

The move to battery-powered underground mining fleets is gathering speed. It is also opening up miners to a new realm of possibility

By Peter Braul

Battery electric vehicles (BEVs), once considered fringe, have rapidly come onto the radar of every OEM in the underground mining industry. Almost all of them are working on new battery-driven models or ways to convert existing products to electrical power. That shift might seem a little outsized, given the number of mines that have actually deployed battery electric technology to full effect. But Goldcorp's vice-president of corporate affairs and energy, John Mullally, predicts that the rate of adoption of BEVs will accelerate rapidly over the next five years and expects many underground mines built in Canada will choose battery-powered vehicles over a diesel fleet, and even underground mines already in operation will consider a shift to an all-electric underground fleet.

"By moving away from diesel and by achieving other reductions associated with the use of clean technologies, Goldcorp can avoid more than 7,000 tons of CO₂ and eliminate three million litres of diesel fuel, one million litres of propane and 33,000 megawatt hours of electricity every year," said Mullally, who also stressed the positive impact on air quality and noise level that has already been noted by the development miners at the company's all-electric Borden mine near Chapleau, Ontario. The project is one of three in the province on the leading edge of mine electrification. The others include Kirkland Lake Gold's Macassa mine in Kirkland Lake and Onaping Depth, a development project in the Sudbury basin that Glencore fully approved in January, which plans to use an all-electric fleet. It is an unfamiliar place for miners: most technologies used in the business have not changed significantly in decades, if not longer. Now Glencore, one of the world's largest miners, is earmarking \$700 million to build a mine based on equipment that does not exist yet.

Kirkland Lake: tech incubator

Key elements of an all-electric fleet are still in development by most OEMs: large 40-tonne capacity trucks and 14-tonne LHDs are on the horizon, but not yet available. In early March, Artisan Vehicle Systems launched the world's first 40-tonne battery electric truck at its new manufacturing facility in Kirkland Lake. The California-based company has for years been supplying battery-electric drivetrains for RDH and Atlas Copco, and recently took on manufacturing its own mining vehicles as a primary focus. The company's Z40 truck is a

landmark piece of equipment, and Kirkland Lake Gold CEO Tony Makuch said the truck is a "critical part," of plans to expand the mine, which began using electric vehicles in 2012 because of constrained ventilation.

Brian Huff, Artisan's chief technology officer, said the young company has a long history in electric vehicles. "The company was originally formed back in 2003 (as California Motors). I was the first employee," he recalled. "We kind of hit the EV goldrush and ended up selling shovels. We did projects with Volvo, Kenworth and Porsche-specialist Ruf, but mining really fit the bill for us." He explained that as a smaller, specialized company, Artisan is best suited to manufacturing smaller numbers of high-value vehicles instead of mass-producing consumer goods. He also said the company's Silicon Valley roots have drawn in "high level talent," and made them innovative.

With the recent reinvigoration of Kirkland Lake's mining operations, Artisan is planning a "centre of excellence for battery-powered mining vehicles" in the town, which will house the company's manufacturing facilities as it grows. "BEVs are less than one per cent of the market share right now," said Huff, noting that the company's staff, today about 70 employees, is growing rapidly.

Ontario: the gold standard

According to Goldcorp, Sandvik has committed to producing its own 40-tonne truck to be used by Borden by 2020. Once in full production, the mine will be accessible by a long ramp that the truck will need to climb, loaded, without recharging. One of the key differences between the Artisan trucks used at KLG and the proposed Sandvik truck for Borden will be on-board charging. Artisan batteries are swapped out when depleted at a swap station, where they are charged and await the next duty cycle. Huff said the company will also offer on-board charging in the future.

Artisan's Huff stressed swapping batteries is not a major undertaking, "this is due to the ability to load and unload batteries using a mechanism on the truck," he said. "No swapping infrastructure is needed in the mine. Batteries can be swapped in less than 10 minutes, enabling nearly continuous operation." For the time being, Goldcorp's preference is for on-board charging that can plug into existing electrical infrastructure in the Borden mine, meaning no batteries need to be moved in order to charge.

