Urgency to update Germany’s coal mine methane emission factor

This document provides an analysis on the potential underestimation of Germany's coal mine methane emissions, why this could be the case and the recommendations for how to rectify this major oversight on emissions reporting. This will be crucial in advance of the forthcoming EU Methane Regulation.

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About

This report presents evidence of the underreporting of Germany's coal mine methane (CMM) emissions and highlights why the methane emission factor and methodology must be urgently updated. Ember compiled independent emission estimates and methane measurements from Polish lignite, all of which indicate that the emission factor used by Germany underestimates CMM emissions. Finally, we present recommendations to improve Germany's monitoring, reporting and verification (MRV) framework.

Methane is the second most important greenhouse gas contributor to climate change and coal is the largest source of methane in the energy sector in the EU. Achieving the 1.5C pathway requires global CMM emissions to be reduced by 75% by 2030. This can only be done with an accurate understanding of emissions, now even more important in the context of the new EU Methane Regulation.

Highlights

1%

Although Germany produced 44% of the EU's total lignite in 2022, it only reported active CMM emissions of 1.39 thousand tonnes, namely 1% of that reported by the EU.

220

Coal mine methane emitted by Germany could be 28 to 220 times as much as is officially reported.

40-100

Germany considers its lignite coal comparable to that of Poland. However, Germany's evaluation of the methane content of its coal is 40 to 100 times less than the measurements of Polish lignite.

Introduction

Germany underestimates its coal mining emissions

Ember assessed Germany's coal mine methane emission data and is concerned that the significant scale of emissions has not been adequately estimated or assessed.

In 2022, Germany mined 131 million tonnes of lignite coal from surface mines, representing 44% of the 2022 EUs total lignite coal production. However, Germany only reported active CMM emissions of 1.39 thousand tonnes, namely 1% of the total EU's reported active surface CMM emissions in 2021.

Furthermore, methane from Germany's surface coal mines are clearly visible from satellite data, indicating emissions are significant and need to be addressed. The highest methane concentrations are found over the Hambach and Welzow-Süd mines, including the Lusatian Lake District.

Ember analysed methane measurements from Polish lignite and found that emissions could be **184 times highe**r than Germany currently reports. **This would more than double Germany's 2021 methane emissions from the entire energy sector, representing a 14% increase in national methane emissions.** Germany cannot claim to be a climate leader whilst simultaneously underreporting their emissions.

Germany's current methods, which use a single emissions factor, are considered inadequate by EU standards. The upcoming Methane Regulation will require "deposit-specific coal mine methane emission factor" established "on a quarterly basis" and taking into account "methane emissions from surrounding strata".

As a Global Methane Pledge Champion, and the largest EU surface coal mine producer, Germany's oversight on measurements and verification must be rectified. Germany should set an example on "best practise" CMM MRV. To do this will require an overhaul of Germany's outdated and lax existing methodology.

By establishing a rigorous MRV standard, Germany has the potential to significantly enhance the effectiveness of emissions reductions from surface coal mines, both within the EU and globally, as the Methane Regulation mandates importers to attain MRV equivalence.

