BUILDING THE ALL-ELECTRIC MINE:

Starting small, thinking big

Second edition

ABB

ENGINEERED TO OUTRUN

CONTENTS

01 Why electrify your mine? Why now? EXPLORE

02 Let's recap: the last five years EXPLORE

03 Addressing some common concerns EXPLORE

04 You need to electrify. But how? EXPLORE

05 Small steps to success EXPLORE

06 Start your electrification journey with ABB EXPLORE

Why electrify your mine? Why now?

Technology providers and C-suite executives have been preaching electrification as a futuristic ideal for some time.

However, electrification is no longer a futuristic concept. **The past few years have shown it's a proven method of significantly boosting performance, as well as reducing emissions.** From haul trucks to loading equipment and conveyors, it's now possible to electrify a wide range of vehicles and machinery. These days, everyone can take steps towards an "all-electric mine", where small, smart shifts deliver big performance gains.

This transition is becoming increasingly critical for mining, for a number of reasons. First, the industry accounts for up to 7% of all greenhouse gases. At the same time, declining ore grades need more energy to extract, and new mining projects are often located in remote areas, far from established power infrastructure. Together, these realities make the integration of renewable energy sources not just desirable but essential for ensuring reliable, cost-effective, and low-emission operations across the mining value chain. Ultimately, this also improves productivity, efficiency and safety.

But for many in mining, questions remain, with **30% of mining leaders reporting being behind their 2030 decarbonization targets.** While far from ideal, this figure is perhaps unsurprising. After all, C-suite executives aren't the ones implementing change, operational managers are. On top of this, KPIs are relentless, safety must always come first, and any change must maintain or increase profitability.

At ABB, we believe in starting small but thinking big. By advancing technology and transforming mindsets, our teams foster a collaborative spirit. In this way, the mining industry can supply the materials needed for a low-carbon future, such as lithium for electric vehicles and rare earth elements for wind turbines. Moreover, mining teams will experience minimal disruption, and gradually accumulate both carbon and financial savings.

It turns out, many mining leaders are on board with the change: **53% said they are expecting to transform over the next 5 years.** ABB is committed to working with mines to bring about this transformation: starting small but thinking big, supporting you with current technologies, and into future developments.

Sustainable mining in Canada

Thanks to haul truck trolley assist infrastructure from ABB, Canadian company Copper Mountain Mining reduced the carbon emissions of its electrified trucks running on trolley by 90%, compared to the diesel-powered trucks. Not only this, but its trucks now run with twice the speed, ensuring higher performance.

Learn more >>

Let’s recap: the last five years

It’s been all change for mining in the last five years, since our 2021 whitepaper on building the all-electric mine. Falling commodity prices and rising costs have squeezed the industry, and many companies have missed production targets. This transition is becoming increasingly critical as ore grades continue to decline, requiring more energy to extract and process the same amount of metal.

Against this complex backdrop, mining talent now has higher expectations. Many now look for a technology-first work culture, where fair pay, job security, flexible working practices, and career prospects all come together as standard.

But while the years have undoubtedly been tough, electrification has progressed. Mines embracing electrification are starting to deliver speed, efficiency, and safety, as well as decarbonization.

As a result, many mining companies agree electrification is necessary for boosting productivity, efficiency and safety, as well as decarbonization.

Pilot projects are offering blueprints for progress, helping build confidence and momentum. From Canada to South Africa and Australia, we at ABB have been commissioned to conduct 26 studies across 9 countries globally since 2021, including 6 successful trolley installations, and a seventh in progress.

ABB conducted 26 electrification studies across 9 countries

All change now: addressing some common concerns

It's understandable to be cautious about futuristic technology and solutions. After all, the focus is often on immediate concerns, with cost per ton being a top priority. Additionally, mining is a strategic industry, and replacing a multi-million-dollar diesel fleet isn't something that can happen overnight.

Let's explore the questions, queries, and concerns that mining teams have about electrification, and consider whether a "start small, think big" approach could be beneficial for your organization.

Question 1:
Is now the right time?

Some may doubt if it's the right time to invest in electrification, especially as electrification technology does evolve. Why not wait another five years to electrify, when the technology could be even better?

