ELECTRICMINE.COM

The Electric Mine Consortium

COUNTING DOWN TO 2030

ELECTRIC MINE CONSORTIUM

SLATE

STATE OF PLAY

About State of Play and Slate Advisory

About State of Play™

State of Play was initiated in 2014 to create a platform to support industry discussion of innovation and performance at a strategic level, macro-level insights into the industry ecosystem, and more effective strategy execution and business design for competitive advantage.

State of Play has undertaken 4 global surveys – 2015, 2017, 2019, and 2021. We have also undertaken drill-down research work into specific themes including Critical Minerals in 2022, Electrification in 2020, Cybersecurity in 2019 and the specific mining industries of South Africa and India in 2017.

State of Play is now a leading voice for industry leaders and decision-makers. Our research is the basis for strategic decision-making and investment analysis globally, across operators, suppliers, investors, and government. Our work directly impacts on-the-ground innovation efforts such as the Electric Mine Consortium and countless in-house innovation acceleration programs.

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About Slate Advisory

Slate provides strategic advice to the natural resources, energy and infrastructure industries to help solve the challenge of adapting to external forces. Slate advises established businesses on navigating these forces, through the design of business and functional strategy and tailored reviews. Slate also builds new businesses based on deep industry insight, through the design of business models and bringing together partners, capital and capability.

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The State of Play team would like to recognise and thank the following companies for their active participation in the consortium and their contributions to this report:

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Zenith energy
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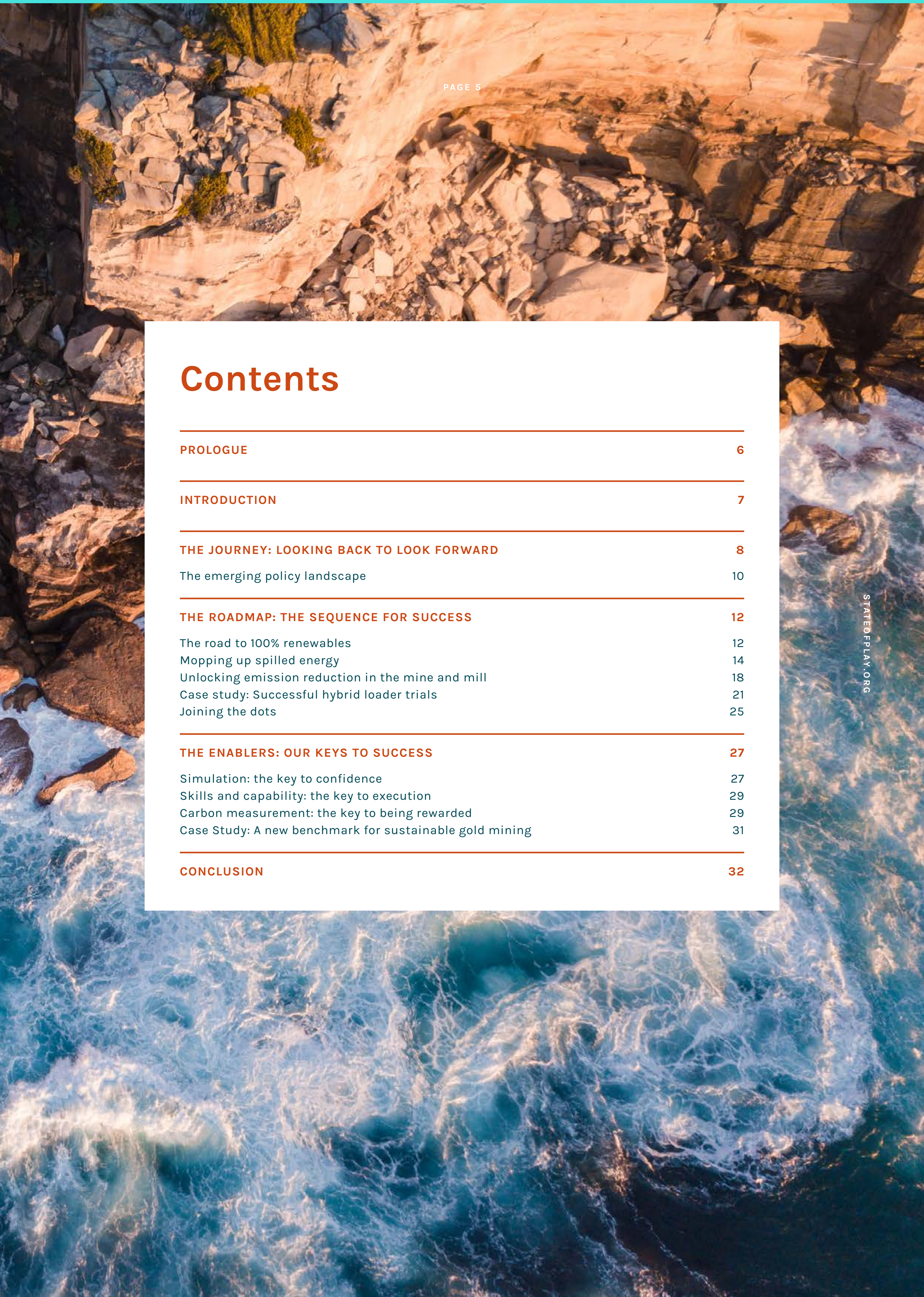

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Prologue

Early in 2020, State of Play undertook a series of industry-wide research activities on electrification in mining. The work catalysed a growing demand for active and urgent collaboration to understand the drivers of mine electrification, identify the key enabling technologies and accelerate its adoption.

As a result, the Electric Mine Consortium (EMC) was established. Founding membership was comprised of base, precious and battery metal producers, who recognised early the imperative to produce zero-emission products for their customers and to meet mounting investor expectations, among other prerogatives. Thus, the objective of the EMC is:

To accelerate progress towards the zero-carbon and zero-particulate mine through:

1. Resolving key technology choices
2. Shaping the supplier ecosystem
3. Influencing policy, and
4. Communicating the business case

In the last 3-years, such imperative has only grown stronger. The pressure to decarbonise is enormous, driven by shifts in international and domestic regulation, as well as growing stakeholder activism.

As a result, EMC participation has grown from the founding 12 companies to today's 23 (12 mining and 11 services companies).

As a collaborative vehicle, the EMC has proven it can play a pivotal role in speeding up technology development to achieve such expectations. If left to overcome the challenges as individual mining companies, the pace of transition to a low-emission global economy may be threatened by the carbon intensity of upstream raw material producers.

Introduction

With little time left to meet the world's growing commitment to climate change, the mining industry is striving to deliver low-emission products to market, whilst maintaining operational and economic efficiency. To make the transition as seamless as possible, companies must orchestrate a carefully sequenced decarbonisation strategy, embracing both new technology as well as new operating models.

The shift presents a new set of strategic options, each with their own risks and opportunities. A willingness to embrace change and a culture that fosters innovation will be required, no matter which pathway companies choose to go down.

This report aims to translate what we have learnt as the EMC in the last 3-years into a high-level decarbonisation roadmap. It intends to provide clarity on a number of the key decision points mining companies will inevitably reach as they decarbonise their operations.

The roadmap begins with switching fossil fuels for renewable energy - the fundamental enabler for almost every other change that follows. It then outlines the need for energy storage and demand management to overcome the intermittency and ensure a stable and reliable power supply. Supporting this is the electrical reticulation infrastructure, the backbone of an electric mine.

With a reliable source of zero emission power, it can be directed to the two largest emission producers in the mine, the fleet and the processing plant. Encouragingly, many processing plants can consume renewable energy as a like-for-like swap with fossil fuels, requiring little conversion or replacement. On the other hand, companies will need to convert their existing diesel vehicles to battery electric in order to consume renewable energy.

The above synopsis barely scratches the surface. The following report will dig a little deeper into how companies can achieve these outcomes, whilst recognising that this is going to take more than just updates to technology – it represents a fundamental organisational change management challenge that should not be understated.

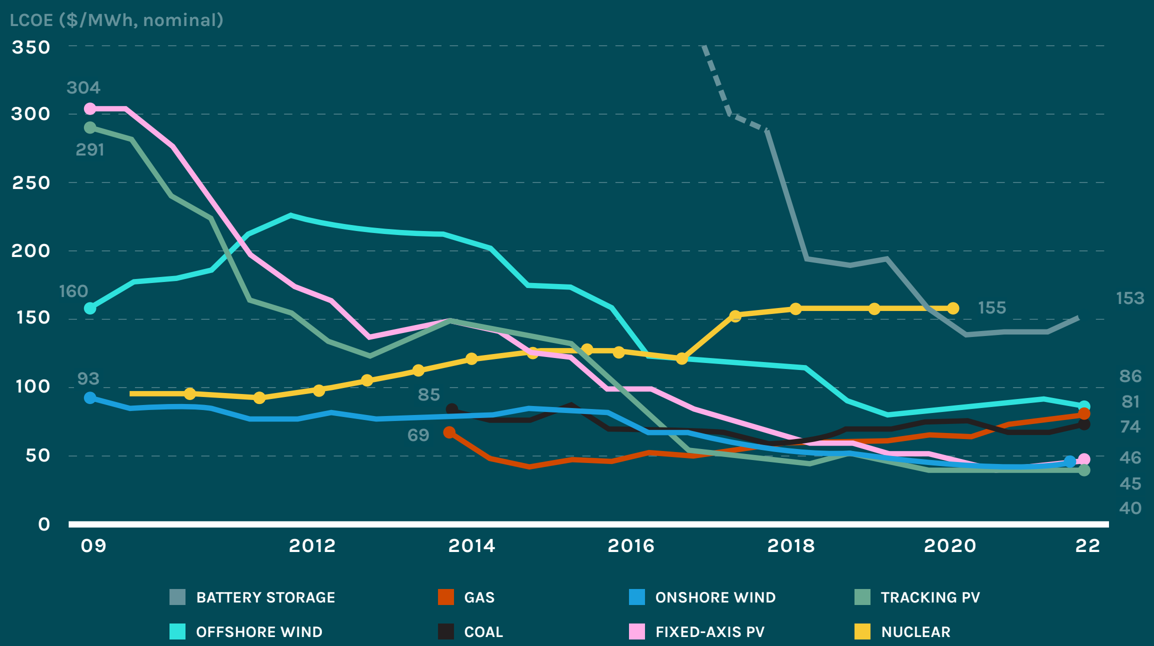
The journey: Looking back to look forward

The EMC has only been operating for three years, however, in that time the world's appetite to combat climate change has intensified dramatically.

The uptake of carbon emissions reduction targets at a national, sub-national and company level has been enormous since the Paris Agreement was mobilised in 2015. In 2020, 53% of global emissions were covered by net-zero emission targets. At the end of 2022 this number was 88%[1].

The proliferation of low-emission energy technology, including solar and wind, has exceeded expectations at every step. More renewable energy is being built today than any other generation capacity[2], supported by sustained reductions in the unit costs of their implementation.

FIGURE 1: GLOBAL LEVELISED COST OF ENERGY (LCOE) BENCHMARKS, 2009-2022



Source: Bloomberg New Energy Finance

The transition to electric vehicles (EVs) has progressed at record-breaking pace. While countries like Norway have already achieved a new car market that is 90% EV, the largest car market in the world, China, has just reached a market share of 25%. This represents a growth rate of 93% since 2021, with analysts suggesting that the market will reach 35% by as soon as this year[3] - a tipping point for incumbent internal combustion engine (ICE) manufacturers.

