Underestimation of coal mine emissions

Australian Projections provides actuarial advice on issues of national policy, such as aged care, education, energy and climate. We are trying to help Australians and their politicians contribute to climate policies. This submission to the Climate Change Authority is in response to their issues paper of May 18. It replaces a submission made on 23 June. Please contact Dr Richard Cumpston on 0433 170 276 or richard.cumpston@gmail.com with any questions.

Summary

Australia's open cut mines are reporting fugitive emission intensities only about one-tenth of those reported by underground mines. This appears to be due to prescribed methane estimation methods partly based on research 30 years old, rather than deliberate under-reporting.

Making the arbitrary assumption that open cut coal mines have the same fugitive emission intensities as underground mines suggests that fugitive emissions from open cut mines were under-estimated by about 80 Mtonnes of CO2 equivalent in 21-22.

We conclude that

- Emission estimates for underground coal mines may be about right
- Methane emissions from open cut mines appear to be strongly underestimated
- Current emission estimation methods for open cut mines should be abandoned
- Open cut coal mines should be required to measure their emissions directly
- Regulatory authorities should use satellite observations as broad checks
- Retrospective changes to Australia's emission reports may be needed
- The Climate Change Authority needs reliable data to meet its responsibilities.

1. Introduction

1.1 Current projects of the Climate Change Authority

The Authority's issues paper of 18 May 2023 listed four current tasks

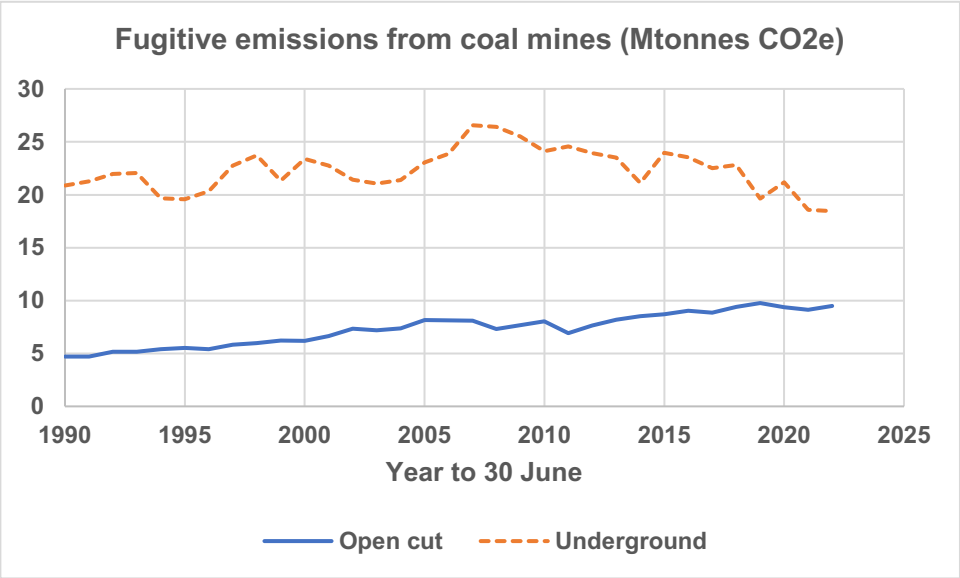
- Advice on emission reduction targets for Australia's next nationally determined contribution under the Paris Agreement
- Advice for the Minister for Climate Change and Energy on the Annual Climate Change Statement for 2023
- Review of the Carbon Credits (Carbon Farming Initiative) Act 2011
- Review of the National Greenhouse and Energy Reporting Act 2007.

1.2 Relevance of this submission to the Authority's current projects

This submission questions the validity of the prescribed methods for estimating methane emissions from open cut coal mines, under the NGER (Measurement Determination) 2008. It thus relates to the Authority's review of the NIGER Act. If the prescribed methods have been seriously under-estimating coal mine emissions, this will have implications for Australia's nationally determined contribution, and for the Authority's advice to the Minister on the Annual Climate Change Statement.

2. Fugitive emissions from Australian coal mines

2.1 Emission estimates



The above estimates are from figure 19 of DCCEEW's "Australia's emission projections 2022".

