Tackling Australia's Coal Mine Methane Problem

An in-depth briefing on the scale of methane emissions from Australia's coal mines and potential actions to reduce leaks and mitigate their impact on the climate.

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Written by
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About

Ember has conducted an in-depth analysis to equip policymakers and campaigners to understand the scale of methane emissions from Australia's coal mines.

The report provides an overview of the policy levers and practices which could lead to a reduction in coal mine methane, and makes recommendations targeted at improving the measurement, reporting, mitigation and, ultimately, avoidance of coal mine methane emissions. Particular focus is given to Queensland and New South Wales - Australia's two largest coal mining states.

We assessed data from the Australian Greenhouse Emissions Information System, Clean Energy Regulator, Australian Chief Economist, Department of Natural Resources and Mines, International Energy Agency and Global Energy Monitor.

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Executive Summary

Methane leaking from coal mines will blow Australia's already weak 2030 climate targets

Australia's coal mines have a methane problem. In 2019, they released 68% of Australia's methane emissions from the energy industry overall, making coal mines a larger contributor than both oil and gas. What's more, new evidence suggests emissions are underreported and are actually significantly higher than this.

Methane leaking from coal mines has been ignored for many years, but tackling it is the 'low hanging fruit' in Australia's effort to combat climate change. Methane is a potent and fast-acting greenhouse gas, which is 82.5 times more powerful than carbon dioxide over 20 years, making the task of reducing methane levels even more important in the near-term.

Reducing coal use, and legislating the end of new coal, are crucial to this goal. To tackle leaks immediately, existing technology must be used to directly measure methane emissions as well as capture and/or utilise the methane leaking from active and closed coal mines. It is up to the Australian government to legislate a robust plan to rapidly reduce leaks in the short term and jump-start a just transition to phase out coal.

01 Australia's CMM causes more global heating than all of Australia's cars

In 2019, coal companies reported via the Australian Greenhouse Emissions Information System (AGEIS) that their mines leaked 898,000 tonnes of methane into the atmosphere, representing 5% of Australia's total GHG emissions. Methane's short-term climate impact is 82.5 times that of carbon dioxide, making the methane released by coal mines equivalent to 74.3 million tonnes of CO_2. This is greater than the 44 million tonnes of car CO_2 emissions reported in AGEIS for 2019.

02 Coal Mine Methane emissions twice as high as official estimates

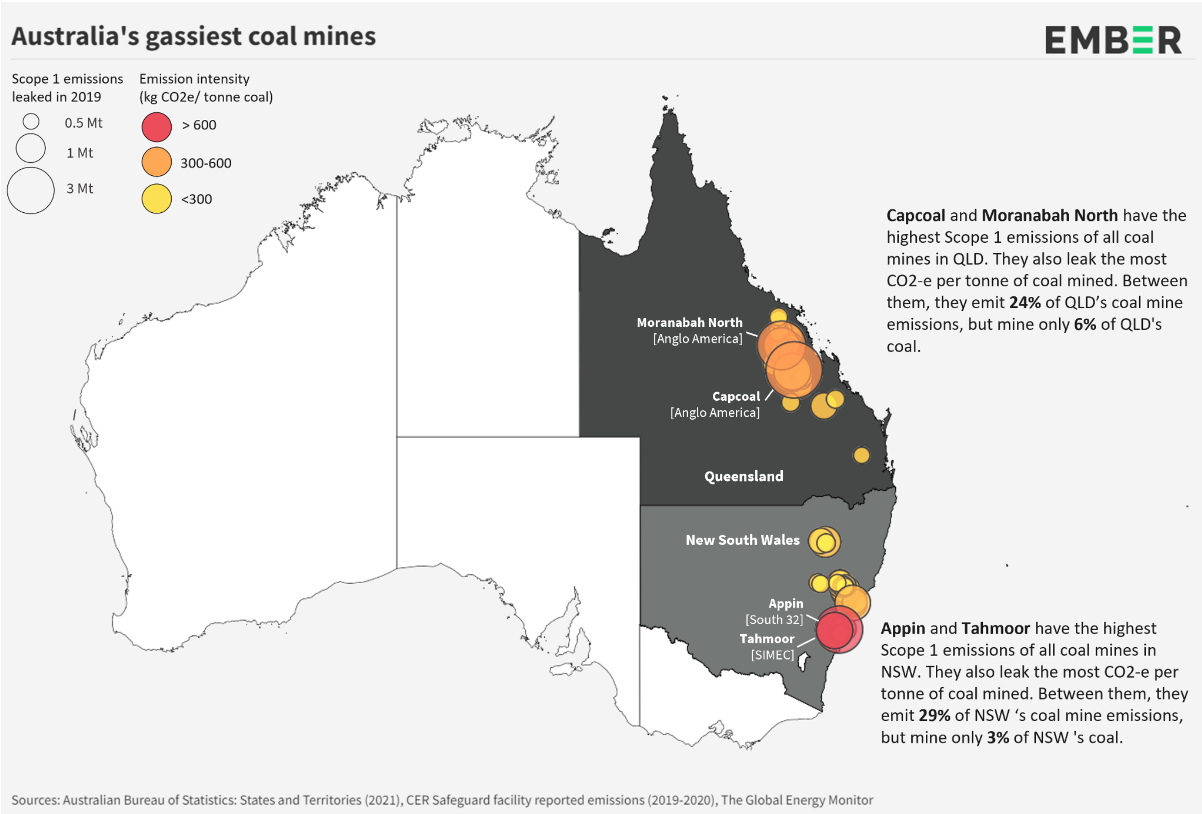
The IEA estimated that Australian coal mines emitted 1.8 million tonnes of methane in 2021, double the officially reported figures. Independent satellite measurements have also uncovered underreporting of methane emissions from Australian coal mines. Open-pit mines show the greatest disparity between reported and measured emissions. Emission factor based reporting must be replaced with direct, source and site level methane measurements if Australia aims to seriously address its CMM emissions.

03 The worst performing coal emits over 10 times more than the least emitting.

In Queensland, the two gassiest mines emitted 24% of reported scope 1 emissions from coal mines, while in New South Wales the two gassiest mines emitted 29%. Not all coal is equally gassy - the gassiest 25% of coal emits 68% of coal mine emissions whereas the best performing coal only emits 4%. To realise the most impactful emission reductions, efforts should first be concentrated on the gassiest coal mines.

04 Emissions likely to rise not fall

Australia is the world’s 6th largest coal mine methane emitter and on track to become the 3rd worst. Existing methane leaks aren't being plugged with any urgency. Mines are not voluntarily stepping up to implement methane abatement technology. What's more, new coal mines are likely to result in further increases in methane leaks, and 45% of these are thermal-only mines. Queensland's proposed mines will double the state's current emissions. In NSW, two recently approved mine extensions could emit a further 112 Mt CO_2-e in their lifetime.


Australia's gassiest coal mines
EMBER
Scope 1 emissions leaked in 2019
0.5 Mt
1 Mt
3 Mt
Emission intensity (kg CO2e/ tonne coal)
> 600
300-600
<300
Moranabah North [Anglo America]
Capcoal [Anglo America]
Queensland
New South Wales
Appin [South 32]
Tahmoor [SIMEC]
Capcoal and **Moranabah North** have the highest Scope 1 emissions of all coal mines in QLD. They also leak the most CO2-e per tonne of coal mined. Between them, they emit **24%** of QLD's coal mine emissions, but mine only **6%** of QLD's coal.
Appin and **Tahmoor** have the highest Scope 1 emissions of all coal mines in NSW. They also leak the most CO2-e per tonne of coal mined. Between them, they emit **29%** of NSW 's coal mine emissions, but mine only **3%** of NSW 's coal.
Sources: Australian Bureau of Statistics: States and Territories (2021), CER Safeguard facility reported emissions (2019-2020), The Global Energy Monitor

Introduction

Understanding the problem of coal mine methane

Climate change is already transforming life across Australia. Communities in the country's south-east are battling unprecedented floods across many of the same areas that were burnt out only two years ago. The IPCC report released in March 2022 highlighted that Australia is set to suffer greater climate impacts than any other advanced economy, including a significant increase in deaths and damage due to heatwaves, fires, and sea level rise.

One of the most potent greenhouse gases causing our climate to change is methane (CH_4), and one of the largest sources of global methane emissions is coal mining. In Australia, a major producer, exporter and user of coal, coal mine methane forms a significant proportion of national greenhouse gas emissions and poses a huge challenge to achieving the country's emission reduction targets.

Global resolve to tackle methane

Methane (CH_4) is the second biggest contributor to human caused climate change after Carbon Dioxide (CO_2). According to the IPCC, methane emissions have already led a 0.5 degree rise in average global temperatures since 1900.

When measured over a 20 year horizon, fossil methane has a global warming potential (GWP) 82.5 times more than CO_2 with an atmospheric lifetime of just 12 years, compared to centuries for CO_2. This makes rapidly reducing methane a prime target to slow down climate change in order to stand a chance of limiting temperature rises to 1.5 degrees. Methane mitigation was highlighted by the IPCC as a vital step for short and long term gains on regulating surface temperature.

Globally, political focus on reducing methane emissions has grown significantly in recent years. At the COP 26 climate talks in November 2021, the United States and the European Union led the launch of the Global Methane Pledge, a commitment by over 100 countries to reduce anthropogenic methane emissions by 30% on 2020 levels by the end of the decade. Although it was shunned by Australia, the country will be impacted by the global momentum to reduce methane emissions.

One specific example of Australia's coal industry needing to tackle its methane emissions arises from the European Union's carbon border adjustment mechanism (CBAM). This regulation, which is currently going through the European Parliament, seeks to prevent polluting activities being outsourced to countries with weaker climate regulations. CBAM works by EU importers buying certificates corresponding to the carbon price that would have been paid had the goods been produced under the EU's own rules. Methane emissions are expected to fall under the CBAM radar. In the context of Europe banning Russian coal imports due to the war in Ukraine, this will have direct consequences for Australian coal exporters.

Methane leaks are now visible from space, and polluters are being held to account. Several new satellite programmes are under development to further improve our understanding of the scale and location of anthropogenic methane emissions, including the MethaneSAT initiative led by the Environmental Defence Fund.

In December 2021, the European Commission proposed legislation targeting methane emissions, including coal mine methane. The legislation has important consequences for countries such as Poland (mining most of the EU's methane intensive coal), and Germany, the Czech Republic and Romania which have abandoned coal mines. An overview of the proposed legislation is provided in this video. Following the China-US joint declaration on confronting climate change in 2021, China has announced a methane action plan, aimed at cutting methane emissions in major industries, including coal mining.

