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CONTENTS

News, Plant and Equipment

Features

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Russia's Daltransugol increases coal transshipment 15.5% in Feb amid higher rail deliveries

SC Daltransugol (DTU), a coal terminal at the Vanino Port managed by JSC Port Alliance, transshipped 1.367 million tonnes of coal in February 2025, up 15.5% compared to a year earlier, the stevedoring company said.

It was previously reported that the terminal handled 949,700 tonnes in January, down 27.3% year-on-year.

Coal transshipment in January-February 2025 thus amounted to 2.317 million tonnes (data for January-February 2024 has not been disclosed).

"Daltransugol's cargo turnover increased 15.5% in February this year. The growth was driven by a positive trend from Russian Railways in increasing coal shipments for export to Far Eastern ports," the company said.

Daltransugol is one of the largest coal terminals in Russia by cargo turnover. It is located at the deepwater bay of Muchke in Khabarovsk Territory. It has access to the Trans-Siberian and Baikal-Amur mainline railways. The port, which was built in 2008, is designed to transship coal from SUEK to end consumers in China and other Asian countries.

Daltransugol received resident status at the Free Port of Vladivostok in September 2020 to implement a project for increasing the terminal's capacity from the current 24 million tonnes a year to 40 million tonnes a year by building a third stage. The work is due to be completed by August 31, 2026.

The terminal handled 14.5 million tonnes of coal in 2024, down 9% from 2023.

Port Alliance, which was established in March 2024, also includes JSC Murmansk Commercial Seaport , Murmansk Bulker Terminal LLC, Tuapse Bulker Terminal LLC and Maly Port LLC in Nakhodka, Primorye Territory. The company's five assets have combined capacity to handle over 53 million tonnes of cargo per year. All of these companies were previously part of the National Transport Company.

Thiess secures three-year contract extension with QCoal

Thiess has inked a three-year contract extension with QCoal at its Northern Hub operation in Queensland, with an additional three-year extension option.

The contract, valued at $590 million, will see Thiess continue to provide full mining services at the site, including statutory control, mining activities, maintenance and asset management, and rehabilitation works.

Thiess executive chair and chief executive officer Michael Wright said the company was pleased to build on its strong relationship with QCoal.

“Thiess is proud to continue our work with QCoal at their Northern Hub operation, extending our long-term relationship focused on providing safe and efficient mining operations, and progressive rehabilitation,” Wright said.

Thiess has operated in the Collinsville region since 1995, providing employment opportunities and supporting the local economy.

Thiess group executive – Australia east Rae O’Brien highlighted the company’s commitment to the local community.

“Thiess has been part of the Collinsville community since 1995, supporting the local economy and community, and providing employment opportunities within the region,” O’Brien said.

“Our work at QCoal Northern Hub commenced almost 20 years ago in 2007, and Thiess is pleased to have this opportunity to continue working in the region alongside QCoal.”

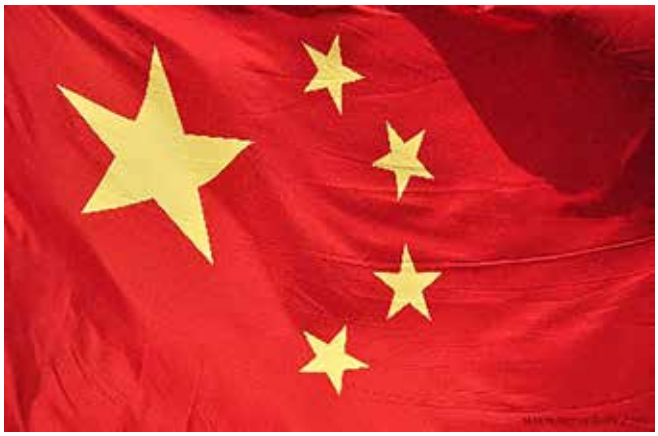
The contract extension further strengthens Thiess’ presence in Queensland and reinforces its position as a key mining services provider in the Australian resources sector.

It comes after Thiess recently secured a 16-month contract extension at the Wahana East Extension project in South Kalimantan, Indonesia.

The contract extension officially commenced in January 2025 and will see Thiess continue delivering full mining services such as load and haul, drill and blast, and pit dewatering.

Under the agreement, the company will also implement a circular economy-based waste management system in the local community and provide entrepreneurial training programs to empower local businesses to promote sustainable growth.

China could restart import controls on coal as oversupply mounts



China could re-establish import controls on coal, after leading industry groups warned on mounting oversupply in the world's biggest market for the fuel, according to a recent report.

The bank said a complete ban is unlikely given China's obligations to the World Trade Organisation, but purchases could be discouraged if the authorities impose delays or inspections on imports, analysts including Sara Chan said in a note. Similar controls were imposed in 2014, 2017 and 2018.

China maintained a cap on coal imports of about 300 million tons until 2022, but has blown past that level in the last couple of years due to energy security concerns. The country bought a record 543 million tons last year.

Now, demand is falling well short of expectations, resulting in a rapid decline in prices and a continuous drop in mine profitability, the China Coal Transportation and Distribution Association and the China National Coal Association said. To cope with persistently high inventories of the fuel, miners should control output, and importers should curb shipments of lower quality fuel, it said.

Beijing has prioritised coal production in recent years to avoid a repeat of the power crunch experienced in 2021, with Russia's invasion of Ukraine in 2022 reinforcing the strategy. The policy has been successful in ensuring energy security but has come at the expense of progress on decarbonisation and has led to a spate of fatal accidents at mines.

Surging output and tepid demand have weighed on the market in recent months. The country's benchmark for thermal coal prices has dropped to 699 yuan a ton, its lowest level since March 2021, according to China Coal Resource.

Spot prices may soon test the market floor set by government-regulated annual contracts of 675 yuan a ton, local trading platform ocoal.com said in a note.

US coal power retirements to double by 2025

US power retirements are set to double by 2025, with more than 12.3GW of capacity planned for retirement during the year, according to the Energy Information Administration (EIA).

This marks a 65% increase from 2024, with coal accounting for 66% of these retirements.

The EIA has announced that US power generators plan to retire approximately 8.1GW of coal-fired power generation capacity in 2025.

This represents a significant increase compared to the 4GW retired in 2024.

The EIA highlights a sharp decrease in coal retirements in 2024 compared to the 9.8GW retired annually over the preceding decade.

Among the largest coal plants due for retirement in 2025 is the 1.8GW Intermountain Power Project in Utah. An 840MW natural gas combined-cycle power block will replace it in July.

Other significant retirements include the 1.33GW J H Campbell in Michigan and the 1.27GW Brandon Shores in Maryland.

Natural gas retirements are also on the horizon, with 62% coming from V H Braunig Units 1, 2, and 3 in Texas and Eddystone Units 3 and 4 in Pennsylvania.

These plants are retiring old steam units installed between 1966 and 1974.

The Tennessee Valley Authority's (TVA) Johnsonville station will retire 16 simple-cycle combustion turbines totalling 754MW.

The TVA plans to replace them with 10 new aeroderivative gas turbines, adding 500MW of capacity.

Petroleum-fired power plants, which constitute 2.3% of US generating capacity, are also seeing retirements.

in 2025, 1.6GW of petroleum-fired capacity is scheduled for retirement.

The Herbert A Wagner power plant in Maryland will retire three oil-fired units totalling 828MW, while the TVA's Allen power plant will shut down its 20-unit combustion turbine site totalling 427MW.

The EIA's short-term energy outlook forecasts record power consumption in the US for 2025 and 2026.

The surge is due to higher electricity demand from AI and cryptocurrency data centres, along with increased use in homes and businesses for heating and transport.

The EIA predicts power demand to reach 4,179 billion kilowatt hours (kWh) in 2025 and rise to 4,239 billion kWh in 2026, exceeding the previous record of 4,082 billion kWh set in 2024.

Will China's new renewable energy pricing speed up coal's exit?

A shift to competitive auctions could accelerate the move to renewables, but much depends on how the policy is designed and implemented

China's central government has announced a major reform in how renewable power is priced.

Until now, wind and solar farm operators have been guaranteed a fixed price (pegged to coal power rates) for a portion of the electricity they generate. Any output beyond that quota had to be sold at lower, more variable prices.

The new policy will see this coal-linked pricing system replaced by competitive auctions that determine the price for electricity from new wind and solar installations. Since coal power is relatively expensive to produce, this change is expected to considerably lower the price of renewable electricity specifically and electricity generally.

Local governments will draw up detailed plans and implement the auction-based system by the end of the year. The new pricing rules will apply to wind and solar projects completed after June this year, while earlier projects will continue to follow the older fixed-rate, coal-benchmarked model.

More than just a pricing adjustment, the policy may reshape China's entire power sector. However, with coal still dominating power generation, the policy must be carefully designed to ensure that renewables displace coal and cut emissions.

How does the new pricing mechanism work?

The new Chinese system is similar to the Contract for Difference (CfD) mechanism used in the UK and other markets. Renewable energy generators bid against each other to supply electricity to the grid at a fixed "strike price". When the market prices fall below the strike price, the government pays the generator the difference. When market prices exceed it, the generator must pay back the surplus. A dedicated fund, typically managed by the grid operator, handles these balancing payments to and from generators.

In countries like the UK, CfDs have successfully lowered renewable energy financing costs by providing stable revenues. But CfDs do have drawbacks. For instance, renewable generators might keep producing electricity even when prices drop below zero, delaying essential maintenance in order to maximise income. This has happened with wind power in Germany, where generators continued producing even when electricity prices turned negative.

Another challenge is choosing which market price to reference for payments. CfD payments are often based on day-ahead market prices, which could limit flexibility within the same day. Conversely, using real-time market pricing might discourage generators from planning their production efficiently.

CfDs can also complicate risk management, particularly for wind power. Because wind generation naturally fluctuates, operators might miss opportunities to sell power at peak market prices during calm weather. For example, wind operators in Spain have experienced huge fluctuations in revenue.

Limitations of implementation in China

China's power sector differs significantly from western markets, with coal still dominant and government intervention common. As of late 2024, coal accounted for about 60% of China's power generation, with prices and market share locked in through medium- and long-term contracts.

China's spot electricity market remains small and often provides distorted pricing signals. This raises questions about whether the CfD market reference price will accurately reflect the marginal cost of generating electricity. For instance, in Shandong province, which gets 70% of its electricity from coal, the marginal electricity price is largely determined by coal generation costs. Coal generation typically has significant fuel and maintenance costs that

should, in theory, ensure positive market prices. However, the province has still experienced negative spot market prices for over ten hours at a time, forcing generators to pay to generate power.

Shandong province has experienced negative spot market prices, meaning generators have to pay to generate power

Another challenge arises from the falling costs of wind and solar projects. The anticipated strike prices for renewables are already far below current coal-based benchmark prices (approximately RMB 0.38 per kilowatt-hour). Companies may bid even lower to secure contracts, resulting in a lower return on investment. Furthermore, if local governments strictly regulate bidding price ranges – as the recent reform suggests – competitive bidding could lose its effectiveness, clustering bids at the regulated minimum price and effectively reverting to government-controlled pricing.

Renewables must replace as much coal power as possible, not merely add new wind and solar capacity to coexist alongside it

Renewable dispatch in China is controlled by government policy and grid operators rather than market signals. Grid operators emphasise control, creating a disconnect between responsibilities and incentives. This centralised dispatch system, without self-correcting market mechanisms, limits renewables' ability to meaningfully replace coal, even when sufficient renewable generation is available.

CfDs may also unintentionally discourage companies from innovation and equipment upgrades, as new generation capacity bids must compete against older capacity that still benefits from higher subsidies or fixed reference prices.

What the future holds

The success of CfDs in China will depend on policy design and implementation. Three main scenarios can help illustrate this:

Scenario 1: Priority for renewables and rapid coal phase-out

Renewables receive dispatch priority, minimising curtailment. CfDs stabilise renewable revenues, and efficient spot markets allow wind and solar to quickly displace coal. Coal operates mainly as backup and its market share falls quickly. Because market electricity prices remain higher than renewable strike prices, the CfD system generates a surplus. This surplus can fund energy storage, smarter dispatch systems, or lower industrial electricity for businesses. This scenario sees the biggest emissions cuts.

Scenario 2: Gradual coal phase-out, competition slower to form

RECOMMENDEDChina faces three challenges to a coal-free future

Coal's market share declines gradually through targeted policy interventions, with coal generators still competing in the market alongside steady renewables growth. Spot market prices hover near the strike price for wind and solar and remain lower than coal's average cost, keeping the surplus/deficit account balanced. Renewable dispatch remains heavily influenced by government interventions and emission reductions progress slowly.

Scenario 3: Locked-in coal market share, limited renewable impact

China's substantial coal power capacity (around 1,300 gigawatts) remains dominant, running at high utilisation rates and maintaining elevated prices. The spot market is restricted, forcing renewable operators to compete fiercely for limited bilateral contracts. Spot market electricity prices frequently fall significantly below renewable strike prices, causing deficits in the CfD system. If these losses are distributed among business consumers, as currently occurs, the price of electricity will increase for them. Renewable capacity grows, but curtailment increases, failing to significantly replace coal or improve the energy mix.

Policy design is key

China's adoption of CfDs is an important reform in renewable energy pricing. Yet outcomes depend on detailed policy design and practical implementation. For CfDs to support meaningful emissions cuts, renewables must replace as much coal power as possible, not merely add new wind and solar capacity to coexist alongside it.

If CfDs consistently generate large deficits, it would indicate that renewables are relying too heavily on subsidies and surplus conditions. If CfDs remain consistently profitable, it signals that renewables are successfully challenging coal's market dominance.

The new CfD mechanism will need support both from policymakers and the market. Changes in the financial health of the CfD system – specifically the surplus/deficit account – will serve as an indicator of whether renewables are effectively displacing coal. Ultimately, clear, top-down market design and proactive policy improvements are essential for enabling CfDs to promote China's energy transition and rapidly decarbonise its power sector.

Australia's dominance in coking coal plus supply squeeze could derail India's steel growth

The Indian steel industry faces challenges as coking coal demand grows amid supply issues. Insights from Coaltrans India 2025 highlight India's reliance on Australian coal, rising met coke imports, and strategies like blending domestic coal with high-quality options.

The challenges and opportunities facing the Indian steel industry, particularly concerning coking coal supplies and the reliance on Australian metallurgical coal, provided the key takeaways from the Coaltrans India 2025 conference in New Delhi.

Supply-demand imbalance

The head of marketing strategy for steelmaking coal at a major mining company presented a sobering outlook on the future of coking coal supply, emphasising that its growth is failing to keep pace with increasing demand.

Australia currently supplies roughly half of the global coking coal market, which totals approximately 331 m tonnes, with the remainder coming mostly from suppliers in the United States, Canada and Russia.

Russia primarily supplies hard coking coal (HCC) and pulverised coal injection (PCI). US supplies are mostly high-volatility coking coal, with a smaller share of HCC. Canadian supplies are about 60% HCC, while Australia predominantly produces HCC and premium hard coking coal (PHCC), both essential for the Indian steel industry's baseload, according to the expert.

"When I look at supply, I struggle to see how these supplies will unfold to match up with Indian demand for coking coal," the expert told delegates, pointing to a lack of new projects, scarce capital and a bleak investment climate in Australia and other regions. The depletion of existing coal reserves would further exacerbate the issue and there would be a growing supply deficit just when demand is expected to rise, the export added.

Indian steelmakers fulfilled the Ministry of Steel's goal of producing 144 m tonnes of crude steel in the year to 31 March 2024. The ministry has set a goal for capacity to reach 300 million tonnes by 2030.

To achieve that, however, Indian steelmakers will need to secure about 220 m tonnes of coking coal every year, Fastmarkets understands.

According to an Indian steel industry official, about 60% of India's coking coal imports came from Australia in 2019, but that percentage has gradually declined over the past five years, with Indian steelmakers increasingly turning to Russia and the US for supplies.

Steelmakers adapt to thin margins

Faced with this challenge while operating in a thin profit-margin environment, India's steelmakers have been exploring alternative strategies, including experimenting with non-premium HCC and compacting the coal using stamp charging to enhance the coke strength after reaction (CSR) of the coke produced.

While this method offer some improvement in quality, PHCC remains essential for the base load of coke plants. Additionally, increasing PCI rates has proven helpful in optimising costs over the past few years.

Rising met coke consumption, imports

Rising demand for steel was fueling the surge in India's met coke consumption, BigMint Technologies analyst Nishtha Mukherjee told delegates, adding that it would reach 70 million tonnes by 2030, up from 40 m tonnes in 2020.

She said that to try and meet this demand, Indian met coke capacity is expected to expand by more than 50% by 2030, rising to 85 million tonnes with output forecast to rise to 65 million tonnes. Current capacity is 56 million tonnes, with output at 48 million tonnes, Fastmarkets understands.

But escalating demand has also led to a near-doubling of India's met coke imports, Mukherjee added, which are predicted to have risen from 2 m tonnes in 2021 to an estimated 6 m tonnes by the end of March 2025

Over-reliance on Australian met coal

Adding a layer of complexity, in his presentation to the conference, the lead analyst at the Institute for Energy Economics & Financial Analysis (IEEFA) think-tank, Simon Nicholas, highlighted the growing risks associated with India's heavy reliance on Australian met coal. He said that, despite volumes gradually declining, India still imported more than 42 m tonnes of met coal from Australia in 2023.

He focused on several key issues, including the rising environmental, social, and governance (ESG) concerns surrounding coal mines in Australia, which could affect investment and production; the uncertainly over the availability of bank financing for met coal projects; and the potential impact of these factors on met coal prices. He also said the Australian government had a history of overestimating future met coal exports.

To mitigate these risks and to ensure a stable supply of coking coal for the Indian steel industry. Nicholas said India should further reduce its dependence on Australian coking coal by diversifying its supply chains and by exploring alternative technologies for steel production.

To this end, he added, the Indian government has already asked Indian steelmakers to blend domestic met coal with Australian and other superior varieties of coking coal.

Nicholas also pointed to a statement by Whitehaven Coal, which said: "Over the longer term, the expected structural shortfall in global metallurgical coal production, particularly the long-term depletion of HCC from Australian producers combined with increased seaborne demand from India, is anticipated to drive [up] metallurgical coal prices."

This sentiment underscores the urgent need for strategic planning and proactive adaptation in the Indian steel sector, Nicholas added.

More coal deposits secured in DPRK

The coal industry of the DPRK strives to secure much more deposits of coal.

As of now this year, more than 450 reserve coal faces have been secured throughout the Ministry of Coal Industry.

The Sunchon Area Youth Coal-mining Complex made progress in securing deposits of coal by intensively dispatching tunnelling platoons to the areas with rich deposit and favorable mining condition and fully supplying equipment and materials.

The Kaechon Area Coal-mining Complex and the Tokchon Area Coal-mining Complex have made successes in securing reserve coal faces by scrupulously conducting the work to improve the general technical and skill levels of tunnelling workers and organising a campaign in which one overtakes and learns from others and swaps experiences with them.

The Tukjang Area Coal-mining Complex and the Kujang Area Coal-mining Complex are raising the utilisation rate of tunnelling equipment including rock drills and compressors and tightening cooperation among processes to secure much more deposits of coal.

China iron-ore imports hit by weather-related disruptions

China's iron-ore imports in the first two months of 2025 fell by 8.4% from the same period a year earlier, curbed by weather-related supply disruption in major producer Australia.

The world's largest iron ore consumer brought in 191.36-million metric tons of the key steelmaking ingredient during January and February, customs data showed.

The number works out to a monthly average of 95.68-million tons. That compared to 112.49-million tons in December and a monthly average of 103.2-million tons in 2024.

China combines import data for January and February to smooth out the impact of the week-long Lunar New Year holiday, the timing for which changes each year.

The annual fall is largely because of weather-related supply disruption in major supplier Australia, said analyst Shan Peng at trading company China Base Ningbo Group.

"But the total volumes are around 10-million tons higher than our earlier forecast, probably because miners stepped up shipments after the cyclone effect retreated," Shan added.

A survey from Reuters in February showed that analysts expected to see an annual slump of at least 10% for January and February.

Operations at Western Australia's major iron ore hubs – Port Hedland and the Dampier – had been suspended due to cyclone Zelia, the most severe cyclone since April 2023.

Rio Tinto RIO.AX, the world's largest iron ore producer, expects a loss of 13 million tons of iron-ore from cyclones that have hit Australia's west coast and disrupted iron ore shipments this year.

China's iron ore imports in March will likely top 100-million tons as miners ramped up shipments to achieve quarterly and annual targets after cyclones disrupted shipments in the prior two months, analysts said.

China's steel exports over January-February rose 6.7% from the year earlier to 16.97-million tons, the customs data showed.

Steel imports in the first two months fell 7.2% year-on-year to 1.05 million tons.

Trump authorises his administration to open new coal-fired power plants in the US

President Donald Trump says his administration will open new coal-fired power plants in the U.S. to help the U.S. compete economically with other countries.

