, we presented methane engagement frameworks and the rationale behind them. Here, we show how the frameworks can leverage the Net Zero Standards for Diversified Mining and Oil and Gas [214; 215]. Company assessments against these standards can be integrated into the engagement frameworks to help inform engagement priorities.

The intention is that the Net Zero Standards will be updated to ensure they continue to serve investor requirements. The metrics on methane in both standards will most likely be updated, informed by this guidance paper. The status of the Steel Methane Programme will also be relevant to updates on the Net Zero Standard for Diversified Mining. As and when the metrics are amended, we will similarly provide an update to how they relate to the methane engagement frameworks.

## Methane metrics in the Net Zero Standard for Oil and Gas

The current methane metrics in the Net Zero Standard for Oil and Gas are as follows:

- **5.iv.a:** Is the company a member of OGMP 2.0 and has it made a public commitment to the “gold standard” of constant improvements in methane reporting covering all assets in-line with this initiative?
- **5.iv.b:** Has the company explicitly set out the date when, consistent with OGMP membership commitments (i.e. within three years of it becoming a member), it will publish an independent and externally verified assessment of its methane emissions which integrates direct measurement with estimations (OGMP level 5)?

- **5.iv.c:** Has the company disclosed methane emissions consistent with OGMP level 5, both on an absolute basis (in metric tonnes) and intensity basis (in tCH<sub>4</sub> per PJ of total upstream production). An additional energy-based denominator should be disclosed for mid-stream or distribution companies as appropriate. The denominator of any intensity target should be clearly disclosed.
- **5.iv.d:** The strategy to reduce methane emissions is clearly stated and references the contribution of AND action on emission sources (venting, flaring and leaks), AND prioritisation, AND coverage, AND the use of best available measurement technology.
- **5.iv.e:** Has the company committed to zero routine flaring by 2030 in line with World Bank and UN initiative and minimise non-routine flaring?
- **5.iv.f:** Has the company set a medium-term methane emissions reductions target stating a base year, base year value, target year, target year reduction with both absolute and intensity values and an interim milestone.
- **5.iv.g:** [Not currently operational] Is the methane emissions pathway indicated in f) aligned with the relevant benchmark?

Note that in the context of the current iteration of 5.iv.b, OGMP 2.0 verification is considered equivalent to independent and externally verified assessment.

In 5.iv.g, the intention is to ultimately test targets using the benchmarks provided in Section 5.5.

Below we show the oil and gas methane engagement framework with references to the relevant Net Zero Standard for Oil and Gas metrics.



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# Oil and gas methane engagement framework

## Measurement, reporting and verification

### Does the company provide comprehensive methane disclosures?

- In both units of absolute emissions (tCH<sub>4</sub>) and methane intensity (tCH<sub>4</sub>/GJ)? **5.iv.c**
- Disaggregated by business segment, basin, product/throughput type?
- Using the same boundary for numerator and denominator in intensity figures?
- With full disclosure of the calculation methodology, including measurement units and conversion factors used?
- Providing the % breakdown of emissions sources by type (non-routine flaring, routine flaring, venting, fugitive) across all segments, including non-operated and abandoned/unused assets, with clear definitions of each source?

### Does the company have high-quality MRV in place or a commitment to do so?

- Using multiple, complementary monitoring systems?
- Across all segments, including non-operated and abandoned/unused assets?
- Providing the % breakdown of emissions/production covered by different measurement technologies, including details on frequency, duration, detection thresholds, and quantification uncertainty?
- Achieving OGMP 2.0 Gold Standard pathway, with published target dates to reach OGMP 2.0 Level 5 reporting for all operated and non-operated assets? **5.iv.a**
- Providing the % breakdown of emissions/production covered by different OGMP 2.0 reporting levels? **5.iv.b**
- With external verification? If so, data inspections or independent measurement?

## Targets

### Has the company set a sufficiently ambitious target to reduce methane emissions, by 2030 at the latest? **5.iv.f**

- Covering all business segments and assets, or with a timeline to cover all?
- In terms of both absolute and intensity, using methodology described above?
- By business segment, basin, product?
- If indexed, providing a base year and value?
- Specifying role of production (incl. field depletion), intensity declines and divestments/acquisitions? **5.iv.g**
- Aligned with IEA NZE benchmark? (See [Section 5.5](#))

## Strategy

### Has the company set out a comprehensive, effective and adequately resourced strategy for methane mitigation? **5.iv.d**

- With a comprehensive LDAR programme covering all segments and assets, including abandoned/inactive wells?
- With zero routine flaring and minimising non-routine flaring? **5.iv.e**
- With systems to recover associated/excess gas to reduce venting and flaring, and new production contingent on adequate gas takeaway capacity?
- With steps to improve flare performance, including zero tolerance for unlit flares?
- With plans to replace/retrofit/adapt high-emitting equipment and processes?
- Prioritising heaviest-emitting sources?
- Stating current- and forward-looking capex and opex figures? Including plugging/decommissioning costs and liabilities?
- Providing timeline and milestones?
- Linking milestones to expected emissions reductions?
- Referencing a methane marginal abatement cost curve (MACC)?

## Industry engagement

### Has the company joined major initiatives on methane? **5.iv.a**

- OGMP 2.0?
- OGDC?
- GFMR?
- MGP?

### Has the company engaged its NOAs and NOJVs on methane?

- On MRV practices?
- Frequent sharing of emissions data?
- Alignment with its strategy and targets?
- In contract terms?
- Sharing best practice?
- Providing technical or financial support?

