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Direct emission measurements for coal mines

Richard Cumpston & Hugh Sarjeant

This submission is intended to help Australians contribute to climate policies. It looks at the long-standing problems with emissions reporting by Australian open cut coal mines, and suggests how emissions reporting could be improved. Other notes on climate change are available on https://www.australianprojections.com.au/climate-change. Please contact Dr Richard Cumpston, a director of Australian Projections, on 0433 170 276 or richard.cumpston@gmail.com with any questions.

Summary

There is increasing evidence that emissions from some Australian open cut coal mines are grossly under-reported. This is partly because Method 1 allows mines to report at a standard emissions intensity, regardless of their actual intensity. Mines can also choose to use Methods 2 or 3, which are based on the gas content of their coal seams.

The Climate Change Authority has recommended that Method 1 be phased out as a matter of urgency, and Method 2 be urgently reviewed. The IMEO-funded flights over Bowen Basin coal mines in 2022 and 2023 will provide valuable data for this review, and for the development of a method using direct emission measurements.

The Minister for Climate Change and Energy has asked the Department of Climate Change, Energy, the Environment and Water to consider which of the Authority's recommendations can be implemented by 30 June 2024. This submission is to the Department.

We recommend that, for open cut mines:

- Method 1 be abandoned for emissions from 30 June 2024
- Methods 2 and 3 be urgently reviewed, taking into account the IMEO results
- a Method 4, using direct measurements, be urgently developed,
- coal mines be required to use Method 4, when available, to measure emissions daily
- coal mines be required to report emissions quarterly
- flights or satellites be used to check mine reports
- research be carried out on temporal emission variations, as they may cause flights or satellites to overstate average emissions
- the Clean Energy Regulator have the right, for Safeguard and UNFCCC purposes, to adjust emission reports taking into account flight or satellite observations.

1. Emission measurement methods for Australian coal mines

1.1 Measurement methods for underground coal mines

The Climate Change Authority's 2023 review of the NGER legislation says

"To estimate fugitive emissions associated with coal extraction in underground coal mines, the Measurement Determination limits the choice of method to Method 4 … sensors are installed to monitor the composition and flow rates of gas venting from the mine shaft." (p68).

Sensors are generally based on those required under state safety legislation. This use of direct measurements from sensors may explain why satellite observations have found that reported emissions from underground mines are about right,

1.2 Measurement methods for open cut coal mines

Figure 4.4 of CCA's 2023 review of the NGER legislation shows that about 60% of fugitive emissions in 21-22 from open-cut mines were reported using Method 1, and the rest using Method 2. Method 1 assumes methane emission intensities specified for each state. Mines using Method 1 are not required to report other greenhouse gas emissions (CER 2023 p50).

CCA noted that 72% of fugitive emissions were reported using Method 1 in Queensland, and 26% in NSW (p73)

Method 2 uses mine-specific in situ gas modelling. One or more representative domains have to be established, where *"a domain means an area, volume or coal seam in which the variability of gas content and variability of gas composition in the open cut mine has a consistent relationship with other geological, geophysical or special parameters located in the area, volume or coal seam".* Representative samples are taken from at least 3 boreholes in each domain, Samples must be taken to a depth at least 20 metres below the planned pit floor. An unbiased model is developed to estimate the gas in place. If mining is to extend into further seams not modelled, new modelling is required. The emissions in a year are based on the exact areas mined in a year, together with an assumed proportion of the gas below the pit floor. (CER 2023 pp 51-54)

Method 3 is the same as Method 2, except for additional requirements to use an appropriate standard for gas sampling. Methods 2 and 3 were introduced in 2009 (Saghafi 2013).

1.3 Development of Method 1 for open cut coal mines

"In the early 1990s, a method of estimating fugitive gas emissions from open cut coal mines based on direct measurement of gas plumes emitted from 17 open cut mines in the Sydney and Bowen Basis 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 (one or a group of coal mines). Subsequently, an average emission factor of 0.017 t of CO2 equivalent per tonne of raw coal was established for the open cuts of the Bowen Basin … and 0.045 t of CO2 equivalent for the Hunter Coalfield." (Saghafi 2013)

Table 1 shows the gradual increases in Method 1 state emission factors since 1993.

