IIGCC

Methane emissions from fossil fuel operations

Consultation Paper

Summary

Methane is a potent greenhouse gas, with anthropogenic emissions of the gas responsible for c. 30% of global warming since pre-industrial times. The fossil fuel sector is responsible for a significant fraction (c. 37%) of these emissions and offers the greatest abatement potential. To keep 1.5 °C in sight, a 75% reduction in fossil fuel methane emissions is needed by 2030 (relative to 2022). This action is needed in addition to rapid reductions in carbon dioxide (CO_2) emissions, which primarily determine long-term warming. Indeed, the two gases can be tackled together. Methane reductions require a combination of i) decreasing underlying fossil fuel production—and associated CO_2 emissions—and, ii) methane abatement, which decreases the methane intensity of production.

While methane is a key climate issue and a major part of fossil fuel producers' operational emissions, it is not a straightforward topic for investor engagement and corporate action. Its effects on climate are different to those of carbon dioxide. Emissions are often poorly disclosed due to lack of direct measurement. Sources can be diverse, and often associated with accidental leaks in oil and gas. Mitigation techniques are similarly varied and technical.

The purpose of this paper is to support institutional investors' engagements with fossil fuel producers on methane. It highlights key points from climate science on the topic and summarises the policy landscape around the world. Additionally, it sets out how satellite measurement of methane emissions is changing the reporting landscape, provides an overview of the current state of methane emissions and describes abatement techniques. We provide two key analytical outputs: A) methodologies for assessing company methane targets; B) an engagement framework that leverages the Net Zero Standards for Oil & Gas and Diversified Mining.

NEXT STEPS:
This consultation will lead to two publications:
1) A summary briefing comprised of the key points and engagement frameworks presented in this document;

2) A background paper (a revised version of this document) which includes the technical context required to inform detailed engagements.

We kindly request reviewers to primarily focus their feedback on the key points, engagement frameworks, and target assessment sections.

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1. Introduction

Methane (CH_4) concentrations in the atmosphere today are more than 2.5 times greater than pre-industrial levels (1; 2). Observations over recent decades show accelerated increases (**Figure 1a**), primarily driven by anthropogenic emissions (**Figure 1b**).

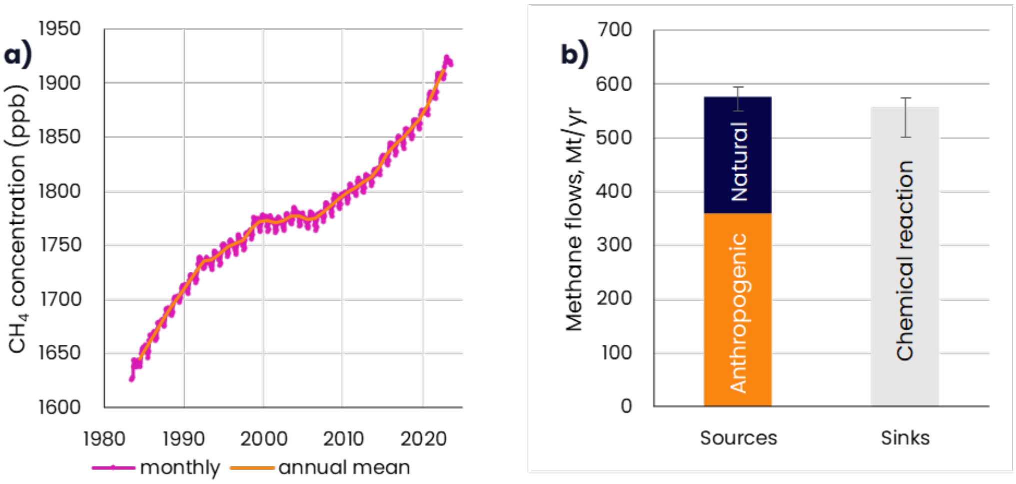

Figure 1: Methane concentrations and anthropogenic emissions. a) Global-mean surface methane concentrations from NOAA's Global Monitoring Laboratory (143). b) Total anthropogenic and natural methane emissions ('sources') and total sinks of methane, plotted against RH axis (same units). Data are top-down estimates averaged over 2008-2017 from Saunois et al. (6). Uncertainty bars shown.

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

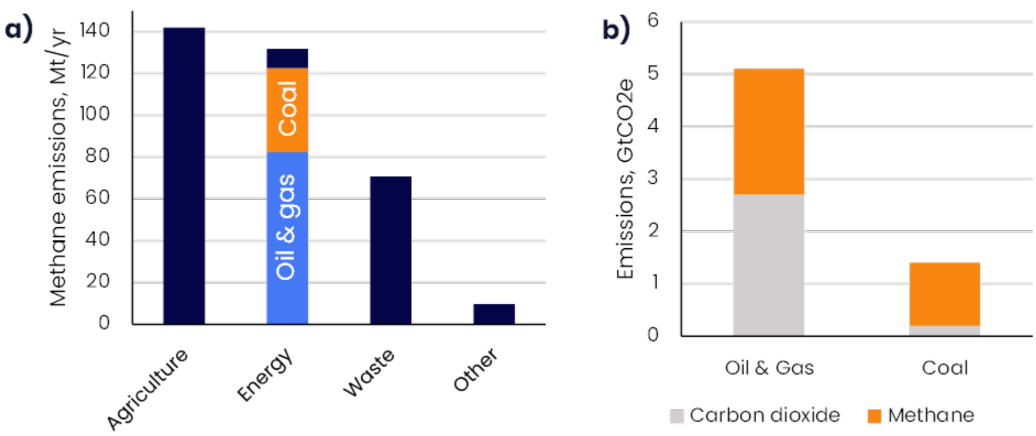

Figure 2: a) Breakdown of global anthropogenic methane emissions in 2022, from IEA's Global Methane Tracker (66). This report focusses on methane emissions from oil & gas and coal. The remainder of methane emissions from the energy sector come from bioenergy. **b)** Scope 1 & 2 emissions from fossil fuel production, processing, transport and refining for 2022. From ETC (2023), Fossil Fuels in Transition (107). Methane is expressed in CO_2e using GWP100 = 30. As we explore later, CO_2e is not well-suited to target-setting or understanding climate outcomes.

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 3**). In this paper, we will explore the ways in which stringent methane emissions reductions of this nature can 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.

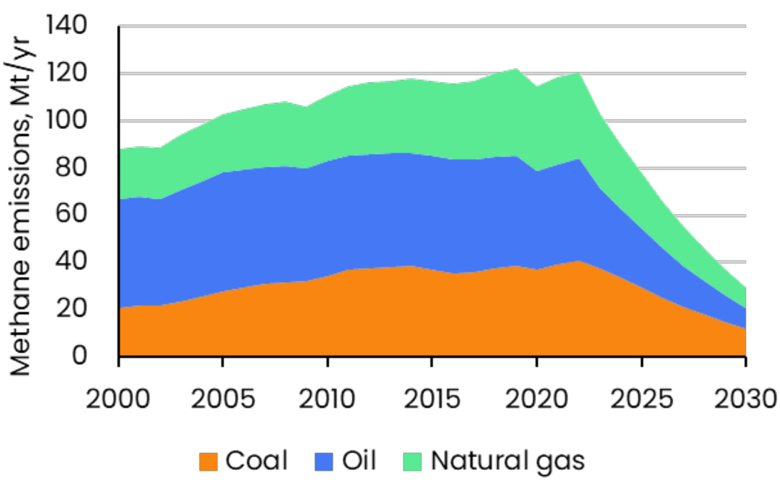

Figure 3: Historical methane emissions from fossil fuels and projections to 2030 from the IEA's NZE. Steep declines in emissions are required from each fuel to achieve a 75% reduction in 2030 vs. 2022. Figure from the IEA Global Methane Tracker 2023 (3).

1.1 Scope of this paper

Methane emissions more broadly are of three types: biogenic (produced from microbial decomposition in oxygen-poor environments); thermogenic (produced as part of the geological formation of oil, gas and coal); and pyrogenic (from incomplete combustion) (4). There can be both natural and anthropogenic sources of emissions from these categories, as shown below.

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

In this paper we focus on thermogenic methane from anthropogenic sources: methane emissions from fossil fuels. Within this we focus on fossil fuel operations: operational emissions of fossil fuel producers and/or companies handling processing, transmission or distribution. We do not examine methane emissions from end-use consumption, which are relatively insignificant (and outside of the operational control of fossil fuel companies).

Both investor-owned and state-owned corporates are considered in this paper. While investor members are more likely to be able to engage directly with the former, we also discuss potential levers for engaging state-owned enterprises, which are responsible for the majority of global methane emissions.

2. The climate science context

Investors are now largely familiar with carbon dioxide (CO_2); they understand that there is an approximately linear relationship between cumulative emissions of CO_2 and warming, and that 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, it is nonetheless highly influential on the global climate. Here we provide a brief review of the climate science on methane to highlight the key messages for framing engagement on methane emissions, so that investors can discuss methane with the same confidence as CO_2.

2.1 In brief

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

1) Long-lived greenhouse gases like CO_2.
The warming impact of these gases depends primarily on their cumulative emissions over centuries or more.

2) Short-lived climate forcers, including methane (CH_4).
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_2 emissions **and** the annual emissions of CH_4 and other short-lived climate forcers at that time.

Keeping warming to 1.5 °C requires urgent reductions in anthropogenic methane emissions; IPCC scenarios compatible with 1.5 °C show an average emissions decline of 34% by 2030 on 2019 levels. It also requires that we stay within a limited CO_2 budget, which demands rapid falls toward near zero CO_2 emissions over the next few decades.

Tackling methane should be seen as an essential part of climate action, rather than an alternative cutting CO_2 emissions. Indeed, as we show later, the two gases can be tackled simultaneously in relation to fossil fuel production.

2.2 Methane: a short-lived gas

Methane has a short lifetime in the atmosphere of c. 9 years (5). It is primarily removed by chemical reaction with the hydroxyl radical , OH (6).

As with other greenhouse gases (GHGs), it is the concentration of methane in the atmosphere that determines its contribution to warming , 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 fast removal of methane, 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 (7; 8). Second, reducing methane emissions can quickly lead to falling concentrations, reversing the recent warming it has caused (9; 10; 11).

Key point 1: The temperature of peak warming will be determined by a combination of: a) cumulative emissions of CO_2 (and other long-lived GHGs) 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 (11).

The removal of methane by oxidation ultimately leads to the production of atmospheric CO_2 . In the case of fossil methane, this is new CO_2 in the climate system , and explains why fossil CH_4 has a marginally higher global warming impact than non-fossil CH_4 (12).

It is true, then, that even after the 'removal' of fossil methane, some climate impact remains through the production of CO_2. But, in practice, the total CO_2 yield from methane emissions is relatively insignificant.

The lifetime of methane is short and dominated by one process. CO_2 is very different in this respect. Nearly half of annual emissions are relatively quickly partitioned into the upper ocean and the biosphere on land but the remaining added CO_2 can persist in the atmosphere for centuries to millennia, only gradually removed by several different geochemical processes (9). 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_2. Despite being present at far lower concentrations in the atmosphere (**Table 2**), growth in methane concentrations has contributed one quarter of the radiative forcing of CO_2 since 1750 (13).

	Concentrations (ppm)		**Effective radiative forcing (W/m²)**
	1750	**1750**	
Methane	0.729	0.729	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) (13).

The global warming potential (GWP) metric quantifies the radiative forcing of a pulse emission of gas relative to the equivalent pulse emission of CO_2, averaged over a fixed time period. **Table 3** shows how this GWP decays over time, owing to its short lifetime.

	GWP-20	**GWP-100**	**GWP-500**
CH4 (fossil)	82.5 ±25.8	29.8 ±11	10 ±3.8

Table 3: GWP emission metrics for methane. GWP averages the radiative forcing due to a one-off pulse emission, over a fixed time period, compared against a pulse of the same mass of CO^2 (13).

Note that the value of GWP is not the ratio of radiative forcing at the end of the time period but the value averaged over it. The former would fall off more rapidly: the radiative forcing of a tonne of fossil methane decays to just c. 2-3 times that of CO_2 within several decades, as it oxidises to yield c. 2-3 tonnes of CO_2.

[1] Radiative forcing is the change in the net energy balance (in Wm-2) at the top of the atmosphere between incoming energy (from the sun) and outgoing energy (from the Earth system).
[2] 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. (11)
[3] 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.
[4] Altitude of emissions is also relevant, but this is generally only a consideration in the aviation sector and with respect to CO2.

