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Maintenance and Production Strategies for BEVs in Underground Mining

EVMO Project Technical Report

Prepared for the Electric Vehicles in Mining Operations (EVMO) Project

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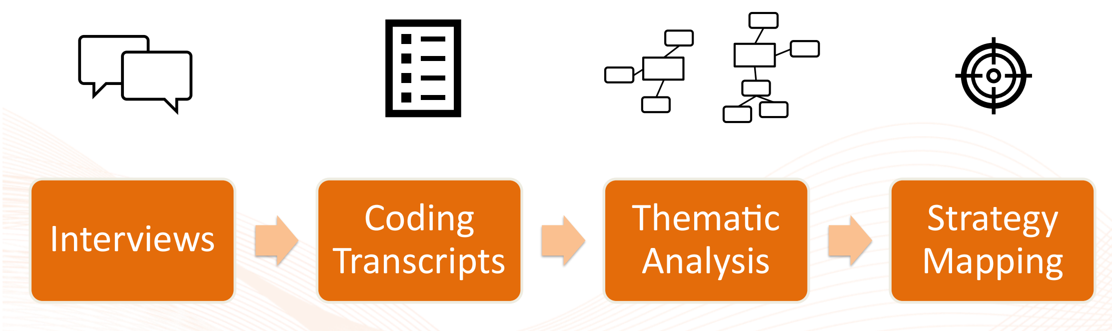
Executive Summary

Battery Electric Vehicles (BEVs) can introduce significant changes to underground mining operations. This project explored the impacts and changes to the production and maintenance departments of underground mines in Canada that operate fleets of BEVs. The project aimed to identify the ways mining organizations have adapted to BEV technology. These adaptations include changes made to equipment and infrastructure, workforce education/upskilling and the introduction of new processes and management approaches.

Three mine sites participated in the study: the New Afton Mine (New Gold, British Columbia), the Macassa Mine (Agnico Eagle Mines, Ontario) and the Odyssey Mine (Agnico Eagle Mines, Quebec). Each site was visited between mid-2024 and early-2025, and in-depth interviews were conducted with site personnel about their experiences working with BEVs. The project aimed to capture qualitative insights from direct user experiences with the new equipment. Personnel from maintenance, operations and management departments were all interviewed. The recorded interviews were then transcribed, and the text was coded/tagged to help link common themes across interviews. A thematic analysis process[1] was used to identify the major themes in interviewees' responses and to develop a set of 15 strategies for adapting to and managing BEVs (the process is described in the figure below).



All 15 of the strategies are available on the EVMO project website and can be used to support worker education and upskilling on topics related to BEV adoption. This report collects the strategies together into a complete case study report. The strategies have been recorded and openly shared with the goal of improving the odds of future BEV deployments in underground mines around the world, by increasing the level of knowledge on the benefits and challenges of battery electric vehicles.

[1] Virginia Braun & Victoria Clarke (2006) Using thematic analysis in psychology, Qualitative Research in Psychology, 3:2, 77-101, DOI: 10.1191/1478088706qp063oa.

BEV Maintenance Strategies

Creating a Dedicated Maintenance Team

Objective

Create a dedicated BEV maintenance team, including both electrical and mechanical technicians, to take the lead on all BEV-related issues.

“I think the biggest success is a dedicated team that gets highly focused and highly intimate with the equipment, and has a vested interest in managing it and making a program successful”

Electrical Superintendent

Justification

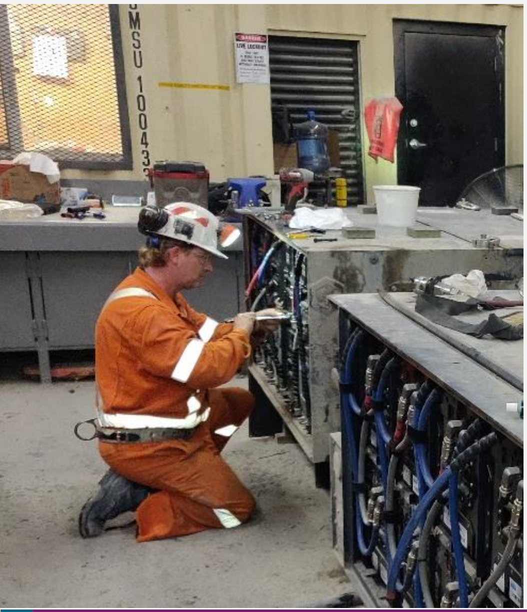
At New Gold’s New Afton mine, the electrical maintenance department was found to be the first point of contact for battery electric vehicles (BEVs), since the bugs they were working through were typically electrical in nature.