"After years of being held captive by Environmental Extremists, Lunatics, Radicals, and Thugs, allowing other Countries, in particular China, to gain tremendous Economic advantage over us by opening up hundreds of all Coal Fire Power Plants, I am authorising my Administration to immediately begin producing Energy with BEAUTIFUL, CLEAN COAL," Trump said in a Truth Social post.

The amount of electricity produced from coal declined from a high of 1,847 terawatt hours in 2010 – enough to power more than 171m households – to a low of 675 terawatt hours in 2023 – enough to power 62.5m homes. Approximately 40% of the remaining coal-fired capacity in the US is planned to be retired by 2030, according to a 2023 study by the Institute for Energy Economics and Financial Analysis.

Trump's announcement provided no details on how the goal would be accomplished.

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Mantashe says 'King Coal is back' as Seriti launches a new colliery

The coal industry was supposed to be going the way of the dodo, but it is actually showing no sign of being an endangered species.

Coal producer Seriti Resources had the official launch for its Naudesbank Colliery near Carolina, Mpumalanga recently, and Minerals and Petroleum Resources Minister Gwede Mantashe said more were in the pipeline.

"King Coal is back!," a jovial Mantashe told Daily Maverick as he stood on a muddy embankment overlooking the open-cast mine as big yellow machines rumbled around a swelling mound of coal.

"We are still mining coal aggressively everywhere where we find it. There is no limitation. Look at this mine, it has a 20-year life," Mantashe, a former coal miner himself, said.

Mantashe's unapologetic affection for coal is well known.

But the public perception is that a new mine in South Africa – let alone a new coal colliery – is as rare as hen's teeth.

South Africa is a party to the Paris climate accords, committing it to reducing its carbon emissions as part of the overarching goal to hold "the increase in the global average temperature to well below 2°C above pre-industrial levels" and pursue efforts "to limit the temperature increase to 1.5°C above pre-industrial levels".

But Mantashe told Daily Maverick that the Naudesbank Colliery is the third new coal mine to open in Mpumalanga in the past six months.

And on the global stage, coal is displaying renewed signs of life.

According to the Global Energy Monitor, coal capacity in 2023 – the last year for which the data is available – grew 2% worldwide.

"Since the 2015 Paris Climate Agreement, almost all countries have reduced their coal-fired power plant capacity under development, and more than half the countries with coal-fired power plants have reduced or kept operating coal capacity flat," it said in its latest annual review of the sector.

"However, despite promising momentum, the world's operating coal power capacity has grown 11% since 2015, and global coal use and coal capacity reached an all-time high in 2023."

China, in 2023, accounted for two-thirds of new coal capacity. But outside of China, the report noted that "the coal fleet also saw a small 4.7GW uptick for the first time since 2019".

And 2023 also saw the biggest net increase in coal capacity worldwide since 2016.

Finance taps still open

It has also been the case that a growing number of banks have stopped providing finance for new coal projects – there would almost certainly be more capacity for the fossil fuel were it not for that trend.

But the brakes have also been applied on this front.

"In 2023, 23 top private financial institutions adopted new or updated coal policies, a significant slowdown from the 57 that adopted policies in 2022," the Global Energy Monitor report noted.

In his remarks at the opening on Friday, Mantashe pointedly said: "Coal is growing and the discussions are changing… coal mining will be here in South Africa for about 200 years."

Future historians will evaluate the accuracy of that assertion.

There are a number of reasons that coal has not gone into the precipitous decline that had been expected and that many greens have hoped for.

The green energy transition and global decarbonisation drive are in full throttle, but not yet at the pace needed to set the fossil fuel industry on the road to extinction.

China – as is often the case – has been the driving force. It is a leader in green energy but has also been adding new coal capacity at a rapid pace even as its dizzying rates of economic growth have slowed.

Trump 2.0 is also breathing new life into coal, and the fossil fuel industry still has a lot of clout worldwide, even as it claims to be embracing the energy transition.

But as they say, turkeys don't vote for Christmas.

In the case of South Africa and other developing economies, the standard argument in defence of coal is that poorer nations should not have the same burdens as their wealthy peers whose own path to prosperity was paved with fossil fuels.

Critics say this is short-sighted as key markets such as the EU impose punitive measures on imports with heavy carbon footprints. And developing economies are and will continue to bear the brunt of rapid climate change – so it is in their interests to also decarbonise.

Seriti, a privately held, black-owned company, is in some ways a microcosm of these wider issues.

The mine will employ 300 workers and produce a million tonnes of coal a year for export – so it will create jobs and bring hard currency into South Africa.

Seriti also has a green unit – Seriti Green – and it has a 900MW renewable project. Of that, 155MW of wind energy will be used to power the company's coal mines.

Coal producers are going green while simultaneously producing more of the stuff that has stuffed up the climate.

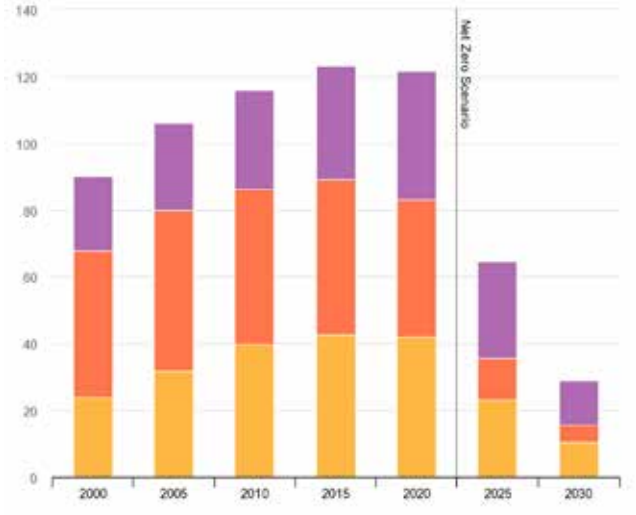
Coal may or may not be a thing in South Africa in 200 years. But the sun is hardly setting on the industry just yet.

Strategies to reduce z from fossil fuel operations

Methane emissions from fossil fuel operations are a significant contributor to human-caused methane emissions, and addressing these emissions presents a valuable opportunity for near-term climate action. Methane is a potent greenhouse gas, with a much higher warming potential than carbon dioxide over a shorter time frame.

Fossil fuel operations account for more than one-third of human-caused methane emissions. These emissions represent one of the best near-term opportunities for climate action because the pathways for reducing them are known and understood. Achieving a 75% reduction in emissions from fossil fuel operations, as set out in the IEA's Net Zero Emissions by 2050 Scenario would take the world most of the way towards fulfilling the Global Methane Pledge.

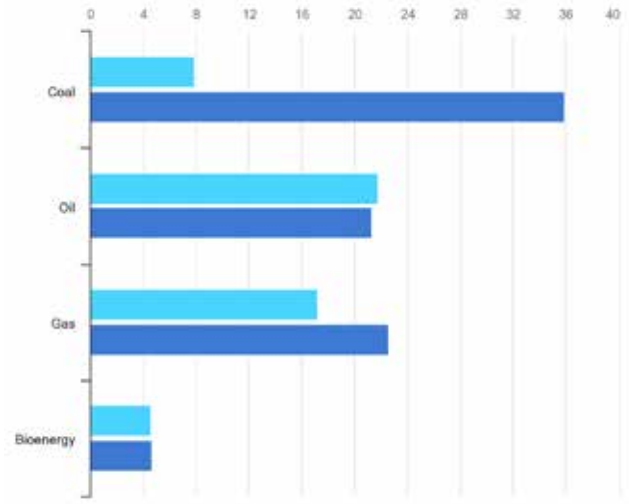
Methane emissions from fossil fuels, historical and in the Net Zero Scenario, 2020-2030



A BROAD COALITION IS NEEDED TO PUT METHANE EMISSIONS FROM FOSSIL FUEL OPERATIONS ON A PATH TOWARDS NET-ZERO

Countries that have joined the Global Methane Pledge currently account for over 45% of total human-caused methane and for about one third of methane from fossil fuel operations. Even if these countries take every available step to reduce emissions within their borders, it would still not deliver a 30% reduction in global emissions by 2030. Forward-leaning countries need to capitalise on the momentum created by the Global Methane Pledge to bring new members to the coalition.

Methane emissions from energy from Global Methane Pledge participants and non-participants, 2021

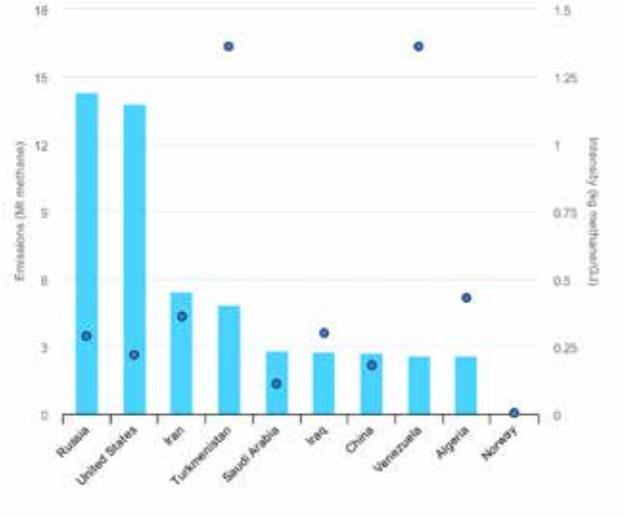


EMISSIONS CAN BE GREATLY REDUCED USING PROVEN TECHNOLOGIES AND POLICIES

The methane emissions intensity of oil and gas operations varies greatly across countries, with the best performing countries having an emission intensity over 100 times lower than the worst performers. High emission intensities from oil and gas operations are not inevitable; they are an

"above-ground issue" that can be addressed cost-effectively through a well-established combination of high operational standards, firm policy action and technology deployment.

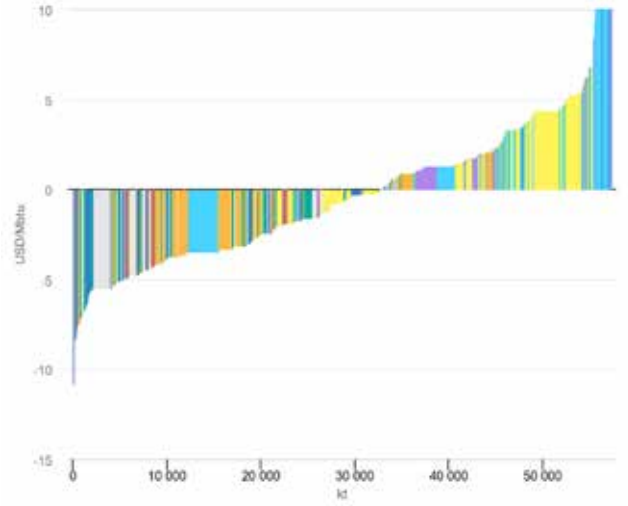
Over 40% of oil and gas emissions could be reduced at no net cost using well-known existing technologies



The technologies and measures to prevent methane emissions from oil and gas operations include leak detection and repair campaigns, installing emissions control devices, and replacing components and devices that emit methane in their normal operations.

The cost effectiveness of abatement measures vary by country, depending on the prevailing emissions sources, capital and labour costs, and natural gas prices. We estimate that it is technically possible to avoid over 70% of today's methane emissions from global oil and gas operations. Based on average natural gas prices over the past five years, over 40% of methane emissions from oil and gas operations could be avoided at no net cost as the outlays for the abatement measures are less than the market value of the additional gas that is captured. Based on the elevated natural gas prices seen in 2021, almost all of the options to reduce emissions from oil and gas operations worldwide could be implemented at no net cost.

Marginal abatement cost curve for oil and gas-related methane emissions by mitigation measure, 2021

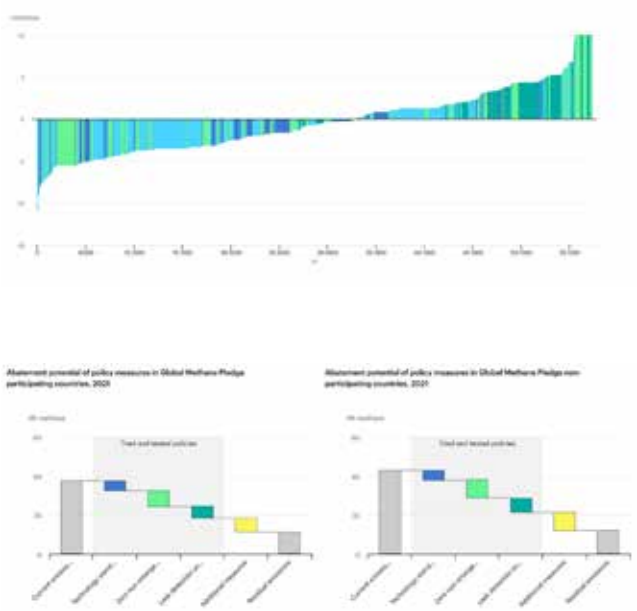


UNIVERSALLY ADOPTING TRIED-AND-TESTED POLICIES WOULD CUT WORLDWIDE EMISSIONS FROM OIL AND GAS OPERATIONS IN HALF

As outlined in Curtailing Methane Emissions from Fossil Fuel Operations, a range of well-established policy and regulatory tools exist to help countries create the right incentives. These "tried and tested" policies include leak detection and repair requirements, equipment mandates and measures designed to limit non-emergency flaring and venting. Adopting these policies globally would reduce emissions from oil and gas emissions by half.

There are additional available policies available that would result in the full adoption of all technically feasible abatement options and lead to a 70% reduction in methane emissions from oil and gas operations. These include emissions pricing, financing instruments, and performance standards that would need to be supported by robust measurement-based monitoring regimes.

Marginal abatement cost curve for oil and gas-related methane emissions by policy option, 2021



Several countries have adopted elements of these tried and tested policies, but no country has adopted all of them. Even early movers on methane regulation need to redouble their efforts to reach their full abatement potential. In parallel, these countries can support others by providing technical assistance and support, especially for countries that may be considering methane emissions for the first time.

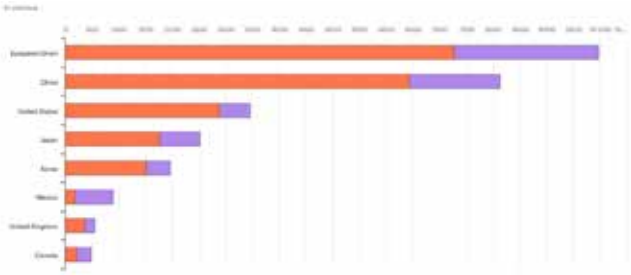
The IEA's Policies Database brings together more than 350 examples of policies that can directly or indirectly support methane abatement. Building on these examples, the IEA has prepared a detailed "how-to" guide for policy makers looking to develop new methane policies and regulations. This Regulatory Roadmap and Toolkit collects the experience of regulators around the world and can serve as a blueprint to support further technical assistance and capacity building efforts.

INCENTIVES, DIPLOMATIC ENCOURAGEMENT AND INSTITUTIONAL SUPPORT COULD LEAD TO MAJOR REDUCTIONS FROM INTERNATIONALLY TRADED OIL AND GAS

Much fossil fuel production takes place in countries that have not joined the Global Methane Pledge, yet around 40% of their oil and gas production is exported to countries that joined the Pledge.

These importers can encourage reductions from their trading partners through a mix of actions, including diplomatic pressure, incentives, technical and institutional support, and trade measures. Examples include financing instruments, emissions certificates, price premiums for lower intensity gas, minimum intensity standards and border adjustment mechanisms. Efforts are more likely to be effective if paired with technical and institutional support to enhance regulatory capacity and mitigate distributional impacts. If countries with strong methane commitments enrol their trading partners, this could reduce global emissions from oil and gas operations by more than 10 Mt, boosting the reductions that could be achieved through domestic action alone by around 50%.

Methane emissions of imported oil and gas in selected countries and regions, 2020



EARLY WARNING SYSTEMS TO PINPOINT LEAKS COULD FACILITATE TIMELY ACTION AND LARGE REDUCTIONS IN EMISSIONS

Efforts to improve transparency in emissions data could be particularly effective at bringing in new partners while simultaneously improving our understanding of emissions. The European Union has committed to several efforts to improve the transparency of emissions data, including funding the International Methane Emissions Observatory, actively supporting the Oil and Gas Methane Partnership 2.0, and proposing to collect and make public information collected from operators and importers under its recently proposed methane regulations. These measures may encourage the uptake of measurement and reporting standards and help companies and countries identify abatement opportunities.

Satellite technology in particular has the potential to drive significant reductions. Existing satellites and processing technologies can already detect and quantify large leaks over a wide geographic area. Governments and companies should explore establishing transparent systems to efficiently alert regulators, operators and other stakeholders to large leaks as soon as they are detected. This would require creating a network of contacts to allow rapid communication of leaks to those on the ground best able to address them. Based on current instruments and capabilities, we estimate that such a system could already avoid close to 3 Mt of methane emissions associated with large emissions events each year. Private companies and industry groups may also look to establish similar dedicated networks of monitoring devices covering their facilities to rapidly accelerate their responses to leaks.

VOLUNTARY INITIATIVES CAN PLAY A KEY ROLE IN ENSURING TIMELY REDUCTIONS

Along with actions by governments, the industry and investment community have important roles to play in driving rapid cuts and furthering abatement efforts. Companies can often move more quickly than governments, particularly where regulatory capacity is limited; companies are also closer to the problem at hand and have the required technical capabilities to manage methane emissions. Investors and financiers can play an important role by sending clear signals that good performers will be rewarded, as well as working with companies to set targets and hold them to account.

A number of oil and gas companies have already set targets to limit emissions, or reduce their emissions intensity. There are many voluntary, industry-led initiatives including the Methane Guiding Principles, the Oil and Gas Climate Initiative, the Oil and Gas Methane Partnership 2.0 and the China Oil and Gas Methane Alliance. Through these initiatives, companies have committed to reduce their emissions intensity over time, advocate for sound methane policy and regulation and to be more transparent about their emissions. While these initiatives are a promising step, they have so far not delivered demonstrable reductions on a wide scale. In order to drive the level of reductions needed, companies should adopt a zero tolerance approach to methane leaks from their facilities.

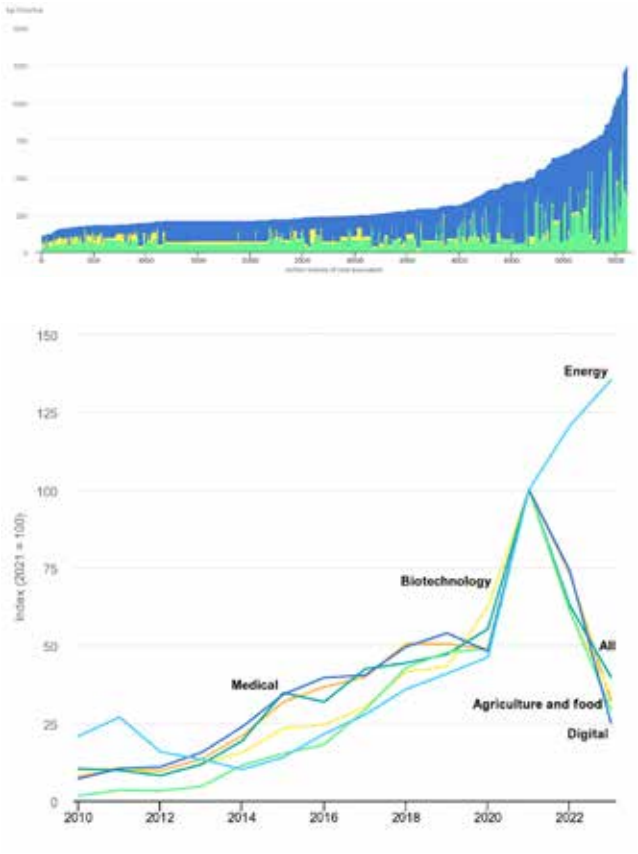
AVOIDING METHANE EMISSIONS FROM COAL IS CHALLENGING BUT MITIGATION OPTIONS EXIST

Tackling methane from coal operations is more challenging than for oil and gas operations. Reductions in consumption can play a major role in bringing down methane emissions but there are also significant opportunities to reduce emissions in the near term based on existing technologies. In the IEA's Net Zero Emissions by 2050 Scenario, coal use drops by 55% from 2020 to 2030, and by almost 90% by 2050. This decline would significantly cut methane emissions from coal mines as well as emissions of CO2 and other air pollutants; emissions reductions would be even larger if concentrated on the worst-performing coal assets. For example, removing the worst-performing quartile of production would remove around 25 Mt of methane while removing the best performing quartile would only remove about 4 Mt.