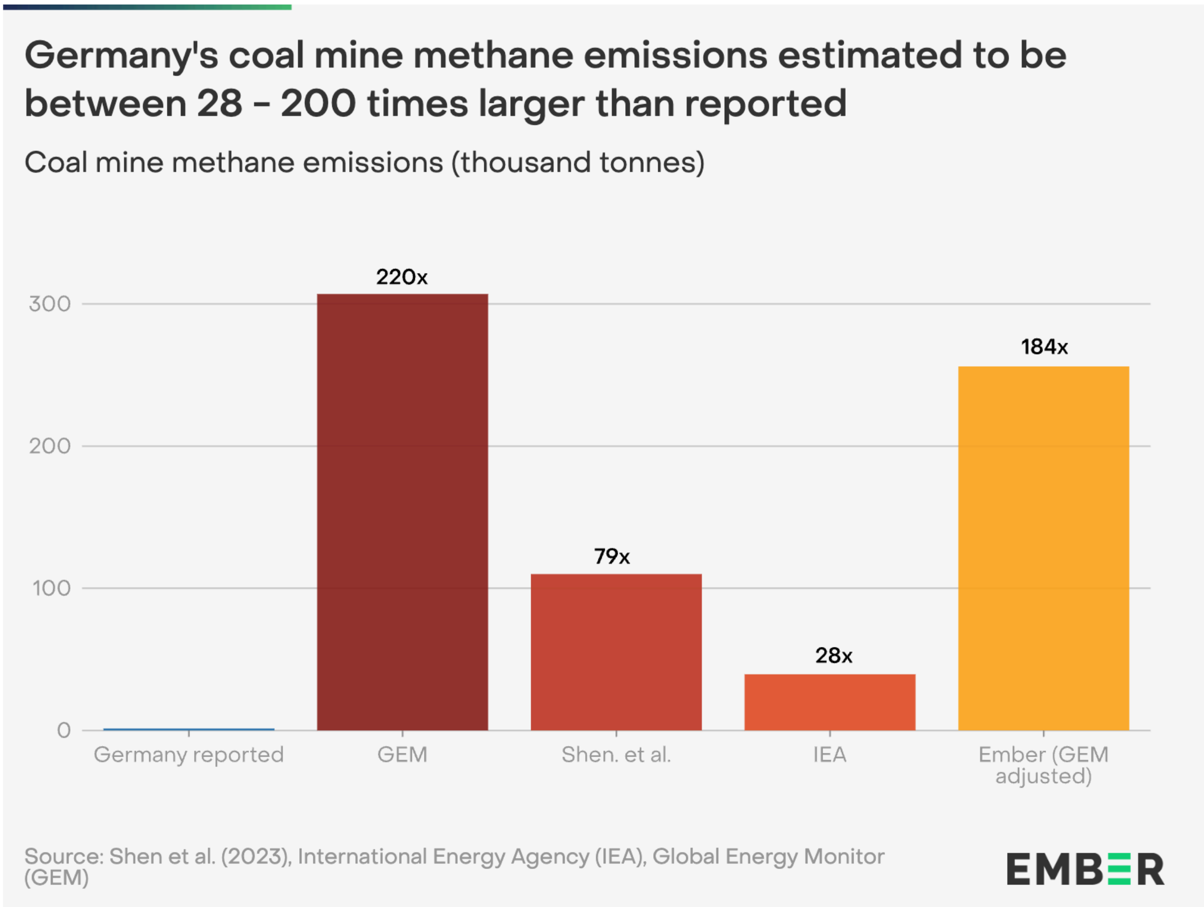
Ember highlights 3 recommendations which Germany can take:

1. **Measure:** Require surface mines to directly measure and model their current and future methane emissions, including after closure
2. **Avoid:** No coal mine expansions and phase out the gassiest mines first
3. **Mitigate:** Require methane mitigation at active and closed coal mines

Comparison of estimates

Ember compared government-reported emissions to three independent estimates from the International Energy Agency (IEA), Global Energy Monitor (GEM) and Shen et al. (2023). The studies rely on bottom-up and top-down methods, described in the Supporting Materials.

Findings from **all three studies agree that Germany is underreporting its CMM emissions**, although there are significant differences in the scale. Ember's previous analysis found that Germany was the country with the largest disparity between reported and independently estimated emission within the EU.



The studies indicate that Germany emits between 28 to 220 times as much as it officially reports from active coal mining operations. The largest estimates (by GEM) suggest Germany emits an additional 300,000 tonnes of methane emissions annually.

Using methane's short-term climate impact over 20 years (GWP 20), this would mean Germany's CMM emissions are between 3-25 million tonnes of CO2e, equivalent to some of the country's dirtiest coal power plants. Using methane's 100 year climate impact, CMM emissions would be equivalent to 1-9 million tonnes of CO2e.