BEVs are highly specialized equipment, so there was a need for a focused team that could triage issues and become the primary knowledgebase for BEVs in the maintenance department.

Implementation

Implementing a new strategy always faces risks and challenges, some of the documented issues faced in creating a dedicated BEV maintenance team included:

- Defining clear responsibilities for each type of BEV maintenance activity between the dedicated BEV team and the traditional electrical and mechanical (mobile) maintenance teams.
- Defining how the teams communicate and integrate with the traditional planning and maintenance groups.
- Creating clear processes for organizing and documenting BEV-related work, e.g. defining which work order system different BEV issues belong to.
- Dealing with limited availability of human resources to support BEVs and service equipment.
- Handling the unexpected workload of HVAC maintenance planning and execution for the charger cooling equipment.



Progress to Date

The maintenance department are currently operating two crews in the dedicated BEV team, each with a supervisor, planner, electricians and mechanics.

The dedicated team takes responsibility for all preventative maintenance tasks, BEV troubleshooting and battery management, along with deploying the charging and power distribution infrastructure.

The dedicated team has led to significant improvements in first-response times for BEV troubleshooting and maintenance.

Investing in Workforce Capacity

Objective

Build a workforce of dual-ticketed electrician/heavy duty mechanics to act as first responders during BEV troubleshooting.

Justification

BEVs introduce more complexity in diagnosing issues than is typical for diesel equipment, at least partly because the electrical and mechanical systems in a BEV are more deeply intertwined. Effective troubleshooting typically requires a background in both mechanical and electrical systems.

Comprehensive experts on the BEV can act as first responders to troubleshooting issues, enabling more efficient distribution of maintenance/repair activities to the traditional electrical and mechanical groups.

Implementation

In a new approach, a group of technicians began training as both electricians and heavy-duty vehicle mechanics through the apprenticeship programs at Thompson Rivers University.

The dual-ticketed approach isn't focused only on the battery electric vehicle. The goal is to create well-rounded technicians and avoid them defaulting to their primary trade if they are not directly working on BEVs.

Over the 4-year journeyperson program, technicians rotate through periods working in the mill, working underground installing power distribution cables, gaining experience with the dedicated BEV maintenance team and on a 10-week schooling period.

"What we've learned with BEVs is that the trade-lines are much more blurred than they've ever been before"

Electrical Superintendent

Progress to Date

Currently three mechanics are being trained as electricians, and three electricians are being trained as mechanics in the first cohort of dual-ticketed apprenticeships.

Once fully trained, the six new technicians will form the backbone of the dedicated BEV maintenance team.

Procuring OEM Support Technicians

Objective

Utilize OEM knowledge and communication lines to the factory through battery support technicians, to supplement in-house troubleshooting capabilities.

Justification

A battery as a service (BAAS) technician has access to the OEM's resources, such as advanced diagnostic software and error code definitions, as well as direct communication access to the factory engineering team. The BAAS technician augments and enhances New Gold's own troubleshooting capabilities.

Battery maintenance, module rebalancing and defining optimized charging schedules are all new activities with significant uncertainty and limited prior experience in the team. BAAS technicians take responsibility for the associated workloads and costs of battery management.

Lithium-ion batteries and BEV technology have not fully matured yet, until they have, BAAS technicians can be used to mitigate adoption risks.

Implementation

Initially BAAS technicians were only available on the day shift, this reduced the confidence by production supervisors on the night shift that their BEV-related issues can be handled promptly.

Early BAAS technicians lacked the hands-on experience for efficient troubleshooting of issues; however, their access to factory engineers bridged the gaps. As early adopters of BEV technology, expectations needed to be tempered for the commercial readiness of the industry and the availability of experienced technicians.