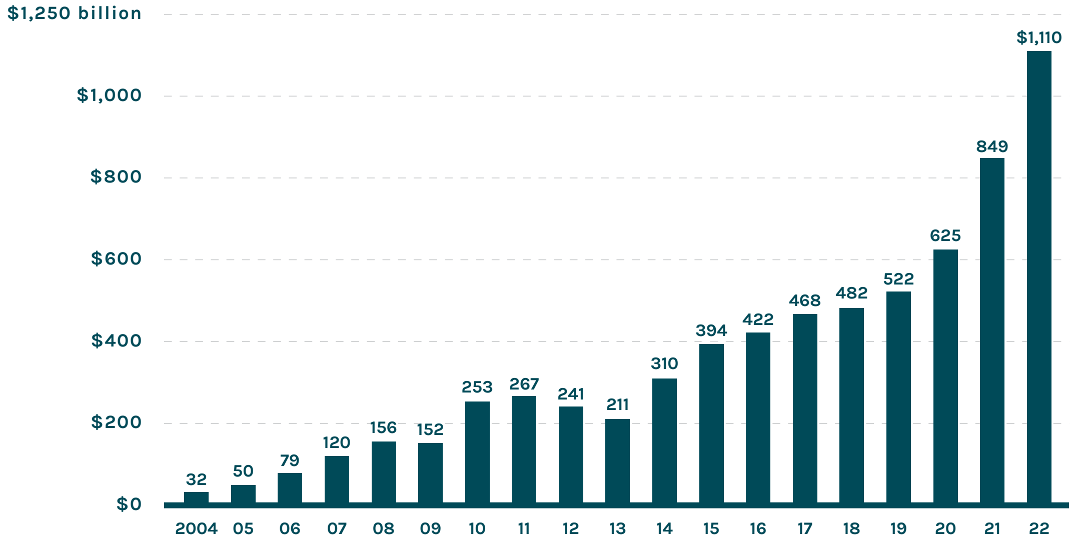
Plans to phase out fossil fuels are becoming a reality. For several years now, the appetite for new coal projects has diminished. Around 75% of planned coal plants have been scrapped, which is the equivalent to avoiding a 56% expansion of the global coal fleet. In OECD countries, cancellations outnumber new plants 6:[4]. In recent years, this trend has started to repeat for gas projects. The REPowerEU initiative recently approved by the European Union aims to cut the use of natural gas by 41% by 2030. Furthermore, voices at COP27 in Egypt have called for a non-proliferation treaty on all fossil fuels to be established.

1 Climate Action Tracker
2 BloombergNEF
3 Bloomberg
4 E3G

The financing ecosystem is heading in the same direction. The majority no longer want to fund fossil fuel projects, and instead are making more capital available than ever before to low-emission projects and technologies. Investment in the energy transition is up 40x since 2004 and grew by 28% in 2022[5] alone. Since COP26, the Glasgow Financial Alliance for Net Zero (GFANZ) membership has grown by over 20%, and now represents over $150 trillion in assets under management. Furthermore, the Net-Zero Banking Alliance (NZBA) now represents 40% of global banking assets.

FIGURE 2: GROWING INVESTMENT IN THE ENERGY TRANSITION

Energy transition investment grew 28% in 2022, and is up 40x since 2004.



Source: Nat Bullard; Bloomberg New Energy Finance

Carbon trading markets (both voluntary and compliance) are growing rapidly. More than 40% of global greenhouse gas emissions are now subject to a carbon price[6], with the market for carbon offsets expected to expand from $2 billion in 2022 to $100 billion by 2030[7]. Updates to Australia's safeguard mechanism announced in early 2023 are following suit, but still lack the ambition of leading global markets.

On a regulatory front, the last few years has seen an uptake of climate-based litigation. Cases against both the public and private sector are going to trial across the globe, ranging from breaches of climate obligations to 'greenwashing'. At an international scale, the United Nations is currently voting to pass on a key resolution that will have the international court of justice advising on what obligations states have under international law to protect against the negative impacts of climate change.

These examples, coupled with the speed of their emergence combine to deliver a powerful message – the world's energy transition is well and truly underway.

5 BloombergNEF
6 OECD.org
7 Morgan Stanley

The above progress did not materialise on its own. It took strong leadership, strategic investments, and a supportive policy environment in a critical mass of countries, companies and individuals who have led the way. It offers a beacon of hope that through well thought out collaboration, investment, and regulation we can meet our Paris Climate Agreement target of limiting global warming to 1.5 degrees. However, on closer inspection, it also reminds us that a lot more needs to be done.

Australia has recently implemented the first meaningful policy intended to address climate change in over a decade. The announcement of the Federal target to reduce emissions by 43% by 2030, coupled with the reform to the safeguard mechanism is a step in the right direction, however, still lags global expectations. Around the world, nations have progressed much further. Germany has matured their climate roadmaps to include sectoral emission targets, and Finland has legislated an aggressive approach to reach net-zero by 2035 and net negative (absorbing more CO2 than they emit) by 2040.

Representing between 4-7% of the world's emissions[8], the mining industry has an important role to play in global decarbonisation efforts. The EMC members and partners alone represent the emissions of a small country the size of Denmark. It is highly likely that as we get closer to 2030, there will be more attention on mining as a sector, driven predominantly by both domestic and global policy reform.

Australia is in a unique and enviable position. It has everything available to become the first mining industry to fully decarbonise. As world leaders in per capita rooftop solar power generation, with one of the highest penetrations of wind and solar energy of any gigawatt scale grid in the world, Australia has the space, the climate, and the resource advantages to lead the transition. Several EMC member companies have already recognised this, including Bellevue Gold and BHP (West Musgrave project[9]), who are in the process of developing assets with over 80% renewable penetration.

The emerging policy landscape

The pace of change in policy efforts to accelerate decarbonisation is showing no signs of slowing down. If anything, it is likely to ramp-up, as policy makers look to target high emitting industries more specifically.

As it stands, there are several policy enablers and barriers relevant to both the global and domestic mining markets that if addressed, have the capacity to fast-track mine decarbonisation. An overview of some of these potential policy levers is outlined below:

Mining fleet conversion: The mining industry replaces each piece of equipment from its core fleet every 3-6 years, which presents an opportunity for mining companies to rapidly transition their fleets from diesel to electric. In support of this, the EMC's policy working group is considering a DPM Code of Practice that will see each member identify a date by which they will no longer have any diesel equipment in their underground mines.

'Green' accreditation: Australia's mining industry is built on supplying customers in export markets, which are all decarbonising at different rates. Customers will increasingly look to procure their products based on embedded carbon as scope 3 emission requirements become more important. The industry needs credible, cutting-edge traceability technology and regulatory regimes to support the 'green premium' value capture. Guarantee of origin regulation is central to validate green metals pricing; enabling investors to assess green products accurately and proportionately.

Capital funding and taxation: Whilst low-rate government loans to reduce the upfront cost of electric technology can be a powerful policy lever it is unlikely. Instead, the provision of accelerated tax-write offs for electric equipment is a more likely pathway. The government has a history of utilising tax concessions to stimulate capital investment, most recently removing fringe benefits tax for electric vehicles within companies.

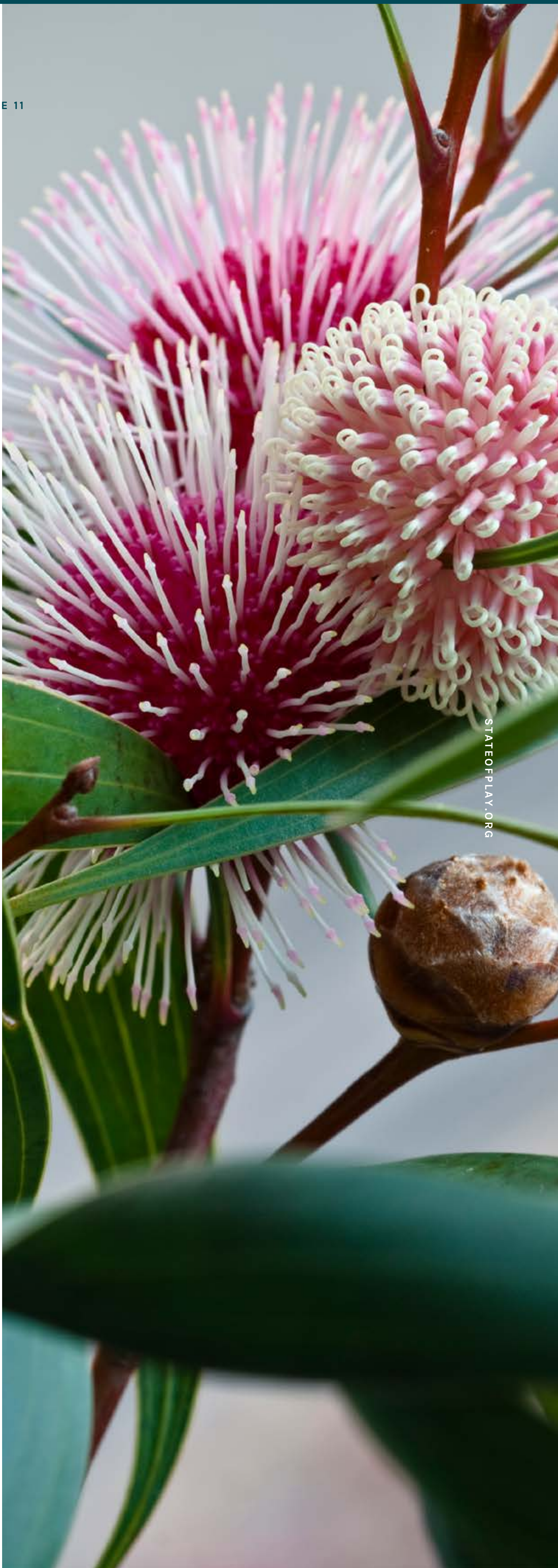
Safeguard mechanism: Reviewing the threshold for the safeguard mechanism with a view to lowering it to 25,000 tonnes per annum, would broaden the compliance market and share the costs of transition across more facilities. This would also have the benefit of aligning with NGER reporting levels, however it is unlikely that the mechanism will be modified before the next federal election.

8 McKinsey
9 OZ Minerals

Energy supply: The life of mine (most of which are less than 15 years) can create uncertainty around investment in the installation of renewable energy generation due to the high CAPEX and long payback periods. The ability for near-grid or off-grid mines to connect to shared energy infrastructure can support risk and cost sharing, helping mitigate uncertainty around life of mine extensions so that the business case for renewable energy installation is more favourable. Australian state governments may also consider establishing renewable energy zones co-located with active and prospective mining areas.

Transmission: Government aimed at maximising the number of mines and projects that have access to a renewable energy supplied grid will open opportunities for power purchasing agreements (PPAs) within competitive electricity markets and nationally traded large-scale green certificates. Possible policy approaches include renewable energy mining zones, incentivising third-party energy project and transmission investment, and support for commercial collaboration between mine sites to develop shared infrastructure.

Domestic wind turbines: For remote, isolated mines to reach high penetration renewables, smaller wind turbines are required (1, 2 and 4MW turbines). More smaller wind turbines are less risky to maintain and operate than fewer larger turbines. Small turbine manufacturers exist in Australia, but they typically don't serve mining. Government policy can look to target the development of a large-scale turbine manufacturing industry in Australia, either via existing mechanisms such as a larger Advanced Manufacturing Growth Fund or new mechanisms such as investment incentives.



The roadmap: The sequence for success

The uptake of net-zero targets has been rapid. As we are now well into the process of integrating these targets into operations, the world's focus has shifted from "do you have a target?" to, "how will you achieve your target?". In essence, answering this question is what the EMC is all about.

Since its inception, the EMC and its members have developed a leading knowledge base for what it takes to achieve net-zero mining operations. From a theoretical standpoint, we have been able to build a strong understanding of the areas that were once considered contentious. At a high-level, the question surrounding sequencing of investment and implementation of electrification technologies has been largely resolved for most mining methods, with the first step in all cases being energy generation – an area that has benefited from enormous global investment and policy support.

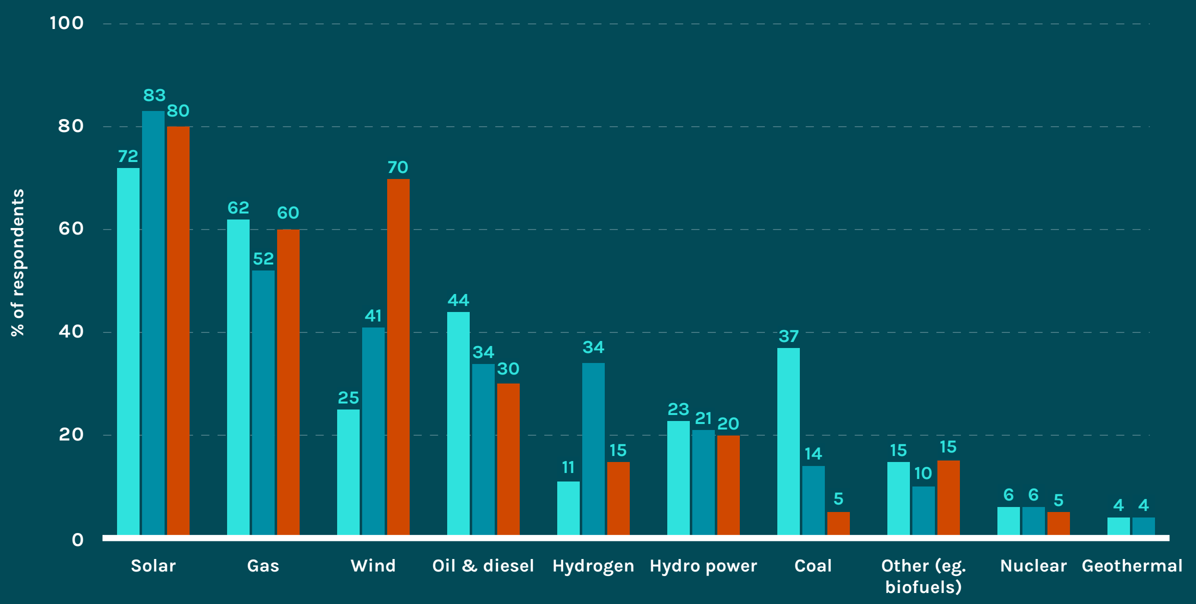
The road to 100% renewables

It's clear that renewable energy (RE) is the key that unlocks the pathway to net-zero. Renewable energy now accounts for approximately 35% of Australia's total electricity generation[10], which has doubled since 2017 (16.9%). This trend is consistent globally, with renewable energy generation increasing from ~9% in 2017, to ~14% of the global energy mix in 2023[11].