What is coal mine methane?

‘Coal mine methane’ is an umbrella term referring to methane released from coal seams as a result of mining activities. Global estimates of coal mine methane indicate that it is a major contributor to climate change, and to the national emissions of coal-producing countries.

The International Energy Agency’s annual Global Methane Tracker included coal mine methane emissions for the first time in 2022, finding that coal mines produce more methane than both the oil and gas sectors. In its flagship report Net Zero by 2050, the International Energy Agency’s (IEA) optimal decarbonisation pathway included a reduction in coal mine methane emissions of 75% by 2030.

Sources of methane from coal mining

While greenhouse gas emissions are often associated with coal in terms of emissions during the burning of coal to produce electricity, the mining and processing of coal is also highly polluting. The process of organic decomposition and compression that led to the creation of coal seams also produced methane which remains trapped and embedded throughout coal seams. During mining, this methane escapes from the coal seams and is released to the atmosphere in several ways, before, during and after coal mining operations.

In surface or ‘open pit’ coal mines, methane is released as coal seams are broken up and coal extracted for processing. In underground mines, methane is drained from target coal seams prior to mining operations because the gas is highly explosive and poses a significant safety risk. Then, as a seam is progressively mined, the mine’s ventilation system constantly monitors the level of methane, pumping fresh air to ensure that methane levels remain below the explosion risk threshold. The methane that is extracted in this way is called ‘Ventilation Air Methane’ or ‘VAM’, and is usually vented (released directly) to the atmosphere. However, VAM can be captured and used. Methane emissions continue for decades after mining stops, as the gas gradually permeates from the underground formations and escapes through disused mine shafts to the surface.

In Australia, methane emissions account for roughly 80% of Scope 1 emissions for underground mines and 60% for open pit coal mines. [Scope 1 emissions are all Direct Emissions from the activities of an organisation or under their control]. The major sources of methane which occur throughout the lifetime of a coal mine are depicted in Figure 1. Throughout this report we refer to all these sources as coal mine methane (CMM).

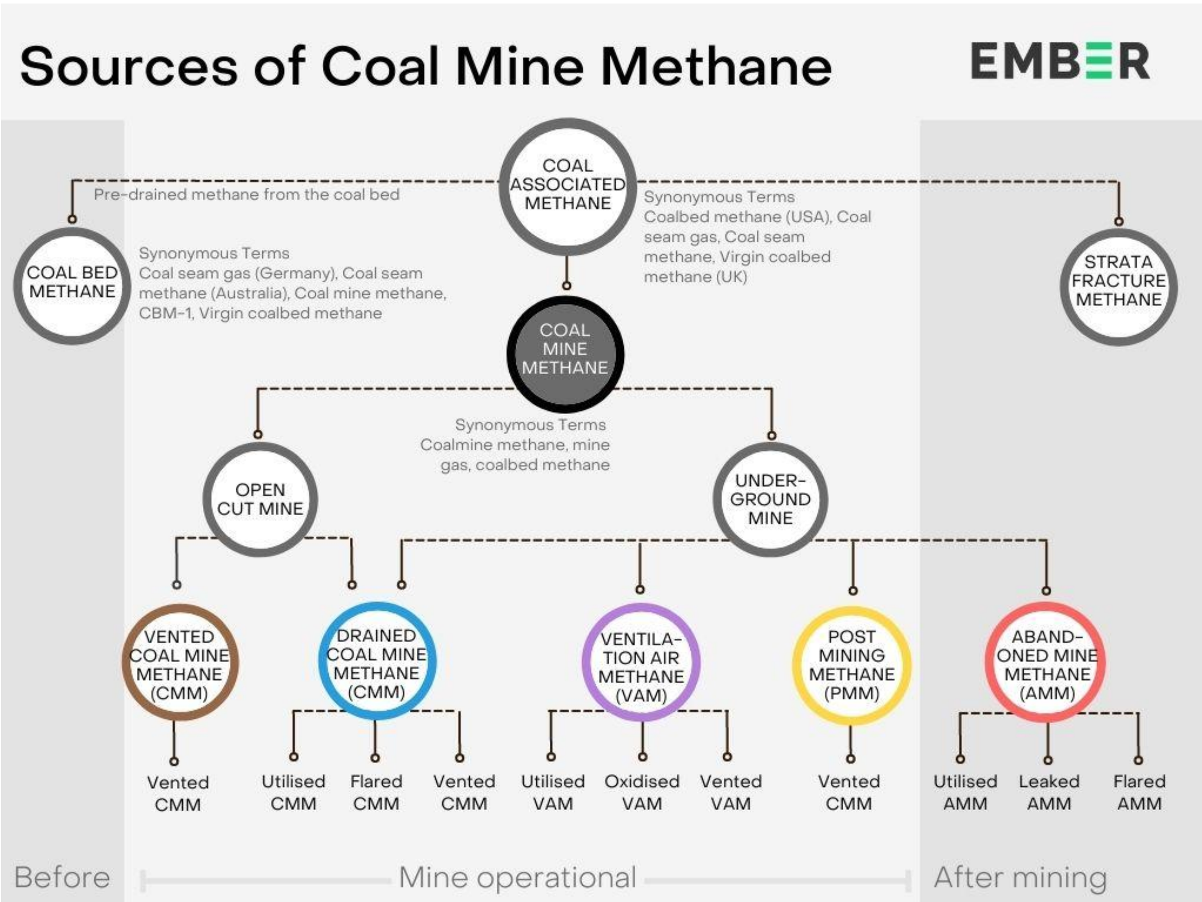


Figure 1: Sources of coal mine methane

Global estimate of coal mine methane emissions

Coal is the largest energy sector emitter of methane, ahead of both oil and gas according to the IEA Methane Tracker 2022. The IEA estimates that 43.6 million tonnes (Mt) of methane leaked from global operational coal mines in 2021. Using methane's 20-year GWP, this means that active coal mines emitted 3,597 Mt of CO_2 equivalent greenhouse gases that year. This is more than the 2020 emissions of India and Japan combined.

According to the IEA, the six largest national emitters account for almost 90% of estimated global CMM emissions. China is the largest polluter, corresponding to the massive amounts of coal it produces, and Russia is in second place due to its deeper, more methane-intensive coal mines. Australia is ranked sixth, narrowly following India and the US.

There is an enormous amount of uncertainty around CMM volumes globally, with the possibility that methane emissions are about 70% higher than reported in official data. Many current estimates are based on desk research extrapolating from tonnages of coal mined. In reality, different coal seams can have methane levels differing by many multiples, and there can be major differences even between neighbouring mines.

Surface coal mines had previously been assumed to release relatively little methane. However, new research from Global Energy Monitor and satellite data indicate that surface mines can be major emitters (for example the Manglai mine in China). This is highly relevant in the Australian context, with several satellite-based studies highlighting surface coal mines in Queensland as a potentially underestimated source of methane emissions (see our section on the Bowen Basin below).

Australia's current approach

Coal mine methane is a major part of Australia's greenhouse gas emissions and poses a huge challenge to achieving the country's emission reduction targets.

Australia's coal industry and economic context

In 2019, Australia mined around 500 million tonnes of coal, approximately 60% of which was used as thermal coal (for electricity generation) and 40% as metallurgical coal (for steel production). Approximately 90% of Australia's coal production occurs in Queensland and New South Wales, with the remaining capacity mined in Victoria, Western Australia and

Tasmania. In 2020, three coal companies controlled almost half of Australia's black coal production: Glencore with 74.3 million tonnes, BHP with 57.1 Mt, and Yancoal with 47.9 Mt. Coal supplied 51% of Australia's electricity in 2021, according to Commonwealth Government statistics, though it is worth noting that only the three eastern states (Queensland, New South Wales and Victoria) rely on coal for over 50% of energy needs. The other five states and territories use a combination of fossil gas and renewables.

In 2020, Australia exported 367 Mt of coal. Around 40% (150 Mt) of this was exported to Japan and South Korea, two countries that have joined the Global Methane Pledge and thereby committed to rapidly reducing methane emissions. Given that it is possible, as discussed later in this report, to produce lower methane-intensity coal, this could have consequences for the resilience of Australia's current trade relationships if competitor coal export countries are faster to adopt methane reduction measures.

Emissions measurement and regulation in Australia

The National Greenhouse and Energy Reporting (NGER) scheme provides the framework for monitoring and reporting greenhouse gas emissions across all sectors in the Australian economy. Under the legislation underpinning the scheme, the National Greenhouse and Energy Reporting Act 2007, facilities that emit greenhouse gases must, if their emissions or energy generation/consumption exceed certain thresholds, report their annual emissions to the Clean Energy Regulator (CER).

The NGER scheme sets out the reporting requirements and methods for emitters. Underground mines are required to directly measure the amount of methane produced, while surface mines are able to apply 'emissions factors' to estimate the amount of methane produced per tonne of raw coal produced.

The Clean Energy Regulator maintains the Australian Greenhouse Emissions Information System (AGEIS), which is the platform for official greenhouse gas figures in Australia. These figures, along with Government-led verification and measuring activities, form the basis of Australia's annual reporting under the Paris Agreement. The Australian Government emissions figures use methane's 100- year GWP (28), hiding its higher short term impact.

Importantly, coal mine methane emissions contribute towards mining companies' Scope 1 emissions and Australia's domestic emissions regardless of whether the coal is exported or not. This is in contrast to the CO_2 emissions from burning coal, which can be either Scope 2 or Scope 3 emissions for the mine operator and for Australia.

The measurement and mitigation of coal mine methane in Australia are severely lacking in both rigour and attention from policy-makers. Official estimates of Australia's coal mine methane emissions already indicate a massive problem for Australian and global efforts to combat climate change, but - alarmingly - there is mounting evidence that these estimates are inaccurate and that the problem could be even larger than reported figures show.

Australia's emission reduction targets

Australia has committed to net zero emissions by 2050, announced just ahead of the COP26 talks. Australia's Nationally Determined Contribution under the Paris Agreement is an emissions reduction of 26-28% on 2005 levels by 2030. According to analysis by the Climate Action Tracker initiative, if all countries followed a similarly underwhelming level of climate ambition as Australia, global climate change would exceed 4°C.