Table 1 : Development of Method 1 emission factors

State	Emission factors				
	1993	1/07/2017	1/07/2020	1/07/2022	1/07/2023
New South Wales	0.045	0.054	0.061	0.061	0.061
Victoria		0.00027	0.0003	0.0003	0.0003
Queensland	0.017	0.020	0.023	0.023	0.031
Western Australia		0.020	0.023	0.023	0.023
South Australia		0.00027	0.0003	0.0003	0.0003
Tasmania		0.017	0.019	0.019	0.019

The increase from 0.023 to 0,031 at 1 July 2023 for Queensland is discussed in DCCEEW's 2023 consultation paper on proposed amendments to the NGER Scheme. It was based on about 1100 drill samples from the Queensland Government's Petroleum Exploration Dataset, selected so as to exclude samples from outside active coal mine fields,

2. Evidence of under-reporting by Australian open cut coal mines

2.1 Recommendations by Climate Change Authority

In its 2023 review of the NGER legislation, the Climate Change Authority recommended phasing out Method 1, and reviewing Method 2, as matters of urgency (see 4.2). In support of these recommendations, CCA said

"*Over the past five years developments in satellite technologies and inverse modelling … have resulted in new sources of data to estimate facility level emissions.*" (p55)

"Remote sensing technologies … are being deployed by researchers around the world to quantify facility-level emissions from the top-down. Some studies using these technologies have concluded that some methane emissions may have been underestimated at some Australian facilities using traditional bottom-up approaches for estimating fugitive methane emissions." (p70)

On pages 72 and 73, the CCA quoted two different satellite observations for the one open cut mine: 5.8 ± 1.3 and 1.1 ± 0.5 Mtonnes of CO2 equivalent. Reported annual emissions were 0.5 Mtonnes. The large difference between the two satellite observations suggests that wide margins of error can occur. For another open cut mine, the satellite observation was 0.8 ± 0.4, compared with the reported value of 0.2.

CCA also quoted observations for three different open cut/underground combinations, and for one underground mine, all showing reported emissions falling within the range of the satellite observations.

2.2 Reported emission intensities for open cut and underground coal mining

We have a separate reason for concern about the adequacy of reported emissions for open cut coal mines. We think that underground and open cut coal mines are often located close together, extracting coal from the same coal seams. If so, their emission intensities should be roughly similar. Figure 2 of DCCEEW's consultation paper for the 2023 proposed NGER reforms suggests that methane content varies linearly with depth. No systematic data are available about coal mine depths. Assuming underground mines are twice as deep as open

pits suggests that emission intensities of open pit mines should be 50% of those of underground mines. But Table 2 shows that open pit emission intensities have averaged about 10% of underground intensities. This suggests gross under-reporting by some open pit mines.

Underground coal mines can reduce their reported methane emissions by flaring or use as energy, but we understand no flaring or use of methane is done by Australian open cut coal mines. All other factors being equal, this should give lower emission intensities for underground mines.

The Climate Change Authority's 2023 review of the NGER legislation said

"Fugitive emissions are defined by IPCC as the intentional or unintentional release of greenhouse gases that occur during the extraction, processing and delivery of fossil fuels to the point of final use". (p66)

Reported emissions include the CO2 equivalents of all greenhouse gases, not just methane. From Figure 4,4 of the review, methane emissions reported by underground mines are about 85% of total reports, while methane reports by open cut mines are about 95% of total.

