Global Energy Monitor

BRIEFING: JUNE 2024

The hidden threat: Abandoned coal mine methane emissions in the EU

Executive Summary

When a coal mine is closed, methane emissions from the site can continue for years unless operators take proactive mitigation measures. Global Energy Monitor's (GEM) new granular dataset on abandoned coal mines suggests that underground mines in the European Union (EU) that have closed since 2015 collectively emit nearly 200 thousand tonnes of methane per year, equal to the potential emissions from the Nord Stream gas pipeline leak. But the actual emission levels remain largely unchecked and unreported in many countries due to legal ambiguities over accountability for abandoned sites, incomplete information about the profiles of abandoned mines, and the absence of a comprehensive Monitoring, Reporting, and Verification (MRV) framework.

The introduction of a new EU regulation on methane emissions reduction in the energy sector is a vital step towards closing this gap. Although this regulation represents significant progress, its full implementation will take years to complete. During this transition period, emissions from old coal mines will continue. The inquiry into whether the EU can substantially reduce emissions and establish an effective MRV framework

among all member states is crucial for the region's journey towards achieving its net zero goals.

Key findings

- GEM data indicate that methane emissions from operating coal mines in EU coal-producing countries could total 1,721 million cubic meters (MCM) per year. This is 36% higher than the International Energy Agency's (IEA) estimate and 32% higher than the figures officially reported by the EU (907 kilotonnes (kt)) to the United Nations Framework Convention on Climate Change (UNFCCC) in 2023.
- The emissions from all abandoned underground coal mines that have closed since 2015 could collectively amount to 298 MCM, or approximately 200 kt per year, under the scenario calculating abandoned mines as dry.
- Poland has the highest number of abandoned underground coal mines (sixteen) in the EU (53 total), as well as the highest emissions from such mines, releasing an estimated 110 MCM of methane. Notably, this amount accounts for nearly 40% of the EU's total abandoned mine methane (AMM) emissions.
- Just six mines account for half of the methane emissions (152 MCM, or 102 kt) from all of the EU's abandoned underground mines captured in this report.
- Major data uncertainties remain — over 60% of abandoned underground mines had an unknown flooded or dry status, which can greatly affect emissions estimates.
- Economic constraints and government policies are the two primary drivers of coal mine closures across the EU, although other factors also play a role.

Background

Top energy organizations have identified the need to cut methane emissions from coal mines in tandem with reducing coal consumption. This is especially important given

that coal demand remains high as a result of the energy crisis triggered by the rapid economic rebound in post-pandemic years and Russia's invasion of Ukraine. Dedicated abatement measures are therefore essential to driving emissions reductions at the pace and scale needed to limit the overall global temperature increase to 1.5°C above pre-industrial levels.

The IEA estimates that the global energy sector was responsible for nearly 135 million tonnes (Mt) of methane emissions in 2022. Of this amount, the IEA reports global coal operations were responsible for just over 40 Mt of methane emissions (30.5 Mt from thermal coal production and 10 Mt from coking coal production) and nearly 5 Mt of methane leaks, representing more than 10% of total methane emissions from human activity. Yet, emissions from abandoned coal mines are not included in the IEA's Global Methane Tracker, as reliable data on abandoned mines are typically not available for most countries.

While a number of organizations and governments, such as the U.S., and Germany, track abandoned coal mines at the individual mine level, the practice is not yet standard in the industry. An in-development international working group on MMRV (Measurement, Monitoring, Reporting, and Verification) comprising 13 countries seeks to standardize and improve the tracking and management of emissions, providing a consistent set of technical criteria for reporting emissions and operating data across various levels of data availability. However, this group's current MMRV focus primarily targets the natural gas supply chain.

As highlighted by the IEA, emissions from abandoned coal mines could constitute a substantial portion of global methane emissions from coal mines, particularly given the large number of mines that have closed or are stated to close as countries commit to

phasing out coal in the coming decades. In November 2023, a first-of-its-kind provisional agreement was reached to curb EU methane emissions. Once formally enacted, these regulations will require companies in the oil, gas, and coal sectors to not only limit venting from their active assets, but also to maintain an inventory of closed, incactive, and abandoned assets so that monitoring and mitigation of their emissions can occur.

In the words of Mr. Raymond Pilcher, Chair of the United Nations Economic Commission for Europe's Group of Experts on Coal Mine Methane, "Until coal mining companies and the countries that host these mines can fully account for methane resources that are co-located with coal deposits, we cannot fully appreciate [...] the threat that it poses to the local and global environment if it escapes to the atmosphere unused." Clearly, the need for a comprehensive global abandoned mines database has never been more pressing.

In anticipation of this need and in an effort to bridge the data gap, GEM has begun tracking retired coal mines in its Global Coal Mine Tracker, which includes 5,226 active and proposed coal mines and projects responsible for 90% or more of global coal production. As of the April 2024 update, this dataset now also includes over 1,200 retired and abandoned coal mines around the world. GEM specifically gathered data on coal mines from the EU that were closed between 2015 and 2023. The database includes geographic information about the mines (such as their location), closing method (sealed, venting, flooded, filled-in, or unknown), date abandoned, and estimated methane emissions in million cubic meters per year at the time of abandonment. Additionally, GEM tracked the reason for closure and the mine site status after closure.

Methane emissions from active coal mines are underestimated in the EU

The coal sector accounts for about 30% of global methane emissions from energy, according to the IEA, totaling 135 Mt in 2023. However, in the EU, coal was the largest emissions segment within the overall energy sector, contributing 845 kt out of a total 2,393.95 kt, including coal, oil and gas, and bioenergy.

GEM's latest data show that the operating coal mines from EU coal-producing countries emitted a combined total of 1,721 MCM of methane per year, approximately 1,150 kt of methane annually. This figure is 36% higher than the IEA's estimate, and 32% higher than the figures officially reported by the EU (907 kt) to the United Nations Framework on Climate Change in 2023.

One of the most important reasons for the discrepancy, as GEM's previous coal mine methane report points out, is the high degree of variation in reporting detail from country to country,[1] with some countries likely underreporting emissions.

The degree of underreporting is further evidenced by how differences between inventory reporting and satellite-observed methane differ regionally. Based on recent research, independent estimates built off GEM's coal mine methane data and other data align more closely with satellite data than official statistics. Asset-scale data, like the information provided here, is therefore essential for helping reconcile estimates.

[1] See our CMM methodology page.