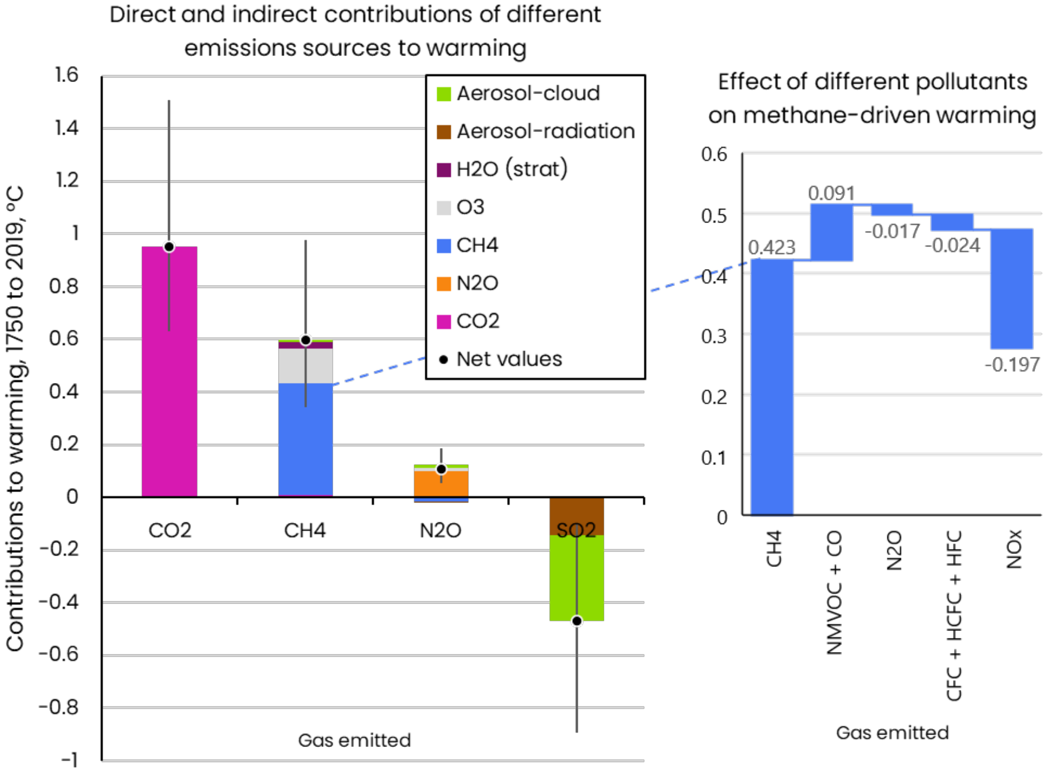

Figure 4: Warming due to methane emissions (left) is greater than the warming due to the changes in methane abundance (right). a) Warming contributions 1750 to 2019 due to emissions of CO_2, CH_4, N2O and SO2. Emissions of these climate forcers cause warming or cooling due to direct and indirect contributions (i.e. promoting the formation of another climate forcer as per the legend). b) Warming contributions from the concentration of CH_4 in the atmosphere in 2019 relative to 1750. A number of different pollutants (x-axis) affect the concentration of CH_4, such that the final warming effect of the rise in methane concentrations, 0.28°C, is less than the effect of methane emissions, 0.6 °C.

It is not just through increasing methane concentrations that methane emissions cause warming. **Figure 4a** shows how methane and other major climate pollutants like N2O and SO2 additionally affect climate through indirect influences on other climate forcers. Methane emissions lead to the production of tropospheric ozone (O3), another short-lived climate pollutant, which additionally has detrimental effects on respiratory health and plant productivity (14; 15; 11). More minor warming effects from methane emissions come from the production of CO_2, enhancement of stratospheric water vapour, and influences on aerosols.

The emissions of other gases also affect methane concentrations, and therefore its warming effect, as shown in **Figure 4b**. The strongest effect is from NOx, which decreases methane lifetimes and has affected warming from methane by -0.2 °C since 1750, meanwhile other gases slightly increase the lifetime of methane.

Comparing **Figure 4a** and **Figure 4b**, 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 abundance, **0.28 °C** (5; 13).

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 (5; 13).

These two different figures can be confused and lead to different statements about the role of methane in climate change. However, it is the larger number—the warming attributable to methane emissions—that is relevant when considering the effects of corporates' methane emissions.

[5] The yield of CO2 is c. 75% molecule-to-molecule, and, given the difference in the mass of each molecule, 1 kg of CH4 generates c. 2.1 kg of CO2 (13)
[6] Whereas methane from decomposition or incomplete combustion of organic matter would yield CO2 that may only recently have been removed from the atmosphere via photosynthesis.
[7] How significant is this new CO2? As fossil methane emissions are currently around 120 Mt/yr, this would equate to c. 250 Mt/yr CO2 emissions (see footnote 4), on the order of half a percent of total CO2 emissions. This is relatively insignificant.
[8] There is a dynamic equilibrium in the surface ocean between atmospheric CO2 and aqueous CO2 in the ocean. Higher atmospheric concentrations drive CO2 into the ocean, where it then participates in chemical reactions that reduce seawater pH (ocean acidification). However, CO2 is less soluble in warmer waters; the capacity of the ocean to take up additional CO2 declines in a warming climate.
[9] Due to the CO2 fertilisation effect, higher CO2 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.

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_2 emissions allowable) for 1.5 °C or any level (16; 15). Indeed, as changes in methane emissions rapidly impact climate, the chance of limiting warming to 1.5 °C is strongly influenced by future pathways of methane emissions (17).

Key point 2: In IPCC 1.5 °C scenarios with low/no overshoot, 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 thus far.

Owing to their different atmospheric lifetimes, different emissions pathways are required of CO_2 versus methane for the effect of each gas on global temperature to stabilise (18), as can be understood from **Figure 5**.

- CO_2 emissions must reach near zero for stabilisation of the CO_2 effect on temperature (19) (see **Figure 5c**)

- CH_4 emissions must remain constant (to be precise, decline by less than 1% per year) for stabilisation of the CH_4 effect on temperature (20; 21) (see **Figure 5b**)

In line with this, while net zero anthropogenic CO_2 emissions will stabilise warming, net zero GHG emissions will lead to gradually declining temperatures (**Figure 5c**), due to the inclusion of short-lived gases. Net zero GHG emissions occurs decades later than net zero CO_2 in most climate scenarios (18).

While complete cessation of anthropogenic methane emissions is implausible, meeting Paris goals requires more than simply to stabilise the methane contribution 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, anthropogenic methane emissions are reduced by a mean of:

- **34%** below 2019 levels by 2030, and
- **44%** below 2019 levels by 2040 (18).

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 (20).

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, cites that methane mitigation can provide **0.3 °C** of avoided warming by the 2040s (22). It is important to remember, however, that these 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 SO2 (shown in **Figure 4a**) 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 (5). This foreseeable 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

Annual emissions of gases in the so-called Kyoto-basket (CO_2, CH_4, N2O, HFCs and others) are generally aggregated and disclosed on a CO_2-equivalent (CO_2e) basis by weighting by a GWP metric (7; 23; 24). Methane emissions are often reported in this manner.

While ubiquitous, this approach is limited in its usefulness for understanding climate change, primarily because the GWP approach lumps together short-lived and long-lived climate pollutants (8; 10; 9; 7). A defined pathway of CO_2e emissions can lead to very different climate outcomes over time depending on the breakdown of emissions between different gases, most importantly CO_2 and CH_4 (24). In these cases, a high-CO_2/low-CH_4 pathway leads to lower near-term but higher warming indefinitely thereafter, versus a low-CO_2/high-CH_4 pathway (24).

To see this in action, examine the emissions profiles in **Figure 5**; if these are aggregated CO_2e pathways, very different climate outcomes would occur depending on the mix of CO_2 and CH_4 in annual emissions.

Key point 3: GHG metrics like CO_2e that aggregate CO_2 and CH_4 can be ambiguous with respect to climate outcomes. For this reason, it is best to keep methane and carbon dioxide separate in reporting and targets.

Aggregating emissions as CO_2e obscures the fact that methane's warming effect is short-term and reversible (via emission reductions), whereas the warming effect of CO_2 is near-permanent. Tackling methane at the expense of addressing CO_2 emissions commits the world to higher temperatures ad infinitum (9; 24; 8); the two gases must be addressed together.

Reporting gases on a disaggregated basis, or at least in 'baskets' grouped by lifetime (the approach taken under the Montreal Protocol), removes this climate ambiguity (24; 25).

In terms of meeting specific climate goals, the emphasis is best placed on limiting cumulative emissions of CO_2, i.e. keeping to a carbon budget, while limiting future emissions of CH_4 to specific rates (7).

Key point 4: Deep methane emissions cuts are essential for maximising the chance of meeting Paris climate goals. However, they must not come at the expense of efforts to mitigate CO_2 emissions. CO_2 emissions lock the world into higher temperatures in the long term.

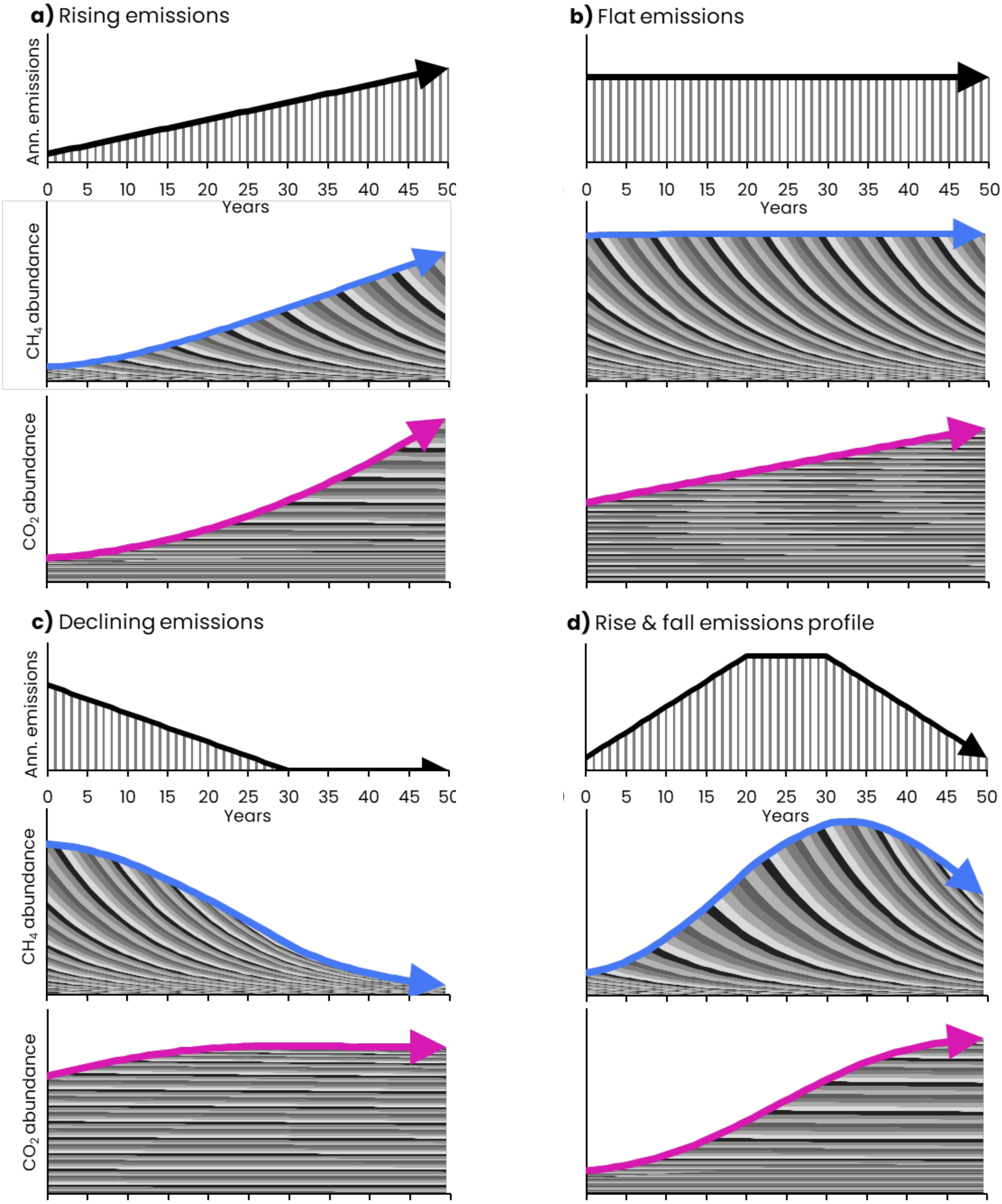

Figure 5: Illustrative annual emissions profiles (top; black line) and resulting atmospheric abundance changes in CH_4 (middle; blue line) and CO_2 (bottom; pink line). Four scenarios shown in subplots a-d. GHG abundances correspond relatively linearly to global warming. Stacked greyscale curves illustrate 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_4 and a 2,000-yr timescale for CO_2 (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_4 and CO_2 abundance curves. Note that, if this profile was in terms of CO_2e, it could be comprised of variable amounts of CH_4 and CO_2. A CO_2e profile could be entirely CH_4 or entirely CO_2. But the climate outcome would differ markedly depending on the choice, as illustrated.

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 (**Figure 4**). While these changing concentrations can be measured and are increasingly well-documented, the exact contribution of different constituent emission sources is generally more uncertain.

There are two approaches to determining methane emission inventories (collections of individual emission sources), at corporate, regional, or global levels (6):

- **Bottom-up** approaches aggregate emissions from multiple individual sources, whether measured or estimated with emission factors
- **Top-down** approaches couple overarching observations with inverse modelling

These two approaches yield quite different numbers for different categories of global methane emissions (6), with top-down approaches often considered more accurate as they are constrained by observations. The fundamental issue for bottom-up approaches is that they are only as reliable as their component parts—which, for fossil fuel operations, are the emissions from different assets and facilities. Yet currently, the vast majority of reporting on these sources does not integrate direct measurement (3; 6).

Countries report national emission inventories to the UNFCCC. The IPCC provides guidance for the construction of these inventories, which covers methane from fossil fuel operations (26; 27; 28). 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. 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.