Table 2 : Emission intensities for open cut and underground coal mines

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-ground
2001	6.44	23.08	229	92	0.0281	0.2508	0.112
2002	7.00	22.09	253	92	0.0277	0.2401	0.115
2003	7.28	21.25	268	82	0.0271	0.2591	0.105
2004	7.30	21.24	280	83	0.0261	0.2559	0.102
2005	7.77	22.23	306	87	0.0254	0.2555	0.099
2006	8.15	23.46	314	97	0.0260	0.2419	0.107
2007	8.13	25.22	323	94	0.0252	0.2683	0.094
2008	7.72	26.50	318	103	0.0243	0.2573	0.094
2009	7.50	25.98	341	105	0.0220	0.2474	0.089
2010	7.86	24.82	361	115	0.0218	0.2158	0.101
2011	7.49	24.34	351	108	0.0213	0.2254	0.095
2012	7.29	24.26	387	96	0.0188	0.2527	0.075
2013	7.93	23.73	420	114	0.0189	0.2082	0.091
2014	8.38	22.33	439	123	0.0191	0.1815	0.105
2015	8.63	22.55	443	124	0.0195	0.1819	0.107
2016	8.88	23.75	446	122	0.0199	0.1947	0.102
2017	8.96	23.03	453	114	0.0198	0.2020	0.098
2018	9.14	22.67	466	109	0.0196	0.2079	0.094
2019	9.59	21.23	496	94	0.0193	0.2258	0.086
2020	9.62	20.42	480	96	0.0201	0.2123	0.094
2021	9.37	19.89	446	88	0.0210	0.2267	0.093
2022	9.24	17.53	448	88	0.0206	0.1991	0.104
2023	8.99	16.28	431	84	0.0209	0.1938	0.108
Average 00-01 to 22-23					0.0223	0.2263	0.099
22-23 as a % of 00-01					74%	77%	96%

Fugitive emissions in Table 2 are from figure 26 of DCCEEW's "Australia's emissions projections 2023", and are for black and brown coal. The chart book calendar year values were interpolated to get values for years to 30 June. We understand from DCCEEW that fugitive emissions from brown coal are of the order of 0.01 to 0.02 Mtonnes of CO2e~ a year. Production tonnages are for black coal only, and are taken from DISR's "Resources and energy quarterly September 2023: historical data", and similar earlier publications. Emission intensities were estimated by dividing emissions by production.

2.3 Our 2023 conclusions about coal mine emission measurements

In a 28 June 2023 submission to the Climate Change Authority, Australian Projections concluded 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.

These conclusions were based on 22 years of open cut and underground coal mine emission intensity data, and on limited satellite observations.

2.4 Problems created by inadequate emission reporting methods

The Minister's request to the Authority (see 4.1) referred to the increased importance the reforms to the Safeguard Mechanism place on the accuracy of emission reports. Offsets required from facilities under this mechanism depend on their emission intensity relative to other facilities in the same industry. Inadequate reporting methods for open cut coal mines are resulting in excessive offset requirements for underground coal mines, while many open cut mines will unfairly receive Safeguard Mechanism Credits.

Inadequate reporting methods may also be causing international problems for Australia. Based on increasing evidence from satellite measurements, bodies such as the International Energy Agency are commenting on the under-reporting of our fossil fuel emissions:

"The IEA estimates that methane emissions from coal mining in Australia are about 81% higher than the national inventory data. For the oil and gas sector, IEA's estimates are 92% higher than the national inventory data." (Institute for Energy Economics and Financial Analysis, June 2023)

This may affect our ability to negotiate free trade treaties, or avoid penalties under evolving cross border mechanisms.

3. IMEO-funded flights over coal mines

3.1 IMEO flights over coal mines in Poland, Australia and India

The IMEO 2023 Report, dated 1 December 2023, lists four UN-funded studies

- study 20 by the AGH University of Science and Technology Poland, German Aerospace Centre DLR, Technical University of Munich and Swiss Federal Laboratories for Materials Science and Technology, to design, measure and

reconcile top-down and bottom-up estimates of methane emissions from Polish coal mines, with measurements from June 2022 to October 2023

- study 21 by Airborne Research Australia, an Australian Bowen Basin pilot campaign, with initial measurements in 2022, and a second phase of measurements in September 2023
- study 22 by the Indian Institute of Technology Bombay, of greenhouse gas emissions from abandoned coal mines
- study 23 by Bremen University, using airborne in situ and remote sensing to determine methane emissions from Bowen Basin coal mines.

Studies 21 and 23 have been combined, with a peer-reviewed paper expected late in 2024 or early in 2025.