Australia did not sign the Global Methane Pledge and very few mechanisms to reduce coal mine methane are either required of, or have been voluntarily adopted by, the country's coal industry. There are readily available and effective ways to mitigate emissions of coal mine methane. Given methane's huge global warming potential over its 12-year atmospheric lifespan, pursuing these pathways would provide Australia with a critical 'quick win' in its effort to reduce emissions.

The challenge of comparing methane and carbon dioxide

Global Warming Potential (GWP) is a measure to express the effects of GHGs in CO_2 equivalent terms. Given that CH_4 absorbs much more energy when in the atmosphere, but has a shorter lifetime than CO_2, the IPCC considers its impact over 20 years (GWP = 82.5) and over 100 years (GWP = 29.8). One of the shortcomings of this metric is that it assumes a constant value of methane's effects over time, when in reality it varies significantly.

Historically, the 100-year value has been used by Governments and in major international agreements on the basis that global warming is a long term challenge.

At Ember, we propose to use the 20-year GWP. Climate change is an emergency, and the next 20 years are critical with regards to climate action. Methane's short atmospheric lifetime means emissions reductions can reduce global heating in the near term.

Throughout the report, we are often required to use the 100-year GWP in order to draw comparisons to Australia's official reporting on GHGs, and Scope 1 emissions. Whenever possible, we provide both the 20-year and 100-year GWP values.

"Not an either/or" Carbon dioxide and methane do not need to be compared using GWP as only concerted action against both greenhouse gases will address the current climate crisis

The Scale of Australia’s Coal Mine Methane

Australia’s CMM emissions are larger than official estimates

Coal mine methane is the largest contributor to Australia’s energy related methane emissions, but estimates derived from satellite data indicate that the scale of CMM emissions could be far greater. If Australia continues with proposed mines, coal production will be five times the level necessary for a 1.5 degree pathway.

Current estimates of coal mine methane

Government estimates

According to the AGEIS database, 898 thousand tonnes (Kt) of methane was emitted from Australia’s active and abandoned coal mines in 2019. Coal mine methane accounted for 68% of the 1.3 million tonnes of methane emitted by the energy sector that year, emitting almost three times the amount of methane from the oil and gas industry (329 Kt). Acknowledging methane's fast acting impact, that means Australia’s methane emissions in 2019 had a short term climate impact equivalent to 74.3 million tonnes of carbon dioxide, more than the AGEIS reported annual CO_2 emissions from car use across Australia (44 Mt in 2019), and equal to a 20% additional short term climate impact to all of Australia’s direct CO_2 emissions in 2019 (374 Mt).

AGEIS data shows that the majority (62%) of Australia’s reported CMM emissions are from active, underground coal mines. Surface mines produce 30% of CMM emissions, whilst the remaining methane leaks are from post mining activities and abandoned mines.

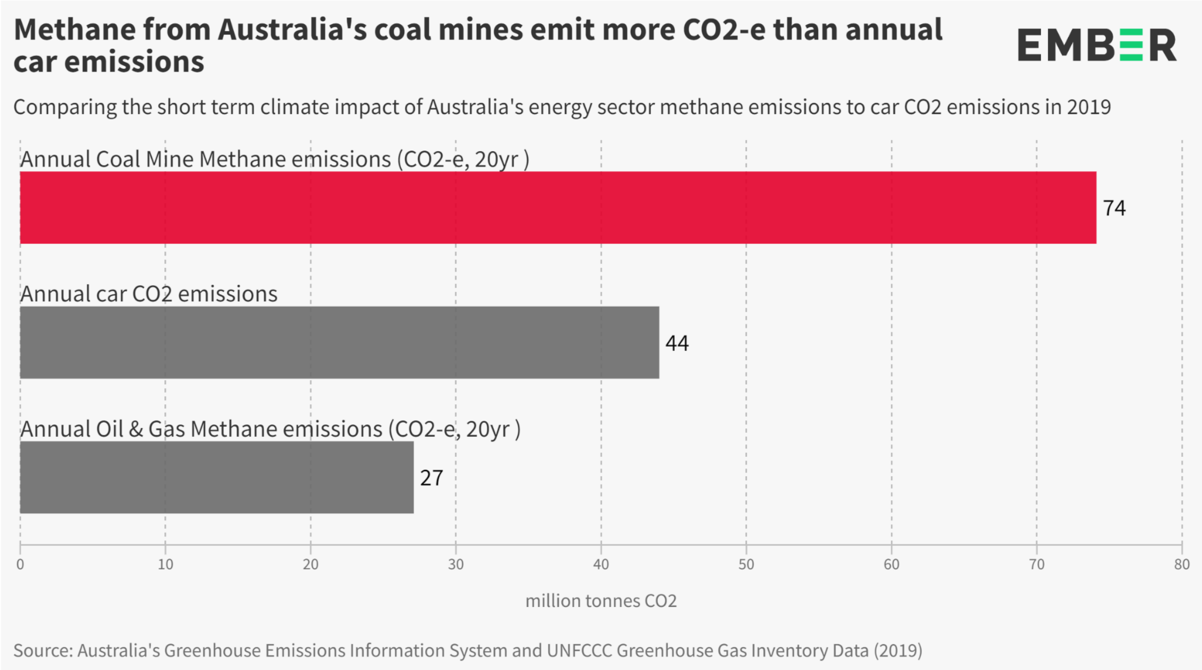


Figure 2: Australian coal mine methane emissions have a short term climate impact of 74 million tonnes of CO_2.

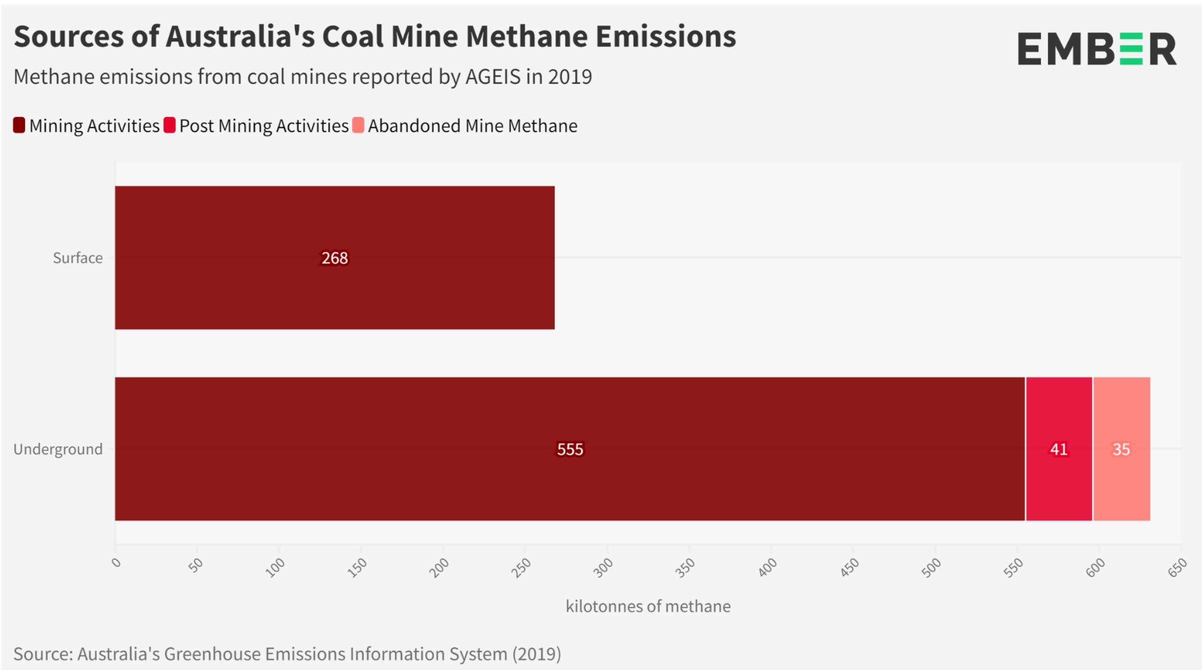


Figure 3: Sources of Australian CMM as reported to AGEIS (2019)

Uncertainty in national methane emission estimates

As noted earlier, Australia accounts for its surface and underground mines differently. For underground mines, it requires direct measurements at the mine level. Although equipment is often not calibrated to measure the absolute quantity of methane that gets released to the atmosphere, these estimates should be relatively accurate.

For surface mines however, even though methane represents the largest source of GHG emissions, Australia uses standardised emissions estimates linked to volumes of coal produced. These factors do not take into account the variation in gas content between different coal seams, which means the uncertainty associated with estimates is very high, anywhere between ±50%, or a factor of two higher. Indeed, researchers have shown the wide variation in the methane intensity of coal in Australia; measurements from 10 open cut coal mines in Queensland showed certain mines have emission factors ~50 times higher than others.

When operating in regions with low gas volumes (below $0.5m^3/t$), surface mines can use a "low gas zone" default emission factor to estimate emissions. The regulation states that due to difficulties in accurately measuring low gas volumes, the default emission factor, which assumes negligible methane content, is appropriate. Scientists have warned that this regulation needs to be urgently updated; not only does the technology exist to accurately measure in low gas zones, but the current method does not take into account methane content in low gas coals. Given the strong global warming impact of methane, coal mines within this category may still have significantly higher methane emissions than estimated using the default factor.

Considering that 80% of Australia's mines are surface mines, the differences can have a very large impact on the country's reported emissions, and, as discussed further below, satellite measurements of CMM plumes have started to uncover the scale of the problem.

The IEA recently increased their estimate of Australia's CMM emissions by 59%. This is after new evidence from satellites measuring methane emissions over the Bowen Basin. Their calculations suggest that Australia's CMM emissions were 1.8Mt in 2021, twice that reported by the Government. This would mean coal mines added 16% to Australia's direct CO_2 emissions in 2021(343Mt CO_2). Using methane's short term climate impact, this is equivalent to 149Mt of CO_2-e, equal to a 43% additional short-term climate impact on top of all of Australia's direct CO_2 emissions.