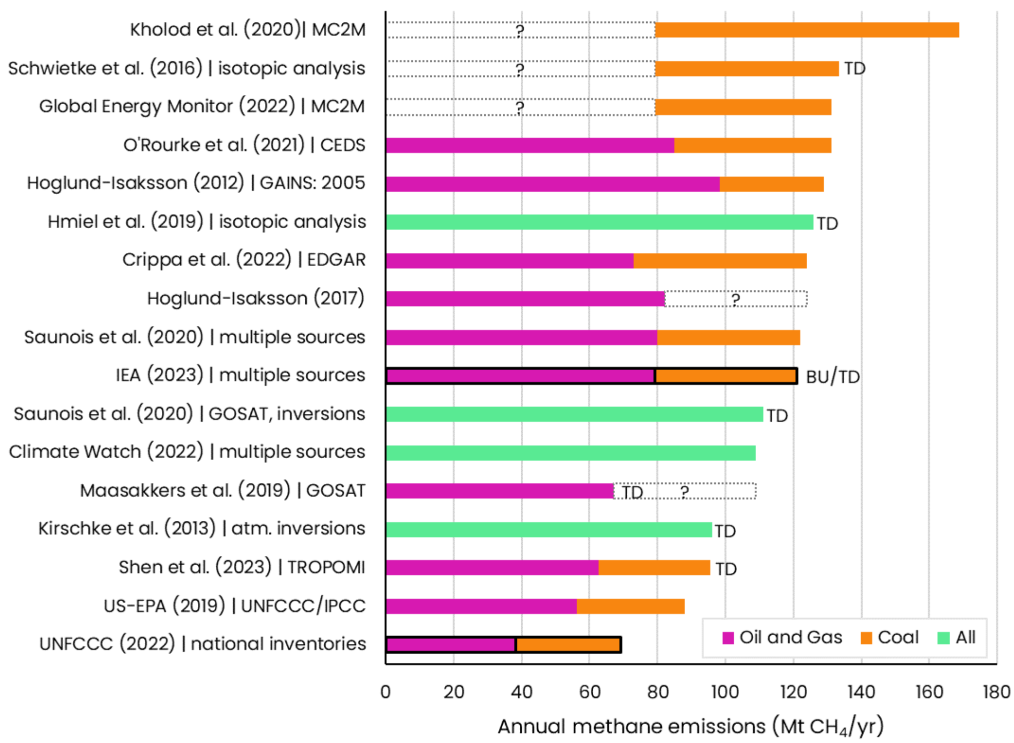

Figure 6: Comparison of global fossil fuel methane emissions estimates. Data sources/methodologies indicated for each estimate. Where estimates only provide data for one of oil & gas or coal, a blank box with '?' is used for the missing data, using the IEA's figures for oil & gas or coal, as relevant. All estimates are constructed using bottom-up methods except where specified 'TD' for top down. Key UNFCCC and IEA estimates in outlined in black.

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 in to their public reporting.

Beyond regulation, industry-led methodologies, such as the Natural Gas Sustainability Initiative (NGSI), also inform data-handling and reporting practices (29). And, as discussed in 3.3 IMEO initiatives, the International Methane Emissions Observatory (IMEO) is supporting corporates to advance towards direct measurement through industry reporting initiatives.

In **Figure 6** we compare independent estimates of global methane emissions from the fossil fuel sector against UNFCCC inventories. Of the 17 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.

The IPCC notes that Tier 1 approaches in oil & gas may "easily be in error by an order of magnitude or more" (26 p. 4.39), while in surface mining and underground mining Tier 1 approaches have an uncertainty of a factor of 3 and a factor of 2, respectively (26). 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 reason for frequent underestimation (30; 31; 32; 33).

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.

3.2 Importance of direct measurement

Direct measurement 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 (34)
- 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 (3)

3.3 IMEO initiatives

The International Methane Emissions Observatory (IMEO), established by the UN Environment Programme (UNEP) with European Union support, is attempting to address the measurement gap in several ways. UNEP is commissioning measurement studies (35; 34) 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.

IMEO coordinates the Oil and Gas Methane Partnership (OGMP) 2.0, a platform for company reporting on methane, and evaluates company performance (35; 33). It is also preparing the Steel Methane Partnership, which will fulfil a similar role as the OGMP 2.0 in serving 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 reporting level across assets (see below), as well as any targets on methane reductions that they will have. We expect that the reporting levels will show a good high-level correspondence between initiatives.

- **Level 1:** Emissions reported at aggregated source categories or country level only
- **Level 2:** Emissions reported at aggregated source categories using source-specific activity data and regional/country-specific emission factors
- **Level 3:** Emissions reported by detailed source type using available source-specific 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 (top-down) measurements

We will discuss corporate performance against these reporting levels, and the nature of targets set, in sections 5.3 and 6.3.

Key point 6: IMEO is building asset-level disclosure and best-practice sharing platforms for fossil fuel producers, with a clear goal to progress to direct measurement-based reporting. Joining OGMP 2.0 or SMP, as relevant, is a good early objective for a company engagement.

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 (36), aircraft-based sampling (37; 38), and satellite remote sensing (32; 39).

The exercise of accurately characterising corporate methane emissions is challenging, especially in oil and gas operations where there are a large number of emission points, and where emission 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.

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 (40). 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 often required to convert this into an emissions estimate.

Key point 7: Both bottom-up (component level) and top-down (facility level and higher) measurements are needed to build reliable estimates of corporate methane emissions. There are a host of measurement technologies available, and a sophisticated approach employs multiple monitoring systems.

Methane can be detected and measured through its interactions with infrared light (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 (41).
- Cavity-enhanced absorption spectrometry (CEAS). An enhanced 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 (42).
- 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 (36; 43).
- 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 (44; 45).

Laser-based techniques for direct sampling are also sometimes referred to under active optical gas imaging, as opposed to passive approaches such as infrared cameras (46).

In situ sampling can be done at fixed installations or as part of ground-based (36) or airborne surveys (37; 42). Ground-based networks can be site-level or international in scale (36). 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 used handheld, fixed, or used as part of ground-based or aerial survey systems (e.g. the MAMAP instrument) (47). 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 (48; 46; 49).

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.

[10] 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.

Satellite instruments can be divided into two main categories:

- 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** (39).

- o Current examples: GOSAT (2009); TROPOMI (2017)
- o Planned missions: GOSAT-GW (2024); MethaneSAT (2024); Sentinel-5; GeoCarb; CO_2M; MERLIN

- Point-source imagers.

With fine pixel resolution (<60 m), these instruments are used to image and quantify **individual plumes of methane** (39).

- o Current examples: Sentinel-2 (2015); GHGSat (2016); PRISMA (2019); EnMAP (2022).

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 (35). Tackling these accidental large leaks identified by area-flux mappers could make a significant contribution to overall CH_4 emissions as they comprise roughly 10% of oil & gas CH_4 emissions (32).

	Component level				Facility level				Regional-global		
	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**
In situ sampling - Laser spectroscopy - Gas chromatography - HiFlow sampling	●	●	●	●	●	●	●		●		●
Imaging - Infrared cameras - Satellite instruments			●	●	●		●	●	●	●	
Atmospheric LiDAR - Ground-based - Airborne					●				●		
							'remote sensing'				

Table 4: Grouped measurement technologies and their use in different types of monitoring systems. Orange 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.

IMEO's MARS aims to connect satellite detection of methane plumes with a notification process to promote on-the-ground mitigation (34). 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 (32). While an individual satellite is inherently limited in temporal and spatial coverage, a constellation of satellites makes for a more formidable measurement system, notwithstanding the difficulties instruments have of retrieving readings when there is cloud cover, or in the following environments: offshore areas, snowy or ice-covered regions, and high latitudes.

Some companies are now using satellite data to improve their own measurement capacity (33).

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 the other which is unaffected. The difference in return signals provides a measure of the methane abundance. Surveys can be either:

- Ground-based, exploiting the back-scatter of the signal by aerosols at different levels in the atmosphere. This technique is known as range-resolved DIAL (RR-DIAL) (50; 40).

- 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) (51; 52; 53).

DIAL instruments can scan across a range of angles, as well as from a range of positions, allowing for the spatial resolution of methane plumes (54). They can be highly accurate but require technical expertise to operate and interpret (40). 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) (50).

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. Modelling may be required to extend and aggregate observations in time and space.

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 top-down measurements will increasingly hold corporates to account on their reporting of methane emissions. New satellites coming online in the next few years will support these efforts.

4. The policy context

4.1 A changing policy landscape

Policymakers globally are increasingly acknowledging the need to act on methane, as indicated by the growth of the Global Methane Pledge (GMP) to 155 participating nations as of December 2023, comprising just over half of global fossil methane emissions (55) (56). Led by the U.S. and the EU, signatories 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"* (57).

While there is no explicit national-level commitment in the GMP, 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 (58). Around half of the policies target fossil fuel methane emissions exclusively, with 8% addressing both fossil fuel and biogenic methane (58). The oil and gas sector is the primary focus of these policies, making up 76% of this total.

The fewer coal policies may be due to the relatively faster global transition away from coal, possibly reducing the sense of urgency to tackle its operational emissions (58). This is perhaps exacerbated by a prevailing misconception that coal mine methane emissions cease upon closure—when abandoned mine emissions are significant and growing in importance (58; 59; 60).

Key point 9: The progressive tightening of methane regulations globally suggests a growing transition risk for fossil fuel companies that lack strong methane management plans. The risk is especially clear within the oil and gas sector, where policies are progressing more rapidly.

4.2 Tackling methane emissions: a policy roadmap

The following bullet points outline a simple progression towards a mature policy environment for managing fossil fuel methane emissions, drawing from the *IEA's Regulatory Roadmap and Toolkit* (59):

1) Information-based policies: Serving as the foundational step, these policies aim to improve emissions data, for instance by requiring companies to estimate, measure and report emissions. Considering the limitations of the widely used IPCC Tier 1 and 2 reporting methods (see Section 3.1) this requires policies that promote direct measurement methods, supplemented with top-down approaches (61).

2) Prescriptive policies: These policies mandate the adoption of recognised best practices, such as restrictions on venting or flaring. By enforcing proven methods for emission reduction, they can secure significant methane emissions reductions (62).

3) Performance-based policies: With the goal of encouraging innovation, these policies establish specific standards—such as emission reduction targets—but do not prescribe methods for compliance. They can be used in addition to prescriptive measures and provide flexibility in how to meet further emission reductions. Their effectiveness hinges, however, on the availability of reliable reporting systems for establishing a baseline and quantifying progress (59; 63).

4) Economic instruments: These instruments offer financial incentives for compliance, making methane abatement more cost-effective. However, similar to performance-based instruments, they require a solid data infrastructure and regulatory enforcement to price emissions accurately and prevent underreporting by companies seeking financial benefits.

Achieving a coherent and ambitious policy framework requires the practical ability to measure and verify emissions accurately. Without this, the most ambitious policies, such as those based on economic incentives and performance standards, are not enforceable with accuracy.

Key point 10: An effective policy environment for addressing fossil fuel methane emissions relies on the establishment of a robust data infrastructure as its foundational element. Without this, policies based on performance or financial incentives for compliance lack credibility.

4.3 Policy maturity in top methane emitting countries

In **Figure 7** we show the coverage of fossil methane emissions by national regulations (per the maturity scale in Section 4.2) across the 25 highest-emitting countries globally, by IEA data. Over half of these emissions come from countries that have not committed to the GMP's 2030 emissions reduction target.

Additionally, China and Iran, two of the top four emitters and both non-signatories to the GMP, have not yet progressed to adopting performance-based or economic policies in their oil and gas sectors. The former's recently updated methane strategy has received criticism due to the absence of any explicit reduction targets (64). However, it does emphasise measuring, reporting & verification requirements and technology standards, which may potentially lay the groundwork for more rigorous measures in the coming decade (65; 66).

The chart also reveals that while economic instruments are adopted by most of the top 25 emitters, covering 68% of their emissions, they often precede the implementation of information-based policies. Olzak et al. (58) highlight that this common absence of regulations mandating regular measurement, estimation and reporting of methane emissions, is an important weakness in the current global policy landscape.

Finally, it is important to note that the existence of the full spectrum of policies does not guarantee efficacy.

For instance, despite the comprehensive regulatory framework of China's coal mine sector, persistent increases in emissions have been observed through satellite studies. These have been attributed to the issuance of exemptions for gases with lower methane concentrations, as well as non-compliance with MRV requirements (58; 67). This case underscores the need for rigorous monitoring and enforcement.

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).

Key point 11: Globally, economic policy instruments are common, but frequently not supported by information-based policies. Engagement with policymakers will be essential in addressing this regulatory gap, along with investments in advanced satellite technologies for independent monitoring of compliance.

Box 1: EU Methane Regulation Proposal

On 15 November 2023, the EU Council and Parliament reached a provisional agreement on the EU's Methane Regulation Proposal, as part of their "Fit for 55" legislation package (152). The law is expected to take effect in 2024, after formal adoption by the Council and Parliament (153). In its current form, the regulation imposes strict requirements on European operators, including MRV and the implementation of leak detection and repair (LDAR) surveys. Additionally, it requires proof of no emissions for inactive, plugged, and abandoned wells, along with MRV duties for closed or abandoned coal mines.

The regulation also tackles emissions beyond the EU's borders. It seeks to foster global emissions transparency through the implementation of a "**global methane emitters monitoring tool**" and "**rapid response mechanism**" for addressing major emission sources globally. Furthermore, beginning in January 2027, importers will be required to comply with the regulation's MRV criteria and meet specific methane intensity requirements by 2030.

With financial penalties in place for non-compliance, 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 production11 (59; 150). Additionally, the "methane footprint" of the EU's imported gas is three to eight times higher than that of its domestically produced gas (151). This underscores the significant leverage of the block in the global methane mitigation effort—an aspect that is not captured by **Figure 7**, which displays territorial methane emissions.