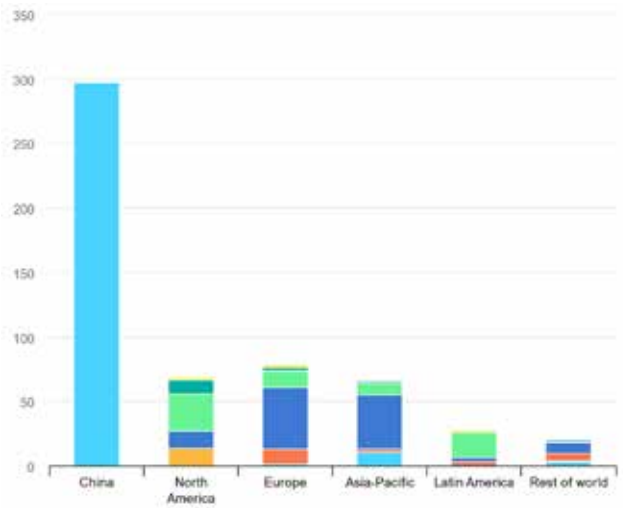
While reducing coal use would go a long way towards reducing emissions, policies and measures are still needed in the meantime to address methane leaks from coal operations. These include requirements for operators to capture methane using degasification wells and drainage boreholes prior to the start of production. For mines already in operation, ventilation air methane is often already captured. This can be used as an energy source,

for example to heat mine facilities or for coal drying. These technologies have already been implemented in numerous sites, but are still far from being standard industry practice. Policies and regulatory regimes are needed to broaden their use, either by creating proper incentives or by directly mandating that mine operators adopt these technologies.

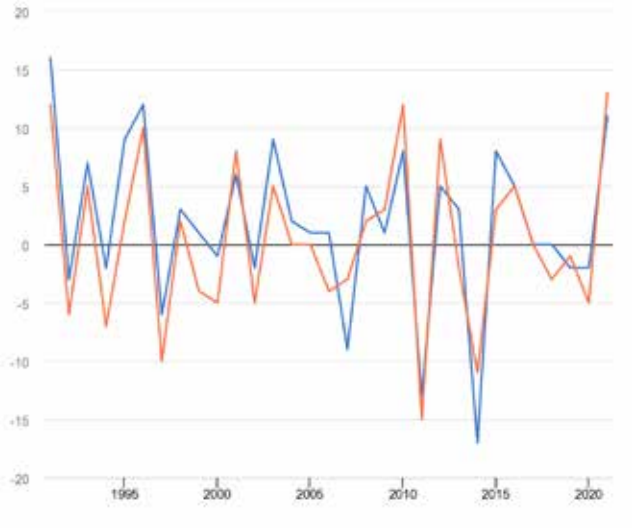
Indirect CO_2 and methane emissions from global coal supply, 2021

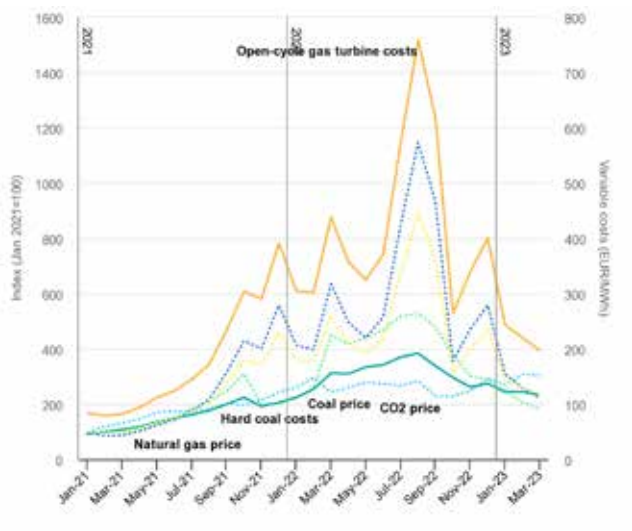


Solar PV and wind forecast by primary procurement type, 2023-2024

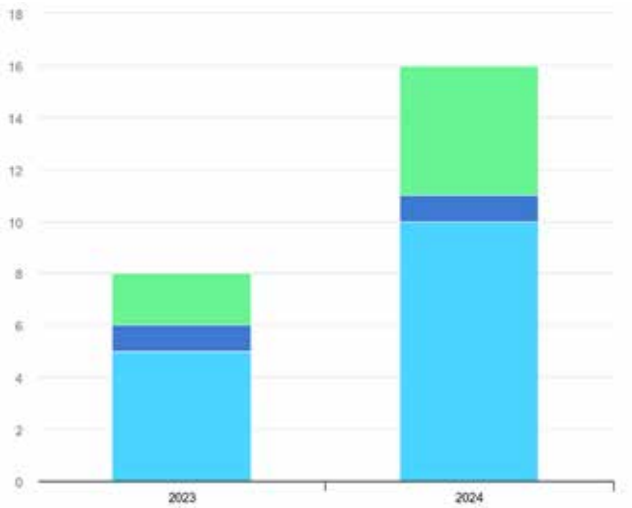


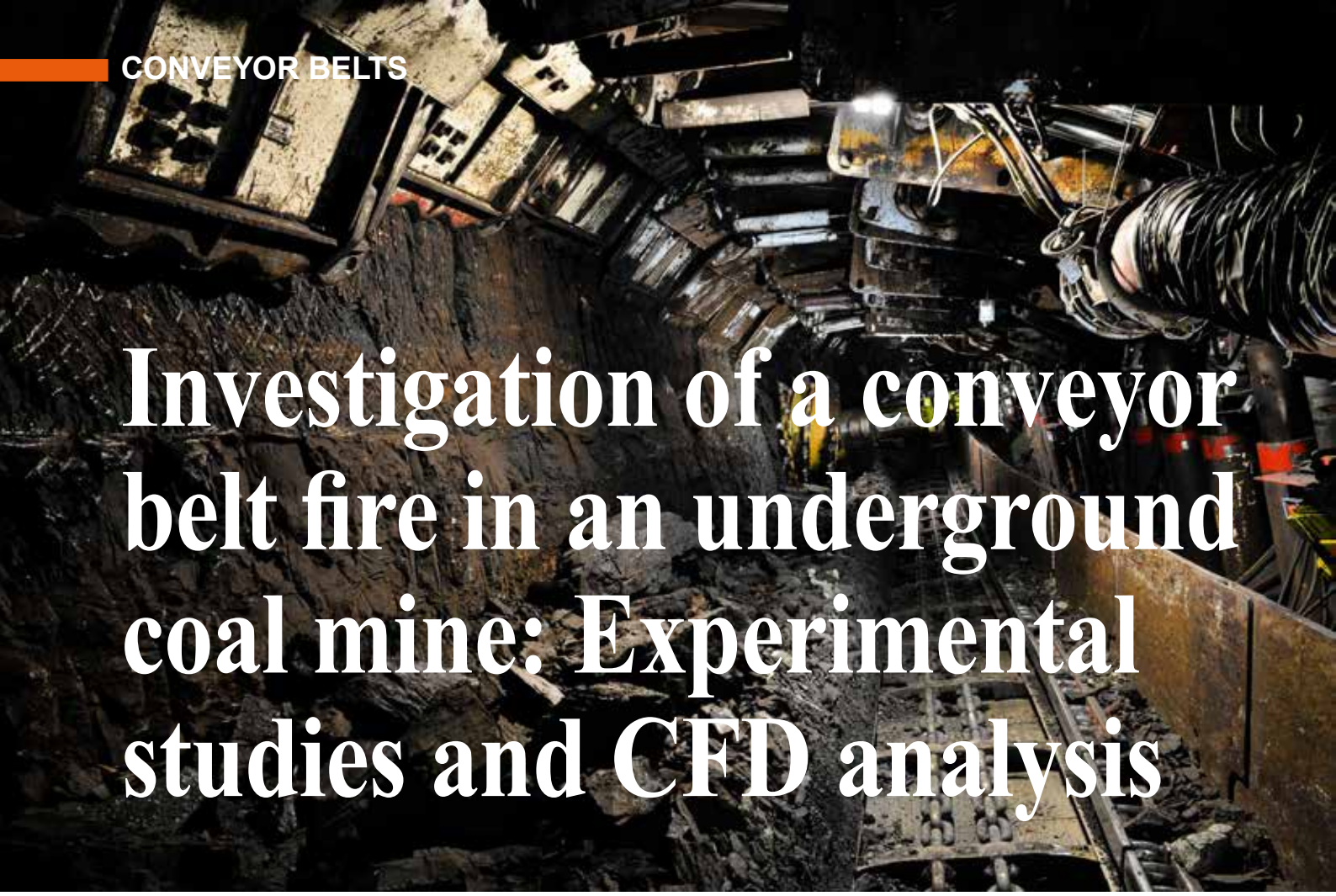
Correlations between annual heating degree days and final direct consumption of natural gas in buildings in the European Union, 1991-2020





Natural gas consumption displaced by projected additional renewable energy supply in the European Union in 2023 and cumulative in 2024





Investigation of a conveyor belt fire in an underground coal mine: Experimental studies and CFD analysis

Coal produced in underground mines is transported to the surface by means of conveyor belts throughout long roadways. The combustion of belts puts a large number of employees at great risk. Underground collieries differ from other underground mines -due to the combustible nature of the product. The most prevalent cause of belt fires in underground coal mine is spontaneous combustion due to oxidation of the coal, which also enables the conveyor belt to burn over time. In 2014, a belt fire in an underground coal mine in Manisa-Soma, Turkey caused 301 fatalities. A study has been conducted on this accident for approximately 3 years, consisting of combustion tests in a purpose-built research gallery, comparison of the test results with mine records of the accident, and CFD modelling of the mine environment. The intensity of the fire was sufficient to redirect the air flow underground, causin large amounts of toxic gases to fill almost the entire mine in approximately 15 minutes. It is recommended that CFD analysis be used in planning emergency action strategies in underground mines.

INTRODUCTION

In underground mining, there are many factors that can cause problems ranging from minor accidents to catastrophes. One of the most important of them is the quailty of air in underground airways, because low levels of oxygen or increased concentrations of dangerous gases endanger the health and safety of mineworkers. On the other hand, it is obvious that a healthy workplace results in greater productivity.

Since mining operations began, natural air flow has been used to provide ventilation by exploiting the air pressure differences between different parts of the mine. Altough this is an efficent method of ventilation, in some cases it does not suffice, such as dead end volumes, crosscuts, and blind spaces where the air cannot enter naturally. In order to provide fresh air entry for workers and the efficient operation of machinery, and to dilute contaminant to below the regulatory limits, high air flows are providee via fans.

The air flow that is needed for adequate ventilation has to be calculated in order to guarantee sufficent fresh air is present in both standard operational circumstances and exceptional circumstances or accidents. For example, during routine excavation and transportation work, the required amount of air to dilute the exhaust gases from machines should be calculated, as well as the flows needed in the case of an accident followed by a mine fire. However, there is another risk that is particularly associated with underground coal mining operations – that of conveyor belt combustion. The combustion process starts with coal oxidation, and

if unchecked can ignite the conveyor belt, producing substantial volumes of toxic gases. Barros-Daza *et. al*. (2021) classified belt fires according to the type (stage) of the fire and method of firefighting. The main hazards include reduced visibility, toxic effects of carbon monoxide (CO), and elevated air temperatures downstream of the fire (Perzak *et. al*., 1995). Five gaseous products of belt fires have been identified, i.e., carbon monoxide, carbon dioxide, hydrogen cyanide, hydrogen bromide, and sulphur dioxide (SO2) (NIOSH, 1988; Krawiec, 2021; MSHA, 2008).

In underground ventilation studies the complex air volumes, comprising multiple galleries or branches, are divided into sections with the same aerodynamic characteristics. Each section is assigned an air resistance and the obtained circuits are solved through network techniques such as the Hardy Cross method (Diego, Torno, and Toraño, 2011). In the past 10 years significant improvements have been made in software for ventilation plannoing purposes. There are different tols for calculating and rapidly testing the network, such as VENTSIM, VNET-PC, or VENPRI. In all cases, each software type employs a database of air resistances taken from specialised bibliographies or field measurements.

Ventilation studies are a type of fluid mechanics problem, and the most sophisticated method in this field is computational fluid dynamics (CFD). CFD allows for the calculation of the variables that define fluid movement in three-dimensional spaces, after a laborious procedure of model creation, meshing, and adjustment of the equations.

CFD is widely employed and validated in industry for solving fluid problems , with immediate applications in the calculation of ventilation flows in all kinds of systems, as shown by Ballesteros- Tajadura *et al*. (2006) and Hargreaves and Lowndes (2007), with particular relevance in multiphase studies of fire situations (Galdo Vega *et al*. 2008; Yuan and You, 2007). Chen *et al*. (2019) used CFD to simulate fire and smoke movement in a serious fire incident in a road tunnel.

In 2014, an accident occurred at an underground coal mine in Soma-Manisa, Turkey, in which 301 workers died. More than 250 of these workers were employed on a production panel (the S panel) located on the return airway. In this article, the events that developed after fire occured will be discussed more than the cause of the accident. Immediately after the accident, the entire mine was filled with highly concentrated gas emitted by a belt burning in an area where the air flow was almost 0.3 m/s., which is not sufficient to clean the air in a gallery under normal conditions. The conveyor involved was not a flameproof belt (legislation at the time did not require this).

The esperimental part of the investigation was conducted in a research gallery in which more than 100 conveyor belt fires have been simulated. Reliable data could not be obtained from all experiments, since belt burn-in did not occur in every case. Furthermore, due to the high gas concentration, it is extremely risky to enter the gallery to obtain data while an experiment is under way.

The data at the time of the accident was taken from the sensors in the mine and used as input for the CFD analysis. The results of the CFD analysis are comparable with the data from the sensors. The CFD analysis showed that the thermodynamics of the mine completely changed due to the fire.

THE RESEARCH GALLERY

IA research gallery was built with the aim of creating an environment similar to that in which the accident occurred, in order to investigate the combustion mechanism of the conveyor belt, to characterise the combustion products, and to determine the sequence of appearance and concentrations of these products. The section of the gallery where the tests were carried out was 16 m^2 in cross-section,

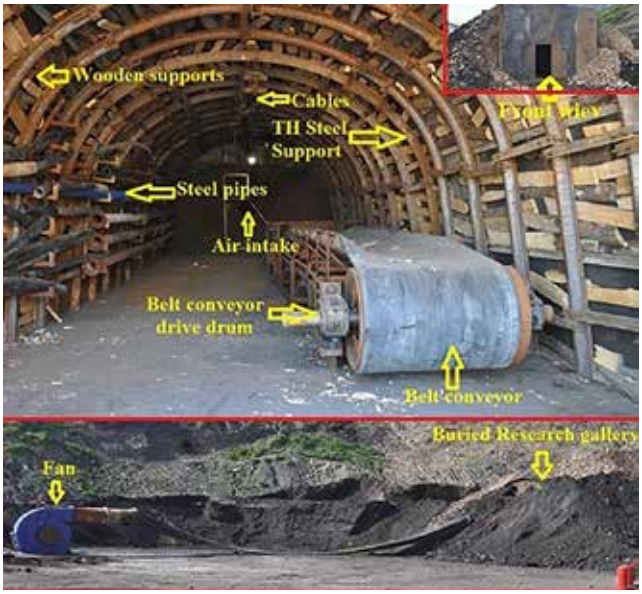


Figure 1: Photograph of the research gallery, showing support elements and auxiliary equipment.

Figure 2: Burning conveyor belt during the experiments, and burnt wood support materials and burnt belt after experiments.

Figure 3: Air velocity measurements, (a) air inlet clearance (5.39 m/s); (b) air velocity inside the gallery (0.67 m/s).

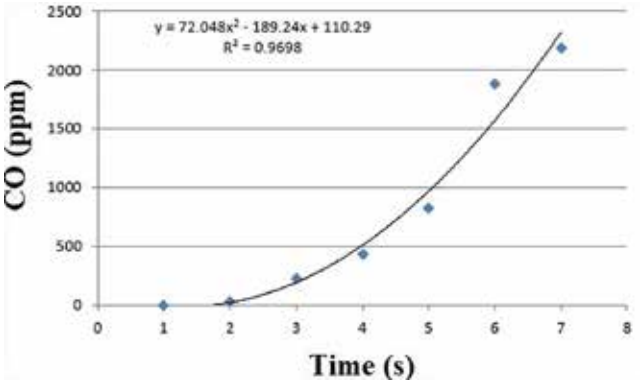


Figure 4: Change in CO concentration with time during the first experiment.

the same as the site of the fire, and the support and auxiliary equipment were the same. **Figure 1** shows a photograph of the gallery. Two gas sensors were used to determine the types and time-dependent concentrations of gases released by the combustion of the belt in the gallery. One sensor was used to measure the amounts of carbon dioxide (max. 500 ppm), carbon monoxide (max.10 000 ppm), methane (max. 4%) and oxygen, and the other measuring hydrogen cyanide (max. 50 ppm), hydrogen sulphide (max. 100 ppm), chlorine (max.50 ppm), and oxygen.

CONVEYOR BELT COMBUSTION EXPERIMENTS AND RESULTS

Various methods were attempted to burn conveyor belts, including using synthetic thinner, gasoline, coal, wood reinforcement material, coal-wood mixtures, and igniting them with an oxygen source. However, combustion only occurred in conveyor belts where coal and wood materials were used together. During these trials, the belt was not subjected to any force, also its temperature was adjusted to ambient. In some trials, experiments were carried out by placing the coal over the belt drum and the belt.

Combustion and post-combustion images obtained in the first experiments are given in **Figure 2**. As can be seen, the experiments were recorded both from the front of the gallery and from the back (inside). The front of the gallery was kept open in the first experiments, but it was sealed with steel in the later stages of the belt burning experiments and the camera was enclosed in the gallery.

In the combustion experiments, an opening was provided behind the gallery to simulate the air flow in the mine, allowing the intake of air from the fan (**Figure 1**). Air velocity measurements in this opening and inside the gallery are given in **Figure 3**. Approximately 100 experiments were carried out. One of the data- sets from the CO sensor during the first experiment is given in **Figure 4**. The gas sensors were calibrated after each experiment.

Gas measurements were taken in all tests. The most important information gained from these measurements is that the amounts of gas released after belt fire are very similar. As shown in **Figure 5**, the amount of oxygen in the ambient air is 8.12% (frequently below 3%), the CO level is higher than 10 000 ppm (the sensor's CO measurement limit), the carbon dioxide level is above the measurement limit of the sensor, and the concentration of methane is 3.86%. Although there was no methane in the environment before combustion, the sensors detected methane once combustion had started. It was found that the combustion gases that contain hydrocarbons can be detected as methane by the sensors. When the belt started to burn, a very strong flame appeared and it was very difficult to extinguish this fire. The main reason for this is that the hydrocarbons produced by combustion of the petroleum-derived belt material act as a fuel and feed the fire. Data on the gases measured with the other sensor is given in **Figure 6**.

As seen in **Figure 6**, in addition to CO, CH_4, O_2, and CO_2, hydrogen cyanide, hydrogen sulphide, and chlorine were also emitted. These gases can be quickly fatal if inhaled at high concentrations. In the conveyor belt burning experiment depicted in **Figure 6**, the hydrogen cyanide concentration in the ambient air was measured at 50 ppm (the upper limit of detection by this sensor). The chlorine concentration was 17.6 ppm, hydrogen sulfphde concentration 78.9 ppm, and CO concentration 500 ppm (also the upper limit of detection for this sensor, measured above 10 000 ppm with the other sensor). Legislation does not permit work in atmospheres containing less than 19% oxygen, and more than 2% methane, 0.5% carbon dioxide, 50 ppm (0.005%) carbon monoxide and other dangerous gases. The maximum hydrogen sulphide concentration permitted for 8 hours of operation is 20 ppm (0.002%). The upper measurement limits of the sensors used in these experiments wre exceeded for some gases – according to the law, the limit of the sensors in the mine cannot be less than twice the allowable values. Since no information was available on the actual gas concentrations,

Figure 5: Variation in gases in the ambient air as a result of conveyor belt burning (experiment carried out on 3 July2015).

a best-fitting approach was used to estimate concentrations. The simulated CO concentration in the environment is depicted in **Figure 7**. In this approach, both the sensor data in the mine during the accident (the sensor data in the mine was cut off about 3 minutes after the start of the fire) and the time-dependent gas concentration data from the experiments conducted in the research gallery were used.

GAS DATA OBTAINED FROM SENSORS IN THE MINE

Belt fires pose a great risk not only for underground coal mines, but also in other enclosed environments. It is thus very important to examine the events that occurred during the fire in the mine and the behaviour of the toxic gases that were evolved.

In an underground coal mine, a fire on a belt transporting coal may becomr so intense that it affects the thermodynamic conditions across almost the entire mine.

Ventilation in underground mines is provided using pressure differentials. The air moves from high pressure regions to the low pressure regions. However, as the temperature in the gallery increases with the burning process, the air pressure also increases.

