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The Electric Mine Consortium:

A CASE STUDY IN TRANSFORMATIVE COLLABORATION

ELECTRIC MINE CONSORTIUM
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About State of Play

About State of Play™

State of Play was initiated in 2012 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 5 global surveys – 2013, 2015, 2017, 2019 and 2021. We have also undertaken drill-down research work into specific themes including Electrification in 2020, Immediate Covid-19 Response 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 our major sponsors

METS Ignited works with Australian suppliers to the mining industry, global miners, research organisations and capital providers to improve the competitiveness and productivity of the Australian METS sector. Its five areas of strategic focus to help strengthen the global competitiveness of the Australian METS sector are: a shared vision; strengthening collaboration in the mining innovation system; addressing gaps in the ecosystem; raising your profile; and promoting world class clusters.

Adrian Beer, CEO
www.metsignited.org

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.

www.SLATEadvisory.com

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Prologue

Early in 2020, State of Play undertook a series of research activities on electrification in mining. Over 40 companies participated in the workshops that were held, and another 450 individual surveys were completed by industry representatives.

The research identified the key drivers and barriers of mine electrification, highlighting the need for some form of collaboration to accelerate adoption.

As a result, five mining and seven services companies self-selected to form the founding members of the Electric Mine Consortium (EMC). Since inception the participation has expanded to a total of 17 highly respected, commercially astute mining (8) and services (9) companies.

The miners are primarily base or precious metal companies, driven by the imperative to produce zero-emission products for their customers and meet mounting investor expectations. 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 short time since the establishment of the EMC, the drive for change in the broader resources sector has accelerated. The largest global companies are investing directly in low emissions technology or working collectively to source solutions, for example FMG's investment in hydrogen generation and the Rio Tinto, BHP & Vale- driven "Charge On" initiative (incl. over 20 other patron companies). There is a growing, immediate demand for low emissions solutions, with technology and manufacturing capacity in many cases constraining the supply response.

The EMC is emerging as a key vehicle for the decarbonisation of the mining industry, particularly for underground operations, and will remain responsive to the rapidly changing external environment.

CONSORTIUM MEMBERSHIP IS MADE UP OF:

Mining Companies

8
Members participating in the Consortium

16
Countries with member entity operations

12
Commodities represented by member entities

89
Assets owned by member entities

9,965ktCO_2
Aggregated volume of member Scope 1 and Scope 2 CO_2 emissions

59,245
People employed by member entities

$71bn
Combined market capitalisation of member entities in AUD

Services Companies

5
Publicly traded partners

12
Partners participating in the Consortium

160+
Countries with partner organisations

72,725
People employed by partner entities

$184bn
Combined market capitalisation of partner entities in AUD

Introduction

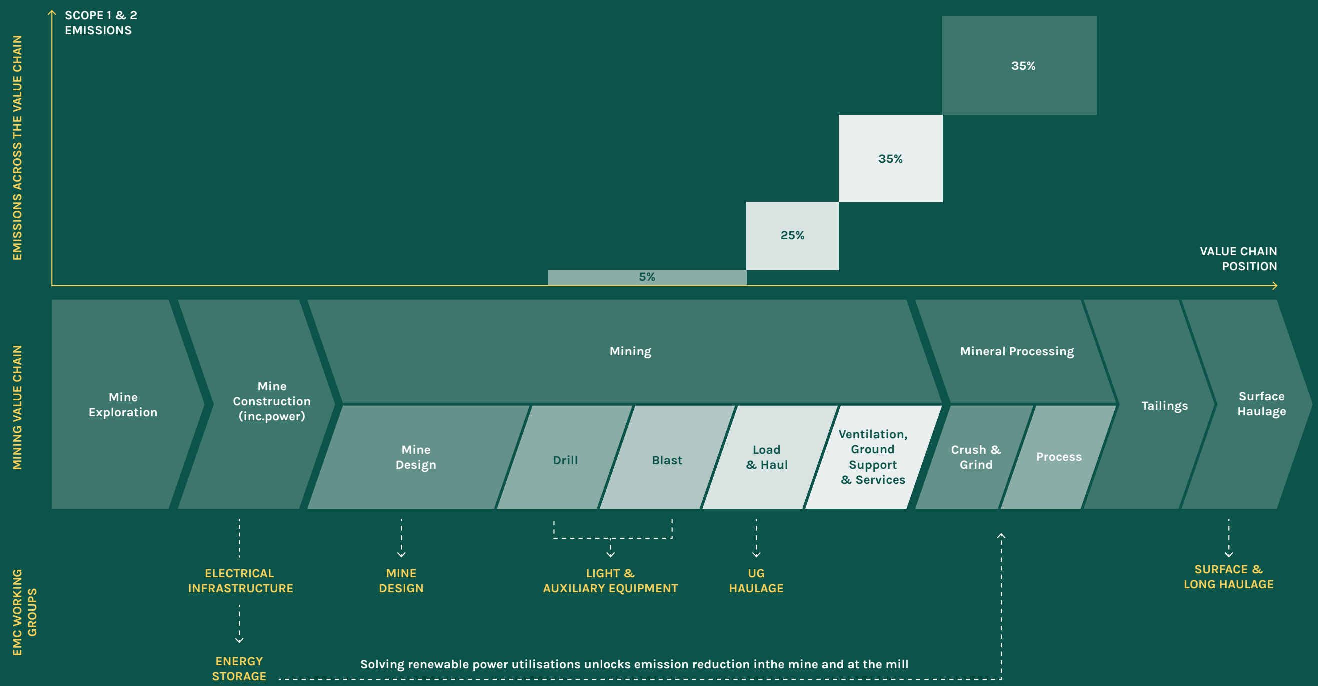
The journey to zero

More than 70% of the world's emissions are now covered by net-zero pledges.[1] We expect that in the coming years company pledges will transition from statements to committed targets.

Across the industry, most major mining companies have aligned on an emission reduction target of 30% by 2030, progressing to carbon neutrality by 2050. In a similar vein, we expect these targets will keep accelerating and become more highly scrutinised, with metrics potentially evolving to include carbon intensity (e.g. emission per tonne), rather than against a 'point in time' benchmark.