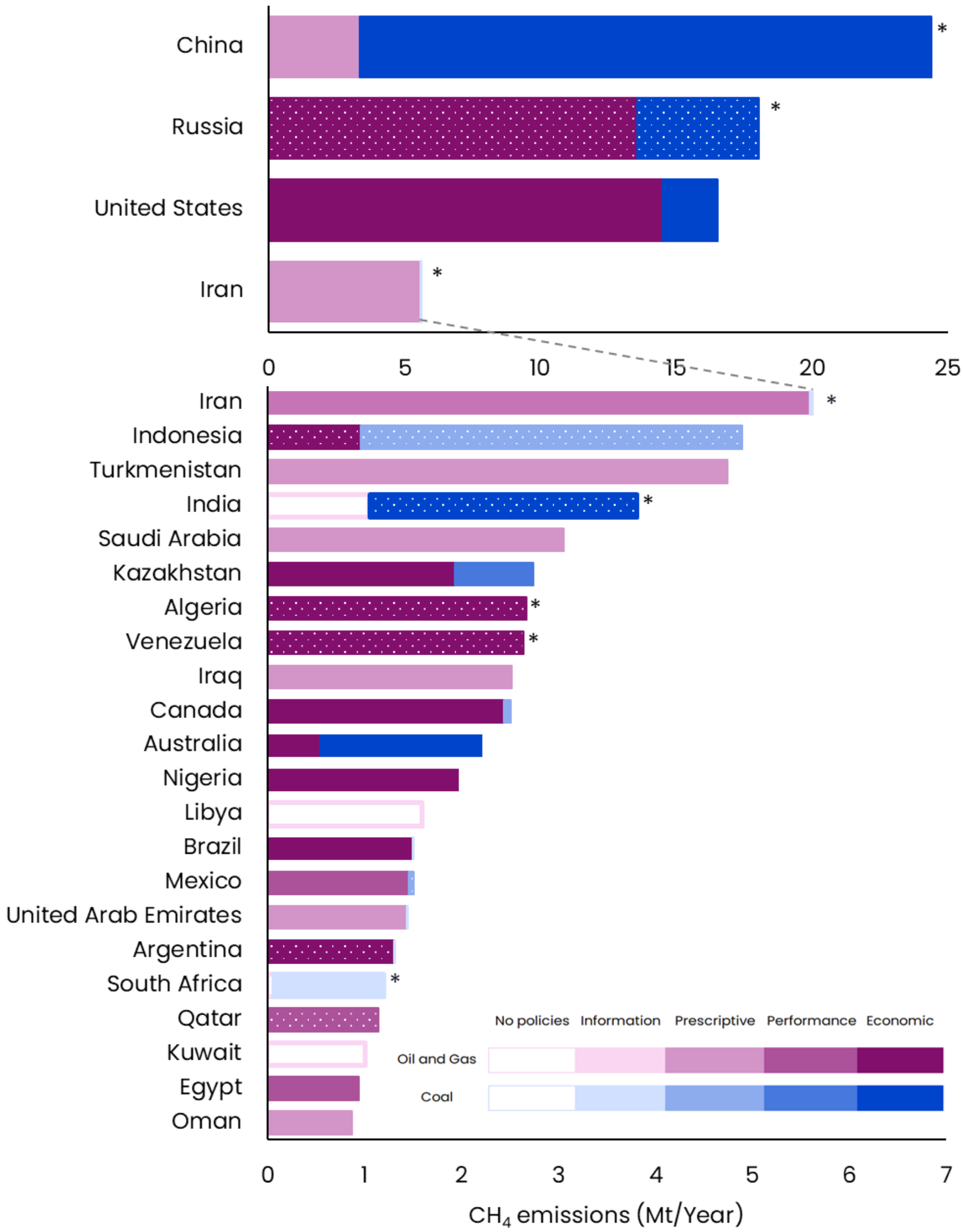

Figure 7: Policy coverage of annual methane emissions among the top 25 global fossil fuel emitters, based on the IEA's 2023 Global Methane Tracker (3). Policy information is drawn from the IEA's policy database(157), with supplementary data from Olczak et al. (58) and the Global Methane Pledge(160). Darker shading indicates a generally more robust framework, with stippling denoting the absence of informational policies and asterisks identifying non-signatories to the GMP.

[11] Calculation based on Eurostat EU natural gas import data (167) and Our World in Data production statistics (159).

5. Tackling methane from oil & gas operations

5.1 Introduction

Estimates of global methane emissions from oil and gas operations vary significantly. As shown in **Figure 6**, the UNFCCC national inventories sum to 38 Mt CH_4 (68), which is substantially lower than independent estimates using both bottom-up and top-down approaches (3; 6; 69; 70), which vary between 57-98 Mt CH_4. For analytical consistency, we rely here on the IEA's estimates of approximately 80 Mt (3). According to the IEA, methane accounts for approximately half of the oil & gas sector's 5.1 Gt CO_2e scope 1 and 2 emissions, marking a key opportunity for the sector to reduce its operational impact (62)

Figure 8 illustrates the breakdown of methane emissions in the oil & gas sector among the world's 25 highest-emitting countries, as per IEA data. In 2022, these nations collectively emitted 71 Mt CH_4, c. 90% of the sector's global total. The five highest emitters – the U.S., Russia, Iran, Turkmenistan and China - were responsible for over half of the total. The figure also reveals substantial variation in methane intensities among these nations (the highest of which is Turkmenistan), highlighting the importance of local management practices (71).

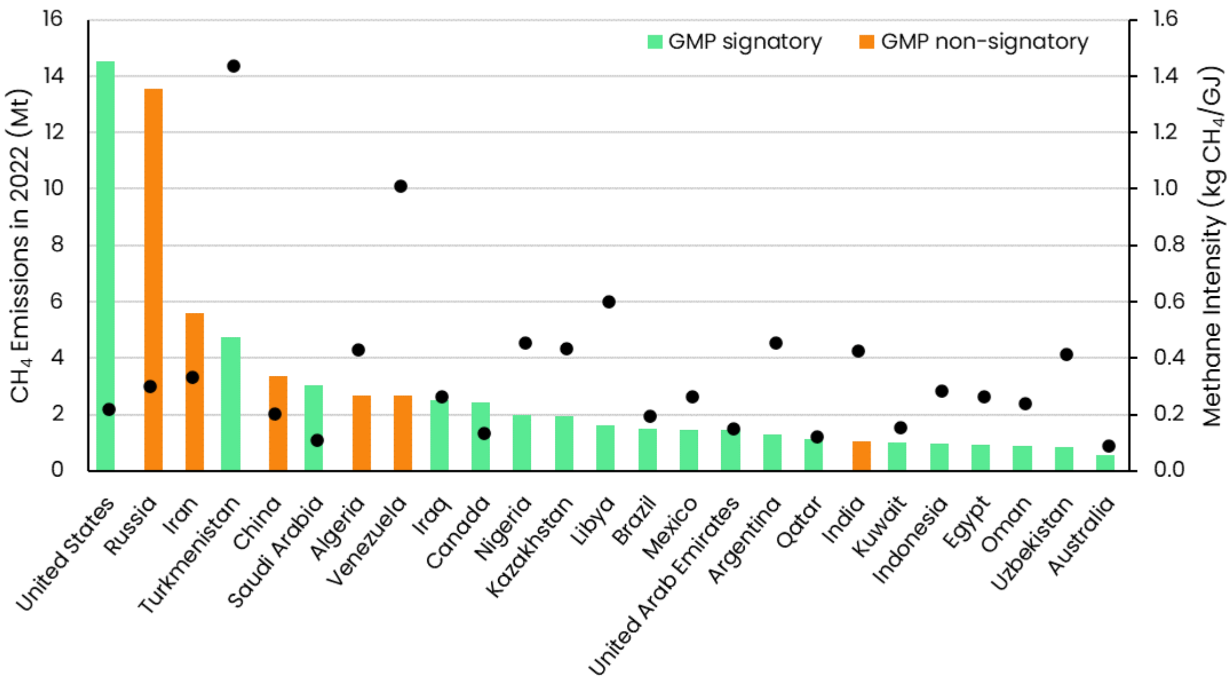

Figure 8: Top 25 global methane emitters in the oil & gas sector. Intensity figures are calculated by dividing total oil and gas emissions over total oil and gas production for the year 2022. Sources: the IEA's 2023 Global Methane Tracker (3) for national emissions, Our World in Data (158; 159) for production statistics (158; 159), and signatory data from the Global Methane Pledge (160).

Emissions also appear to differ substantially between International Oil Companies (IOCs), publicly traded entities with multinational operations, and majority state-owned National Oil Companies (NOCs). **Figure 9** shows bottom-up estimates of corporate methane emissions by Global Energy Monitor (GEM), based on reported production and region and segment-specific emission factors. 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%) (72).

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 (73).

However, their relative isolation from shareholder engagement and lesser stakeholder scrutiny often leads to lower accountability on environmental performance. Additionally, these state-owned companies are relatively concentrated in nations that are non-signatories of the Global Methane Pledge, such as Russia, Iran, China, and Algeria (73; 74). We address barriers to investor engagement with NOCs in Box 2: Strategies for Engaging with NOCs

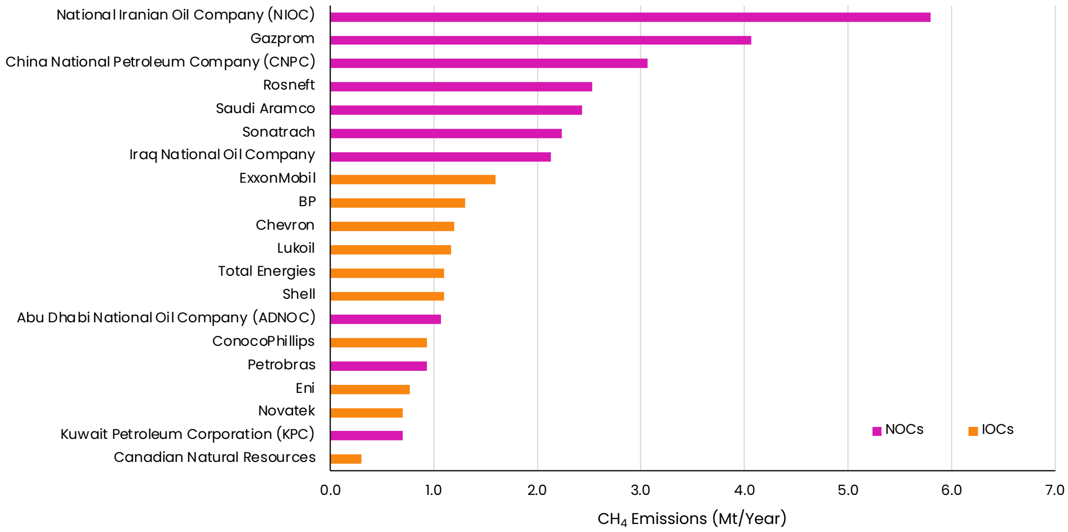

Figure 9: Methane Emissions by Top 10 IOCs and NOCs according to Global Energy Monitor data (72).

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) Engagement via IOCs

One means for investors to influence NOCs is via the joint venture relationships between NOCs and IOCs **(75; 76; 77)**. These are partnerships characterised by shared ownership, governance, and the distribution of risks and profits **(75)**. 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 (roughly 5% of global production) **(76)**.

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 **(75; 76)**. For a more comprehensive understanding of these pathways of influence, the 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).

B) Policy engagement

Investors can engage with domestic policy on methane in NOC countries, to raise the floor on mandatory methane action. A case in point of such engagement occurred in 2021 when investors representing US$6.23 trillion AUM urged the Biden administration for stricter methane regulations in a collaborative letter **(78)**. The initiative coincided with the administration's efforts to update federal methane regulations, providing a platform for investor input into the regulatory revision process (78).

C) Engagement with banks

Banks, an important source of finance for NOCs, can also support improvements in practice (79), including by placing conditions on financing, and using credit relationships to engage on methane management. Banks can also facilitate the issuance of financial instruments such as sustainability-linked bonds and transition bonds, which may be used to support methane mitigation **(74)**. Investors can engage with banks to encourage them to manage these methane-related risks on their balance sheets or business relationships **(79)**.

D) Direct engagement with NOCs and NOC governments

Direct engagement with companies can also be successful, especially where investors have some equity stake. For example, after investor engagement under CA100+, Petrobras agreed to join the OGMP 2.0 and the Oil and Gas Climate Initiative's (OGCI) "Aiming for Zero Methane Emissions" flaring monitoring initiative **(80)**.

Additionally, investors can engage NOC governments directly, who provide a mandate for NOC activities. As sovereign lenders increasingly incorporate climate risks into credit decisions, governments owning NOCs could face rising borrowing costs and engagement on their use of proceeds **(81; 82)**.

Key point 12: Global oil & 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, policy engagement, engagement with banks, and direct engagements with NOCs and NOC governments.

5.2 Origin of oil & gas methane emissions

Since methane makes up around 90-95% of natural gas, emissions can occur throughout the entirety of its value chain. In crude oil value chains, methane emissions occur during oil production and processing due to the frequent association of gas deposits with oil reserves (83; 84).

As shown in **Figure 10**, the production segment is the sector's primary origin of methane emissions, responsible for approximately 80% of the total, excluding consumption-related emissions. Notably, the majority of these emissions are dominated by oil production, while midstream emissions appear to be almost exclusively associated with natural gas and LNG infrastructure. Across all segments, current satellite detection of individual large leak events, or "super-emitters", is relatively low (4%), although this proportion may rise with advancements in satellite data acquisition and processing (61; 59).

Between segments, emission sources also diverge. In the natural gas midstream segment, approximately 65% of emissions are fugitive, arising from unintentional leaks caused by equipment failures. Conversely, around 74% (65% of the sector's total) of production-related emissions are caused by venting - the deliberate release of waste gas streams for safety or design reasons (27; 3).

An additional 9% of the sector's total emissions results from incomplete flaring during oil production, where gas is burned off, releasing CO_2 rather than CH_4. However, this combustion to CO_2 is rarely complete, allowing some methane to escape. Worse, flares are sometimes active but unlit. Recent research indicates a significant underestimation of methane emissions from flaring, with actual emissions in major U.S. gas-producing areas being five times higher than government estimates, and flaring efficiency recalculated to around 91%, markedly lower than the previously estimated 98% (85; 86).

Finally, it is important to note that corporates sometimes misidentify intentional (vented or flared) emissions as unintentional (or 'fugitive') (51). For instance, an aerial survey in British Colombia identified 75% of emissions as venting or flaring, contrasting with earlier classifications of 73% as fugitive (51). Misclassification could hamper abatement efforts, as the distinct emission sources have distinct solutions (see 5.4 Mitigation approaches) (51; 87).

Key point 13: Oil and gas methane emissions are concentrated in the upstream segment, and throughout transmission and distribution for natural gas. According to where a company operates in these value chains, the nature of emission sources under their scope (and suitable mitigation strategies) will vary.