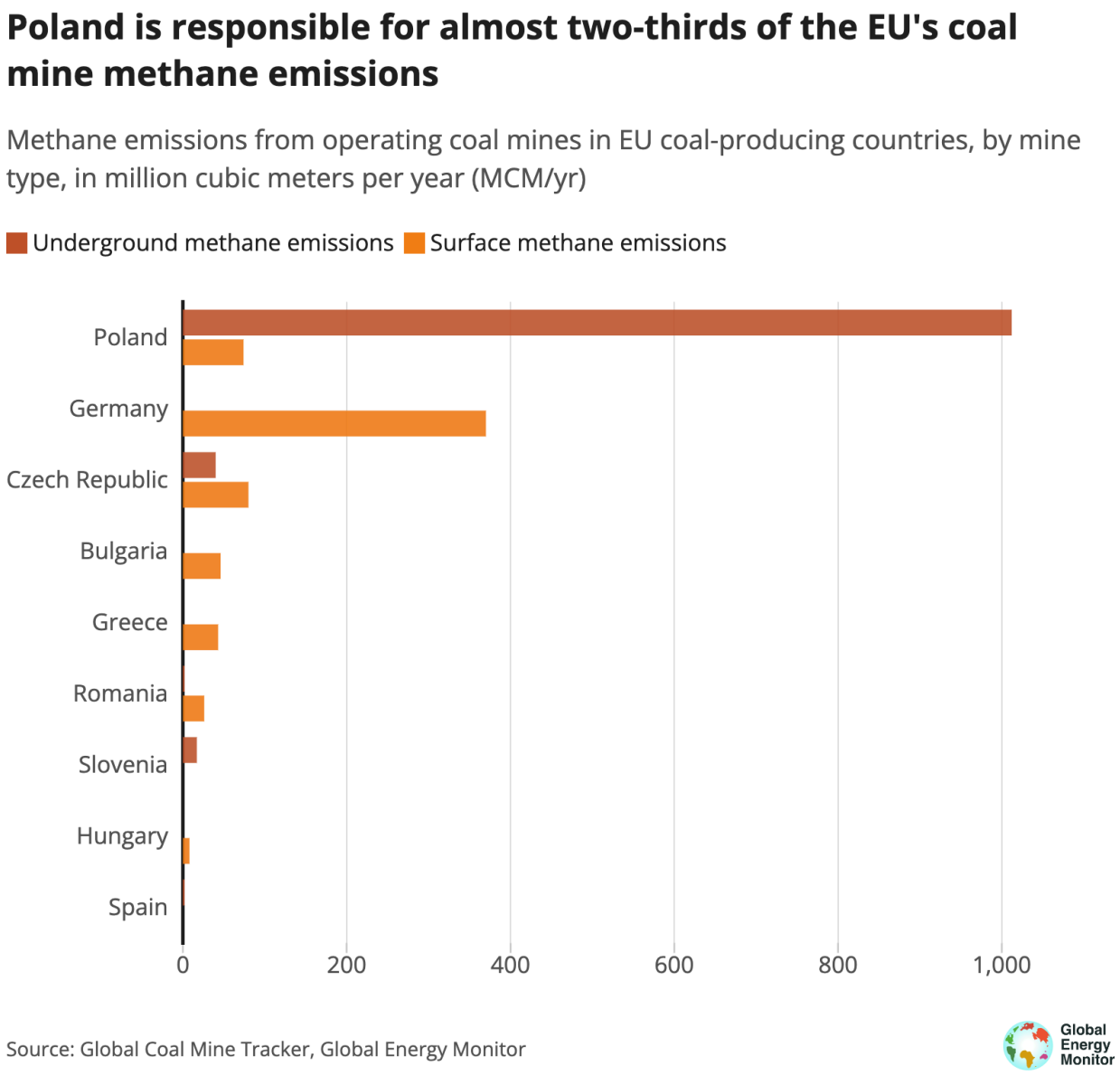


Figure 1

Coal mine type and operational depth heavily influence the methane emissions. For instance, Poland produces less coal than Germany but emits almost three times as much methane. This is because Germany's coal production comes from surface mines, whereas 45% of Poland's coal production is from deep underground mines, which are associated with higher pressure and gas content. Similarly, the Czech Republic

produces nearly the same amount of coal as Bulgaria but emits more than twice as much methane (Figure 1).

Among the existing EU coal-producing countries, Poland (1087 MCM), Germany (370 MCM), and the Czech Republic (80 kt) are responsible for the bulk of the EU's active coal mine methane emissions. Together, coal mines in these three countries emit 1,577 MCM of methane per year.

Methane emissions will continue even after mine closure

Coal mining activities leave a lasting mark on the environment. They create pathways, similar to underground tunnels, that allow long-trapped gas, primarily methane, to escape into the atmosphere. This process illustrates how coal mines contribute to climate change, regardless of whether the extracted coal is ever burned.

When active mining operations cease, methane emissions decrease but do not stop overnight. Underground coal mines typically emit more methane than surface mines. This is because underground mines tend to contain higher ranks of coal than surface mines, and because coal seams are able to retain more methane under high pressure, increasing with depth. When deep seams are mined, a higher amount of methane is released from the seams, as well as from the surrounding rock layers.

Abandoned underground coal mines experience an initial decline in emissions, followed by a period of near-steady release that can persist for decades. Even sealed mines aren't immune, as methane can find pathways through natural cracks or man-made gaps, escaping into the atmosphere.

Abandoned mine assets in the EU

The Global Coal Mine Tracker has documented all known abandoned coal mines in EU countries that were closed between 2015 and 2023, where information is available, including granular data on mining depth, coal rank, historic production, closing year, post-mining status, and more. This timeframe was chosen because, for mines prone to flooding, methane emissions decline rapidly within ten years or fewer, and once flooded, these mines emit almost no methane.

Through extensive research, GEM has identified 70 abandoned coal mines (53 underground mines, 17 surface mines) that have closed in the EU since 2015. Leveraging the peer-reviewed Model for Calculating Coal Mine Methane (MC2M) — the product of a 2020 study led by Nazar Kholod of the Pacific Northwest National Laboratory and industry experts — GEM estimated the coal mine methane (CMM) emissions at closure for these mines.[2]

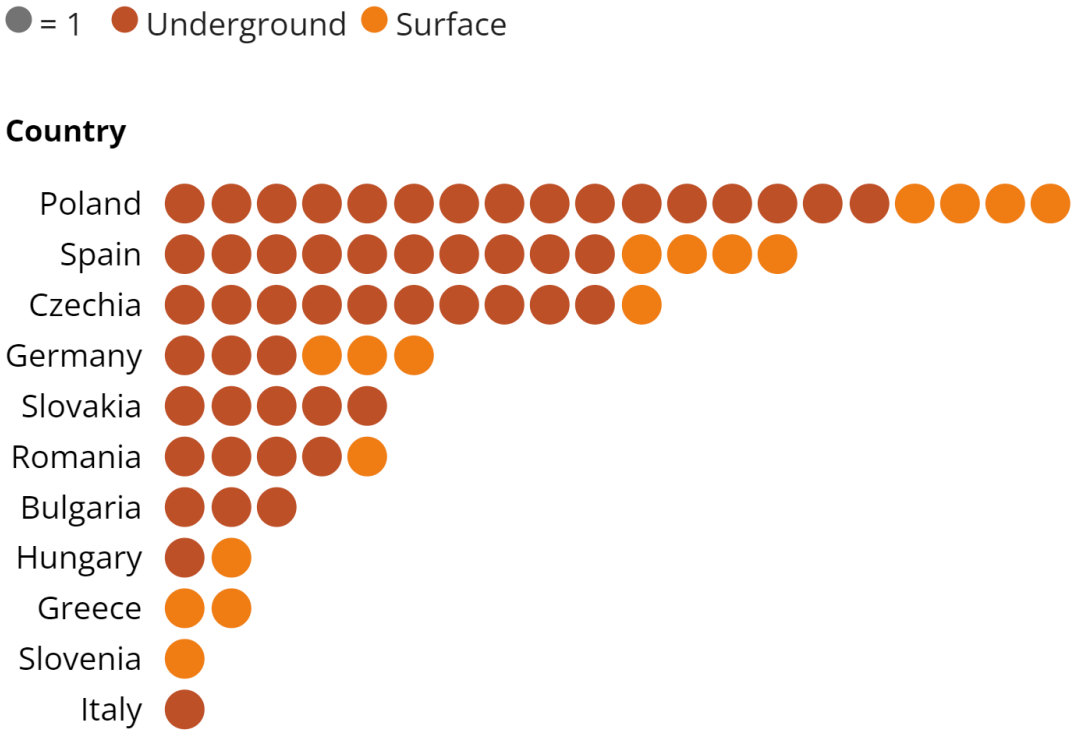
Poland has 20 abandoned and closed coal mines, 80% of which are deep underground hard coal mines. The number of underground operations makes Poland the country with the highest amount of methane emissions after closure. Although Spain and the Czech Republic rank second and third in number of abandoned mines, their emissions at mine closure are overshadowed by those of Germany, which has only six coal mines. This emissions-per-mine discrepancy is due to the fact that Germany's abandoned mines have significantly higher production capacities, and half of them are very deep hard coal mines, resulting in elevated methane emissions (Figure 2).