The Electric Mine Consortium's work is critical in achieving these emission reduction targets for our member companies. We have developed six high-impact, fast-moving working groups focused on key mine electrification challenges, which if solved, provides the technology solution set to achieve zero-emission mining within a typical mine-to-mill value chain. These are:

1. Mine design (incl. ventilation)
2. Energy storage
3. Electrical infrastructure
4. Heavy underground equipment
5. Light and auxiliary equipment
6. Surface and long haulage



Source: State of Play

1 The United Nations

In addition to the mentioned working groups, the consortium has identified six enabling groups which support the resolution of the major challenge areas and the overarching ambition. These are:

1. Data sharing
2. Financial modelling
3. Carbon measurement
4. Skills and capability
5. Policy and regulation
6. Marketing and communications

In many cases, the pathway to achieve the full scope of emission reduction commitments is not a clear or simple route. Renewable energy technology is mature, however mine electrification is not. The delineation between industry leaders and followers is becoming more distinct – in some cases, a clear roadmap has been articulated, whilst in others there remains a disconnect between corporate objectives and practical realities.

Challenge 1: Energy storage	Mine scale energy storage technologies are not yet operatonally or economically proven in mining.
Challenge 2: Mine design	Traditional asset design does not enable the realisation of the full benefits of mine electrification.
Challenge 3: Underground haulage	Zero carbon load and haul equipment is not yet commercially available or technically viable U/G at scale.
Challenge 4: Light BEVs and ancillary equipment	Economic and operating assumptions for light BEVs and ancillary equipment on site are unclear.
Challenge 5: Electrical infrastructure	Lack of understanding on the supporting infrastructure requirements for all electric equipment and vehicles.
Challenge 6: Surface and long-road haulage	Zero-carbon surface and offsite haulage vehicles are not yet commercially available or technically understood.

Enabler 1: Data sharing	Accelerate learnings through 'virtual trials', whereby each member gains the analysis and insight of each trial as if it were run on their own site.
Enabler 2: Financial modelling	Help reticulate the overall value impact of mine electrification, including financial and carbon emissions.
Enabler 3: Carbon measurement	Identify a suitable carbon measurement platform which can track emission production in real time, project performance and integrate with existing operational platforms.
Enabler 4: Skills and capability	Aggregate the capability needs of the mining companies, so they can be articulated to training providers, and supply of new skills accelerated.
Enabler 5: Policy and regulation	Identify where the regulatory landscape may require updates at the right pace for new technologies and procedures.
Enabler 6: Marketing and communications	Target the mining industry and wider business community to generate awarenes of the EMC and proposition.

Many of the smaller, more nimble companies are taking on leadership roles. Those looking to move fast in the underground industry are not relying on the traditional tier 1 mining companies to pioneer the adoption of technology necessary to achieve their emission reduction targets.

Around the globe, we are already seeing companies being held to account. Shell has been made legally responsible for cutting their emissions by 45% by 2030 by a Dutch court, meanwhile, Santos has been sued for their 'clean fuel' claims and net zero target by 2040 despite plans for fossil fuel expansion.

Whilst most companies now report on their scope 1 and 2 emissions, more transparency and accountability is being demanded by stakeholders in the communication of decarbonisation objectives and the pathway to achieve them.

The leading miners are aware that the pressure to decarbonise is going to impact the economics of mining, creating new challenges around capital allocation decisions and divestment activity. Internally, the ability to communicate the business case for electrification and adapt capital allocation frameworks accordingly will be key.

The mining industry is relatively niche and complex compared to other global industries. Overwhelmingly, a major risk to achieving carbon targets is the availability of zero-emission technology. Whilst some of this will emerge from the mass market (e.g. batteries, renewable energy, charging) where exogenous investment and innovation will drive supply, other areas bespoke to mining (e.g. heavy haulage) will be constrained by industry limitations. Joint efforts between operators and suppliers will be required to scale up capability.

The second part of the EMC ambition focuses on achieving zero-particulate mining. The impact of harmful exposure to diesel particulate matter (DPM) from diesel energy generation is a serious concern. The DPM, as well as the 40 other toxic pollutants emitted from vehicles and generators, pose short and long-term risks to health, from minor effects such as headaches and nausea all the way to serious illnesses such as cancer. In Australia alone, 1.2 million industry workers are exposed to dangerous levels of DPM.[2] 80% of the industry believe there will be a major health-related industry class-action over the next 15 years, with DPM the second highest health risk.[3] Zero-emission mining will not only improve environmental outcomes, but it will also help protect the health of the workforce.

2 Safe Work Australia

3 State of Play

Mine design: New Principles

An all-electric mine is going to fundamentally change a number of traditional mine design principles. Whilst the retrofitting of brownfields assets may be limited by sunk capital, existing assets can still reap the rewards associated with the replacement of diesel fleets, upgrading of assets and adoption of new procurement procedures. Investment in these areas will create an inundation of new data, providing ample opportunities for optimisation and innovation.

Greenfield assets offer an opportunity to demonstrate the true value impacts of full electrification from day one of operation, with one of the largest areas being ventilation (~35% of emission generation). In addition to lower operating costs, we may also see the economic viability of deposits change, unlocking marginal ore bodies. Consortium members are already beginning to incorporate electric mine design learnings in their due diligence processes.

Currently there is no way to holistically demonstrate or validate the assumptions associated with these new design principles given the limited application of such technology at scale and within a single operation. The EMC's mine design working group, led by OZ Minerals, is currently running a global crowd challenge to attract companies and individuals from around the world to propose approaches for developing a scalable electric mine design simulation platform. In parallel, Gold Fields have partnered with Dassault Systemes to apply advanced simulation techniques to greenfield designs currently under construction.

Ultimately, simulation tools with rapid iteration capability could unlock an entirely new way to build and operate mines unlike any in the past.

Scope 1: Equipment on the ground

The supply chain for the electrification of mine sites is immature. Procurement and sourcing of zero-emission equipment is in its early stages and remains one of the major barriers to achieving emission targets. In an attempt to bridge this gap, the consortium has made considerable steps in understanding why availability is such an issue, and how to address it.

