

Annual coal mine methane emissions are linked to tens of thousands of deaths

Methane drives the formation of ground-level ozone, an invisible greenhouse gas that is also harmful to human health. Each year of continued coal mine methane emissions at current levels leads to around 26,400 preventable deaths over the following decades.

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About

This report quantifies mortality from ozone formed by coal mine methane emissions, applying the McDuffie et al. (2023) health impact methodology to country-level data from the [Ember Coal Mine Methane Data Tracker](#). It sets out the atmospheric pathway from emission to mortality, presents global premature mortality estimates, and ranks countries by absolute deaths caused. A methodology section details data sources, calculation approach and limitations.

Summary

Methane reacts with sunlight and other atmospheric gases to form ground-level ozone, a respiratory toxin with no safe exposure threshold. Agriculture, waste and oil and gas all contribute to methane emissions alongside coal. When coal is mined it releases methane directly into the atmosphere, and that methane drifts across continents, contributing to the same global ozone burden.

Annual coal mine methane (CMM) emissions commit an estimated 26,400 (95% confidence interval (CI): 11,500–41,700) deaths over the following decades. The people affected live in regions far from the mines where it originates and methane emissions are not adequately incorporated into the air quality and ozone management frameworks that would be needed to protect them.

Closing or reducing active mining remains the most effective way to cut this toll, and deploying abatement technology at mines that stay open is the next-fastest lever. Technology that is already commercially available today could avoid an estimated 12,600 (95% CI: 5,500–19,900) of these deaths, cutting the toll by nearly half.

01

More than half of all deaths trace back to a single country.

China's coal sector accounts for an estimated 20,100 deaths over the following decades, more than the rest of the world combined – a measure of where the coal mine methane originates, not where people are harmed, since the resulting ozone disperses globally.

02 **Closure sharply cuts emissions but doesn't stop them entirely.**
Closing a mine remains the fastest way to reduce its methane output. But some emissions continue for decades afterwards. The United Kingdom, which mines very little coal today, still carries an ozone-linked mortality burden from abandoned mine methane seeping through sealed shafts.

03 **The burden falls on people who had no say in it.**
Because methane-derived ozone disperses globally, a tonne released anywhere raises mortality risk everywhere. The per-country figures here measure responsibility, not exposure.

04 **The tools to fix this already exist.**
Pre-drainage, VAM oxidation and mine gas capture are all commercially proven, all underdeployed. The only thing missing is the obligation to use them.

This is a reminder that the harm from methane doesn't stop at the climate. Every coal mine that continues to operate is adding to a global health burden that's almost entirely invisible in how we regulate air quality today.

Rebekah Horner

Data Analyst, Ember

Coal mine methane is an invisible threat with a very real human cost, linked to an estimated 26,400 premature deaths through ozone pollution.

The burden is concentrated in a handful of coal-producing countries, but the consequences are global, because methane doesn't respect borders. Nearly half of this toll could be avoided with technology that already exists, which is why this is as much a public-health issue as a climate one.

Nishant Bhardwaj

Director, Ember

Pollution linked to coal mine methane has negative consequences for air quality

The harm from coal mine methane is not just local. A tonne of methane vented from a single mine impacts global ozone levels and therefore global mortality. The mine and the deaths are separated by thousands of miles and by a regulatory gap that has never been closed.

A global health burden governed by neither climate policy nor air quality regulation

Methane escapes into the atmosphere. It persists for around 12 years, travelling across borders, before reacting with sunlight and other gases to form ground-level ozone, which is why the health effects show up far from the mine itself, rather than concentrated around it.

Ozone is a respiratory irritant with [no safe exposure threshold](#), meaning even low levels of exposure carry some health risk. Breathing it in repeatedly over time inflames airways, degrades lung function and accelerates death from chronic obstructive pulmonary disease, lower respiratory infections and cardiovascular disease.

The methane released from coal mines contributes to these ozone-related deaths. The deaths are not localised to the mine or mining region but are distributed across continents and among populations with no mechanism

linking their illness back to its source. This diffuse, invisible impact is systematically excluded from the visible costs of coal and from the accounting of every regulatory body that oversees coal mine operations.