Additionally, some wonder if electrification will change how their mines and mining assets are operated. They worry they'll choose the wrong solution for their fleet, which will likely comprise vehicles from multiple vendors, and about whether their infrastructure will need to be changed to meet the demands of new equipment.

However, highly effective electrification technologies are already available, and the reality is that targets aren't going away any time soon. If you don't adopt electrification technology today, you may face bigger disruption tomorrow. Mining teams need to prepare for electrification, so that when the time comes, they don't face massive capital expenses all at once.

On top of this, electrification is a proven upgrade, not an abstract idea, delivering speed, efficiency, and reliability. At some point, mines will all have to electrify. Recent research shows promising trends:

- **42% of mining companies are planning to invest in the decarbonization of their haulage fleet by 2026**
- **68% are planning to electrify at least 25% of their fleets by 2030**

42%

plan to invest in haulage fleet decarbonization by 2026

Early-stage design thinking and planning are crucial to success. If your trucks are moving towards the end of their lives and are due an upgrade, you can start small by upgrading some of them now to prevent big changes in the future.

The best electrification providers are also future-ready and vendor-agnostic, meaning their technology can be used across all vehicle types and OEMs, and no matter what happens down the line, you can flex and scale.

Collaboration for net zero

Multinational company Komatsu is working with ABB to create electrification and decarbonization solutions. With a dedicated team of representatives from both technology leaders, the two companies are exploring go-to-market strategies. The goal? Net zero emissions for heavy industrial machinery.

Learn more >>

Productivity:

Electric trucks are twice as fast as diesel trucks.

Efficiency:

You can charge many electric mining trucks without human intervention, reducing downtime associated with refueling or recharging.

Safety:

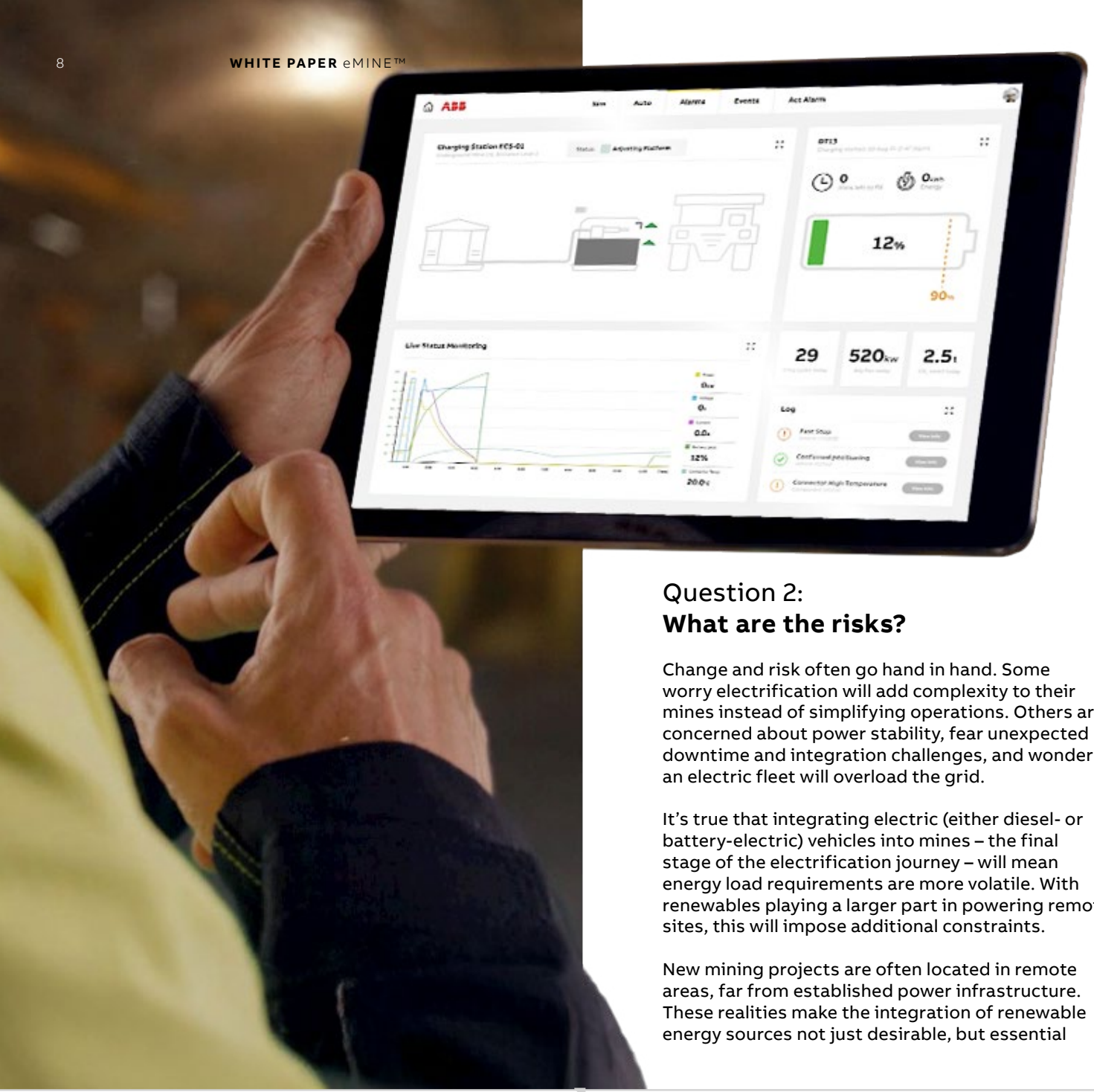
Electrification and automation also improve worker safety: electrification can reduce the number of harmful pollutants and noise levels in underground mines, while autonomous hauling and robot automated connection devices (ACDs) mean people don't have to carry out dangerous tasks.

