ELECTRIC MINE CONSORTIUM

# Driving Decarbonisation

A Decarbonisation Roadmap presented by the Electric Mine Consortium

Our Participants —

# Powering our collective journey

The Electric Mine Consortium's (EMC) Decarbonisation Roadmap outlines the path towards a zero particulates, zero carbon electrified mine. It introduces best practices in mine electrification, provides an overview of the milestones needed to accelerate an Australian underground mine to Net Zero by 2035, and suggests initiatives that could drive the industry towards an electrified future.

The roadmap has been generated from years of industry leading insights from within the Electric Mine Consortium: 200+ people from 20+ participants across miners, OEMs, power suppliers, data modelers, and other services companies who honed our collective knowledge through open collaboration and trusted knowledge exchange.

Together we have seen over 70 equipment trials, focused workstreams in 5 critical areas, over 36 major workshops, and more than 15 non-commercial engagement forums with OEMS and CEOs. We have also been involved in the creation of financial and ESG models, 5 market-wide expressions of interest, the full development cycle of new electric equipment, government policy consultations, and countless conversations with global experts.

The Electric Mine Consortium participants are consistently at the forefront of mine electrification and decarbonisation; our collective expertise, unique non-competitive structure, and industry-spanning systems-oriented perspectives put us in an ideal position to present this Roadmap and its associated set of suggested initiatives.

# Table of contents

# Methodology and sources

## Scope

The Decarbonisation Roadmap presented by the EMC outlines major projects and enablers to address the key mine electrification and emissions reductions challenges in the Australian industry. These projects are intended to optimise the collective resources invested, and to be innovative and ambitious (yet achievable) in supporting mining electrification.

## Forward outlook

A critical component of a decarbonisation roadmap is flexibility and the creation of optionality in the face of changing conditions. The Decarbonisation Roadmap outlined here is designed to support the mining industry as it stands in 2024, and as such is subject to change with the maturing landscape.

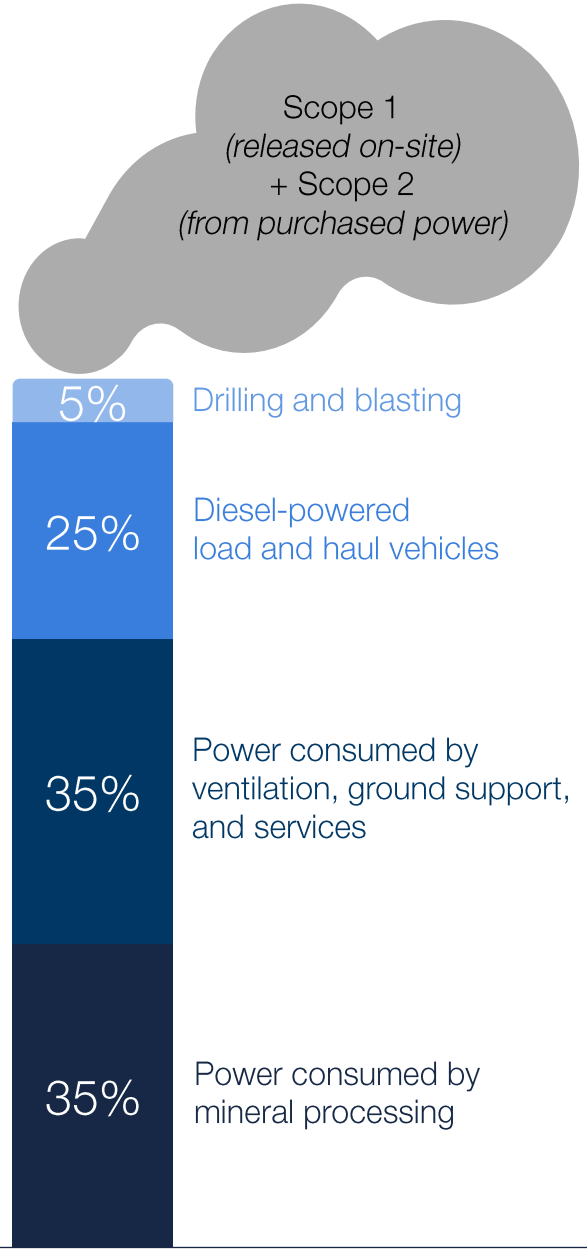
# Where mining emissions come from

Despite the well-known negative health and environmental effects of diesel particulate and greenhouse emissions, and the growing public and regulatory support for greener business practices, *most* miners have only committed to reduce their Scope 1 + Scope 2 emissions to Net Zero by 2050.