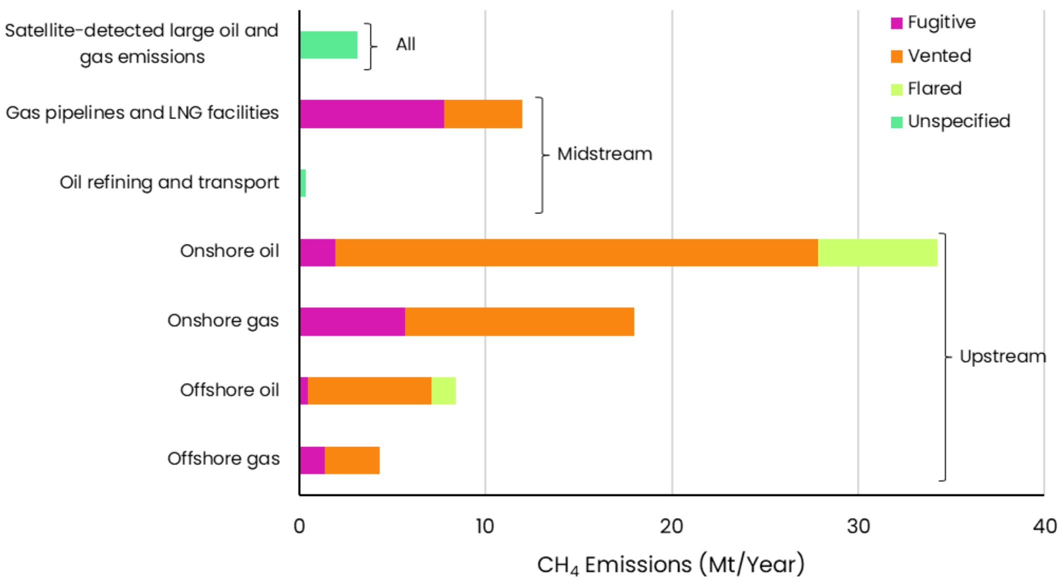

Figure 10: Oil and gas methane sources per segment. Using data from the IEA 2023 Global Methane Tracker (3) but excluding emissions resulting from consumption. Chart adheres to SBTi's segment categorisation of the O&G value chain (upstream, midstream, downstream) (161).

5.3 Status of methane emissions reporting and target setting

precise monitoring and disclosure of methane emissions essential for investors, as part of understanding company exposure to transition risks (88).

As of January 2024, membership of the leading oil & gas methane reporting framework, the IMEO's Oil and Gas Methane Partnership (OGMP 2.0) stands at 125, up from 62 in 2020 (34; 55). Its 'Gold Standard' rating approves oil & gas companies that have robust implementation plans to achieve measurement-based reporting (levels 4 and 5) on:

- **operated assets** by 2024 (based on 2023 data)
- **non-operated** assets by 2026 (based on 2025 data) (35).

In 2022, 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, meaning they should move to levels 4 and 5 across operated assets in 2024. However, despite representing about **34%** in global oil & gas production, 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 suggests significant underreporting, as acknowledged by IMEO in their 2023 OGMP 2.0 report (34).

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 (34); the norm is still a reliance on emission factors.

As companies progress into measurement-based reporting (levels 4 and 5), all things being equal, 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 (34). 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.

Key point 14: Until companies establish credible, measurement-based reporting methods (i.e. OGMP 2.0 Levels 4 and 5), emission disclosures and reported performance against targets should be treated with scepticism. The issue is perhaps most acute with respect to intensity targets, which are based on industry-wide comparisons.

Methane intensity has become the industry's preferred method for communicating emissions performance (89). Among OGMP 2.0 upstream oil and gas companies, 76% have set intensity targets, usually targeting the OGCI's **0.2%** benchmark (34).

Indexed reduction targets, which measure % emissions reductions against a specified baseline, are less common. Industry majors like Repsol, ExxonMobil, bp and TotalEnergies are among the few that have adopted these, alongside their physical intensity targets (90; 91; 92; 93).

As **Figure 11** shows, numerous companies report having already passed their intensity performance targets (any company below the x axis). A notable example is OGCI, an alliance of 12 IOCs, which collectively report having achieved an average methane intensity of **0.17%**, exceeding their industry benchmark of 0.2%, well in advance of the 2025 target year (94).

Given the absence of comprehensive measurement-based reporting and the frequent exclusion of non-operated assets from such targets—in some cases exempting up to 65% of a company's production (75)—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 (62).

Disclosures from individual companies also acknowledge that intensity figures are rendered uncertain by a lack of reliable measurement. bp, for instance, reported a methane intensity of 0.05% in 2022, well below the OGCI target (95). However, the company conceded that this figure was subject for revision as measurement accuracy improves. Similarly, Shell indicated that their reported methane intensity for 2022 was an "estimate only", citing ongoing measurement challenges (96).

The variety of methods for calculating methane intensity, presented in **Table 5**, complicates the interpretation of intensity targets (89). For example, Occidental reported an intensity of 0.26% using OGCI methodology, but 0.13% when applying NGSI guidelines (97). The OGCI method does not factor oil production into 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. This hinders investors' ability to compare industry performance. Consolidation around a single approach would be beneficial; we suggest that the IEA approach—using total methane emissions in the numerator and total energy-based production in the denominator, for both natural gas and oil—is the simplest and most widely applicable method.

Key point 15: To aid industry comparability, we encourage convergence upon methane intensity measured as total emissions (by product or segment or business), divided by total energy production (over the same boundary as the numerator). The resulting unit will be tCH_4/TJ or equivalent.

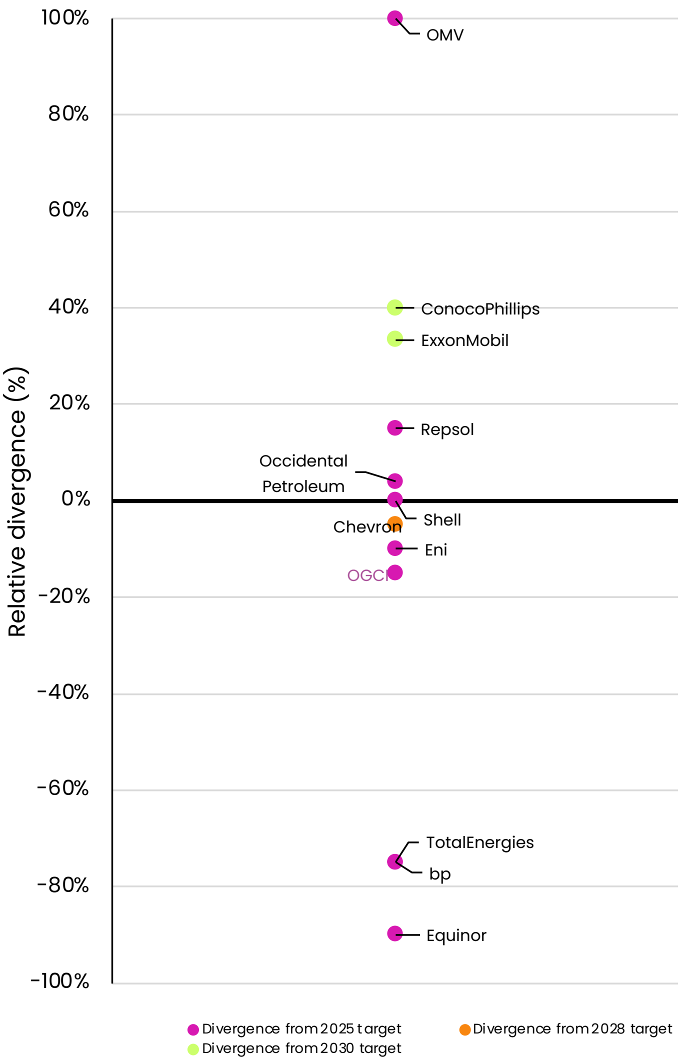

Figure 11: Divergence from methane intensity targets for selected O&G majors in most recent reported emissions. The divergence is calculated as the percentage difference between the companies' current performance and their respective targets (target date indicated by colour). Calculating divergence enables performance against targets of different types to be compared on a common baseline. Sources: Shell, 2023 (164); TotalEnergies, 2023 (90); bp, 2023 (91); ExxonMobil, 2023 (92); Repsol, 2023, (93); ConocoPhillips, 2023 (114); Occidental Petroleum, 2023 (97); OMV, 2023 (165); Eni, 2023 (116); Chevron, 2023 (166); OGCI, 2023 (94).

Organisation	Intensity target	Intensity calculation methodology
OGCI	≤0.20% by 2025	$\frac{\text{Upstream oil and gas emissions } (m^3)}{\text{Marketed natural gas } (m^3)}$
NGSI	Methodology only	$\frac{\text{Segment } CH_4 \text{ emissions from natural gas (t)}}{CH_4 \text{ content of natural gas throughput (1000 cu ft)}}$
MiQ	≤2.00% to ≤0.05%	$\frac{\text{Segment emissions from natural gas (gCH4)}}{\text{Energy throughput of natural gas (mmbtu)}}$
One Future Gas Coalition	Collective target of ≤1% by 2025	$\frac{\text{Total CH4 emissions across participant collective gas operations (kt } CH_4)}{\text{Total gross gas production (Bcf)}}$
IEA (NZE)	Natural gas: 0.5% by 2030 Oil: 0.3% by 2030	$\frac{\text{Total natural gas or oil } CH_4 \text{ emissions (Mt)}}{\text{Global marketed natural gas or oil production (EJ)}}$

Table 5: Methane Intensity Targets and Calculation Methodologies According to Industry Guidelines. Note that the MiQ's 2.0 intensity target is the compulsory threshold for MiQ certification. MiQ measures emission intensity across distinct segments of the natural gas value chain. The NGSI takes a similar approach but with an alternative segmentation of the value chain, requiring different calculations. Sources: IEA, 2023 (62); OGCI, 2023 (98); NGSI, 2021 (99); M.J. Bradley & Associates, 2018 (100); MiQ, 2021 (101); One Future, 2017 (102); One Future, 2023 (103).

5.4 Mitigation approaches

In the IEA's NZE scenario, methane emissions from natural gas and oil drop by approximately **76%** and **80%** by 2030, respectively (104). One-third of the total reduction comes from production declines, while the remainder is achievable through the deployment of established mitigation technologies, including Leak Detection and Repair (LDAR) programmes and upgrading outdated equipment (105).

Implementing these technologies is projected to cost USD 75 billion through 2030, less than **2%** of the industry's 2022 net income (106; 105). Comparing to the value of the retained methane using average gas prices from 2017 to 2021 suggests that up to **40%** of methane emissions could have been mitigated at no net cost. This rises to **80%** using 2022 prices (104). Even without a market for the captured gas, an emissions price of $20 per tonne CO_2-equivalent would make nearly all mitigation measures financially viable (104)—markedly below the US's recently announced fee of $900–1,500 per tonne of methane ($30-50/t$CO_2$e) for facilities emitting over 25 ktCO_2e a year (107; 108).

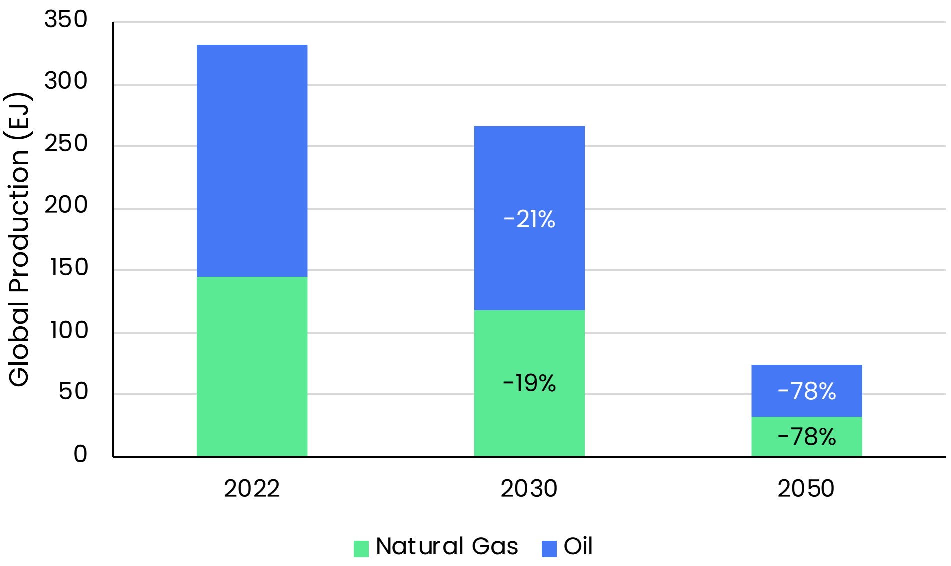

Figure 12: Oil & gas production reductions in the IEA NZE. Source: IEA Net Zero Roadmap (104).

As shown previously in **Figure 10**, the majority (65%) of oil & gas methane emissions occur due to **venting** (3). Some key strategies and examples to reduce venting-related methane emissions are:

I. Replacing high-emission devices, such as natural-gas driven pneumatic equipment, to "zero-bleed" equipment which does not rely on natural gas pressure and instead uses clean power sources such as electricity or compressed air (109; 61). Similarly, wet seals in centrifugal compressors are known to heavily absorb and vent methane but can be easily replaced by dry seals (109; 110).

II. 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 dehydrator venting emissions, crucial for maintaining pipeline integrity, can involve installing flash tank separators and optimising glycol circulation in dehydration systems (109; 111).

III. Excess gas recovery and utilisation: Utilising "vapour recovery units" to capture and pressurise hydrocarbon vapours can enable their redirection into pipelines for commercial or onsite use, reducing emissions while maximising resource utilisation (110; 109). Where immediate market distribution is not possible, capturing and transporting gas for storage is another viable option (112; 105).

Flaring, which partially converts CH_4 into CO_2 through combustion, is often preferred over the direct release of methane emissions through venting (113; 110; 83). However, in addition to limitations related to incomplete combustion, flaring is a significant source of CO_2 and pollutants that are harmful to human health (105; 109; 85). Flares are also energy-intensive to keep lit, especially at times of low flow. According to the IEA, ending non-emergency flaring by 2030 would cut flaring volumes by **95%** (62). As such, adopting the World Bank's "zero routine flaring (ZRF) by 2030" pledge is one of the most important early measures for oil & gas producers to take. Indeed, many may get there sooner, with companies like Shell, ConocoPhillips and Eni targeting zero routine flaring as early as 2025 (96; 114; 115; 116).