Decarbonization:

Electrified trucks running on trolley truck trolley assist infrastructure can reduce carbon emissions by up to 90% compared to diesel-powered trucks.

Reliability:

Electric machines have fewer moving parts than diesel engines, leading to reduced maintenance requirements and lower downtime. This inherent simplicity enhances the reliability of electric mining equipment.



Question 2:
What are the risks?

Change and risk often go hand in hand. Some worry electrification will add complexity to their mines instead of simplifying operations. Others are concerned about power stability, fear unexpected downtime and integration challenges, and wonder if an electric fleet will overload the grid.

It's true that integrating electric (either diesel- or battery-electric) vehicles into mines – the final stage of the electrification journey – will mean energy load requirements are more volatile. With renewables playing a larger part in powering remote sites, this will impose additional constraints.

New mining projects are often located in remote areas, far from established power infrastructure. These realities make the integration of renewable energy sources not just desirable, but essential for ensuring reliable, cost-effective, and low-emission operations across the mining value chain.

The reality is that electrification isn't just about replacing fuel, it's about smarter mining. Power balancing solutions can ensure a stable, reliable energy supply. With robust planning of grid infrastructure and battery energy storage systems, combined with mine production forecasting, you can minimize load peaks and address volatility on the generation side.

There is an added benefit, too. Fuel prices are becoming increasingly volatile. Those who rely predominantly on electricity (some of which is self-generated) will not be exposed to any soaring fossil fuel costs.

On top of this, digital monitoring and automation tools can prevent failures before they happen, and fully integrated electrification and automation, complemented by digital solutions, reduce operational complexity.

Question 3:
How will my team adapt?

Some are concerned about their workforce and capabilities: specifically, they worry their team won't be able to adapt to new vehicles and machinery. Operators are accustomed to driving a diesel fleet and new processes can mean retraining. Additionally, there are fears that automation might equate to job losses, and doubt that electrification truly makes work safer or easier.

The truth is that to be successful, electrification and automation need to stay closely tied together. The move towards electrification and automation will require an integration of power and fleet management systems, to enable best use of renewable power sources and optimization of energy use and greater efficiency.

But automation works with miners, not against them: streamlining their workflow and making their working environments safer. Zero diesel fumes means better air quality and healthier workers. Electric systems reduce fire hazards and explosion risks. Additionally, with less vibration and noise, employees will be less fatigued, leading to fewer accidents.

Moreover, technology can be a significant draw for younger workers. With an aging workforce and negative perceptions of mining among the younger generation, mines that don't adapt may struggle to attract new talent. Technology can also play a key role here. A source of empowerment in itself, the vast majority (68%) of our respondents also said they see technology as a driver for diversity, noting that it can particularly attract Gen Z talent. After all, Gen Z is the digital generation. Technology can show Gen Z that mines are not like they imagine – but instead digitalized and automated.