Coal mine methane contributes to ozone-related health impacts far beyond the mine

1

Methane escapes

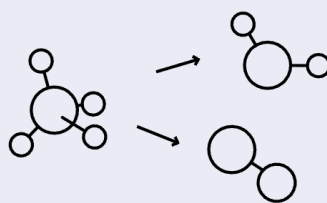
Methane is vented from active and abandoned coal mines into the atmosphere.



2

Methane starts a reaction chain

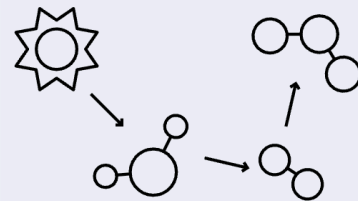
As methane breaks down, it creates reactive radicals that convert NO into NO₂ and set ozone-forming chemistry in motion.



3

Sunlight forms ozone

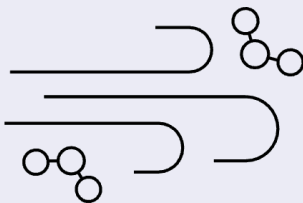
Sunlight splits NO₂, allowing a released oxygen atom to join O₂ and form harmful ground-level O₃.



4

Winds carry ozone

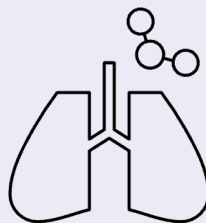
Winds can carry ozone thousands of miles from mines, exposing distant communities across borders.



5

People breathe ozone

Breathing ozone inflames airways, worsens asthma, reduces lung function and increases cardiovascular stress.



6

Ozone harms health

Ozone formed from coal mine methane is associated with 26,400 deaths, while proven controls can stop pollution at its source.



Source: Ember

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Coal mine methane leads to an estimated 26,400 deaths over the following decades

Global coal mine methane emissions have been [broadly flat since the implementation of the Global Methane Pledge](#) in 2021. In line with those broadly flat emissions, the lifetime mortality committed by each year's coal mine methane has barely changed, an estimated 26,100 deaths (95% CI: 11,300–41,200) from 2020's emissions and 26,400 (95% CI: 11,500–41,700) from 2023's. Annual coal mine methane emissions continue contributing to ozone mortality for as long as methane persists in the atmosphere before breaking down.