"We're nowhere near the plateau [in BEV technology], so I think there's value in having a company guy on hand"

Mobile Superintendent

Progress to Date

4 BAAS technicians report under the electrical maintenance group, and work closely with the dedicated BEV maintenance team and the production teams.

BAAS technicians were deployed 24/7 to cover the night shift, improving BEV availability and boosting the overall confidence in BEV performance.

Adapting to BEV Troubleshooting Requirements

Objective

Adapt troubleshooting and maintenance processes to BEV technology requirements.

Justification

With the adoption of early BEV models, the root causes of faults weren't always apparent or easy to diagnose. The source of maintenance issues varied, including errors of operation, damaged components, hard-to-locate loose connections, or a simple lack of experience with new equipment.

Occasional operator errors, like not paying close enough attention to the battery gauge, could lead to draining the battery in a difficult location, e.g. on the ramp. Unfamiliar equipment warnings, such as a thermal cutback from elevated coolant temperatures, often lead operators to avoid using available BEVs because of perceived unreliability.

"We had our fair share of mechanical issues, for sure, but I think the larger portion of attention that had to come to these early BEV units was electrical. I don't know if you would have seen that coming"

Mobile Superintendent

Integrating BEV maintenance into the mobile maintenance resource planning and scheduling process was complicated by BEV issues being more electrical than mechanical, hence, requiring input from more stakeholders than typical for mobile equipment.

Implementation

Technicians were equipped with the tools needed to troubleshoot BEVs, primarily laptops, and were trained on the OEM diagnostic software. Vehicle diagnostics may not always indicate the exact cause of the problem, but they provide enough system information for technicians to determine the source of issues. Some BEVs provide access to data over Wi-Fi, while others require a physical link.

New processes for safely removing a BEV from the ramp were introduced, working with the OEM technicians and factory support, to avoid expensive production downtime.

Progress to Date

The electrical and mobile maintenance planning teams engage in more frequent communication when handling BEV issues. Through regular coordination of resources, they schedule BEV maintenance to minimize downtime.

Charging and maintenance bays being located near one another lead to quick feedback loops between operators, technicians and OEM staff on maintenance issues and common failure points.

Plans are underway to add telemetry to chargers to provide more insight into the equipment's performance. BEV management will also be centralized within the incoming Integrated Operations Center (IOC), to support coordination between technicians, supervisors, planners and schedulers.

Reducing Maintenance Workspace Risks

Objective

Create workspaces suitable for maintaining batteries and BEV support equipment.

Justification

Maintenance of batteries and BEV support equipment primarily takes place in two locations, the BEV maintenance bay and the charging bays. The design of both bays had to accommodate moving the batteries around independently of the vehicles and have ways of handling the cables and coolant lines.

The regular maintenance activities for the battery packs were unexpectedly frequent, involving disassembly and rebalancing of packs and modules. The modules alone weigh approx. 120 kg and moving them via trolleys risked back strains. The chargers and cooling equipment also required ongoing cleaning, filter replacement and preventative maintenance.

Implementation

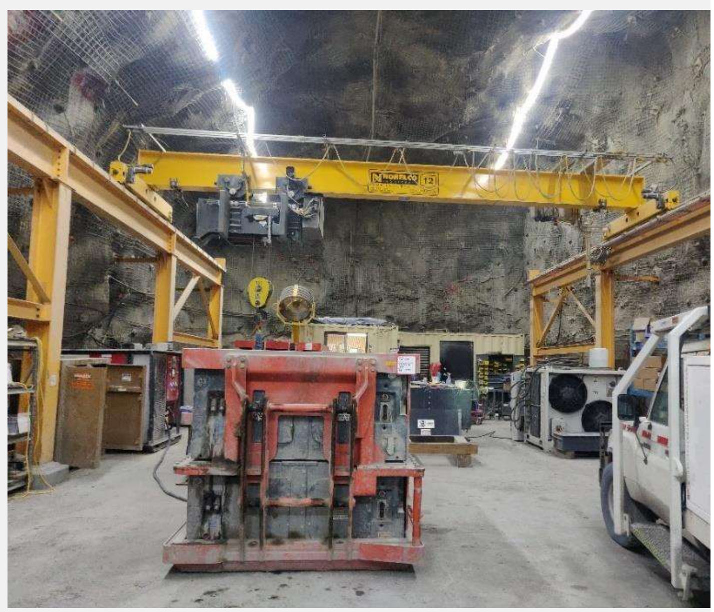
For the BEV maintenance bay, a dedicated facility was created to separate BEV activities from the diesel fleet. The bay included a concrete slab floor, an overhead gantry crane, chargers and cooling equipment for disassembling/assembling packs, and height-adjustable trolleys for moving modules. The height of the overhead crane ended up being too low, slightly complicating the disassembly of packs.