The mining industry is following the same trajectory. Over 80% of the industry see solar as the most widely used source of energy in mining operations over the next 15-years, followed by wind (70%)[12].

STATE OF PLAY 2021: WHAT ENERGY SOURCES WILL BECOME THE MOST WIDELY USED IN YOUR COUNTRY'S MINING COMPANIES OVER THE NEXT 15 YEARS?

RESPONDENTS GIVEN THREE ANSWERS



Source: SOP Analysis 2019, 2021, 2022

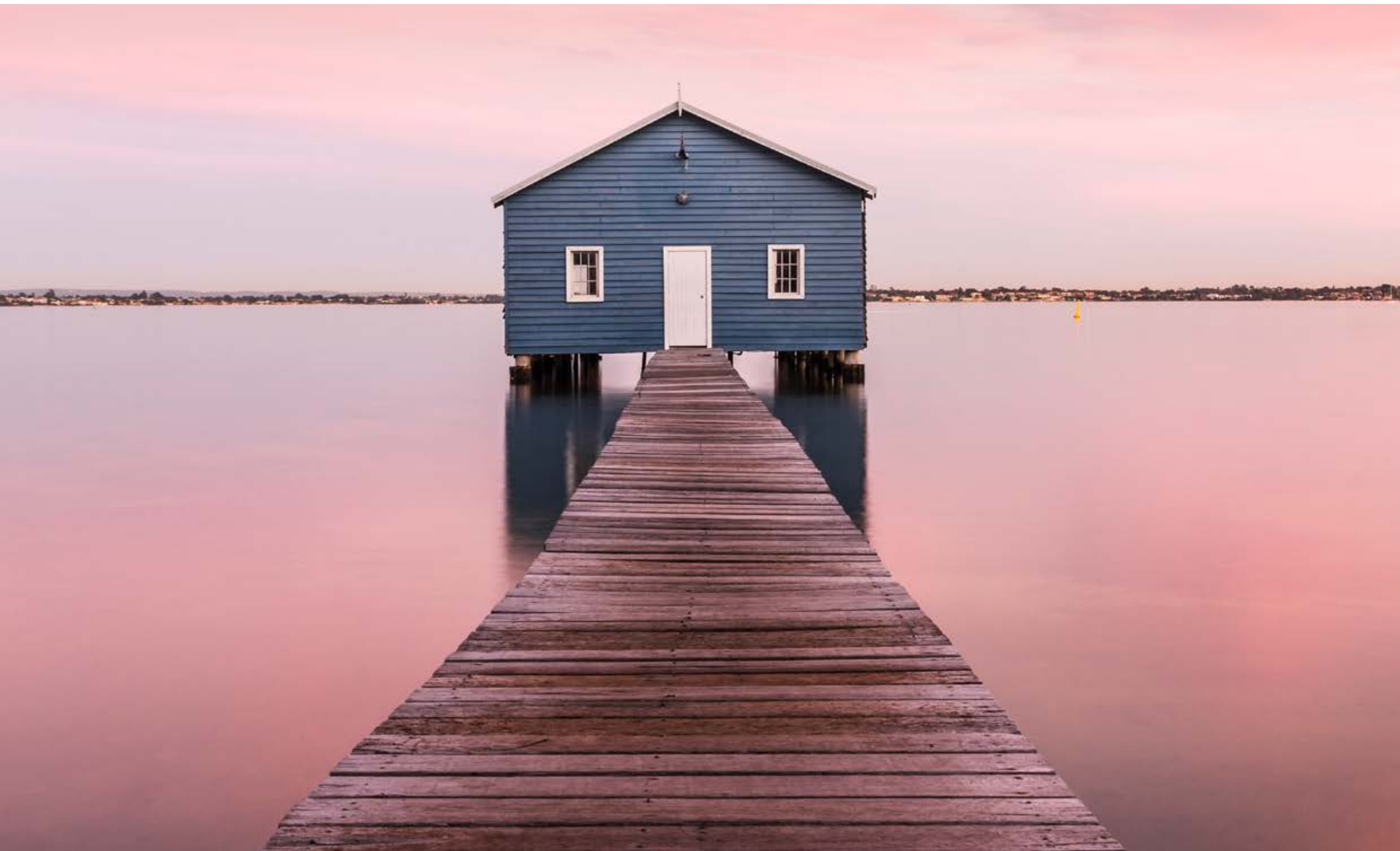
10 OpenNEM
11 Statistical review of World Energy 2022
12 State of Play 2022

With such growth in adoption, the technical understanding of renewable energy technologies has matured significantly in the last 10-years. Unlike many other areas of mine electrification, there is little need for piloting and testing of renewables – while still complex technically, implementation is now more a matter of commitment to the investment and optimisation of the mix and capacity.

Among EMC participants, there is a consensus that if mine sites can construct a renewable energy generation capability that supplies at least 70-80% of their energy needs (with the remainder met through batteries and diesel generation), they should be able to achieve at least a 30% total emissions reduction (depending on the individual characteristics of the mine).

For mine sites proximal to the competitive National Electricity Market (NEM), grid connection is the cheapest source of energy. Those sites on the 'edge of the grid' must evaluate whether building infrastructure to reach the transmission network or developing their own source of power is best for them. This decision will often come down to the life of mine, with the longer the life creating a better business case for on-site renewable energy generation.

Our view of energy supply extends beyond the infrastructure, with much of the members' work maturing to focus on how to best leverage 'spilled energy', whereby generation exceeds demand. Capturing the excess (instead of letting it go to waste) allows for energy to be stored for deployment during periods where renewable energy is insufficient and presents valuable opportunities for demand management. Successfully implementing these techniques has the potential to take a 30-40% emissions reduction figure all the way to 100%.



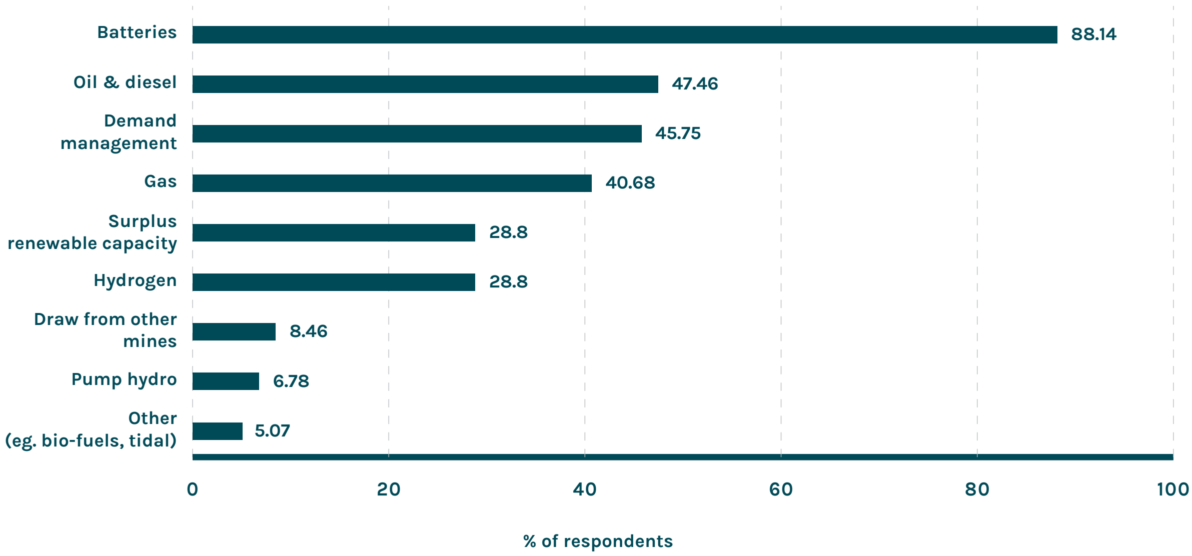
Mopping up spilled energy

Energy storage

The most obvious solution to spilled energy is through storage. 88% of the industry believe batteries are the most likely form of back-up power for remote mine sites using renewable energy[13]. For decades, humans have been capturing and transporting energy using batteries. It is not a new phenomenon. However, in a mining context, the ability to capture excess renewable energy, store it in some form of battery, and discharge at another time is not widespread. Even for sites with a high renewable penetration, under unfavourable weather conditions they currently fall back on fossil fuels to fill the void. A 24/7 mining operation needs consistent, reliable power, and without a zero-emission baseload source such as the grid (or nuclear power), energy storage is required to achieve net-zero.

WE ASKED: FOR REMOTE MINE SITES USING RENEWABLE POWER, HOW WILL THE ELECTRIC SYSTEMS BE SUPPLEMENTED WHEN THIS SOURCE ALONE IS INSUFFICIENT?

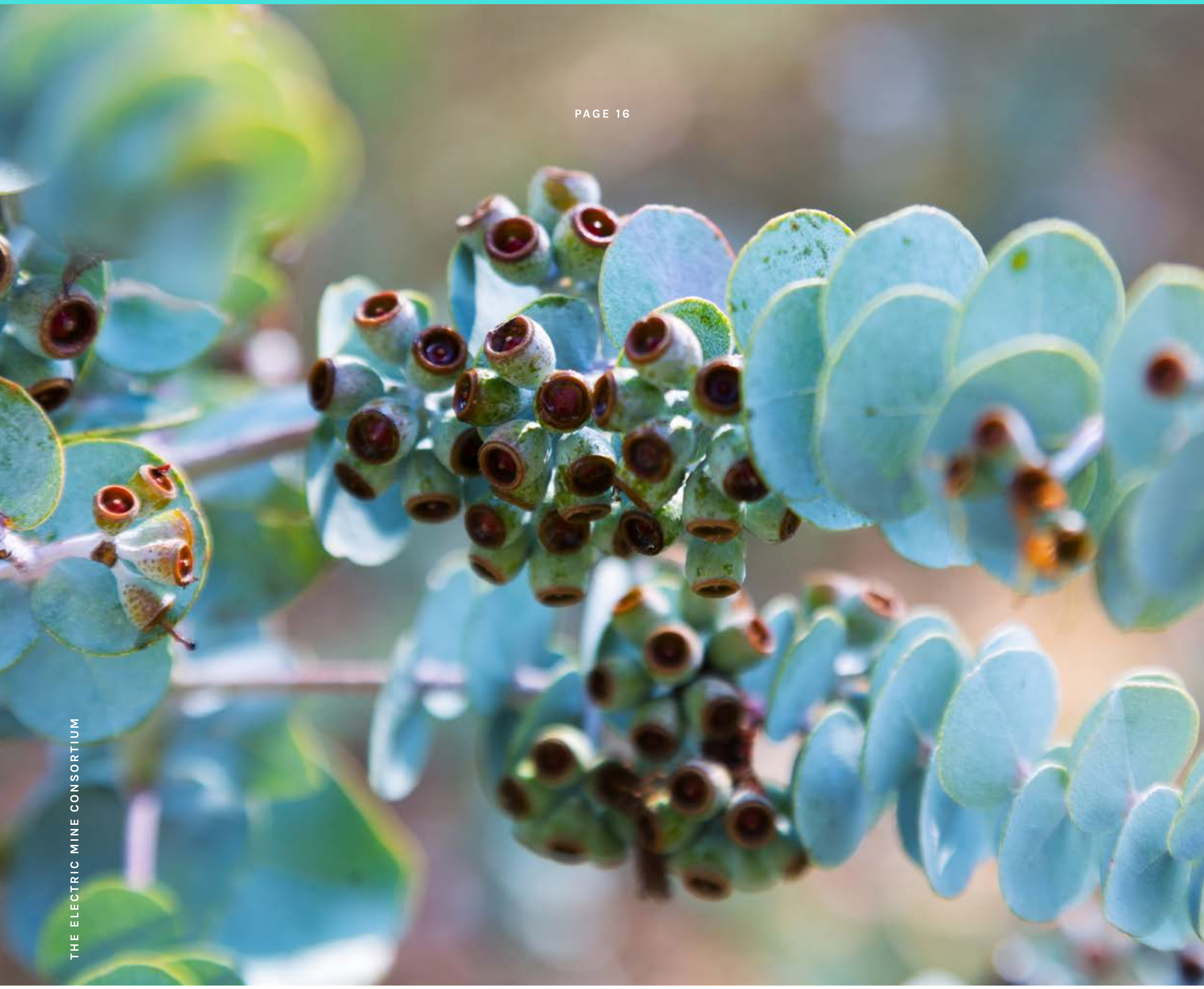
RESPONDENTS GIVEN THREE ANSWERS



Source: SOP Analysis

The jury is still out as to which technology is best suited to a mining context. Popular lithium-ion applications, whilst useful for maintaining power supply quality and inertia support, typically only provide energy over a short period of time (<40 minutes). Mining operations need a discharge period of approximately 4-8 hours to complement renewable energy availability. Despite lithium-ion applications becoming more competitive in duration, the EMC is therefore focusing on alternative types of technology solutions, some of which we have analysed are outlined in detail below:

	A-CAES (Compressed air)	Flow (Vanadium Redox)	Flow (Zinc Bromide)	Gravity	PHES (Pumped Hydro)	Underground Hydrogen	Lithium-Ion	Molten Metal	Sodium Sulphur	Iron-Air	Nickel-Hydrogen	Solar Thermal
OPEX	Medium	Medium	Medium	Low	Low	High	Low	Unknown	Low	Low	Low	Low
CAPEX	Medium to High	High	Medium	Medium to High	High	High	Medium	Unknown	High	Ultra-Low	High	High
Commercial Readiness in Grid Scale Applications	2–3	3–4	2	2	6	1–2	3–4 (medium duration)	1–2	1–2	1	1	3–4
Lifespan	Very Long: 30 - 50 years	Long: 20 + years	Long: 20 years	Very Long: 30 - 50 years	Long	Long	Long: 20-30 years	Long: 20 years	Medium: 15 years	Long: 20 - 30 years	High: 30+ years	High: 30-40- years
Response Time	Very Slow: 10-20 seconds	Instant	Instant	Slow: 1 - 5 seconds	Very slow	Unknown	Instant	Instant	Instant	Unknown	Instant	
Energy Efficiency	Low	Medium	Medium:	High	Medium	Medium	High	Medium - high	High	Low	High	
Duration	Medium: 4 - 12 hours	Low: 3 - 8 hours	Long: 5-24 hours	Medium: 4 - 12 hours	Very Long: 4 - seasonal storage	Very Long	Low: <4 hours, not fully mature at 4-12 hours	Medium: 4 - 12 hours	Long: 5 - 24 hours	Long: 100 hours (commercial scale unknown)	Medium: 2 - 12 hours	Long: 4–24 Hours
Geographical Dependency	High: Compressed air is stored in large underground reservoirs	None	None	Moderate: requirements depend on system type	Very high: Topography requirements, limited water at rural mine site, environmental approvals, and large footprint	High: At large scale applications, hydrogen is stored in underground reservoirs	Low: sensitive to environmental conditions	None	None	None	None	Moderate: Requires large areas with high sunlight requirements



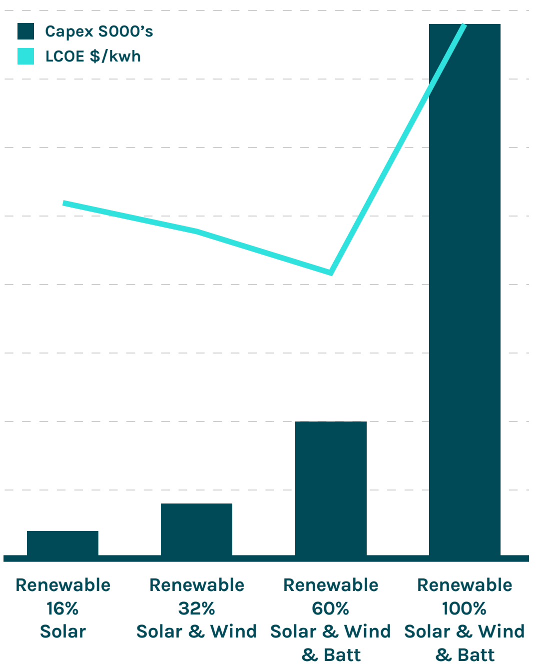
Mines in Australia will typically prioritise the installation of solar and wind generation as the first step towards net zero operations, with a renewable contribution of 10% to 20% readily achievable. The intermittent nature of renewable supply dictates that deeper penetration of renewables will require over-capacity of solar and wind and a critical role for energy storage.

Sizing of an energy system requires the balancing of several variables:

— Capital costs for renewable technologies that are getting cheaper at different rates
— Local climate conditions for solar and wind
— Local load characteristics with a significant change expected due to electrification
— Trade-off between renewable overcapacity vs storage
— Existing energy generation cost and emissions
— External impacts and trends such as carbon and fuel prices

EMC analysis of a template underground mine in Western Australia transitioning from diesel generation to renewables over a 10-year mine life is illustrated in the diagram below. The levelised cost of electricity (LCOE) is lowest at a renewables penetration of 60%, achieved through 4x overcapacity of wind and solar (i.e. 100MW of capacity for an average 25MW load) and modest storage. There is significant spilled energy in this scenario, representing a cost in the short term but an opportunity in the longer term.

Importantly, the cost of a transition to 100% renewables is non-linear and currently non- economic due to the prohibitive cost of commercially available storage technologies.



The landscape of long duration energy storage (LDES) technologies is relatively new, but rapidly evolving. Despite the need for LDES being well recognised, adoption thus far has been slow and is perceived as risky due to:

1. Various technologies on the market, each with different suitability and integration requirements.
2. Total cost is uncertain, due to unknown and bespoke infrastructure and integration requirements
3. Most technologies have not been proven at large scale, or within a mining context
4. Many solutions are not yet commercially available and require significant manufacturing scale-up

The collaborative vehicle of the EMC aims to break the 'catch-22' cycle and has adopted a process to share risk and capital to overcome the above challenges and kick-start investment.

As a first step the EMC conducted a market-wide discovery process. 20 different LDES vendors expressed their interest for their technology solution to be considered for a pilot. Eleven technologies were shortlisted with each currently undergoing detailed evaluation by the EMC members.

Upon completion of the evaluation, the EMC will select (at minimum) three solutions to progress to a detailed study. Several members will select a use case and conduct a pre-feasibility study on these technologies. The learnings of each of the studies will then be shared between the companies, and others in the consortium.

The approach is simple and based on the intrinsic characteristic of data – it can be replicated without cost. The members will gain the insights of three different PFS' for the cost of one, accelerating both the technical and economic understanding of LDES solutions, and reducing the risk of investing time and effort into a 'white elephant' technology. It will significantly speed up the ability for companies to comfortably progress to feasibility study, financial investment decision and pilot stages.

Demand management:

The combination of an energy source that is variable, coupled with an energy storage solution, is creating novel complexities when it comes to management of energy supply and demand. Once these complexities are understood and can be controlled, the ability to optimise the variability by matching supply (generation) and demand (usage) can drastically improve productivity, reduce costs, and decrease emissions.

There are several ways to achieve this, however each require a shift in operating philosophy from one centred on continuous processes to energy optimisation. The two main approaches are split into:

1. Changes in the physical technology or operating equipment
2. Investment in digital technology that supports optimisation decisions

Firstly, the physical technology will need to be able to cope with the sporadic ramping up and down of its use. Many of the current solutions are not suited to this and will therefore need to be replaced with alternate technologies. For example, BHP have chosen to invest in vertical roller mills (VRM's) instead of semi-autonomous sag mills (SAG) to process their ore[14]. VRM's can easily be turned on and off to align with energy availability, whilst SAG mills typically run continuously and need a constant energy source.

14 Australian Financial Review; Oz Minerals

Secondly, there is value in a digital solution to support mine operators in optimising energy efficient production. The EMC is of the belief that this will come in the form of an energy management system (EMS) that provides forecasted and real-time information on power generation and demand across the different aspects of mine operations. The EMC also believes that the system should be capable of controlling and optimising the individual energy network components automatically.

The EMC has engaged with leading technology companies to understand the supplier ecosystem. There is strong capability readily available in the control of energy generation microgrids. However, the integration of long-term load planning and optimisation, together with live control of operating loads, will require further product development.

The EMC's investigation into this area is ongoing, supported by a market wide discovery process and ongoing engagement with suppliers. EMC members are expected to scope and pilot an appropriate energy management system in FY2024.

Unlocking emission reduction in the mine and mill

With a sufficient and well managed supply of renewable energy, the next phase of implementing a decarbonisation strategy lies in understanding where exactly to direct the power. The equipment within the mining fleet and the processing plant are the biggest consumers of energy within the value chain and are therefore the main areas of effort.

Depending on the size of the fleet, and assuming the use of renewable energy, full electrification of mining equipment (drill, blast, load, haul and supporting services such as refrigeration and ventilation) can unlock approximately a 35% emission reduction. Another 35% reduction can be unlocked by decarbonising the mineral processing stage. These figures are based on a typical underground gold mine - reductions will differ between mine sites, however no matter the site, these two areas remain the major areas of focus for carbon abatement.

The fleet:

The consortium has split their focus on the mining fleet into three categories:

1. Light and auxiliary vehicles (drill, blast and supporting vehicles)
2. Underground haulage (load and haul)
3. Surface and long haulage

Light and auxiliary vehicles (drill, blast and supporting vehicles):

Despite having limited carbon emissions impact, the light and auxiliary vehicle category was seen as important to the EMC to enable a shift in mindset and to gain insights at low cost, with a minor impact on production. As these vehicles are often operated in hotter areas of the mine with less ventilation, electrification also improves the environmental conditions and air quality for the workforce by emitting less heat, zero-diesel particulates and zero emissions.

With very limited original equipment manufacturer (OEM) supply across this category, the EMC members sought the option to trial OEM machines where available (e.g., Normet) and worked at length with cutting edge retrofitting providers such as Zero Automotive where off the shelf solutions were not available[15].

Two significant areas of battery retrofit options were for services vehicles (Integrated Tool Carriers, ITs) and light vehicles. The EMC began working with 3ME Technology in 2020 to deliver a retrofit of a Volvo IT L120, and with Zero Automotive in the retrofit of the 70-series Toyotas that are ubiquitous on global mine sites.

During the last two years, the EMC members have also ordered or commenced trials of alternate purpose-built vehicle types to move people around a mine. In this process, South32 and Evolution Mining have uncovered, and are now working with, Safescape in Australia to deliver the Bortana electric light vehicle and Rokion in Canada respectively.