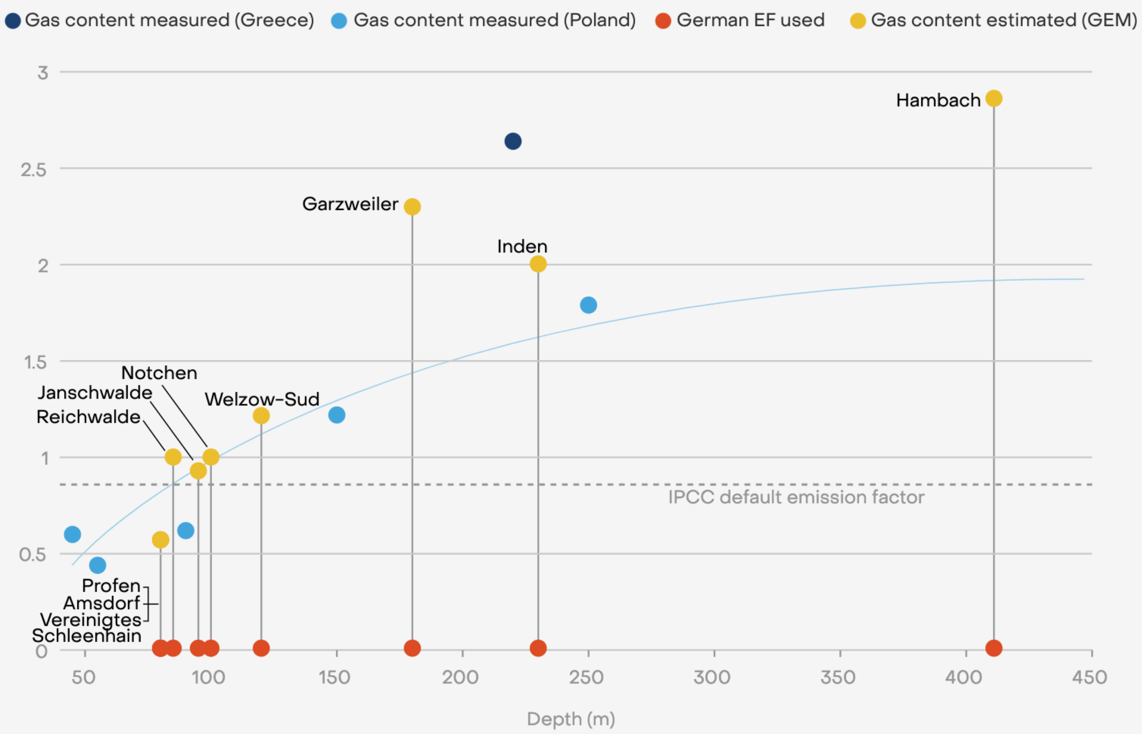
Ember update to GEM estimate

Ember estimated Germany's methane emissions, following the peer-reviewed Model for Calculating Coal Mine Methane (MC2M) methodology, as used by GEM and described in the

[Supporting Materials](). We compiled company data on coal production for the latest reported year (2022 when available, otherwise 2021), coal mine depth as described in company reports or academia, and [used data from Polish lignite samples]() to estimate the gas content of German lignite at varying depths, as plotted below.

The German CMM emission factor is significantly lower than methane content measured in Polish lignite samples

Relationship between methane content of lignite coals and their depth in Europe (kg methane / tonne coal)



Source: Germany National Inventory Report (2023), Baran et al. Investigations of methane content in lignite coals, Vasiliadou et al. Extraction Study of Lignite Coalbed Methane as a Potential Supplement to Natural Gas for Enhancing Energy Security of Western Macedonia Region in Greece · Global Energy Monitor (GEM)

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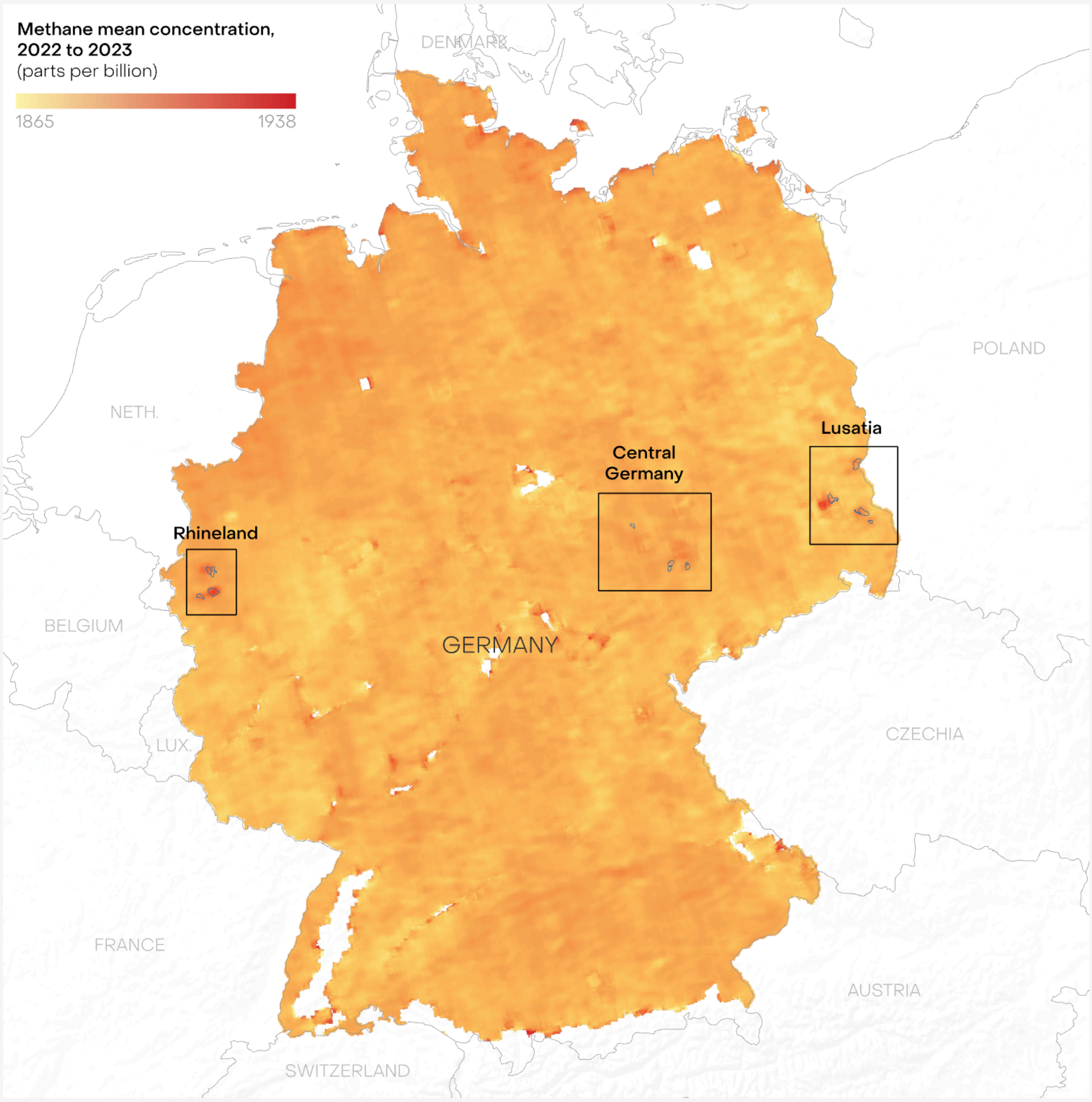
Applying this methodology, Ember estimated Germany's coal mine methane emissions at approximately 256,000 tonnes annually. While this figure aligns with the upper range of independent emission estimates, it remains within the uncertainty range established by Shen et al.'s analysis of Germany's CMM emissions from TROPOMI satellite data.