The maintenance bay was located at the clean air raise on the ventilation circuit, to improve air quality and reduce dust circulation. The charging bay was similarly located at a clean air raise, to lower the overall maintenance burden of the chargers and cooling equipment.

Progress to Date

Based on learnings by the maintenance teams, the following recommendations were made to further improve the use of the workspace:

- The concrete floor should be as flat as possible for moving and assembling modules and packs.
- Install plastic wheels on the trolleys to better manage loads on rough floors.
- Apply low friction (neoprene) coatings on the storage tables to make it easier to move modules on and off the trolleys.
- Appropriate drainage is needed to avoid standing water in the maintenance bay.
- Install jib arms to improve cable and coolant line management.



Implementing Effective Battery End-of-Life Processes

Objective

Establish a streamlined and cost-effective process for managing end-of-life BEV batteries, including evaluation, disposal, and storage management.

Justification

As an early adopter of battery-electric vehicles in 2012, Agnico Eagle's Macassa Mine had to establish its own in-house battery team, since services like BaaS did not yet exist. Managing disposal of the large volumes of used cells and packs posed significant operational, environmental, and regulatory challenges.

For instance:

- High-discharge activities (e.g., uphill hauling) shorten battery life due to heat, while improved practices have doubled battery life in some cases (from 8 months to 2–3 years).
- Batteries retired when amp-hour capacity drops to 60–70%.

The mine has faced challenges such as:

- Determining when to replace a cell, module, or pack.
- Costs for adapting second-life deterred past efforts.
- High recycling costs ($3–4/lb.).
- Storage issues, leading to the creation of a "graveyard."

Implementation

Three steps were used to navigate battery disposal effectively:

1. **Establish an Evaluation Process:** Identify what end-of-life looks like for your operation
    - When is the battery no longer able to complete a cycle or activity vs. when a battery faulty.
2. **Navigating End-of-Life:** Optimize recycling and disposal costs by evaluating providers.
    - Breaking down battery packs to lower voltage states reduces hazards and costs (including for transportation and storage).
    - Understand your options for recycling with the OEMs (original equipment manufacturers). Compare recycling costs across providers.
3. **Storage Management:** Develop clear guidelines for long-term storage to mitigate risks.
    - Be prepared to allocate dedicated resources to manage the "battery graveyard."

Progress to Date

Macassa has implemented a full-time position dedicated to battery decommissioning and repurposing usable cells where possible. Although engineering costs have hindered second-life applications, ongoing storage efforts provide flexibility for future uses. Challenges persist with international shipping due to regulatory barriers.

Update: Macassa is now exploring a Battery-as-a-Service (BaaS) model, shifting some end-of-life responsibilities to the OEM.

Enhancing Onsite Battery Evaluation Practices

Objective

To reduce maintenance costs and downtime by improving onsite battery evaluation practices. Enable teams to accurately assess battery state-of-health, isolate faults at the module or cell level, and make informed decisions about repair, reuse, or retirement.

Key Points

Operators are the first line of defense.
Maintenance teams rely on operators to detect and report performance issues, but this approach can delay root cause identification.

Not all degradation is equal.
Batteries must be evaluated to determine whether the issue is isolated to a single cell or module—or if a full pack replacement is warranted.

Onsite repair capability exists but is underused.
Cell-level replacement can now be done onsite, but inconsistent evaluation standards limit its application and impact.

