Mining Magazine

White Paper

Building the all-electric mine

Mapping out the technologies and ingredients needed in the electrification of mining equipment

NET-ZERO EMISSIONS

In association with

Electrification

Is the key to decarbonization

Attend any (virtual) conference or roundtable discussion in the mining industry today and the topic of decarbonization is bound to come up. Mining companies are right to highlight the critical role that minerals like copper, iron ore, nickel, zinc, lithium and cobalt play in reducing carbon emissions. However, there is no hiding the fact that mining – in its current form – is itself a carbon-intensive activity.

Scope 1 and 2 emissions from the mining sector (excluding fugitive-methane emissions from coal mining) currently account for one percent of all global greenhouse gas emissions, according to McKinsey[i]. Between 40 and 50 percent of these emissions come from diesel used in mobile equipment, and an additional 30 to 35 percent comes from electricity generated from non-renewable sources[ii].

Under pressure from investors, governments and the general population, many of the world's largest miners are targeting major reductions in Scope 1 and 2 emissions by 2030 and net-zero carbon emissions by 2050.

To reach these targets, mining companies will need to make substantial investments in the key enablers of decarbonization – namely electrification of equipment, machines and transitioning to the use of renewables for electricity generation.

Electrical equipment has had a role in mining for at least 130 years, when ABB supplied its first electrical motor for a mine hoist in Sweden. All-electric systems have been commonplace in minerals processing for several decades, aided by the fact that work is performed by stationary equipment with high but stable power requirements such as crushers, grinding systems and conveyors. However, complete electrification of the mine area has hitherto been impossible due to the involvement of mobile equipment such as haul trucks and loaders for which charging and onboard solutions are still in their infancy.

In a recent survey with more than 450mining executives conducted by State of Play, a research group focusing on innovation in the mining industry, 63 percent of respondents said risk aversion was holding back the implementation of electrification technologies . Moreover, 88 percent said cost was a major risk of electrifying a mine site.

Despite their hesitation, mining companies will have little choice but to embrace electrification if they are to achieve zero-emissions goals. Full electrification of mobile equipment in the mine area, integrated with digital and autonomous solutions to maximize the efficiency and availability of these systems and lower lifetime operating costs, will be central to achieving this goal.

In this white paper, we take a deep dive into the practicalities of electrifying mobile mining equipment and, by extension, achieving an all-electric mine. The following ABB experts provided input to the white paper:

Mehrzad Ashnagaran, Global Product Line Manager – Electrification and Composite Plants

Nic Beutler, Global Product Manager - Power System & Charging Solutions

Marcos Hillal, Global Product Line Manager - Automation and Digital

Jérôme Rossé, Global Product Manager – Automation

[i] https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/Sustainability/Our%20Insights/Climate%20risk%20and%20decarbonization%20What%20every%20mining%20CEO%20needs%20to%20know/Climate-risk-and-decarbonization-What-every-mining-CEO-needs-to-know.ashx

[ii] https://www.mckinsey.com/industries/metals-and-mining/our-insights/creating-the-zero-carbon-mine

[iii] https://www.stateofplay.org/publications

ABB'S six ingredients
For successful electric operations

1. Interoperability

Mine fleets comprise vehicles from multiple vendors. ABB charging infrastructure follows open standards to remain vendor-agnostic, meaning it can be used across all vehicle types and OEMs. This allows the customer to make a one-off investment and maximize the uptime, productivity and return on investment of every piece of charging equipment.

2. Mobility/flexibility

Strategically placing charging points throughout the mine means trucks remain charged for longer and optimizing their usage and overall mine productivity while avoiding the need for additional tramming routes and vehicles.

These points of charge need to be able to adapt to changes in the mine's design throughout the lifetime of the mine.

3. Energy management

Integrating battery electric vehicles into mines means energy load requirements are much more volatile. Whilst renewables are becoming more relevant in particular for remote sites, they impose additional constraints.

Smart planning of grid infrastructure and battery energy storage systems, combined with mine production forecasting, can be used to minimize load peaks and address possible volatility on the generation side.

4. Connection interface

Ruggedized and mine-approved automated connection interfaces must be designed to withstand the harsh environmental conditions in many mines and high-power demands of large mining trucks. This requires open mechanical and electrical standards and effective collaboration with vehicle suppliers.