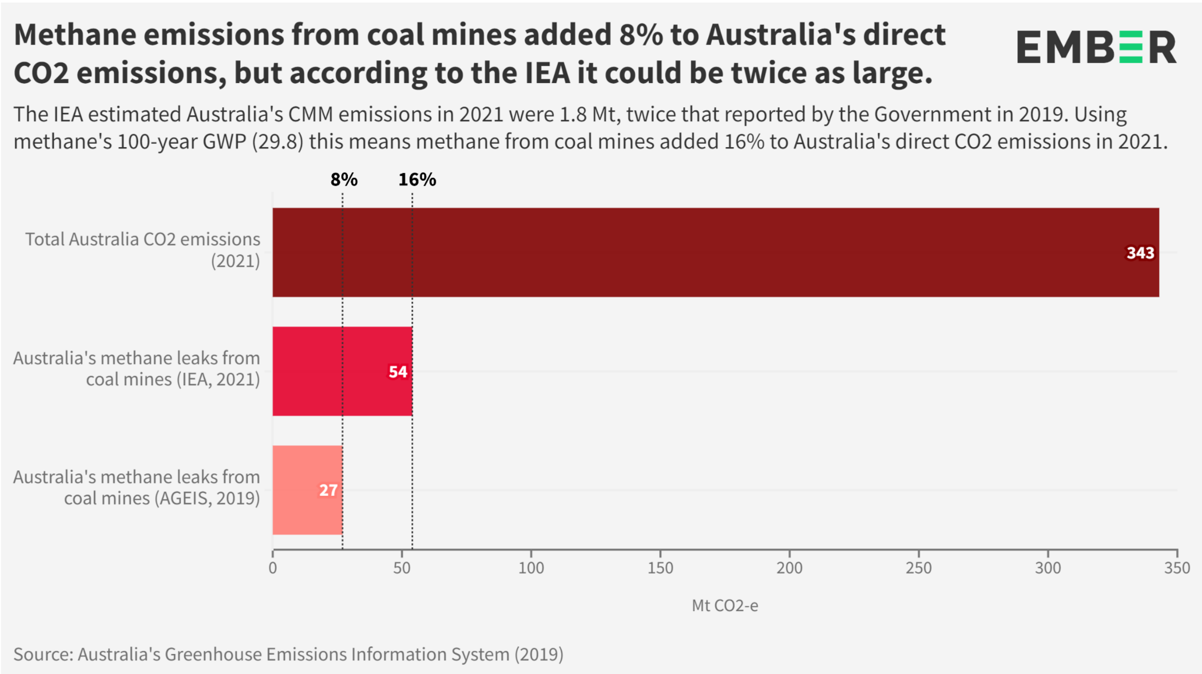


Figure 4: The IEA estimates Australia's coal mines emit twice the amount of methane they officially report, adding 16% on top of Australia's direct CO_2 emissions.

Australia's coal expansion plans

Australia is currently ranked third after China and Russia for the number of coal mines under development, highlighting the potential for domestic CMM emissions to rise even further. According to the Australian Chief Economist, Australia has committed to 28 Mt/yr of new coal capacity, and has another 455 Mt/yr of capacity planned (either publicly announced or in feasibility stages).

According to Australia's Department of Industry, Science, Energy and Resources, there are currently 69 proposals for new coal mines, or expansions to coal mines. Nine mines are classified to be in the "Commited stage", which means they have received necessary government approvals, financing and often have already started construction of pre-works.

The United Nations Environmental Programme's Production Gap report estimated that coal output needs to fall by 11% each year to 2030 in order to limit global warming to 1.5°C. It should be noted that the commercial viability of proposed coal projects is constantly shifting, and the projects may not reach final implementation. However, if Australia's proposed production capacity is realised, the country will by 2030 be producing more than five times the maximum production amount to achieve a 1.5° compliant pathway in 2030.

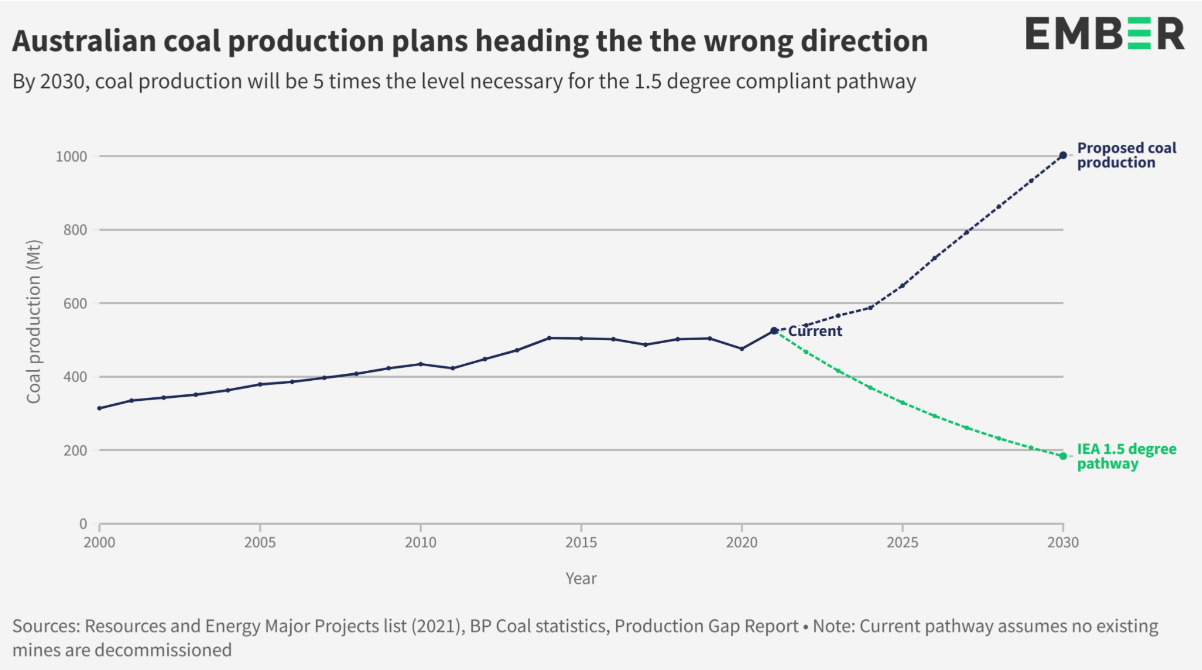


Figure 5: By 2030, Australian coal production will be 5 times larger than the amount needed to achieve a 1.5° compliant pathway in 2030

Coal Mine Methane in Queensland and NSW

Queensland and New South Wales dominate Australia's reported CMM emissions, producing 74 Mt CO_2-e in 2019 - over 3 times the annual CO_2-e emissions from Australia's commercial aviation industry.

Queensland reported coal mine methane emissions

Queensland hosts the highest number of operating coal mines of all Australian states and territories. These 54 mines account for over half (57.7%) of Australia's CMM emissions and represent 33% of the state's methane emissions. On average, 65% of Queensland's coal is metallurgical coal, the majority of which is produced from the state's 44 open pit mines. Queensland's coal industry reported 517,990 tonnes of methane emissions (15 Mt CO_2-e), accounting for over 9% of the state's total CO_2-e emissions. Using methane's short-term climate impact this is equivalent to 42 Mt CO_2-e, adding 38% to Queensland's direct CO_2 emissions in 2019.

In 2019, 34 coal mines within Queensland - or 63% of the state's mines - reported their emissions to the Clean Energy Regulator (CER). According to data released by the CER from the NGER scheme, eight of the ten gassiest mines in Queensland are metallurgical, underground mines, a number of which have been found to regularly breach greenhouse gas emissions limits.

Ember's mine-by-mine analysis found that in Queensland, two super emitters accounted for almost one third of all emissions reported to the CER in 2019. Capcoal and Moranabah North mines, both run by AngloAmerican, accounted for ~29% of CER reported coal mining emissions, even though they produce only 6% of Queensland's net coal output.

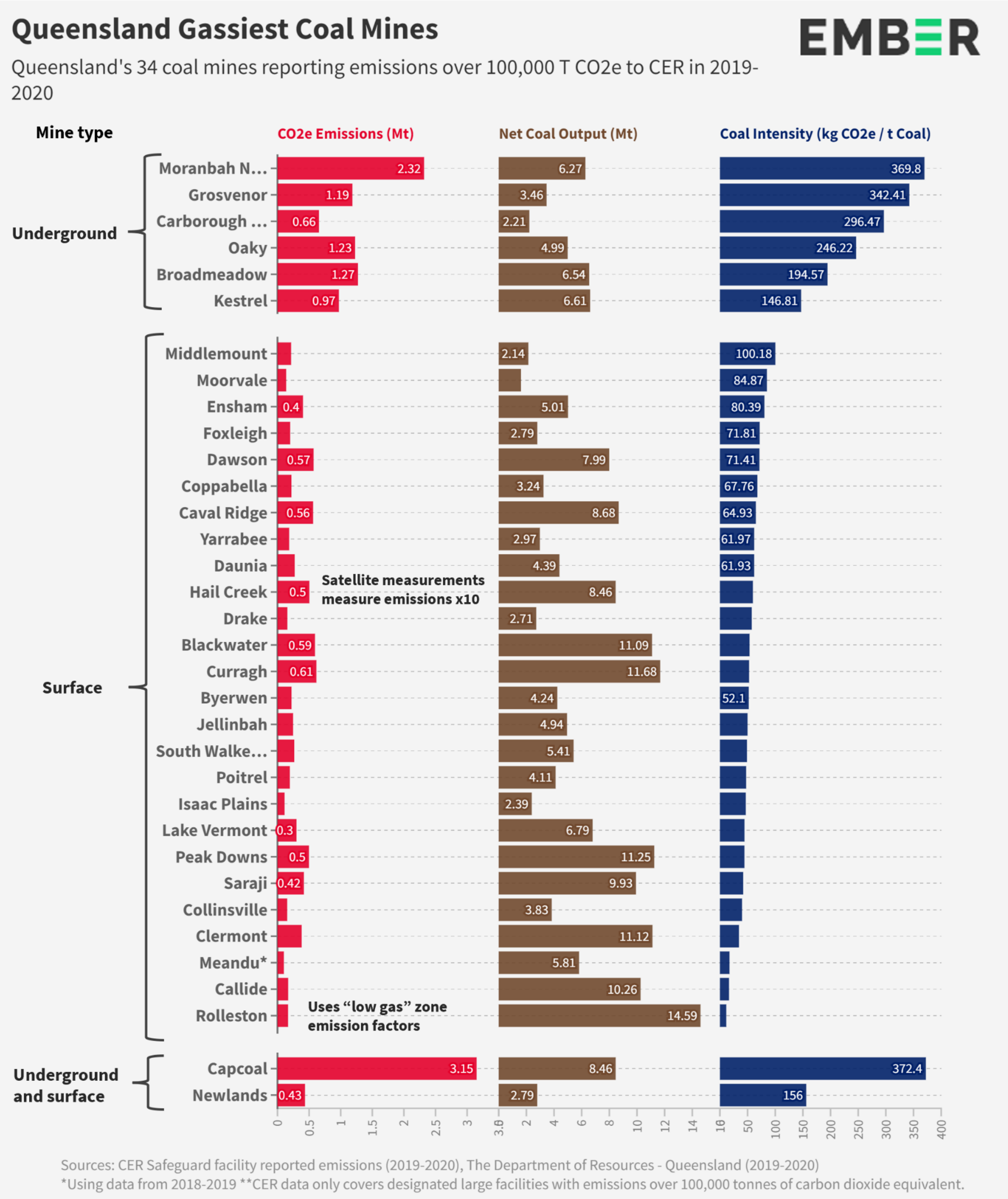


Figure 6: Queensland mines that reported emissions over 100 kT in 2019-2020, ordered by gassiness of coal.