Satellite sees Germany's CMM

Using data from the TROPOMI instrument onboard Sentinel-5P, Ember calculated average methane concentrations from 2022-2023 from repeat daily overpasses. Methane from coal mines is visible when examining Germany overall, even with the large background noise.

Methane from coal mines visible from space



Source: Ember

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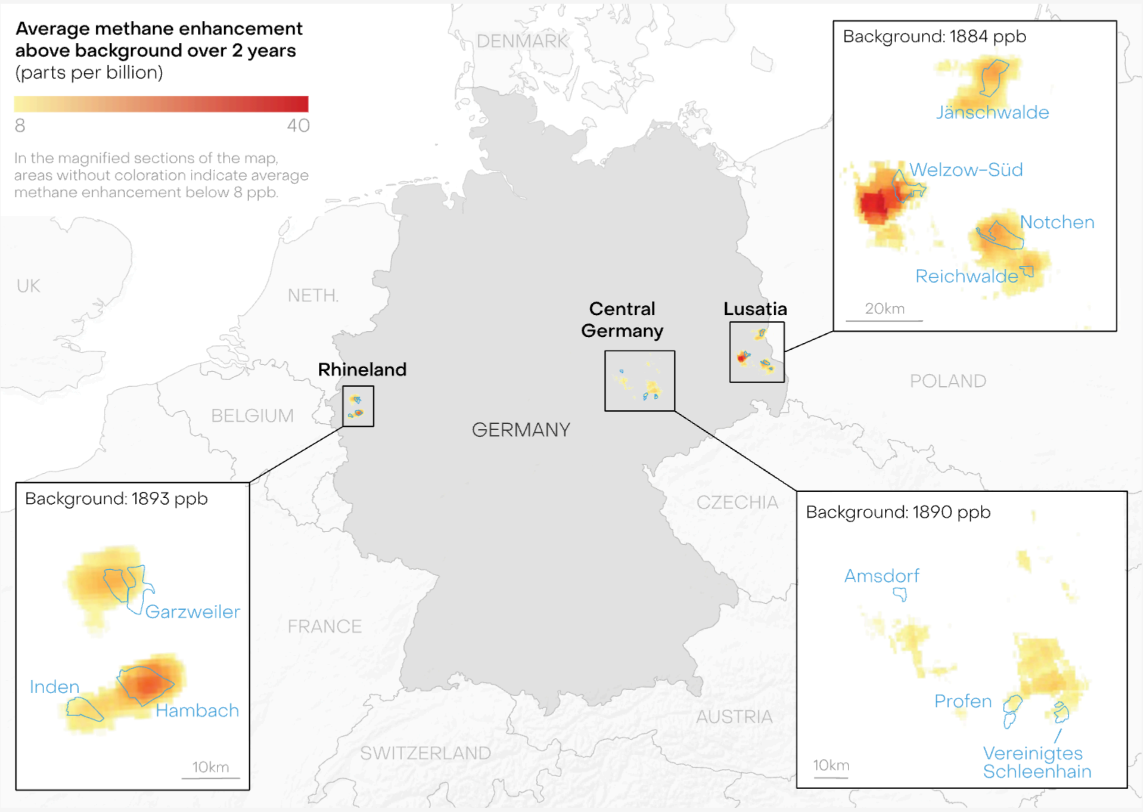
To more accurately pinpoint the localised methane concentrations, Ember analysed the methane enhancements above background for the three active lignite coal mining areas. Large-scale methane enhancements were detected over the majority of the coal mines, with particularly strong enhancements seen over coal mines in the Lusatia, and Rhineland region.