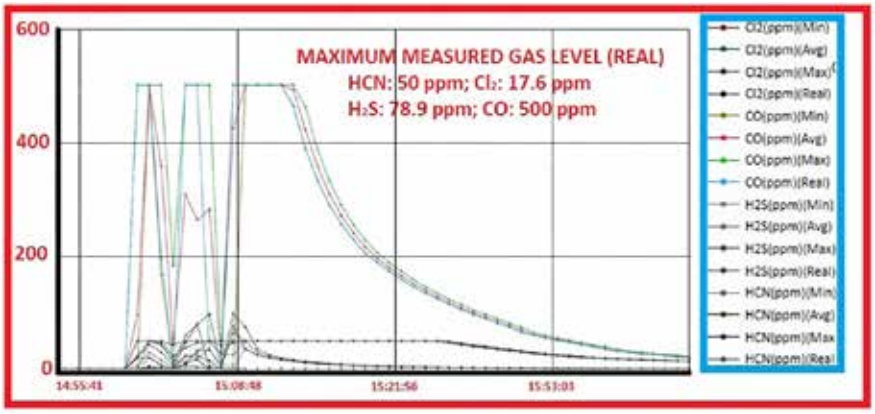


Figure 6: Gas concentrations in the gallery air (experiment carried out on 15 September 2016).

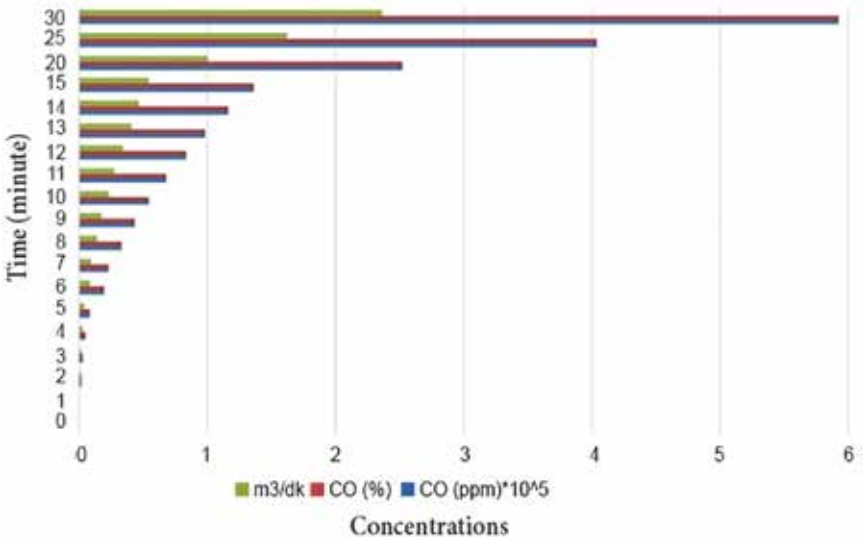


Figure 7: Estimated CO concentration in ambient air 30 minutes after the start of the fire.

Therefore, the heated air will move from the fire zone to the other parts of the mine. This movement can be very rapid, substantially altering the ventilation conditions underground.

A CFD analysis was carried out in order to accurately determine how the air flow in the mine was affected by the fire. For this purpose, the structural layout of the mine, and the features of the equipment used (secondery fans, ducts etc.) were modelled. The CFD model view of this mine is shown in **Figure 8**. The gallery walls In the area where the belt fire occurred are composed of rock, not coal. However, there was coal on the belt, the wood support elements, as well as the supporting steel sets . For this reason, an effort was made to create a srealistic an environment as possible in the experimental gallery. In CFD study, the data obtained as a result of the experiments carried out in the research gallery was used.

The data, from the CO sensors numbers 431, 501 and 545 and CH4 sensor 404 is listed in **Table I** (extracted from the Committee Report).

CFD ANALYSIS

The mining model for the CFD analysis was prepared on a 1:1 scale. In this model, the air gates employed in the mine, secondary and main fans, ducts and in-mine settlement were operated exactly as was done in the mine Using the ANSYS FLUENT CFD solver, the mass and momentum conservation equations (Navier-Stokes equations) were solved in order to calculate the air flow (given in **Equations 1** and **2**).

Mass conservation equation:
Equation 1

$$\frac{\partial p}{\partial t} + \nabla.(\rho\vec{v}) = S_m$$

Here S_m is the user-defined source term added to the continuous phase.

Momentum conservation equation:
Equation 2

$$\frac{\partial}{\partial t}(\rho\vec{v}) + \nabla.(\rho\vec{v}\vec{v}) = -\nabla p + \nabla.(\bar{\bar{\tau}}) + \rho\vec{g} + \vec{F}$$

Here
p is static pressure
$\bar{\bar{\tau}}$ stress tensor
$\rho\vec{g}$ gravity effect
$\vec{F}$ external effects (contains user-defined source terms)

The stress tensor is defined as in **Equation 3**.

Equation 3

$$\bar{\bar{\tau}} = \mu\left[(\nabla\vec{v} + \nabla\vec{v}^T) - \frac{2}{3}\nabla.\vec{v}I\right]$$

Here, μ is the molecular viscosity and I a tensor.

Heat transfer and mass transfer are important in this problem as well as the Navier-Stokes equations, The conservation of energy and transport equation for species are solved as follows (**Equations 4** and **5** respectively).

Equation 4

$$\frac{\partial}{\partial t}(\rho E) + \nabla.\left(\vec{v}(\rho E + p)\right) = \nabla.\left(k_{eff}\nabla T - \sum_j h_j\vec{J}_j + \left(\bar{\bar{\tau}}_{eff}.\vec{v}\right)\right) + S_h$$

k_{eff}: effective transmission coefficient (when k+k_t, k_t is given as a turbulent thermal conduction coefficient)
$\vec{J}j$: diffusion of species
j: diffusion of flow.

Equation 5

$$\frac{\partial}{\partial t}(\rho Y_i) + \nabla.(\rho\vec{v}\,Y_i) = -\nabla.\vec{J}_j + R_i + S_i$$

Here,
Y_i: local mass fraction for each species
R_i: the production of net species formed by the chemical reaction
S_i: user-defined sources.

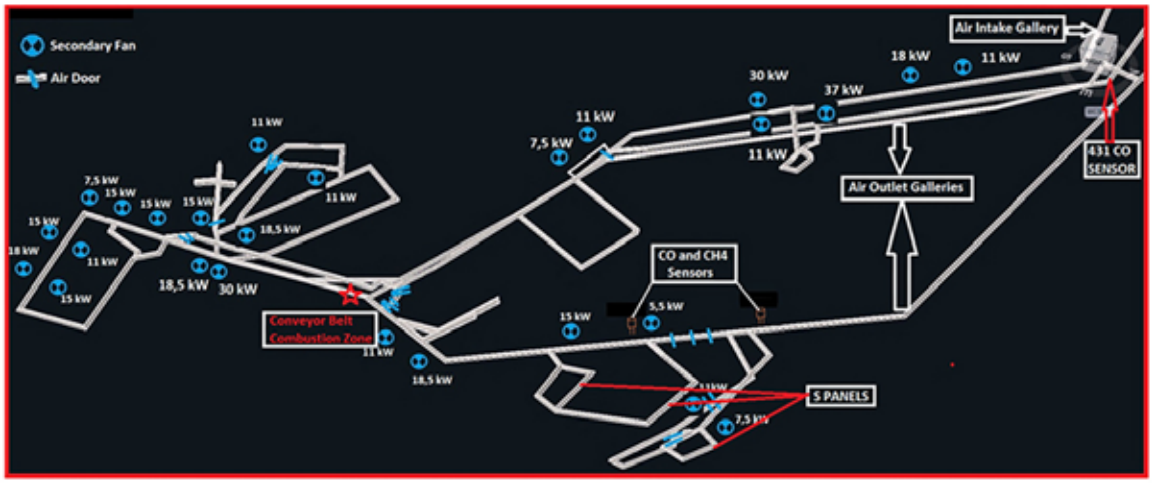


Figure 8: Simplified model of the underground mine and data used for CFD analysis.

Table 1: Gas concentrations measured in the mine during the belt fire

Time	Sensor 431, CO (ppm)	Sensor 501, CO (ppm)	Sensor 545, CO (ppm)	Sensor 401, CH4 (%)
14:54:00		0	4.973	
14:56:00		0	4.973	
14:57:00		0	6.969	
14:58:00		0	12.957	
14:59:00		0	56.871	
15:00:00		0	128.729	
15:01:00		0	282.427	
15:02:00	1.961	0	454.090	
15:03:00	1.961	50.980	500*	
15:04:00	25.867	135.294	500*	
15:05:00	73.678	249.020	500*	
15:06:00	169.302	378.431		
15:07:00	312.737	500*		
15:08:00	500*	500*		
15:09:00	500*	500*		
15:10:00	500*			
15:11:00	N/A			
15:12:00	N/A			
15:13:00				N/A
15:14:00				N/A
15:15:00				3.904
15:16:00				N/A
15:17:00				N/A

*Higher values could not be read because 500 ppm is the upper limit of the sensors used in the mine. According to the law, work is not permitted in places where there is less than 19% oxygen, more than 2% methane, more than 0.5% carbon dioxide, more than 50 ppm (0.005%) carbon monoxide and other dangerous gases. The highest concentration of hydrogen sulphide allowed for 8 hours of operation is 20 ppm (0.002%).

In gaseous underground coal mines, turbulence ventilation is used in order to dilute the gases in the gallery walls and evacuate them from the mine air. The main purpose is to allow the air to flow in a swirling manner and to remove the dangerous gases that settle in the spaces on the gallery walls before they reach a high concentration. There are several methods for integrating this situation into the numerical model. In these methods, the k-e turbulence model is used in CFD analysis to ensure that the air flow in the model is under turbulent flow conditions. The k-e turbulence model has been used in addition to previous models to consider the effect of turbulence in numerical modelling. Accordingly, the turbulent kinetic energy equation and corresponding diffusion rate equation are solved (**Equations 6** and **7**).

Equation 6

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_i}(\rho k u_i) = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right] + G_k + G_b - \rho\varepsilon - Y_M + S_k$$

Equation 7

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_i}(\rho k u_i) = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right] + G_k + G_b - \rho\varepsilon - Y_M +$$

In these equations;

G_k: turbulent kinetic energy production from velocity gradients

G_b: rising turbulent kinetic energy production

Y_M: unstable expansion allowance for compressible turbulence $C_{1\varepsilon}$, $C_{2\varepsilon}$, and $C_{3\varepsilon}$ are constants, the Prandtl numbers of turbulence for k and ε are specified as σ_k and σ_ε. Finally, S_k and S are user- defined source terms.

More detailed information about the equations given above can be found in the ANSYS FLUENT Theory Guide (2013).

The data required for the fire scenario simulation was determined from a literature survey (Wang *et al*., 2009; Galdo Vega, 2008) and our research results. The model in the literature for such a fire is termed the 'pool fire' (Guan *et al*., 2013) A 7.5 MW fire was simulated for the fire model. In order to establish similarity in CFD analysis, a fire model should be selected. When the fire models were examined, it was understood that the perfect combustion model for diesel was similar to this study. According to Wang *et al*. (2009) and Galdo Vega *et al*. (2008), the pool fire for diesel is considered as complete combustion. The perfect combustion equation for diesel is

Equation 8

$$C_{10}H_{22} + 15.5(O_2) + 58{,}28(N_2) \rightarrow$$
$$10(CO_2) + 11(H_2O) + 58.28(N_2)$$

The atomic mass units of elements and combustion equation variables used in the analysis are given in **Tables 2** and **3**, respectively.

CFD RESULTS

The movement of the CO gas with time is depicted in **Figure 9**, and that of CH_4 gas in **Figure 10**.

From the distribution of CO and CH_4 depicted in **Figure 11**, it is evident that the air flow undergoes a significant change within the gallery. The pre-fire air flow is represented by the green colour, while the post-fire air flow is shown in red. Notably, the return air that should exit the mine is redirected back into the mine after the fire. This phenomenon is primarily attributed to the increased temperature and pressure in the fire zone, causing the heated air to move towards cooler regions of lower pressure. While a portion of the CO and CH_4 gases escapes the mine, some gases are redirected back inside due to the intensive emission of CO gas and the limited gallery space. The altered thermodynamic conditions of the mine also contribute to this phenomenon.

In order to analyse the flow direction change the velocity, flow, gas distribution, and temperature were calculated in different regions of the flow volume. **Figure 12** shows the locations of six of these measurement points.

The mass flow versus time graphs for four of these measurement points are shown in **Figure 13**. It can be seen that the mass flow value at points 3 and 4 is initially positive,becoming negative after about 1000 seconds.

With the change of direction of the air flow, it is seen that the mass flow rates increase rapidly in the main galleries, especially at measurement points 1 and 2, after 800 seconds. Velocity-time plots at the same points are shown in **Figure 14**. Flow lines of one of the fans in the mine are shown in **Figure 15**.

The mass ratio-time graph for CO at measurement point 3 is shown in **Figure 16**. CO reaches this area in about 8 minutes from the start of the fire. Fluctuations between 1220 and 1800 seconds are due to the change in direction of the air flow. This measuring point is the region where the CO gas has the lowest dissemination in the surrounding galleries.

The mass ratio-time graph for CO at measurement point 5 is shown in **Figure 17**. CO gas reached this region in about 900 seconds from the start of the fire. The sudden changes observed at 1260 seconds are attributed to the change in direction of flow in this region.

The temperature-time graph at measurement point 4, where the flow changes direction, is plotted in **Figure 18**.

Finally, the mass ratio-time graph for CO gas at measurement point 6 on the main roadway, where the flow moves by changing direction, is shown in **Figure 19**. It can be seen that the CO gas reaches this region in approximately 1440 seconds.

According to the data obtained, the flow accelerated due to the energy input in the fire zone and combined with the diffusion of gases in the air, caused the air flow to change direction at measurement point 4. The air flow in this main roadway, which is responsible for transporting polluted air to the atmosphere, underwent a reversal some time after the start of the fire.

CONCLUSIONS

In 2014 Soma-Manisa, one of the most important underground coal mines in Turkey, experienced a major accident. The cause of this accident, which had significant consequences, was a belt fire.

In this study, it was found that in addition to combustion products such as CO and CO_2, gases such as HCN, Cl_2, and H_2S, which are quickly fatal at low concentrations, are also released during a belt fire.

Another important finding is that the thermodynamic conditions in an underground mine can change completely in a very short time, depending on the magnitude of the fire.

The belts are made of petroleum derivatives, and hydrocarbon products are among the gases formed during combustion. These products are registered as CH_4 by the gas sensors.

Table 2: Atomic mass units of elements.

Element	H	C	N	O
Ma	1	12	14	16

Table 3: Combustion equation variables.

	Element and compound formula	Element and compound weight (Ma)	Stoichiometric mole number	Element and compound total weight (M)	Reaction total (Ma)	Total flow rate [kg/s]	Flow rate (kg/s)
Reactants	$C_{10}H_{12}$	142	1	142			0.048 874 59
	O_2	32	15,5	496	2269.84		0.170 716 879
	N^2	28	58,.8	1631.84		0,781 25	0.561 658 531
Products	CO_2	44	10	440			0. 151 442 392
	H_2O	18	11	198	2269.4		0.068 149 077
	N_2	28	58.28	1631;84			0.561 658 531

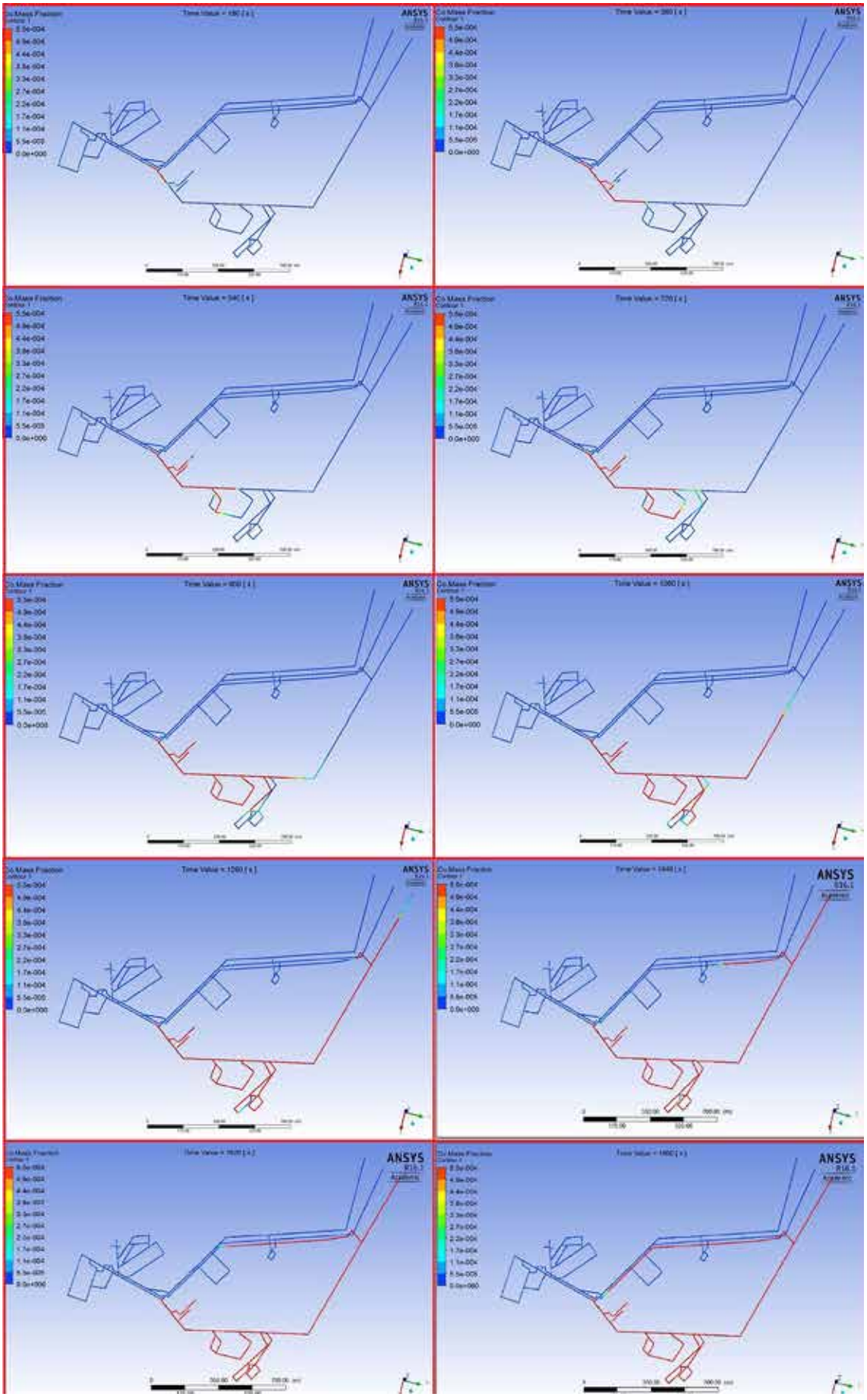


Figure 9: Path of CO gas during belt fire. A: 180 s, B: 360 s, C: 540 s, D: 1080 s, E: 1440 s, F: 1800 s.

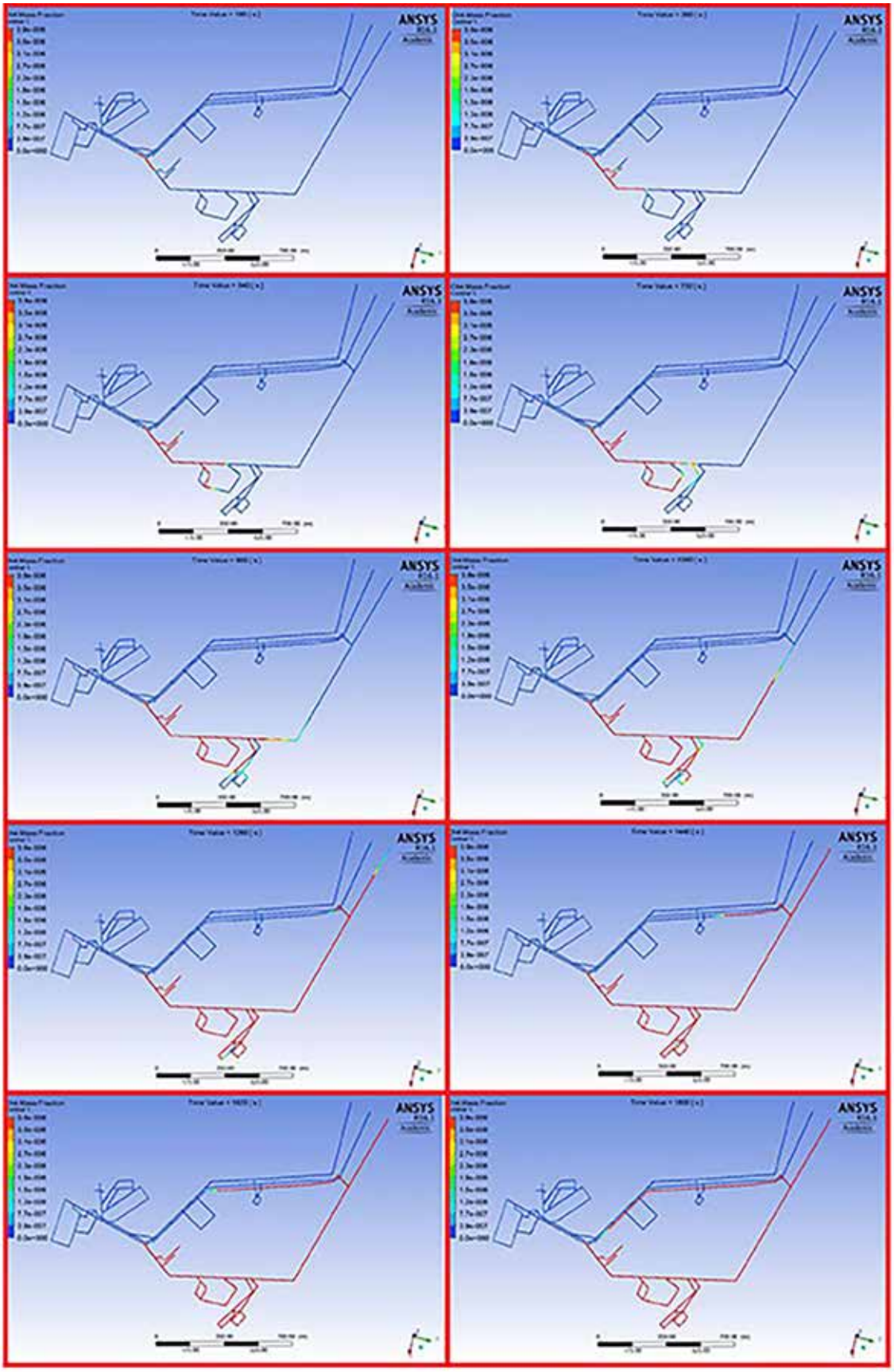


Figure 10: Schematic of change in air flow direction due to fire.