New South Wales reported coal mine methane emissions

Methane leaking from NSW's coal mines accounts for 34% of the state's methane emissions (37,9,540 tonnes of methane) and contributes 42.3% of Australia's CMM emissions. This amounts to 11 Mt CO_2-e, representing 8% of NSW's annual CO_2-e emissions. When using methane's 20-year GWP, CMM emissions are equivalent to 31Mt CO_2-e, responsible for an additional climate impact of 32% on top of NSW's direct CO_2 emissions in 2019.

According to NSW Coal Services there are 39 operating mines, 22 of which are open cut surface mines and 17 underground. Approximately 85% of production in the state is thermal coal, making up two thirds of Australia's total thermal coal production.

In 2019, two thirds of all facilities reporting emissions to the CER in NSW were coal mines (28 mines or 72% of all coal mines in NSW). Nine of the 10 gassiest mines in NSW are underground mines for which methane reduction technologies are readily available.

In NSW, the two highest emitting mines, namely Appin and Tahmoor underground mines, were also the gassiest and emitted 24% of CER reported coal emissions whilst producing less than 3% of NSW's coal.

In 2021, one of the mines producing the gassiest coal in Australia - Tahmoor coal mine run by SIMEC Mining - received approval to extend the mine life by 10 years to 2032. Annual methane emissions are estimated to be 1.6 million tonnes of CO_2-e, increasing the state's already hefty annual coal mine methane emissions by 14%. Using the short term climate impact of methane, the mine will leak the equivalent of 62 million tonnes of CO_2 within the next 10 years.

The recently approved Narrabri Underground Stage 3 mine run by Whitehaven Coal is likely to become the highest methane-emitting thermal coal mine in Australia when Whitehaven Coal begins mining the gassiest part of the coal seam.

Narrabri Stage 3's environmental impact statement reports Scope 1 lifetime emissions of 31 Mt CO_2-e. This is equivalent to 6% of Australia's entire CO_2-e emissions in 2019 from just one coal mine, and this is all before considering that methane should actually be measured on a 20 year horizon, after which emissions would be closer to 50 Mt CO_2-e.

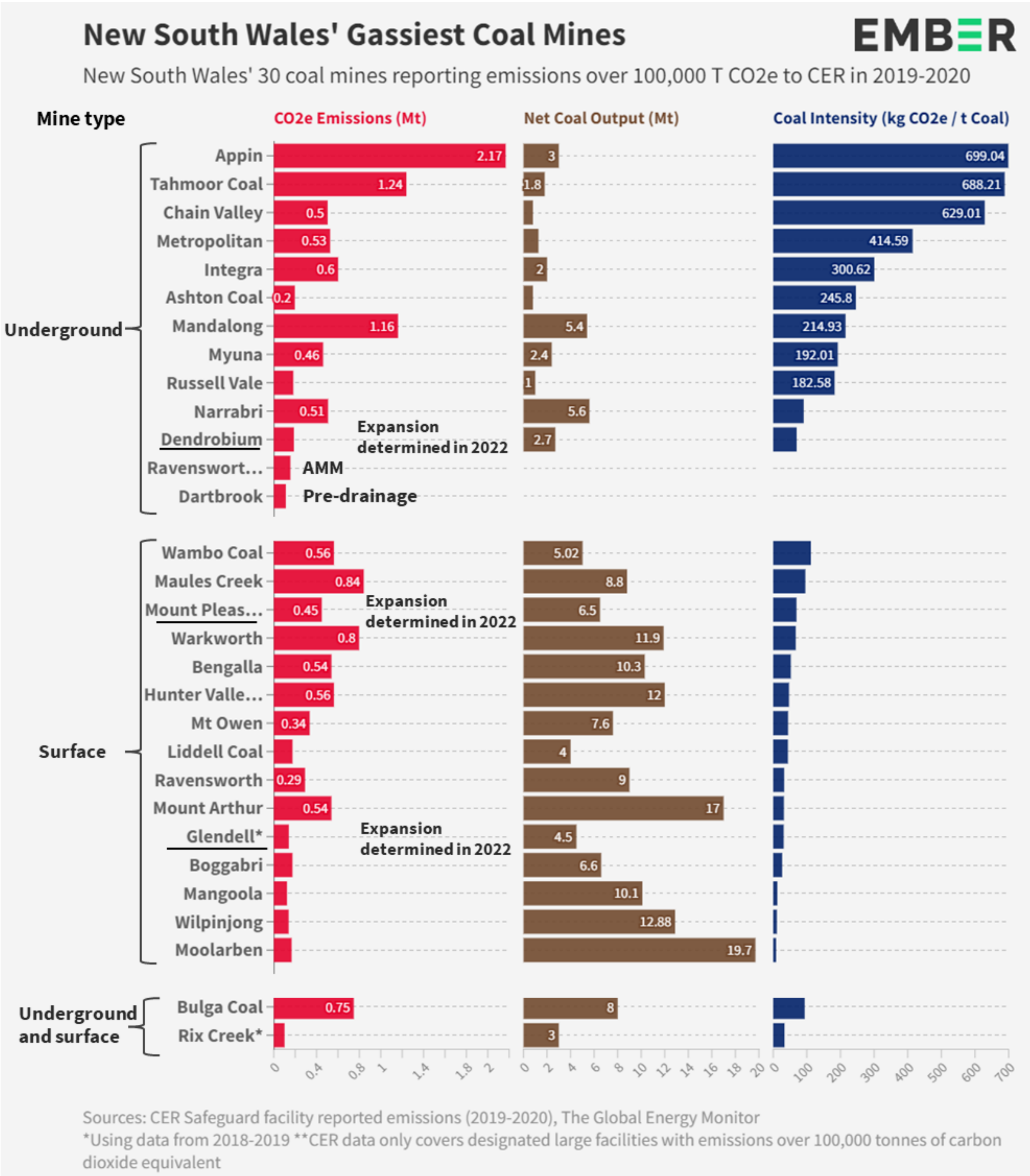


Figure 7: New South Wales mines that reported emissions over 100 kT in 2019-2020, ordered by gassiness of coal.

Proposed Coal Mines

Australia's proposed coal mines make the country the third highest potential emitter of new CMM emissions after China and Russia. Approved mines will double Queensland's and NSW's current Scope 1 & 2 emissions.

According to the Australian Chief Economist, there are 68 coal projects in the pipeline for Queensland and New South Wales, including some which have already received approval from the Government. The majority of the proposed new capacity (45%) will come from thermal-only coal mines whilst metallurgical-only mines represent 18%. A number of recently approved coal mines are listed in Appendix A & B, however information on emission estimates is limited as many environmental impact statements are not accessible.

Global Energy Monitor found that Queensland has more coal under development than any state or province in the world, and the state hosts some of the country's most controversial mine openings. Of 44 proposed mines, our research indicates that 34 are likely to proceed to production as planned, including two major coal mine proposals already in the public consultation stages; Winchester South (Whitehaven Coal) and Valeria Coal Project (Glencore). We calculate that this will result in at least 855.8Mt CO_2-e emitted to the atmosphere - an average of 21.4Mt/yr calculated over the 90-year lifespan of the longest duration project. This would more than double the current annual scope 1 and 2 emissions of Queensland's coal industry.

In New South Wales, the Independent Planning Commission has approved eight major new coal projects and expansions in the last three years which will cumulatively emit a total of 74.77 million tonnes CO_2-e in scope 1 emissions alone. This equates to approximately 4.46Mt CO_2-e on average every year over the life of the projects.

In addition, in 2022 NSW will determine three further coal expansions; Glendell Continued Operations Project, Mount Pleasant Optimisation Project and Dendrobium Mine Extension Project. If all are approved, a further 31.4 million tonnes CO_2-e in scope 1 emissions will be emitted over the life of these projects. Significantly, the Dendrobium Mine Extension Project is proposing to extend to a more gassy seam, which would more than triple its current Scope 1 GHG emissions.

Proposed coal mines in the Galilee Basin

We researched the predicted methane emissions from the largest proposed coal mines in Queensland and New South Wales and found many to use emissions factors which are likely to underestimate emissions.

In Queensland, the Carmichael coal mine by Adani Corporation, the first of a number of planned “megamines” in the Galilee basin, is facing much local opposition as Scope 1 & 2 emissions of 200 Mt of CO2-e are to be emitted in its lifetime. This represents close to 40% of Australia's entire emissions in 2019, but we believe the figure could be far worse.

Emission estimates used the “low gas zone” regulation even though results from the mine's Greenhouse Gas Report indicate some seams have a gas content above the low gas zone, at which point gas compositions can switch to close to 100% methane.

Other major mine proposals in the basin including the Galilee Coal Project by Waratah, China Stone by Macmines Austasia and Kevin’s corner by GVK use outdated emission factors which underestimate methane emissions. For underground mines, the proposals use a default emission factor from 2010, a figure smaller than the emission factor for surface mines in Queensland even though underground coal is generally gassier.