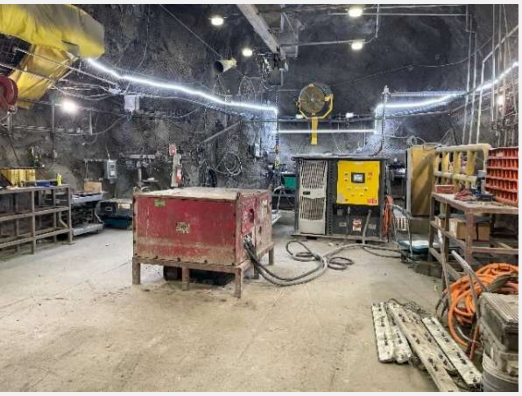
Implementation

Maintenance staff are being trained to distinguish between localized cell or module failures versus systemic pack degradation—prioritizing actionable evaluations over blanket diagnostics.

A site-specific asset tracking spreadsheet now logs preventative maintenance (PM) activity, battery capacity trends, and observed faults, helping identify repeat issues, flag at-risk batteries, and guide end-of-life decisions.

"We have our own 'battery team' out of necessity, but it was a key enabler for the change management. Cross-training and skilling were critical"

Maintenance Superintendent



Progress to Date

The battery maintenance bay has been active since day one, with over a decade of refinement behind its practices. Technicians now rely heavily on laptops and BMS tools to guide diagnostics and track battery performance.

While the in-house team remains highly capable, ongoing questions persist about the long-term balance between internal ownership and increased OEM support through service contracts or embedded roles.

BEV Production Strategies

Investing in Battery Bay Attendants

Objective

Improve the efficiency of the battery swapping process and improve the overall availability of chargers and cooling equipment.

Justification

Battery swapping is a time consuming, multi-step process for vehicle operators requiring them to drop the used pack, disembark their vehicle, secure the machine, swap the charging cables, swap the coolant lines, turn on the charger and cooling equipment, board the vehicle, tram to the new battery, engage the new battery to pick it up/install it.

Several issues with the chargers and cooling equipment can result in chargers prematurely shutting down and batteries not charging to the levels required, including operator error when connecting batteries, operators forgetting to turn on/check the cooling equipment and loose connections.

Attendants will act as a fail-safe to reduce intermittency issues with charging, while also improving the efficiency of the swapping procedure.

Implementation

Battery bay attendants are managed by the production department as part of the truck operator team. They also work with the Battery as a Service (BaaS) technicians to understand any ongoing issues with chargers and batteries.

One attendant manages multiple charging bays, responsible for managing the battery swap process, ensuring batteries charge properly and keeping the charging bays clean and tidy. The attendant regularly travels between charging bays, checking the status of all chargers and cooling equipment and coordinating with dispatch to swap batteries as the BEVs arrive.

Progress to Date

The morale of the operators improved as the battery swap process was significantly simplified. The attendants also led to a safer and more consistent process, reducing the number of times operators exit the cab during a shift.

The efficiency of the battery swap process improved, reducing the turnaround time from approx. 15 minutes to 5-7 minutes. The time saved on battery swapping equates to roughly 3-4 extra truckloads over an 11 hour shift in the best case scenario, improving productivity enough to justify the investment in the attendants.

Prioritizing BEVs for Production

Objective

Prioritize BEV trucks over diesel trucks and get buy-in from the operators.

Justification

Immediate buy-in from the truck operators wasn't guaranteed, with several issues leading to poor adoption rates. Operators were highly experienced and effective at using the machines they were used to. New equipment pushed operators out of their comfort zone, and the associated learning curve meant a necessary short-term loss of productivity.

When minor faults like temperature throttling or entering cut-back mode occurred with BEVs, operators would switch to diesel by default, even when a simple rest would often fix the issue.

Getting buy-in from operators also required some upfront adjustments to the new machines to address challenges with the vehicle ergonomics.

Implementation

Ergonomics-related adjustments included updating the seats, the seatbelt design and the vehicle controls to bring them in line with operators' needs. The different style of working with the BEV trucks required additional training to ensure safe and efficient operations.

Presentations as part of the weekly "back to work" meeting raised awareness of the BEV trucks' productivity gains over the diesel trucks each month, since bonuses are tied to overall production numbers this helped drive interest for operators.

Direct requirements were introduced by management to prioritize running BEVs if they are available, and BEVs were given priority over diesel trucks when travelling up-grade.