What's in a battery?

Most commercialized BEVs use some form of lithium-ion battery. And though a few other options are being developed in lab scenarios, for the coming decades lithium is going to continue to dominate the field, according to Brian Huff of Artisan Vehicles. For him, the most interesting thing about lithium-ion batteries are the varieties of ions used. Artisan uses a lithium-iron-phosphate battery which Huff touts as being safer than other options, while retaining solid performance characteristics. For Artisan's four-tonne LHD, the fact that their batteries have a slightly lower energy density is actually an advantage, said Huff. The rough conditions of the mining industry combined with an intense focus on safety are pushing most manufacturers to stay away from the nickel-cobalt-aluminum batteries found in many passenger cars.

Mining vehicle manufacturers do not currently make their own batteries – instead these are sourced from qualified suppliers who can customize chemistry to their clients' needs and have spotless "clean rooms" for manufacturing. Temperature and charge management are where big gains are to be had, according to David Lyon of Medatech. While Medatech chose German supplier Akasol to supply its modular battery system (the cells themselves are produced by specialists for Akasol), Artisan manufactures its own battery management system, but sources the cells themselves from Chinese manufacturers.



Artisan Vehicles Systems' A4 battery

Artisan Vehicle Systems

MacLean Engineering, which supplies Borden with bolters, emulsion charges and other non ore-moving mining vehicles, also uses onboard charging. "We felt that, yes, we can get the new mines, but with onboard charging we can also make these products available to existing mines that want to switch away from diesel, with a high degree of flexibility," said Anthony Griffiths, the company's product manager for fleet electrification. "They can just plug into their existing infrastructure."

Some mines will not be able to consider electrification until equipment size is on par with diesel counterparts. Even if the 14-tonne LHD comes to fruition, there are already 20-tonne diesel loaders that might remain attractive for some. When Macassa switched to BEVs, the price of gold was dropping and a focus on tonnage over grade did not make sense. Macassa's ore body contains some very rich areas directly adjacent barren rock, which incentivizes the pursuit of only the highest-grade material and very tight grade control. In many ways, KLG was an ideal place for BEVs to get started.

Too many reasons to switch

For the past several decades, mining has made gains through economies of scale, simply using ever larger trucks. While today's BEVs are not the largest mining vehicles ever produced, miners like Goldcorp are confident the economics speak for themselves when it comes to justifying the additional cost for BEVs. Goldcorp expects to cut operating expenses by \$9 million per year at Borden through savings in diesel, ventilation costs and the cost of carbon. But dollar figures do not tell the whole story.

"The improved air quality is the factor that doesn't get costed out as easily," said Stuart Lister, director of marketing and communications at MacLean Engineering. "Once you go into a diesel-free mine, the working environment is just so much better. Every mining company we talk to has a different set of drivers for making that transition. In Ontario we have a really good combination of mines getting deeper, a good electricity grid and a government that provides some benefits to reducing your GHGs."

Huff agreed "the intangible benefits" of electrical vehicles are a "really, really big factor" in why mines will move away from diesel. He said, having talked to operators, "they tell us that typically at the end of the day they would be so beat they would just go home and go to sleep. After operating our equipment they'll go home and still have energy and time to play with their kids and be with their families. That's a game changer for those miners themselves. The heat, vibration and poor air quality associated with diesel engines really contribute to fatigue."

In addition to exhaust gases containing diesel particulate, they contain water vapour as well, which contributes to humidity underground, said Huff. "And with no exhaust pipe, you don't kick up as much dust," he added. "They talk about going home and blowing black snot out of their noses after running diesel equipment all day, and that's gone with BEVs." And with a less fatigued and healthier workforce, miners can feasibly expect cultural, safety and productivity gains.

Lister said that if economics and health and safety are not enough to convince miners, the social license argument is strong. According to Goldcorp, the 7,000 tonnes of CO2 equivalent annually saved at Borden alone represent more than the carbon footprint of the island nation of Tuvalu. The 33,000 MWh per year saved is enough energy to power the Cook Islands.