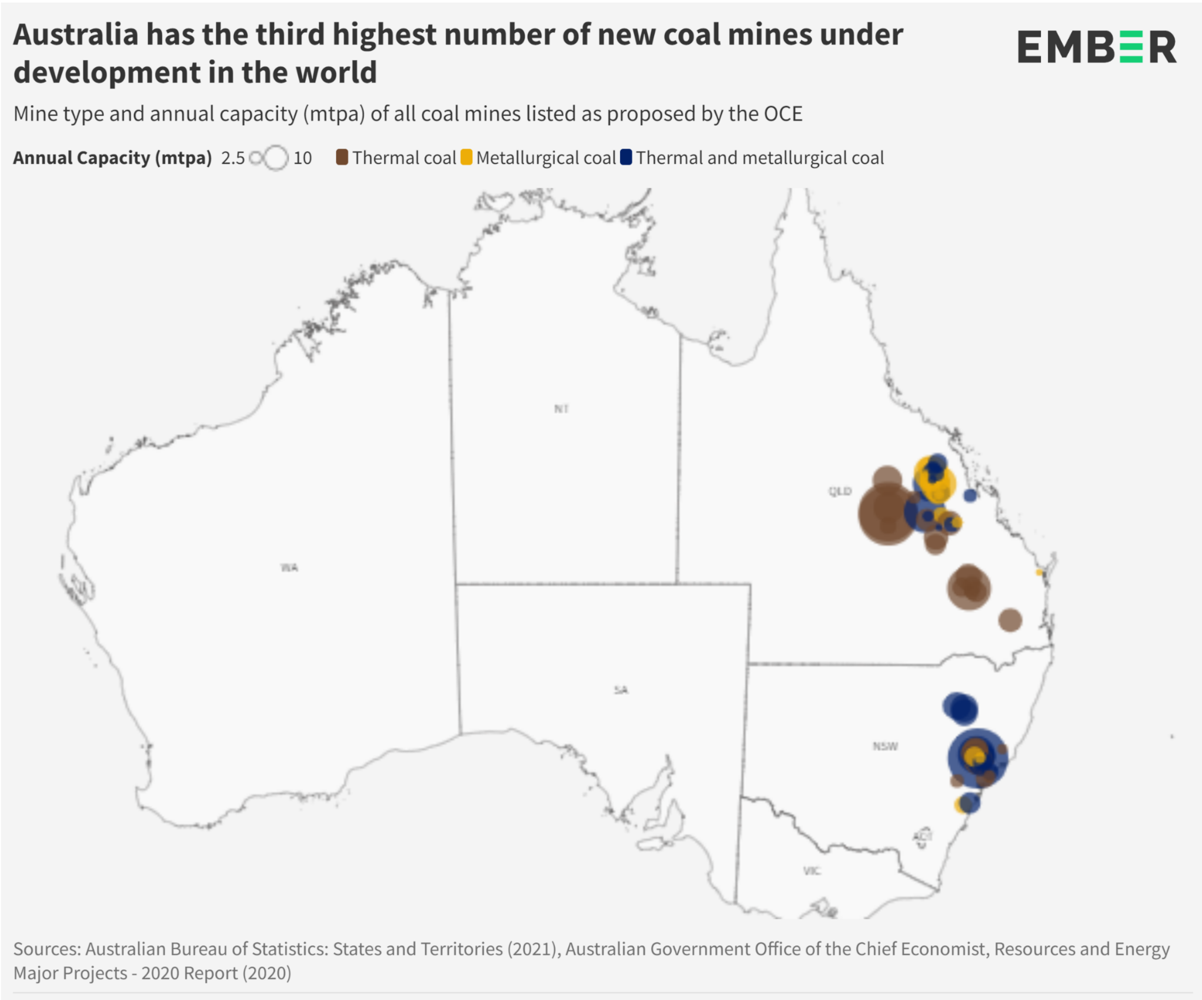


Figure 8: Mines proposed by the Office of the Chief Economist, mapped by mine type and annual capacity.

Abandoned Mine Methane

Methane continues leaking from mines long after mining is stopped. Many mines in Australia remain in "care and maintenance" for years without being fully closed and rehabilitated. The Australia Institute found only eight mines have reached final closure in the past ten years. It is unclear how accurately methane emissions from “care and maintenance” sites are reported.

For example, The Australian Conservation Foundation recently found that in NSW, Ravensworth underground coal mine owned by Glencore had been in “care and maintenance” for seven years and in that time emitted 1 Mt CO_2-e equivalent of methane. The mine continues to leak methane emissions to the atmosphere today, with 156 kt CO_2-e reported to the CER in 2020.

With such a serious lack of accurate data, the 35 kt of methane recorded by AGEIS at abandoned mines is likely to be a large underestimation. As the number of closed mines is forecasted to increase as more and more mines and associated power stations retire, the challenge of properly closing and reporting on abandoned mines will need to be addressed.

Actions to reduce Australia's coal mine methane

CMM as the "low hanging fruit" to combat climate change

The best way to avoid coal mine methane is to phase out coal, especially by putting a stop to new coal projects and pursuing socially just pathways to early retirement for the country's gassiest mines. There are also some quick and easy steps like improved monitoring and capturing methane which are the "low hanging fruit" in Australia's effort to combat climate change.

Understanding the problem - Improvements to MRV

Implementing a comprehensive Monitoring, Reporting and Verification (MRV) methodology across the Australian coal mining sector is vital. There is growing public scrutiny of this problem as highlighted in the Emissions Expose report by the Australian Conservation Foundation, which also found Australia's fifth-biggest coal miner, Peabody, to have been incorrectly reporting their greenhouse gas emissions to the Australian government.

A good comparison would be the oil and gas industry, which together with the International Methane Emissions Observatory (IMEO) has over the last 10 years developed a consistent methodology for measuring methane leaks, with the latest version being the Oil and Gas Methane Partnership (OGMP) 2.0 Framework. Scoping for a parallel partnership to include metallurgical coal producers is already underway. Given that the locations of CMM sources are better known, this strategy would be even easier to implement for the coal mining industry.

The United Nations Economic Commission for Europe (UNECE) and the Global Methane Initiative recently released a best practice guide for the effective management of coal mine methane, focussing on MRV systems deployed by national governments. This guidance could provide a valuable framework for the development of an Australia-specific MRV framework.

Measurement discrepancies in the Bowen Basin

The Bowen Basin is Queensland's major coal mining region. With 44 coal mining operations accounting for 85% of the state's production, this region has become a global example of the disparity between reported CMM emissions and independent measurements.

Using satellite data, the geoanalytics company Kayrros analysed methane emissions over the Bowen Basin. Their findings indicate that the region's coal mines emit 1.6 million tonnes of methane a year, almost double Australia's entire reported CMM emissions. The study also found that coal produced from the Bowen basin has a methane intensity 47% higher than the global average, and nearly 10 times higher than the default emission factor used by surface mines in Queensland (calculated as an average of 7.5kg of methane per tonne of coal rather than the currently used 0.8kg / tonne).

Similarly, an independent team of Dutch researchers used TROPOMI satellite measurements over six coal mines in the Bowen basin and found that in 2018-19 they emitted 570 thousand tonnes of methane. This was well above the total emissions reported by the state of Queensland that year, whilst only representing around 13% of the state's coal production. The research also highlighted Hail Creek, an open cut mine run by Glencore, as it produced methane emissions more than 10 times that reported to regulators.

Measuring

Independent and systematic measurements should be carried out at all active and closed mines, putting an end to the use of default emission factors. Best practice methods such as frequent direct measurement of methane emissions, or the development of a site-specific, in-situ emissions model, will produce more accurate emissions estimates.

If emission factors are used for surface mines rather than direct measurements, according to the UNECE guidance, these should be specific to the mine, determined by initial measurements over a period of at least a month, and then reviewed every 3-5 years. Australian scientists have developed a methodology incorporating direct measurements to substantially reduce uncertainties.

To further improve emission estimates, a combination of 'top-down' and 'bottom-up' methods should be used, making use of existing and emerging satellite technologies to pinpoint methane plumes and compare aerial measurements to mine-reported data. Existing satellite technology that has the potential to calculate the methane intensity of large mines, or clusters of mines, is already challenging Australia's official emissions estimates.

Advances in monitoring technologies means measurements with higher resolution and greater coverage are imminent. New satellites such as EnMAP, Carbon Mapper, CHIME, EMIT and MethaneSat will provide a more thorough picture of Australia's CMM emissions and force improved transparency and methodology in the current MRV system. Governments and companies should utilise this new capability to better understand emissions, and design policy tools to improve tracking and mitigation of CMM.

Reporting

Currently, the emissions data released by the CER and available on the AGEIS database is broad-based, impeding public evaluation of matters like the emissions intensity of different coal mines. We recommend that AGEIS should make their granular data publicly available, with data on individual active mines, their methane intensity, mitigation measures, utilisation and more.

Australia also lacks a comprehensive database of decommissioned mines, and only reports on closed underground mines. This appears to result in AGEIS estimating emissions for only a fraction of closed mines. Furthermore, the potential for significant methane emissions from mines in 'care and maintenance' is particularly concerning and must be investigated.

Verification

Reporting entities should have a formal quality assurance program, including independent review of emission reports prior to submission. The CER should ensure that all reported data is verified, whether through comparing reports to known data benchmarks, through independently running data inputs through standardised calculations, or financing independent checks by third parties.

The use of best-available, high-resolution satellites can support the verification of on-the-ground emissions measurement or estimates and, by the end of 2022, it is expected that satellite configurations will be capable of taking daily measurements at the facility level. 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.

Quick Wins - Mitigating emissions at coal mines

Abatement techniques for CMM are already widely available. Requirements such as capturing methane prior to production, capturing/utilising Ventilated Air Methane, and banning venting should be standard industry practices.

While existing mines continue to operate, there are various methods available for mitigating the scope 1 emissions from coal extraction and processing. Most approaches centre on the combustion or oxidation of methane emitted from underground mines, or around energy and resource efficiency measures across all types of coal mines. Experts in the US have compiled suggestions for policies and regulatory regimes, as these will be needed in order to ensure implementation of CMM abatement projects at the scale necessary.

VAM abatement

The EPA estimates that Ventilation Air Methane represents ~75% of underground mining emissions, and is the largest contributor to CMM emissions. Its mitigation is therefore one of the most promising avenues for reducing methane leaks from operational coal mines.

The dominant means of reducing the climate impact of VAM is capturing the gas and either extracting or destroying the methane. Combusting or passing methane through a flameless oxidiser destroys it, and produces CO_2 and water. Captured methane can also be sold to the gas market, provided there is gas compression and transport infrastructure proximate to the coal mine (in which case the methane becomes a source of scope 3 emissions for the coal mine). While such uses of methane still result in the production (and release) of CO_2, the lower global warming potential of CO_2 means that these mechanisms are still viewed as emission mitigation.

Australia's science agency CSIRO has developed three technologies to mitigate VAM emissions. The 'VAMMIT' machine destroys methane, while the 'VAMCAT' uses a catalytic combustion gas turbine to create electricity from captured methane. The 'VAMCAP' uses carbon composites to capture and concentrate methane from source air (usually a mine's ventilation system) enabling the economic recovery and use of VAM. Both VAMMIT and VAMCAT can be used in environments with low methane concentration (less than 0.3%), enabling their use in relation to ventilated air from working mines. Such latest technologies show that on average 96% of VAM methane can be oxidised. If applied to all underground mines, this technology has the potential to reduce Australia's methane emissions by approximately 45% (420 kt), equivalent to 35 million tonnes of CO_2-e when using methane's 20-year GWP, which is similar to New Zealand's annual CO_2 emissions.