**That means another 25+ years of damage.**

The Electric Mine Consortium has demonstrated that despite the challenges, key players in the Australian mining industry now have the technical and organisational capabilities to accelerate the emissions reduction timeline, delivering better outcomes for both miners and the community. Many of our members have made industry leading commitments and investments in the areas of electrification and decarbonisation.

This Decarbonisation Roadmap lays out the steps to be taken for accelerated Net Zero mining; investing in those steps and leading the Australia into the future is up to the industry.






** Numbers are indicative averages for an underground Australian metals mine, based on an EMC member site.*

# Scope 1 & 2 Net Zero themes in mining

## Clean energy

Across forward-leaning companies (such as those in the EMC), there is a consistent trend toward transitioning to renewable energy sources, with several setting specific, ambitious targets for high percentages of green energy by 2030 and beyond. Many companies are investing in new technologies such as energy storage (lithium and alternatives), hydrogen, and hybrid power stations.

## Electrification of equipment

Several companies have conducted studies and trials for the full spectrum of electric vehicles. Though some companies provide limited or no information on electrification, others have clear targets and plans. Two major issues remain for full electrification: underground load and haul equipment adoption in Australia* and open-pit equipment adoption globally. Given the combined capital and operational risk, most companies are taking a "fast follower" approach in these spaces. Once demand has been catalysed, the industry will then have to grapple with supply chain challenges for the emerging electric equipment.

## Process innovation

A number of innovative approaches are being explored to optimise energy usage, particularly in mineral processing. Examples include utilising time-shifting of energy-intensive processes or the development of processing technologies (e.g., leaching) that are able to flexibly integrate with intermittent renewable energy supply to maximise renewable energy usage (and minimise storage needs), or reducing energy demands through the ventilation-on-demand, the insulation of operational areas to reduce heat loss, and the utilisation of waste heat.

## Carbon offsets and climate solutions

Several companies have established dedicated teams, implemented internal shadow carbon pricing, and are exploring or utilizing carbon credits. Some companies are actively involved in short-term initiatives and have outlines mid-term plans. A limited number of companies have long-term plans for carbon offsets and climate solutions. Some companies provide limited or no information on their carbon offsets.



*Insights gathered from EMC member public roadmaps as of December 2023*

** Australian underground mines typically use uniquely long declines and 65t class haul trucks*

# Roadmap to a Net Zero mine by 2035 – *overview*

| | SHORT TERM – *1-3 YEAR* | MEDIUM TERM – *3-5 YEAR* | LONG TERM – *5-10 YEAR* |
|---|---|---|---|
| **Business decisions**<br>*Correctly understanding electrification's value and risk…* | Companies have a deep, established understanding of their emissions and the value from decarbonisation under a range of future scenarios. | Decision making process is expanded to cover automation options and Scope 3 emissions reduction. | Remaining emissions are abated or offset using high quality carbon offsets with co-benefits. |
| **Renewable energy**<br>*Divesting from a fossil fuel power supply….* | 60-85% renewable energy power supply project(s) are planned. | Renewable power supply is in place; energy storage, management and optimisation processes are developed. | Energy optimisation processes are implemented; decarb. progress based on future tech is developed. |
| **Electric equipment**<br>*Transitioning vehicles and pieces of equipment…* | Transition plans for electric equipment are developed; change management processes are defined and deployed; operational readiness models are developed; funding sources and equipment trials are planned and delivered. | Majority of equipment is in process of transitioning to electric (trials or adoption). | Alternative fuels or technologies are continually explored as a potential niche abatement. |
| **Asset planning & development**<br>*Retrofitting, optimising and future-proofing the mine site…* | Energy management architecture is in place; operations are changed to derive full benefit from electrification; simulations are deployed; mine design improvements are understood; electrical infrastructure is in place. | Mine planning processes are adapted to incorporate future electrification; Energy Management System (EMS) is evolved. | Next phase of mine expansion takes full advantage of electrification opportunities. |
| **Organisational capabilities**<br>*Ensuring the necessary staff, skills, and structures are available…* | Robust culture is established which supports decarbonisation initiatives, with top-down ambition and clear lines of communication and project ownership. | Organisation is more data-centric and automated, with evolved staff roles to support hybrid human/tech teams. | An ongoing faster pace of innovation, technology adoption, and skill transfer is enabled. |