5. Trolley and charging infrastructure

ABB is building on existing solutions and long-lasting experience related to trolley and charging infrastructure for battery-electric mining vehicles. Again, these must be robust enough for the mining environment and capable of matching the high-power demands of battery electric trucks, in order to ensure maximum vehicle uptime.

6. Favorable process and mine design

Adopting new technologies will change how mines and mining assets are operated. Does the civil infrastructure and operational schedule need to be changed to meet the demand of these battery electric vehicles, for example? Early-stage design thinking and planning will be crucial to success.

"Mining companies may be at different stages in their individual journeys towards increased digitalization and electrification but with each passing year the vision of the integrated all-electric mine – one that incorporates optimal design and operations for more efficient, sustainable energy and resource consumption – gets closer to becoming a reality."

By Nic Beutler

Key Technologies:
Charging stations and trolley lines

Electrification of even the smallest vehicles in the mine was unimaginable until last decade, when the first commercial electric vehicles began appearing on public roads. Today, smaller vehicles – such as personnel vehicles, transport vehicles, loaders, and small haul trucks – can be retro-fitted with battery packs. In future, OEMs will simply design and build battery-electric vehicles from scratch. Eventually, large haul trucks will also be able to run entirely on battery-electric technology, thanks to a combination of charging stations and trolley lines. Whether operators choose one, the other, or both of 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;

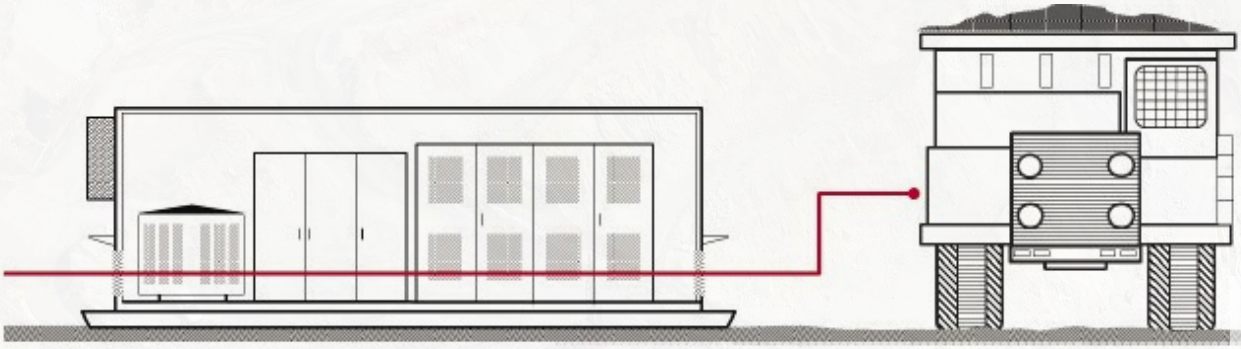
Power availability throughout the mine area; and

Other operational limitations imposed by the mine design.

Charging stations

Charging solutions for mining equipment fall into four categories, each one suited to different types of applications.

- **Fast onboard system -** Ideal for large haul trucks used in open-pit mines, which allows for both in-motion along fixed-distance routes enabled by trolley systems and stationary charging. The systems are using a DC power supply.
- **Fast offboard system -** Ideal for smaller haul trucks used in open-pit and underground mines, where vehicles are in almost-continuous operation with limited (i.e. 15 minutes) idle time. Fast offboard systems are essentially charging stations installed at fixed points throughout the mining area and using DC power supply.
- **Slow onboard system -** 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 system -** Ideal for equipment that is only used intermittently, such as personnel and equipment vehicles, as well vehicles following a battery swapping philosophy. These can hence be charged for a longer time period using a DC power supply.