Like venting, flaring can be avoided by increasing the capture of excess or associated gas for on-site utilisation, market distribution, or storage (112; 105). Alternatively, where flaring cannot be avoided yet, operators should ensure that flares remain lit and are equipped with automatic re-ignition mechanisms, to improve flare destruction efficiency (86; 117).

Fugitive emissions can be managed through LDAR programmes (118; 113). These involve identifying and fixing leaks throughout the supply chain, employing a variety of techniques detailed in 3.4 Measurement techniques (69). Frequent inspections are crucial for the early identification of major and unpredictable emission sources, especially super-emitters (110; 61). Extensive surveying is particularly critical in **midstream gas operations**, where fugitive emissions from large leaks and non-continuous sources are more prevalent (3; 119). Other key strategies include enhancing Boil-Off Gas (BOG) management and minimising methane slip during LNG transit and shipping (110).

Key point 16: A comprehensive methane mitigation plan in oil & gas tackles vented, fugitive and flaring emissions. It commits to zero non-emergency flaring and venting, incorporates advanced LDAR programmes, and continuously improves process and equipment efficiency.

Effective methane abatement relies on multiple conditions being met. Investment decisions that will reduce flaring or venting, for example, often depend on policies promoting the productive use of associated gas or the availability of export infrastructure (112; 59). Moreover, the effective operation of this infrastructure demands skilled management to overcome challenges like capacity constraints and timing mismatches between production start and infrastructure readiness (112).

Differences in these situational factors contribute to the high regional diversity in methane emission intensities, shown in **Figure 8**. For instance, the high methane intensity in Turkmenistan is attributable to obsolete equipment causing leaks and excessive venting, while Algeria's high flaring volumes are a result of inefficient gas transport and processing infrastructure (71).

Addressing such barriers requires targeted support, particularly in economies where financial and technical resources are more constrained. The World Bank's Global Flaring and Methane Reduction Partnership (GFMR), which has obtained a $255 million grant for methane reduction in low- and lower-middle-income regions, marks a notable milestone. Nonetheless, substantial additional efforts will be needed to meet the estimated $12 billion investment gap in these geographies for a 75% methane reduction by 2030 (74; 117).

As well as financial resources, assistance can be delivered as technical support, such as the planned collaboration between U.S. technical experts and Turkmenistan's state-owned company officials to improve the country's methane management practices (120). Additionally, companies can join voluntary industry initiatives such as the Methane Guiding Principles (MGP), which enables members to pool resources and expertise to tackle shared challenges (76).

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.

5.5 Assessing methane targets

Investors want to understand whether their companies' targets are aligned with 1.5°C goals. It is possible to construct benchmarks that establish the requisite level of ambition and enable such comparisons. Here we provide such benchmarks using the IEA's NZE scenario and the Global Methane Tracker 2023. It is vital to note, however, that methane targets are only credible and meaningful when underpinned by accurate measurement-based reporting.

Delivering the headline figure of **-75%** methane emissions from all fossil fuels by 2030 requires methane emissions from oil to fall **80%** and from gas to fall by **76%.** In the IEA's NZE, this is delivered by declines in both production and methane intensity of production (**Figure 13**).

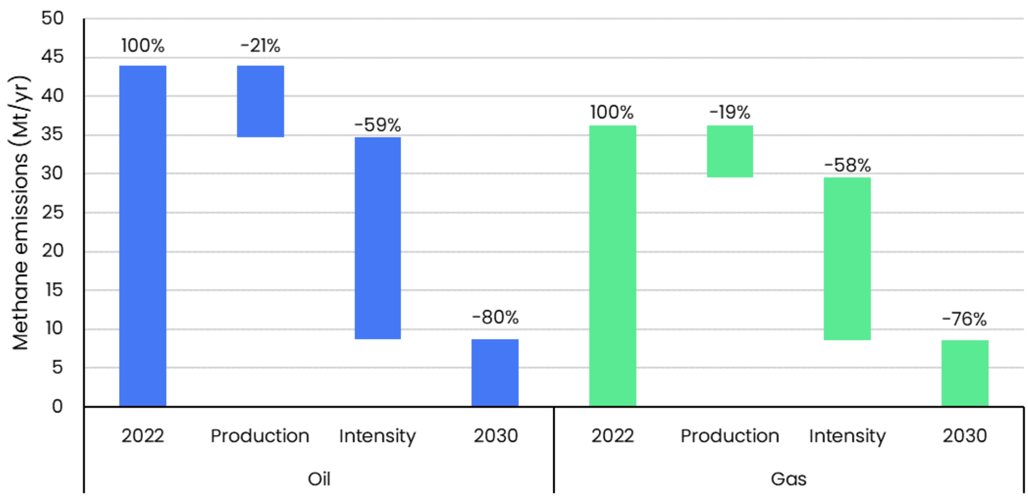

Figure 13: Declines in methane emissions between 2022 and 2030 from oil and gas operations in the NZE. In this scenario, total reductions are driven by a combination of declines in production and methane intensity. Based on Global Methane Tracker 2023 (3) and NZE (104).

Companies that commit to production declines in line with the NZE pathway (**Figure 13**) would need to target methane intensity reductions of **75%** and **71%** in oil and gas, respectively, by 2030, in order to meet the NZE's methane reductions. Companies that pursue 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_2 basis).

An indexed approach to target setting (as shown in **Figure 13**) is based on the historical emissions of a company, and in this way is tailored to its portfolio. There are several pros and cons to indexed targets.

Assessing all companies against the same indexed reductions results in the allocation of higher emissions rights in absolute terms to higher historical emitters; emissions rights are 'grandfathered' (121; 122). This simple approach is pragmatic, but neglects: i) the extent to which corporates have already pursued emissions reductions efforts prior to the base year; ii) how their starting methane intensity compares; iii) interannual variability in methane emissions, which may make the base year unusually high or low; iv) fairness issues associated with grandfathering, though these are less acute in a 1.5°C scenario where there is no room for new long-lead time oil and gas fields in any geography (123).

A potential complication in using indexed targets is that, as emissions measurement and reporting improves, the baseline may change. To make these targets meaningful, and remove adverse incentives against expanding direct measurement, we suggest that re-baselining indexed targets should be allowable—providing these adjustments are clearly justified and stated.

Key point 18: In the NZE, methane emissions decline by 80% and 76% by 2030 in oil and gas, respectively, against 2022 levels. Despite limitations, benchmarks based on indexed declines call for companies to act in line with these overall required reductions. Re-baselining indexed targets (to account for MRV progress) should be allowable but transparently stated and justified.

An alternative form of target setting, as discussed in Section 5.3, uses intensity units. 76% of upstream oil and gas companies in the OGMP 2.0 set their targets in this form (34).

However, several problems prevent the construction of useful methane intensity pathways at this time. Defining the base year value requires using global methane emissions and global production. We know, however, that i) estimates of total global methane emissions vary widely, and that, ii) in general, corporate reporting and UNFCCC inventories both likely understate emissions (**Figure 6**).

Using a credible figure (e.g. IEA estimates) for global methane emissions would result in a global intensity trajectory that exceeds most current reported intensities, even in 2030—rendering it essentially useless as a means for driving necessary reductions. With this caveat in mind, the IEA's NZE methane intensity pathways are as follows (62):

- **Gas:** 1.4% in 2022, falling to 0.5% in 2030
- **Oil:** 1.3% in 2022, falling to 0.3% in 2030

As corporate reporting becomes more reliable (using OGMP levels 4 and 5), this gap should diminish, ultimately allowing for the construction of a meaningful intensity benchmark. In contrast, while there is uncertainty around corporate base year emissions, indexed decline benchmarks are at least unambiguous about what is required from corporates overall.

Added to this difficulty, it is not immediately obvious how each company's targets would relate to a single benchmark definition, given that companies calculate methane intensity in a variety of ways. Convergence upon units of total CH_4 emissions over total energy production (tCH_4/TJ)—the most widely applicable and comparable approach—would remedy this.

A further complication is that, within oil and gas businesses, a distinction can be made between upstream and midstream operations. This is important for the initial magnitude of emissions and methane intensity, and the abatement potential (**Figure 9**).

Key point 19: Given likely corporate underreporting, intensity benchmarks based on global methane emissions from oil and gas may be ineffective at driving necessary reductions. However, as companies move to reporting in line with OGMP levels 4 and 5, their reporting should become more comparable with global benchmarks.

6. Tackling methane from coal mining

6.1 Introduction

Coal mine methane emissions comprise roughly one third of methane emissions from fossil fuel operations (**Figure 2a**) and dominate coal miners' overall operational emissions (**Figure 2b**). Methane emissions can also make up a significant fraction of the operational emissions of diversified miners that hold coal assets (124).

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 6**, other estimates yield higher numbers: recent top-down/hybrid studies put annual global emissions at **33 Mt**, Shen et al. (125); **41 Mt**, IEA (3); while an independent bottom-up assessment from GEM yields **52 Mt** (126).

Figure 14 shows the IEA's country-level methane emissions estimates for the 15 highest emitting coal producers (representing 98% of global coal emissions). These exclude emissions from abandoned mines, which may become increasingly significant in relative and absolute terms as mines are retired (127). Ember estimates that abandoned mine methane emissions add **7 Mt** to the IEA's total (128).

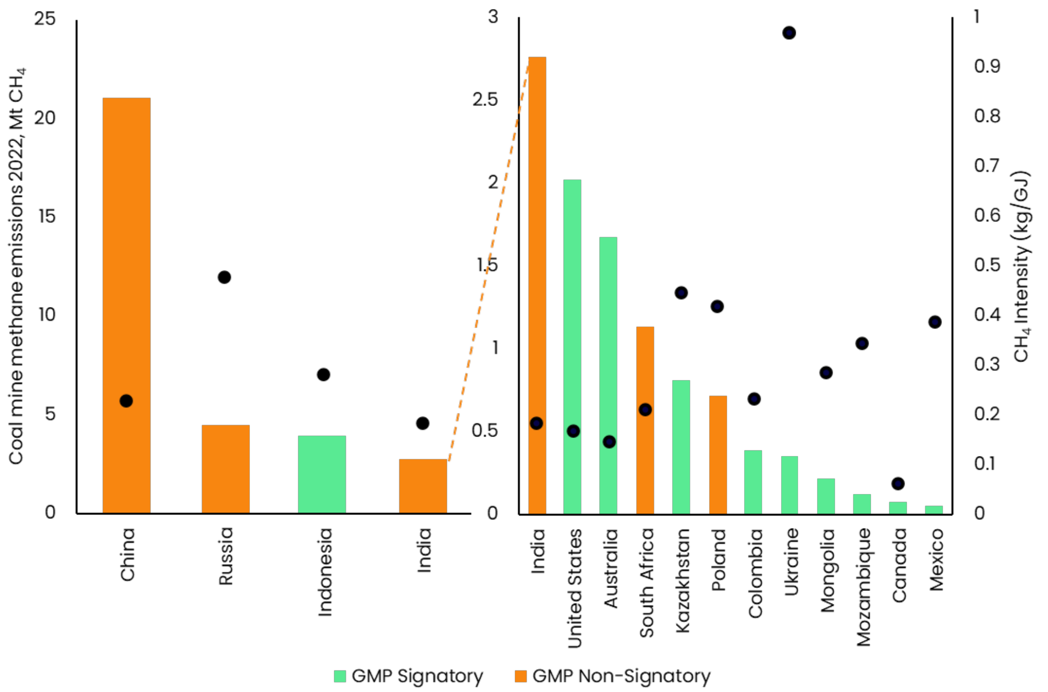

Figure 14: . Coal mine methane emissions in highest emitting 15 nations. Top four on left; top 4-15 on right. Note that methane emission axis is rescaled, whereas intensity axis (black dots) is the same across both panels. Intensity figures are calculated by dividing total coal emissions by total coal production for the year 2022. Sources include the IEA's 2023 Global Methane Tracker (3) for emissions, Our World in Data (162) for production statistics, and signatory data from the Global Methane Pledge (160).

China accounts for roughly half of global coal mine methane emissions, similar to its share of global coal production (129; 125; 66; 126), with the Shanxi province the leading regional emitter by a significant margin (129). According to GEM estimates (126), 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 15** (72). In contrast, the top ten investor- and privately-owned entities are more geographically distributed in both headquarters and operations (72).

[12] 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.

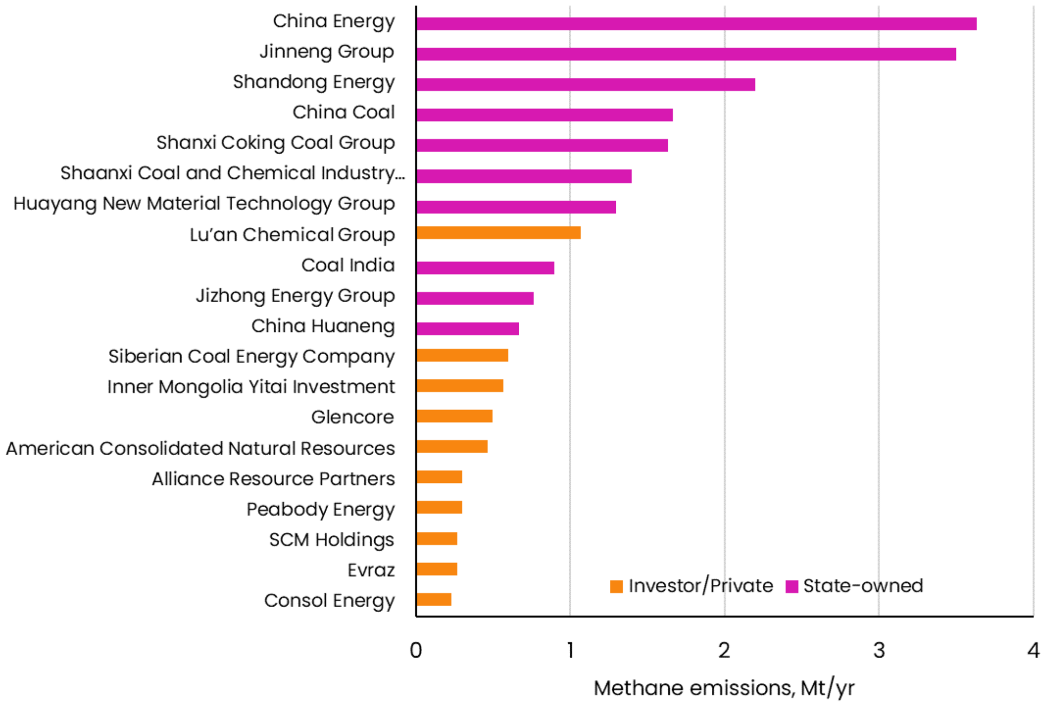

Figure 15: Coal mine methane emissions by top ten SOEs and top ten investor-owned companies, as estimated by GEM (72). GEM use a bottom-up approach with emission factors based on the MC2M methodology outlined in Kholod et al. (127).