The consortium itself spans 86 assets with its members owning over 2200 light and auxiliary vehicles and 500 heavy vehicles. Currently there is a limited number of electrification equipment available for trials in all the companies that would like to, let alone convert a fleet for even one of these sites.

The light and auxiliary equipment market is experiencing supply constraints, but not to the same degree as for heavy equipment. Most companies in the consortium, and several beyond it, have been able to trial at least one battery-electric vehicle. Although not critical to core process, battery-electric light and auxiliary equipment presents a great opportunity to build understanding and acceptance at sites, without compromising mine productivity.

We are beginning to see the supply of light and auxiliary equipment ramp up in the form of new builds and the retrofitting of existing assets, and so do not see supply constraints as being more than a short-term issue. The consortium has already trialled over 20 vehicles across a number of member assets. As such, we will focus predominantly on the resolution of supply of heavy haulage equipment.

The availability challenge

Why is availability an issue?

- **Concentrated supply:** Heavy haulage supply is a small market captured by a small number of competitors. The lack of competitive tension drives an incremental rather than transformational approach. It is not a market overly attractive to new entrants given high upfront development costs and the complexity associated with establishing global supply chains.
- **Revenue models:** Incumbent original equipment manufacturers (OEM) business models rely heavily on spare parts and maintenance. An electric vehicle engine has 20 moving parts, whereas a diesel vehicle has around 20,000.[4] With 90% fewer parts to service, the transition away from diesel equipment to electric equipment will drastically reduce parts and servicing requirements, a significant proportion of revenue for OEMs.
- **Benefits:** Majority of the economic and environmental benefits of electrification lie with the operator, rather than the OEMs, who need to invest heavily in R&D and production. There is currently little incentive for OEMs to make the transition. However, shareholder and stakeholder pressures are beginning to change this – particularly for European manufacturers.
- **Scale-up costs:** Large capital expenditure is required to scale-up manufacturing capabilities from a small number of hand-built prototype vehicles for trials to a full production run. New and retrofitted factories can cost over US$1b.
- **Market fragmentation:** Australian underground mines (typically decline mines) use much larger equipment (>50 tonne) that travel longer distances (fully loaded up inclines) than their counterparts in North America, particularly Canada (typically shaft mines). Industry is yet to commit *en masse* to the electrification of mine sites, meaning OEMs do not have a clear demand signal to catalyse the large-scale investments required.
- **Technology uncertainty:** Battery density is not yet at a point where it can directly compete with incumbent diesel engines on range or refuelling. Questions still remain regarding the charging strategy, and requisite infrastructure requirements, best suited to large equipment. The larger OEMs are currently opting for battery-swap-out, however more frequent charging (e.g. trolley assist), may be required as a supplement for heavier equipment to achieve viability. In the interim, hybrid diesel-electric solutions are being adopted by a number of OEMs.
- **Supply chain shortages:** Bottlenecks in global supply chains for battery cell technology and semiconductors are expected to create a shortage of over 26 million vehicles between 2021 and 2029.[5] It is unclear when these shortages will ease, and whilst not the driving factor, it is playing a role in slowing down the pace of transition.

4 EDF Energy

5 IEA

How can we address the availability challenge?

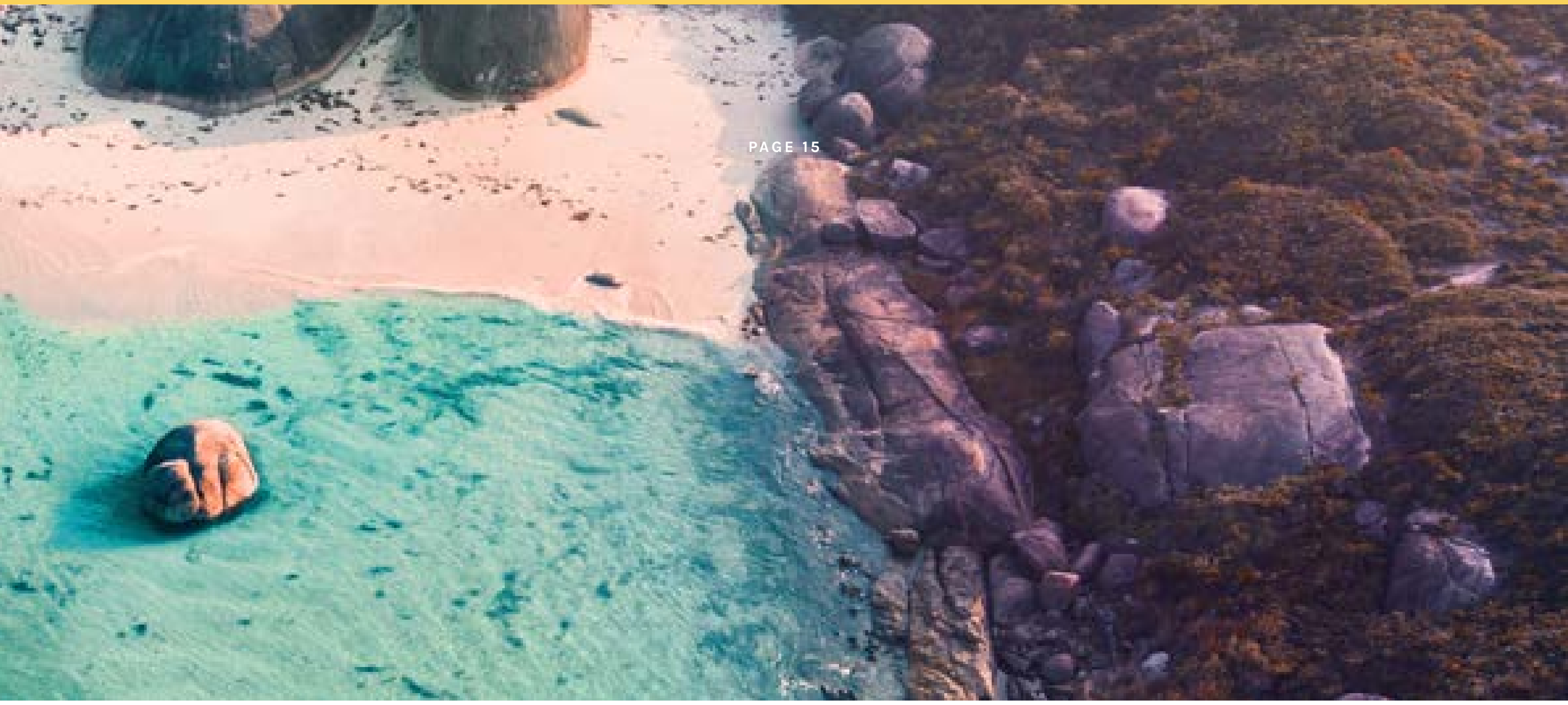
To encourage adequate investment and to accelerate effort from the supply side, new business and commercial models are required:

- **Demand:** Miners need to aggregate their procurement intentions to provide OEMs with certainty and confidence in market demand to accelerate the near-term supply, and long-term development of zero-emission heavy equipment.
- **Manufacturing globalisation:** Miners should encourage suppliers to develop a more evenly spread supply footprint for electric equipment. In particular, the Australian market is ripe for supply ramp ups with significant market opportunities in Western Australia and Queensland.
- **Local battery supply:** The economics of building downstream battery facilities in close proximity to major sources of battery minerals is becoming more compelling as supply chain constraints, and security of supply for critical minerals becomes more important. This is particularly valuable in nations with vast renewable energy resources to power energy intensive processing.
- **Value sharing:** In addressing commercial barriers, discussion of value sharing models for carbon credits and taxation should be up for negotiation between miners and suppliers. Further negotiations with contract miners, as major purchasers and operators of equipment, are possible.
- **New entrants:** There is a *Cambrian explosion* of emerging suppliers racing to bridge the gaps in availability in the light vehicle sector. Looking beyond the industry incumbents for alternate solutions in the heavy equipment sector may provide new opportunities, as demonstrated by the Austmine 'Charge on Challenge'.[6]
- **Ownership:** The nature of battery technology is driving a shift towards new ownership models wherein the supplier maintains ownership to manage maintenance and replacement over the life of the contract (e.g. leasing models).
- **Policy:** Government incentives, research and skills support for local manufacturers can help mobilise investment and underpin demand.

Electrification of vehicles is a fundamental enabler for automation. Whilst the EMC is not focussed on solving interoperability needs (as it relates to automation), it is recognised that the vehicle requirements become more complex when combining electrification and automation. With emerging entrants across the mining fleet, this warrants further thought to enable ongoing innovation and adoption of technology at the desired rate.

6 AustMine

7 Bloomberg New Energy Finance



Total cost of ownership

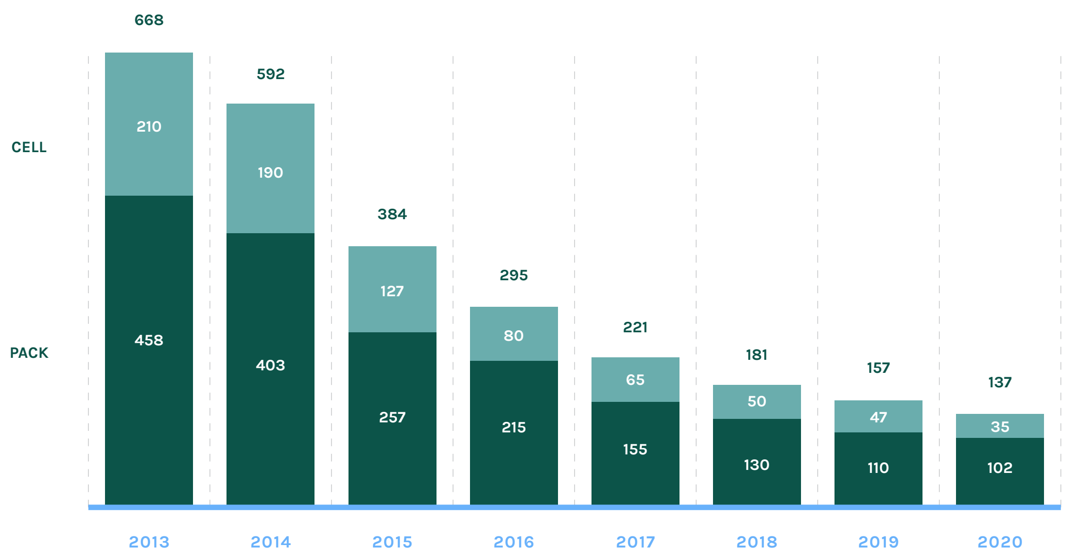
While zero-emission mining equipment may have a higher upfront capital cost, it offers considerable operational cost savings. Industry forecasts estimate capital costs for electric consumer vehicles will converge with internal combustion engines (ICE) by as soon as 2023 as the cost of Li-ion batteries continues to fall.[7] Whilst these forecasts are for consumer vehicles, the industry should expect the cost of niche, mining specific equipment to follow suit.

In the meantime, the delta remains a significant barrier to purchasing decisions for many mining companies. When placing more emphasis on total lifecycle costs of the equipment (incl. fuel, maintenance, warehousing costs etc.) rather than merely the capital cost, the business case for electric vehicles starts to become competitive.

Over a 7-year equipment fleet cycle of ~30 heavy vehicles, the fuel cost savings of switching to electric are around US$17 million, as well as a 59-kiloton reduction in CO_2.[8]

FIGURE: VOLUME-WEIGHTED AVERAGE LITHIUM-ION PACK AND CELL PRICE SPLIT

Real 2020 $/kWh



Source: BloombergNEF

Case study: IGO's business case for change

Companies have set corporate emission reduction targets, however only a small number have updated their capital allocation frameworks to enable the investments required to meet them.

Equipment is a supply purchase, and does not directly impact long-term revenue, therefore the benefits are not always well understood or represented. Considerable work is required to bridge the gap between understanding the value of decarbonising and in unlocking the funds to do so.

IGO have developed an internal funding mechanism to overcome this challenge and help support their aggressive emission reduction targets.

An internal carbon price (currently at a nominal $60/tCO2e) is charged per unit of carbon emissions produced. The funds are then pooled centrally into a decarbonisation fund and drawn upon for emission abatement projects.