## Progress

### Does the company disclose progress against its targets?

- Emissions performance consistent with the form of the targets?
- On track to achieve or exceed targets?
- Is there critical evaluation of the reliability of stated performance against intensity targets?
- Is any re-baselining of emissions and targets transparently stated and justified, with clear disclosure of methodology changes?
- Separating out the role of production (including field depletion), intensity declines and divestments/acquisitions?

### Does the company disclose progress against its strategy?

- Providing details on milestones achieved, e.g. % of relevant equipment replaced/retrofitted and % of identified leaks repaired
- Stating capital spend on methane abatement in the last reporting year



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# Methane metrics in the Net Zero Standard for Diversified Mining

The relevant Net Zero Standard for Diversified Mining metrics are as follows:

- **5.iv.a:** Has the company committed to increase the coverage and quality of methane reporting across all coal assets, including after mine closure, using best available techniques and including external verification?
- **5.iv.b:** [IF 5.iva = Yes] Does the company disclose targets to reduce methane emissions?
- **5.iv.c:** [Not currently operational] [IF 5.iv.a = Yes] Is the methane target aligned with a 1.5°C pathway (on either an intensity or absolute basis)?
- **5.iv.d:** Has the company set out a strategy to reduce its methane emissions that addresses methane emissions pre-, during- and post-mining, AND prioritises abatement of highest emitting coal mines?
- **10.ii.g:** Has the company disclosed total methane emissions on an absolute basis (in metric tonnes) and intensity basis (in tCH<sub>4</sub> per Mt of total coal production)?
- **10.ii.h:** Has the company disclosed mine-by-mine methane emissions on an absolute basis (in metric tonnes) and intensity basis (in tCH<sub>4</sub> per Mt of total coal production)?

Once the SMP has been launched, it is likely that the Standard will incorporate membership of this initiative and Gold Standard performance in its metrics.

While it is currently rare for mining companies to have methane targets, the intention is to ultimately use the benchmarks in [Section 6.5](#) to assess the alignment of any targets in 5.iv.c.

Below we show the coal mine methane engagement framework with references to the relevant Net Zero Standard for Diversified Mining metrics.



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# Coal methane engagement framework

## Measurement, reporting and verification

### Does the company provide comprehensive methane disclosures?

- In both units of absolute emissions (tCH<sub>4</sub>) and methane intensity (tCH<sub>4</sub>/kt)? **10.ii.g**
- On a mine-by-mine basis?
- Setting out the methodology for methane emissions reporting by mine-type (or individual mine)? **10.ii.h**
- Evaluating the reliability of the methodology and stating the rationale for using it?
- Additionally reporting coal mine methane emissions from coal that the company trades?

### Does the company have high-quality MRV in place or a commitment to do so?

- Integrating direct measurement? Providing details on a mine-by-mine basis? **5.iv.a**
- Using multiple, complementary monitoring systems?
- With details on sampling frequency, duration, detection thresholds and quantification uncertainty?
- Reconciling source-level and facility-level observations?
- Covering all coal mines, including non-operated assets?
- With external verification? If so, data inspections or independent measurement?
- Including continued MRV after mine closures?

## Targets

### Has the company set sufficiently ambitious targets to reduce methane emissions? **5.iv.b**

- Has the company set a specific target to reduce its coal mine methane emissions?
- Covering all assets, including non-operated assets, or a timeline to do so?
- In terms of both absolute emissions and methane intensity?
- If indexed to a base year, providing base year value?
- Aligned with the IEA NZE? (see [Section 6.5](#)) **5.iv.c**
- With an interim milestone?
- With separate targets on metallurgical and thermal coal assets, or quantifying respective contributions to an overall target?
- Quantifying contributions to an absolute reduction target from production and intensity declines?
- Coupled with a commitment to achieve high-quality MRV across all assets?

## Strategy

### Has the company set out a comprehensive, effective, and adequately resourced strategy for methane mitigation? **5.iv.d**

- Including degasification and capture/ utilisation prior to and during excavation? [Underground and surface mines]
- Including ventilation air methane destruction or utilisation? If so, which technologies: RTO, catalytic combustion, concentration, or other? [Underground mines]
- Including post-closure abatement measures? [Underground mines]
- Including targeting low-methane coal seams and minimising disturbance?
- Prioritising heaviest emitting mines?
- Setting out technologies involved and their maturity?
- Stating current and forward-looking opex and capex required?
- Providing timeline and milestones for delivery of strategy?

- Linking milestones to expected emissions reductions?
- Referencing a methane marginal abatement cost curve (MACC)?

## Industry engagement

### Has the company joined major initiatives on methane?

- Actively engaging with the Steel Methane Programme (SMP)? Once launched, member of SMP?

### Has the company engaged its partners in JVs and non-operated assets on methane?

- On MRV practices?
- Requiring frequent sharing of emissions data?
- Seeking alignment with the company's methane strategy and targets?
- In contract terms?
- Sharing best practices?
- Providing technical or financial support?

### Similarly, has the company engaged producers providing coal that the company trades?

- On MRV, strategy, and targets?

## Progress

### Does the company disclose progress against emissions targets?

- Consistent with the form of the targets?
- With progress on track to achieve targets?
- With critical evaluation of the reliability of stated performance against targets?
- With any re-baselining of emissions transparently stated and justified?
- Separating out the role of production and intensity changes in overall methane reductions?

### Does the company disclose progress against its strategy?

- Providing details of milestones achieved
- Stating capital spend on methane abatement in the last reporting year



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