6.2 Origin of methane emissions in coal mining

Methane is produced during coalification, the geological formation of coal from 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[13] to coal grains.

As illustrated in **Figure 16**, two factors are pivotal for the potential methane emissions from a coal mine (127; 130):

- Coal rank. 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 therefore more methane available to leak to the surface when the rock is disturbed upon mining (130; 131).

- 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 (28).

On top of these two factors, methane emissions are determined by the method of mining employed and the quantity of coal mined (130).

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 system

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.

[13] Adsorption: the process by which molecules of a gas (or liquid) adhere to a solid surface

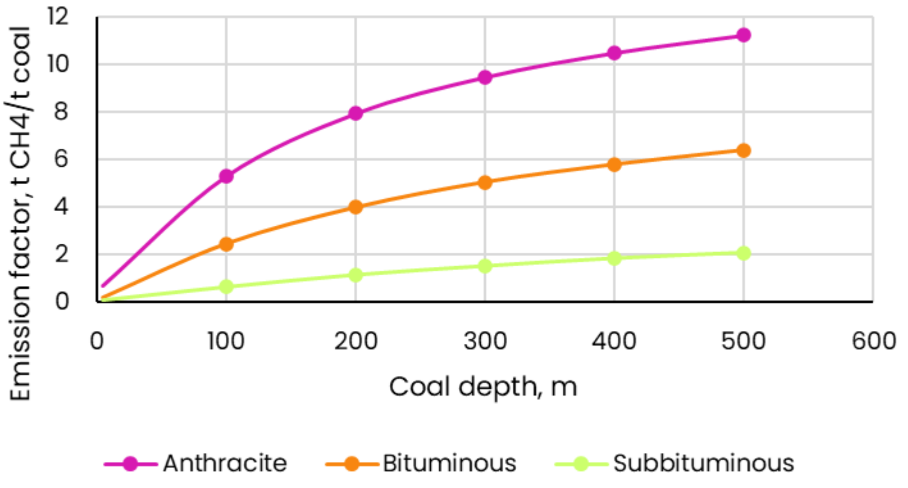

Figure 16: Factors used to predict methane emissions from the MC2M methodology (127; 126). Methane emissions increase with rank of coal and depth of mining.

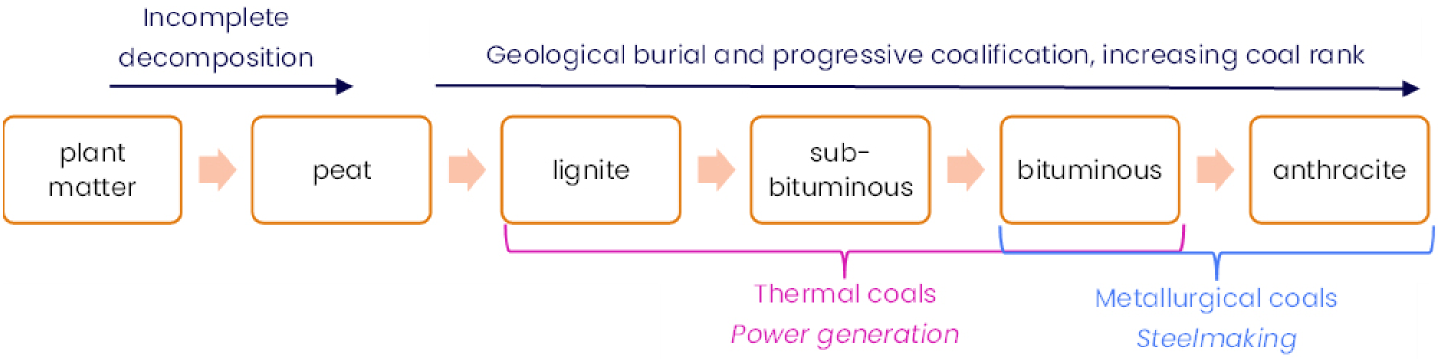

Figure 17: Transition of plant matter to coal grades of increasing rank, from lignite to anthracite (131). Methane emissions increase with increasing coal rank. Carbon content of coal increases and moisture content decreases with increasing rank. Anthracite is sometimes referred to hard coking coal (HCC).

6.3 Status of reporting

Countries report coal mine methane emissions to the UNFCCC using a menu of approaches outlined by the IPCC (27). 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) (128). 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 direct measurement is used in coal mine methane reporting. Due to 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 (27).

As an example, Australia's reporting regulations stipulate a measurement-based approach for underground mines, but a Tier 2 emission factor approach for surface mines (c. 80% of its coal production) (132; 133). This approach has recently come under criticism (133; 134), after independent satellite-based studies concluded that methane emissions from surface mines in Australia's Bowen Basin in Queensland were being significantly underestimated (135; 136).

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 (134). Specific measurement technologies and monitoring systems that could be used are outlined in *3.4 Measurement techniques.*

In a parallel effort to the OGMP 2.0, UNEP is developing a Steel Methane Partnership (SMP), which will serve as a 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 broad structure outlined in Section 3.3. The highest level of reporting (Level 5) in a recent SMP draft includes the following elements (137; 133):

- 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 & gas. Where miners do have targets on methane, these tend to be as indicative pathways as part of an overall CO_2e operational emissions target rather than as a standalone CH_4 target.

Key point 22: UNEP's Steel Methane Partnership, 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.

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 **70%** by 2030 vs. 2022 (3). The **47%** fall in overall global coal production in the NZE by 2030 (**Figure 18**) nearly halves methane emissions, while the remaining reduction comes from decreasing the methane intensity of production.

In underground mines, miners already manage methane for safety reasons. Emissions arise from degasification systems from pre-mining drainage of methane, and from ventilation air systems during operations. These are point sources that are amenable to mitigation (139). Degasification systems offer good potential for capture and/or utilisation of methane as natural gas. In ventilation air, methane concentrations are generally low and fluctuate with time. If concentrations are high enough, methane can be captured and utilised. Otherwise, methane can be destroyed via thermal oxidation; a relatively expensive process but one that is effective even at low concentrations. Methane may also be flared where these techniques are unviable (105).

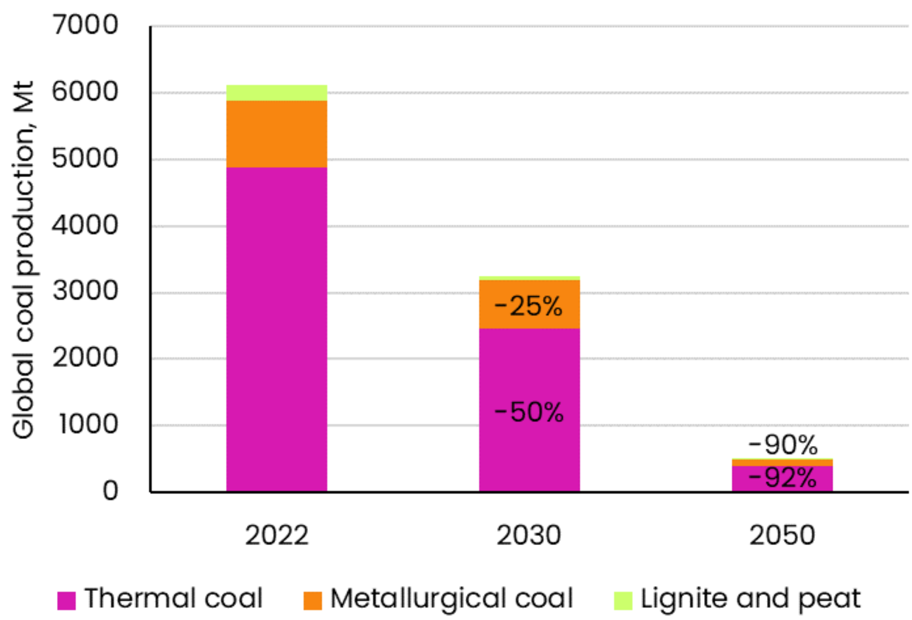

Figure 18: Coal production in the NZE, split out by thermal coal, metallurgical coal, and lignite and peat (123). Percentage declines are relative to 2022.

A comprehensive methane abatement strategy includes measures taken throughout the mine life cycle (139; 105). For underground mines, these include:

I. Before mining: draining and capturing methane via degasification boreholes
II. During mining: capturing or destroying ventilation air methane (VAM) and using techniques that minimise coal seam and rock disturbance
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 (139).

Existing abatement techniques could cut current coal mine methane emissions by **55%** (**Figure 19**), according to the IEA (3). This corresponds to intensity reductions of **70%** at underground mines and **20%** at surface mines (**Figure 20**).

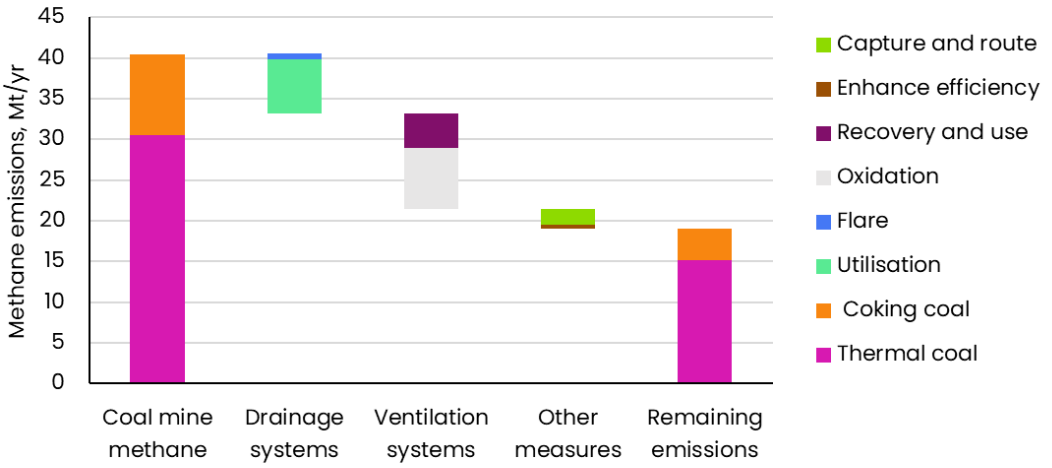

Figure 19: Coal mine methane mitigation approaches. Plot shows the feasible contributions different technologies could make to mitigating 2022 coal methane emissions. From IEA Global Methane Tracker 2023 (3).

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 (105). For example, more than 87% of China's coal production is underground (140), whereas Indonesia's is almost entirely surface (126). 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 (105).

Key point 23: While underground coal mines are typically higher-emitting than surface mines, they also present greater methane abatement potential. Similarly, due to its more frequent underground origin, metallurgical coal is more methane intensive than thermal coal, but offers greater intensity reductions.

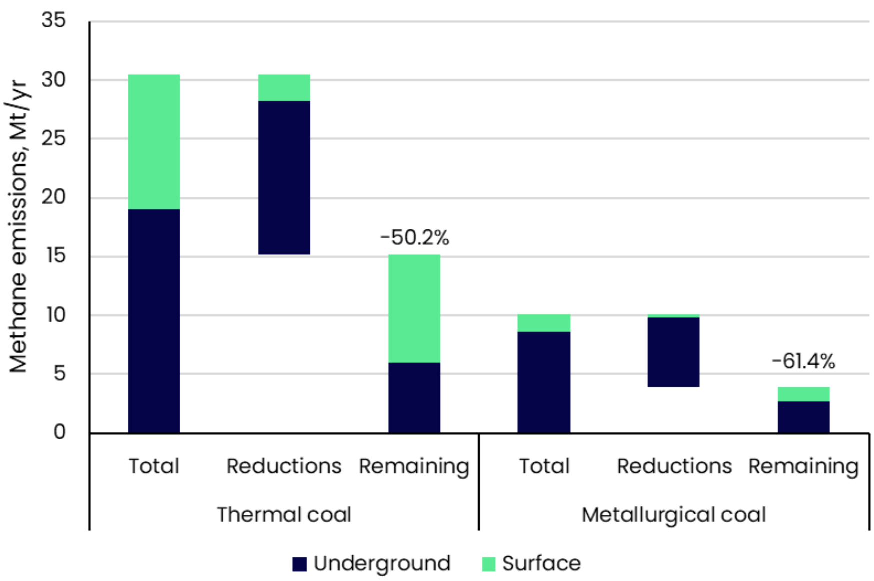

Figure 20: Coal mine methane abatement potential in 2022, broken down by thermal coal and metallurgical coal. Figure adapted from IEA Global Methane Tracker 2023 (3).

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_2e (124; 138). Recognising the importance of the issue, and its unique pathway, investors want to see miners disclose targets specific to methane emissions—insofar as these are meaningful, as we discuss below.