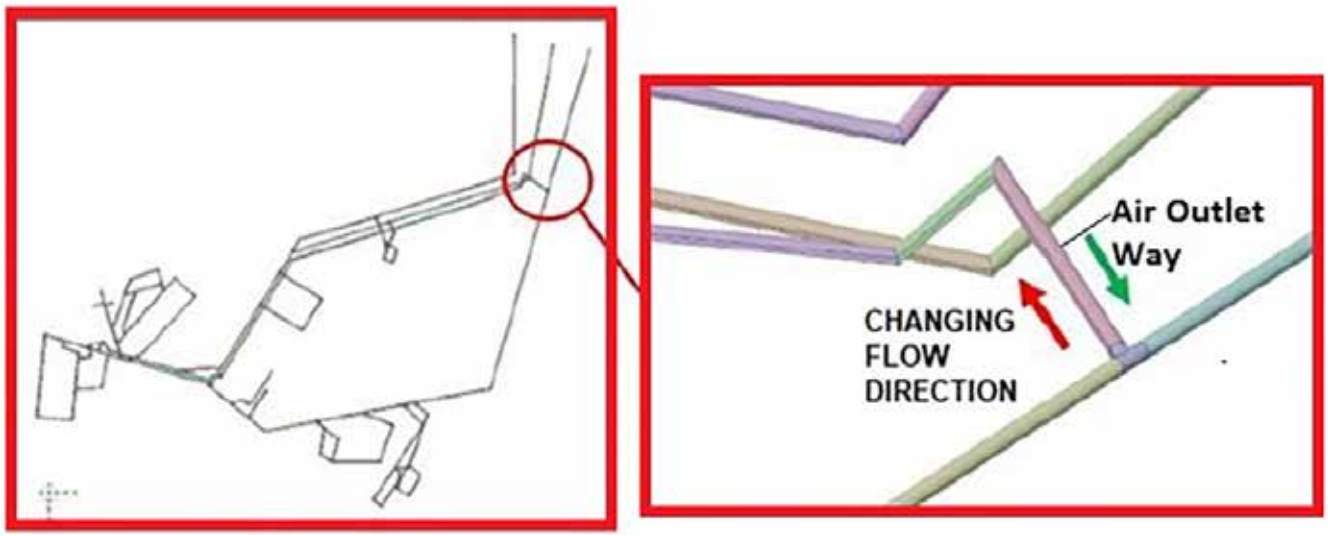


Figure 11: Locations of control points for measuring air velocity and flow rate.

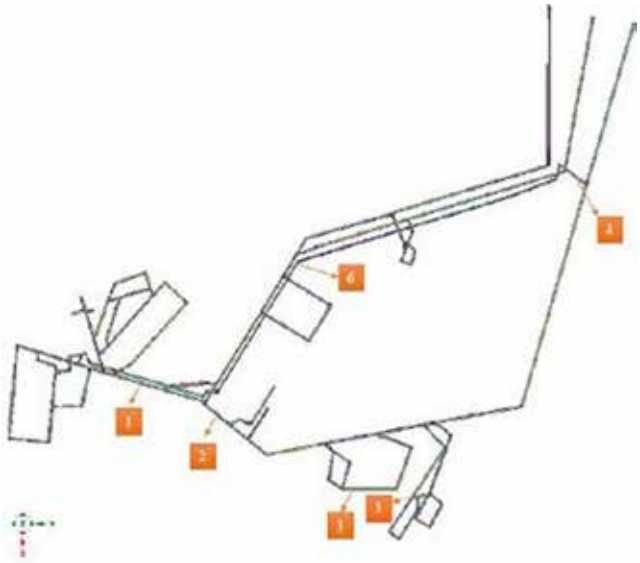


Figure 12: Locations of control points for measuring air velocity and flow rate.

Furthermore, the fact that these by- product gases are themselves flammable makes it very difficult to extinguish a conveyor fire, because the hydrocarbon combustion by-products in the environment continue to burn. Also, these products can accumulate in a part of the mine that is not at risk of fire, with the potential to cause an explosion.

The last important result from this study is that the air circulation in the mine can change unexpectedly due to a fire. For this reason, it is recommended that CFD analysis be used in planning emergency action strategies in underground mines.

REFERENCES

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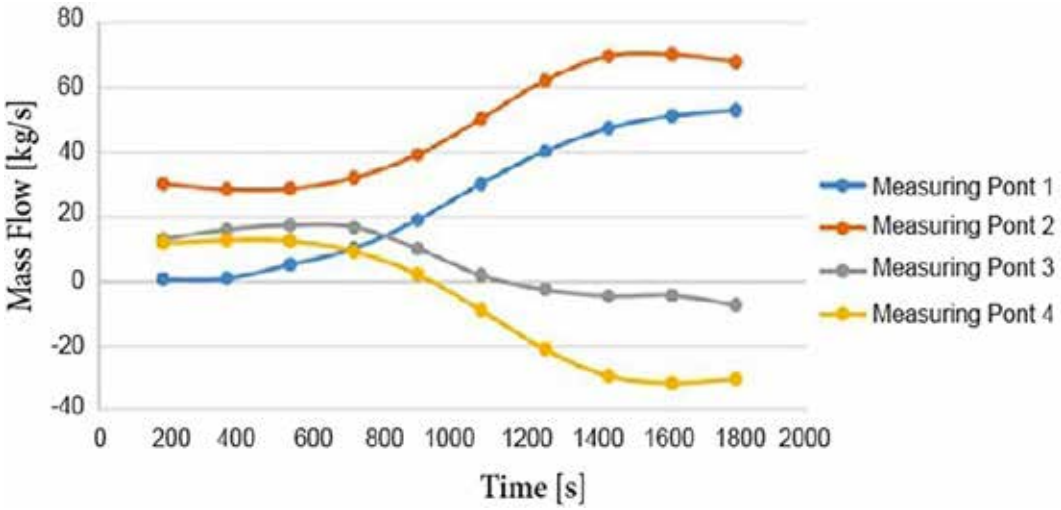

Figure 13: Mass flow vs time graphs for four different measuring points.

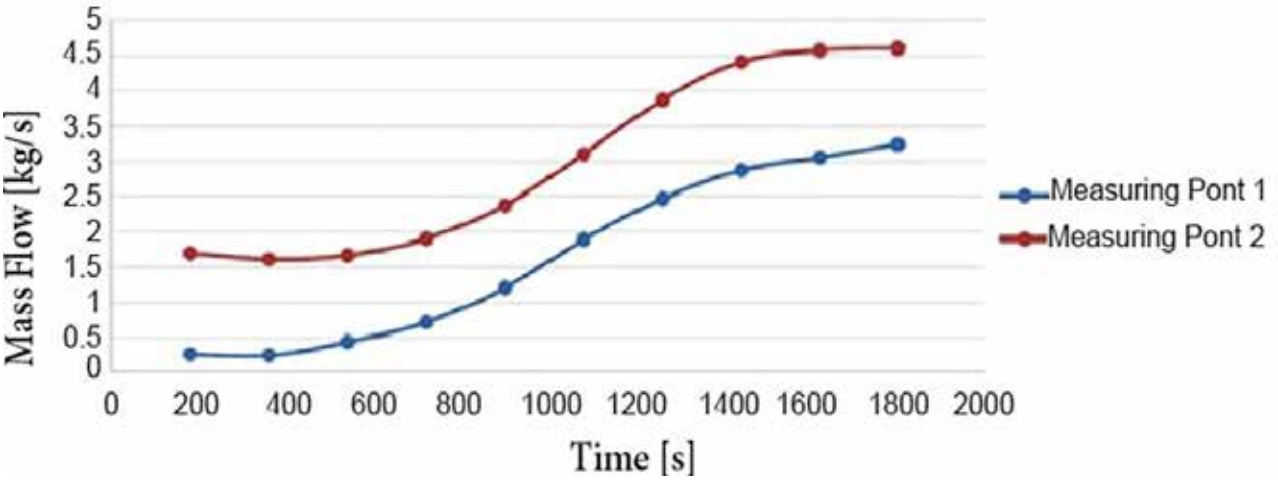

Figure 14: Velocity-time graphs for measurement points 1 and 2.

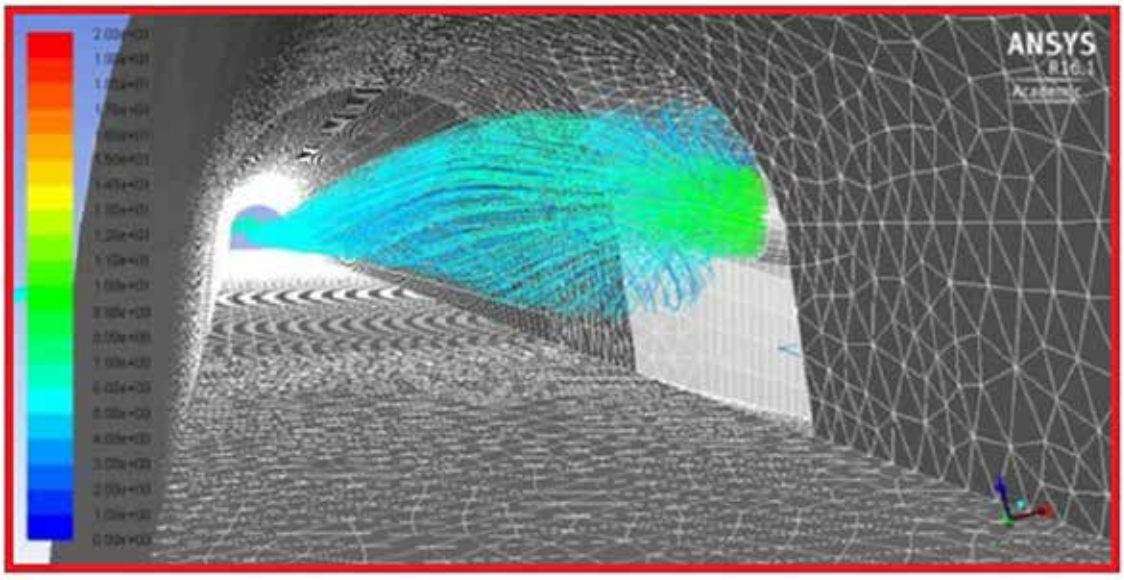

Figure 15: Flow streamlines of a fan.

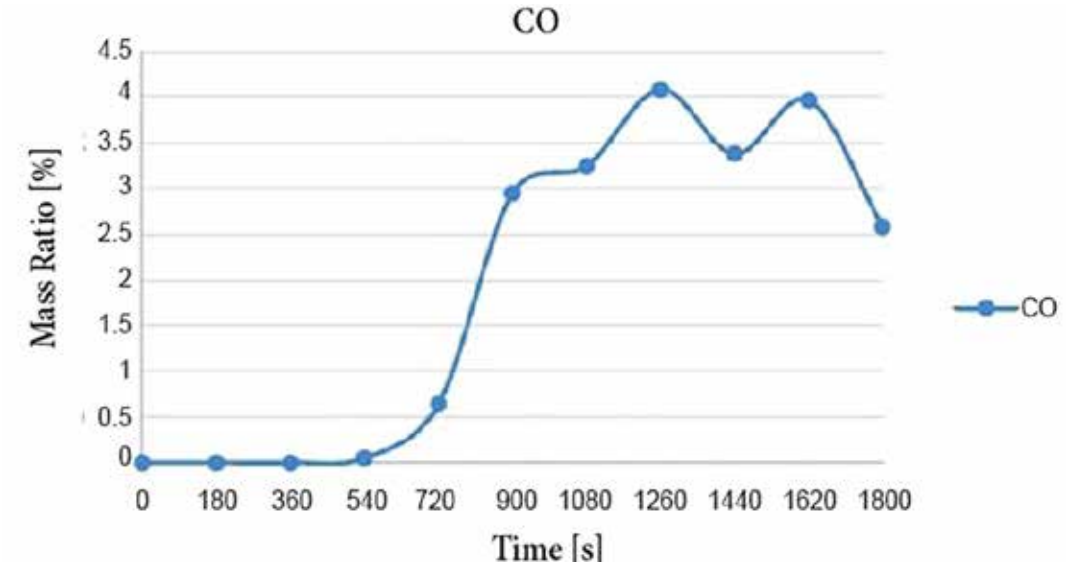

Figure 16: Change in mass fraction of CO gas at measuring point.

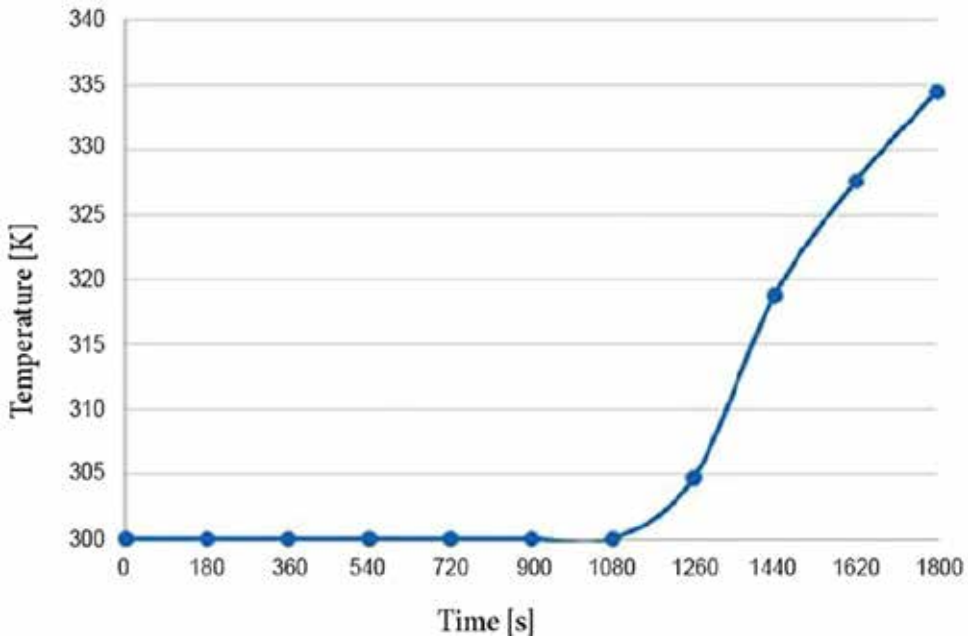

Figure 17: Change in mass fraction of CO gas at measurement point 5.

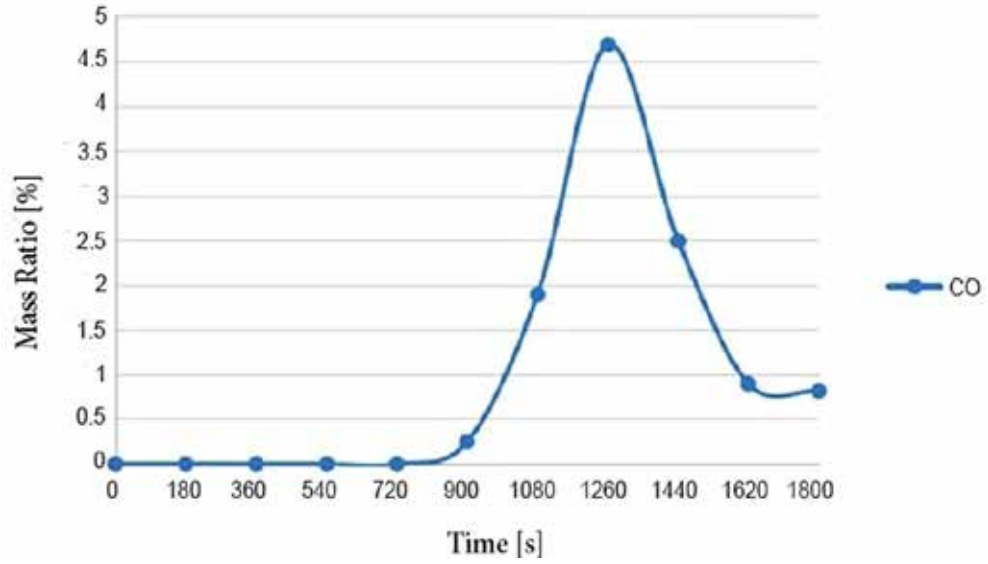

Figure 18: Temperature-time graph at measurement point 4.

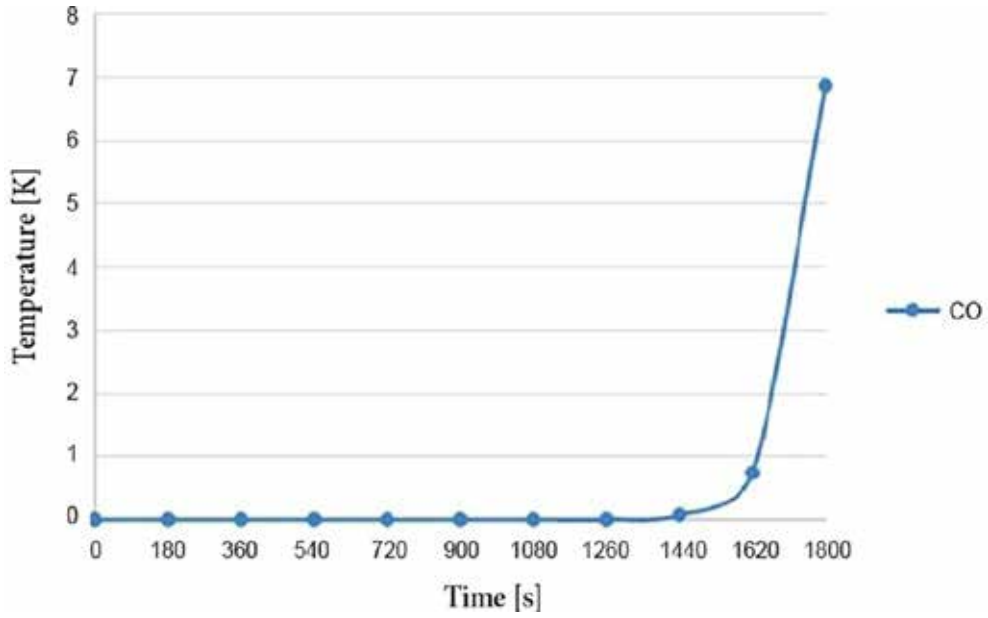

Figure 19: Change in mass ratio of CO gas at measurement point 6.

Coal plants are closing. For some schools, that means lost revenue and fewer jobs for graduates

A faded sign in support of coal sits in a front yard in Craig.

Growing up in Colorado's coal belt, Pike constantly heard his father, uncles and both grandfathers talk about how much they earned in the mines. Most bought starter homes in their early 20s and never borrowed a penny.

After graduating from high school last spring, with no desire to attend college, Pike couldn't resist the lure of Craig Station's starting hourly wage of up to $40 for maintenance workers on heavy mining equipment.

"It's just a really good living," Pike said. "I could be making the same as someone coming out of college, if they even find a job. And I won't be in any debt."

The 19-year-old also knew it would only ever be a temporary job. By the time Moffat County's current class of high school freshmen graduate, in 2028, the utility company that owns Craig Station will shutter its remaining mines and coal-burning units.

Days before his first shift, Pike injured his wrist during a workout and never started the job, complicating his plan to earn "good, fast money" at the mines. Now, much like the town of Craig itself, he's forced to consider what a future looks like without coal as a financial guarantee.