You need to electrify. But how?

In the last three chapters, we've seen that electrification can cut your cost-per-ton, improve productivity, attract new talent, and even reduce your exposure to volatile fuel prices. But which technologies might work best for your mine? Let's look at some of the options.

Electrifying transportation

For large haul trucks to be electrified, mines need a combination of stationary energy transfer and dynamic energy transfer solutions. Both these technologies will require mapping of the mine constraints, including the following:

- The location of the loading and dumping areas
- The resources needed to perform loading and dumping
- Power availability throughout the mine area
- Other operational limitations imposed by the mine design

ABB supports the shift to electric through partnerships with OEMs and system integrators, delivering end-to-end electrification, and providing onboard equipment such as batteries, inverters, and drives. In this way, mining teams can retrofit their diesel trucks to reduce emissions, improve safety, boost productivity, and lower operating costs.

Maximizing battery life in Zambia

A powerful example of this is ABB's collaboration with Hitachi Construction Machinery, piloting the world's first real-world trials of a fully electric ultra-large haul truck—now operating at Kansanshi copper-gold mine—to demonstrate high-efficiency, zero-emission performance in demanding conditions.

Learn more >>

Technologies for energy transfer

Electrifying mine hauling fleets involves dynamic energy transfer solutions and stationary energy transfer solutions.

An innovative point of charge for mining trucks

ABB's technology demonstrator eMine™ Robot Automated Connection Device (ACD) is an interoperable, fully automated, high-power charging solution for electric mining trucks. The device has been tested in harsh environments such as Boliden's Aitik site in Northern Sweden, and is aimed at enabling fast, safe, hands-free connections. The ACD is being developed to ensure lasting compatibility through integrations with a wide range of fleet interfaces, vendor connection mechanisms, and future standards.

Learn more >>

Stationary energy transfer

Stationary energy transfer solutions charge haul trucks while they're still. The solutions can be adaptable and tailored to the haul trucks' specifications and the specific use case. The system can be interoperable, built on open standards with vendor-agnostic connection interfaces, and support both manual connections and Automated Connection Devices (ACDs).

There are four types of stationary charging solutions:

Fast onboard systems are ideal for large haul trucks used in open-pit mines. These systems allow for both stationary charging and in-motion charging along fixed-distance routes enabled by trolley systems. They use a DC power supply.

Fast offboard systems are ideal for all trucks used in open-pit and underground mines aiming for an opportunity charge. These vehicles are in almost continuous operation with limited (i.e. 10-15 minutes) idle time. Fast offboard systems are essentially charging stations that use DC power supply and are installed at fixed points throughout the mining area.

Slow onboard systems are ideal for stationary equipment like drill rigs and bolters that occasionally need to be transported from one point in the production area to another and take a long time to charge. Like most devices in the world that are directly connected to the electrical grid, these systems can use AC voltage.

Slow offboard systems are ideal for equipment that is only used intermittently, such as personnel and equipment vehicles, as well as vehicles following a battery-swapping philosophy. These can hence be charged for a longer time period using a DC power supply.

Dynamic energy transfer

Dynamic charging solutions often use trolley-assist systems. These feed power into a diesel-electric truck, eliminating the need for diesel along the entire length of the trolley line.

Each vehicle is equipped with a pantograph, which collects power through contact with the overhead lines, much like an electric train. Other essential infrastructure includes poles, an overhead line system, a station, and a rectifier station that converts normal AC power to DC at about 1,000 to 2,600 VDC.

Due to the high power demands of the trolley system, operators may need to enhance the site's power capabilities. However, implementing a trolley-assist system on a diesel-electric truck can significantly reduce operating costs, depending on the mine design, including factors like ramp length, ramp gradient, cycle time, and haulage requirements.

In diesel-electric trucks, the diesel engine switches to an idle state while the truck is connected to the trolley system, drawing power from the overhead line. The diesel engine only activates during the final stretch to the pit or crusher areas.