Using the IEA's NZE, and emissions intensity projections from the Global Methane Tracker and Curtailing Methane Emissions from Fossil Fuel Operations report, we set out proposed 2030 benchmarks for indexed methane emissions targets here, and describe various considerations around assessing targets on coal mine methane.

There are two central and connected difficulties with evaluating miners' targets:

- Each miner has a different portfolio of mines, with specific methane emission characteristics

- Methane emissions may not be accurately characterised, whether in the base year or on an ongoing basis

Neither of the above should preclude taking action—there is potential for abatement at all mines (unless all such actions have already been taken), and the urgency of the need for emission reductions means that mitigation actions should not be delayed in lieu of establishing a multi-year measurement baseline. Nonetheless, ensuring high-quality measurement is a foundational action that will help miners both to set meaningful targets and track their progress over time.

In **Figure 21** we show overall indexed declines in methane emissions from thermal and metallurgical coal from the IEA NZE. The 70% decline in coal mine methane by 2030 (vs. 2022) is comprised of 73% and 63% reductions from thermal and metallurgical coal, respectively (105; 104).

These overall reductions involve both intensity and production declines, as shown in **Figure 21** (3). 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.

Mining companies that commit to production declines in line with the NZE would need to target intensity decreases of 45% in thermal coal and 50% in metallurgical coal to achieve the total methane reductions (105). Miners maintaining higher levels of production would need to pursue steeper intensity declines in order to meet the overall NZE benchmark (though may still be considered misaligned on a scope 3 CO_2 basis).

These indexed declines are for the global mean; well-resourced miners could reasonably be expected to pursue more aggressive pathways.

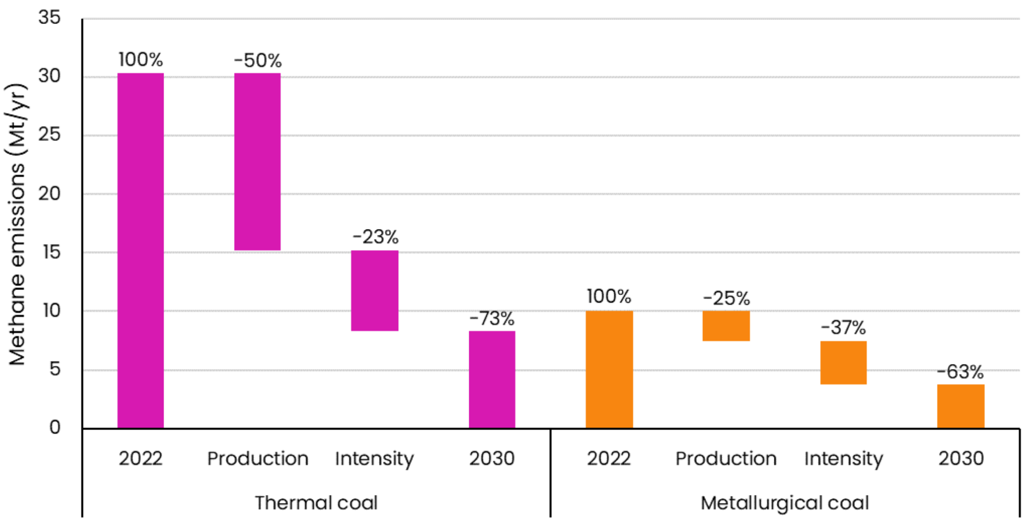

Figure 21: Declines in methane emissions between 2022 and 2030 from thermal and metallurgical coal mining in the IEA NZE. In this scenario, total reductions are driven by a combination of declines in production and methane intensity. Based on Global Methane Tracker 2023 (3), Curtailing Emissions from Fossil Fuel operations (105) and NZE update (104).

An indexed approach to target setting is based on the historical emissions of a company, and in this way is tailored to their portfolio. Assessing all companies against the same indexed reductions results in the allocation of higher emissions rights to higher historical emitters; emissions rights are 'grandfathered' (121; 122). The same limitations exist for this simple approach as per its use in oil & gas (Section 5.5), namely: i) the extent to which corporates have already pursued emissions reductions efforts prior to base year; ii) how their starting methane intensity compares (especially relevant for intensity targets); iii) interannual variability in emissions that may result in the base year being unusually low or high; iv) fairness issues, though these are less acute in a 1.5 °C scenario where there is no room for coal expansions in any geography (123).

Key point 24: In the absence of high-quality MRV, both methane disclosures and targets should be treated with caution. Given likely corporate underreporting, and high variability of coal mine emissions, intensity benchmarks based on global emissions may be ineffective at driving necessary reductions at many companies.

Any indexed approach to target setting assumes that base year emissions are known, whereas they may only be estimated by emission factor approaches. To avoid perverse incentives against expanding MRV, which may reveal higher than previously thought emissions, it may be necessary—and acceptable—to recalculate base year emissions based on new measurements. Scrutiny may be needed to evaluate whether such recalculations are reasonable.

Each portfolio of mines comes with not only an individual emissions baseline but also different potentials for emissions reductions, which is primarily determined by the breakdown between underground and surface mines. The figures we provide in are broken out by the two products: thermal and metallurgical coal. These have different production pathways and different abatement potentials. In theory, company-specific benchmarks could be designed based on a combination of thermal vs metallurgical and underground vs surface production breakdowns.

Key Point 25: In the NZE, methane emissions from thermal coal and metallurgical coal decline by 73% and 63%, respectively, by 2030 against 2022 levels. Despite limitations, indexed pathways are at least unambiguous about what is required from corporates in sum. Re-baselining as MRV improves should be allowable if transparently stated and justified.

Targets may also be set in terms of intensity units. As intensity units are independent of size, there is no 'grandfathering' effect built into the form of the target itself. However, as discussed with respect to oil & gas, benchmarking targets set in intensity units is fraught with difficulty due to likely corporate underreporting.

Intensity pathways derived from global coal production and global coal methane emissions estimates are likely to exceed reported methane intensities, rendering them ineffective at driving necessary reductions. However, as corporate reporting integrates progressively more direct measurement and becomes more reliable, meaningful comparisons based on intensity should become possible.

The distinction between metallurgical and thermal coal would also be important to consider for intensity targets. Metallurgical coal on average has a higher methane intensity of production than thermal coal, due to its characteristically higher coal ranks and deeper extraction depths. However, it should follow a steeper intensity decline as its production is skewed towards easier-to-abate underground mines.

7. Methane engagement frameworks

7.1 Synthesis

Using the contextual information and analysis in the sections above, we present a framework for engaging oil and gas companies and coal miners (**Figure 22** and **Figure 23** respectively). The objective of these frameworks is to support impactful engagements on methane emissions.

The frameworks leverage the Net Zero Standards for Diversified Mining and Oil & Gas (141; 142). As company assessments become available against these standards, the data can be integrated into the engagement frameworks to help inform engagement priorities. The relevant metrics are set out alongside the frameworks in sections 7.2 and 7.3.

The frameworks begin with high-quality measurement, reporting and verification (MRV) as their foundational element. Properly characterising methane emissions and their variability across assets will enable more efficient and cost-effective abatement efforts. It will also provide the basis for credible targets and robust reporting of progress against them.

Without measurement-based reporting that integrates both bottom-up and top-down site-level reconciliation, corporate methane emissions disclosures and targets should be treated with scepticism. The **OGMP 2.0** and forthcoming **SMP** set out Gold Standard pathways towards high-quality MRV; where companies have not yet joined the relevant partnership, investors may wish to prioritise this in engagements.

The urgency of the problem means, however, that building a perfect measurement baseline should not come at the expense of action. We therefore suggest that investors emphasise MRV and abatement strategy in their engagements

Key Point 26: While it is essential that MRV improves in both oil & gas and coal mining, building an accurate multi-year baseline should not come at the expense of taking proven abatement actions. The issue is too urgent to delay until measurement practices are perfect; investors may wish to emphasise MRV and abatement strategy in their engagements.

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. In turn 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, especially in the context of tightening methane regulations (including covering imports) and increasing stakeholder scrutiny via satellite measurement.

As companies make progress, investors will expect to see this transparently and accurately reported, completing the cycle back to foundations. As MRV progresses over time, reported methane emissions are likely to change, and companies can offer transparency to investors by attempting to re-baseline emissions on the basis of improved understanding of methane sources. Such re-baselining should be scrutinised carefully but ultimately be allowable—if it were not, significant adverse incentives would exist against expanding MRV for companies with methane targets.

Ultimately, investors are looking for companies to plan and implement actions on methane to mitigate substantial climate-related financial risks, and to increase efficiency, consistent with their financial interests. Transition risks are looming as the policy environment strengthens. Meanwhile, reputational risks are growing as the capacity for independent measurement via satellite measurements increases.

7.2 Oil and gas methane engagement framework

Key questions to interrogate whether oil and gas companies' methane strategies are sufficiently comprehensive and ambitious are set out in **Figure 22**. As highlighted, the framework builds on and incorporates the methane metrics in the Net Zero Standard for Oil and Gas:

• **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_4 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?

In addition to investor and company feedback, this consultation paper may influence adjustments to these metrics in future assessment iterations.

In particular, metrics 5.iv.a and 5.iv.b are currently under consideration; the former may focus on OGMP 2.0 membership and the latter on progress towards OGMP 2.0 Gold Standard reporting. 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 test indexed decline targets using the benchmarks provided in Section 5.5. Intensity targets are currently considered not assessable until more companies report in line with OGMP levels 4 and 5 across all assets.

We would welcome reviewer feedback on both the existing set of metrics and these potential adjustments.

Oil & gas

Foundations

Does the company provide high quality methane disclosures?

- In both units of absolute emissions (tCH_4) and methane intensity (tCH_4/TJ)? **5.iv.c**
- By business segment? And reporting intensity appropriate for each segment and product type?
- With bottom-up and top-down reconciliation across all assets?
- Using multiple monitoring systems?
- With external verification?

Has the company committed to continually increase the quality and coverage of measurement, reporting and verification of methane emissions?

- Covering all business segments and assets? **5.iv.a**
- Achieving OGMP 2.0 Gold Standard pathway and with published target dates to reach Gold Standard reporting across all operated and non-operated assets (OGMP 2.0 Levels 4 and 5) **5.iv.b**

Strategy

5.iv.d

Has the company set out an effective strategy for methane mitigation?

- Covering all material emissions sources?
- Zero non-emergency flaring by 2030? **5.iv.e**
- Comprehensive LDAR approach?
- Addressing venting emissions?
- Prioritising heaviest-emitting sources?
- Stating capex required?
- With timeline?
- Referencing marginal abatement cost curve (MACC)?

Targets

5.iv.f

Has the company set a sufficiently ambitious target to reduce methane emissions?

- Covering all assets, or timeline to cover all?
- In terms of both absolute and intensity?
- If indexed, providing a base year and value?
- With an interim milestone?
- Specifying role of production and intensity declines?
- Aligned with benchmark? **5.iv.g**

Industry Engagement

Has the company joined major initiatives on methane?

- OGMP 2.0? **5.iv.a**
- OGDC?
- GFMR?
- Methane guiding principles?

Has the company engaged its NOAs and NOJVs on methane?

- On MRV practices?
- Frequent sharing of missions 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 emissions targets?

- Is this reporting consistent with the targets?
- Is progress 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?
- Separating out the role of production and intensity declines?

Figure 22: Engagement framework for tackling methane emissions in oil and gas. NZS O&G metrics are indicated according to relevance within framework (white boxes).

7.3 Coal mine methane engagement framework

Figure 23 presents key methane engagement questions and the complementary Net Zero Standard metrics for companies that mine coal.

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.iv.a = 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_4 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_4 per Mt of total coal production)?

As with the Net Zero Standard for Oil and Gas, these metrics are not fixed, and may be updated in light of findings from this consultation paper, as well as pilot assessments against the Standard. We encourage reviewers to provide comments to help refine the metrics.

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 use the benchmarks in section 6.5 to assess the alignment of any targets expressed in terms of indexed declines. Intensity targets are not considered assessable with respect to alignment currently, but may become so as MRV practices improve.

Coal mining

Foundations

Does the company provide high quality methane disclosures?

- In both units of absolute emissions (tCH_4) and methane intensity (tCH_4/Mt)? **10.ii.g**
- Mine-by mine? **10.ii.h**
- Integrating direct measurement?
- Using multiple monitoring systems?
- Reconciling bottom-up and top-down measurement approaches?
- With external verification?

Has the company committed to continually increase the quality and coverage of measurement, reporting and verification of methane emissions? **5.iv.a**

- Covering all coal mines?
- Including after mine closure?

Strategy

5.iv.d

Has the company set out an effective strategy for methane mitigation?

- Pre-mining degasification and capture? (Underground and open pit mines)
- Ventilation air methane capture or destruction? (Underground mines)
- Post-closure abatement measures? (Underground mines)
- Prioritising heaviest-emitting mines?
- Stating capex required?
- With timeline?
- Referencing marginal abatement cost curve (MACC)?

Targets

5.iv.b

Has the company set a sufficiently ambitious target to reduce methane emissions?

- Covering all assets, or timeline to cover all?
- In terms of both absolute and intensity?
- If indexed, providing a base year and value?
- With an interim milestone?
- Metallurgical and thermal coal broken out?
- Specifying role of production and intensity declines?
- Aligned with benchmark? **5.iv.c**

Industry Engagement

Has the company joined major initiatives on methane?

- Member of UNEP Steel Methane Partnership?

Has the company engaged its NOAs on coal mine methane?

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

Progress

Does the company disclose progress against emissions targets?

- Is this reporting consistent with any targets?
- Is progress on track to achieve or exceed targets?
- Is there critical evaluation of the reliability of stated performance against targets?
- Is any re-baselining of emissions and targets transparently stated and justified?
- Separating out the role of production and intensity declines?

Figure 23: Engagement framework for tackling methane emissions from coal mining. NZS DM metrics are indicated according to relevance within framework (white boxes).

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Methane emissions from fossil fuel operations

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