[2] See the methodology on estimating CMM emission for more details.

Whereas depth and coal grade tend to be the most important drivers of coal mine emissions on a per-mine basis, production is also a factor for estimating the level of emissions prior to closure, particularly at the country scale. For instance, Greece has only two identified surface coal mines that closed between 2015 and 2023. However, the estimated emissions from these mines while they were still active surpassed those of many other countries with more abandoned coal mines. This difference is primarily due to the significantly larger coal output of Greece's mines compared to those in some other countries (Figure 3).

Poland and Spain have the most abandoned coal mines in the EU since 2015

Number of abandoned coal mines in the EU between 2015 and 2023, by type and country



Source: Global Coal Mine Tracker, Global Energy Monitor

Figure 2

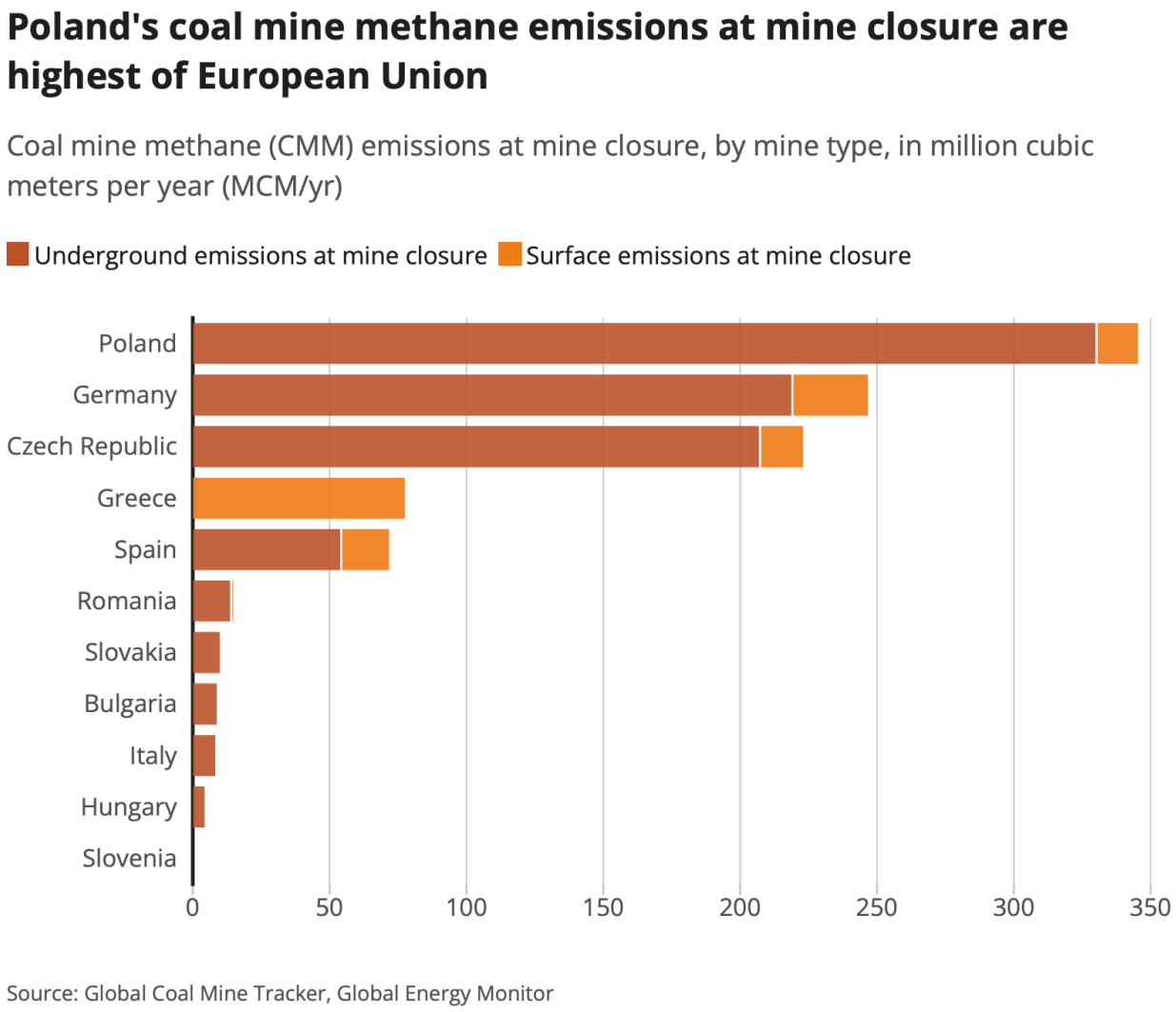


Figure 3

Factors that impact methane emissions from EU abandoned coal mines

When estimating abandoned mine methane emissions, GEM focused exclusively on underground abandoned coal mine assets, as no readily-available study has estimated the potential methane emissions from abandoned surface mines. In general, surface emissions do not appear to be available for emission inventories preparation, which likely explains the lack of official reports on these emissions. Existing methodologies for estimating AMM primarily focus on underground mines, likely due to their significant

number, safety considerations, and deeper seams with higher methane content. While GEM's report does not provide estimates for abandoned surface mines, reviewing estimated data from underground mines can still provide insights into broader methane emission trends from the EU's coal mining sector.

According to the greenhouse gas inventory data reported by the EU in 2023, which specifically accounted for emissions from abandoned underground coal mines, such mines were responsible for emitting 235 kt of methane in 2021, representing approximately one-quarter of total emissions from the coal mining sector. Nevertheless, substantial uncertainties remain due to the limited availability of data needed to address several critical issues. These include the precise timing of mine abandonment, status of mine, levels of methane emissions before mine closure, etc.