The announcement of Craig Station's closure, and that of five other coal plants across the state, followed Colorado's decision to cut in half its carbon emissions by the end of this decade. It's part of a national transition away from fossil fuels that pollute and cause climate change, spurred both by environmental policy and consumer demand. While President Donald Trump has vowed to "unleash" domestic energy, including coal, and attempted to block investments in renewable energy, experts and people here say those efforts are unlikely to fundamentally alter the shift toward clean energy in this corner of Colorado and some other parts of the country.

Preparation for the unfolding energy transition, however, has been uneven, and some states that rely on extraction revenues, such as Wyoming, have resisted changes.

Colorado's Democratic governor, Jared Polis, has pressured state agencies to help local governments survive economic losses from the transition to clean energy, largely by trying to lure new and potentially green industries to these communities. The state also has placed a priority on retraining current coal workers and getting them new jobs. But K-12 schools – the primary vehicle to train future workers in rural communities and also the main beneficiary of coal tax revenues – get only brief mentions in the state transition plans.

"It's really simple: Schools stand to lose millions of dollars per year in dependable revenue," said Daniel Raimi, a fellow at the think tank Resources for the Future who has studied how state and local governments rely on fossil fuels to stay afloat. But most transition policies focus narrowly on short-term employment, Raimi said.

"Everyone thinks about jobs every day," he said. "We don't all think about the source of our school funding every day."

Across Moffat and Routt counties in northern Colorado, school districts stand to lose up to half of their entire tax base when the coal plants shutter. Already, the slowdown of operations has started to erode some local school budgets, worsening long-standing struggles to attract teachers to these rural communities. Several districts and regional colleges have tried to combine resources; they plan to beef up agricultural, nursing and trade classes so students can explore careers outside of the mines.

Educators, parents and young people like Pike can't afford to wait for what comes of the transition. One teacher left the classroom to create a welding school to retrain coal miners, though recent high school graduates have filled the student roster in recent months. Parents who raised families on miner salaries now warn their children against any jobs in extraction industries, cautioning them against chasing a big salary alone.

Pike has watched many friends pack their bags. They leave either for four-year universities or lucrative extraction jobs in other states.

"I would like to keep living here," Pike said, "but I don't know if I have a choice."

Both the nation's production and consumption of coal have dropped by virtually half since 2014, and coal has since slipped to the smallest share of electricity generation in the U.S., behind natural gas, renewables and nuclear. At its peak in the 1920s, coal employed more than 860,000 miners nationwide. Today, only about 40,000 people work in coal mines.

Researchers with the National Bureau of Economic Research have estimated "the demise of coal" could lower local government revenues in coal-reliant counties by 20 percent. But in a 2021 study, they also noted their analysis did not account for the "potential downward spiral" on other parts of a local economy.

"That's not as many workers buying tools or vehicles or homes. That impacts the entire region," said Kirk Henwood, superintendent of the South Routt School District.

The SoRoCo school district, as it's called locally, has accidental experience with the sudden collapse of its funding base.

The rural district of 350 students lost close to a third of its revenue in 2016 when a bankrupt coal firm didn't pay property taxes. A judge later approved back payments, but the experience jolted local leaders. They took rumours of the nearby Hayden Station's closure seriously and moved quickly starting in 2018 to trim the district's budget by leaving vacant positions unfilled and not hiking salaries.

Mineral lease monies, which once made up 40 percent of its revenue, now make up just 10 percent, according to Henwood. But, he added, the cost cutting has made it even more difficult for the district to compete with Steamboat Springs, the wealthy ski-resort town where teachers already earned up to $10,000 more a year.

"Their custodians make more money. Their teachers make more money," Henwood said. "As their tourism continues to grow, our coal's declining at the same time and they can keep spending."

Pike, who attended the only high school in sprawling Moffat County, recalled that many teachers stayed only a year. The high turnover left him feeling disconnected from educators and worried that no one adult cared about his future.

The exception was the National FFA Organisation, an after-school club for students interested in agriculture. His advisers, both teachers who stayed throughout his time in high school, introduced students to topics ranging from wood shop to wildlife management. They assigned metalworking projects too; his senior project – designing, building and selling a chicken coop – tested his welding skills.

"I was like, 'Dang. That's fun,'" he said. "The sound when you start welding – it's just like sizzling bacon if it's right. It just sounds so good."

An FFA adviser noticed Pike's interest in welding, and he received a scholarship to attend the new trade school in town.

Late one recent winter evening, welding fumes filled the air in a brightly lit warehouse near Hayden's cluster of manufacturing

Former public school teacher Kevin Kleckler, right, helps a student during a welding certification class. Klecker started the Colorado Welding Institute in Hayden, Colo. to boost technical education in the region.

hangars. Pike and 14 other adult students – some just finishing a double shift at a nearby mine – fused chunks of metal together and raced the clock on their final certification test. Each paid $2,500 for 10 weeks of classes at the Colorado Welding Institute, the only school on this side of the Rocky Mountains in the state to offer a welding certification.

The institute, started by former Hayden school board member and vocational teacher Kevin Kleckler, opened in April 2022. He said he wanted to better expose students to career pathways beyond the mines, and local schools weren't doing enough to provide that.

"They'll dabble a little with welding here or agriculture there," Kleckler said. "They're not really preparing kids, honestly."

Students in his classes learn to cut and weld structural steel and pipe. They train with plasma cutters and in scenarios to simulate underwater welding, and some of the teenagers with only a certification or two already scored jobs with construction crews and general contractors. Across the state, welders can earn a starting salary of almost $40,000; in Moffat County, with inflated mining wages, entry-level salaries top $70,000.

When Colorado five years ago committed to reducing its greenhouse gas pollution, it recognised the economic cost of that shift and developed grant programs to assist cities and counties as they wean themselves off extraction revenues. A new state Office of Just Transition has $15 million to support local governments trying to lure new employers, improve their infrastructure and retrain coal workers.

But the state's official transition plan, released in late 2020, mentions schools only a handful of times, mostly to note how painful the drop in property taxes will be for the education sector and re-education for current coal workers.

CLIMATE-MINDED REPORTING

Caroline Preston examines how education is being reshaped by climate change.

In an emailed statement, Eric Maruyama, a spokesman for the Colorado governor, did not directly address the state's lack of attention to K-12 schools in the transition plan but said that Polis believes every student deserves a high-quality education that prepares them for the workforce.

"He is proud to have fully funded K-12 schools for the first time since 2009 and updated the school finance formula to fund students' education where they are, helping ensure all students, including those in former coal towns, get the best education possible," Maruyama said.

In Wyoming, the nation's single largest producer of coal, the state has banked on its mineral wealth to make it the biggest spender per student in the Mountain West. As extraction industries erode, any talk of raising revenue another way or investing in a diversified energy sector falls flat in such a conservative, anti-tax state, said Brian

Farmer, executive director of the Wyoming School Boards Association.

Republican Gov. Mark Gordon sparked fierce opposition when he recently pledged to reduce Wyoming's carbon emissions. "People feel that's anti-extraction, that's against the lifeblood of this state," Farmer said.

Already, the coal money that Wyoming relies on to pay for school construction has started to evaporate. The state's only underground mine closed in recent years, and there have been no federal lease sales of coal in Wyoming for more than a decade. State economic analysts have forecast that severance taxes from coal will dip below $90 million by 2030, less than a third of what it was in 2011. Federal mineral royalties, meanwhile, are projected to generate no money for school construction starting this year.

"For counties facing imminent closure and large-scale cutbacks, if they haven't been planning on this for a while, they most certainly will need help," Raimi said.

He's also sceptical that "colocation" – such as retrofitting underground mines to feed water to a hydropower station – could offer a lifeline for coal-reliant communities: "There's physically not enough space to build all the wind turbines and solar panels that you would need to generate the same government revenue." Communities will suffer some short-term economic pain, he said, as they work to create a much more diversified mix of industries.

Still, Megan Degenfelder, the state superintendent of public instruction, said she believes a Republican in the White House again may reverse dwindling mineral wealth. In an emailed statement, Degenfelder said an "increase in mineral revenue off federal lands is expected to occur under the Trump administration and that has the potential to substantially increase revenues for Wyoming schools."

Back in Colorado, some parents and community leaders question whether the Hayden and Moffat County school districts have ignored the inevitable.

Hayden schools, where enrolment now nears 450 students, stands to lose more than half its taxable value when the power plant closes. For day-to-day operations, Colorado's funding formulas will mostly keep Hayden schools afloat: Whenever local revenues drop for a district, the state's pool of money from other districts fills in the gap.

This equalisation, however, doesn't extend to any debt that districts issued for school construction and other facility needs.

In 2018, as talk swirled of the plant's long-away closure, voters approved $22 million in new debt to pay for much-needed upgrades to the Hayden middle and high schools. Any of those voters who also own property will now be on the hook to cover the debt payments once the Hayden Station's share evaporates.

Mat Mendisco, the town manager, warned that homeowners in Hayden – including many laid-off miners – could face potentially skyrocketing tax bills.

"It would be tantamount to a small recession, only in Hayden, forced upon us," Mendisco said.

It's an uncomfortable topic for nearly everyone, including district leaders. Neither the Hayden nor Moffat County school districts made representatives available for interviews. Some families in Moffat question why the district hasn't changed anything about what they're teaching students.

"They don't prepare them for the real world," said Nikki Robison, who had three children in Moffat County schools "Yes, they have math and literature and history. But what, really, will young adults do with that if they don't go to college?"

Robison said she tried to persuade her sons to never work in coal, but they didn't follow her advice: Today, both of them work in the mines with their dad and four other family members.

In early 2021, the Hayden and SoRoCo districts won a $1 million grant from the governor's office to create one of several new rural alliances between K-12 schools, higher education and local employers. The Yampa Valley partnership aimed to create new career and college pathways for students, with nearly $2 million in additional funding to support the expansion of agriculture, energy and natural resource classes.

The partnership's founding director resigned suddenly last year, however, and plans for the energy and natural resource pathways have yet to become a reality. Henwood, who also

Noah Pike's high school graduation cap hangs on mounted deer antlers in his room. The 2024 graduate first started to weld in high school.

Noah Pike, right, talks with his dad, Justin Pike, over dinner at their home. Coal provided well-paying jobs for most of the men in Pike's family, including his dad, who plans to retire soon.

serves as chair of the alliance, said it will now focus on health care and construction trades, including green building.

If the school districts did eventually start an energy and natural resources pathways, graduates might have a chance to someday work in new enterprises that state and local leaders hope to draw to the region.

Both the city of Hayden and Steamboat Springs will pursue geothermal heat in the region as an energy source, with planning grants from the state. One company, from Florida, has pitched converting the Twentymile Mine near both cities into a reservoir for a hydropower project. The state's Office of Just Transition funded a study into a similar proposal to develop hydropower in Craig. And just last year, the utility that operates the Hayden Station proposed turning its coal-burning units into a biomass plant.

No corporate projects have won formal approval yet. Jennifer Pieroni, who works for the Office of Just Transition to connect coal workers with retraining, wondered who will work for those new projects if only 1 in 5 residents have a bachelor's degree or higher.

"If it's not going to be them, who else can apply or even qualify for these jobs?" she said.

There's also little indication so far that the White House efforts to boost domestic energy production will dramatically change the outlook on the ground in this part of Colorado. That said, the Trump administration has hinted that it's working on a "market-based" plan to halt the closure of coal plants.

"We've got to not only grow new production, but we've got to stop digging the hole, which means stop shutting down existing, viable, economic plants," new Secretary of Energy Chris Wright said.

Neither the utility companies involved, nor town officials have indicated that they plan to change course.

Pike, the aspiring welder, said he believes Trump could prolong the life of coal, "but I'm not sure how long." He's overheard his parents and neighbours talking about the clean energy plans for Craig and surrounding coal towns. The geothermal projects will create plenty of jobs, he said, adding that he thinks Steamboat graduates and residents will fill them.

As his wrist recovers, Pike has started looking at openings for welding jobs in the area. So far, he's applied to two but hasn't heard back from either. And he still hopes the mines could at least be a stopgap: He plans to contact Craig Station in the spring to see if he can find temporary work there.

That said, in December, his dad shared some unexpected news: He plans to retire from the plant before it shuts down in 2028. Pike's parents told him they want to sell their longtime Craig home and move out of Colorado entirely.

Pike may leave with them.

"Once the mines close, it will be harder to keep anything open," Pike said. "I don't know, realistically, if there will be a Craig, as a town, in the future."

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Technological demands of the mining industry and the way forward

In recent years, the mining industry has undergone a transformation with the rise of autonomous mining trucks and robots, replacing traditional manual methods. The global mining truck market is experiencing notable growth, with its size expected to increase from USD 25.2 billion in 2024 to USD 35.1 billion by 2033, reflecting a CAGR of 3.74% from 2025 to 2033. Several factors are driving this expansion: *Gordon Barratt of Coal International looks at the evolving demands of mining operations via the use of Haul Trucks and Automation.*

1. The rise in deep-sea mining and offshore exploration activities has led to increased demand for specialised mining trucks capable of operating in challenging and remote environments. These sectors require heavy-duty trucks designed for robust performance in harsh conditions, contributing to the market's growth.

2. There is a growing trend of partnerships between mining companies and truck manufacturers to develop **customised, efficient, and tailored solutions**. These collaborations focus on improving the performance, safety, and reliability of mining trucks, ensuring they meet the evolving demands of modern mining operations..

3. Key Market Trends:
   - **Technological Advancements:** Increasing automation and integration of AI, IoT, and GPS technologies to improve fleet management and operational efficiency.
   - **Energy-Efficient Models:** The development of trucks with lower fuel consumption or electric alternatives to meet sustainability goals.
   - **Demand from Emerging Markets:** As mining activities expand in regions like Africa and Latin America, there is a growing demand for mining trucks suited to different terrains and mining practices.

The mining truck is a colossal vehicle designed to transport heavy loads of mined materials from excavation sites. Towering in size, these trucks can carry hundreds of tons of minerals, ores, or coal in a single haul. Engineered for extreme conditions, they boast robust frames, powerful engines, and durable tires, enabling them to navigate rugged terrain and steep inclines easily. Advanced safety features and autonomous technologies have revolutionised the sector, thus enhancing productivity and minimising human risk. The product contributes significantly to the efficiency of large-scale mining operations, ensuring the steady flow of resources and bolstering the foundations of modern industries worldwide.

The increasing integration of real-time monitoring and data analytics is fostering the market. Mining companies are leveraging advanced sensors and telematics systems to gather real-time critical data from the product. These sensors track fuel consumption, engine health, tire pressure, load capacity, and operating conditions. The data collected is then transmitted to centralised systems where sophisticated data analytics tools process and analyse it. By harnessing the power of data analytics, mining operators can identify inefficiencies, track equipment health, and make informed decisions to enhance overall productivity. Predictive maintenance models can anticipate potential breakdowns and schedule maintenance proactively, minimising downtime and increasing equipment availability. Furthermore, real-time monitoring aids in optimising truck routing, enabling better load balancing and fuel efficiency. The integration of real-time monitoring and data analytics streamlines mining operations and enhances safety by providing insights into

driver behaviour and potential risks. This is revolutionising the mining industry, driving cost savings, improved resource utilisation, and sustainable mining practices.

I was impressed by the technological advancements showcased at MINExpo 2024 in Las Vegas. The event highlighted the crucial partnerships between mining companies and heavy equipment manufacturers like Caterpillar and Komatsu all striving for a sustainable future. These collaborations are key to achieving the industry's net-zero emissions target by 2050. The focus on technology, particularly on carbon emission reduction, driven by the shared goal of achieving net-zero operations by 2050, mining companies are collaborating with heavy equipment manufacturers. My attendance at MINExpo, with its impressive display of equipment and machinery, reinforced my belief in the power of technology to achieve these sustainability targets. The following content highlights some of the key areas of progression from some of our leading mining manufacturers:

CATERPILLAR AFFIRMS LARGE MINING TRUCK PRODUCT LINE COMMITMENT THROUGH THE ENERGY TRANSITION

Caterpillar is reinforcing its commitment to deliver product design choices in alignment with customers' operational, sustainability and productivity goals that increase the value of a machine throughout its lifetime. These designs align with Caterpillar's strategy to deliver integrated site solutions to support customers today and through the energy transition.

As the industry looks to the future, Caterpillar is purposefully designing a modular Cat® 793 large mining truck platform with powertrain flexibility. This platform will include diesel mechanical, diesel electric and battery electric options. Additionally, Caterpillar is leveraging the knowledge and validation acquired through its Early Learner battery electric large mining truck program to drive common platform benefits for its ultra class trucks, including diesel electric and battery electric offerings for the Cat 794, 796 and 798 models.

Caterpillar has a legacy of designing products with 'customers' current and future needs in mind. For decades, Caterpillar and the Cat dealer network have provided flexible solutions to extend the life of mining trucks, including retrofit kits, update and upgrade programs and full machine rebuilds. These options can extend a customer's equipment to align with current products and technologies while reducing total cost of ownership.

Caterpillar Group President Denise Johnson quoted, "No matter the powertrain you desire, we will have a solution. Designing and supporting machine platforms that drive commonality, modularity and a seamless experience across our product lines is not new to us. Our large mining trucks are engineered to integrate with the technologies of today and of the future."

All current diesel electric and battery electric large mining truck platforms are also compatible with the recently announced Cat Dynamic Energy Transfer system, providing immediate benefit to mine sites that want to lower their operating costs and greenhouse gas emissions while providing flexibility for the future.

Caterpillar Senior Vice President Greg Hepler said, "Caterpillar recognises every mine site requires a unique plan to meet their sustainability objectives, which is why we are delivering a suite of integrated energy transition solutions, including machines with powertrain flexibility, energy transfer systems, energy storage and management capabilities, autonomy, and fleet management systems. Together with our Cat dealers, we are committed to supporting customers through every step of their energy transition journeys."

CAT® MINESTAR™ COMMAND FOR HAULING MANAGES THE AUTONOMOUS ECOSYSTEM TO INCREASE HAULAGE EFFICIENCY, ENHANCE SAFETY

Caterpillar's continuous investment and innovation in autonomous haulage with Cat® MineStar™ Command for hauling has resulted in hundreds of trucks operating at

dozens of sites across three continents. Offering multiple layers of protection to enhance safety at the mine site, the Caterpillar autonomous haulage solution drives hauling consistency and predictability at operations to enhance productivity and reduce cost.

Leveraging decades of development and more than 11 years of operational experience, trucks equipped with Command for hauling surpassed 8.3 billion tons (9.1 billion tons) of material autonomously hauled as of September 2024. MineStar Command manages the autonomous ecosystem to increase haulage efficiency through less idle time, bunching at the loader, unnecessary empty travel and wasted fuel.

"Caterpillar stands at the forefront of autonomous technology for a reason. They consistently advocate for a well-rounded solution that delivers and showcases value in safety, productivity, and efficiency. “We are constantly striving for excellence and innovation. We understand that achieving long-term sustainability requires a united focus on people, processes, and technology."

Cat autonomous technology is key to enhancing mine site safety. Command for hauling enhances safety by removing haul truck operators from potentially hazardous conditions. Cat autonomous trucks can detect and react to surrounding conditions and obstacles as well as interact safely with staffed equipment and light vehicles using a combination of our advanced onboard perception system and proximity awareness.

"As the mining industry navigates the energy transition, Caterpillar recognises that productivity and energy management are interconnected and can influence the total cost per ton. To tackle this, Caterpillar is continuously developing and integrating new MineStar capabilities to support battery-electric technology and charging solutions. These innovations will manage the coordination of energy and production across a mine site.

"The mine site of the future will be more complex than ever before as customers strive to meet the same production goals while balancing new challenges like energy management. We believe that the connection between automation and electrification will unlock the potential for a comprehensive ecosystem, integrating technologies to meet or exceed the demands of today and tomorrow."

These technologies enable the trucks to maintain optimal following distances and safe operating speeds and, upon detecting an obstacle or anticipating an interaction, automatically stop or slow the truck’s speed.

Marc Cameron, senior vice president of Caterpillar Resource Industries, adds, “Of all the autonomous statistics and milestones Caterpillar has achieved over the past 11-plus years, the most important is that all of this has been reached without any reported injuries resulting from the mining trucks operating autonomously. We know that safety is of the utmost importance to our customers, and it is our top priority at Caterpillar as well.”

Cat MineStar Solutions impact the hauling operation in multiple ways – enabling fleet assignment, fully autonomous haulage, equipment tracking, production recording, material management, business insights, safety solutions, maintenance solutions and more. An optimised hauling strategy leveraging autonomy helps to support sustainable operations by moving more tons with fewer machines.

With retrofit kits available, today’s range of Cat mining trucks capable of fully autonomous operation span the 190- to 370- ton (210- to 410-ton) class sizes, including the Cat 789D, 793D, 793F and 797F, as well as the electric drive 794 AC and high-altitude 798 AC models. These models can be equipped with a portion of the autonomous kit from the factory, making them “Command-ready” to reduce installation time in the field.

Beyond haul trucks, the Cat 789D water truck platform can be equipped with Command for hauling, providing a fully autonomous solution to manage haul road dust. Additionally, Caterpillar now provides Command for hauling as a fully integrated factory offering on its 139-tonne (153-ton), Cat 785.