3.2 Complex instrumentation and flight paths in Bowen Basin flights

Information on the Bowen Basin flights in 2023 was provided by Professor Jorg Hacker, chief scientist at Airborne Research Australia:

"*Between 5 Sep and 10 Oct we spent five weeks in the Bowen Basin with two identical aircraft carrying different scientific instruments and flying at very different altitudes. One aircraft (we called it "In-Situ aircraft") carried a 1ppb-sensitivity gas analyser measuring CH4, CO2 and H2O combined with meteorological instrumentation measuring for instance wind and turbulence at high resolution. These measurements were made every few metres between 150m and 3000m above the ground. The other aircraft (the "Remote Sensing aircraft") carried a sensor owned by Bremen University that images methane concentrations below the aircraft (like satellites do). This aircraft flew at typically 3500 to 4000m, covering similar locations (ie. mines) as the In-Situ aircraft.*

The two aircraft are motorgliders that had been heavily modified for this type of measurements… The aircraft flew at speeds between about 150 and 180km/h.

The well-known strategy for making such in-situ measurements is to fly vertical "curtains" or "walls" perpendicular to the prevailing wind consisting of individual traverses spaced between 50 and 300m in the vertical, from close to the ground to as high as the plume is visible in the real-time display in the cockpit of the aircraft. The observations from these curtains are then vertically and horizontally integrated to yield the emission flux, provided it was possible to cover the whole extent (horizontal and vertical) of the plume." (email 21 February 2024)

"To my knowledge, the combined use of simultaneous in-situ and remote sensing airborne instrumentation has not been used before for measuring methane emissions." (13 March 2024)

3.3 Evolution of airborne measurement methods

The use of twin planes with different instrumentation and flight paths appears to have evolved from some previous studies. For example, Krautwurst et al (2021) describes flights at about 3000m above ground level with a passive remote sensing MAMAP spectrometer, and with wind field observations by three stationary wind lidars. Conley et al (2017) describes consecutive loops flown around a targeted source region at various altitudes, using only horizontal wind and trace gas concentrations. The 2023 Bowen Basin flights

appear to be a combination of these two approaches, replacing the wind lidar data with high resolution "in situ" recordings.

The IMEO 2023 report said

“The pilot project in Australia demonstrated the capability to collect airborne data at the mine level and finer resolution” (p23)

3.4 IMEO publication policy

IMEO's 2022 report said (p25)

"Results are published in peer-reviewed journals. All measurement emission data are made public (specific locations/owners may be masked to protect business interests in limited situations)."

Peer-review adds enormous value, even if it sometimes takes longer than initially hoped. Publicly available data should allow independent verification of calculations, and may also make possible follow-up investigations into related subjects.

We understand that insights from the preliminary data from the IMEO coal studies will be shared at a European Union of Geophysical Scientists conference in Vienna on 17 April 2024. The session is titled "Quantification of anthropogenic methane sources through atmospheric measurement studies: Finding targets for mitigation worldwide". No estimates for individual Bowen Basin mines based on IMEO flights will be available until the peer-reviewed paper is published.

3.5 IMEO topographic and spectrometer images

The 2022 and 2023 Bowen Basin flights obtained topographic camera mages of open pit mines at a 0.5m resolution. The 2023 flights carried a MAMAP imaging spectrometer capable of identifying locations within the pit where emissions were originating from. We understand these topographic and spectrometer images will be available when the peer-reviewed paper is published.

4. Recommendations by the Climate Change Authority

4.1 Request by the Minister for Climate Change and Energy

The Climate Change Authority’s “2023 review of the national greenhouse and energy reporting legislation” said

“With the general concern about the accuracy of reported fugitive emissions growing, the Minister … wrote to the Chair of the Climate Change Authority in relation to the authority’s review of the NGER legislation in 2023… the Minister drew attention to the recent reforms to the Safeguard Mechanism, and the increased importance these changes place on the accuracy of emissions reported under the NGER scheme.” (p65)

4.2 Recommendations by the Climate Change Authority

The Authority made eight recommendations intended to Increase the accuracy of reported fugitive methane emissions (p9), including

- *15. Phase out Method 1 estimation methodologies for fugitive methane emissions, including as a matter of urgency for open cut coal mining…*
- *17. As a matter of urgency, review Method 2 for extraction of coal in open cut coal mining with respect to sampling requirements and standards…*
- *19. Commission a panel of Australian and international experts to establish a best practice process to document the standards and requirements for making transparent, repeatable and credible top-down measurements of fugitive methane emissions. The panel should be commissioned in the first quarter of 2024, and guidelines for top-down verification measurements published as soon as possible.*