Among these critical factors, estimating emissions from an abandoned mine for any given year after its closure depends upon known or assumed abandonment conditions of the mine (i.e., whether it is flooded or dry). This briefing categorizes abandoned underground mines into three categories:

- **Flooded Mines:** GEM classifies mines as "flooded" and assumes they are 100% flooded if information indicates they have been or will be flooded.
- **Dry Mines:** Mines with documented backfilling of shafts using tailings, clay, or slag aggregate are categorized as "dry." Sealed mines with shafts or portals filled with gravel and capped with concrete are considered "Dry" for this analysis.
- **Unknown Mines:** Any mines lacking information about flooding or backfilling fall into this category.

Generally, data on the abandonment condition of the mine (flooded or dry) are scarce across the EU. Furthermore, mine closure plans vary across member countries, making

it difficult to determine the proportion of flooded and dry mines in this region. Mines which are backfilled can also potentially still flood depending on the local hydrology, though they will do so more slowly than mines which are not backfilled. Lack of complete data on current mine status is an important limitation of this analysis. GEM has partially accommodated this limitation by assuming here that all methane emissions from abandoned mines have ceased after eight years (see Methodology section).

A look at the numbers illustrates the difficulty of determining the proportion of dry and flooded mines: Among the identified 53 underground type of abandoned mines closed between 2015 and 2023 in GEM's dataset, only 19 (36%) had known or assumed post-closure conditions (13 dry, 6 flooded); the status of the remaining 34 mines (64%) is unknown (Figure 4).

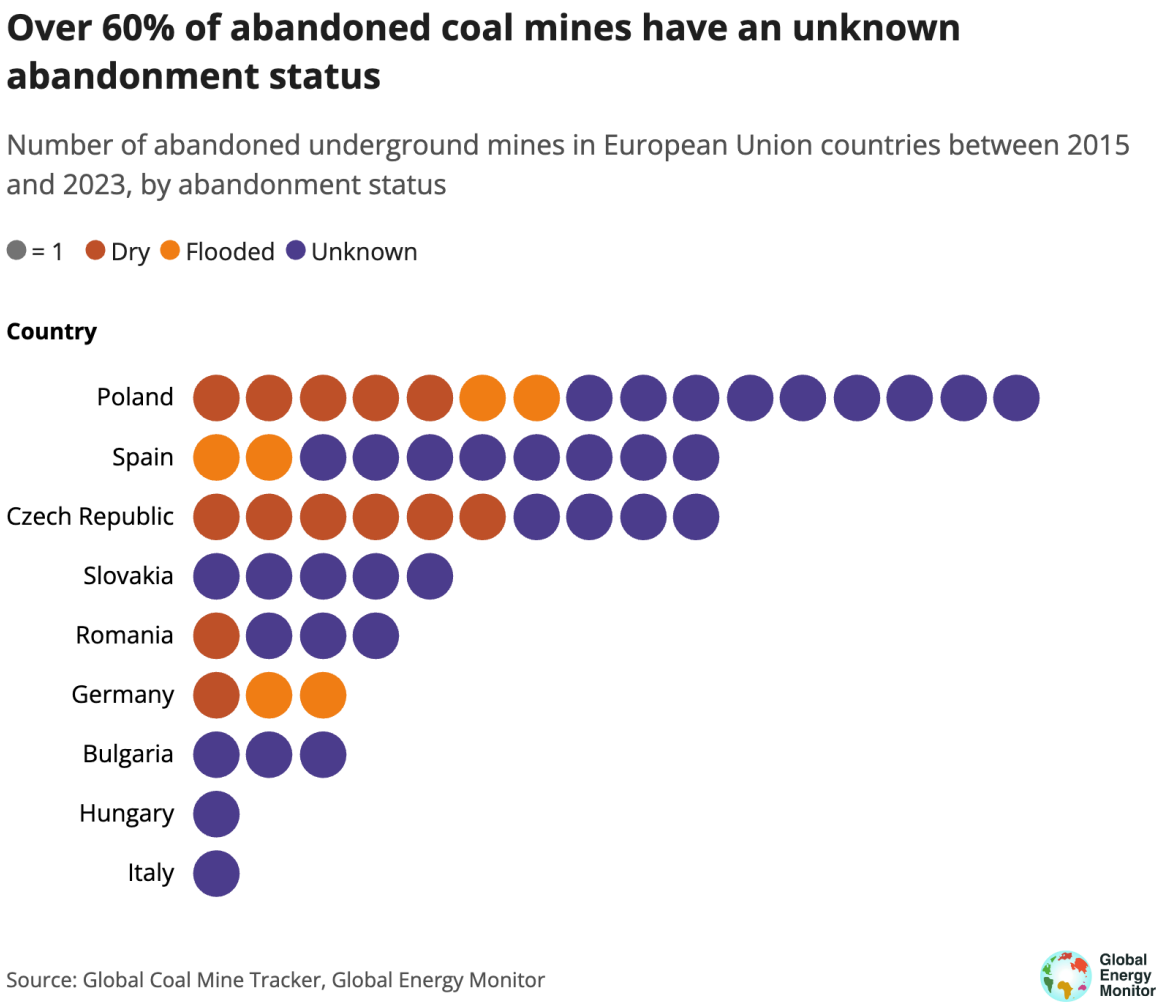


Figure 4

To estimate their emissions, abandoned mines of “Unknown” status have to be assigned a classification as flooded or dry. To address the uncertainty, GEM examined the results under three different contexts (Figure 5). In the first scenario, all “Unknown” mines were assumed to be dry, resulting in a higher estimated methane emission rate of 298.2 MCM per year, or approximately 200 kt per year. This dry scenario produced about 8% more emissions compared to the second scenario where all “Unknown” mines were assumed to be completely flooded, resulting in approximately 275.7 MCM per year, or 185 kt per year (Figure 5).

Gas emissions in mines prone to flooding decline rapidly following closure, typically over less than ten years or so. Even for mines with high methane content and permeable coal seams, rapid flooding can significantly reduce total methane emissions compared to dry mines. Therefore, GEM also explored the best-case scenario that assumes all identified abandoned underground mines are flooded. This approach resulted in significantly lower emissions, roughly 238.7 million cubic meters, a 20% reduction compared to the first scenario (Figure 5).