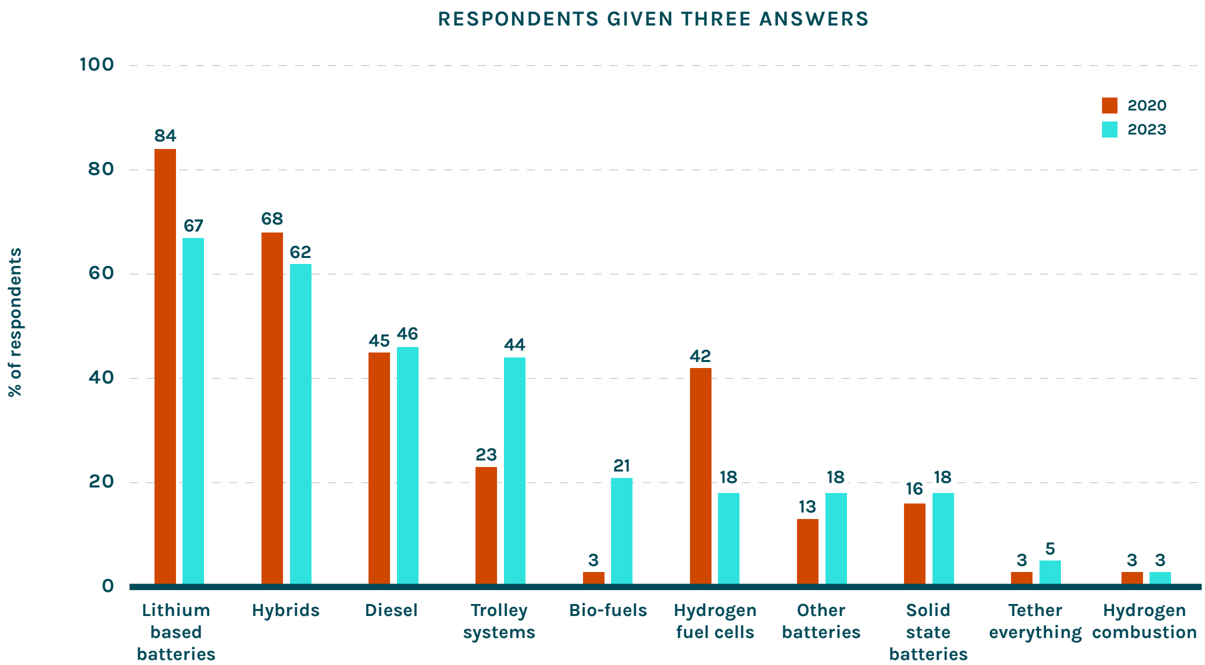
Underground haulage (load and haul):

The majority of the heat, air pollution (incl. diesel particulate matter) and carbon emissions produced in an underground mining context are a result of heavy diesel equipment, making it a high value area for decarbonisation. However, due to the impact on production, size of the equipment and upfront capital cost, this area has remained one of the most challenging for EMC members to transition to zero-emission technology solutions.

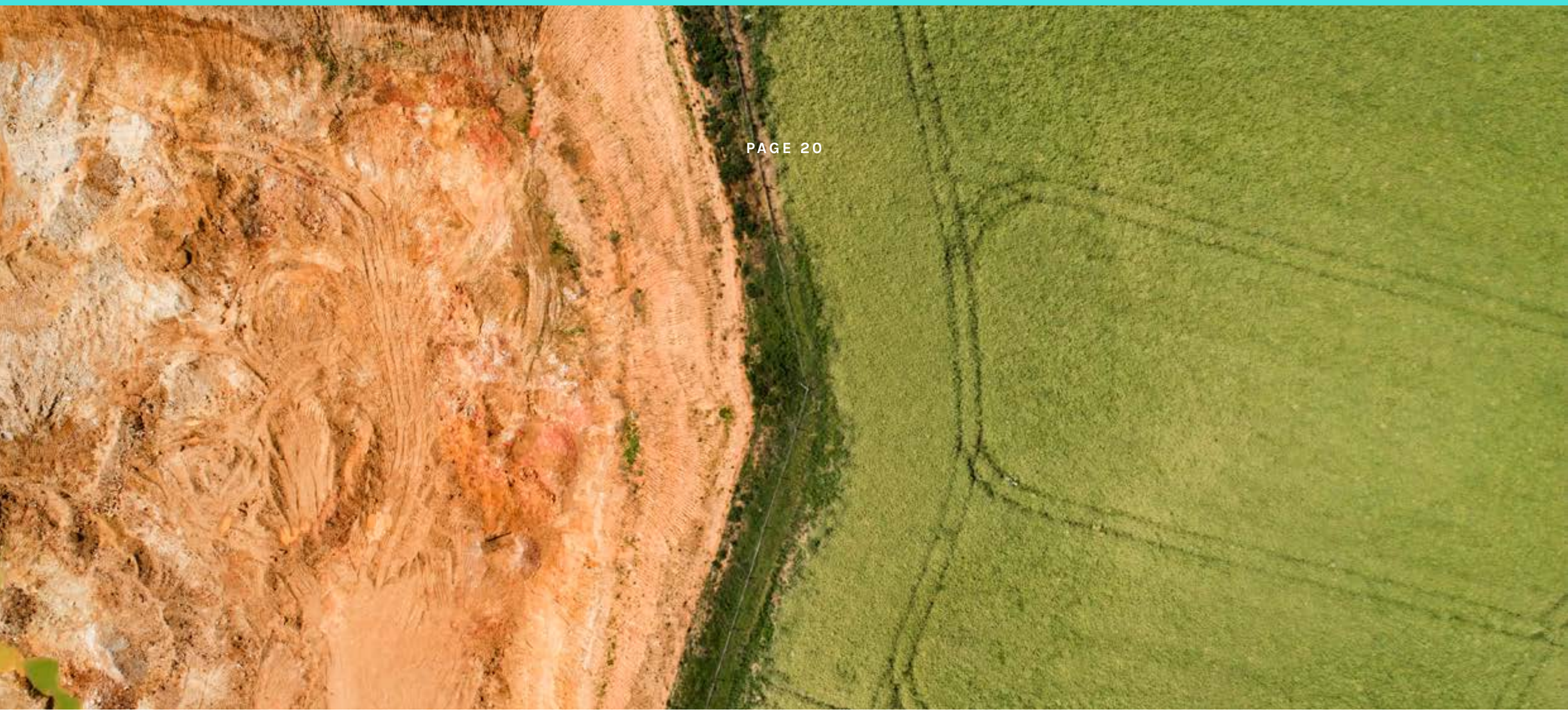
When the consortium was initiated over 2-years ago, one of the major technology uncertainties was around what the dominant energy source for zero-emission heavy haulage equipment will be. To date, a consensus has been reached that in an underground context lithium-based battery electric driven vehicles are the preference, with diesel-electric hybrids a valid option during the transition.

The feasibility of hydrogen fuelled underground haulage has dramatically reduced from initial expectations due to concerns around safety underground, economic feasibility, technology maturity and pace of green hydrogen supply. On the contrary, the interest in both trolley systems (e.g., BluVein) and biofuels has radically increased. Underground conveyors (not included in below figure) are also showing promising economics.

WE ASKED: WHAT WILL BE THE DOMINANT ENERGY SOURCE FOR ELECTRICALLY DRIVEN HEAVY MOBILE EQUIPMENT IN THE NEXT 5-10 YEARS?



Source: SOP Analysis



EMC members who have underground operations in Australia are hampered by the lack of availability of electric loaders and trucks in the size they require to meet current productivity standards. 21-tonne loaders are the typical size used in decline accessed mines in Australia, however the largest capacity battery electric loader available is the Sandvik LH518N LH518B (18-tonne) and Epiroc ST18 SG (18-tonne).

Similarly, the haulage trucks typically used have a 63-tonne capacity, however the largest currently available battery electric truck is the Sandvik TH550B (50 tonne) and Epiroc MT42 SG (42-tonne). The Sandvik TH665B (65-tonne) prototype is currently being trialled at different sites globally.

The consortium members have successfully aggregated demand to encourage and incentivise OEMs to accelerate work to develop larger electric loaders and trucks, which should be available in the late 2020s. In the meantime, the EMC has adopted a philosophy of trialling to learn across both hybrid and electric fleets, as well as across vehicle providers.

ELECTRIC MINE CONSORTIUM TRIALS UNDERWAY GLOBALLY UNDERGROUND

Vehicle category	In operation	Trial complete	Active trial	Awaiting delivery
Trucks	Newcrest (8) Sandvik Z50 Evolution (2) Epiroc MT42		Gold Fields Sandvik Z50	Barminco Sandvik TH665B Newcrest (3) Sandvik Z50
Loaders (LHD)	Evolution Epiroc (2) ST1030	Gold Fields Komatsu HD22 hybrid Newcrest Caterpillar R2900 XE (Field Follow)	South32, Barminco and MMG Caterpillar R2900 XE (Field Follow) Gold Fields Sandvik LH518B	Gold Fields Komatsu HD18 hybrid Evolution Epiroc ST14
Auxiliary/Support Equipment		Barminco Normet Charmec	Gold Fields BIT Volvo L120 Retrofit Barminco Sandvik longhole drill	South32 and Barminco BIT Volvo L120 Retrofit Barminco MacLean SS5 Sprayer Newcrest MacLean ML5
Light Vehicles	Evolution Rokion (2) OZ Minerals Zero Automotive ZED70Ti	Evolution Rokion Note: Several mines tested the first alpha prototype Bortana EV prior to the EMC	Gold Fields Murray Engineering eLV Barminco Zero Automotive ZED70Ti	South32 (3) and Oz Minerals (1) Bortana EV Barminco (additional) Newcrest Zero Automotive ZED70Ti

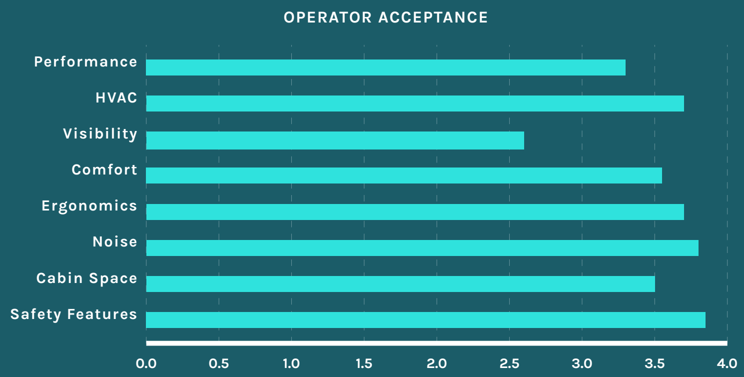
Case study: Successful hybrid loader trials

Given constraints around technology readiness and availability of electric haulage equipment, several Electric Mine Consortium ("EMC") members have investigated the viability of transitionary technologies. Diesel-electric solutions have proven a productive and efficient option for companies wishing to begin their decarbonisation journeys today, whilst also acting as a stepping-stone technology that enables greater optionality when making future electric equipment purchases.

Caterpillar offered trials of the Cat R2900 XE diesel-electric underground mining load haul dump (LHD) loader in Australia through their site field follow process. A number of EMC members have participated in testing the Cat R2900 XE, including South32, Barminco, MMG and Newcrest.

In late 2022, South32 commenced the trial at their Cannington site. The trial was supported by Site, the Cat dealer Hastings Deering (Australia) Limited, and Caterpillar. South32 divided their data collection by measures of success into four categories relating to both the machine and the working environment.

The below table contains South32's finding within the four pillars:

Category	Outcome
Environment Health & Safety Impact Fuel Consumption Heat Exposure DPM / Emissions Safe Design	✔ 34% reduction in fuel consumption (due to electric drive and hydraulic piston pumps)* ✔ 99.99% reduction in DPM* ✔ 100% reduction in CO ppm at idle and 64% reduction at high rev* ✔ 43% reduction in NOx at idle and 61% reduction at high rev* ** When compared to South32's current R2900G fleet.*
Financial Impact Maintenance Costs Asset Costs and Lifespan Production Driven Revenue Changes (increase/ore pass)	✔ 23% increase in productivity (tonners/hr)* ✔ Key takeaway was significant increased production for the same operational scenario loading of ore into the underground crushing circuit from nearby stopes. ✔ Notable reduction in tyre wear, attributed to traction control* ✔ Availability and downtime statistics were not included and found to be not credible due to multiple factors. ** When compared to South32's current R2900G fleet.*
Production Impact Speed of Travel[1] Speed of Gear Change Lift Capacity Availability / Downtime *[1] under different loading conditions and on different inclines*	✔ 20% increase in lift capacity (per bucket)* ✔ The loading capacity of the R2900 XE is 8.6m3 compared to 7.3m3 for South32's R2900G. From this we predicted that there would be an increase in lift capacity of 17.8%. The actual material movement results beat this capacity increase*. ** When compared to South32's current R2900G fleet.*
User Impact Travel Smoothness / Suspension Visibility Profile Movement Parameters Noise Performance	Operator Change Management – Auto dig features were accepted by the operators in the third trimester of the Field Follow. Operator Acceptance of new machine survey results: 

On the back of successful electric bogger trials and the information that was shared, two other members made the decision to purchase approximately 7 of the loaders outright. In one case, the mining company made the decision to replace 4 of their existing diesel loaders with 3 hybrid loaders due to the productivity uplift that was delivered in a trial.

These subsequent purchases speak to the core principles of the consortium – that is, the sharing of information and knowledge to resolve technology choices and accelerate the adoption of mine electrification.