4.3 Consultation by DCCEEW on measurement methods

On 28 February 2024 we were advised by the Climate Change Authority that

"The Minister for Climate Change and Energy has asked the Department of Climate Change, Energy, the Environment and Water to consider which of the CCA's recommendations can be practicably implemented by the end of 2023-24 with a focus on methane emissions, including as part of the annual NGER Scheme update cycle due in June 2024. To inform this consideration the department will continue detailed technical research and analysis and undertake stakeholder consultation as early as possible in 2024"

5. Recommendations for consideration by DCCEEW

This submission makes the following recommendations about changes for open cut mines, and associated research.

5.1 Method 1 should be abandoned for emissions from 30 June 2024

The statutory emission factors used in method 1 are of no value under the Safeguard Mechanism, which rewards or punishes facilities depending on their performance relative to an industry benchmark. The availability of Method 1 as an option for high-emitting mines results in Australia's UNFCCC reports being too low.

5.2 Methods 2 and 3 should be urgently reviewed, taking into account the IMEO results

Methods 2 and 3 contain many subjective elements, and do not appear to have ever been checked against direct emission measurements. The IMEO flight results may show that some mines using these methods have reasonably reported their emissions, while other mines have grossly under-reported. The reasons for the differences should be urgently investigated, as they may be arising from deficiencies in the methods, or in their application.

Some version of Methods 2 and 3 will continue to be needed until a Method 4 has been established.

5.3 A Method 4, using direct measurements, should be urgently developed

A new Method 4 should be introduced for open cut mines, using daily measurements of mine emissions.. This would be equivalent to the present Method 4 for underground coal mines, which is based on direct measurements, and is the only method allowed.

The "Breaking new ground" study of ground-based measurements for Polish underground coal mines (Field et al 2024) may help suggest direct measurement techniques. Results from this study may be available by the middle of 2024. We will be making suggestions about direct measurement techniques in a second submission.

5.4 Coal mines should be required to make direct daily measurements of emissions

Operations such as blasting can produce short-term emission peaks, followed by longer-term emission increases. Daily measurements at about midday should be broadly comparable with measurements obtained by flights or satellites on sunny days, allowing independent checks.

5.5 Coal mines should be required to report emissions quarterly

Emissions should be reported quarterly, allowing quicker corrective action to be taken if needed to meet Australia's legislated climate targets. Quarterly reports from each mine should be publicly available. Safeguard facility in other industries with varying emission levels should also be required to report quarterly.

5.6 Flights or satellites should be used to check mine reports

MethaneSAT, launched on 4 March 2024, may prove to have sufficient resolution to check methane emissions from some of the open pit coal mines, provided they are not located close to other large methane sources (Wikipedia 2024). MethaneSAT data are free. Flights similar to those over the Bowen Basin in 2023 may be needed to measure emissions from smaller mines, and those located close to other sources. Flights should be funded by the Australian government, which might then choose to levy individual mines.

5.7 Research is needed on temporal emission variations

Emissions from open cut coal mines may vary with the time of day, atmospheric temperatures and rain. Emission measurements made by flights or satellites in sunny conditions may thus overstate average emissions. Ground-based measurements made each hour for a year, in a few representative pits, might be needed to establish correction factors for weather conditions. Models of gas flows within and near pits might help reduce the numbers of observations needed to establish correction factors.

5.8 The Clean Energy Regulator should have the right to adjust emission reports

If IMEO flight results differ substantially from Method 2 reports for some mines, this will cause reporting difficulties until a Method 4 can be established. The Clean Energy Regulator should have the right, for Safeguard and UNFCCC purposes, to adjust emission reports taking into account flight or satellite observations.

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Abbreviations

CCA	Climate Change Authority
CER	Clean Energy Regulator
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DISR	Department of Industry, Science and Resources
IEA	International Energy Agency
IMEO	International Methane Emissions Observatory
IPCC	Intergovernmental Panel on Climate Change
NGER	National Greenhouse and Energy Reporting
UNFCCC	United Nations Framework Convention on Climate Change

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