# Roadmap to a Net Zero mine by 2035 – *details*

| | SHORT TERM – *1-3 YEAR* | MEDIUM TERM – *3-5 YEAR* | LONG TERM – *5-10 YEAR* |
|---|---|---|---|
| **Business decisions**<br>*Correctly understanding electrification's value and risk…* | • Use scenario-based valuation models to understand decarb. business case<br>• Understand current and future regulatory and market environment<br>• Drill out mine to understand mine life and improve business case<br>• Collaborate widely to understand new standards and processes<br>• Leverage clean reputation to access financing, partnerships, and talent | • Explore equipment automation as a means of improving efficiency/electrification business case<br>• Understand Scope 3 emissions profile<br>• Mature valuation models based on real-world technology experience | • Work with supply chain partners to mitigate Scope 3 emissions<br>• Offset remaining emissions using high-quality carbon credits |
| **Renewable energy**<br>*Divesting from a fossil fuel power supply….* | • Review existing power supply contracts<br>• Study renewable energy options<br>• Install 60-85% renewable energy generation, via PPA or direct investment<br>• Study energy storage, management, and optimisation options | • Analyse and select energy storage options to increase renewable penetration<br>• Work with on-grid retailers to lock in renewables<br>• Implement energy optimisation processes such as load optimisation in processing | • Install long duration storage technology<br>• Study future technology solutions to further optimise renewable energy usage |
| **Electric equipment**<br>*Transitioning vehicles and pieces of equipment…* | • Signal demand to OEMs, securing equipment supply and design input<br>• Plan equipment trials/purchases based on availability and lifespan<br>• Apply for equipment grants<br>• Trial available equipment, sharing data/learnings where possible<br>• Design and implement operational readiness plans for all site functions | • Adopt electric mobile equipment and associated charging infrastructure across site<br>• Decommission diesel equipment or retrofit to electric where it makes sense<br>• Optimise operating model for electric equipment | • Implement study findings and use new tech to completely remove diesel from operations |
| **Asset planning & development**<br>*Retrofitting, optimising and future-proofing the mine site…* | • Design future fleet, including charging infrastructure and battery swap plans<br>• Build charging infrastructure or battery swap-out stations.<br>• Work with regulators to share knowledge and design optimal operational plans<br>• Study and simulate options to reduce processing energy and LDES demand, e.g., time/load shifting | • Continue to refine safety systems<br>• Study sustainable options for end-of-life infrastructure<br>• Enable EMS to evolve with new tech<br>• Install energy efficient mineral processing technologies | • Apply electric-integrated mine designs to mine expansions |
| **Organisational capabilities**<br>*Ensuring the necessary staff, skills, and structures are available…* | • Set and communicate decarbonisation targets, plan, and lessons learned<br>• Set decarb. governance, reporting, and accountability procedures<br>• Set decarb targets and offer climate-based incentives to staff<br>• Develop staff talent and skills/knowledge pipeline<br>• Develop robust change management capabilities | • Continue to develop skillset of team and build pipeline of new talent<br>• Build capability to analyse new data sources and optimise operations | • Have teams of skilled workers, autonomous electric equipment and AI-driven optimization processes<br>• Identify and adopt new technologies quickly without disrupting the larger system |

# Variables impacting site-specific roadmaps

*Roadmaps need to be adapted to take into account the context of the operation, allowing for multiple variables including:*