Coal-producing countries do not contribute equally to deaths

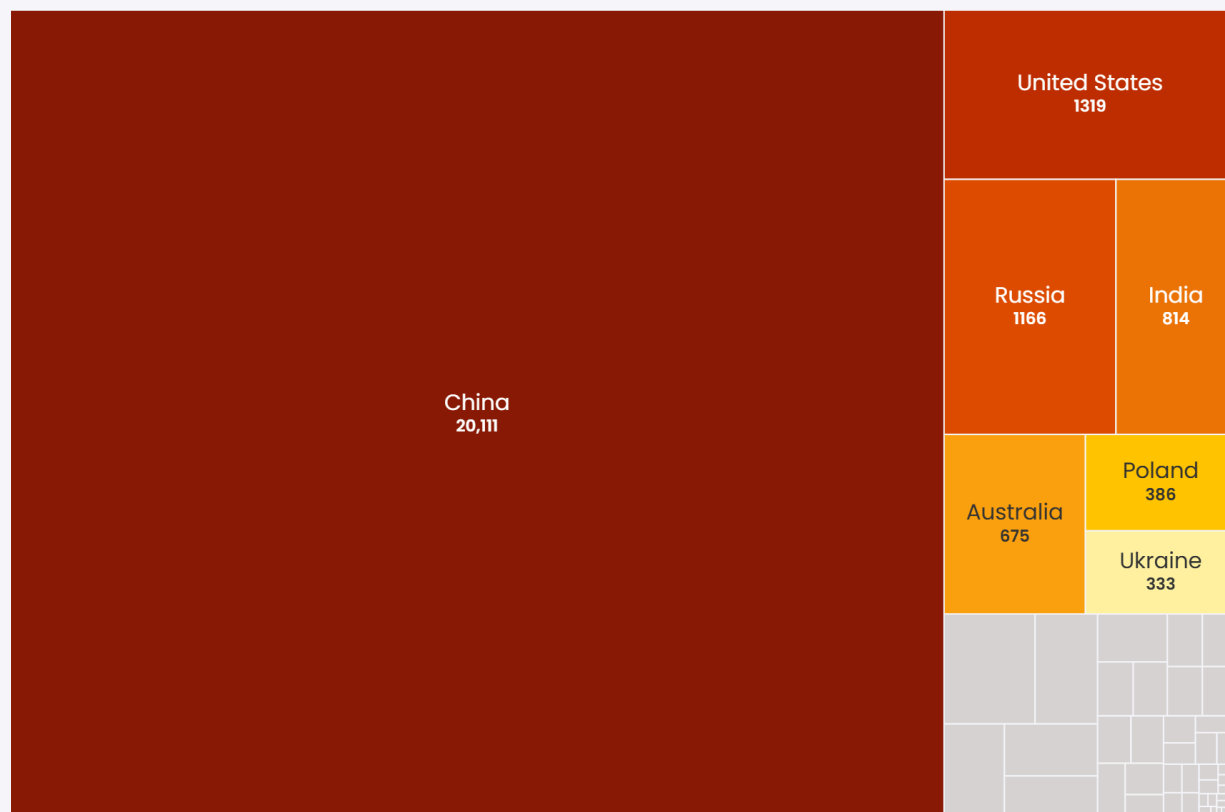
China's coal mine methane emissions represent the single largest source of ozone-related mortality linked to coal mine methane of any country in the world. Its 2023 CMM emissions are responsible for an estimated 20,100 (95% CI: 8,700–31,800) deaths from methane-related ozone exposure globally, more than all other countries combined.

Closing mines outright would cut these emissions fastest, but where mining continues, China is the single largest lever for reducing CMM-linked global ozone mortality: targeted, mine-specific methane mitigation across its coal provinces would have more impact on the global death toll than equivalent action anywhere else, simply because of the scale of emissions involved.

Smaller producers still play a part. The UK remaining active mining will go on to cause an estimated 18 deaths (95% CI: 8–29), on top of the 10 (95% CI: 4–16) from its abandoned mines, meaning legacy emissions now account for more than a third of the UK's total CMM-linked toll, despite the country mining very little coal today.

China contributes to the majority of global ozone-related deaths as a result of 2023 CMM emissions

Number of deaths



Source: Ember's Coal Mine Methane Tracker

Values represent the contribution of 2023 coal mine methane emissions to the ozone-related deaths over the lifetime of that methane

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Kazakhstan's Bogatyr mine causes more deaths than any other