In the future, mines will use fully battery-equipped trucks in combination with the trolley systems. While connected to the trolley line, these vehicles will not only draw power for propulsion but also charge their batteries. On trolley-free sections of the route, they will use the batteries' stored energy to propel, while on downhill sections, energy will be recovered through regenerative braking.

The technology is also evolving: new trolley systems are being designed for full re-locatability and reusability, with modular pre-cast foundations, flexible poles, and lightweight suspension systems. These innovations enable rapid disassembly and reinstallation, allowing mines to adapt to evolving layouts while supporting circularity and reducing CAPEX.

These developments are already addressing feedback from the market. As an industry, we are working together to shape the next generation of dynamic energy transfer solutions, addressing the challenges faced with existing solutions.

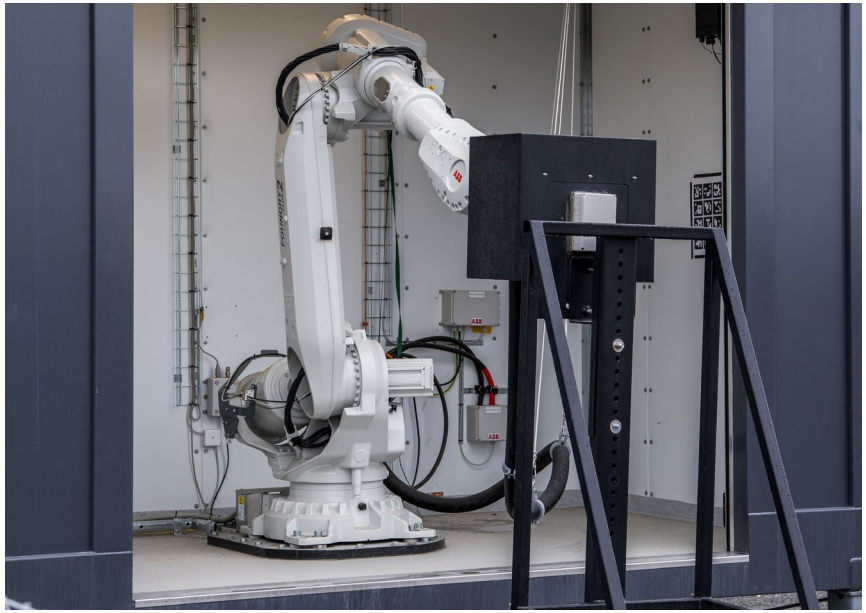
A first for mining

With collaboration from ABB and Epiroc, Boliden deployed the first fully battery-electric trolley truck system on an 800-meter-long underground mine test track, which has now been extended to a 5km segment. This means the mining industry is a step closer to realizing the all-electric mine of the future, with sustainable, productive operations and improved working conditions.

Learn more >>

The role of automation in mining

Automation and electrification go hand in hand. From drill rigs and haulage vehicles to control centers, it's now possible to automate a wide range of mining equipment. Done correctly, automation can be transformative – driving productivity, mitigating workforce shortages, and enabling safer, more efficient operations. And the two technologies are mutually beneficial – with the benefits of automation enhancing the benefits of electrification, and vice versa. Let's dive into some of the details, and take a look at what automation in an electrified mine looks like.



Power and process control

Equipment like battery-electric haul trucks or trolley-assist systems require highly variable loads. Automation platforms integrate power and process control to properly manage this complexity. Whenever demand spikes, automated load shedding prioritizes critical operations. At the same time, the systems use process buffers to smooth disruptions. The result? Production continuity, fewer blackouts, and reduced infrastructure cost.

Asset performance management

Continuous asset monitoring is essential in all-electric mines. Fortunately, automation can help by providing centralized monitoring and predictive diagnostics. This can reduce the need for time-consuming manual inspections – something that's critical in remote or hazardous environments.

Power and energy management

Fully electric fleets are a burden on the grid, with loads spiking during acceleration and charging cycles. Automated energy management systems can analyze operational schedules, vehicle status, and grid conditions in real time – allocating power where and when it's needed, so means mobile equipment can complete tasks without overstretching supply infrastructure.

Energy, equipment, and people management

Automation greatly improves operational management systems. Shedding light on vehicle tracking, charge status, task allocation, and workforce coordination, these systems optimize shift schedules, dispatch routes, and charging logistics according to energy constraints and production goals.