Progress to Date

The higher productivity from the BEVs gained operator interest. Once the initial ergonomics issues were addressed and operators passed the initial learning curve with the new technology overall adoption rates increased.

The additional benefits from improvements in air quality and the working environment helped secure operator buy-in.

"But I think for the most part the [operators] that are running them have really come around and they'd rather be in the BEV"

General Supervisor for Production

Making Battery Swapping Easier and More Reliable

Objective

Make maneuvering the charging cables and coolant lines easier for operators, while reducing the likelihood of damage and dirt ingress into the coolant lines during battery swapping.

“It’s a game changer in keeping the cables and everything in good condition and made it a lot easier for the operators”

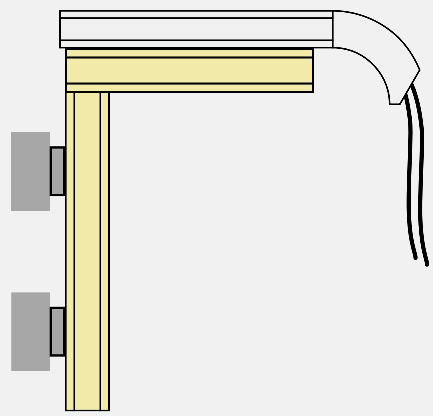
Auto-BEV Technician

Justification

The charging cables together with the battery coolant lines are heavy and hard to maneuver around the charging bay, potentially leading to strain injuries and poor ergonomics.

The cables were often left on the charging bay floor, where they pick up dust and dirt which can find its way into the coolant lines negatively affecting the cooling systems’ reliability.

Implementation



From an information sharing session with another early-adopter mine, the concept for a wall-mounted jib arm assembly was identified to help with charging cable management.

The on-site BEV maintenance technicians developed a design for the jib arms and worked with management to have them installed in the charging bays.

Progress to Date

The jib arms make swapping the batteries physically easier for the vehicle operators, maintenance technicians and battery bay attendants.

The flexible jib arm design works well with the Y-configuration of the charging bays, allowing the cables to swing either way to service whichever battery that’s charging.

The jib arms keep the ends of the cables in good condition, with the side benefit of reduced cleaning and maintenance.

Improving Overall System Reliability

Objective

Reduce the likelihood of failures in BEVs, batteries and support equipment through a holistic set of design choices, equipment monitoring and risk management activities.

Justification

When assessing the risks of failures in batteries and BEV support equipment, New Gold took inspiration from how standard electrical substations are managed underground. The team decided to focus on interventions to reduce the likelihood of failures occurring, while installing backup safety systems to manage risks that might occur.

Implementation

Charging bays were located in the fresh air portion of the ventilation circuit to reduce the exposure to risks caused by operating equipment in moist, dirty and hot air. The ergonomics of battery swapping activities and the charging bay configuration were also addressed to make moving batteries and cable handling more reliable.

On the **charging equipment**, the design of the coolant line connections was modified by the New Afton team to make cleaning the interface simple and quick, and to avoid grit and dirt getting into the coolant systems. The new quick-release coupler also improved the ergonomics for operators changing batteries.

A robust **safety system** was implemented with a fire risk zone located on a nearby exhaust route (150 m from the charging bay). Thermal cameras were added to the safe zone for monitoring damaged batteries/BEVs. Regularly reviewing fire risk plans in a developing mine is a continuous activity.

Equipment monitoring via telemetry systems is being introduced to monitor the charging status and any alerts from the batteries, chargers and cooling cubes in real-time.

Progress to Date

The reduction in dust and dirty air has lowered the charger maintenance workload and the regular preventative maintenance requirements for the cooling equipment, e.g. through less clogging of filters.

This results in chargers that are generally cooler, and cooling equipment that operates more effectively, overall allowing for faster battery charging rates.

The safety system and battery design were put to the test when a battery fell off a boom truck. The battery was monitored closely in the safe zone, then disassembled and tested to ensure it was safe to reenter service.