2.2 Early research on emission estimation methods for open cut coal mines

"In the early 1990s, a method of estimating fugitive gas emission from open cut coal mines based on direct measurement of coal plumes emitted from 17 open cut coal mines in the Sydney and Bowen Basins was developed … Emissions from these mines were determined using an air pollution technique, involving the measurement of wind speed and gas concentrations above the ground in the proximity of emission sources … Subsequently, an average emission factor for methane was established of … 0.17 t of carbon dioxide per tonne of raw coal for open cuts in the Bowen Basin and … 0.045 … for open cut mines in the Hunter Coalfield… These numbers were the basis for what is called Method 1." (Saghafi 2013 p1)

2.3 Prescribed methods for estimating fugitive emissions from open cut coal mines

Section 3.20 of part 3.2.3 of the NGER (Measurement) Determination 2008 describes Method 1, where methane emissions are determined by multiplying the quantity of run-of-

mine coal by state-dependent emission factors for methane. The following table shows the state factors as they were at 1/7/17, and after changes on 1/7/20 and 1/7/23.

State	Emission factors		
	1/07/2017	1/07/2020	1/07/2023
New South Wales	0.054	0.061	0.061
Victoria	0.00027	0.0003	0.0003
Queensland	0.020	0.023	0.031
Western Australia	0.020	0.023	0.023
South Australia	0.00027	0.0003	0.0003
Tasmania	0.017	0.019	0.019

Factors as at 1 July 2017 and 2020 are from past compilations of the National Greenhouse and Energy Reporting (Measurement) Determination 2008, and the amended factor at 1 July 2023 is from the National Greenhouse and Energy Reporting (Measurement) Amendment (2023 Update) Determination 2023. The Explanatory Memorandum for the 2023 Determination said in relation to the Queensland emission factor:

"This update aligns with method developments applied in the National Greenhouse Gas Inventory."

This is concerning, as it suggests that any underestimation of coal mine methane emissions will be reflected in our national emission reports.

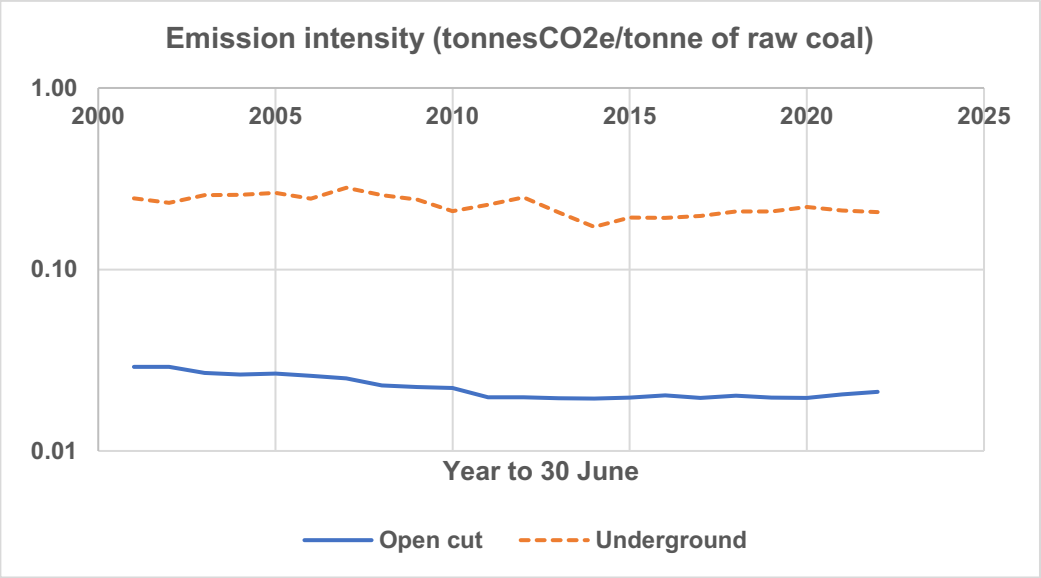
Saghafi (2013 p1) described a decade of further research up to 2012, leading to a mine-specific method, called Method 2 or 3 in the NGER (Measurement) Determination. Method 1 remains available. We have asked the Clean Energy Regulator for the numbers of open cut coal mines using each of the three methods for methane estimation.