The approach allows IGO to provide a mechanism for business units to access funds that support their decarbonisation targets, less constrained by their own budgets. It also helps them to:

- Understand the actual cost of the emissions they produce
- Ensure low emission investment options remain competitive
- Target decarbonisation projects where the most cost-effective impact can be achieved first and;
- Create a cultural mindset shift, whereby new ideas and approaches can be captured and implemented

There is considerable carbon price disparity around the globe. Australian carbon credit units (ACCUs) are currently priced at around $35/tCO2e. The European Union's Emission Trading System prices CO2e at $89/t, and several financial markets imply a $53-107/tCO2e price.[9]

Whilst the carbon price selected by IGO ($60/tCO2e) is high for Australian standards, it better reflects the global market. Applying a lower bound carbon price would reflect a risk mitigation strategy, not a significant intent to address their climate ambitions. IGO will review this price annually and believe it will continue to increase as pressures to rapidly decarbonise operations continue to build.

Scope 2: Powering up

To solve mining's energy challenge, the industry will have to undertake an enormous transition. The shift will not be cheap (although will likely be value accretive) and will have profound second-order effects (e.g. infrastructure and operating models), however if achieved it will radically reshape the environmental impact of the industry.

Energy storage

The size of the prize in switching to 24/7 renewable energy power generation is a ~70% reduction in total emissions.[10] When combined with zero-emission mobile equipment, a near 100% reduction can be achieved.

The need for consistent and reliable power, coupled with the remoteness of many mine sites, has resulted in a reliance on fossil fuels. Even mines with renewable sources of energy have to fall-back on 'dirty' energy sources when the sun isn't shining, or the wind isn't blowing.

Given the nature of assets in the consortium, our analysis has focused on off-grid mines and therefore doesn't consider power purchasing arrangements.

As such, the immediacy of the storage challenge is one remote mine sites must solve themselves.

Low cost, large-scale time-shifting energy storage (as an additional technology to a micro-grid's firming batteries) coupled with a renewable energy source is emerging as the most plausible option to achieve this. Solar and wind is the clear winner in generation, given its cost-competitiveness, technology readiness and the abundance of natural resources in Australia. However, bulk storage solutions are far less clear.

Several promising storage technologies are developing but will not be broadly adopted until they can be proven, understood and demonstrated at mine-site scale.

In early 2021 the Electric Mine Consortium released an energy storage expression of interest (EOI) to the market to further understand the landscape and kickstart the process to initiate a pilot or trial. We received several responses, with the success criteria focusing on battery responsiveness, round trip efficiency, degradation, capital cost, operating cost, disposal cost, and ability to scale.

The process will lead to the commissioning of the largest mine site energy storage trial the industry has ever seen. The outputs of the technology analysis can be seen in the below table.

10 Based on an underground hard rock mining operation

Type	Strengths	Weaknesses
Compressed Air	Store long durations and low cost. Technologically mature.	Dependent on geographical structure. Knowledge gap in evaluating the potential of available geological resources. Requires large upfront capital investments and due diligence.
Flow (Vanadium Redox)	Long lifespan (20+ years). Offers immediate energy release. Suitable for grid connection of off-grid setting. Power and energy can be scaled independently.	More expensive than lithium ion batteries. Higher voltage and highly oxidative electrolytes puts chemical stress on the materials used in the battery cell.
Flow (Zinc Bromine)	Long lifetimes, modularity, and minimal energy loss throughout the technology's storage duration.	Expensive materials. High cell voltage and highly oxidative elements. Bromine is a highly toxic material through inhalation and absorption.
Gravity	Around 50% cheaper than battery storage technology. Doesn't depend on cost of battery materials/minerals. Short ramp rates. Round-trip efficiency of between 88%-92%. Low operational	Relatively long technical life, which means there is the risk of being stranded by future reductions in cost of competing technologies. Binding geographical constraints.
Hydro	Technologically mature; cheaper. Produces large amounts of electricity over a long duration with low operational costs.	Limited geographical locations; environmental approvals and lack of water at many remote mine sites. High capex.
Hydrogen	Doesn't experience degradation like other batteries; storage capacity only limited by size of facility; high power rates (ie., in the range of 10 MW)	Large scale hydrogen production costs, infrastructure investments, bulk storage, transport and distribution required.
Lithium-ion	High energy density. Do not require scheduled cycling to maintain their battery life. Light weight.	Better suited to discharge time of less than 4 hours; sensitive to environmental conditions (eg. temp); uncertain lifetime; quick degradation; self-discharge; limited storage capacity.
Molten Metal	Light electrodes do not degrade with use. There is no need for membranes or separators, which are subject to wear. No critical minerals required.	Limited ability when faced with high energy demands. Requires significant resources to constantly heat the electrodes and keep them molten. The battery is heavy and difficult to move.
Molten Salt	Salt is an ideal medium because it maintains a wider temperature range in a liquid state, allowing the system to operate at lower pressures.	Existing technology face excessive costs, safety problems or lack of material resources. Molten salts are costly and can be corrosive.
Sodium Sulfur	Round trip efficiency is in the 90% range. Ideal for large-scale energy storage, owing to high energy density and low cost.	Requires a high temperature to liquify the sodium, which is very difficult to operate and increases OPEX. Potential environmental risks.
Solar Thermal	Captured heat can be stored cost-effectively for long periods with little loss of energy.	Not currently competitive with other large-scale applications.
Iron-Air	Can store energy at one-tenth the cost of traditional lithium-ion battery storage systems. Core material iron is readily available thus cheap and consistent price. Extremely safe.	Immature technology. Limited testing and commercial capabilities not proven.

Case study: Gold Fields and the Energy Vault storage solution

Through the Electric Mine Consortium's Energy Storage working group, Gold Fields has partnered with Energy Vault to investigate a 2MW/10MWh energy storage trial to couple with the existing high penetration wind and solar power at their Agnew mine site.

The Energy Vault solution is a gravity battery utilising blocks manufactured on site from mine tailings – a viable alternative when pumped hydro is not feasible.

The round-trip efficiency of the battery is equal to lithium batteries (~80%), with no degradation and a 30-year design life[11] - a far better level of performance than lithium-ion. It is currently one of the lowest costs and most efficient forms of large-scale energy storage for mine site applications.