The capture and beneficial use of CMM is not a new process - the German Creek power station has been powered by both VAM and drainage gas since 2006 - but uptake has been low. VAM emissions are larger by volume but have low methane concentrations, which increases mitigation costs, whereas drained mine gas can have high CH_4 concentrations but is generally a time-limited resource (drained prior to coal activities commencing, or before each new mine extension). These aspects of each emission source influence the economics of adopting the available mitigation measures; without strong incentives in the form of a high carbon price or effective mandatory emission reduction measures, it is less likely that pursuing mitigation of VAM will be an attractive commercial decision for most mines.

This creates the clear need for legislated obligations on coal mines to incentivise or require methane capture and/or utilisation. Implementing legislative bans on venting (releasing methane to the air) forces coal mines to instead capture and use/dispose of CMM - which are readily available actions that can, in some circumstances, provide an additional source of revenue for the mine operator.

It is worth noting that it is currently possible for coal mines to earn Australian Carbon Credit Units (ACCUs) under the Emissions Reduction Fund. Under the 'Coal Mine Waste Gas' Method, the proponents of underground coal mines can earn ACCUs through the emissions that are "avoided" when the coal mine methane is flared, oxidised or used for electricity generation. There are 14 projects registered with the CER under the Coal Mine Waste Gas Method, almost all of which involve electricity generation. Coal mine waste gas electricity generation projects in Queensland have so far been issued with 1,101,402 ACCUs, worth approximately $33m at the current unit spot price of around $30.

Controversially, the Coal Mine Waste Gas Method enables coal mines using the methane for electricity generation to earn additional revenue from the ACCUs on top of what they save through not having to purchase electricity or use their own coal for their electricity needs.

Abandoned Mine Methane (AMM)

Methane emissions from abandoned coal sites can be reduced to almost zero if the mines are flooded. In cases where flooding is not technically feasible, mines can be sealed. The UNECE has published best practice guidance on AMM recovery, including examples from Europe and the US. Even low quality AMM can be used as a resource, as demonstrated by the Durr Megtec with examples in Europe and Australia. Regulations and proper enforcement can ensure these measures are broadly applied even when companies have no profit incentive to manage an abandoned asset. Properly shuttering mines, for example as done by Française de l'Energie, will create jobs in coal regions, bolstering both ecological and social justice.

Big Impact - Phasing out coal

The International Energy Agency's flagship report Net Zero by 2050 demonstrates that no new coal mines or extensions can be approved for development after 2022. The most effective way to address coal mine methane emissions is to reduce the use of coal, particularly in electricity generation. Reducing coal use, and legislating the end of new coal is crucial to this.

No new coal mines

A clear pathway to avoiding emissions is for Queensland and NSW to cease approving new coal mines and coal expansion projects. In particular, the 29 thermal/partially thermal coal mines in Queensland, and 21 in New South Wales should not be approved. A list of these can be found in Appendices A & B of this document.

Focus on closing the highest-emitting mines first

According to the IEA's analysis, the worst performing coal emits as much as 100 times more methane than the least emitting. To see the most impactful emission reductions, efforts should be concentrated on the worst performing coal mines. Focussing on retiring the mines with the highest intensity of methane emissions first will make a much greater impact on GHG reductions. We calculate that in Australia, retiring the gassiest 25% of coal would remove over 22 Mt of CO_2-e emissions, representing 68% of Scope 1 emissions reported to the CER by coal mines in 2019, or 4% of Australia's total CO_2-e emissions. On the other hand, retiring the best performing 25% would only remove about 2 Mt.

It is worth noting that some mines assumed as better-performing may in fact be major emitters. This is particularly the case with surface mines which rely on default emission factor estimates, so improved monitoring is crucial alongside this approach.

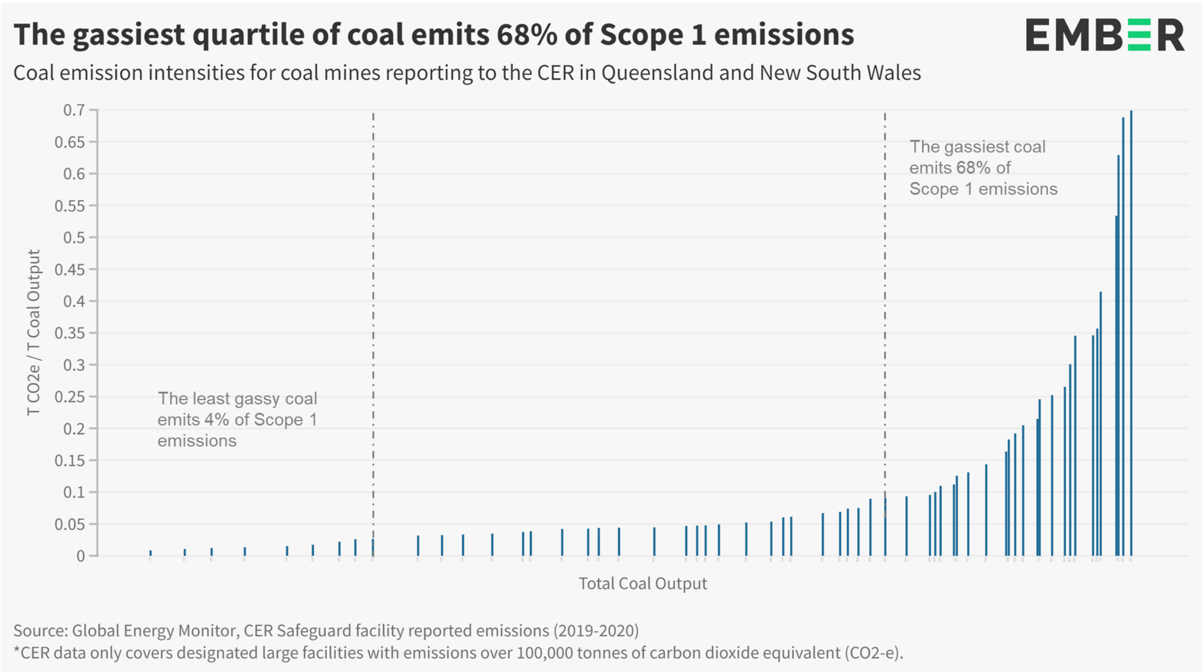


Figure 9: Coal emission intensities for coal mines reporting emissions to the CER in Queensland and New South Wales in 2019.

Phasing out thermal coal

A report by Institute of Energy Economics and Financial Analysis found that Queensland's thermal coal is rapidly reaching technical obsolescence and is of marginal viability, with cheaper and cleaner renewables available.

We calculate that 12.5 Mt of CO_2-e of methane emissions (100-year GWP) could be avoided if the existing thermal coal mines are closed - equivalent to taking almost three million cars off the road, and reducing Australia's total GHG emissions by around 3%.

As the IEA has modelled that no new coal projects should be developed and global financial institutions increasingly commit to thermal coal phaseouts, thermal coal mines are increasingly at risk of becoming stranded assets as they struggle to compete with low cost and low carbon alternatives. Additionally, due to the intensity of methane, developing new thermal coal mines is in stark opposition to Australia's obligation to protect future generations and efforts to reduce GHG emissions.

Supporting Materials

Methodology Notes

The proportion of methane emissions within total Scope 1 emissions for underground and open cut coal mines were estimated through a compilation of literature, and case studies of Australian mines. Sources included: Greenhouse Gas Emissions From Coal Mining Activities and Their Possible Mitigation Strategies, Environmental Carbon Footprint; Caval Mine Ridge Greenhouse Gases EIA, BMA; Ensham Mine Extension Greenhouse Gas EIA, Idemitsu; Mandalong Mine Annual Review, Centennial.

Emission estimates for the Narrabri Underground Mine Stage 3 Extension Project were calculated using reported estimates of 85% fugitive emissions with 30-40% methane content. Source: Narrabi Underground Mine Stage 3 Extension Project (2022) NSW Government.

Estimates of methane emissions from thermal mines were calculated as 47% of total CMM emissions in Australia, from IEA estimates on the split of emissions from coking and thermal mines. Source: Methane Tracker 2022.

Estimates of emissions from future mines were based on publicly available information about the lifespan and estimated scope 1 and 2 emissions from the projects, an estimate of the additional emissions was calculated see Appendix A & B.

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Appendix A

Future emissions from proposed coal projects in Queensland

B.1 Methodology – determining the list of proposed mines

The Federal Office of the Chief Economist ('OCE') 2020 Resources and energy major projects report and accompanying dataset provide a list of proposed coal projects (both new mines and expansions to existing mines) at various stages in the development pipeline. The OCE includes projects from the 'publicly announced' stage onwards, excluding '[e]arlier stages … such as identifying deposits and exploration activities' and including only projects where there has been 'evidence of project activities that support the likelihood that the project will progress to a [Final Investment Decision] within the next five years'. However, desktop research into each OCE-listed project found that 13 of the 47 proposed mines included in the OCE report are unlikely to proceed for various reasons, such as the proponent formally withdrawing from, and not pursuing, regulatory approval processes 5-10 years ago. These projects have been excluded from the calculations below, with the final list comprising 34 most-plausible projects. It is important to note that there are numerous additional proposed projects earlier in the planning pipeline, and that these 34 mines are only a subset of the new and expanded mines that may be approved if current policy settings persist over the coming decade.

B.2 Methodology – determining the potential emissions

Resource projects that meet certain definitions under the Environmental Protection Act 1994 (Qld) are required to prepare and submit an Environmental Impact Statement ('EIS'). The EIS process requires mine proponents to estimate the scope 1 and 2 emissions for their proposed project. Where available, the calculated emissions provided by the mine proponents in their EISs have been used as the basis for determining the scale of potential future emissions.

However, not all of the projects that could feasibly proceed to production have undergone the EIS process; some are currently preparing their EISs, while others have only submitted an Initial Advice Statement under the Commonwealth regulatory framework.