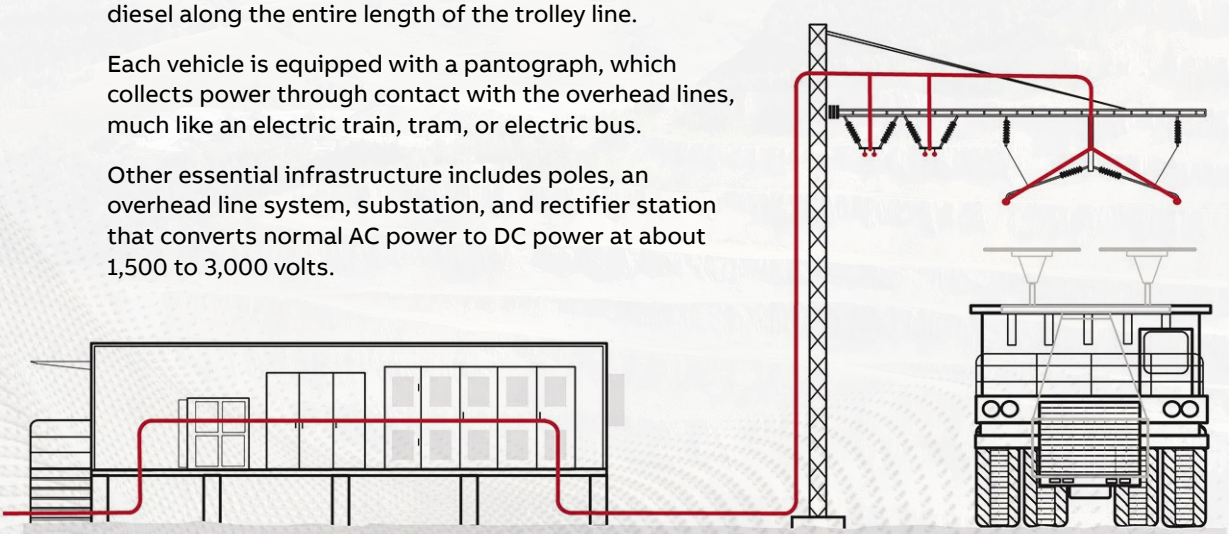


Trolley lines

A trolley-assist system takes a hybrid diesel-electric truck (a truck with an electrical motor and a diesel generator) and feeds power into the 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, tram, or electric bus.

Other essential infrastructure includes poles, an overhead line system, substation, and rectifier station that converts normal AC power to DC power at about 1,500 to 3,000 volts.



Because of the high power requirements of the trolley system, the operator may also have to increase the site's power capabilities. Using a trolley-assist system on a diesel-electric truck can lead to a substantial reduction in operating costs, with the exact extent dependent on the mine design. The main factors include:

- **Ramp length -** The longer the ramp, the less diesel used on the haul route and more in operational expenditure (opex) saved.
- **Ramp gradient -** The steeper the gradient, the less diesel used to overcome elevation, and more opex saved.
- **Cycle time -** Longer cycle times mean that more trucks need to be used, which increases costs; however, if the trolley system is only used to move trucks up a ramp to the crusher and back again, this translates to shorter cycle times, fewer trucks, and more opex saved.
- **Haulage requirements -** The more tonnes hauled, the greater the potential opex savings from trolley-assist.

With hybrid diesel-electric trucks, the diesel engine turns off while the truck is connected to the trolley system, with power obtained through electricity from the overhead line. The diesel engine only switches on during the final stretch to the pit or the crusher areas. In future, mines will use fully battery-equipped trucks in combination with the trolley systems.

The vehicle will recharge while connected to the trolley system and will also charge from regenerative braking while on sections of the route where it operates without trolley assistance.

Case study:

ABB's implementation of trolley system

Demand for trolley-assist systems has increased in the past three to four years. This is largely due to increasing recognition in the mining sector of the important role electrification can play in decarbonizing their operations, as well as to the emergence of a new generation of hybrid diesel-electric trucks which can be attached relatively easily to trolley lines.

The trolley concept has fast become a commercially viable stepping stone towards the all-electric mines of the future. Mining trucks regularly carry 3,000 to 5,000 litres of diesel and consume around 300 to 400 litres per hour while travelling up a 17km ramp in half an hour. By using the assistance of an electric trolley system, vehicles can slash their diesel requirements dramatically and become far more carbon efficient.

One recent example of a trolley-assist system comes from Boliden's Aitik open-pit copper mine in Sweden. Boliden, ABB and several other partners trialled the electrification of four diesel-electric haul trucks on a 700m trolley line, with the goal of reducing annual diesel usage by 800,000 litres and carrying 70 million tonnes of ore per year without using fossil fuel.