Brownfields vs. greenfields underground fleet considerations:

The implementation of a decarbonisation strategy will be quite different for greenfields and brownfields assets. The retrofitting of a brownfield asset must overcome sunk capital and the remaining life of mine. However, it can still reap the rewards associated with the replacement of diesel fleets with electric. From a productivity and efficiency perspective, battery electric vehicles have more power, have 2x more speed, 60% faster acceleration and a 25% faster load time[16]. They offer regenerative braking opportunities, improved cycle times and greater availability due to reduced servicing requirements. Changes are likely to be staggered in a brownfields context (fleet conversion built into replacement plans) to ensure adoption aligns with current operations and meets hurdle rates for investment.

On the other hand, greenfield assets can demonstrate the true value impacts of full fleet electrification from day one of operations. In addition to the above operational benefits, the decision to build an electric mine from the outset allows for more favourable mine designs. An underground fleet is responsible for 30-50% of heat generation. An electric fleet will reduce heat emissions by up to 90% and eradicates DPM, drastically reducing the need for mine ventilation. Given that ventilation can use up to 50% of a mines electricity, the economic benefit of reduced ventilation operating costs can be realised[17]. The ability to design mines with smaller ventilation infrastructure from the outset will also reduce capital costs.

In addition to cost savings, mine ventilation traditionally comprises approximately 35% of an underground mine's scope 1 and 2 emissions, making it a high impact lever for decarbonisation.

Surface and long haulage:

Driven by member demand, the EMC has expanded its original scope to include aspects of decarbonisation of surface operations, as well as underground.

Whilst not applicable to all members, the EMC members focusing on the challenge of in-pit surface haulage have elected to prioritise solutions around the 100-tonne capacity mark, driven by their operational requirements and the typical path for innovation – starting small and scaling up. The 300-tonne ultra-class truck is the focus of the Charge on Challenge and is less applicable to our members, however many are still involved in the initiative with the ambition to learn and translate any insights to smaller applications.

16 Sandvik: 'Power at the end of the tunnel'

17 GMG: Recommended practices for Battery Electric vehicles in underground mining

To date this area has been hampered by technology availability, with a lack of zero-emission surface haulage solutions on the market across both traditional OEMs and retrofit providers. However, battery performance is increasing rapidly, driving the ability to electrify large vehicles, and spurring new and existing players to enter the market. In the last few months EPCA has emerged as a local Australian retrofit partner. They are currently in the process of working with EMC members to deliver a pilot of a 100-tonne electric CAT truck conversion as a demonstration truck for use across industry. The change in battery performance is what has enabled this type of conversion. Two years ago, the proposed retrofit would require filling the entire truck tray with batteries to achieve the required energy density. Today, the batteries are able to fit underneath the tray.

	Battery		Today	End 2023	2024	2025	
TESLA	**The 4680 battery** *(current class leader)*	✔ 244 watt hours per kg ✔ Consumer car range +600km	⚡				
CATL	**The Jilin battery**	✔ 255 watt hours per kg ✔ 10 mins to charge from 10-80%	⚡				
	The sodium-ion battery	✔ 160 watt hours per kg ✔ 50% cheaper than lithium-ion	⚡				
	The condensed matter battery	✔ 500 watt hours per kg ✔ Considered much safer		⚡			
国轩高科 GOTION HIGH-TECH	**The Gotion LMFP Astroinno battery**	✔ 240 watt hours per kg ✔ 1,000km range, 2m km life, 18 min charge			⚡		
SolidPower	**The solid state battery**	✔ TBC watt hours per kg ✔ Super safe, energy dense, next gen				⚡	
Argonne NATIONAL LABORATORY	**The lithium-air battery**	✔ 1,200 watt hours per kg ✔ Super safe					⚡

Note: Electric planes are considered viable at 400 watts per kg.

Source: EMC Analysis 2023

In parallel, members of this work stream have also focused on zero-emission long-haulage and are currently in the process of finalising a market wide expression of interest (EOI) process.

Released in 2022, the Electric Long Haulage EOI was initiated to provide EMC members with an awareness of the technical and commercial readiness of zero-emission long haul options for use in mining, transport, and other industrial applications. It also served as a mechanism to encourage collaboration between the mining and transport industries, both of which are currently exploring how they can best decarbonise.

Approximately 70 vendors were invited to submit a technology solution across the areas of:

1. Surface long-haul electric vehicle conversion (battery); and/or
2. Charging infrastructure to support surface long-haul electric vehicles; and/or
3. Small scale renewable energy infrastructure to interface with charging infrastructure in remote areas; and/or
4. Simulation capability to inform battery design, charging and truck design

17 responses were received, and the process of vendor engagement is currently ongoing.

One of the major learnings from the process so far is how large the cost barrier is. As it stands, a company can go out today and buy a diesel-powered prime mover for around $400k. To convert this truck to electric can cost up to an additional $2 million, driven predominantly by battery costs. That's an almost 500% cost increase. The good news is that if companies can overcome the upfront capital cost barrier they will reap the rewards in reduced operating cost over the life of the truck, a trend consistent with electric equipment across most other mining applications.

This is because the differential between fuel and electricity costs as well as maintenance costs for a diesel and electric trucks are material. Modelling suggests that annual electricity costs are 74% cheaper than diesel costs[18] and maintenance costs are 49% cheaper for electric solutions. This example highlights the need for companies to adjust their view of cost from one of upfront capital cost, to total cost of ownership if they want zero-emission equipment to meet internal procurement requirements.

The impetus to accelerate progress in long haulage is only increasing. This year, California approved its 'Advanced Clean Fleets' rule, which requires all new medium and heavy-duty vehicles sold or registered in the state to be zero-emission by 2036 and will ban new diesel trucks from ports and railyards starting next year[19]. We expect regulation in other jurisdictions to follow suit over the coming years, supported by demand from communities as well as growing vehicle availability.

18 EPCA analysis: *Based on $1.60 per litre diesel cost and $135/Mwh (or 13.5c/kwh)*
19 California Government

Joining the dots

Shifting from a fossil fuel powered mine to an entirely electrically powered mine is a whole-of-systems shift from one energy technology to another. It will cast away several traditional mine design principles and requires a novel approach to an assets physical and digital architecture.

Electrical infrastructure

In our previous publication[20], we detailed the key technical questions the EMC members are attempting to answer when it comes to electrical distribution infrastructure. Through several initiatives, including custom power modelling simulations and physical trials, the members' understanding of the supporting electrical infrastructure required to support a zero-emission mine has grown dramatically.

Ultimately, each mine will need to determine their own electrical loading and estimate the infrastructure required to meet their given load profile. Whilst the details will differ between sites, miners looking to transition to electric should expect to invest in additional baseload generation capacity, higher voltage transmission and a substantial number of additional transformers, amongst other things. The problem is extremely solvable, and the services ecosystem that supplies the expertise is maturing rapidly.

The charging strategies employed will also differ between EMC members, given the diversity in mine designs and fleet sizes, however learnings and insights have still proven valuable when shared. Charging location, charger type (i.e., AC-DC, DC-DC etc.), size of charging bays, feasibility of onboard charging, and shift scheduling are critical considerations for all mining companies.

The diversity of these strategies creates challenges for standardisation. Standardisation is a global challenge, and one that requires significant consultation with equipment providers and manufacturers, as well as policy makers and regulators. The EMC members support a market-wide adoption of an agnostic charging solution and believe it would help radically simplify the electrical infrastructure challenge.

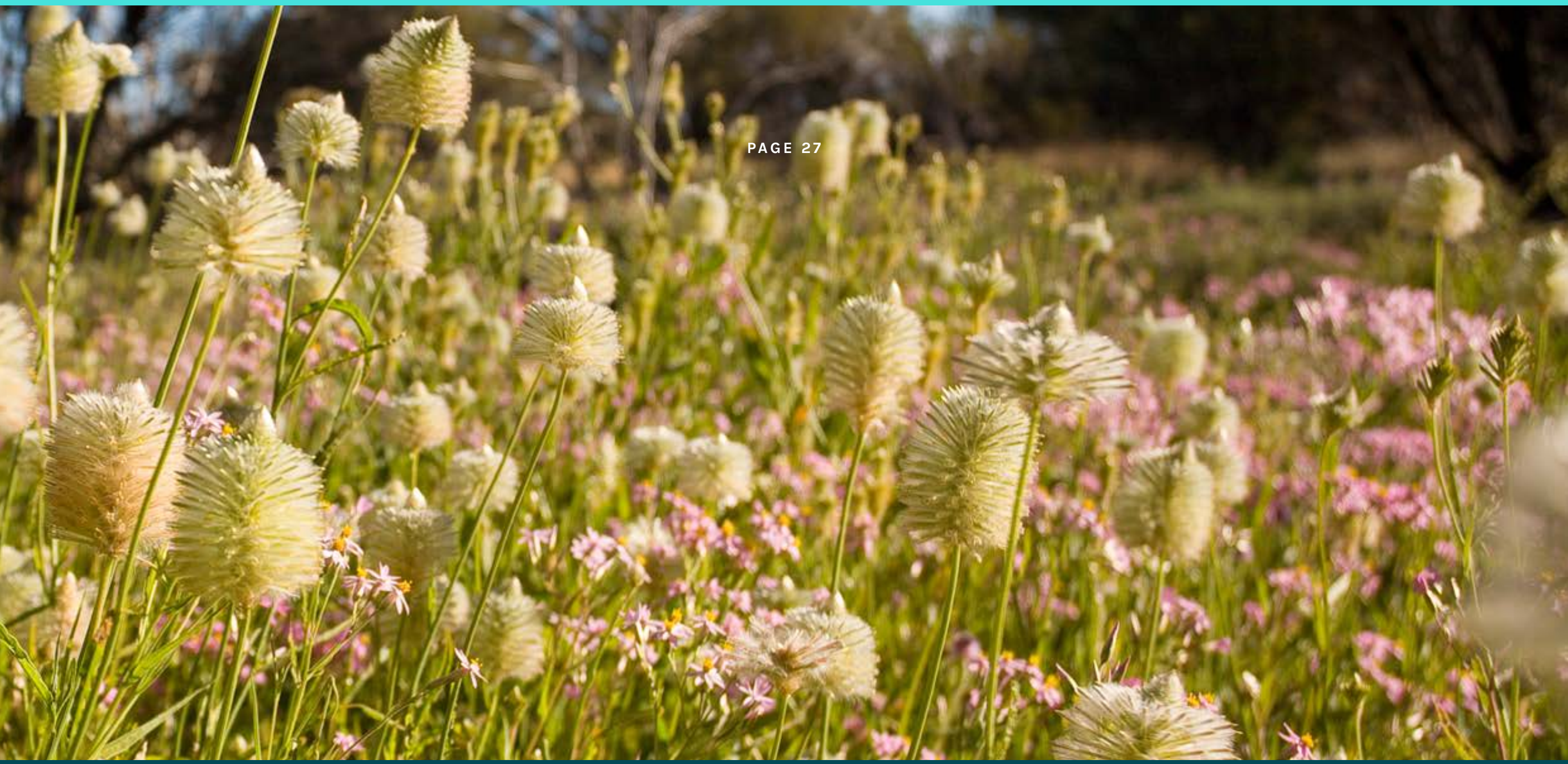
Digital infrastructure

Once in place, electric equipment will unlock a new degree of data driven decision making that can create enormous value. Diesel vehicles produce data, however only at certain points throughout the shift (e.g., whilst refuelling). Electric vehicles are producing a constant stream of real-time data, which when captured and utilised effectively can drastically improve controllability and precision operation.

The abundance of data, combined with the need to schedule the likes of shifts and charging, will likely precipitate both automation and a greater emphasis on algorithmic based scheduling from automated operating systems. An indication of this is how pragmatic but advanced contracting companies are pursuing both electrification and automation in concert – Barminco is a good example of this.

The skill set required to manage a data-driven operating environment will be vastly different to todays. The increased digitisation and automation of electric equipment will allow for a more decentralised workforce, not to mention the different electrician and electrical engineer-based skills in place of traditional diesel mechanics and associated trades.

We expect that an all-electric mine that is data-driven and has highly integrated energy sources (generation, storage, fleet) will initiate a significant cultural shift for the industry.



The Enablers: Our keys to success

So far, the focus in this report has been on the technology – its availability, readiness, and impact. However, as companies edge closer to adoption, they must also overcome internal challenges related to implementation.

The first hurdle lies in unlocking the capital required to invest. Because electrification technologies are currently more expensive than their fossil fuel alternatives, traditional capital allocation frameworks do not look favourably on their adoption. For business leaders to support the transition companies must adopt innovative ways to demonstrate the full value, beyond just the financials. Without top-down understanding and support, implementation will be extremely difficult.