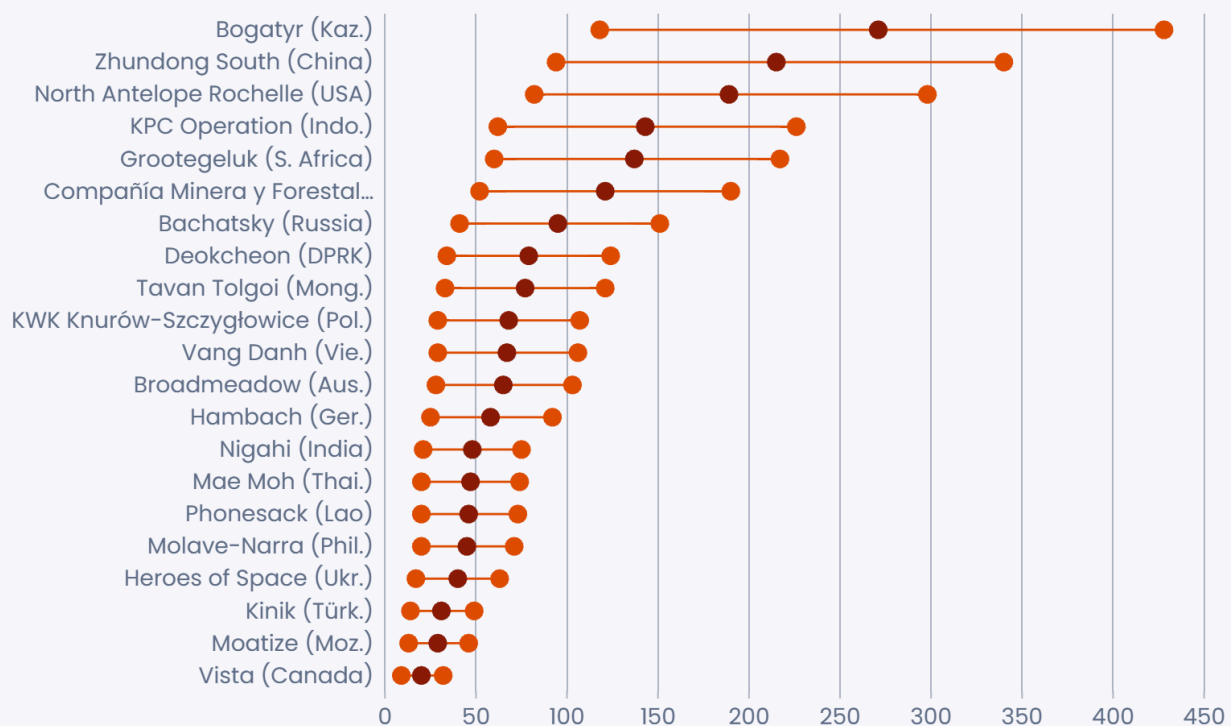
Just ten coal mines, less than 1% of the world's total, are estimated to cause nearly 5% of all deaths linked to coal mine methane emissions (1,983 out of 41,400 deaths worldwide based on GEM's mine-level data). A relatively small number of mines worldwide account for a disproportionate share of mortality, and identifying them is the first step toward reducing it.

Topping that list is Kazakhstan's Bogatyr Coal Mine. In 2024, 356,400 tonnes of methane emissions were released, which are estimated to go on to cause 271 deaths (95% CI: 118–428) over the coming decades, the highest estimated mortality burden among mines in our analysis of Global Energy Monitor [mine-level emissions data](#) (see [methodology](#)).

Its position at the top has less to do with being an unusually leaky mine than with sheer scale: it's one of the largest coal mines in the world, an open-pit operation covering 134 square kilometres that has produced coal continuously since 1970.

A handful of mines carry an outsized share of the world's coal mine methane toll

Number of deaths from the deadliest mine in each country



Source: Global Energy Monitor • Deaths based on GEM's mine-level methane data, using reported emissions where available and GEM's modelled estimates otherwise. Error bars represent the 95% confidence interval of the ozone-related deaths

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Legacy emissions from abandoned mines keep killing long after coal production stops

[Abandoned mine methane](#) (AMM) is methane that continues leaking from a coal mine after it has closed, sometimes for decades, as gas trapped in the surrounding rock slowly escapes.

[The International Energy Agency](#) (IEA) estimates global AMM emissions at 3.3 million tonnes in 2025, equivalent to an estimated 2,510 (95% CI: 1,090–3,960) deaths over the following decades. China accounts for the majority of this on its own: an estimated 2.07 million tonnes of AMM, 63% of the global total, linked to roughly 1,570 (95% CI: 680–2,480) deaths over that same window.

China is therefore not only the largest source of ozone deaths from active coal mine methane, but the largest source from legacy, post-closure emissions too.

Beyond China, the United States (300 deaths, 95% CI: 130–470), Russia (290, 95% CI: 125–455) and Ukraine (130, 95% CI: 57–206) are the next-largest sources. Even countries with much smaller coal sectors, like the United Kingdom (13,000 tonnes), carry an ongoing toll from mines (10 deaths, 95% CI: 4–16) that in some cases closed a generation ago.