The 2MW/10MWh trial is a pilot project, with construction planned to kick-off in Q2/Q3 of 2022. The trial will cost approximately $8m, and is intended to be supported by ARENA, MRIWA, Gold Fields and Energy Vault. This size of this pilot scale trial will unlock curtailed renewable energy generation at the Agnew mine site and increase Agnew's renewable energy fraction from 54% to 56%.

If successful, Gold Fields have ambitions to scale-up to a full-size solution at Agnew and potentially other mines in its portfolio as part of Gold Fields' emissions reduction roadmap.

The EMC is continuing to explore other opportunities for large-scale energy storage demonstration projects. We believe it has benefits for not just remote mines, but the broader renewable energy supply landscape including regional grids and utility scale networks.

11 Energy Vault

Electrical infrastructure

Another integral piece to support the energy transition is electrical infrastructure. Higher renewable energy penetration, as well as the new operating approach associated with electric mobile equipment, imposes different functional requirements for electrical distribution infrastructure.

The Electric Mine Consortium's Electrical Infrastructure working group has drafted a number of key technical design questions to be answered in order for full electrification to be achieved when establishing greenfield mines or undertaking brownfield expansions.

Charging infrastructure	Charging strategy	Demand and optimisation	Supply and integration
1. What system upgrades will be required to handle charge densities and rates? **2.** How can traditional charging infrastructure be improved to create a more ubiquitous supply (e.g. trolley charge)? **3.** How can charging infrastructure be designed for redeployment (i.e. so that it can be easily moved from different locations and assets)?	**1.** How is power delivery to equipment controlled and prioritised, and how will this impact shift scheduling? **2.** How many chargers and charging bays will be required, and where should these bays be located? **3.** What is the optimal case for using each of fast-charging and battery-swapping models?	**1.** What are the key priorities of the operating system (decision-making tool for power network) and what visibility will it require over the network? **2.** How will the mine energy load characteristics change throughout a shift? (incl. static and dynamic loads)	**1.** How does the energy load change, and how Is this impacted by the level and duration of penetration from renewables/storage? **2.** What kV backbone will be required to successfully supply an underground electric mine?

The working group intends to test and ultimately answer these questions through:

— A detailed discovery process, including integration with already completed work through initiatives such as the ICMM, GMG and Charge on Challenge

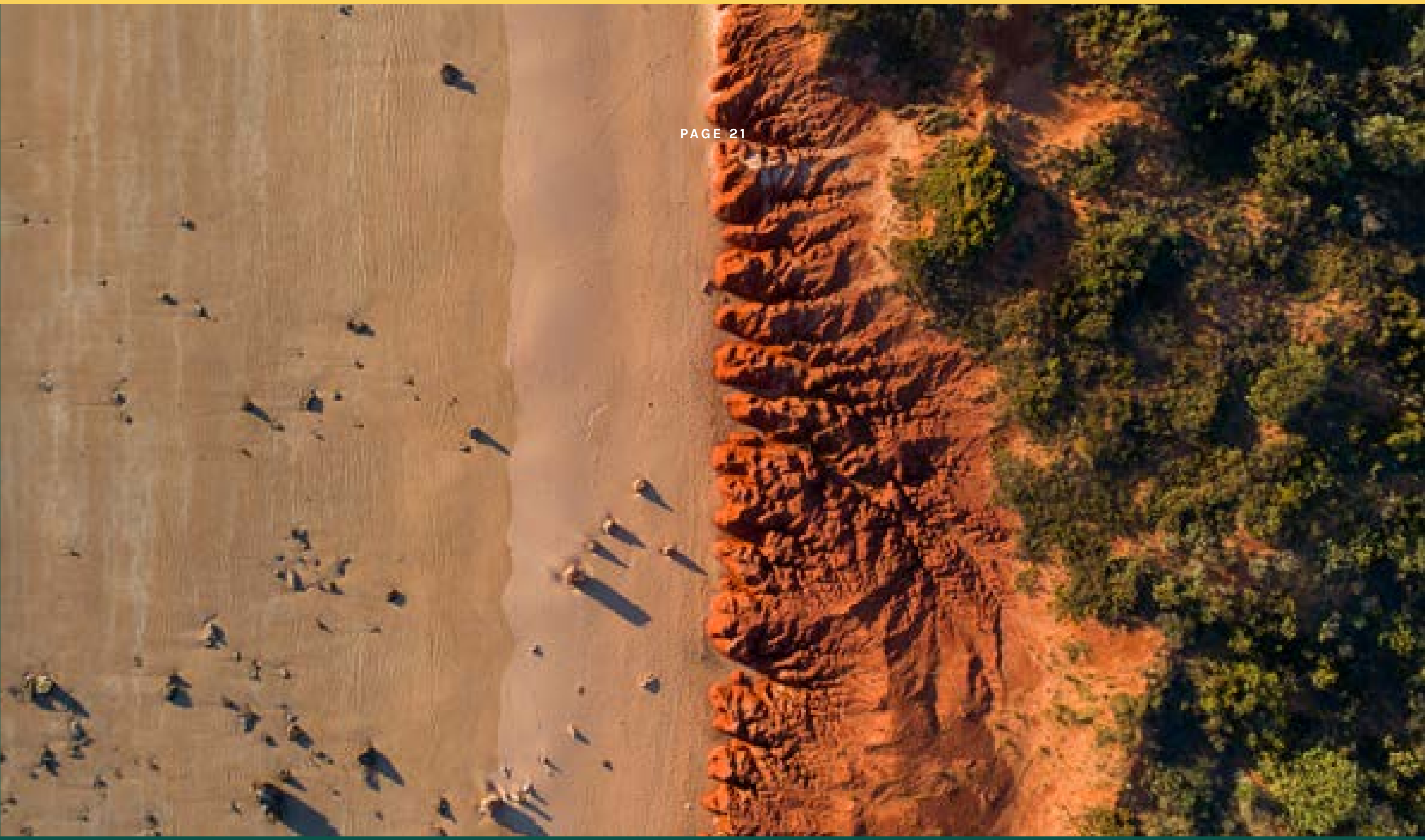
— Hold discussions with equipment OEMs around the globe

— Run several scenarios through a simulation platform, which would be based on an existing consortium member asset and developed in coordination with the mine design simulation challenge

— Integrate with exiting consortium vehicle trials

Another major focus area for this working group is the standardisation of charging infrastructure. 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's efforts will prioritise performance and safety and gives the market the opportunity to guide which technology should be prescribed by regulators. The market-wide adoption of an agnostic charging solution would help radically simplify the electrical infrastructure challenge.