Commodities mined around the world using Command for hauling include iron ore, copper, gold, coal, oil sands, lithium, and traprock. The trucks face extremely challenging mining conditions, from the 40˚ C (104˚ F) heat and red dust in Western Australia to sub-freezing -40˚ C/F temperatures of the Canadian oil sands. They also operate in the deep pit copper mines of South America.

“We create software tailored specifically for each application, allowing trucks to efficiently navigate the axle-deep ruts of the oil sands or the steep grades of deep pit mines,” says Corey Wurtzenbacher, Vice President and General Manager of Technology and Global Sales Support. “Our engineers maintain close contact with mining customers and continuously improve software functionality, which is essential in the fast-paced technology sector to stay at the cutting edge with real-time advancements.”

COMMANDING REACH

Autonomous trucks of the future will play a crucial role in the energy transition, as systems like MineStar Command and

Fleet will be essential to managing the battery usage for battery-electric trucks. Planned new capabilities will play a role in helping mines manage power by monitoring and orchestrating the complex balance of onboard energy, available charging assets and production targets to achieve the lowest operating cost. “It’s critical that one system manages all the energy usages, so, in the future, we are not just managing ore but managing energy as well,” adds Wurtzenbacher.

Caterpillar is also scaling into quarry applications, demonstrated by the company’s collaboration with Luck Stone to deploy Command for hauling at its Bull Run Plant in Chantilly, Virginia, USA. This is Caterpillar’s first autonomous deployment – technology, process, and people – in the aggregates industry and will expand the autonomous truck fleet to include the 90-tonne-class (100-ton-class) Cat 777.

“Instead of automating more than 100 trucks on a mine site that operates 24/7, we’re automating four trucks in a quarry that work 10 hours a day, so it’s not just about the technology,” says Johnson. “It is about how to transform our technology and processes to manage a smaller operation, so it makes money for the customer and does it safely. This can be a foundation for how we as a company move forward into autonomy in other industries.”

MineStar Solutions offers a range of remote and autonomous applications besides autonomous haulage to help further optimise mine site operations. This includes Command for drilling to automate the drilling operation, Command for dozing to enable remote dozer operation and Command for underground to enable remote operation of load-haul-dump (LHD) machines.

CAT® 785, 789 AND 793 NEXT GENERATION TRUCKS ADVANCED FEATURES IMPROVE PRODUCTIVITY AND SAFETY

The Caterpillar 125-to-240-ton (150 to 260 ton) productivity class mining trucks – Cat® 785, 789 and 793 next generation models – feature multiple new product developments. Next generation trucks are built on an advanced common platform with common electronic architecture, cab, and controls. “These next generation mining trucks feature a flexible technology platform and optional configurations to help each mining operation meet their goals,” says David Rea, vice president and general manager of Cat Rigid Frame Trucks, Bodies and Buckets.

All models are direct mechanical drive and boast the latest electronically controlled transmission with Advanced Power Electronic Control Strategy (APECS). The transmission offers smooth gear shifts for a smoother ride and delivers productivity and efficiency improvements. Forward momentum and torque are maintained while shifting with optimum gear selection resulting in faster acceleration.

There are more than thirty new or improved features with the next generation truck design, focusing on safety, productivity, and operator confidence. Truck development is focused on six key areas:

- Productivity-boosting cab
- Operator-focused environment that ergonomically accommodates a wider range of drivers
- Confidence-building controls that advance safety and operator confidence
- Innovative connectivity that offers increased data transfer speed, power of electronic control modules (ECMs) and advanced underlying architecture
- Improved maintenance
- Built for the future

CAT® DYNAMIC ENERGY TRANSFER SYSTEM, THE CAT® 798 AC MINING TRUCK

With its 372-tonne (410-ton) nominal rated payload, the Ca[t]® 798 AC electric drive trucks deliver the highest standard payload available in its class size, higher speed on grade, easier maintenance and excellent resistance braking performance. The high-altitude arrangement (HAA) 798 AC features a 363-tonne (400-ton) payload, refreshed cab plus the latest performance, maintenance, and safety upgrades.

At MINExpo, the hardware was installed for the new Cat® Dynamic Energy Transfer system prototype which can be used to power the 798 AC's electric drive system during operation. This fully Caterpillar-developed system is designed to transfer energy to both diesel electric and battery electric large mining trucks while they are working around a mine site. This allows it to charge a battery electric truck's batteries while the machine is operating, improving operational efficiency and machine uptime.

Cat DET is comprised of a series of integrated elements, including a power module that converts energy from a mine site's power source, an electrified rail system to transmit the energy and a machine system to transfer the energy to the truck's powertrain. During the show, the 798 AC truck was positioned with the prototype onboard attachment arm connected to a 73-meter (240-foot) section of the Cat DET rail system.

FEATURES AND PERFORMANCE

Standard Cat Payload Monitoring System technology delivers accuracy within 3%, with less sensitivity to load placement in the truck bed. Offering better accuracy with overload situations, it also reports carryback measurements to improve payload tracking. Consistent with other Cat mining trucks, the haul road management tool tracks and benchmarks haul road conditions to improve road maintenance and maximise truck lifecycle performance. The ability to correlate trend data to repair records and failure data helps to improve productivity, performance, and safety.

All high-altitude AC-drive mining trucks, like the exhibited 798 AC, can now be equipped from the factory Command ready to streamline integration of Command for hauling for future autonomous operation. The latest controller design improves data communication capability by increasing transfer rates through the serial port in Command mode. Monitoring of ton-kilometer per hour improves tire health monitoring for better tire management, especially at Command sites. An available health interface module (HIM) provides an interface for third-party collision avoidance/proximity detection, tire monitoring and driver safety systems.

Like all Cat mining trucks, the 798 AC now has braided harnesses and replaces p-clip fasteners with more rugged systems to improve durability. Monitored through onboard diagnostics, the integrated auto lube system improves greasing capability, enhances pump reliability, and prevents tank overfill and pressurisation via auto shutoff. A ground-level reservoir provides easier access for inspection, refill, and maintenance. Also available, the solid bar rock ejector improves performance in demanding applications where chain rock ejectors are less effective.

REDUCING EMISSIONS

The diesel-electric design of the 798 AC, as well as all Cat AC-drive trucks, delivers high payload, fast speeds, and excellent acceleration, so miners get the most from the fuel burned. Equipping the truck with DET to make use of electric power on certain sections of the haul road provides opportunities to reduce fuel burn even more. To optimise fuel consumption at the mine site, the 798 AC offers a range of engine power options from 2,050 to 3095 kW (2,750 to 4,150 hp). Engines are compatible with diesel blended with lower-carbon intensity fuels like biofuels and renewable fuels, as well as blends with synthetic fuels.

"Caterpillar and Cat dealers provide a variety of tools to assist miners in achieving their emissions-reduction goals. These tools include scale studies designed to optimise empty

machine weight, minimise carryback, and ensure maximum payload. Site assessments examine multiple aspects of the mine site to enhance haul road efficiency, resulting in faster cycle times, improved productivity, reduced maintenance costs, and lower fuel consumption per cycle. Additionally, Cat Reman and Cat Rebuild programs help preserve raw materials, conserve energy, and reduce emissions."

KOMATSU: CONTINUITY, EFFICIENCY …AND IMPRESSIVE RESULTS.

When it comes to mining machines hauling their unimaginable loads Komatsu are also one of the leaders within this great industry of ours.

For more than a century the company has been creating value for its customers through manufacturing and technological innovation, partnering with others to empower a sustainable future where people, business and the planet thrive together. Every aspect of their truck manufacturing capability is rigorously engineered to help reduce cost per tonne. From multiple innovative fuel saving features to industry-leading build quality and longevity, Komatsu offer a super-sized range of truck hauling capacities.

The technological advancements showcased at recent international exhibitions were impressive, and I appreciated the opportunity to reach out and engage with the Komatsu team.

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MQW: QUESTIONS

1. **MQW: How does Komatsu integrate new technologies to improve fleet management?**

- **Answer:** At Komatsu, we leverage decades of experience optimising mining operations to help our customers increase productivity, improve efficiencies, and reduce operating costs. Whether a mine aims to move more material with its existing fleet or achieve cost savings through operational enhancements, our fleet management technologies provide intelligent solutions tailored to those needs. Our industry-leading solutions, including DISPATCH Fleet Management System (FMS) and Frontrunner Autonomous Haulage System (AHS), offer real-time optimisation of loading and hauling operations, ensuring efficient dispatching and decision-making at every stage. Komatsu's autonomous haulage technology, coupled with the reliability and durability of our electric drive trucks, has helped mines worldwide improve productivity while reducing the total cost of ownership, delivering cost savings and promoting zero harm through safer, more consistent operations.

- We recognise that a truly optimised fleet extends beyond individual truck performance to the entire mining operation. Our open supervisory platform allows customers to manage mixed fleets by integrating with various systems and equipment across mine site operations. Using Wi-Fi and LTE connectivity, real-time data from onboard health and performance monitoring helps drive predictive maintenance strategies, ensuring truck servicing is based on actual conditions rather than fixed-hour intervals. Additionally, our mining technology solutions team works closely with customers to integrate and implement these technologies, analyze data, and drive optimisation across all tools within the platform. As a leader in autonomous haulage, Komatsu has commissioned over 815 autonomous haul trucks across more than 20 sites in five countries, setting the standard for efficiency, safety, and productivity in modern mining.

2. **MQW: How are Komatsu trucks evolving to take into account challenging and remote environments?**

- **Answer:** As mining operations push further into remote and challenging environments, equipment must evolve to withstand extreme conditions while maintaining efficiency and reliability. Komatsu collaborates closely with customers to anticipate these challenges and develop solutions tailored to their specific needs. Whether it's increasing payload capacity, optimising engine performance for high altitudes, or equipping trucks with cold-weather kits, we take an application-engineering approach to ensure our machines are optimised for the conditions in which they operate.

- Our engineering process follows a continuous improvement methodology – Plan, Do, Check, Act (PDCA – to ensure that our equipment is not only designed to meet initial specifications but is also continually assessed for real-world performance. This iterative approach allows us to work alongside customers over time, making necessary adjustments based on operating data and feedback. Our truck designs consider key factors such as haul distance, lift, ground conditions, and material abrasiveness, ensuring that mining operations in even the harshest environments can maximise efficiency and uptime. By remaining flexible and adaptive, Komatsu provides the performance and reliability mining companies need to operate successfully in these evolving conditions.

3. **MQW: There is a growing trend of partnerships between mining companies and truck manufacturers to develop customised, efficient, and tailored solutions. Who is Komatsu partnering with and are there any case studies of how this has developed over time?**

- **Answer:** At Komatsu, we recognise that meeting the evolving demands of the mining industry requires collaboration with strategic partners who bring specialised expertise to the table. For example, in the development of trolley-assist systems, we focus on building reliable haul trucks and electric drive motors, while partners such as ABB and Siemens contribute their expertise in designing and optimising trolley lines, electrical substations, and power distribution systems. By working together, we ensure that the full trolley-assist solution maximises productivity, reduces fuel consumption, and lowers carbon emissions, helping mines achieve their sustainability goals while improving operational efficiency.

- In the pursuit of alternative energy solutions, Komatsu is collaborating with General Motors to develop hydrogen fuel cell technology, positioning us at the forefront of power transformation in mining. Our Power Agnostic Drive Train (PADT) platform is designed to accommodate future energy sources, allowing for seamless integration of new power technologies as they become viable replacements for traditional mechanical drives. Additionally, our long-standing partnership with Cummins continues to drive innovations in high-altitude engine performance, ensuring that our trucks can deliver the necessary horsepower in oxygen-limited environments.

- As the mining industry evolves, Komatsu remains committed to embracing new technologies and working with partners to develop the most efficient, sustainable, and adaptable solutions for our customers. These partnerships enable us to stay ahead of industry shifts and deliver mining trucks that meet the challenges of today while preparing for the demands of tomorrow.

Effective lubrication and sustainability

The mining industry's drive for increased productivity, utilising ever-larger machinery, places immense pressure on maintenance and lubrication systems. In mines and quarries worldwide, operators strive to minimise costs and maximise uptime in challenging environments. This evolution demands that machinery designers and lubricant system manufacturers create systems capable of handling the increased loads and sizes of modern mining equipment. Effective lubrication is essential for reliable and economical operations, and selecting the right lubricants and services is crucial to meeting these evolving demands and improving profitability.

Coal International **looks at the current challenges for the maintenance of machines and components.**

The unprecedented productivity levels of modern equipment create significant challenges for maintenance staff. Larger components and increased load limits demand that machinery designers and lubricant system manufacturers create reliable systems that can effectively lubricate and sustain these machines.

Indeed, lubrication is a critical aspect of maintaining mining equipment. The right combination of lubricant and its timely application can make a significant difference in the efficiency and lifespan of the machinery. To understand the importance of lubrication in mining operations there is a need to examine the key challenges faced by lubricants within the mining sector.

CHALLENGES OF LUBRICATION IN MINING OPERATIONS

Key challenges include:

- **Harsh Environment**: Mining sites are filled with dust and contaminants that can significantly degrade lubricants, affecting machinery performance and longevity.

- **Heavy Loads**: Equipment used in mining operations must withstand extreme loads, requiring high-performance lubricants with strong load-bearing capacities, such as those designed for high weld load or Timken load conditions.

- **Difficult Application Areas:** Large and heavy machinery like draglines and shovels pose difficulties in lubrication, as certain components are hard to access for regular maintenance.

- **Moisture Exposure:** Mining environments are often high in moisture, which can compromise lubricant effectiveness, leading to increased wear and potential equipment failures.

- **Extreme Temperatures:** Mining operations are exposed to fluctuating temperatures that can accelerate lubricant degradation, making it crucial to select temperature-resistant solutions.

- **Monitoring and Maintenance Challenges:** Due to the remote locations of mining sites, monitoring and maintaining equipment such as excavators, dumpers, and shovels can be difficult. For example, in 2020, one of Coal India's subsidiaries, BCCL, managed 36 coal mines, including 11 underground, 16 open-cast, and 9 mixed mines, along with 8 coal washeries, demonstrating the scale of maintenance complexity.

- **Centralised Control Issues:** Mining areas are often vast and spread across remote locations, making it challenging to implement streamlined lubrication and maintenance programs efficiently.

- **Health and Environmental Concerns:** Modern lubrication solutions must balance performance with safety by eliminating carcinogenic and toxic ingredients while maintaining efficiency. Additionally, the demand for eco-friendly lubricants is rising to minimise environmental impact without compromising effectiveness.

KEY CONSIDERATIONS FOR EFFECTIVE LUBRICATION IN MINING OPERATIONS

- Selection of Lubricant: Choosing the right lubricant is crucial for optimising machine efficiency and reducing wear and tear. A well-suited lubricant enhances performance and extends equipment lifespan.

- Frequent Reapplication: Regular lubrication ensures smooth operation, preventing unnecessary friction and damage to critical components.

- Economic Benefits: Proper lubrication minimises equipment failures and reduces maintenance costs, leading to significant long-term savings.

- Environmental Impact: Using an efficient lubrication system helps lower energy consumption and reduces environmental impact by minimising waste and emissions.

- Monitoring and Adjustment: Continuous monitoring and periodic adjustments of lubrication systems improve their effectiveness, ensuring optimal performance and reliability.

By addressing these factors, mining operations can enhance equipment durability, improve efficiency, and promote sustainable practices.

MINING LUBRICANTS: CLASSIFICATION BASED ON THEIR CHEMICAL COMPOSITION

Lubricants consist of base oils and additives. Depending on the base oil type they are classified into mineral and synthetic. Mineral oils are derived from naturally occurring petroleum. Even though they are more affordable than their synthetic counterparts and are still used in the largest amount, they have several drawbacks. First they are made out of natural components and consist of chemical elements such as sulphur or phosphorus that are considered major contaminants.

Additionally, they are typically sensitive to temperature changes and have a lower pour point and flashpoint compared to synthetic ones. These disadvantages are compensated by adding performance boosting additive packages after oil Purification. Synthetic oils are made synthetically, through chemical reactions. The goal is to create purer and more innovative alternatives to conventional industrial lubricants. Unlike their mineral counterparts, synthetic oils have a higher viscosity index, meaning they are more stable at different temperature ranges. Their high flash point means they are a perfect solution for heavy duty industries like mining, where there are common fire related safety hazards.

ADDITIVES

Performance boosting additive packages are used to enhance the performance of both mineral and synthetic oils. They increase their existing properties as well as add new traits to them. Many additives are used in today's high performing mining lubricants. Some of them are detergents, dispersants, friction modifiers, corrosion inhibitors, antioxidants, foam inhibitors, and viscosity index improvers.

MINING LUBRICANTS CLASSIFICATION BASED ON THEIR APPLICATION

Modern mining machines are bigger, faster and more powerful. Lubricant manufacturers continue to produce and enhance their products to meet the ever changing needs of sophisticated heavy mining equipment.

HYDRAULIC OILS

Hydraulic fluid serve as an energy transfer medium in hydraulic machinery that plays a fundamental role in mining. Additionally they serve as excellent sealants and lubricant agents. Hydraulic fluids are highly versatile and are used across various heavy- equipment and heavy-duty industries such as mining. They remain stable even when exposed to the harshest temperatures which makes them suitable for demanding working conditions.

GREASES

Greases are a mixture of base oil, performing enhancing additives, and thickeners. Heavy duty greases are purposefully created to ensure the highest performance in the most unfavourable working and climatic conditions. Like in engine oils, base oils and greases can be mineral or synthetic. On the other hand, based on the thickener type, greases are classified into calcium greases, aluminium complex greases, lithium greases, bentone greases, polyurea greases, sodium greases and so forth.

INDUSTRIAL OILS

Industrial oils are specifically designed to support heavy mining equipment even in the most demanding working environments. These oils are highly versatile. They provide exceptional anti wear, anti friction, and anti corrosion properties. Additionally industrial oils have great thermal stability, low foaming properties and water separation properties.

GEARBOX AND TRANSMISSION OILS

Gearbox and transmission oils are used in different transmission types and have different chemical compositions. There are various semi-truck and heavy duty applications. As such they are used in various heavy equipment industries including mining and construction

Today's machinery can be as large as houses, with some booms extending up to 300 feet. Depending on the machine type – whether it's a shovel, dragline, or drill – key components can be either electrohydraulic or electromechanical. Some draglines possess enormous hydraulic systems and electrically driven gears, with sump capacities reaching thousands of gallons. Rolling stock, including bulldozers and large haul trucks, are powered by diesel engines. Many loading and hauling equipment designs feature hydraulic systems powered by diesel generators.

Given the rising operational costs, mining companies must continuously monitor the performance of their heavy mobile equipment. Profitability depends on the ability to accurately diagnose performance issues before they lead to production downtime.

Equipment maintenance costs represent between 30% and 50% of direct mining expenditures. Most often, mining companies employ traditional preventative and reactive maintenance programs for critical equipment, which accept much of the maintenance peoples time. It is pure fallacy to suggest that even in today's automated operations that maintenance people are non-existent, every one's car for instance suffers occasional breakdowns and to have to wait several hours for a mechanic can be mega frustrating.

New advancements in equipment monitoring technology enable time constrained technicians and engineers to discover, diagnose and act on a fault before it results in production downtime or considerable damage to the equipment or operator. By remotely accessing onboard equipment data, personnel can immediately view and analyse equipment and operator performance through a variety of dashboards, user defined key performance indicators and alarms, to facilitate immediate action.

While equipment monitoring is not new to the mining industry, traditional methods, unstable technology, and the extreme mining conditions have; often plagued the effectiveness of these first- generation solutions.

Maintenance personnel can now monitor the entire mining fleet and receive early warnings of developing problems, prompting action, and reducing negative impact on operations. Vital equipment spends less time on the shop floor and more time in the mining field.

Similarly, it is always suggested that maintenance personal take advice and support from lube marketing companies to get their oil analysis and trends monitoring done for each individual equipment. Such expertise in Condition Based Monitoring (CBM) and Total Fluid Management (TFM) services are now available to operations worldwide. It is important for mine companies to partner with lubricant suppliers that can understand and account for the diverse needs of each operation. For example, in today's off-highway equipment world, the driving force in new product development is to enable end users to have lower operating costs. Equipment manufacturers have responded by increasing equipment efficiency, primarily by increasing equipment size, increasing the load carrying capacity and operating speeds while constantly striving to reduce both equipment cost and weight. Increasing equipment size has triggered the increase in the engine's size and horsepower, which in turn has placed more demand on the drivetrain hardware components (i.e., transmission, axles, hydraulics, and gears) and correspondingly on the fluids that lubricate these components and keep this equipment running optimally for their expected useful life cycle.

Typically, there have been increases in power, power density and torque with each successive model. This increase in power density generates more heat, raising oil sump temperatures throughout the drivetrain. Transmissions, differentials, and final drives are subjected to increasingly higher loads as machines become capable of shifting larger quantities of material and much faster. The surface finish of components, their design and metallurgy have steadily improved, but they still require the highest level of lubrication to deliver maximum performance and remain durable.