## Asset variables

ORE EXTRACTION METHOD: Underground | Open pit

STAGE: New project | Established, operational mine | <10 years remaining

ASSET LIFE: Longer life assets provide more opportunity to recover capex

LOCATION: proximity to infrastructure (including grid) | remote

CURRENT EQUIPMENT/INFRASTURE EXPIRY DATE: renewing soon | sunk time-cost

## Technology variables

RENEWABLE FEASIBILITY: Solar/wind generation | low solar/wind prospects

FULL ELECTRIC FLEET FEASIBILITY: high | moderate | low

VIABILITY OF ALTERNATE MATERIAL MOVEMENT AND FUELS

EXPECTED IMPROVEMENT CURVE for new technologies

OPTIONALITY: incorporating flexibility to adopt emerging technologies

## Strategy variables

COMPANY PORTFOLIO: single-asset | modest | diverse

PORTFOLIO CHANGES: e.g., mergers and acquisitions, care and maintenance

BUSINESS and MARKET MODELS: e.g., contractors, LME green stream

STAKEHOLDER PRESSURE: e.g., shareholders, finance partners

CAPABILITY and APPETITE for INNOVATION

## External variables

COMMODITY PRICE CYCLES

LEGISLATION, FINANCING, and PERMITTING: e.g., diesel tax rebates

LOCAL COMMUNITY: e.g., First Nations, economic and environmental considerations

AFFORDABLE SUPPLY OF ELECTRIC EQUIPMENT

GRID RENEWABLE PENETRATION

# New approaches for a green future

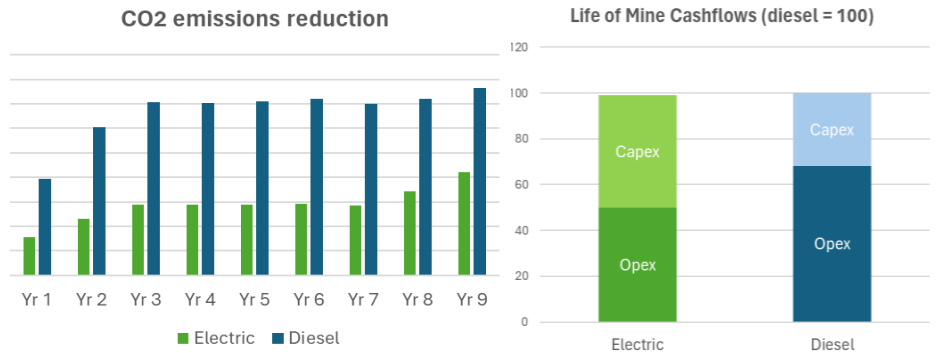
*The following pages contain our suggestions of industry strategies to accelerate emissions reductions across the five areas of a typical roadmap, based on our experience leading collaborative work in the industry. By investing in such strategies, the Australian mining industry can set up for a decarbonised future.*

# Understanding the value case

Transitioning to an electric mine requires capital investment in equipment and infrastructure, typically at a higher cost than legacy diesel equipment. However, the capex is offset by lower opex, with the payback period depending on assumptions about future costs and equipment productivity. Financial models comparing the Net Present Cost of electric versus diesel equipment for a particular mine can help decision makers quickly understand the business case levers and make robust investment decisions. In parallel, mine design models can be adapted to incorporate new mining assumptions and value levers. The whole business case for electrification also includes critical benefits that are difficult to value, for example the elimination of DPM in the underground environment or the social cost of carbon. As the industry learns more about electric equipment, the assumptions, inputs, and confidence in the model will improve. Potential participants include services companies and miners.

## Miners are asking: Are my assumptions about the viability of electrification reasonable, given the uncertain future…?

- *What is the Capex/Opex tradeoff for electrification?*
- *What if the cost and performance of BEV's improves rapidly?*
- *What if BEVs last longer and are more reliable than diesel equivalents?*
- *What will my emissions reduction from electrification be and what is the financial value at different carbon prices?*
- *What will the value look like under differing diesel price scenarios?*
- *What if my finance costs increase if I am slow to adopt decarbonisation?*
- *What can I afford to pay for low emissions energy?*
- *What if I could extend my mine life; how would that improve the payback on electrification?*
- *What if I can achieve a price premium for my low carbon product?*




*Example model results (Electric Mine Consortium Financial Model, developed in partnership with Model Answer)*

# Shared renewable infrastructure projects

**Shared renewable infrastructure in the mining industry is a novel concept that can significantly empower the emissions reductions of energy-intensive mining hubs.** These projects have the potential to lower the capital risk of low-emissions energy infrastructure for any one company, thus making otherwise uneconomic projects economical and accelerating the provision of renewable energy capacity that might otherwise have struggled to get established. These projects break the current commercial infrastructure model, and require support through opportunity identification, facilitation of early stakeholder interaction, and strategic problem solving of barriers. Potential participants include governments, Indigenous groups, local community and business groups, and co-located mining and services companies.