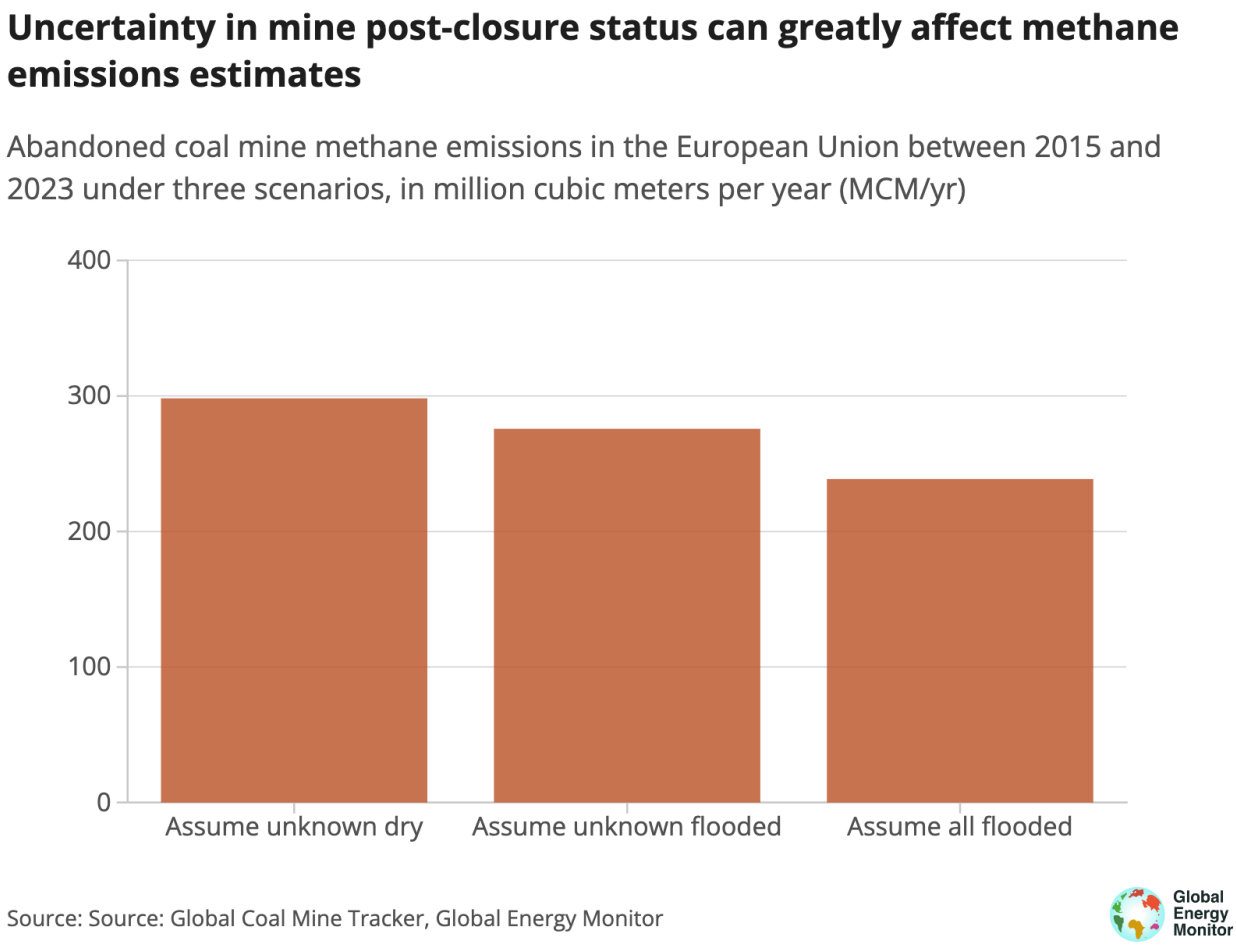


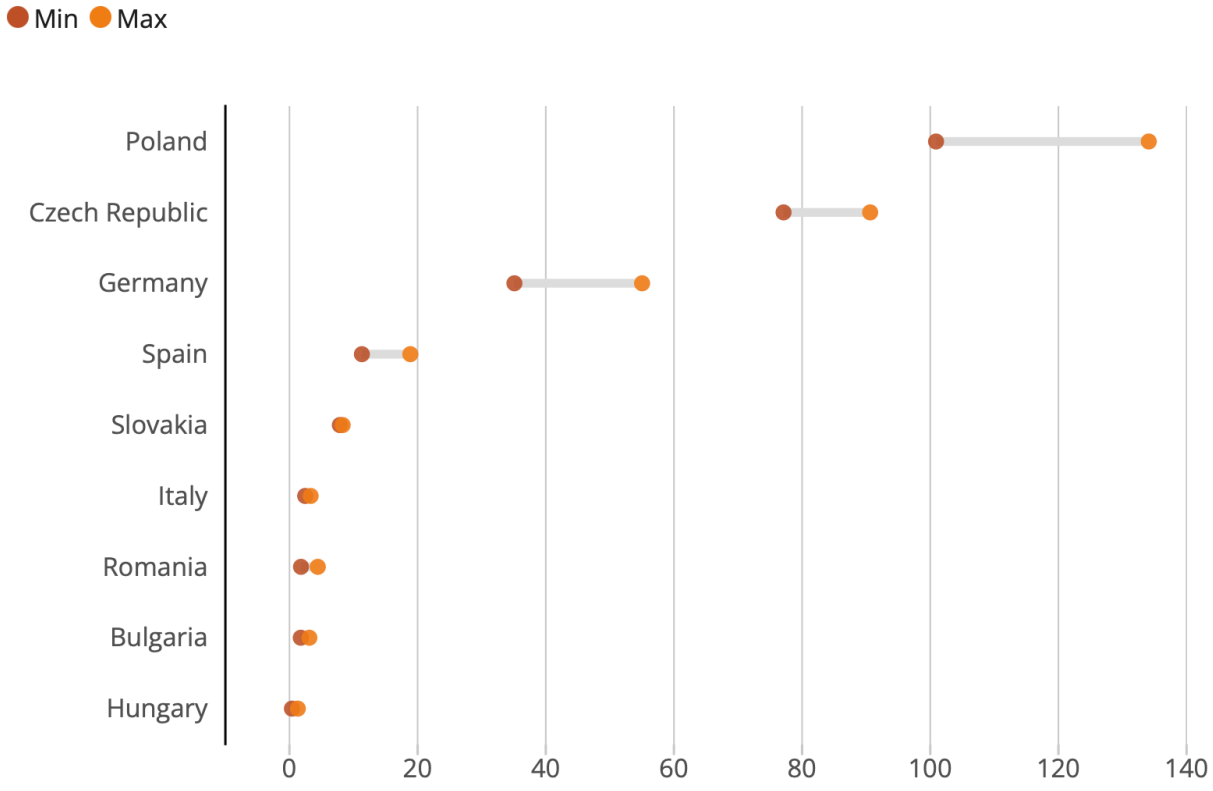
Figure 5

A closer comparison of AMM emissions under the scenario assuming all unknown mines are dry and the scenario assuming all abandoned mines are flooded, regardless of the current status of some mines, reveals significant discrepancies, particularly for

major emitters like Poland. The potential impact of flooding abandoned mines is substantial: Assuming all abandoned underground mines were flooded, Poland could see an estimated 11% reduction in AMM emissions compared to the first scenario where all unknown abandoned mines are assumed dry. Germany presents another compelling case: Flooding abandoned mines could lead to a dramatic decrease in AMM emissions, exceeding 36% compared to the scenario with dry mines (Figure 6).

Flooded vs. dry: How mine status impacts methane emissions

Comparing emissions under the assumption that all abandoned mines are flooded (**Min**) versus the assumption that all "unknown" abandoned mines are dry (**Max**), in million cubic meters per year (MCM/yr)



Source: Global Coal Mine Tracker, Global Energy Monitor
Note: Data includes only abandoned underground coal mines that were closed between 2015 and 2023

Figure 6

Which country emits the most?