How to power an electric mine

Not long ago, materials and machinery were considered the core assets of a mine. Today, power is joining the list of critical resources. The reason? In the electric mine, energy is central to daily performance – with reliable, efficient power directly affecting productivity, safety, and uptime.

In this section, we'll look at the challenges and opportunities presented by energy management in a mine. We'll look at how mines can source, store, and manage energy more intelligently, and explore into how even small shifts in energy strategy can deliver big, measurable gains.

Energy as an asset: challenges and opportunities

Managing energy in the electric mine comes with a number of challenges. After all, fleet electrification significantly increases power demand, sometimes even doubling it. And many mines operate in remote areas or near the edge of the grid, where expanding infrastructure is both difficult and expensive.

To cap it off, utility providers can be reluctant to increase capacity unless absolutely necessary, since doing so requires major capital investment. This means that, without timely upgrades to power supply, mines face the real risk of blackouts, reduced productivity, and costly downtime.

But hope is not lost. Far from it. From relocatable renewables to battery energy storage, there are a number of energy management solutions for mining teams to consider.

Renewable energy and grid infrastructure

Electrification should go hand in hand with sustainable power sources. After all, an electric truck running on coal-powered electricity can be more polluting than a fully diesel-powered truck.

In mining, fixed infrastructure isn't always practical, particularly during exploration phases or short lifecycle projects. Relocatable renewables can sometimes be used instead. These can be deployed more quickly and scaled as needed – providing both flexibility and resilience.

Storage design and integration

For mining teams, battery storage isn't just an add-on, it's a necessity: required to smooth out the volatility inherent to wind and solar power. On top of this, advanced digital twin technology and load forecasting tools let mining teams simulate, plan, and optimize their energy systems in real time. This can enable smarter deployment of long-duration storage, and ensure seamless integration of renewables, delivering predictability in an era of volatile generation.

Power quality and control

In a fully electric mine, power quality is directly linked to operational reliability, as power instability can cause unplanned equipment downtime, reduce asset lifespan, and pose safety risks. With more renewables and electrified systems coming online, ensuring clean, consistent power becomes even more critical.

Advanced power management and control systems can make a big difference. Through real-time monitoring, automation, and intelligent switching technologies, mining teams can maintain stable, high-quality power in even the most demanding conditions.

Energy optimization and value assessment

Gone are the days that energy is just a cost or a sustainability metric. With the right tools, the shift to electric means mines can rethink how energy creates value, and garner insights that lower energy costs, reduce emissions, and extend asset life.

Particularly useful are the digital platforms that integrate energy usage, generation, and storage data into a unified view. Paired with predictive analytics and scenario modeling, these platforms allow mining teams to make smarter decisions – from optimizing battery charging cycles to timing loads to coincide with off-peak tariffs.

Small steps to success

There are a few ways of building a successful electric mine. But in general, there is a three-step process underpinning the transformation.

1 Design: plan for success

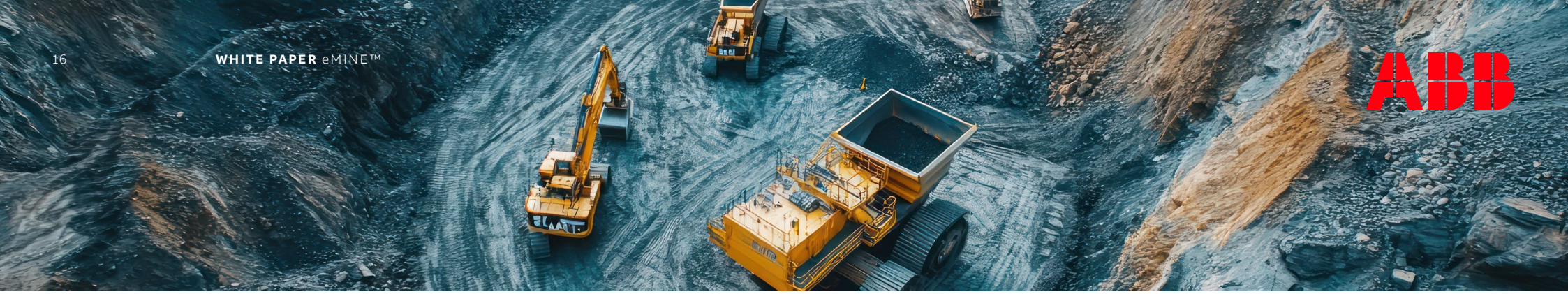
We carry out a system wide assessment to identify key processes, mine conditions and electrification goals to determine if vehicle, conveyor or hoisting-based methods are best. We use data-driven modeling and simulation to allow for informed decisions that aim to avoid costly retrofits later.