2.4 Black coal emission and production data from 2000-01 to 2021-22

Year to 30 June	Emissions MtCO2e Open cut	Emissions MtCO2e Under-ground	Production Mtonnes Open cut	Production Mtonnes Under-ground	Emission intensity Open cut	Emission intensity Under-ground	Intensity ratio Open/ Under
2001	6.66	22.75	229	92	0.0291	0.2473	0.118
2002	7.34	21.42	253	92	0.0290	0.2328	0.125
2003	7.21	21.07	268	82	0.0269	0.2570	0.105
2004	7.38	21.41	280	83	0.0264	0.2580	0.102
2005	8.16	23.05	306	87	0.0267	0.2649	0.101
2006	8.14	23.87	314	97	0.0259	0.2461	0.105
2007	8.12	26.57	323	94	0.0251	0.2827	0.089
2008	7.31	26.43	318	103	0.0230	0.2566	0.090
2009	7.68	25.52	341	105	0.0225	0.2430	0.093
2010	8.04	24.11	361	115	0.0223	0.2097	0.106
2011	6.94	24.57	351	108	0.0198	0.2275	0.087
2012	7.64	23.94	387	96	0.0197	0.2494	0.079
2013	8.21	23.52	420	114	0.0195	0.2063	0.095
2014	8.54	21.13	439	123	0.0195	0.1718	0.113
2015	8.71	23.97	443	124	0.0197	0.1933	0.102
2016	9.04	23.53	446	122	0.0203	0.1929	0.105
2017	8.87	22.52	453	114	0.0196	0.1975	0.099
2018	9.41	22.81	466	109	0.0202	0.2093	0.096
2019	9.76	19.64	496	94	0.0197	0.2089	0.094
2020	9.39	21.19	480	96	0.0196	0.2207	0.089
2021	9.13	18.59	446	88	0.0205	0.2113	0.097
2022	9.49	18.45	449	89	0.0211	0.2073	0.102
Average					0.0225	0.2270	0.100

The above emission intensity estimates were obtained by dividing the emissions in 2.1 by production volumes from DISR 2023 and similar earlier publications.

2.5 Emission intensity trends



Emission intensities have been plotted on a log scale, to help show the greater variability of the intensities for underground mines, as compared with those for open cut mines. This may be due to the majority of open cut mines adopting the fixed values in method 1. Intensities for open cut mine appear to have dropped a little after 2010, perhaps reflecting the new availability of methods 2 and 3 for low-gas-content coals.

2.6 Potential underestimation of fugitives from coal mining in 21-22

From 2,4, open cut coal mines reported 9.49 Mtonnes of CO2 equivalent emissions in 21-22, with an emission intensity of 0.0211. If they are assumed to have the emission intensity of 0.2073 reported by underground mines, the emissions from open cut mines become

9.49 x 0.2073 / 0.0211 ie about 93 Mtonnes.

This suggests that fugitive emissions from open cut coal mines were underestimated by about 80 Mtonnes.

3. Emission intensities for Queensland coal mines``

3.1 Estimated emission intensities for Queensland Safeguard coal mines

Mine	Region	Emission intensity (tonnes CO2e/tonne raw coal) Year to 30 June					
		2017	2018	2019	2020	2021	2022
Open cut mines							
Rolleston	Southern	0.011	0.012	0.011	0.011	0.012	0.012
Caval Ridge	Northern	0.039	0.035	0.038	0.037	0.047	0.019
Callide	Southern		0.014	0.018	0.016	0.019	0.025
Hail Creek	Northern	0.056	0.055	0.032	0.034	0.041	0.031
Saraji	Northern	0.025	0.023	0.026	0.029	0.036	0.031
Clermont Coal	Central	0.034	0.033	0.031	0.034	0.044	0.032
Lake Vermont	Northern	0.019	0.024	0.024	0.037	0.042	0.033
Collinsville Opencut	Northern		0.038	0.041	0.033	0.046	0.036
Poitrel	Northern	0.031	0.029	0.031	0.033	0.042	0.040
Drake Mine	Northern	0.031	0.032	0.034	0.039	0.041	0.043
Blackwater	Central		0.041	0.042	0.047	0.048	0.047
South Walker Creek	Northern	0.036	0.033	0.031	0.037	0.049	0.048
Jellinbah East	Central	0.046	0.049	0.053	0.052	0.045	0.049
Daunia	Northern	0.048	0.051	0.049	0.050	0.053	0.049
Curragh	Central	0.038	0.038	0.036	0.042	0.056	0.049
German Creek	Central	*0.050*	*0.050*	*0.050*	*0.050*	*0.050*	*0.050*
Moorvale	Northern	0.037	0.048	0.048	0.069	0.052	0.051
Coppabella	Northern	0.036	0.044	0.052	0.051	0.053	0.052
Newlands	Northern	0.067	0.052	0.139	0.095	0.083	0.053
Middlemount	Central	0.049	0.050	0.056	0.071	0.055	0.055
Byerwen Coal Mine	Northern		0.061	0.053	0.038	0.042	0.055
Yarrabee	Central	0.047	0.052	0.051	0.050	0.056	0.060
Goonyella - Riverside	Northern	0.053	0.053	0.053	0.054	0.066	0.065
Dawson	Southern	0.035	0.043	0.047	0.055	0.048	0.071
Baralaba	Southern					0.081	0.072
Foxleigh	Central		0.046	0.055	0.054	0.063	0.075
Ensham OC	Central				0.080	0.134	0.079
Carmichael	Northern						0.115
Isaac Plains	Northern			0.038	0.036		
Meandu	Southern			0.013			
Millennium	Northern	0.054	0.049				
Open cut total		**0.039**	**0.036**	**0.036**	**0.040**	**0.046**	**0.043**
Underground mines							
Oaky Creek Coal Complex	Central	0.162	0.101	0.166	0.184	0.143	0.150
Kestrel	Central	0.072	0.074	0.049	0.114	0.164	0.162
German Creek - Grasstree	Central	0.262	0.253	0.370	0.501	0.435	0.287
Carborough Downs	Northern	0.074	0.069	0.148	0.235	0.171	0.394
Grosvenor	Northern	0.277	0.226	0.199	0.212	0.159	0.475
Moranbah North	Northern	0.237	0.313	0.382	0.385	0.530	0.716
Cook	Central	0.228	0.558	0.254			
Underground total		**0.187**	**0.198**	**0.227**	**0.267**	**0.276**	**0.302**
Open intensity as % underground		21%	18%	16%	15%	17%	14%