Scope 3: Outside the fence

Mining's impact "outside the fence" is far-reaching. Its influence on local communities, economic development, biodiversity and global warming cannot be understated, and as mentioned earlier, will only become more intensely scrutinised.

Scope 3 accounting

When referencing the zero-carbon mine, these "outside the fence" impacts are measured by scope 3 emissions. A mining companies scope 3 emissions include all indirect emissions that occur in the value chain, both upstream and downstream (e.g. supply chain and transport). Mining is responsible for ~6% of global greenhouse-gas emissions. Only ~1% of this comes from scope 1 and 2 emissions, with the remaining generated in the value chain, in offshore downstream processing and through methane leakage.[12]

Whilst scope 1 and 2 emissions are very well understood and reported on by the industry, the tracking of scope 3 remains riddled with accounting complexities. From our analysis, less than 10% of mining companies globally report publicly on their scope 3 emissions.

FMG is a leader in reporting standards, having just announced their target to achieve net zero scope 3 emissions by 2040. Anglo American aims to halve scope 3 emissions by 2040, whilst Rio Tinto, Vale, Glencore, and Newmont have all stated varying reduction targets as well.

The EMC recognises the broader need to measure their carbon footprint in real-time, from scope 1, 2 & 3. Currently, there is a heavy reliance on external consultants for end-of-month style reporting using spreadsheets and manual processes. The ability to understand high value areas for carbon reduction efficiencies requires visibility and ideally an internal platform that can track operational emissions in real-time.

The EMC is in the process of clarifying the requirements of such a platform and hope to go to market with an expression of interest for a solution.

Someone else's scope

Miners will increasingly need to become more aware of their scope 3 emissions, whilst also recognising that they are also a part of someone else's supply chain.

Mining currently accounts for roughly half of the carbon footprint of a battery cell,[13] and there is a growing demand from downstream customers to reduce this through low or zero-carbon raw materials.

This demand is manifesting in two ways. Firstly, we are seeing the emergence of premium commodity pricing for those products considered 'green' or 'clean'. Emirates green aluminium has been reported to fetch a $12-14 premium per tonne, [14] Boliden's 'green' copper products are already fetching a small premium, [15] Bellevue Gold have announced they will sell their 'cleaner' gold for more than the standard global price, and Vulcan Energy's zero-carbon lithium is touted to be giving them preferential supply to tier-one European battery and automotive customers. [16] No one knows how long first movers will enjoy premium pricing, however in the longer-term we expect this will morph into a condition of supply.

The second way this is emerging is through the changing behaviour of capital markets. ESG practices are now becoming a requirement for financing. There are a number of third-party certification bodies around the globe that provide verification for green products. A number of exchanges have introduced their own certification bodies, such as the London Stock Exchange, who have introduced a 'Green Economy Mark' for those who constitute a 'green' business[17]. Consortium member Blackstone Minerals has announced their partnership with Circulor to track the ESG impact of their nickel through the blockchain. Metrics include carbon intensity, biodiversity impact, water use and energy mix, all of which will be made available to their downstream customers.

Regulation is following suit. 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.[18] Any batteries not meeting the new regulation will be banned. Placing the responsibility on manufacturers to demonstrate that they are meeting these requirements has significant implications for the miners who provide these raw materials.

Bringing Australia along

Accelerating the adoption of zero-emission technology is well placed to create real value, not only for the mining companies themselves, but for the broader community too.

Whilst Australia as a nation has an abundance of wind and solar energy, which is by far the cheapest source of power, it is not currently considered dispatchable. If the Australian economy wishes to pursue its zero-emission domestic energy supply objectives, solving the energy storage challenge should be a key focus.

In 2020, roughly 600MW of new renewable energy capacity was added to the Australian energy mix.[19] By 2040, Australia will require up to 21GW of new dispatchable resources to support the transition to renewables.[20] As Australia reduces its reliance on coal and gas fired power, large-scale batteries will play a large role in supporting the reliability of renewable energy. In the last 12 months, a flurry of major energy storage projects have been announced in Australia, majority being lithium-ion chemistry.

The remote mining operations in the EMC and our large-scale pilots have a unique opportunity to show leadership in demonstrating the role that long-duration battery storage (other than lithium) can play in the power grid, beyond just stabilisation.