For this project, ABB provided a digital substation, including a 4.8-megawatt rectifier, connected to the ABB Ability System 800xA control system. This solution is ABB's first-ever application for heavy-duty trucks in mining industry. It provides best-in-class digital capabilities through ABB Ability, ABB's cross-industry digital offering.

Following the trial, Boliden announced that it will install an additional 3km of trolley line at Aitik. It will also install 1.8km of trolley line at the Kevitsa mine in Finland and convert 13 diesel mining trucks to diesel-electric for use on the new system. It says these investments will reduce greenhouse gas emissions over the life of the mines to 15 percent at Aitik and 9 percent at Kevitsa respectively.

Integration of electrification
With digitalization and automation

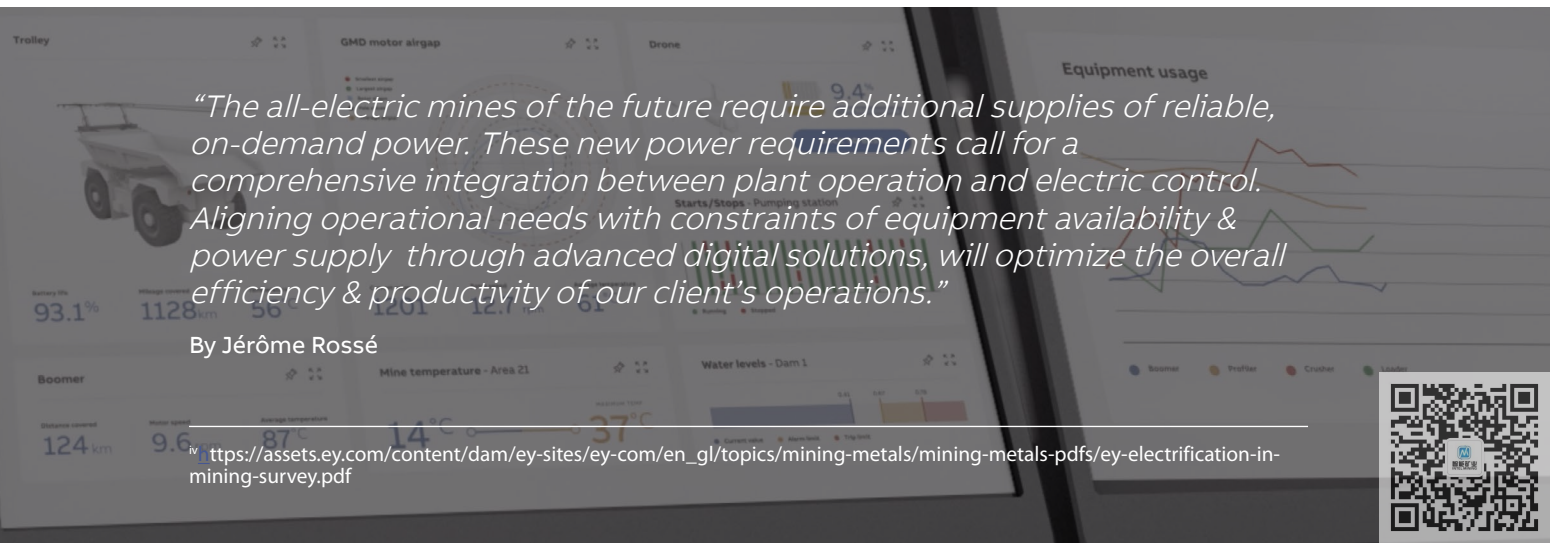
The more electrical equipment introduced to a mine, the greater the need for digital and automated solutions to maximize the performance and efficiency of the operation and enable operators to make better decisions.

For example, a plant-wide operation management system is crucial for electrical mobile equipment, where the operator needs to know where the vehicle is, how far it is from the next charging station, whether it has enough energy to fulfill the next task, and how much charging time is needed to give it enough energy to fulfill that next task. Digital and automated solutions are also essential to handling the different peaks added to the electricity grid as a result of fleet electrification. When diesel is the sole energy source of a fleet, acceleration and deceleration of vehicles imposes no burden whatsoever on the grid. All-electric fleets bring in a problem unfamiliar to mine operators: constant shifts in electricity demand, which can lead to overloading of the grid and potentially a blackout for the entire operation.

