Energy Industries and Fugitive sector: Coal Mining Emissions

Christy Lewis[1,3], Ryan Driskell Tate[2,3], Dorothy Lan Mei[2,3]
1) WattTime, 2) Global Energy Monitor, 3) Climate TRACE

1. Introduction

The underground, geological process that produces coal also produces greenhouse gas emissions (GHGs), primarily carbon dioxide (CO_2) and methane (CH_4). These gases remain trapped in the underground coal seams until the coal is mined. During the process of extracting coal, these gases can be released into the atmosphere. For this reason, coal mine emissions are classified by the Intergovernmental Panel on Climate Change (IPCC) under *1.B Fugitive Emissions from Fuels.* Even after active mining is complete, methane may continue to be released from these abandoned mines [1].

Climate TRACE utilized coal mine data from Global Energy Monitor's Global Coal Mine Tracker, which includes production and capacity data for 3,164 coal mines globally. Using methane gas content from the tracker, and capacity factors from literature, Climate TRACE was able to estimate annual emissions from these mines. Note, In Climate TRACE's 2023 release of source level data, only active mines had methane emissions estimated and abandoned coal mines and CO_2 emissions were not included.

2. Dataset

The main dataset employed for this work was from The Global Energy Monitor in their Global Coal Mine Tracker (GCMT; https://globalenergymonitor.org/projects/global-coal-mine-tracker/). Global Energy Monitor's CH_4 as a worldwide dataset of coal mines and proposed projects. The tracker is updated annually and provides source level details on ownership structure, development stage and status, coal type, production at operating mines, capacity at proposed mines, workforce size, reserves and resources, geolocation, and other categories.

The tracker gathers data from publicly available sources: (1) government data, including national energy and resource plans, environmental permits and applications; and national datasets; (2) reports by state-owned and private mining companies, including quarterly and annual reports; (3) news and media reports, including local, international, and trade outlets; (4) local non-governmental organizations (NGOS) monitoring companies, mining activity, and developments; (5) on the ground contacts who can provide first-hand information.

The information was collected by an international team of researchers, with fluencies in Chinese, Russian, Spanish, and Turkish. Wherever possible, Global Energy Monitor circulates data for vetting and review to researchers familiar with local mining conditions. Input data from this tracker was used to estimate emissions, described in the sections below.

3. Input data

The following metadata was used to estimate emission factors and methane emissions for coal mines.

Coal mine data

Coal mine location, name, country, and owner are all based on the dataset provided by Global Energy Monitor in their Global Coal Mine Tracker (GCMT; https://globalenergymonitor.org/projects/global-coal-mine-tracker/). In order to create a temporally comprehensive dataset (2015-2022), previous versions of GEMs coal mine tracker were used. These datasets were used to identify mines that were open previously, and closed, or to identify past activity for mines that are currently open.

Capacity Factor

Capacity factor values were gathered from relevant literature for specific regions in China and the U.S. For all remaining regions, a global average capacity factor was used based on China and the U.S.

China: Yangpin Ju, et al. (2019) used a stochastic model to estimate the regional capacity utilization for 15 years in China [5]. Climate TRACE utilized these capacity factors for Chinese mines using the following rules:

1. If a mine was in a state provided in the paper above, and we were estimating emissions for a year provided in the paper above, the exact capacity factor was used.
2. If a mine was in a state provided in the paper above, and we were estimating emissions for a year not provided in the table, the mean across all 15 years for that state was used.
3. If a mine was not in a state provided, but we were estimating for a year provided, the mean across all states for that year was used.
4. Finally, if a mine was not in a state, and we were not estimating emissions for a year in the table, the mean of the entire table was used.

USA: The U.S. Energy and Information Administration (EIA) provides state level, annual capacity factors for coal mines in the U.S [6]. Climate TRACE utilized these capacity factors for US mines using the following rules:

1. If a mine was in a state provided in the paper above, and we were estimating emissions for a year provided in the paper above, the exact capacity factor was used.

2. If a mine was in a state provided in the paper above, and we were estimating emissions for a year not provided in the table, the mean across all 15 years for that state was used.
3. If a mine was not in a state provided, but we were estimating for a year provided, the mean across all states for that year was used.
4. Finally, if a mine was not in a state, and we were not estimating emissions for a year in the table, the mean of the entire table was used.

All other locations: For all other coal mine locations and years, an average of all U.S. and Chinese capacity factors was applied.