13 Tesla

14 Business Times

15 Reuters

16 Fast Markers

17 FieldFischer

18 Share Cafe

19 Clean Energy Council

20 Australian Energy Market Operator

Skills and capability

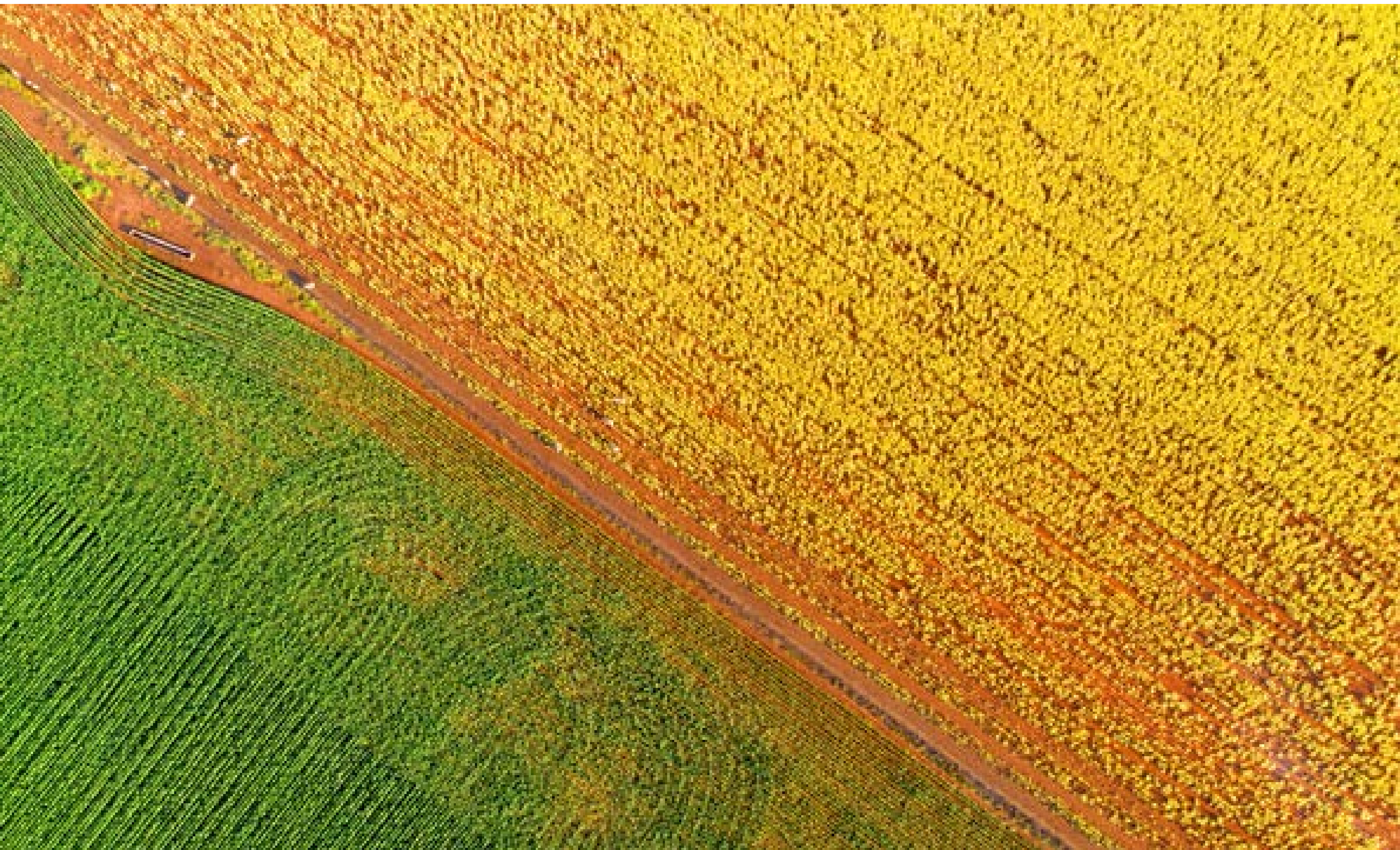
The zero-emission, zero-particulate mine will operate differently to traditional mines. With such widespread technology and operating model changes comes significant shifts in people, capability and skills requirements. Modelling conducted by the Victorian Automotive Chamber of Commerce estimates there is only currently 500 qualified electric vehicle technicians in the whole of Australia.

The EMC has formed an enabling group focused on the skills challenge to collectively develop the people and capability needs for the future. In partnership with TAFE, Government and several universities, the work aims to:

1. Increase industry attractiveness to address skill shortages by repositioning the industry as clean and technologically advanced.
2. Understand the major gaps in capability that need to be addressed in the next 3-5 years as brownfields mines start their transition and greenfields mines come online.
3. Understand the sharp increase in system and analytical capability required that will underpin the operational transition to electrification.

These focus areas will allow the EMC to articulate their needs to the market, particularly to education and training providers, in order to support the transition.

Mining is only a small part of the broader global energy shift. The skills and capability requirements that the EMC aims to articulate will likely be translatable to a number of other industries experiencing similar challenges.



Conclusion: A collaborative sweet-spot

Most companies espouse the value of collaboration. However, in practice it generally remains elusive and is typically fragile. The Electric Mine Consortium model is unique and has proven to be very successful, having been formulated at a critical time for the industry. Never in our experience have we seen this level of depth in engagement and sharing between companies in such a short space of time.

It is well understood that to achieve such an ambitious objective of zero-emission mining in the desired timeframes, combined industry effort is required. The consortium has been designed as an enabler for this and follows a set of simple principles:

1. Remain focused on high-value challenge areas
2. Challenge areas have broad applicability and are not sensitive to company intellectual property
3. Leadership and accountability are driven by the mining companies
4. Consortium design is agile and evolves as the external environment changes

Success is demonstrated in what we have been able to deliver so far. Keeping in mind we have only been operating for 12 months, we have achieved the:

Mobilisation of an active leadership group of 8 mining companies and 9 services companies, spanning across 12 different commodities

Aggregation of demand to influence the supply and policy ecosystems

Raising of external awareness of the initiative, including a CEO agreement for a joint public statement on decarbonisation mission

We have catalysed a wide range of influential projects with the EMC members and partners, these include:

The EMC's key focus going forward will remain on delivering on the current working and enabling groups with members and support from partners for expanding the number of pilots and trials.

There are a number of additional areas for future consideration that have emerged in completing this work over the last 12 months.

Some of these include:

1. Automation - Electrification is understood to be a foundation enabler for the automation of production equipment
2. Processing and value-added products
3. The achievement of zero emissions, rather than net-zero, which requires achieving a 100% renewable energy fraction
4. The ability to capture 'green premium' pricing for products through accreditation

THE ELECTRIC MINE CONSORTIUM

CONSORTIUM ACHIEVEMENTS SO FAR:

Mobilised a 10MW/h battery storage trial with Gold Fields worth $8m, with funding support from ARENA [funding application in progress]

Commissioned the development of a data sharing platform to achieve the 'virtual trial' ambition and create critical mass for scaled learnings and adoption

Mobilised a skills and capability enabling group to close the people gap for an electrified, automated mine, with delivery participation from TAFE, Universities and Government.

Building a financial model to understand, and communicate, the true value of electrification, built on a portfolio of equipment cost models.

Commissioned a major global crowd challenge for mine simulation technology with Unearthed and OZ Minerals.

Mobilised a working group to select a common carbon measurement platform for standardisation and certification.

Commissioned and supported over 20 vehicle and equipment trials and pilots across 8 consortium sites.

Provided design input into the research and development of various zero-emission equipment and technologies.