Using GEM's methodology for estimating AMM emissions, the average emissions from abandoned underground coal mines across the EU under the aforementioned first two scenarios (all "Unknown" mines are dry vs. all "Unknown" mines are flooded) collectively amounted to 287 MCM or 193 kt of methane per year.

Poland holds the dubious distinction of having the most abandoned underground hard coal mines in the EU. This translates into being the EU's largest AMM emitter, releasing an estimated 110 MCM of methane. Notably, these emissions account for nearly 40% of the EU's total AMM emissions.

The Czech Republic is the second largest AMM emitter in the EU, contributing approximately 90 MCM of methane. Two large-scale underground mines, ČSA Coal Mine and Darkov Coal Mine, that both closed in 2021 are responsible for nearly 70% of the country's AMM emissions.

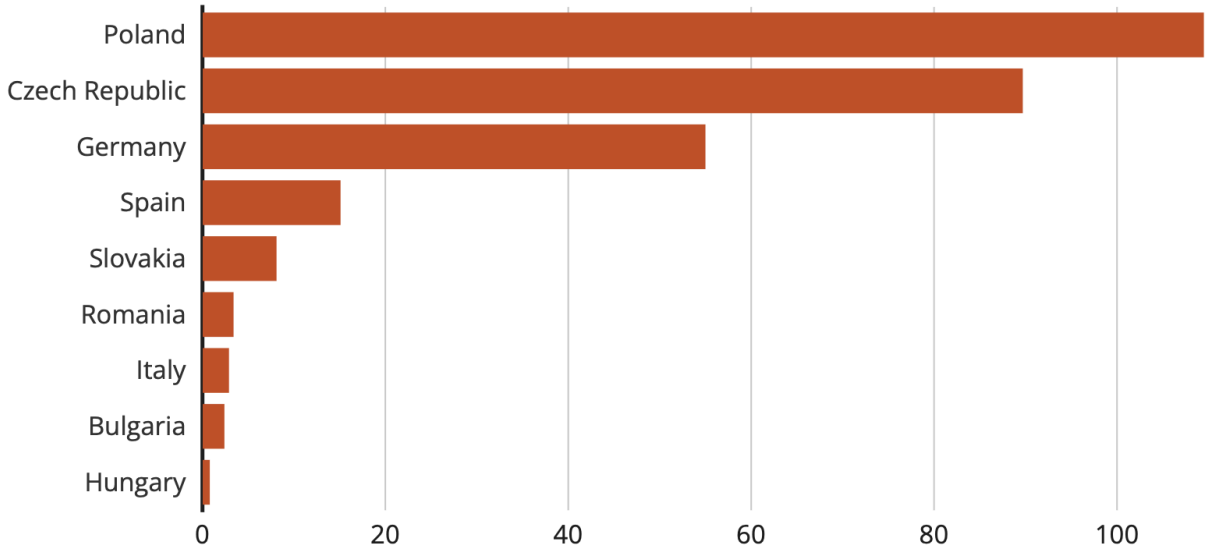
Despite having only three identified abandoned underground mines closed between 2015 and 2023, Germany ranks as the third largest AMM emitter, releasing approximately 55 million cubic meters of methane. This is likely due to the extreme depth of its mines and their high-quality anthracite coal, which may have a higher gas content. Germany is also a global leader in AMM utilization, meaning it has extensive experience in capturing methane emissions from abandoned mines, reportedly utilizing 99% of their total AMM emissions, primarily for electricity generation through combined heat and power plants.

The combined AMM emissions from these top three countries contribute almost 90% of the EU's total AMM emissions.

As measurements are limited for underground coal mines closed between 2015 and 2023 captured by this briefing, there's a high risk that AMM emissions from these EU coal-producing countries are underestimated. For instance, countries like Romania reportedly have swathes of abandoned coal shafts. Romania's abandoned underground coal mines released nearly 195 thousand tonnes of methane in 2021, representing 85% of the EU's abandoned mine methane (AMM) emissions, according to Romania's GHG inventory reported to the UNFCCC in 2023. However, the exact number of abandoned mines remains unclear due to limited available information. This lack of documentation translates to a potentially underestimated emissions level in our current analysis.

Poland, Czech Republic, and Germany are responsible for almost 90% of the EU's total abandoned mine methane emissions

Average estimated methane emissions from coal mines abandoned in the EU between 2015 and 2023, in million cubic meters per year (MCM/yr)



Source: Global Coal Mine Tracker, Global Energy Monitor

Note: Estimated abandoned mine methane emissions calculated by averaging the potential emissions if mines of unknown closing status were flooded or dry

Figure 7

Top emitting abandoned underground mines in the EU

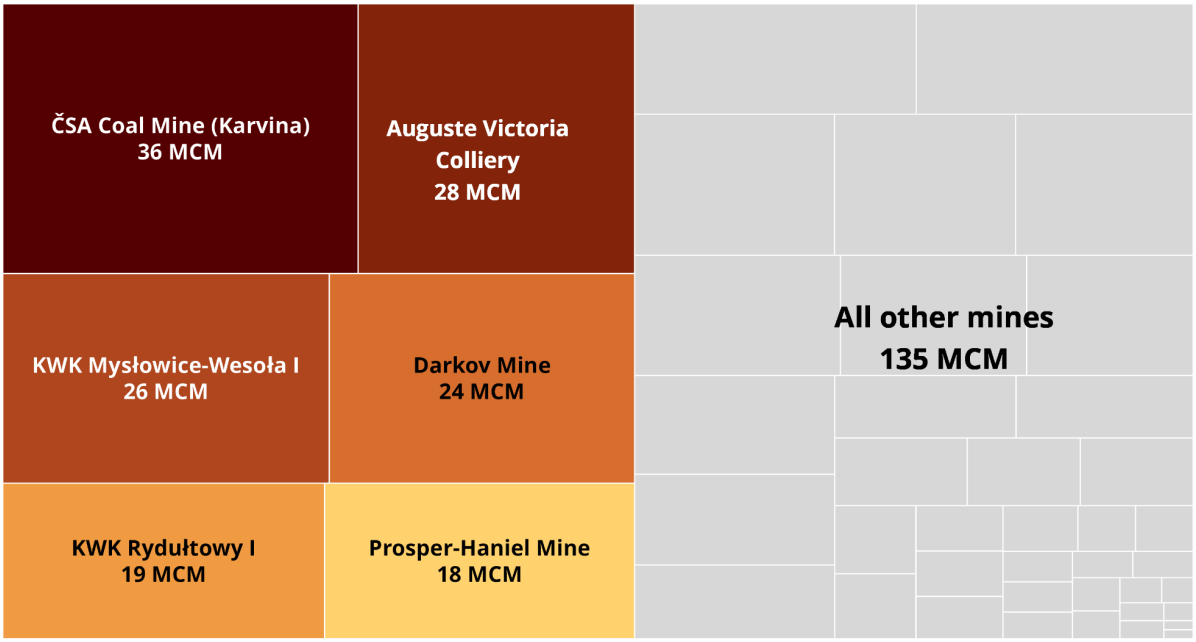
A closer examination of the average AMM emissions of individual mines under two scenarios (all "Unknown" mines are dry vs. all "Unknown" mines are flooded) reveals that just six mines account for half of the methane emissions (152 MCM, or 102 kt) from abandoned underground mines in the EU (287 MCM, or 192 kt). These top mines were all from the top emitting countries, with the Czech Republic hosting ČSA Coal Mine (Karvina) and Darkov Mines, Germany hosting Auguste Victoria Colliery and

Prosper-Haniel Mine, and Poland (by far the largest emitter in the dataset) hosting KWK Mysłowice-Wesoła I and KWK Rydułtowy I.