Emission estimates for each mine are from CER (2023) and similar earlier publications. Emission intensity estimates were obtained by dividing emissions by raw coal production data from the Queensland Government (2023), and sorted by 21-22 emission intensity separately for open cut and underground mines. Similar data for 19-20 are in Assan (2022).

3.2 Data issues

Emission estimates are only available from CER for Safeguard facilities, which report at least 100,000 tonnes of CO2 equivalent emissions in a year. For example, the Isaac Plains open cut mine produced coal throughout 16-17 to 21-22, but only exceeded the Safeguard threshold in two years.

Available emission estimates for German Creek are for the open cut and underground mines combined. We assumed an emission factor of 0.05 for the German Creek open cut mines, and attributed the remaining emissions to the German Creek underground mine.

3.3 Reported emission intensities for Queensland open cut and underground mines

Open cut mines reported emission intensities ranging from 0.012 to 0.115 in 21-22. The highest estimate was for a mine which began production in 21-22, and the high value may reflect timing differences, with emissions occurring before production. The emission intensity for all open cut mines of 0.043 for 21-22 is based on the production of all mines that reached the Safeguard threshold in 21-22. The 0.043 is higher than the 0.023 method 1 value for Queensland, but the method 1 value is for methane, while the published emission values include all gases.

Underground mines reported emission intensities ranging from 0.150 to 0.716 in 21-22, with an overall intensity of 0.302.

4. Satellite observations of coal mine methane emissions

4.1 Use of TROPOMI observations for Queensland super-emitters

Sadavarte et al (2021) describe the use of TROPOMI satellite observations from 2018 and 2019 to estimate methane emissions from super-emitting coal mines in Queensland. They identified three emission plumes, one from the Hail Creek open cut mine, one from the Moranbah North, Broadmeadow and Grosvenor underground mines, and one located close to the Grasstree underground mine. Given the limited resolution of the TROPOMI observations, and the close vicinity of other coal mines for the second and third plumes, they could not distinguish the contributions by individual mines. TROPOMI is a tropospheric monitoring instrument, launched on the Sentinel-5 Precursor satellite on 13 October 2017.

The satellite observations were screened for cloud-free coverage, low aerosol content, solar zenith angle, viewing zenith angle and smooth topography. 75 orbits containing a total of 124 clear-sky observations were selected and used for emission estimation. The presence of clouds from January till June limited the availability of TROPOMI data, but the quarterly coal production numbers showed little variation in 2018 and 2019.

95% confidence limits for their emission estimates were stated to be ±22% for the first plume, ±32% for the second and ±42% for the third. They noted that their estimates for the first plume were more than 35 times higher than a bottom-up estimate, consistent with a bottom-up estimate for the second plume, and a factor of 2 higher for the third plume. These estimates suggest Australia's reported emissions for underground coal mines are of the right order of magnitude, but those for open cut mines are strongly under-stated.