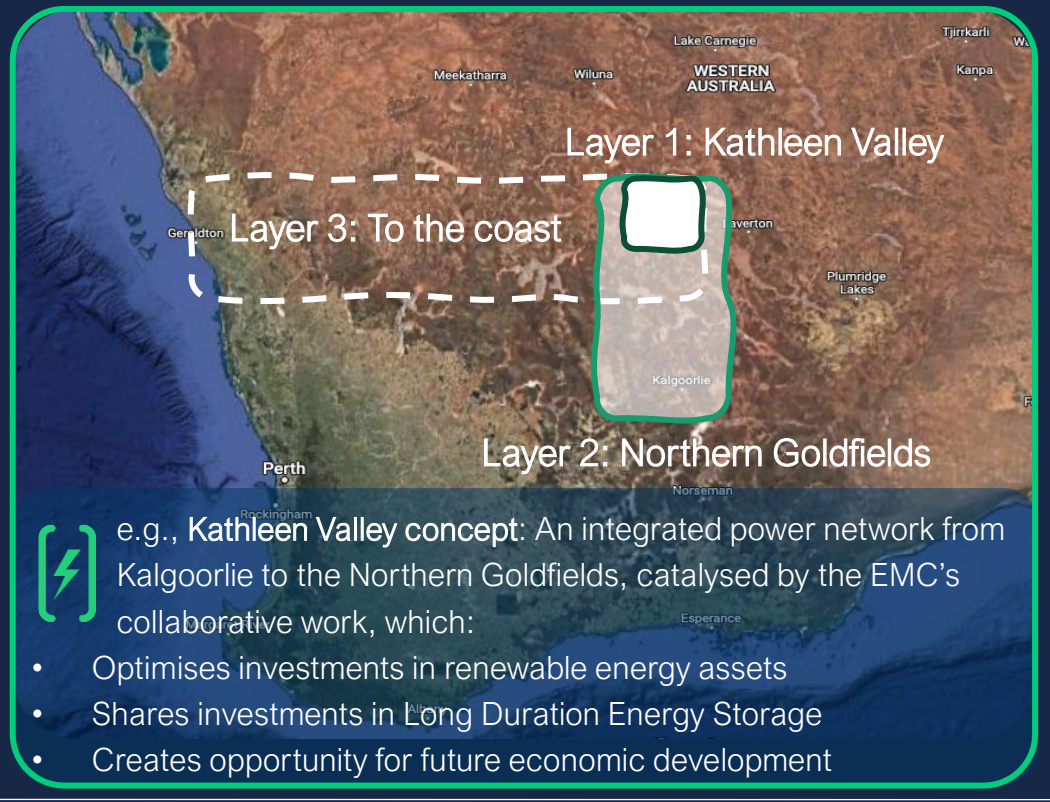
## SHARED ENERGY INFRASTRUCTURE STAKEHOLDERS

**Governments:**
- Energy transition
- Efficient approvals
- Industry & social buy-in

**Native title owners:**
- Land access and approvals
- Local skills and employment
- Investment funding

**Miners/ customers:**
- Energy security
- Long term cost certainty
- Social acceptance

**Public & private funding:**
- Investment expertise
- Long term returns
- Portfolio opportunity




e.g., **Kathleen Valley concept**: An integrated power network from Kalgoorlie to the Northern Goldfields, catalysed by the EMC's collaborative work, which:

- Optimises investments in renewable energy assets
- Shares investments in Long Duration Energy Storage
- Creates opportunity for future economic development

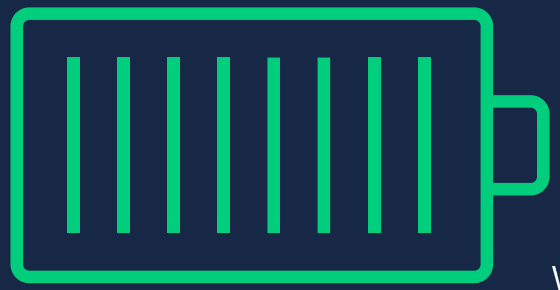
# Energy storage studies

**For remote mine sites, energy storage is crucial** to enable high renewable energy penetration throughout periods of low natural generation (e.g., nighttime). A comprehensive industry investigation into the options and opportunities surrounding Long Duration Energy Storage (LDES) will help companies to make smart investment decisions, but requires input data from mining companies, an understanding of the decision-making methodology surrounding the purchase of LDES equipment, and a commitment to share the learnings broadly. Potential participants include research institutes and battery manufacturers.

How reliable is Long Duration Energy Storage (LDES)? What happens if it fails?

What capacity can LDES currently achieve, at what price? How will this change in the future?

What technology options are available? Which ones are the best?



How will the existing lithium battery roll-out impact demand for other technologies?

Will storage increasingly play multiple roles as part of the interconnected network?