"Our attitude has always been we're better off to have [batteries and charging equipment] in fresh air. And to have a robust safety system around monitoring, maintenance and a plan to move them when we need to"

Superintendent for Production and Construction

Leaning into Brownfield Constraints

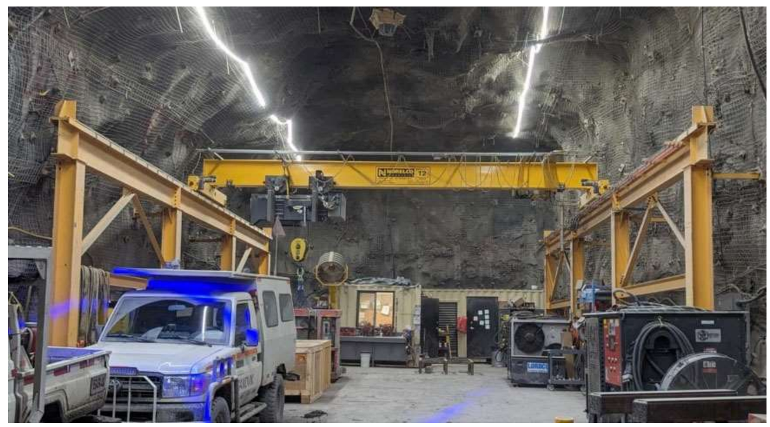
Objective

Learn to manage having a charging bay that is not in the optimal location due to mine design constraints.

Justification

Initial recommendations for the location of the charging bay placed it in the middle of the haul route, allowing for regenerative charging down to the bay when the BEV battery is low. However, the charging bay had to be located at the top of the haul route based on the available real estate in the level.

Implementation



Constraints on available space resulted in the charging bay being located next to the maintenance bay where the dedicated Auto-BEV team and the Original Equipment Manufacturer (OEM) technicians were based. The charging bay location was also at a clean air raise.

A small satellite charging station was also installed at the haulage level, with an off-board high voltage charger but no battery swapping infrastructure.

Progress to Date

The main benefit realized was the short feedback loop created between operations and maintenance teams when the charging and maintenance bays were co-located, especially in the early stages of implementation when everyone was learning.

The immediate feedback loop helped accelerate learning, catch issues early and with implementing new strategies and solutions (such as the jib arms).

Now that the system is established the magnitude of the benefit is reduced, but having the immediate communication loop is still useful for troubleshooting performance issues.

The satellite charging station acts as a backup to help boost a low battery enough to get it back to the full charging bay for a swap.

"It was a boon to that early implementation, when our technicians were learning, when our operators were learning, when our supervisors were learning"

Superintendent for Production and Construction

Comparing Battery as a Service (BaaS) vs. Battery Ownership

Objective

Evaluate the operational, financial, and contractual trade-offs between Battery-as-a-Service (BaaS) agreements and direct battery ownership to support informed decision-making on long-term electrification strategies.

"The reason you internalize your battery team is that you're making the switch to 'it needs to run.' OEM people aren't [always] experts in running a mine, and the incentives aren't aligned with running a mine."

Electrical Engineer

Key Points

BaaS can mask true operating costs
Hidden fees in usage-based agreements can inflate hourly operating costs beyond initial expectations.

Terminology matters
Misaligned contract language and inconsistent definitions across vendors make it difficult to compare and negotiate agreements effectively.

Justification

As BEV programs mature, battery strategy has become a top cost driver. Choosing between BaaS and ownership impacts not only capital allocation but also maintenance control, lifecycle flexibility, and contractual risk.

Inconsistent terms—such as what defines "uptime", "readiness", or "degradation limits" can lead to misaligned expectations and costly misunderstandings.

Implementation

The operations team developed a standardized terminology guide for BaaS and battery ownership agreements. This internal reference would serve as a foundation for negotiations, procurement evaluations, and contract reviews.

It was important that key terms like performance guarantees, minimum charge cycles, and service-level thresholds were clarified with the OEM as they would have significant impacts on the true operating cost.

The team use the guide to align internal stakeholders and reduces friction in supplier discussions.

Progress to Date

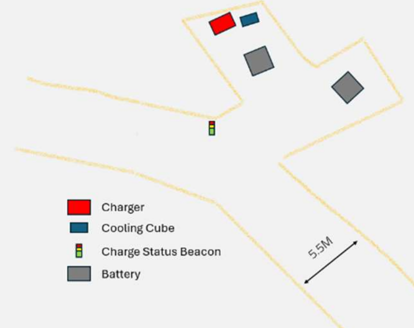
Entered into BaaS agreement.