Here, data availability on flooding status made a big impact. For example, Germany's Auguste Victoria Colliery, the second highest emitting mine, was closed in 2015 with shafts potentially being infilled, resulting in approximately 28.3 MCM, or 19kt, of methane emission. If this mine had in fact been flooded, it could have emitted a staggering 70% less methane (8.4 MCM, or 5.6 kt). For the other mines in the top six, owing to their more recent closure dates or known abandonment statuses, emission estimates did not significantly differ under the different scenarios.

Around half of abandoned coal mine methane emissions in the EU come from just six mines

Average estimated emmissions from abandoned coal mines in the European Union between 2015 and 2023, in million cubic meters per year (MCM/yr)



Note: Estimated abandoned mine methane emissions calculated by averaging the potential emmissions if mines of unknown closing status were flooded or dry

Source: Global Coal Mine Tracker, Global Energy Monitor

Global Energy Monitor

Figure 8

Reasons behind mine closure and the post-mining development

The decline of the coal industry, leading to mine closures, is happening for various reasons. Resource depletion, the end of a mine's life, rising production costs, closure of associated power plants, and government coal phaseout plans can all trigger closure decisions.

Government intervention through phasing out subsidies and mandating shutdowns is the primary reason behind 24 of the 70 mine closures of between 2015 and 2023. For instance, Germany ended subsidies for its domestic coal mining industry, leading to the closure of its last hard coal mine in 2018. Similarly, Spain implemented its Coal Mining Closure Plan, resulting in the shutdown of most of its mines that same year.

Economic and financial factors (18 mines) and reserve depletion (eight mines) also played significant roles. These factors included high operational costs, declining coal demand due to power plant phaseouts, and overall unprofitability as state subsidies diminish.

However, the reasons for closure remain unknown for a significant number of abandoned mines (eight mines), highlighting the need for an MRV framework to improve data collection and transparency in future mine closures.

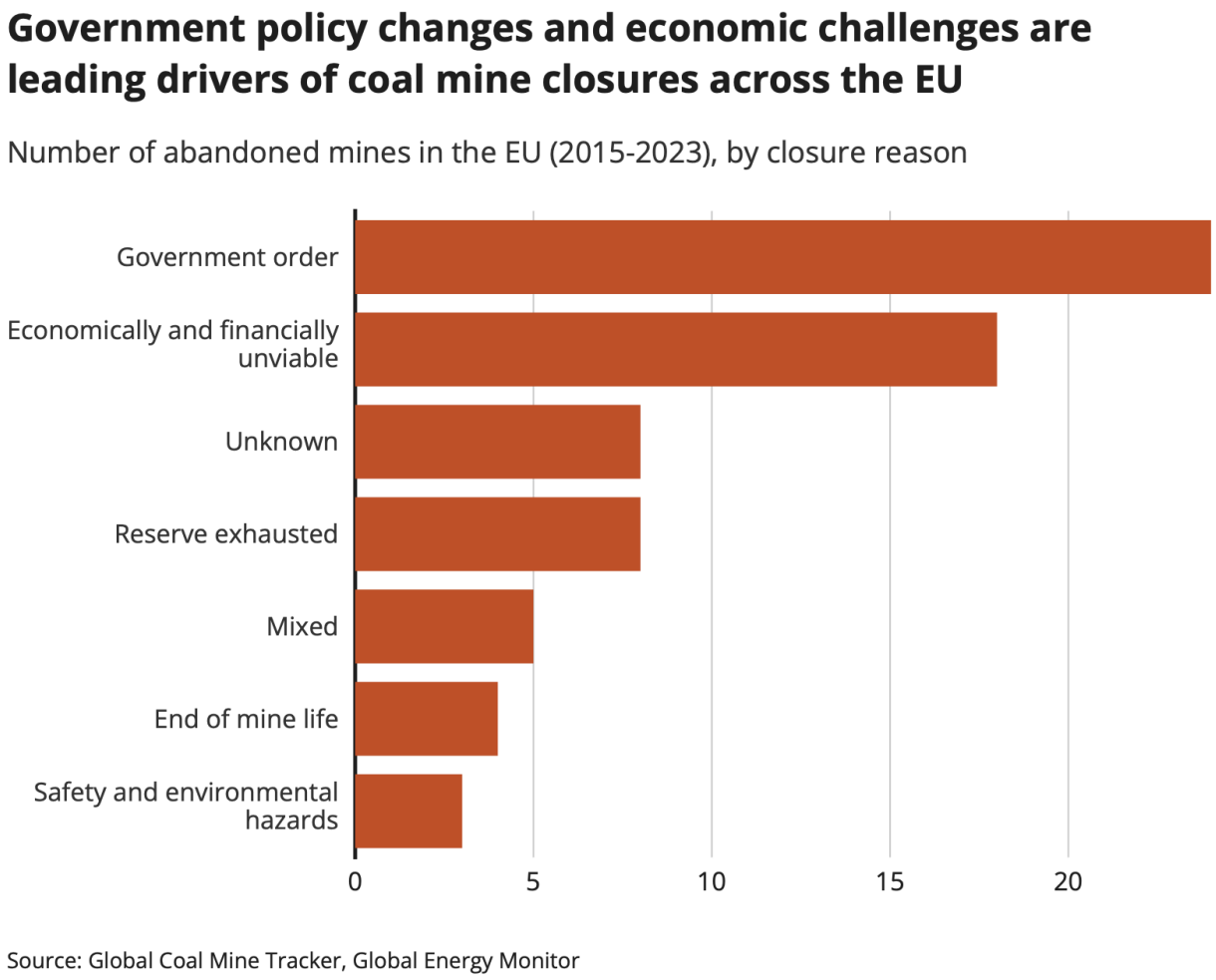


Figure 9

In contrast to the environmental disruption caused by operational mines, post-mining development offers a chance for positive transformation. Ideally, this involves sustainable land reclamation projects that restore ecological balance and create new opportunities. Depending on remaining resources, some mines might be repurposed for other uses, such as being transformed into solar farms or industrial parks or being established as nature reserves. For instance, the Trbovlje-Hrastnik Mine in Slovenia transitioned into a solar power plant after closure in 2022.

However, significant challenges remain. The cost associated with reclaiming abandoned mine sites can be substantial, depending on the size and complexity of the site. The financial burden likely contributes to the high number of abandoned mines — nearly 16% of the mines we analyzed were classified as “abandoned,” the majority being underground. These neglected sites represent missed opportunities for environmental restoration and economic revitalization. Additionally, the lack of proper documentation for a significant number of abandoned mines, classified as “unknown,” hinders understanding of their current status and post-mining development potential.