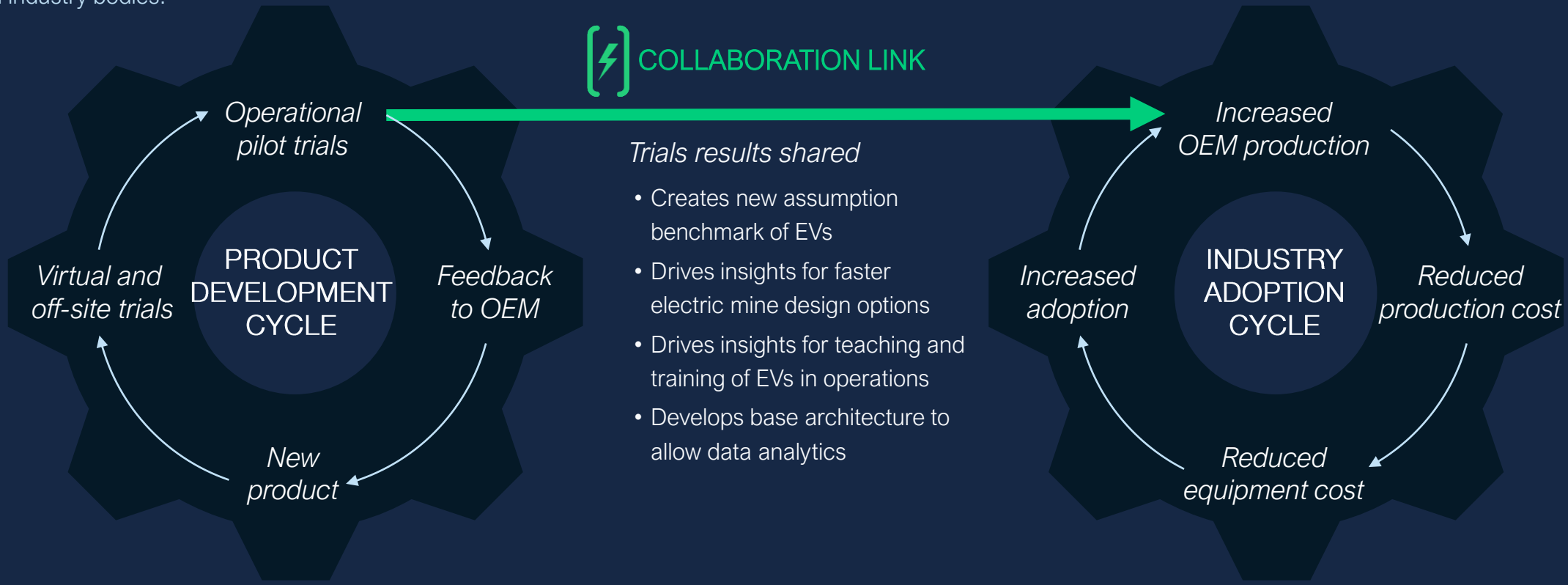
What impact will evolving infrastructure connectivity have on requirements and sequencing?

How could the market for electric vs thermal storage evolve?

What role will green fuels play in optimizing generation ?

# Collaborative trials for new technologies

**The innovation cycle for new electric technology** provides opportunities for collaboration throughout the end-to-end development and trials pipeline. While EMC miners have led the way in electrification trials, many Australian miners lack confidence in the performance, safety, and usability of new low-emissions equipment. Trials are a critical pathway for the industry to build trust in these technologies, but they can be costly, operationally disruptive, and difficult to plan. Collaboration offers a solution: companies should engage with OEMs for product development and supply, collaborate on simulations and off-site trials that minimize operational disruption, or share learnings and data to accelerate the industry adoption (and reliable, affordable supply) of electric equipment. Potential participants include OEMs, mining companies, and industry bodies.