For new open-cut mines, Method 1 from the National Greenhouse and Energy Reporting Measurement Determination was used to estimate fugitive emissions based on run-of-mine coal production. The use of this method is indicated by green highlighting in the overview table below. It should be noted that no equivalent factors-based method is available for underground mines (which directly measure the methane content of ventilated air and drained waste gas), so proposed underground mines without proponent-estimated emissions could not be reflected in the emissions totals. For projects that comprise expansions to existing mines, the reported emissions from the existing mines and publicly available information about the scope of the expansion were used to calculate likely emissions from the new mine works where possible. This method is indicated by orange highlighting in the table below.

Detailed table of proposed coal projects, associated emissions, and data sources

Project name	Proponent	Type of project	Annual additional coal production (mtpa)	Average annual scope 1 + 2 emissions (kt CO2-e)	Life-of-mine emissions (kt CO2-e)	Methane emissions (20yr GWP, t CO2-e)	Source / notes
Alpha	GVK Hancock Coal	New open-cut	40	766.0	24,509.0	41435	Supplementary Environmental Impact Statement ('SEIS') - Appendix Q, pg Q-4
Baralaba South	Baralaba Coal	New open-cut	5	85.0	1,615.0		Projected mine lifespan: 19 years, per Initial Advice Statement.
Carmichael	Adani / Bravus	New open-cut + underground	10	2,285.0	205,650.0	97150	Environmental Impact Statement ('EIS'), Ch 8, pg 8-3.
China First (Galilee Coal Project)	Waratah	New open-cut + underground	40	2,304.0	72,978.0	2467143	EIS, Ch 8, pg 8-3.
China Stone	MacMines Austasia	New open-cut + underground	38	4,707.0	235,350.0	1410357	EIS, Ch 10, pgs 291, 293
Colton	New Hope Coal	New open-cut	1.1	18.7	187.0		Projected mine lifespan: 10 years based on public project description.
Comet Ridge	Bowen Coking Coal	New open-cut	1.6	27.2	217.6		Projected mine lifespan: 8 years based on public project description.
Dysart East	Bengal Energy	New underground	1.9	*Not available*	*Not available*		No public emissions data or *Measurement Determination* method available (underground coal mines require direct monitoring of fugitive gases).
Elimatta	New Hope Coal	New open-cut	5	314.1	10,121.1		Annual operating and construction emissions: EIS Assessment Report, p 24. Life of Mine ('LoM') emissions calculated based on 32 project lifespan of mine + 2 years' construction (per Report).
Grosvenor phase 2	Anglo American	Underground expansion	6	1,554.4	*Not available*		Annual emissions calculated based on reported emissions for existing mine (4-yr average) and project information that it will expand mine by '25-40%'. No timeframe could be found for mine lifespan so LoM emissions not calculated.
Hillalong	Shandong Energy Group	New open-cut + underground	4.2	243.0	4,131.0		Annual emissions: EIS Assessment Report, p 91. LoM emissions calculated based on 20-year projected project lifespan.
Ironbark No. 1	Fitzroy Australia	New underground	2.7	*Not available*	*Not available*		No public emissions data or *Measurement Determination* method available

Project name	Proponent	Type of project	Annual additional coal production (mtpa)	Average annual scope 1 + 2 emissions (kt CO2-e)	Life-of-mine emissions (kt CO2-e)	Methane emissions (20yr GWP, t CO2-e)	Source / notes
	Resources						(underground coal mines require direct monitoring of fugitive gases).
Isaac Plains Complex (Isaac Downs)	Stanmore Coal	Open-cut expansion	1	126.6	2,153.0		LoM emissions: EIS, Ch 12, table 12-6. Annual emissions calculated by dividing LoM total by 17 (projected mine lifespan).
Kevin's Corner	GVK	New underground	30	2,037.0	59,089.0	1060840	SEIS, pg 46
Lake Vermont Meadowbrook	Bowen Basin Coal Pty Ltd JV	Open-cut + underground expansion	7	259.4	5,835.8		Project entails extension of production lifetime of existing mine by '20-25 years'. Annual emissions assumed to be equivalent to those reported for existing mine; LoM emissions calculated as annual emissions x 22.5 to represent the middle of possible lifespan range.
Moorlands	Cuesta Coal Limited	New open-cut	1.9	32.3	969.0		Projected mine lifespan: 30 years based on public project description.
Moranbah South	Anglo American and Exxaro Resources Ltd	New underground	18	1,000.0	30,000.0	*Not available*	Annual emissions: EIS Assessment Report, p 73. LoM emissions calculated based on 30 year projected mine lifespan.
New Acland (Stage 3 extension)	New Hope Coal	Open-cut expansion	4.5	182.9	2,417.7		LoM emissions: EIS, Ch 10, pg 10-5. Annual emissions calculated by dividing LoM total by 13 (projected mine lifespan).
North Surat - Collingwood	New Hope Coal	Open-cut	9	153.0	3,060.0		Projected mine lifespan: 20 years, per Initial Advice Statement.
North Surat - Taroom	New Hope Coal	Open-cut	12	204.0	5,100	*Not available*	Projected mine lifespan: 25 years, per Initial Advice Statement.
Olive Downs	Pembroke Resources	New open-cut	15	910.0	71,912.0	608929	EIS Appendix G, pg 45.
Red Hill Mining	BHP Billiton / Mitsubishi Alliance	New underground	14.5	407.0	24,214.0	1999643	EIS, Ch 12, pg 12-17.
Rolleston (phase 2)	Glencore, Sumisho, IRCA	Open-cut expansion	5	256.0	5,894.0		EIS Assessment Report, pg 33.
Saraji East	BHP and Mitsubishi	New underground	7	836.0	16,720.0		LoM emissions: EIS, Ch 11, pg 11-35. Annual emissions calculated by dividing LoM total by 20 (projected mine lifespan).

Project name	Proponent	Type of project	Annual additional coal production (mtpa)	Average annual scope 1 + 2 emissions (kt CO2-e)	Life-of-mine emissions (kt CO2-e)	Methane emissions (20yr GWP, t CO2-e)	Source / notes
South Galilee	Alpha Coal Pty Ltd and AMCI (Alpha) Pty Ltd	New open-cut + underground	35^	357.0	12,505.0	*Not available*	EIS, Ch 11, pg 11-8.
Springsure Creek	Adamelia Resources	New underground	7	426.1	17,044.0		LoM emissions: EIS Assessment Report, pg 61. Annual emissions calculated by dividing LoM total by 40 (projected mine lifespan).
Styx (Central Queensland Coal)	Mineralogy	New open-cut	2	428.0	3,450.0		EIS, Ch 12, pg 12-40.
Talwood	Aquila Resources	New open-cut	3.6	61.2	856.8		Two lifespan estimates given in 2021 flyer for sale of mine (10 and 18); calculation uses 14 year assumption.
Taroborah	Shenhuo Group	New open-cut + underground	5.73	72.8	1,529.0		LoM emissions: EIS, App 16, pg 15. Annual emissions calculated by dividing LoM total by 21 (projected mine lifespan).
The Range	Stanmore Coal	New open-cut	5	301.0	7,826.0		Annual emissions: EIS Assessment Report, pg 57. LoM emissions emissions calculated based on 26 year projected mine lifespan. Note that the Report only included the maximum/highest year emission figure.
Valeria	Glencore	New open-cut	20	340.0	12,240.0	*Not available*	Projected mine lifespan: 36 years based on public project description.
Walton	Aquila Resources	New open-cut	1.6	100.0	800.0		Annual emissions: EPBC Initial Advice Statement (Nov 2017), pg 39. LoM emissions calculated based on 8 year projected mine lifespan (not including construction).
Washpool	Aquila Resources	New open-cut	7.2	122.4	1,836.0		Projected mine lifespan: 15 years based on public project description.
Winchester South	Whitehaven Coal	New open-cut	15	556.0	15,600.0	95700	EIS, App H, pg 43.
			TOTAL	21,473	855,810	1,985,308	

Appendix B

Summary of new coal mine GHG emissions approved by NSW IPC

Project	Approval Date	Total Scope 1 GHG (Mt CO2~e)	Scope 1 GHG (Mt CO2~e per annum)	Total GHGEs - life of mine (Mt CO2~e)	Source/Notes
Narrabri Underground Stage 3	01/04/22	31.19	1.36	479.57	Narrabri Underground Stage 3: NSW IPC, Narrabri Underground Stage 3 Extension Project, 1 April 2022, pg 29
Mangoola	26/04/21	3.25	0.41	107.94	Mangoola Coal COP: NSW IPC, Mangoola Coal Continued Operations Project (SSD 8642), SoR, 26 April 2021, pg 24
Tahmoor South	23/04/21	19.31	1.60	93.8	Tahmoor South: NSW IPC, Tahmoor South Coal Project (SSD-8445), SoR, 23 April 2021, pg 73. N.B. 19.31 Mt Scope 1 emissions assumes that proposed flaring and power generation from waste methane occurs. Unabated Scope 1 emissions were projected to be 26.69 Mt CO2-e.
Maxwell Underground	22/12/20	9.9	0.37	337	Maxwell Underground: NSW IPC, Maxwell Underground Coal Mine Project (SSD-9526), SoR, 22 December 2020, pg 30
Russell Vale	8/12/20	1.42	0.28	11.1	Russell Vale: Total Scope 1 and 2 data sourced from Russell Vale UEP Development Consent, 08.12.2020, pg 11, Scope 3 data sourced from Russell Vale Revised Underground Expansion Project (MP09_0013) | Secretary's Final Assessment Report, September 2020, pg 66. Annual average GHG emissions Scope 1 and 2 data sourced from Appendix 8, GREENHOUSE GAS AND ENERGY ASSESSMENT, Russell Vale Revised Underground Expansion Project, FINAL, Umwelt (Australia) Pty Limited, July 2019, pg 5
Vickery Coal Project	12/08/20	3.1	0.12	369.9	Vickery Extension Project: Total emissions sourced from NSW IPC, Vickery Extension Project (SSD 7480), SoR, 12 August 2020, pg 47. Annual average Scope 1 emissions sourced from NSW DPE, Vickery Extension Project (SSD 7480) | Assessment Report, May 2020, pg 122
Rix's Creek South Mine	12/10/19	0.8	0.04	72.4	Rix's Creek: NSW IPC, Rix's Creek Continuation of Mining Project (SSD 6300), SoR, 12 October 2019, pg 82. Annual avg emissions were derived by dividing total Scope 1 and 2 emissions by the 21 year mine life.
United Wambo	29/08/19	5.8	0.25	265.9	United Wambo: NSW IPC, United Wambo Open Cut Coal Project (SSD 7142), SoR, 29 August, 2019, pg 43
Total		74.77	4.46	1737.61	