Learning from a Decade of Charging Infrastructure & Design

Objective

The goal of Macassa's charging infrastructure strategy is to support efficient, reliable, and scalable electric vehicle operations underground. By optimizing charger placement, managing battery thermal conditions, and building internal maintenance capabilities, the site aims to extend battery life, reduce downtime, and improve operator adoption—all while adapting to physical and organizational constraints unique to brownfield mining environments.

Key Points



Geomechanics drove layout constraints.
The Y-shaped layout of the swapping station enables efficient battery swap logistics in a narrow heading but limits charger placement flexibility.

Single-side charger placement adds complexity.
Chargers are installed on one side of the station, with cables and cooling lines extended across the heading to the other side of the Y, using HVDC splitter boxes—a workaround developed in-house.

Battery cooling is essential but often missed.
Connecting the cooling lines from the cooling cube during charging can double or triple battery life, but it requires consistent operator attention.

Operator errors can erode performance.
Skipping steps—especially cooling—adds unproductive time and shortens battery lifespan, underscoring the importance of user-centered design and training.

Internal teams fill critical capability gaps.
A dedicated battery team manages diagnostics, fault tracking, and periodic maintenance. This internal ownership enables faster response and better data capture.

Visibility improves accountability.
Fault beacon lights near roadways help non-technical staff spot and respond to charging issues quickly.

Implementation

Macassa adapted an existing Y-shaped heading, originally built for refueling, to support BEV charging within the site's geomechanical constraints. With limited space for chargers, the team developed an internal solution using High Voltage DC splitter boxes and cable routing to service both sides of the station. Battery cooling was reinforced through operator training and procedural reminders to ensure glycol lines were connected during every charge. To improve fault response, beacon lights were added near roadways for increased visibility. Internal teams took ownership of battery lifecycle management, creating custom tracking tools and building in-house expertise to reduce dependence on suppliers.

Early Site-Level Lessons in Brownfield BEV Implementation

Objective

To integrate BEVs into underground operations in a way that upholds safety, maintains equipment reliability, and supports long-term operational flexibility. This required developing in-house capabilities, adapting to equipment and infrastructure constraints, and navigating the steep learning curve that comes with early-stage adoption—while remaining aligned with corporate ESG commitments and regulatory expectations.

Key Points & Lessons Learned

Start internal training early and progressively.
"We're trying to put in place mandatory training—safety awareness first, then hands-on, then full diagnostics."

Don't assume OEMs are ready with complete training or documentation.
"At first, we didn't have a training program. We built it in-house—using input from other sites, conferences, and the OEM—but it took pressure and persistence to pull it together."

Reliability improves over time, but early adopters must manage risk.
"Getting early adoption of this technology means you're working with a product that's not 100% mature. That's just the reality."

Battery performance and autonomy have generally met expectations.
"We didn't have big issues with batteries. They've been quite reliable."

Plan with equipment providers for the integration into brownfield electrical networks.
"We said: are you selling only to new mines, or do you want your machines to work in 30-year-old mines too?"

Engage OEMs early on infrastructure compatibility.
"We didn't want to change the whole electrical system for 50 years just to match one charger. So the OEM worked with us on a solution at the machine level."

Design issues can introduce unexpected safety risks if not well understood.
"If your battery is fully charged and you go downhill, your dynamic braking disables—that's a big safety issue."

Corporate support evolves with experience; early lessons shape future direction.
"There's not yet a clear corporate vision like 'let's go BEVs'. We're all still in learning mode."

Progress to Date

Since the first BEVs introduced in 2022, both operational and technical maturity have significantly advanced. In-house training programs have been established for operators, mechanics, and electricians, supported by lessons from industry peers and persistent collaboration with OEMs. Safety protocols are now in place for battery-related incidents, and technical staff are equipped to respond to and learn from system faults.

Initial issues with charger compatibility and equipment integration into legacy power networks have largely been addressed through on-machine filtration and adjusted design specifications. Battery reliability and autonomy have proven consistent with expectations, and frontline teams are increasingly confident in their ability to manage BEVs independently.