The ownership of coal mines can change upon their closure. The former operators responsible for daily operations and management may not necessarily be responsible for managing coal mine methane emissions. In some cases, the government assumes ownership of abandoned coal mine properties and oversees mine closure and abandoned mine methane management. For instance, Spółka Restrukturownictwa Kopalń S.A. (SRK), a state-owned company in Poland, currently manages twelve abandoned underground mines and is responsible for mine closures, liquidation, and asset management of closed mines. Poland plans to transfer all mines slated for closure to SRK.

In many instances, the ownership of abandoned coal mines remains unclear, which may account for the lack of progress or uncertainty in post-mining development.

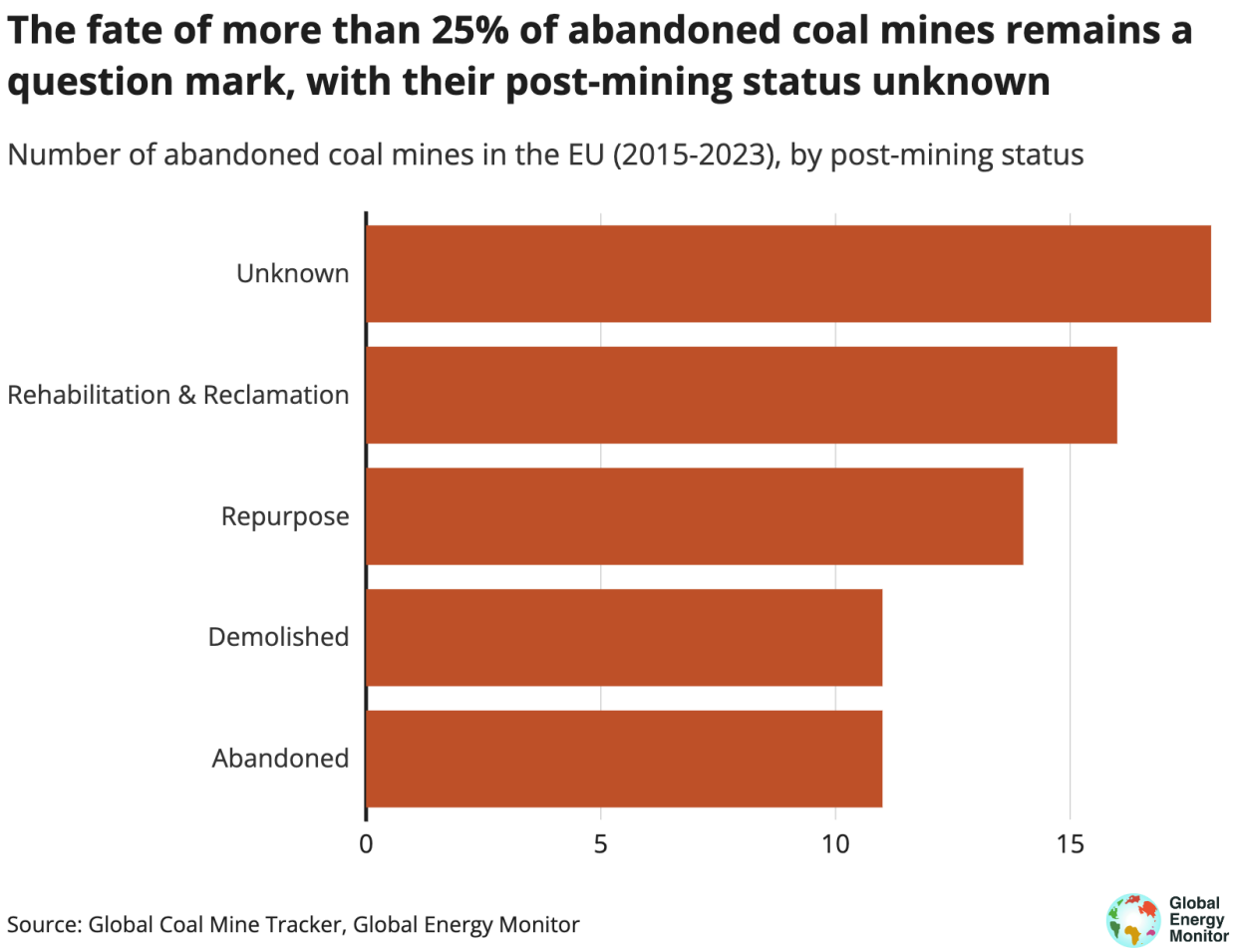


Figure 10

Methodology

Global Energy Monitor adapted the Kholod et al. (2020) methodology for calculating AMM globally to our granular and global dataset of abandoned coal mines. This involves first calculating the annual methane emissions from the mine when it was operational. This model, M2CM, integrates data on coal grade, mine depth, and a published emission factor which accounts for the average internal geometry of the mine. (The details about GEM's adaptation of the Kholod et al. (2020) formula can be found on the methodology wiki.) The AMM model used here takes this initial gas flow rate and then applies one of two annual decline equations based on whether the mine is dry or flooded. For flooding status, we assume (as described above) that mines

closed by infill emit at the “dry mine” rate for eight years after closure, whereas intentionally flooded mines emit at the “wet rate.” Published data indicate that flooded mines cease emitting methane within a decade. Given that mines closed by infill can still flood (albeit more slowly) we set all mines’ emissions at zero after eight years by including only mines which closed after 2015 in our dataset. Like Kholod et al. (2020), we assume that all gas is eventually vented to the atmosphere. The main difference between the parameters laid out in Kholod et al. (2020) is that our inputs are mine-scale production data, rather than global projections of production and abandonment. Because we do not have data for every mine about whether they are dry or flooded, we assign lower and upper limit values to these data.

It is important to note that while some countries may have implemented measures to capture and utilize methane from abandoned mines — like Germany at a reported 99% utilization rate — this analysis focuses on the overall potential methane emissions before such mitigation. Our approach is consistent with how Kholod et al. (2020) conducted emissions estimation.

Existing capture efforts in countries beyond Germany may lead to lower methane emissions to the atmosphere than our estimates.

About the Global Coal Mine Tracker

The Global Coal Mine Tracker (GCMT) is a public registry of the world’s coal mines and proposed projects. The tracker provides asset-level details on ownership structure, development stage and status, coal type, production, workforce size, reserves and resources, methane emissions, geolocation, and over 30 other categories. The tracker uses wiki pages to document each coal mine and is updated annually.

About Global Energy Monitor

Global Energy Monitor (GEM) develops and shares information in support of the worldwide movement for clean energy. By studying the evolving international energy landscape and creating databases, reports, and interactive tools that enhance understanding, GEM seeks to build an open guide to the world's energy system. Follow us at www.globalenergymonitor.org and on Twitter @GlobalEnergyMon.

MEDIA CONTACT

Dorothy Lan Mei

Project Manager, Global Coal Mine Tracker

dorothy.mei@globalenergymonitor.org