Methane enhancements over Germany's active coal mining regions



Source: Ember

To check whether the methane enhancements are only associated with coal production, a [database of oil and gas infrastructure](#) is used. An analysis of the database shows that there are no oil and gas facilities located in the study regions of Lusatia and Rhineland. In Central Germany, however, some of the enhancements are observed over regions that are not coal mines which may be due to oil facilities (see [Supporting Materials](#)).

The table below lists the maximum methane enhancements within each mine boundary. There is a large variation in the methane enhancements between the mines. The largest enhancements are found at Welzow-Süd (34 ppb) and Hambach (28 ppb) mines.

Maximum methane enhancements measured by TROPOMI for individual coal mines in Germany

Coal Mine Name	Region	Depth (m)	Annual Coal Production (MT)	Maximum Methane Enhancement (ppb)
Garzweiler Coal Mine	Rheinland	180	30	18
Inden Coal Mine	Rheinland	230	15	15
Hambach Coal Mine	Rheinland	411	23	28
Welzow-Süd Coal Mine	Lausitz	120	10.4	34
Notchen Coal Mine	Lausitz	100	14.5	22
Jänschwalde Coal Mine	Lausitz	95	11.1	21
Vereinigtes Schleenhain Coal Mine	Central German	80	10.5	11
Reichwalde Coal Mine	Lausitz	85	12.5	18
Profen Coal Mine	Central German	80	5.9	10
Amsdorf Coal Mine	Central German	80	0.3	4

Source: Ember

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Concerningly, this exercise identified one of Germany's largest methane enhancements to the south west of the Welzow-Süd mine, over a chain of artificial lakes (pit lakes) under construction in the Lusatian Lake District. The district is transforming several decommissioned lignite surface mines into Europe's largest artificial lake district. This is a large emission source which has potentially not been accounted for in Germany's methane emission estimates, and could pose a serious safety risk.

Ember plans further analysis to quantify emission rates associated with these large-scale coal mining methane enhancements using TROPOMI data and Integrated Methane Inversion run on Amazon Web Services. This will enable the emissions rates to be calculated from the methane concentrations over the mining regions.

Changes in year-on-year elevation caused by mining excavation are not accounted for in the TROPOMI algorithm, so may introduce a source of uncertainty into the methane enhancements. For more information on the methodology used please refer to the Supporting Materials.

The problem with Germany's current emission factor

Germany uses a single emission factor, measured in 1989, to calculate the methane emissions from all of its lignite coal mining operations throughout the country. This single emission factor lacks verification, is significantly different to lignite coal measured in Poland, and does not take into account methane emissions from surrounding strata. Here we highlight why the emission factor used by Germany is not adequate for estimating its coal mine methane emissions.

Inadequacy of single emission factor

A single emissions factor is insufficient for estimating surface coal mine emissions because the **methane intensity of coal mined is not constant in time**. Methane emissions are affected by factors such as the mines' location, depth, and change in the permeability of coal seams as overburden is removed. This level of variability is not captured with a single emission factor.

However, Germany currently relies on a single emission factor, based on a 1989 study by Rheinbraun AG, a lignite mining company. The German Lignite Industry (DEBRIV) states that methane content from borehole samples was measured, ranging from 0.00 m^3/t to 0.05 m^3/t, and that the average methane content was 0.015 m^3/t.

Single emissions factors are not an appropriate starting point for effective methane measurement or management at surface mines. Awareness of this issue is increasing in other countries that mine coal. For example, this has also been highlighted by the Australian Climate Change Authority, who have called for a review *"with respect to sampling* *requirements and standards estimation methodologies for fugitive methane emissions*" when applied to surface coal mines "*as a matter of urgency*".

40-100 times lower than lignite coal from Poland

Ember analysed the methane emission factor reported by Germany, and compared it to in-situ gas content, and depth measured from lignite samples in Europe (data was available for Poland and Greece, see data here).

Germany considers its lignite coal to be comparable to that from Poland, as stated in the National Inventory Report (NIR), and confirmed by Betzenbichler et al. in 2016.

However, Germany evaluates the methane content of its coal as significantly lower. Depending on the depth of the coal sample, **Germany's emission factor is anywhere between 40 to 100 times lower than in-situ measurements of Polish lignite.**

In general, a mine's methane intensity will increase relative to the depth of the coal mined. Although there are exceptions to this rule as the methane intensity of coal can vary significantly between regions, basins and coal mines. Germany's emission factor does not take into account variations in depth, or variations in coal geology throughout the country.