Activity
GEM's 2023 GCMT provided either production or capacity information for each mine. In some cases, both were provided. If both were available, Climate TRACE used production, and calculated capacity using the capacity factors listed above. Some mines have activity data available in previous versions of the GCMT. Those mines will have varying activity between 2021 and 2022 data. No activity data was available before 2021, so the earliest available activity data was backfilled until the year that the mine opened.

For mines where only capacity was available, activity was calculated using the capacity factors described above.

Capacity
For mines where only capacity was provided, Climate TRACE used the capacity as provided. If activity was provided in GEM's GCMT, capacity was calculated by dividing the activity by the capacity factors described above. Capacity values were backfilled to the year that the mine opened.

Emissions Factor
The emissions factor for each mine is a function of two things: the *methane gas content* of each mine, and the *emission factor coefficient*.

Methane gas content: The gas content of a coal isotherm is dependent on the depth of the mine, and GEM estimated the methane gas content of each mine using the approach laid out in *Global methane emissions from coal mining to continue growing even with declining coal production* [2]. Climate TRACE utilized the methane gas content provided by GEM for each mine. GEM provided the value in cubic meters per tonne (M^3/tonne) of coal produced, and Climate TRACE applied a conversion factor provided by the EPA to convert the methane gas content to tonnes of CH_4 [3] .

Emission factor coefficient: In order to convert the CH_4 gas content into an emissions factor, the emission factor coefficient must be applied. This is due to emissions from coal pillars and methane in coal seams that are in the surrounding area. Ju et al. (2016) reported that this coefficient is in the range 1.3 to 2.0. For this work, Climate TRACE used an average of 1.65 [4].

The two values described above are combined as in Equation 1 in order to produce the emissions factor for each mine.

$$Emission\ factor(mine) \ = \ (Methane\ Gas\ Content(mine)\ /\ 1.4703e3)\ *\ 1.65 \qquad \text{(Eq.1)}$$

4. Model

Once the metadata above was determined, calculating emissions used Equation 2. Climate TRACE combined CH_4 emissions factor (in tonnes CH_4 per tonne of coal) with activity (in tonnes of coal) to derive tonnes of CH_4 emissions per mine per year.

$$CH4\ Emissions\ (mine) \ = \ CH4\ Emissions\ Factor \ * \ Activity \qquad \text{(Eq.2)}$$

Equation 2 was applied to 3,164 coal mines globally to estimate their methane emissions for years 2015 to 2022.

5. Reporting of emissions on Climate TRACE

Coal mining emissions data for this sector is hosted in the Climate TRACE website: https://climatetrace.org/. This emissions sector is equivalent to the United Nations Framework Convention on Climate Change (UNFCCC) sector “Fossil Fuel Operations 1.B.1.a - Coal Mining and Handling”. Climate TRACE default emissions values were reported as CH_4, and CO_2 equivalent 20- and 100-year global warming potential (CO_2e 20yr and 100yr GWP).

References

1) https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/2_Volume2/19R_V2_4_Ch04_Fugitive_Emissions.pdf
2) Kholod, N., Evans, M., Pilcher, R.C., Roshchanka, V., Ruiz, F., Coté, M. and Collings, R., 2020. Global methane emissions from coal mining to continue growing even with declining coal production. *Journal of Cleaner Production*, *256*, p.120489. https://www.sciencedirect.com/science/article/pii/S0959652620305369
3) Environmental Protection Agency (EPA). *Updated Coal Mine Methane Units Converter Available at:* https://www.epa.gov/cmop/coal-mine-methane-units-converter. Accessed: 01 September 2023.

4) Ju, Y., Sun, Y., Sa, Z., Pan, J., Wang, J., Hou, Q., Li, Q., Yan, Z. and Liu, J., 2016. A new approach to estimate fugitive methane emissions from coal mining in China. *Science of the Total Environment*, *543*, pp.514-523. https://doi.org/10.1016/j.scitotenv.2015.11.024
5) Ju, Y. and Wang, X., 2019. Understanding the capacity utilization rate and overcapacity of China's coal industry and interprovincial heterogeneity. *IEEE Access*, *7*, pp.111375-111386. DOI: 10.1109/ACCESS.2019.2933948
6) EIA, 2023. *Annual Coal Report.* Available at: https://www.eia.gov/coal/annual/. Accessed 01 October 2023.