Lubricant manufacturers have developed specialised engine oils, transmission, and drivetrain oils to provide the appropriate level of performance. Over the past few years for instance, Indian lubricant manufacturers have developed specialised power transmission fluids designed to provide the appropriate level of performance required to meet stringent OEM specifications. Higher operating temperatures coupled with higher load factors has driven the development of new oils with increased wear protection, enhanced friction performance, in addition to a number of other performance attributes.

Power transmission fluids (in SAE 10W , 30 & 50) are specially designed heavy duty transmission fluid for off-highway power shift and certain non-synchronised manual

transmissions, wet brakes, final drives and hydraulic systems meeting the rigorous performance requirements of Caterpillar TO-4, Allison C-4 and other off-road equipment specifications. It contains carefully selected base oils assuring the up most oxidation, thermal and shear stability for long oil life while the specialised additive system provides additional oxidation resistance, balanced frictional performance, wear protection and maximum power transfer during operation. They also contain additional special additives to enhance cold temperature performance, rust, corrosion, and foam protection, along with outstanding compatibility of clutch friction material and seals. The use of such dedicated driveline fluids brings in huge benefits in terms of increased performance and massively increased protection. There are also the final drive axle oils (FDAO) and synthetic gear oils which are available in not just the Indian market.

For shovels, hydraulic oils are now available from lube marketing companies which can increase productivity and even help in reduced fuel consumption leading to substantial savings for the users. Long drain hydraulic oils are also available which can provide 50%-100% increase in the oil drain interval (ODI). All such oils have passed the tests during various field trials conducted in Indian conditions.

In engine oils selection, the mining industry needs to move from the API CH4, CI4, CI4 Plus to the CJ4 grades in SAE 15w40 viscometrics. To increase fuel economy, some users contemplate using lower viscometrics like 5w30 etc., but many OEMs have their reservation about engine durability. Extending oil drain intervals in off highway engines and machines can be challenging though. Dirt ingress and coolant leaks occur more frequently, and at times oil drain intervals are established to minimise damage from such problems. The cost reduction associated with longer oil and filter change intervals must be balanced against the risk of shortened engine life and the cost associated with less reliability if oil drain intervals are extended too far. Thus, correct fluid and adherence to proper lubrication regimes is important not only to achieve higher productivity but also to reduce cost of repairs and downtime. Using the correct specialised fluid undoubtedly can cost more, but that cost is still insignificant when compared to the cost of the equipment, repairs, and lost revenue in downtime. Low-price generic fluids are not robust enough, nor do they have the correct specifications to protect gear and transmissions components in high performance and heavy machinery operating in hostile conditions.

Given the use of the correct lubricant, maintaining fluid integrity is still an important consideration. Machines are usually working in dusty conditions so filter conditions must be maintained properly to achieve extended equipment life. As an alternative to manual lubrication, automatic lube-delivery technologies have been introduced specifically for machinery in the off-highway marketplace. Automatic centralised lubrication systems in different configurations have gained significant ground by enabling the right lubricant to be supplied at the right time and at the right lubrication point -- without manual intervention. The size of a machine, type of required lubricant, number of lubrication points and other factors will guide initially in choosing the most viable centralised lubrication system for an application. The primary purpose is to supply lubrication points continuously with metered lubricant while the machinery is in operation and all the bearings are moving.

CONCLUSION

Today's centralised lubrication systems factory-installed on mining machinery have minimised the need for lube techs in most cases. These computerised systems are now capable of dispensing the right product, in the right amount, to the right point, and at the right time.

There are several centralised lubrication system manufacturers that offer a wide range of system types and designs to meet the needs of any mining application.

Most lubrication systems consist of a grease pump, a motor to drive that pump and some sort of injector or valve to control or measure lubricant volume. Most utilise a programmable logic controller (PLC) to program the frequency of the lubrication replenishment cycle. As sophisticated as some of these systems are, maintenance and proper set-up is essential to ensure that their benefits are realised.

Lubricant manufacturers have continued to improve their products to meet the needs of bigger, faster machines. Although most lubricant suppliers are not lubrication system specialists, many have the resources to provide technical support, offering sound advice for selecting the products best suited for the applications.

The products commonly used in mining equipment can be divided into three groups: heavy-duty lubricating oils, such as EP oils for enclosed gear drives; multipurpose engine, circulating and hydraulic oils for engine, bearing lubrication and fluid power; and general-purpose grease, for normal industrial bearing applications and specialised mining products.

Walking draglines for example may require lubricants for the exceptionally large plain bearings that support the entire frame of the unit as it moves through the walking process.

These lubricants may have a high concentration of lubricating solids or soft metals dispersed into a stiff grease and delivered in small bags (for the walking mechanism without an automatic delivery system) just ahead of the peak loading area. This grease is referred to as a Walking Cam lubricant.

An effort to reduce the number of lubricants on a machine has driven the development of multipurpose products designed to meet several different applications from a single lubrication system. The various components to be lubricated may include the open gears, guide rails, main table bearings and various smaller slides and bearings.

Coal as a responsible energy source

Coal should not be sacrificed at the altar of the just energy transition which champions renewables as the panacea to the world's electricity access challenges. This is the view of Michelle Manuke CEO of Future Coal, an organisation that continues to advocate for coal as a responsible energy source and one that remains crucial to developing Regions.

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There is still an abundance of coal resources in the world and there is an opportunity now under sustainable coal stewardship to extract more value per tonne of coal by looking at it beyond its traditional uses but equally by applying best available technology and innovation to develop it says" Michelle Manuke.

Future coal is an industry body that has been around for nearly 40 years. It was previously called the World Coal Association and was started by coal producers from around the world. Manuke explains that the organisation regarded these days as a think tank, have been on a journey over the past five years with the message "what is coal why do we need it"?

"About five years ago there was a real recognition that we had lost control of the narrative which misrepresented many of the real opportunities, particularly in innovation and technology around coal. A lot of the negative perceptions were based on outdated views of coal and not the real and full understanding of the nature of the importance to so many," she adds.

Coal, says Manook, is not just about power (energy) , but is crucial to industries like steel, cement, chemicals, and sectors like agriculture (for fertilisers). Coal also plays a role in renewables for wind turbines. So, the stories and understanding about coal was being missed.

Towards the end of 2023 the world coal association changed its name to Future Coal." The main reason we did that was to communicate and to really shine a light as many of us know, Coal is not going anywhere fast. We cannot just tell the story of a producer any longer, even our organisation had to change, you cannot just tell the story of the consumer, you have to now tell the story of the value chain."

"So, Future Coal is now a platform where we talk about something called sustainable coal stewardship. It is really looking at the opportunities in pre-combustion, combustion and beyond combustion. "This is a journey and now the membership is effectively the coal consuming and

producing nations and it is really about encouraging and inviting those members across the value chain to come and join” .

Manook states that the organisation is noticing that people are wanting to share the opportunity but also the challenges. “In that regard our conversations are very much with governments, the finance investment, insurance sectors and our own industry.

“Because even our own industry is sometimes not as informed as it could be or not necessarily presenting the best case. It has been a really important journey and now we are just on this journey to talk about sustainable coal stewardship and how as a value chain we can evolve and contribute both economically and environmentally.”

A STRATEGIC ASSET

Manook adds that there should be no reason coal is not part of an energy efficient and energy transformation journey. “We do not say energy transition because we do not believe it is about transitioning away from coal. We believe it is about transitioning towards the innovations and technologies that are important.”

She says the view among sections of the media and elsewhere is that coal is a stranded asset and that's why people do not invest in the sector. It is not a stranded asset but a strategic asset it is much better to look at it as a strategic asset and to enable it to be a better contributor to the nations that choose it.

“But it does require a framework that is of a level playing field and a policy environment that does not disadvantage you and does not bias the funding,” says Manook .

“As an organisation, we are not saying everyone should use coal. We do not take that position. We take position that what is right for you is what we should support as long as you are doing it in a way which is economically and environmentally responsible. From an energy perspective, that conversation, if it is that cold energy is right, then let us

do it, but let us do it with the best technology to reduce all emissions."

The UN's inter-governmental panel on climate change (IPCC) stated 7 years ago that there is no near-term 100% credible renewable scenario stop despite this, Manook points out that trillions of dollars have been spent chasing solutions that fall short of replacing reliable, affordable base low power.

"So, we know this, but we are still trying to push a very expensive transition and channel funds in this very biassed way towards something we know is not 100% reliable. We have done some research with the ASEAN centre for energy that effectively says to replace say 106 GW,- is four to five times more expensive to do with the renewable option, to the tune of hundreds of billions of dollars and it is still not reliable. These facts have to be communicated" she explains.

Manook says negative sentiment on coal is based on old technology. But we know there is new technology. Japan and China are running the most efficient coal fleets in the world. Up to 99% of coal pollutants can be abated through these known technologies. That is not just about CO2 with carbon capture. All the things we know attached to old technology and old power stations can be corrected.

"We believe in responsible investing in sustainable coal stewardship. Companies need to not only think about their own profits. Even though coal is a participant and an important component in so many other industries, the enabler for economies is power cheap, reliable, affordable, and safe. And if we know we can apply a technology that can actually manage the emissions, while then it should not be disqualified." She adds that in the UK, there was no such thing as a just transition.

"Those communities are some of the poorest, experiencing quite high levels of unemployment and poverty increasingly there is recognition that this just transition is difficult to replace. The issue is that we are forcing a solution that is not viable in any way, it does not give us reliable or affordable energy and it does not support communities at large."

"So, we really need to stop talking about transition away from something. We need to start talking about energy additions or energy transformation and that has to be a conversation around innovation and technology."

"If you want to use the words energy transition, let us talk about transition towards abated coal solutions, towards the best abatement opportunities that exist for energy. I believe in the resource, but I also know the resource has to be better and those technologies exist."

Manook says that in coal, South Africa has a resource to give it energy security and resilience. "You want resilience and self-reliance, and you have a resource that can give you that. You must be allowed to do it."

FutureCoals report, Coal's Future: New report charts path to sustainability – points out that with regard to emission reductions, high efficiency low emissions (HELE) coal plants and carbon capture and storage technologies could reduce emissions by up to 1,412 Mt CO2 annually – equivalent to removing 310 to 560 million SUV,s from global roads. In terms of economic growth – replacing coal plants with ultra – super critical plants could inject over $1.5 trillion into the global economy.

In contrast, replacing coal with alternative energy would cost an additional $2.7 trillion due to shortfalls in output. The report further notes that coal remains essential to key sectors, including steel (70% production), cement (90%), and aluminium (60%) , while also producing cost-effective hydrogen and providing critical minerals like copper, cobalt, nickel, and more for renewable energy and battery storage.

Manook pointed out in a recent op-ed in the Sunday Times: "Preaching 'abandon coal and embrace renewables' is hypocritical and out of touch with reality. It dismisses the challenges faced by poorer nations, where energy poverty is a life-and-death issue. If we are all to have a slice of the energy cake we need a new, affordable recipe – with abated coal as the key ingredient."

At Mining Indaba this year, she called on the finance, investment, and insurance sectors to rethink what "responsible investing" really means. "One of the key questions is: Is it responsible or ethical to back energy policies that leave countries poorer and more vulnerable?" she concludes.

Michelle Manook: "if we are all to have a slice of the energy cake, we need a new, affordable recipe – with abated coal as the key ingredient."

Proposed subjects for Coal International

Every issue of ***Coal International*** contains the latest news, new plant and equipment, health, safety and sustainability and digitisation issues affecting the industry. Site visits plus a one on one interview with top executives and engineers within the industry. All year round focused articles from exploration through to production. A major feature throughout each issue will be: Reducing your carbon footprint, Sustainability and Mining Innovation.

January

- Transitioning to an electric mine
- Autonomous Mining Trucks
- Underground scoop trams
- Underground ventilation systems
- Conveying underground
- Asset management and finance
- Signals and communications
- Continuous miners
- Dust suppression
- Rock reinforcement and ground support

Copy date: 30th January 2025

March

- Hydraulic mining shovels
- Underground crushing equipment
- Underground drilling rigs
- Mining automation
- Crushing and Screening
- Explosives technology
- Lubrication
- Sustainable mining practices
- Longwall systems

Copy date: 30th March 2025

May

- Pumps and water management
- Rock reinforcement and ground support
- Wheel loaders
- Transitioning to an electric mine
- Conveying
- AFC Stage loader review
- Longwall developments
- Open Pit mining
- Online training solutions
- Big Data and mining

Copy date: 30th May 2025

July

- Wheel loaders and Scoop trams
- Surface and underground conveying
- Crushers
- Sustainable mining
- Underground mining trucks
- Ventilation systems
- Collision avoidance
- Room and pillar
- Continuous miners
- Machine monitoring The IoT

Copy date: 30th July 2025

September

- Mining automation and information management
- Underground crushing equipment
- FLP Underground drives
- Scoop trams
- Gas monitoring
- Dozers
- Transitioning mines to sustainable future
- Dewatering pumps
- Health and Safety innovations
- Coals Role in the energy transition

Copy date: 30th September 2025

November

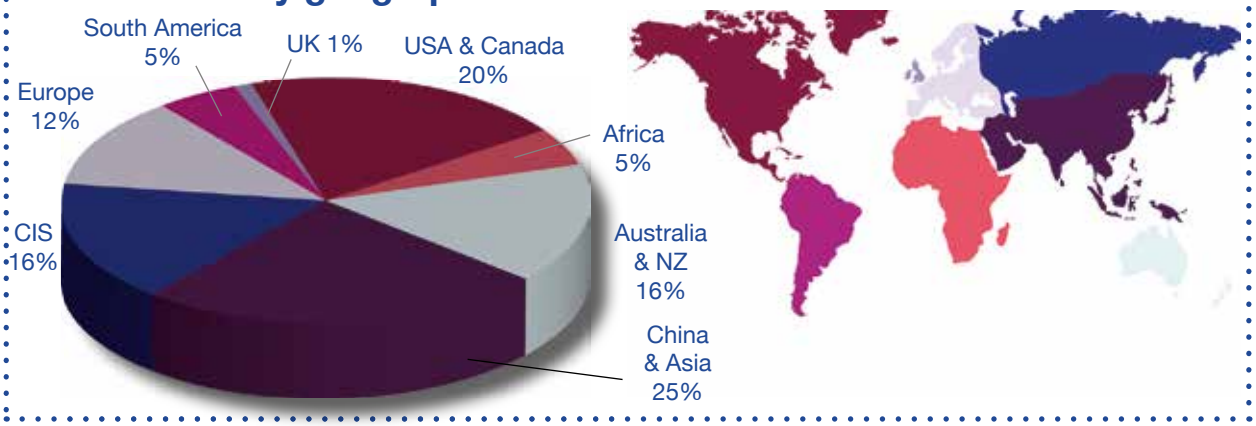
- Hybrid mining machines
- Underground shuttle cars
- Autonomous mining
- Underground conveyor dust suppression
- Screening equipment
- Underground drilling rigs and reinforcement techniques
- Transitioning to a low carbon mine
- Carbon capture and storage
- Shearers
- Draglines

Copy date: 30th November 2025

Further articles of interest will be added throughout the year, if you would like to forward articles for consideration please contact gordon.barratt@tradelinkpub.com

Coal International will be attending major exhibitions around the world (as listed on page 4) ensuring your message reaches its intended audience. Prior to attendance at exhibitions we will ensure that a digital copy reaches all Operating Companies/ Mining Operations personnel, this will include Head Office: CEO's, Technical Directors, Procurement Departments and CFO's Mine site: Mine Manager, Electrical/ Mechanical Engineers and Health/Safety officers. Printed Bonus copies will also be available for distribution from the event attendance.

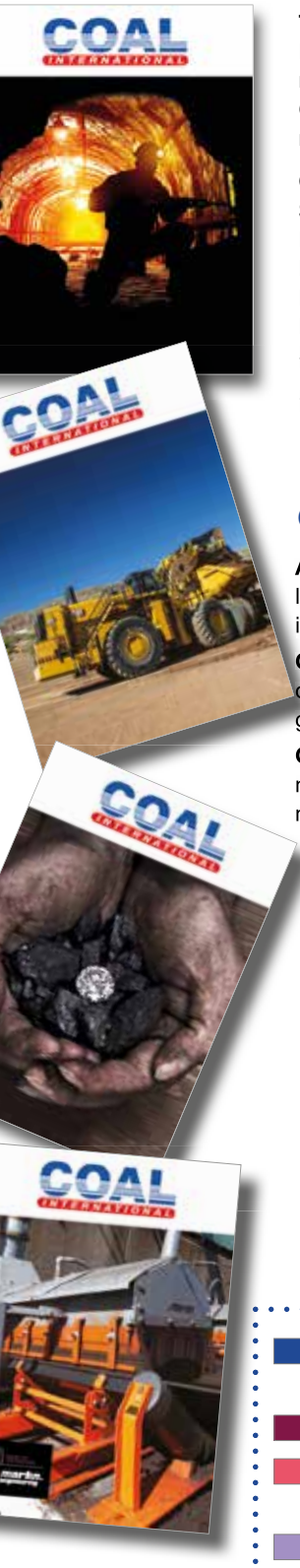
Circulation by geographical area











Overview

Tradelink Publishing's flagship publication, Coal International is probably the oldest English language coal magazine in the world. Established in 1858 as the Colliery Guardian, it is distributed to an international database of mining professionals involved in the buying cycle that include:

Operating companies
Senior management i.e. CEO, CFO and Directors
Procurement departments
Mine managers
Mine Electrical Engineers
Mine Mechanical Engineers
Safety and sustainability departments

Coal International expanded to become an international publication when the UK's coal industry was privatised in the mid – 1980s.

We understand your need to get your marketing message out to the intended audience, *Coal International* is regarded as the worlds No 1 publication serving the Coal Industry for equipment suppliers and service companies. With over 180,000 mining professional contacts on our database this publication truly reaches a worldwide audience.

- Digitally Published six times a year
- For our attendance at Major mining exhibitions *Coal International* will be printed and distributed from our stand and can also be printed in a variety languages
- Besides a wealth of feature and technical articles, site visits and industry news, Coal International also covers health & safety, sustainability, technological innovation and financial news, alongside new products & equipment in every issue covering both underground and surface operations.

Coal International topics to be covered throughout the year 2025

Advancements in Clean Coal Technology: Exploring the latest innovations aimed at reducing the environmental impact of coal mining and usage.

Global Coal Market Trends: Analyzing shifts in coal demand and supply, with a focus on emerging markets and geopolitical influences.

Coal Mining Automation: The rise of autonomous machinery and its impact on productivity and safety in coal mines.

Carbon Capture and Storage (CCS): Evaluating the effectiveness and future potential of CCS technologies in mitigating climate change.

Health and Safety Innovations: New strategies and technologies to improve worker safety and health in coal mining operations.

Coal's Role in Energy Transition: How coal can fit into a sustainable energy future, including hybrid energy systems and coal-to-liquid technologies.

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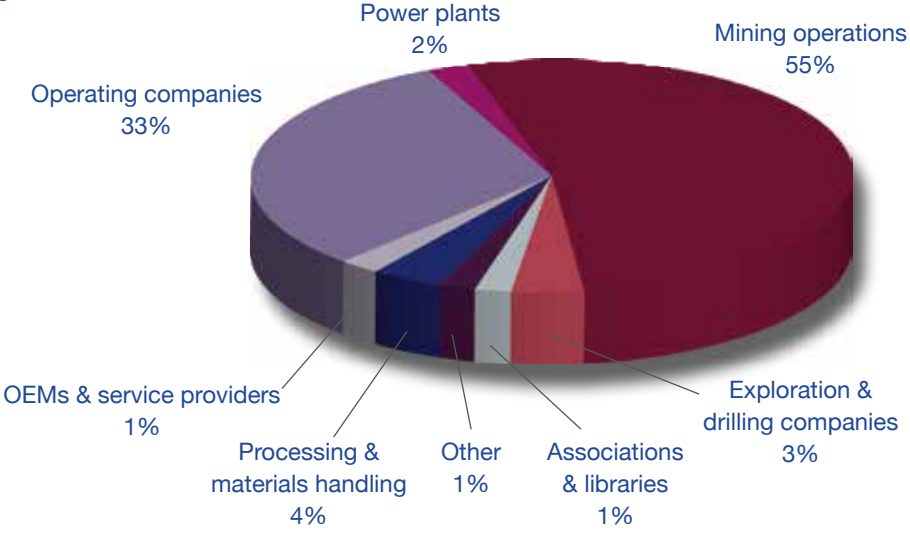

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Over the last year, we have extensively increased our database to give our advertisers more value for money by engaging with a far bigger audience than we ever imagined. The digital versions of both journals will be available to in excess of 18,000 mining and quarrying companies who will receive FREE digital copies for all employees, a digital copy will be sent directly to the provided email address/s. Receiving a digital copy will also enable access to our new look website www.mqworld where news, feature articles, case studies, video and past issues can all be accessed.

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