Secondly, we are in the midst of a global skills shortage. The mining industry is not only undergoing a period of significant change, but it is also competing for the talent that will mobilise the shift. A shortage of skilled workers has the potential to hinder the industry's progress towards zero-carbon. Reskilling, upskilling and attraction of new talent will be key.

Finally, the rapidly evolving regulatory and policy landscape is amplifying the risk of perceived 'greenwashing', particularly around carbon intensity and emission targets. The importance of ESG reporting, data accuracy and verification are increasing, and the supplier ecosystem that services mining is only just beginning to emerge. Not only a risk mitigation tool, but accurate carbon measurement also has the potential to unlock financial rewards for companies who deliver low-emission products to market.

Simulation: the key to confidence

Given electrification technology is relatively immature, in many cases the operating assumptions are uncertain or have not yet been validated. Whilst educated assumptions can be injected into models, companies demand a higher degree of confidence to invest.

The EMC believes simulation technology should be developed and used as an efficient means to test and iterate the operating assumptions and provide a holistic demonstration of the full value case. With this tool at their disposal, companies can build a business case that can be communicated to leaders for strategic endorsement.

Existing simulation platforms are limited by their ability to solve event based and continuous models synchronously. This is exacerbated by the fact that mining companies distribute decisions to optimise individual components of the value chain, rather than viewing the value chain as a single and integrated process. Furthermore, traditional simulation providers have not yet invested in developing mining specific solutions due to the complexity, and relative size of the mining market when compared to other industries. As a result of these factors, a simulation product that can produce a highly accurate simulation of a fully electrified mine does not yet exist.

In an effort to fill the gap in the market, the EMC completed a global crowd challenge to develop a scalable electric mine design simulation platform – ultimately won by a partnership between South African companies Simulation Engineering Technologies (SET) and Simgenics.

Their co-developed platform allows for a large mitigation of the risks inherent in designing, building, and operating electric mines. It can complete full-scope, multi-vendor simulations of the demonstration mine, compare diesel and electric vehicles and their capabilities, consider all relevant interdependencies of a mine using a systems approach, simulate multiple energy supply and storage scenarios and technology mixes, and test multiple scenarios to optimise mine designs.

Recommendations made to businesses include operating strategy recommendations, risk discussions, graphical representations of outputs, simulations to model various mine systems to identify potential risks with mine electrification, and recommendations to support decarbonisation decisions.

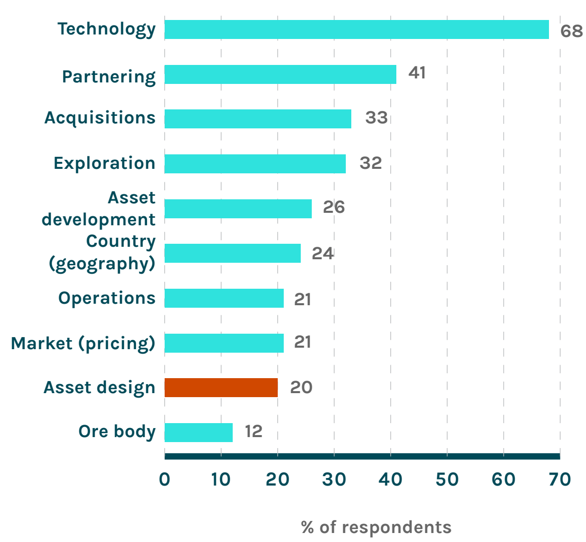
The platform is designed to be scalable both in terms of its roll-out and its extension to include new capabilities. Near-term development steps include extending the current mine pilot to the whole mine site, integrating the electrical infrastructure design with shaft, material handling, conveyors, and automation design, establishing a formal post-pilot co-development feedback process, comparing automated vehicles in an electric mine context, and allowing for novel technologies such as vertical conveyors. The team will also pursue greater integration with common mine planning tools such as Vulcan and Deswik to establish a feedback loop between the simulation and modelling processes.

If delivered, the software platform can be configured with existing mine plans to not only rapidly test and compare individual design choices (e.g., diesel vs. electric BEV), but also iterate entirely new mine layouts and designs until the optimal option becomes obvious.

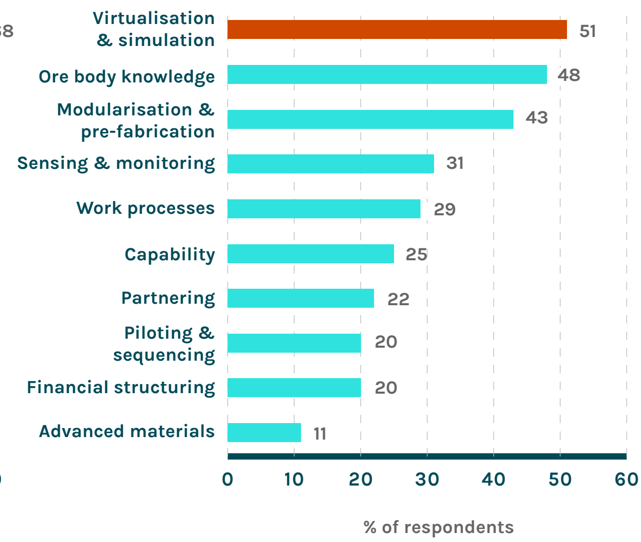
Mining companies are inherently risk averse when it comes to innovations in asset design. In fact, the industry believes it is the second most unlikely area mining businesses will accept risk in order to increase financial returns. Simulation technology on the other hand, is arguably the most influential technology in terms of progressing innovation and adoption of mine electrification designs and technology, allowing it to reach its full value potential. The industry believes virtualisation and simulation technology will have the biggest impact on project delivery over the coming years.

WE ASKED: AS A MINING BUSINESS, WHERE WOULD YOU ACCEPT RISK IN ORDER TO INCREASE FINANCIAL RETURNS? AND WHAT INNOVATIONS WILL HAVE THE BIGGEST IMPACT ON MAJOR PROJECT DELIVERY?

RESPONDENTS GIVEN THREE OPTIONS



HIGH RISK PROBLEM...



...HIGH IMPACT SOLUTION

Source: SOP Analysis

Skills and capability: the key to execution

The transition to electric and low-emission technologies is creating a demand for new skills in the mining industry. Unprecedented automation, system integration and data driven optimisation will impact the capability required at both management and operational levels.

New technologies are already impacting the mining workforce. As adoption grows and their impact combines, the shifts in the skills required will continue to evolve and accelerate. It is likely that the transition will be a period of constant change.

To respond effectively, companies need to firstly understand the change in skills requirements (gap analysis), and secondly deliver on those skills through either recruitment, retraining or upskilling.

As brownfield mines commence their transition and greenfield electric mines come online, the major gaps in capability that need to be addressed will become clear. There is however a fundamental mismatch in timeframes that needs to be considered. Companies will be fast to identify the gaps, but it will likely take significantly longer for them to fill it.

The Australian Industry ETI estimates that 80% of the jobs required in 2030 have not been invented yet[21]. The industry therefore needs a model that can proactively meet skills needs as they arise. An ethos of innovation in skills development, emphasising rapid outcomes, the best global sourcing and incentivised self-learning is necessary. Micro-credentials and rapid accreditations may be required in the early stages of the transition to give companies the best chance of success.

There are currently around 90,000 people working in emission intensive industries in Australia, of which ~60% of these work in coal or fossil fuel electricity generation[22]. As the demand for fossil fuel generation and coal mining continue to diminish, the opportunity and need for retraining and reskilling grows.

In the short-term, evolution of the current workforce may suffice in filling the gaps. However, in the medium to longer term, the industry will need to increase its attractiveness to address skills shortages. As electrification mainstreams previously bespoke mining skills, the industry will be competing against other sectors for talent. If the 'perception issue' mining has is not addressed, mining may fall behind in the global competition for skills.

Current indicators are bleak, with the number of graduate mining engineers falling from 333 in 2015 to just 47 in 2020[23]. Core to the industry's ability to attract talent will be the improvement of mining's perception from that of a 'dirty' and 'extractive' industry, to one that is digitally advanced and necessary for the global energy transition.

The Electric Mine Consortium is developing an initiative to support the industry to build the skills base required to operate an electric mining industry. The CEOs of the EMC's members have endorsed the vision and will reconvene later this year to consider the proposal. The consortium has proposed a set of principles for designing an open, non-profit Electric Skills Foundation that will attract, train, and re-skill workers for this industry.

The foundation would provide micro and rapid credentials sourced globally and endorsed by credible coordinators. The design is proposed to be industry-led, with EMC CEOs on the board, contributing to the work. The consortium is seeking support, including invitations to sit on the board, in-kind company support to build capability, public support, and offers of corporate support and pilots to use the foundation as a primary tool in resourcing the greenfields and brownfields electric mines. Our goal is to help build a skilled workforce for the electric mining industry and meet the growing demand for skilled workers in this sector.

Carbon measurement: the key to being rewarded

Mining accounts for roughly half of the carbon footprint of a battery cell[24], and there is growing demand driven by downstream customers, investors, and regulation to reduce this through the provision of low-carbon materials.

Companies such as Northvolt, the leading European battery maker, has announced it will carry a carbon footprint which is approximately one third that of comparable industry producers. The company is targeting a 25% share of the global battery manufacturing market by 2030. In a similar fashion, the EU has released mandatory requirements on the carbon footprint in lithium-ion battery production. From 2026, all lithium-ion batteries will have a carbon intensity performance class label. By mid-2027, batteries must comply with maximum footprint thresholds. Any batteries not meeting the new regulation will be banned.

21 Australian Industry ETI Skilling Australian Industry for the Energy Transition
22 Australian Industry ETI Skilling Australian Industry for the Energy Transition
23 Monash University
24 Tesla

The essence of the EMC is to help companies evolve to respond and meet these expectations, however as it is a relatively new frontier, there are few mechanisms in the market that verify, prove, or reward the companies that do.

To reach the next step in its maturity, the mining industry needs a tool that can accurately measure the carbon intensity of a commodity at each stage of the value chain. It then needs an accreditation system or body that verifies the claims and unlocks the ability for companies to differentiate themselves based on the stated carbon intensity in the marketplace.

These are two different, yet interrelated requirements. The EMC has established a work stream focused on the former – the development of a carbon measurement tool that has real-time tracking, accounting, and reporting capabilities which allow the definition of baselines and can measure the deployment of decarbonisation initiatives. Whilst this sort of technology has been developed and is relatively established in other industries (e.g., fast moving consumer goods), mining companies often still rely on manual spreadsheets and external consultants to provide a point in time snapshot of their emissions profile. As the legal obligations to report emissions become more complex and stringent, the traditional approach will not suffice. Companies need to invest in more advanced carbon measurement technologies.

When measured effectively, the ability for companies to communicate the reduced carbon intensity of their products to market brings in opportunities to create real value. The concept of 'green premiums' is divisive, and industry has not yet converged on how this may play out, however the data suggests that it is real. 77% of the mining industry believe there will be a carbon-based price differential in the next 5-years[25]. It will likely manifest in alternate ways, such as through preferential supply, especially as downstream customers are forced to reduce their scope 3 emissions (refer to the above Northvolt example). There is also the opportunity for those companies who show greater environmental stewardship to access financing at a cheaper rate. McKinsey analysis suggests the cost of capital can be up to 25% more expensive for companies with low ESG scores[26].