4.2 Use of Sentinel-SP data to estimate Bowen Basin methane emissions

Kayrros (2021) used public satellite data from the Sentinel-SP satellite to estimate annual methane emissions from the Bowen Basin at 1.6 million tons. This is equivalent to about 36 Mtonnes of CO2 (using Australia's outdated conversion rate of 25 tonnes of CO2 per tonne of methane). By contrast, reported emissions in 19-20 from the Northern region of Queensland were about 10 Mtonnes of CO2 equivalent. These reported emissions excluded mines below the Safeguard threshold, but included non-methane gases. The methodology used by Kayrros, and the confidence limits on their estimate, are not stated. Their estimates suggest that reported emissions for the Bowen Basin are much too low.

4.3 Future availability of methane data from MethaneSAT

MethaneSAT is a planned American-New Zealand space mission currently scheduled for launch in January 2024. The mission is planned to be an Earth observation satellite that will monitor and study global methane emissions in order to combat climate change (Wikipedia 2023).

5. Conclusions

5.1 Emission estimates for underground coal mines may be about right

The prescribed methods for emission estimates for underground mines are based on direct measurements, and do not involve numeric assumptions (other than a destruction efficiency of 0.98 for coal mine waste gas flared). It seems likely that most waste gas exits through the mineshaft, and can be readily measured. Limited satellite data suggest that reported emissions from underground coal mines may be of the right order of magnitude (see 4.1).

5.2 Methane missions from open cut mines appear to be strongly underestimated

The prescribed method 1 for open cut mines uses state emission factors, partly based on limited research in the early 1990s. Only 17 mines were measured, which in hindsight was too small a sample. Given that underground mines have more opportunities to capture waste gases, it is implausible that open cut mines should have emission intensities only one-tenth of underground mines (see 2.4). The TROPOMI satellite observations suggested that one Queensland mine had methane emissions 35 times higher than its reported total emissions (4.1).

5.3 Current emission reporting methods for open cut mines should be abandoned

Method 1 is resulting in Australia under-reporting its methane emissions in regard to the UNFCCC, the Paris Agreement and the Methane Pledge. It is also making the Safeguard mechanism less effective, with high-emitting mines having little incentive to abate or offset their emissions. Methods 2 and 3 are only intended for low gas content mines, and rest on a number of suspect assumptions.

5.4 Open cut coal mines should be required to measure their emissions directly

There should be several methods available to measure the concentrations and velocity of waste gases immediately above open cut mines. Drones and planes are a possibility, but

would only provide intermittent observations. A network of gas detectors could be installed permanently across the top of open cut mines. It might be possible to use transit devices, monitoring the transmission losses across the pit at the spectral frequencies of waste gases. Much of the technology currently used by underground coal mines might be applicable. Government-funded research could help develop reliable estimation methods.

5.5 Regulatory authorities should use satellite observations as broad checks

Satellite observations are only available on days of low cloud cover, have high measurement uncertainties, and have difficulty in distinguishing between emissions from nearby mines. The Clean Energy Regulator currently receives audited emission reports from miners, and could have its responsibilities extended to comparing the emission reports with satellite data for mine clusters.

5.6 Retrospective changes to Australia's emission reports may be needed

Direct measurement of emissions from open cut coal mines may confirm that past estimation methods have severely understated emissions. Australia's nationally determined contribution includes a 43% reduction below 2005 levels by 2030. Should the 2005 emissions be adjusted retrospectively? Section 3(2)(b) of the NGER Act 2007 requires Safeguard emissions between 1 July 2020 and 30 June 2030 to not exceed 1,233 Mtonnes of CO2 equivalence. Should Safeguard emissions reported from 20-21 on be adjusted retrospectively to values likely to have been produced by updated reporting methods?

5.7 The Climate Change Authority needs reliable data to meet its responsibilities

Sections 14, 15 and 15A of the Climate Change Act 2022 give the Climate Change Authority important new responsibilities. To meet these responsibilities, the Authority needs reliable data.

Acknowledgements

We are grateful to staff of the Clean Energy Regulator for help with data. The opinions expressed are however our own.

Abbreviations

CCA	Climate Change Authority
CER	Clean Energy Regulator
CO2	Carbon dioxide
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DISR	Department of Industry, Science and Resources
NGER Act	National Greenhouse and Energy Reporting Act 2007
UNFCCC	United Nations Framework Convention on Climate Change

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