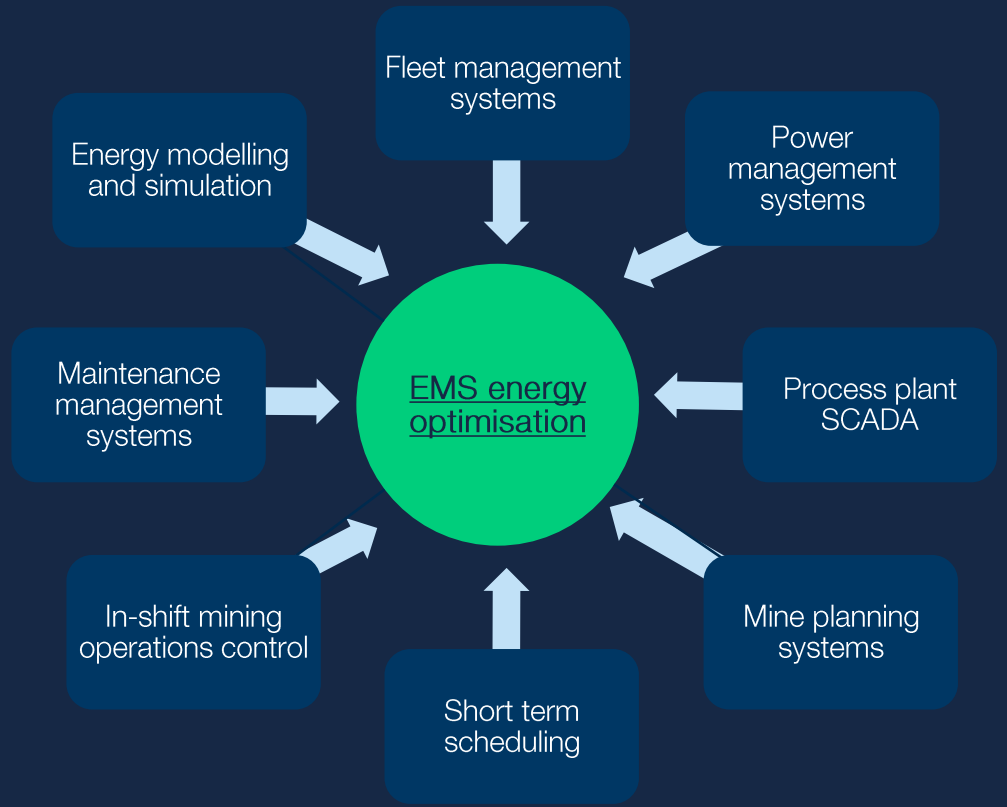
# Energy Management Systems (EMS)

Optimising energy management will be critical to the future performance of mining operations. Energy demand profiles will change due to new loads, e.g., high-capacity battery charging, trolley assist systems. As a result, peak energy demand (and associated costs) will be significantly higher if they are not actively managed. On the energy supply side, the incorporation of renewables into the energy mix adds complexity to the supply profile, with variation through the 24-hr cycle and annual seasons. Active energy management presents an opportunity to optimise energy cost and emissions and reduce risk to operations. Energy optimisation opportunities are available across the full scope of timeframes – from life-of-mine planning and forecasting, down to sub-second process control. Potential participants are engineering, services, software and modelling companies, and miners.

Exploiting energy management opportunities requires a system-wide view, with integration of data from various existing and new systems (see diagram).

The EMC undertook a market EOI to explore the EMS software products in the market. Whilst several suppliers put forward promising products, it is clear that new partnerships will be required to generate an integrated EMS.

There is an opportunity for the industry to shape the direction for EMS. Given the industry-wide challenge, there is an opportunity to drive towards an open industry standard or system approach.

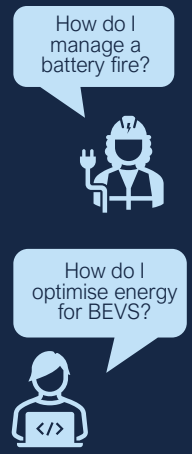


# Network-based skills development

Decarbonisation and electrification require new technology, infrastructures, and processes. This calls for new skills, capabilities, and levels of confidence throughout the industry, from on-site operators and maintenance people, through to IT and corporate sustainability teams. This collective need for net capability building presents an opportunity to develop collaborative tools, peer support, and co-beneficial transfer of knowledge within a traditionally competitive industry. Potential participants include OEMs, other suppliers and services companies, groups of mining companies, industry bodies, and government.

## CURRENT SKILLS GAPS

- Electrical maintenance
- Electrical safety
- Energy optimisation
- Operations of new technology
- Charging and battery optimisation
- Battery emergency response
- Carbon measurement and reporting
- Data management and analysis
- Policy compliance
- Grant engagement




## TRADITIONAL SKILLS PLATFORMS

Skill gaps may be addressed in entry-level and ongoing training programs. However, developing the expert-led electrification and decarbonisation curriculum content for these formal programs take time, leaving a skills gap.