Little of these emissions are actively captured or monitored, and there is typically no regulatory obligation to do so. Their legacy abandoned mines emit continuously, with limited adoption of methane capture, utilisation, oxidation or flooding and pressure management, and in most cases no regulatory obligation to monitor point sources or abate emissions.

Coal mine methane is pushing countries past ozone targets they cannot meet on their own

Ozone standards exist in [104 countries worldwide](#), yet methane is absent from the core regulatory frameworks of the world's largest emitters, including the EU and the US.

The EU's revised [Ambient Air Quality Directive](#), which entered into force in December 2024, identifies ozone as the second leading cause of air pollution mortality in Europe. In 2022, only [16% of EU monitoring stations](#) met the long-term objective of 120 micrograms per cubic metre. Poland exceeded that target in [46 air quality zones](#) – the worst record in the EU. Poland's ozone exceedances are likely driven by multiple factors, including transboundary pollution transport and other precursor emissions.

Poland is also the EU's single [largest source of coal mine methane](#). It contributes 65% of the EU's total CMM emissions in 2023 and accounts for the vast majority of fossil fuel methane super-emitter events detected by satellites across EU energy infrastructure in 2025.

The EU's [National Emission Ceilings Directive](#) regulates nitrogen oxides, sulphur dioxide, ammonia, non-methane volatile organic compounds and fine particulate matter. Methane (an ozone precursor) is not among them.

[The Gothenburg Protocol](#), which underpins the Directive, is currently being revised, and a December 2025 Executive Body session confirmed broad support among Parties for including methane, with working group discussions on

collective methane goals continuing into 2026. That revision is the most consequential live regulatory opportunity for CMM.

In the United States, the [Clean Air Act](#) doesn't regulate methane as an ozone precursor. States with areas that fail to meet the Environmental Protection Agency (EPA)'s ozone standard are required to reduce local ozone precursor emissions, but methane is classified separately as pollution that crosses state or national borders, so current plans have no obligation to address it.

More than 115 million Americans live in counties currently designated as failing to meet the EPA's 2015 ozone standard, and some of that burden traces back to methane emitted by coal mines on the other side of the world.

Abatement is the fastest way to shield against ozone produced from coal mine methane

[According to the IEA in 2025](#), pre-drainage and ventilation air methane oxidation together could technically abate around 48% of current global coal mine methane emissions, avoiding an estimated 12,380 (95% CI: 5,376–19,546) deaths over the coming decades. Both are already commercially deployed in a number of coal-producing countries. Wider adoption is held back by several factors, including cost, site-specific technical feasibility and infrastructure constraints, but the absence of any regulatory obligation to do so remains a key barrier.

[Pre-drainage is mature and commercially deployed](#) in Australia, the US and China. [Ventilation air methane oxidation is less advanced](#): China operates 13 ventilation air methane (VAM) projects and is the clear global leader, while Australia and the US have only trial-stage or limited deployment. Elsewhere uptake of either technology remains minimal.