An integrated solution for continuous power and process control can manage this issue. In the event of a power-supply disturbance (due to say, too many trucks trolleying up an incline or too many trucks charging their batteries at the same time), less-critical process sections are shed in milliseconds, preventing a blackout. Using integrated power and process control to make use of existing thermal and material buffers in the process typically costs a fraction of what it would cost to buffer the power supply with large battery installations.

Another critical question that arises in an all-electric mine is how to manage the constraints imposed by new battery-electric vehicles and/or trolley lines on mine planning and operations. Having an integrated energy and operations management solution is key to tying together these critical aspects. The solution should automatically control and optimize energy for the mine's load cycles, while also managing allocation of people and assets in a way that takes into consideration energy-management requirements. If successful, the result is better operational efficiency and reduced power usage and operating costs.

Notably, automation is not only an enabler of but also a beneficiary of electrification. In the aforementioned State of Play survey, 98 percent of respondents said mine automation was the technology that will benefit the most from electrification. As EY notes, electric motors require less maintenance and human intervention than non-electric motors [iv]. With the rise of electrification, EY predicts autonomous vehicles, autonomous drones and remote-controlled operational systems will be rolled out more widely through mining operations.



"The all-electric mines of the future require additional supplies of reliable, on-demand power. These new power requirements call for a comprehensive integration between plant operation and electric control. Aligning operational needs with constraints of equipment availability & power supply through advanced digital solutions, will optimize the overall efficiency & productivity of our client's operations."

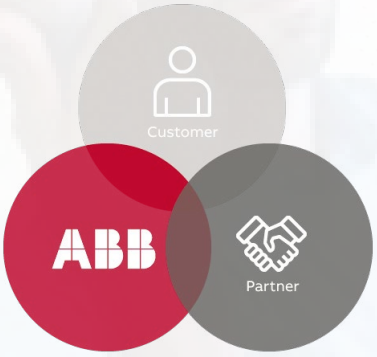
By Jérôme Rossé

[iv] https://assets.ey.com/content/dam/ey-sites/ey-com/en_gl/topics/mining-metals/mining-metals-pdfs/ey-electrification-in-mining-survey.pdf

Solving the key challenges
Of electrification

The foundation of the all-electric mine of the future will be a system of integrated products tailored to that mine's specific needs and specifications, not individual products that can be bought off the shelf and plugged in. This raises three challenges that mine operators and technology providers will have to address if they are to enable and accelerate the adoption of electrical solutions.

1. Strategic partnerships between OEMs and technology providers



The market for electrification of mobile mining equipment is still in its infancy, as demonstrated by the fact that no original equipment manufacturer (OEM) yet offers fully battery-electric vehicles straight off the shelf.

Furthermore, there are still countless bottlenecks in the market for which technological solutions do not yet exist.

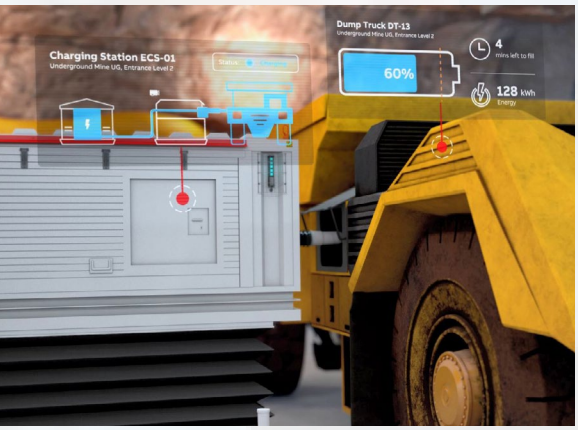
For example, 3-5 MW charging solutions will be required if large haul trucks are to ever go fully battery-electric, but there is currently no way of transferring such large amounts of power to a truck via a connector.

In order to overcome such challenges, OEMs and technology providers will be required to collaborate more than ever before.

As early examples of such cooperation, ABB recently signed successive Memorandums of Understanding with Hitachi Construction Machinery, Liebherr Mining Equipment, Stäubli and MEDATech aimed at accelerating the transition to all-electric mines. Under these various agreements, the companies will share expertise and collaborate in bringing solutions to the market that will reduce emissions associated with heavy machinery in mining.