## COMMERCIAL EXAMPLES

- Trades education
- Tertiary education
- Organisational workshops
- Online courses
- Annual accreditation programs

## NETWORK-BASED SKILLS DEVELOPMENT

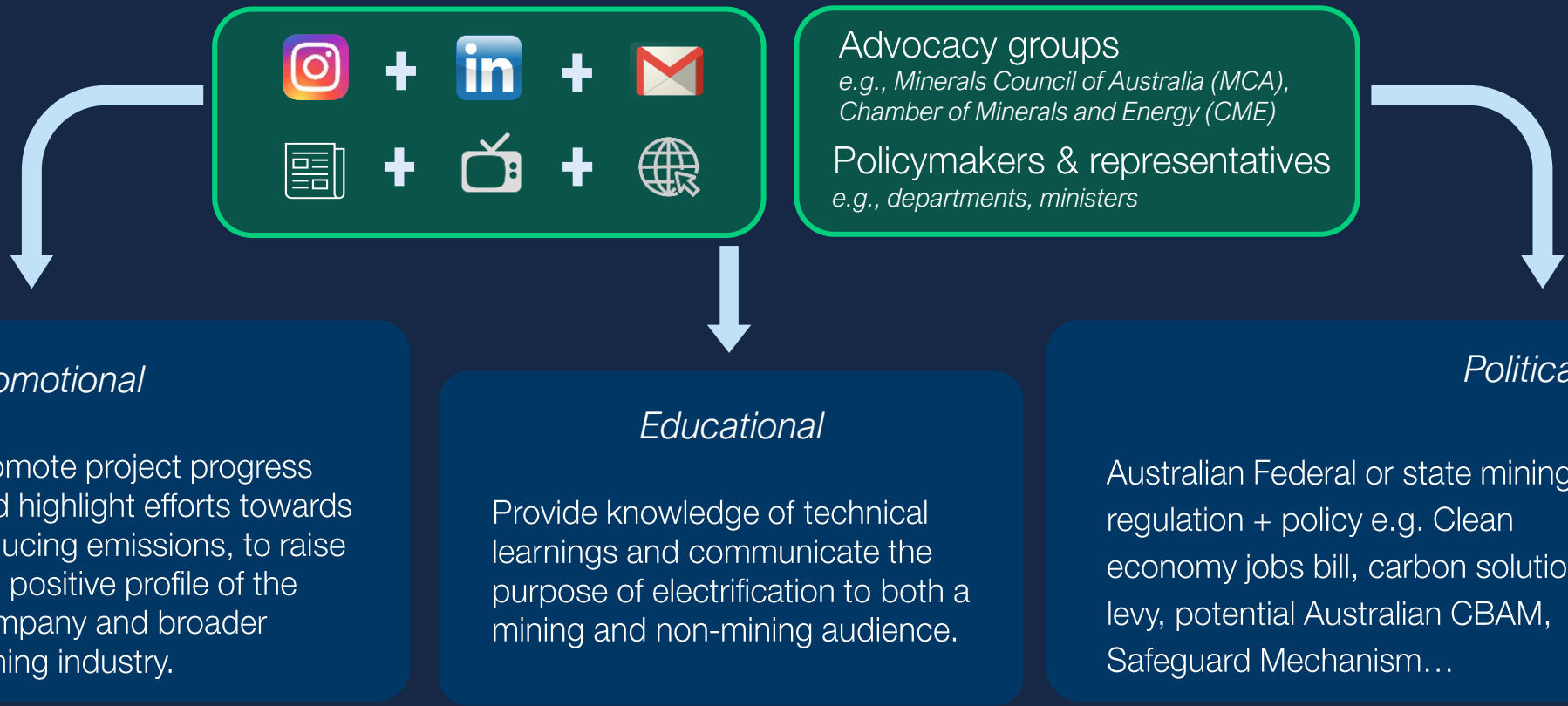
To accelerate the upskilling of Australia's mining industry, common questions may be answered, and emerging knowledge may be shared in more open forums, such as cross-organisational workshops or regular networking events for specific skills groups. Such communities of practice are inexpensive and flexible, allowing knowledge to flow rapidly from the forefront of experience to wherever the industry needs it, regardless of organisation or level of seniority.

## COLLABORATIVE EXAMPLES

- EMC workshops
- EMC carbon group
- Conferences
- Decarbonisation social meetups
- Formalised networks driven by companies

# Public and political advocacy

Motivated companies in the mining industry can actively promote their decarbonisation journeys to bolster market, investor, and community support, and influence industry and global ambition and attitudes around mining, electrification and decarbonisation. They can also engage with policymakers to understand the regulatory landscape of the present and future, and to educate governments about how they can best support decarbonisation and electrification. Mining companies are often operating on the frontier of low-emissions solutions and are well-placed to share their deep understanding of the challenges facing mine decarbonisation and the structural changes required to solve them.



ELECTRIC MINE CONSORTIUM

Over the last four years, the Electric Mine Consortium has been dedicated to powering the mining industry's journey towards a decarbonised future.

The mining industry is now primed for electrification…

**ARE YOU READY?**