Rhine Basin cannot be assumed to be representative of all of Germany

In-situ gas contents can vary greatly within a country as there is often a large spatial variability of methane content of coals, even within a basin. In Poland, the Upper Silesian coal basin covers an area less than 2% the size of Germany but methane content varies significantly both vertically and horizontally. In shallow seams alone, the methane content can vary by a factor of 100 (between 0.01 and 1 m^3/t coal).

This raises the concern that the current emission factor, based only on samples from the Rhine basin, may not be representative for all of Germany's coal. The 2016 study by Betzenbichler et al. (referenced within Germany's NIR), highlights the same concern, and states that after requesting further information from DEBRIV, there were no further updates to the data.

Additional methane from the surrounding strata

During the excavation of coal at a surface mine, the methane within the mined coal seam will be released, **as well as methane within the surrounding (unmined) strata**. The IPCC guidelines state "*To account for the methane that migrates from surrounding strata, the assumed emissions factor should be based on measured variables such as gas content, and qualitative characteristics such as permeability*".

To account for these additional emissions, the U.S. Environmental Protection Agency multiplies coal production by a gas content emission factor and a **150-percent emission factor** to account for emissions from over- and under-burden (U.S. EPA, 2016).

There is no indication that Germany has taken into account methane emissions from the surrounding strata within their emission factor estimates.

Emission factor lacks verification

Germany's National Inventory Report (NIR) claims that secondary references substantiate the findings of the 1989 Rheinbraun AG study, however, this is not the case. None of the references provide information to determine the applicability or robustness of the geological sampling program used. Information on the number of drill holes, sampling techniques, depth of samples, porosity, and methane content have not been publicly disclosed.

For more detail on the references included within the NIR, and why they do not substantiate the emission factor, see the Supporting Materials.

Recommendations

Germany claims to be a climate action champion. The country is also a signatory of the Global Methane Pledge and has therefore committed to measuring and reducing methane, but can only do this if it understands its emissions. It is up to the German government to implement a robust plan to measure and rapidly reduce its coal mine methane emissions. In doing so Germany has the opportunity to set an ambitious best-practise industry standard both within the EU and globally.

Ember recommends urgent changes that Germany should make to quickly get a grip on their methane emissions from surface mines, highlighting best practice measurement, and a pathway for how to avoid and mitigate future emissions.

Best practice measurement for surface mines

Best practice measurement for surface mines combines a number of technologies to generate a multi-input model. The approach should take into account methane variability, spatial and climatic factors, and changes to the permeability of the coal seam, as well as major pollution events.

In brief, Ember suggests the following should be considered:

- Measurements of geotechnical cores to establish the methane content across all the gas bearing strata, combined with field coal gas models, to derive a site-specific emission factor for surface operations, which are verified by an independent body;
- Complementary total site-level measurements should be conducted to ensure site-level reconciliation with source-specific measurements.

Decommissioned surface mines

Surface mines should be required to undertake direct measurements and model their emissions after closure, including reliable gas measurements from waters of pit lakes. A 2017 study at the pit-lake Vollert-Sued in Germany also found elevated methane concentrations in the water. This is particularly important as pit-lakes can be more susceptible to limnic eruptions, posing a serious safety risk.

Verification

Reporting entities should have a formal quality assurance program, including independent review of emission reports prior to submission, as stated in the upcoming EU Methane Regulation.

Satellites and drones are an emerging approach for the verification of national inventories, and regulators should consider the calibration of satellite observations with data from land-based monitoring systems.

Reducing Methane Emissions

Avoid

A clear pathway to avoiding methane emissions is for Germany to cease approving coal expansion projects, and focus on phasing out coal mining at the gassiest coal mines first.

For closed mines, Germany must reassess its legislation on the rehabilitation of surface coal mines via the creation of pit-lakes. Avoiding emissions from these sources can be done by utilising alternative rehabilitation methods.

Mitigate

Whilst existing mines continue to operate, there are methods available to mitigate methane emissions.

Best practice methane mitigation in surface coal mines is pre-mine drainage, as indicated in a recent study from the University of Queensland. The method is widely used across the mining industry, and involves designing and implementing a series of planned wells to either flare or utilise the drained methane prior to mining. For the best possible mitigation results, this process begins months ahead of mining at a particular mining domain, and continues throughout the life of the mine.

This practice has a twenty year history in the mining industry, especially in the USA, where surface mines are often found to have relatively lower gas content to those of underground mines.

At pit-lakes, methane extraction and utilisation could be considered as a mitigation option.