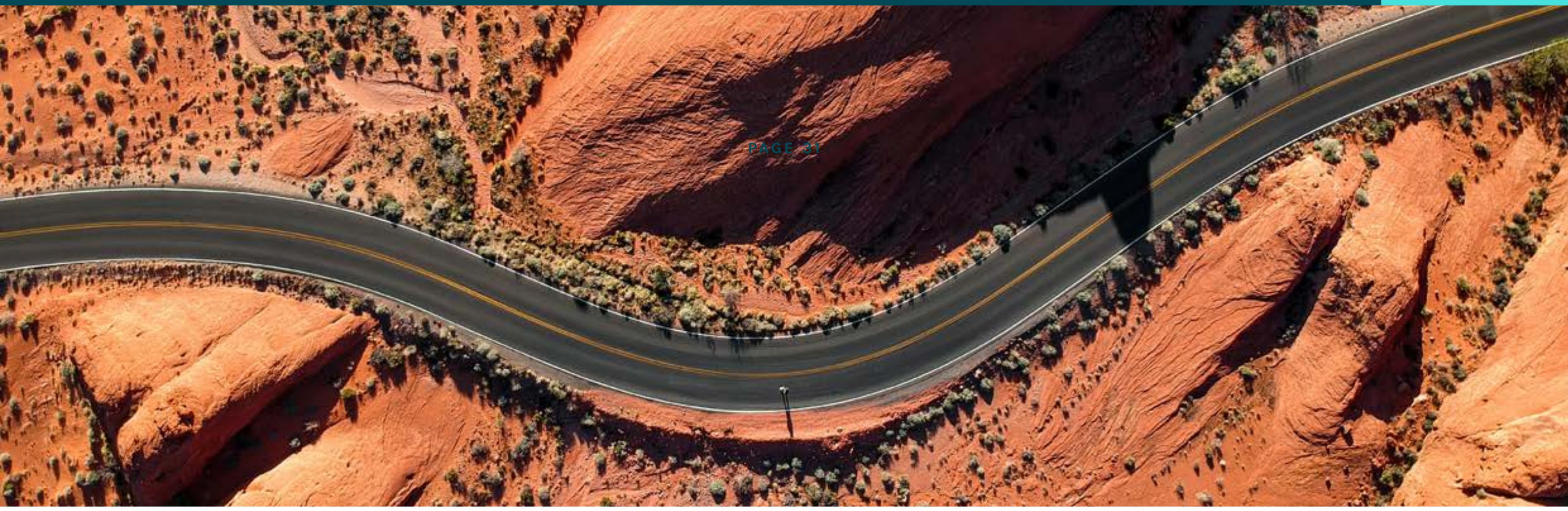
An accreditation or verification system that is globally recognised will unlock these benefits even further. Transparency at such a scale will drive emission reductions through accountability and comparison, allowing companies to compete based on carbon intensity. Several exchanges have introduced their own certification bodies, including the London Stock Exchange, who have introduced a 'Green Economy Mark' for those who constitute a 'green' business[27], however a more sophisticated and specific approach for mining is required.

One of the EMC's goals is to help establish a system of green minerals accreditation that will accelerate the transition towards a greener future. We aim to do this by rewarding companies that achieve a certain level of validated green performance through a range of mechanisms. This system would require the active participation of investors, customers, and governments, who will direct their support appropriately to those companies that meet the required standards.

We see this vision as a "flywheel" of green accreditation and accelerated decarbonisation, consisting of three main components. First, precise measurement of performance will be carried out using advanced analytics technology. This measurement will be used to validate and accredit the performance of companies, which will be overseen by credible bodies. The second component of the system is transparency and benchmarking of performance, which will be catalysed by a group of producers.

Finally, the third component of the system will be value flowing to producers based on their performance, driven by customers, financiers, and government policy. This value will provide incentives for producers to achieve the required level of validated green performance. We believe that this vision will be transformative, as it will provide a clear incentive for companies to move towards greener practices. Through this system, we can create a more sustainable future, where we can balance the needs of industry and the environment.

25 State of Play: Critical Minerals
26 McKinsey
27 Field Fischer



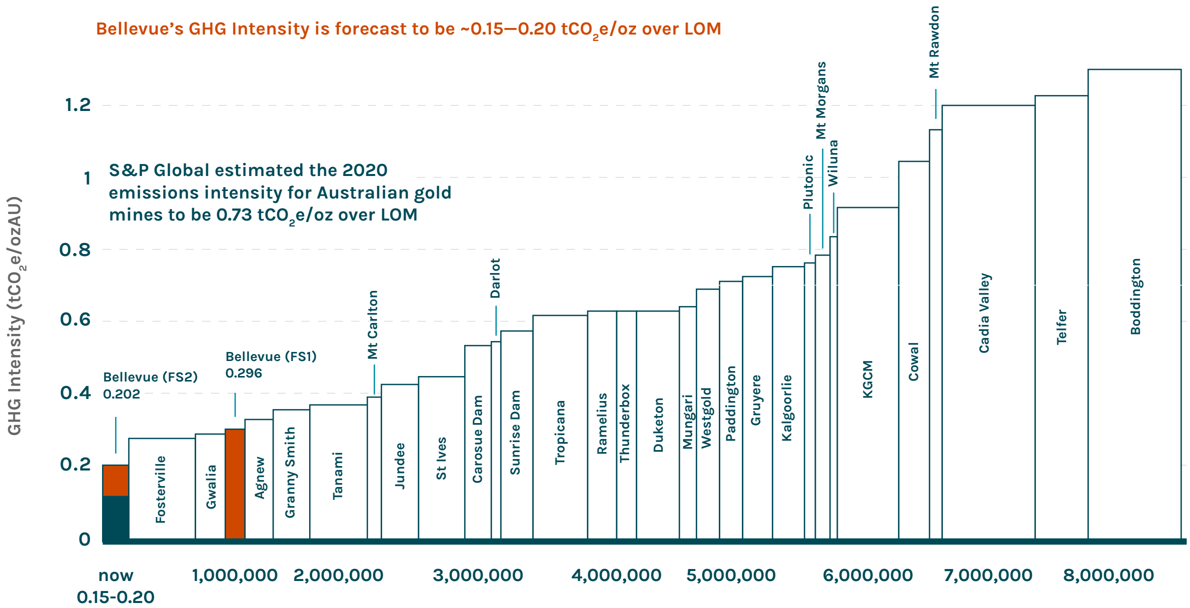
Case Study: A new benchmark for sustainable gold mining

EMC member Bellevue Gold is emerging as the new benchmark for sustainable gold mining in Australia. Their focus on carbon measurement and abatement is driven by a combination of top-down leadership and bottom-up incentives.

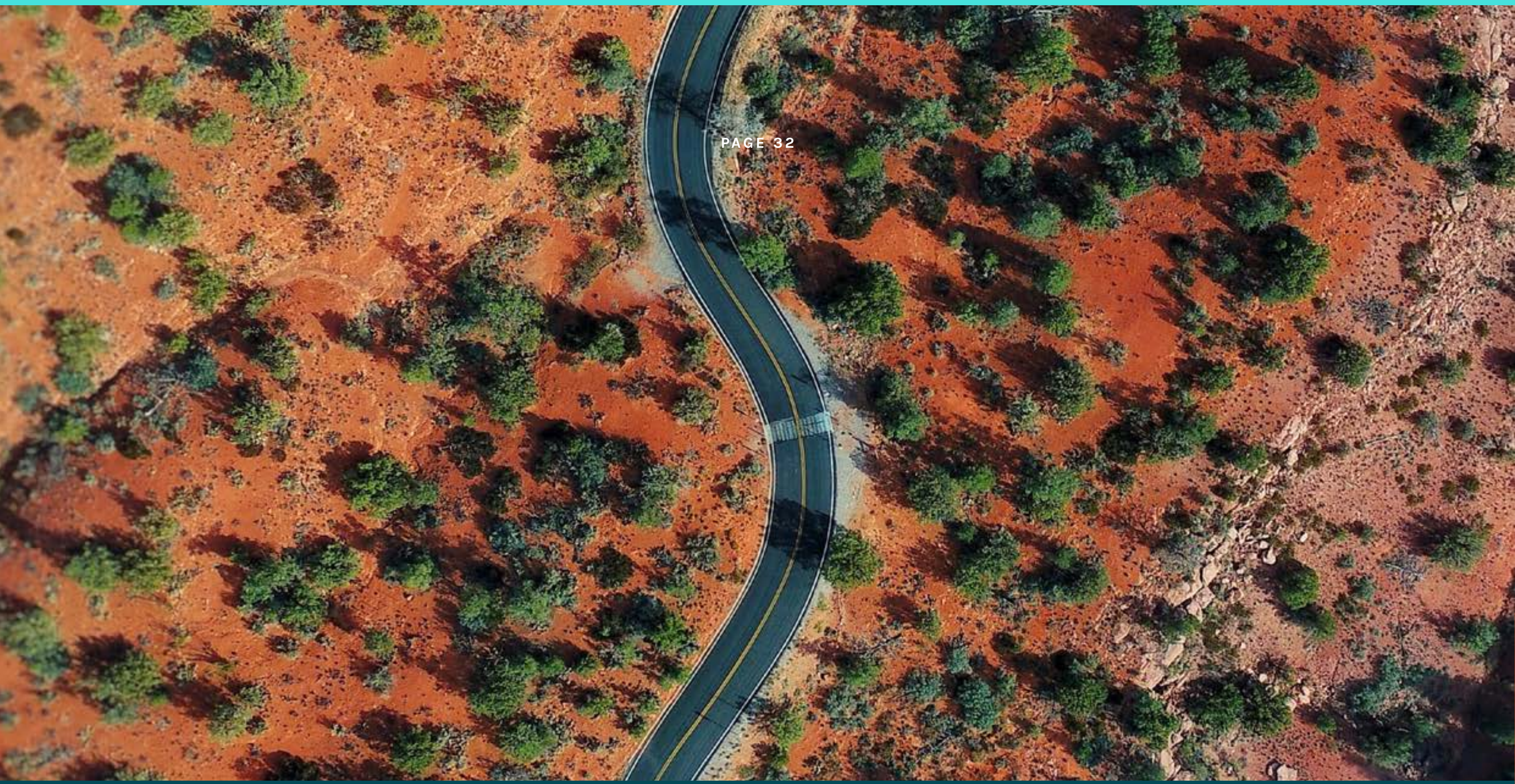
On track to enter production in late 2023, Bellevue Gold has best-in-class sustainability aspirations to be a net zero (Scope 1 and Scope 2) emission operation by 2026. This target is supported by Sustainability Performance Rights for all staff, that will vest when the net zero target is achieved.

The ability to deliver on their net zero aspiration is underpinned by their investment in an off-grid power station with (fellow EMC member) Zenith Energy, which will provide ~80% renewable energy penetration across the year. Further emission reductions may emerge through the capture of spilled energy into a Long-tern Duration Energy Storage (LDES) solution, the accelerated roll-out of electric vehicles and flexibility in energy intensive processes such as time-shifting crushing to align with periods of spilled renewable energy.

Taking all of this into account, when in operation, Bellevue Gold is forecast to have the lowest greenhouse gas (GHG) emission intensity of any Australian gold mine. They believe that through accurate carbon measurement and certification and a unique refining agreement, they will be able to differentiate themselves from their peers on the basis of this achievement, unlocking premium pricing potential for the sale of their 'green gold'.



Source: All data sourced from public company disclosures, with GHG emissions and annualised production averaged over the last 2-7 years of available reported data. Since the Stage 1 Feasibility Study, the Bellevue Gold figures have decreased, and recent data points from other mines have been added. S&P Global issued a report on 18 August 2021, which stated the average 2020 GHG emissions intensity in Australia to be 0.73 tCO_2e/oz.



Conclusion

When we started this journey in early 2020, the industry's understanding of mine electrification and the readiness of its enabling technology was nascent and immature. Whilst the pathway to full mine-electrification is still not a clear or simple route, our understanding of the many moving pieces has grown in leaps and bounds. So too has the ecosystem of mining companies, service providers and financiers.

Whilst they all share the same ambition, EMC member companies have tackled the last few years in different ways. Some have made aggressive moves towards their end goal of producing a zero-emission product, whilst others have used this time to study and understand the entire landscape in preparation for a wholesale transition.

Despite the EMC's progress, the mining industry as a whole is not moving fast enough towards its decarbonisation targets. With less than 7-years left to meet 2030 targets, including the Australian Government's 43% reduction target, the imperative to translate understanding of low-emission technologies into widescale adoption is vital.

The technology necessary for companies to meet such 2030 targets is available today. The dominant question lies in each company's ability to calculate the business case in financial terms. Industry leaders have recognised this as an issue, and we are starting to see creative approaches to mine design, technology use and commercial structures emerge as a result, however not at a fast enough rate.

For most companies, the ability to deploy capital for new, zero-emission technology remains constrained, as business leaders continue to go through the process of shifting their mindsets from a steady state view of mining operations, to one that is more flexible and responsive to energy requirements. Cultural change is particularly challenging in the context of brownfield assets, which have sunk capital, an existing workforce and incumbent processes that must be overcome.

On the other hand, the shift is in some ways easier when starting from scratch. There are several fully electric mines being designed for greenfield assets within the EMC, with members extremely optimistic about the success of implementation in such contexts. These leaders will pave the way for the next generation of mines and prove as crucial case studies for industry step-change.

Not only will progress inspire within a mining context, but it has the power to change perceptions within the wider community. Whilst within the industry we have been talking about the distinction between future facing metals and fossil fuels for many years now, it is only now starting to gain traction more broadly, including within the political arena. The recognition that this segment (base, precious and battery metals) of the mining industry is crucial for the energy transition will position it as a more attractive industry for skilled workers, whilst also supporting financing efforts for new technology and designs.