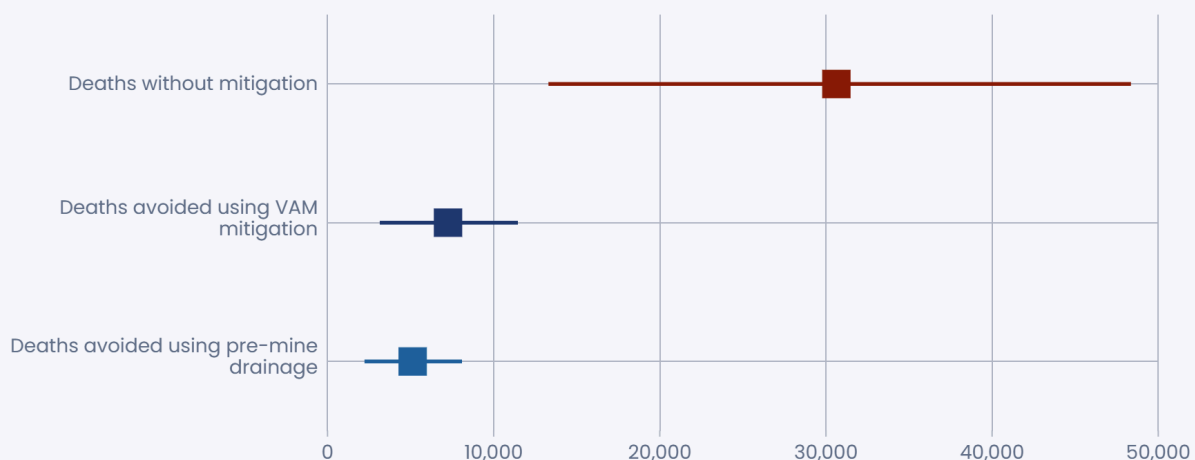
Methane capture and use at closed mines is a third, complementary technology, and some countries already do it well. Germany [captures and uses an estimated 99% of its abandoned mine methane](#), equivalent to avoiding around 15 deaths (95% CI: 7-24) a year from ozone-related mortality, primarily through combined heat and power plants, and is one of [United Nations Economic Commission for Europe \(UNECE\)](#) named best-practice case studies.

France's [La Française de l'Énergie](#) has captured and used methane from abandoned mines in the Nord-Pas de Calais basin continuously since 1978, one of the longest-running AMM programmes in the world, extracting [26 million cubic metres](#) in 2018 alone, equivalent to avoiding an estimated 13 deaths (95% CI: 6-21).

The result is a health burden that is preventable and yet compounds year after year. Every tonne of methane captured or destroyed translates directly into fewer deaths, distributed globally.

Adoption of VAM mitigation and pre-mine drainage could reduce ozone-related deaths from CMM by 40% globally

Number of deaths



Source: International Energy Agency • Values represent the contribution of 2024 coal mine methane emissions from the IEA to the ozone-related deaths over the lifetime of that methane
Error bars represent the 95% confidence interval of ozone-related deaths

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Recommendations

Bring methane into the ozone-precursor frameworks that currently exclude it.

Across three of the world's most consequential air-quality regimes (the EU's National Emission Ceilings Directive, the US Clean Air Act and the UNECE Gothenburg Protocol), nitrogen oxides and volatile organic compounds are treated as regulated ozone precursors, while methane is either absent entirely or explicitly excluded. While the Gothenburg Protocol is currently under revision, closing this gap in all three policies would address the same blind spot.

Mandate pre-drainage and VAM oxidation at new and operating mines where technically feasible.

With an estimated 48% of global CMM emissions technically abatable using commercially proven technology, deployment is the fastest route to avoid around 12,600 deaths (95% CI: 5,500–19,900) from each year's 80-year mortality toll.

Extend monitoring obligations to the countries with the largest

abandoned-mine liability. The [EU Methane Regulation](#) already requires Member States to measure emissions from closed and abandoned coal mines from May 2026 and submit mitigation plans by February 2027. Extending EU-style measurement and mitigation requirements to countries like China, Russia and Ukraine would address the large majority of this liability that currently falls outside any regulatory framework.

Halt approvals of new coal mines and mine expansions. Every tonne of coal mine methane in this analysis comes from mining that has already happened or is already planned. Blocking new mines and expansions is the only measure that prevents this mortality burden from growing further, rather than mitigating a burden that already exists.

Supporting materials

Other causes of death related to coal mining

Coal mining also carries a separate, well-documented health burden distinct from the methane-driven ozone deaths quantified in this report, including occupational lung disease among miners, air and water pollution in mining communities and elevated injury risk from mining accidents.

Black lung disease and silicosis are lung conditions caused by breathing in coal and silica dust over many years. [Cases have nearly doubled worldwide](#), from 36,000 in 1990 to 60,000 in 2017, and almost half of them are now in China. In the US, black lung disease had almost disappeared after dust-control laws were introduced in the 1970s, but it's come back: rates among coal miners climbed from [0.5%](#) of claimants in 1978 to an estimated [10%](#) of underground miners nationally by 2017 (up from 7% in a 2012 survey), mainly because miners are cutting into more rock to reach coal, which releases more silica dust.