EU Methane Regulation Opportunity

As highlighted previously, in line with the upcoming EU Methane Regulation, Germany is required to update the current MRV methodology for surface mines. This means they must use the emissions factor based on coal deposit and specifically, the regulations state;

"As regards surface coal mines, mine operators shall use deposit-specific coal mine methane emission factors to quantify emissions resulting from mining operations. Mine operators shall establish those emission factors on a quarterly basis, in accordance with appropriate scientific standards and take into account methane emissions from surrounding strata. "

European standardisation organisations will be requested to draft harmonised standards for measurement and quantification of methane emissions from coal mines. **As the largest surface coal miner in the EU, it is Germany's responsibility to lead the effort to determine, and implement accurate MRV at surface mines.**

Although surface mines in Europe are exclusively for lignite coal, globally surface mining is commonly employed for methane-intensive hard coal, including coking coal. Improving MRV standards at surface mines in the EU can have a substantial positive impact globally, since imported coal must comply with the EU's MRV equivalence requirements.

Supporting Materials

Methodology

Independent estimate by Global Energy Monitor

Global Energy Monitor employs its Global Coal Mine Tracker to estimate methane emissions at individual mines worldwide, aggregating the data on national and global scales. They provide baseline estimates for coal mine methane emissions, which utilise mine-level activity data, such as production, operating depth, methane content at depth, and an emission factor to account for methane from over and under burden, following the peer-reviewed Model for Calculating Coal Mine Methane (MC2M) methodology.

Using the MC2M methodology, GEM estimates that the emissions from Germany surface mines could be up to 307,000 tonnes per year. GEM applied gas content for “brown” coals in their calculations after a Polish study showed emissions of 2.5 dcm3/kg at a pressure of 10 bar for lignite. This estimate may therefore be overestimating Germany’s CMM emissions.

Independent estimate by Shen et al.

The study by Shen et al. estimated national and global CMM emissions using top-down methodology. The study used 22 months (May 2018-Feb 2020) of satellite observations from the TROPOMI instrument to better quantify national fossil fuel emissions worldwide.

The study estimated annual coal methane emissions from Germany to be 110,000 tonnes. The 95th percentile range is notably wide, ranging from 6,000 to 280,000 tonnes indicating a significant uncertainty of -95% to +155%. This considerable range underscores the uncertainty linked to methane emissions from the coal sector in Germany. In comparison, methane emissions from the oil and gas industry was estimated at 200,000 tonnes annually, with a more constrained 95th percentile range of 160,000 - 240,000 tonnes, showing a much smaller margin of +/- 20%.

Emission factor lacks verification

Not all studies references in Germany's NIR substantiate the CMM emission factor

Emissions and trend (1.B.1)

3.3.1.1 Underground mining – hard coal

Hard coal is no longer mined in Germany.

3.3.1.2 Open-pit mining – lignite

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 2	AS	CS

3.3.1.2.1 Category description (open-pit mining – lignite)

Activity data

Table 96: Usable output of lignite, in millions of t.

1990	1995	2000	2005	2010	2015	2020	2021
356.5	192.7	167.7	177.9	169.4	178.1	107.4	126.3

(Statistik der Kohlenwirtschaft, 2022)

Emission factors

In keeping with figures of the DEBRIV German lignite-industry association (DEBRIV, 2004), an average emission factor of 0.015 m^3 CH_4/t (corresponds to 0.011 kg CH_4/t) is assumed for German lignite. This emission factor is based on a 1989 study of RWE Rheinbraun AG (DEBRIV, 2004) and has been substantiated by publications of the German Society for Petroleum and Coal Science and Technology (DGMK) (DGMK, 1992).

No lignite storage takes place; usage is "mine-mouth", i.e. extracted coal is moved directly to processing and to power stations.

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14/04/2023

Source says:

In 1989 Rheinbraun AG measured methane content from boreholes ranging from 0 to 0.05 m3/t. The average methane content was 0.015 m3/t. Mentions the Öko-Institut measured a methane content of 0.02 m3/t. Source does not include any further measurements, data or evidence to support EF.

Source substantiates emission factor? **PARTLY**

Source says:

States the emission factor is 0.015 m3/t, but does not substantiate the emission factor with any further studies or information.

Source substantiates emission factor? **NO**

CLIMATE CHANGE National Inventory Report, Germany – 2023

Table 97: Emissions in category 1.B.1.a.ii – open-pit mining

Emission factors	m^3 CH_4/t	kg/t
CH_4 from extraction	0.015	0.011

Emissions and trend

Table 98: Emissions in category 1.B.1.a.ii – open-pit mining

Gas	Total emissions			Trend		Remark
	1990	2020	2021	Since 1990	With respect to the previous year	
Methane	3.9 kt	1.2 kt	1.4 kt	-64 %	17 %	The emissions have been decreasing as a result of reductions in lignite production.

3.3.1.2.2 Methods (open-pit mining – lignite)

The emissions from open-pit lignite mining are calculated with the Tier 2 method.

3.3.1.2.3 Uncertainties and time-series consistency (open-pit mining – lignite)

The emission factor used for calculating methane emissions from lignite production is based on maximum methane content levels and thus represents the upper limit of possible methane emissions. It thus already includes possible emissions from transport and storage. Numerous studies have shown that a negative uncertainty of - 33 % must be assumed (DEBRIV / DGMK research report / Forschungsbericht 448-2, DGMK (1992)).