Knowledge for the common good

It was at a battery electric vehicle workshop in May 2016 when David Sanguinetti recalled having the realization that “Oh my god, BEVs are real and clearly important to a lot of people.” Sanguinetti is the innovation manager for the Canada Mining Innovation Council’s underground mining group. “We had to move to a larger room because we literally had people flying across from Europe for this one-day BEV workshop,” he said.

At the end of the day, Heather Ednie, managing director of the Global Mining Standards and Guidelines group, made a pitch: all stakeholders in the industry had to work together towards widespread adoption of this new tech, or there would be chaos. She appears to have been convincing: not long after, Sanguinetti was coordinating more than 100 different voices, including all the major miners and OEMs, to produce a guideline. The aim: to make sure that with a myriad of battery chemistries, sizes and charging options available for various equipment, mines still worked well as a whole.

“The biggest issue during the creation of the first edition was related to the performance testing section,” said Sanguinetti. “Miners were saying ‘we need an apples to apples comparison,’ but OEMs didn’t want to go there. Now we’re working on the second edition of the guidelines and OEMs are lining up to contribute.” And, he noted, OEMs have realized that hiding knowledge is not always advantageous. It might be more important for an OEM to show off its ability to rapidly adopt new technology and adapt to changing conditions than to highlight performance metrics that will be obsolete soon anyway. “Everyone has realized that whatever your performance is right now is going to be different in six months anyway,” said Sanguinetti.

Batteries are ever changing, and Huff noted there are several battery chemistries in lab development that could mean significant improvement. “There is talk of solid lithium batteries, and getting rid of electrolytes,” he said. And thanks to the new guidelines for performance testing, OEMs will be able to quantitatively show the performance gains to their clients, making them more likely to be the first to invest in new gear.

Relationships between OEMs and their mining partners are far different in the pioneering BEV space. “We’re not just price-takers anymore,” said Goldcorp’s Mullally. Instead, the companies work together to solve problems as they come up, big or large. That open communication is a tradition started by Kirkland Lake Gold, which had to approach open-minded OEMs like Atlas Copco and RDH to create machines to spec, since nothing existed on the market at the time.

MacLean Engineering’s Griffiths said sometimes the adjustments can be very small and simple, but just would not be considered in conventional mining. “With our diesel machines, we had two different units that had different-sized cable reels,” he recalled. “Goldcorp asked, when we go all-electric, if we could make them all the same. It was a very simple fix but it was something that had never occurred to us with diesel units, which are seldom plugged in.”

The miners, too, take an open approach. “We exchange notes on a regular basis,” said Mullally of his colleagues at Glencore and KLG.

What can’t be done?

Electrification has opened up the design of mining vehicles to a huge variety of interpretations. David Lyon, business development manager at Canadian engineering firm Medatech, said choosing the right combination of batteries and motors involves careful balance. Medatech supplies the powertrains used in MacLean equipment, but is actively researching future applications. “In the mining space we’re looking at equipment that has as low as a 60 kilowatt motor and as high as 400 kW,” he noted. The bat-

teries in MacLean equipment currently use a combination of nickel-manganese-cobalt oxide and lithium-titanate-oxide chemistries, which he said is optimal for their intended use.

In many circumstances it is not necessary for a vehicle to run for eight hours without charging. “In surface mining or any haulage application, we reduce the onboard battery but we decrease the charge time,” said Lyon. “We’re looking to use chemistry that has an extreme level of power input, so that while a truck is dumping it can be charged in two or three minutes.”

Yes, he said it: surface mining. “We’re engaged in a project already,” he reported. With low grades, extreme tonnages and air quality concerns of their own, open pits are a sort of Holy Grail for BEV technology: if they can work there, they can work anywhere. While Sanguinetti was working on the first edition of the guideline, he said open-pit electrification was considered in the realm of the impossible. It has only been a year since then. “Now, we’re into the second edition and I’m aware of at least two OEMs that are working on open pit projects.” **CM**

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