Methodology

Emissions data

Methane emission estimates are drawn from the [Ember Coal Mine Methane Data Tracker](#), which integrates multiple sources: United Nations Framework Convention on Climate Change (UNFCCC) national greenhouse gas inventory reports; the United States' Energy Information Administration gap-filled UNFCCC series for countries with incomplete reporting; and IEA Methane Tracker independent estimates. The IEA Methane Tracker is also used to obtain data on abandoned mine methane emissions and emissions saved via abatement technologies.

Health impact quantification

The [McDuffie et al. \(2023\)](#) coefficient (760 deaths per Mt CH₄, 95% CI: 330–1,200) estimates the ozone-related mortality attributable to a pulse of methane emissions, integrated through the end of the century (roughly 80 years from the year of emission) to capture the great majority of that pulse's decaying ozone-forming effect. However, because methane's atmospheric lifetime is only 9–12 years, most of this mortality burden occurs within the first two decades after emission.

[Global Burden of Disease \(GBD\) 2019](#) and [Shindell et al. \(2012\)](#) estimate that each Mt of CH₄ emitted increases global surface ozone concentrations by approximately 1.4 parts per billion over that period, and McDuffie et al. (2023) translate this into a mortality estimate of 760 deaths per Mt CH₄ over the same period. We apply this coefficient directly to each year's emissions (Deaths = CH₄ × 760), attributing that 80-year mortality total to the year of emission.

Mine-level ranking

Mine-level deaths are estimated using the [Global Energy Monitor's Global Coal Mine Tracker](#), which provides an independent, bottom-up methane emissions estimate for each of 5,347 mines worldwide, based on coal type, gas content, mine depth and production volume.

We apply the same coefficients from McDuffie et al. (2023) to each mine's estimate to calculate a single year's committed mortality. Where GEM records a reported emissions figure for a mine (available for around 170 mines in six countries, mostly from national government data for 2023–2025), we use the reported figure. Otherwise we use GEM's modelled estimate. This is a different methodology from the Ember Tracker used for the global and country-level numbers elsewhere in this report, which compiles emissions data reported to the UNFCCC.

Abatement potential and deaths avoided

Pre-drainage and VAM oxidation abatement potential are estimated at 7.46 Mt/yr and 9.54 Mt/yr respectively (around 21% and 27% of the 35.7 Mt/yr global CMM total), based on current commercially deployed technology. Applying these shares to the global death toll gives an estimated 5,500 deaths avoidable through pre-drainage alone (95% CI: 2,400–8,700), 7,100 through VAM oxidation alone (95% CI: 3,100–11,200), and around 12,600 through both combined (95% CI: 5,500–19,900) – leaving a residual toll of around 13,800 deaths that current abatement technology cannot address (95% CI: 6,000–21,800). These figures describe technical potential assuming full deployment. Actual abatement today is far below this level.

Ozone regulatory standards

National standards referenced in this report are drawn from: [World Health Organisation \(WHO\) Air Quality Guidelines](#); [EU Directive 2024/2881/EU](#); [US EPA National Ambient Air Quality Standards \(NAAQS\)](#). Compliance status is drawn from the [European Environment Agency \(EEA\) Europe's Air Quality Status 2024](#) and national environment agency reports.

Gothenburg Protocol revision

References to the Gothenburg Protocol revision process draw on [UNECE Executive Body session records](#). As of the publication date of this report (30 September 2026), methane has not yet been formally included in the Protocol. Negotiations are ongoing, with broad Party support confirmed at the December 2025 session.

Correction note

The mine-level chart has been updated to now show operating mines only and uses reported emissions where available. As a result, Broadmeadow (Australia), Vista (Canada) and KWK Knurów-Szczygłowiec (Poland) replace proposed or zero-reporting mines.

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