They will jointly explore possibilities to apply ABB's electrification solutions to mining mobile equipment.

2. Designing the mine based on the-all electric mine concept



The very first step in building an all-electric mine will be redesign of the mine in order to optimize and ensure the best operational performance from electrification.

Traditional, mining companies seek the assistance of third-party engineering, procurement and construction management (EPCM) firms or consultants during the feasibility stage.

However, these parties have yet to enter the market for electrification. In the absence of other parties, technology providers will need to be involved in electrification from the study, consulting and design phases.

This collaboration will continue through the study, engineering, and proof of concept phases and even the execution phase.

In the design phase, the technology provider will need to develop an understanding of the mine's operational conditions and constraints and learn what the customer wants to achieve from electrification.

The provider should then be able to leverage its own knowledge and products in order to recommend:

- **Optimized solutions** (e.g., charging, trolley, hoists, conveyors, or a combination of two or more of these solutions) that suit the geology and operational constraints of the mine;
- **Integrated electrical solutions** that take into account load scenarios based on duty cycle, harmonics, voltage dip mitigation and network protection; and
- **The correct technology** for each application, considering energy efficiency and environmental impact.

3. Training workers in new technologies

Upskilling of workers to meet the demands of electrical, digital and autonomous systems will also be of the utmost importance.

For example, having a driving license for a large haul truck does not automatically make someone capable of operating an electric vehicle with a complex onboard interface and stringent charging requirements. If driverless technology is involved, this will result in a further shift away from traditional driving skills and towards skills like data processing and technical planning.

In the new digitally powered workplace that goes hand-in-hand with electrification, employees will move from routine tasks to roles requiring a higher level of thinking and an ability to manage the human-to-machine interface. The bottom line is that electrification will require intensive training in new competencies and an open mindset to allow for the change to happen.

"Digital Transformation and sustainability: two trends that will continue to drive innovation in mining. A partnership is required between the trusted technology partner with proven domain experience and mine operators, to embrace new technologies that optimize productivity, sustainability and, ultimately, profitability. The journey towards the all-electric, digital and sustainable mine is on the way, together with the increased automation and electrification that comes with it."

By Marcos Hillal

Conclusion

Acquiring a fleet of battery-electric vehicles or installing a trolley line is just one of the innumerable steps in the journey to becoming all-electric.

Building a successful all-electric operation requires implementation of a network of integrated electric, digital, and automated systems – from mine to port. This requires a change in mindset and ongoing partnerships with OEMs and technology suppliers. ABB launched ABB Ability™ eMine to enable it to partner with mining companies in their journey towards building an all-electric mine.

With eMine™, ABB works with operators from the start of the planning phase to design fit-for-purpose solutions integrated with its own digital applications. By integrating the whole mine digitally, ABB Ability™ eMine enables mining companies to plan, monitor and control processes, optimize operations and energy usage.

ABB's portfolio of advanced digital services continues streamlining production after the all-electric operation is up and running. These digital solutions collect and analyze asset and operational data to enable ABB's mining experts to remotely identify, categorize and prioritize actions to support mining operations. The result is a mine that not only minimizes CO_2 emissions but also maximizes energy efficiency and overall mining performance.

"We are on the curve with the mining industry, aligned with its aims and with total belief in the approaches that are needed for the future of mining. Mining companies that can find a way to overcome the initial CAPEX barriers and take a calculated risk on some of the methodologies, be it charging infrastructure, battery swapping, trolley systems or a combination, combined with harnessing the power of digital knowledge, use of data and reliable automated processes, will have an advantage in the market and see returns which will benefit their operations and the world beyond the mine too."

By Mehrzad Ashnagaran

It’s time for the all-electric mine

Get started with ABB Ability™ eMine. For your world, and mine.

Transitioning to an all-electric mine is going to take new thinking. New plans and designs. New training for your workers. And a whole new outlook on your operation.

It is not a simple task. ABB not only understands these requirements, we can also equip you to meet them with ABB Ability™ eMine.

eMine™ makes the all-electric mine possible with purposeful approach, proven methods, electrification & digital systems - all integrated from mine to port.

Get your copy of the interactive brochure and see how eMine™ can electrify your mine while improving the world beyond it.


Mining Magazine
In association with
ABB