For the emission factor and the activity data, a consistent source is used throughout the entire time series.

3.3.1.2.4 Category-specific quality assurance/control and verification (open-pit mining – lignite)

General and category-specific quality control, and quality assurance in conformance with the requirements of the QSE manual and its associated applicable documents, have been carried out by the Single National Entity.

In the framework of verification for the current report, various data sources for activity data in coal mining, and the relevant EF used, were compared with the corresponding sources and EF of other countries (cf. Table 99). A by-country comparison of specific emission factors for open-pit mining shows a broad range, with Germany in the lower part of the range, in a position comparable to that of Poland. The 2011 NIR (p. 103) noted that the Czech Republic uses the average IPCC default factor, in keeping with the fact that the coal mined in that country, in comparison to the coal mined in Poland and Germany, consists to a larger extent of sub-bituminous coal. The degree of coalification (rank) – and, thus, the methane content – of such coal is higher than that of the lignite found in Poland and Germany (sources: NaSE-Workshop (2004), personal communication of DEBRIV (2004)). This conclusion was also reached by a report prepared by VERICO (Betzenbichler et al., 2016b).

Source says:

Confirms that Germany is similar to Poland with respect to the type, and methane emissions of coal. Questions the representativeness of using the "old" 1989 study based in the Rhine Valley for the whole of Germany. State that after asking DEBRIV for more information, in fact, they have never pursue any update on EF.

Source substantiates emission factor? **NO**

Source: Germany National Inventory Report (NIR), DEBRIV. (2004, 15. September 2004) Mitteilung vom Deutscher Braunkohlen-Industrie-Verein e.V. an das IKP Stuttgart/Interviewer: I. Stuttgart. DEBRIV., DGMK. (1992). Ansatzpunkte und Potentiale zur Minderung des Treibhauseffektes aus Sicht der fossilen Energieträger Betzenbichler (2016b). Erarbeitung wissenschaftlich-methodischer Grundlagen zur Umsetzung der Empfehlungen aus den internationalen Inventarüberprüfungen – Verbesserung des Qualitätsmanagements und der Verifikation der deutschen Emissionsinventare.

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TROPOMI analysis

Daily TROPOMI data with a spatial resolution of 5.5 km × 7 km was extracted for Germany and annual mean values were calculated using Google Earth Engine. The years 2022 and 2023 were selected for analysis, as the TROPOMI algorithm was improved in November 2021 to include a bias correction over reflective surfaces. This means that after November 2021, there is TROPOMI data over the lakes to the west of Welzow-Sud mine. To examine the long term signal, the average of the two years was used in the analysis.

To identify the methane enhancements for the three mining areas, a bounding box was applied to each region. The local background concentrations were calculated from the 10th percentile value in the boxes. The anomaly was then calculated by subtracting the methane concentrations from the background level. The background level for each region is shown in the figure. This approach has been applied to TROPOMI data in a previous study for the oil and gas industry.

The mine boundaries were obtained by manually extracting mine polygons from a satellite derived dataset of surface mines using QGIS. These polygons were used to calculate the maximum enhancements directly above the mines (listed in the Table).

To verify the source of emissions in the vicinity of each coal mine, the locations of oil and gas infrastructure were plotted using a database of oil and gas infrastructure. This confirms that the enhancements in the Lusatia and Rhineland are related to coal production, but that oil refineries may contribute to some of the enhancements in the Central Germany study region. The Salzbergen Crude oil refinery is approximately 7.5 km north of Vereinigtes Schleenhain Coal Mine and the Leuna, Spergau crude oil facility is approximately 20 km north west of the Profen coal mine. This may explain why enhancements are observed over regions that are not coal mines in Central Germany.

The GMTED2010 elevation data used by the TROPOMI retrieval algorithm is static, and does not capture year-on-year changes in depth caused by mining activities since the dataset was created. This may introduce a source of uncertainty in the retrieved methane data. To estimate this error, data of the true elevation of the individual mine pits for the years 2010, 2022 and 2023 would be required.

About Ember

Ember is an independent, not-for-profit energy think tank that aims to shift the world to clean electricity using data. It gathers, curates and analyses data on the global power sector and its impact on the climate, using cutting edge technologies and making data and research as open as possible. It uses data-driven insights to shift the conversation towards high impact policies and empower other advocates to do the same. Founded in 2008 as Sandbag, it formerly focused on analysing, monitoring and reforming the EU carbon market, before rebranding as Ember in 2020. Its team of electricity analysts and other support staff are based around the world in Australia, the EU, UK, Turkey, India, China and Indonesia.

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Image credit

Wojciech Stróżyk / Alamy Stock Photo