2 Build: seamless integration

We implement charging and power solutions without disrupting operations. We adapt infrastructure and processes to accommodate electric equipment.

3 Operate: maximize operational gains

We transition to all-electric operations for higher efficiency, lower emissions, and safer working conditions. We optimize maintenance and energy usage for long-term sustainability.



Electrification success

We also prioritize our six ingredients for electrification success: interoperability, mobility, energy management, connection interface, trolley and charging infrastructure, and favorable process and mine design.

Decarbonizing copper in Chile

Chilean mining company, Antofagasta Minerals, is working with ABB to electrify its processes, automate its operations, and move towards a net-zero emission haulage solution. As principal technology provider, ABB is delivering its innovative solutions as well as its expertise, to help the company plan for success in its decarbonization roadmap.

Learn more >>

Interoperability
Mine fleets comprise vehicles from multiple vendors. Our charging infrastructure follows open standards to remain vendor-agnostic, meaning you can use it across all vehicle types and OEMs. This allows you to make a one-off investment and maximize the uptime, productivity and ROI of every piece of your charging equipment.

Mobility and flexibility
Strategically placing charging points means trucks remain charged for longer. It also optimizes their usage and overall mine productivity and avoids the need for additional tramming routes and vehicles. We ensure points of charge can adapt to changes in the mine's design throughout the lifetime of the mine.

Energy management
Integrating battery-electric vehicles introduces more volatility in energy load requirements. While renewables are increasingly prevalent at remote sites, they also impose additional constraints. We plan grid infrastructure, use battery energy storage systems, and leverage mine production forecasting, to minimize load peaks and mitigate potential volatility on the generation side.

Connection interface
We design our ruggedized, mine-approved automated connection interfaces to withstand harsh environmental conditions and high-power demands. By leveraging open mechanical and electrical standards, along with effective collaboration with vehicle suppliers, we ensure reliable performance.

Trolley and charging infrastructure
We build on our extensive expertise and proven solutions in trolley and charging infrastructure to support battery-electric mining vehicles. Our solutions are robust enough for the mining environment and capable of matching the high-power demands of battery electric trucks.

Process and mine design
Adopting new technologies changes how mines and mining assets are operated. We take this into account when designing new projects, undertaking early-stage design and planning to ensure success.

Let’s collaborate

The ‘six ingredient’ process is all well and good. But to transition to an electric mine, collaboration is key. Your key technical supplier should work with you, every step of the way. Adopting a tailored approach, it should identify the best steps for your mines.

At ABB, we consider all your current challenges, barriers, and constraints. We help you take your first step towards big gains, ensuring minimal disruption for maximum impact. We work with your team to assess and develop tailored technical specifications, so your shift to electric is a triumph.

A focus on fleet electrification

Industrial group Sumitomo is collaborating with ABB to explore joint solutions for decarbonizing the operations of mining machinery with a focus on fleet electrification. The two companies are devising strategies to meet the demanding requirements of industrial applications.

Learn more >>

Start your electrification journey with ABB

Every great journey starts with a first step. While profitable electrification won't happen overnight, ABB will work with you to gradually transform your operations. The goal? Zero emission, fully electric mining operations, integrated with automation and digital systems.

Together we will embark on a journey of well-planned steps. With over 130 years of experience in electrifying mines, our track record speaks for itself. We'll work with you, not around you, delivering our tried and tested products with seamlessness and precision. Electrification delivers results. Partner with us to electrify your processes, machinery, and vehicles, and achieve reductions in CapEx, OpEx, and CO2 emissions. Success will depend on phased implementation, technology readiness, fleet cycles, infrastructure maturity, and business goals.

Start small today

Take your first step to electrification.

Contact an ABB Expert

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