Powering Trucks for the Long Haul

Diesel engines may be here for the foreseeable future, but a host of alternative fuels, technologies and electrification options are moving swiftly through the ranks

By Carly Leonida, European Editor

Komatsu also has an aggressive trolley development and testing schedule starting in the second half of this year for both standard and autonomous trucks. (Photo: Komatsu)

There are many good reasons why the majority of the 52,200 haul trucks in service today at mines across the globe (number taken from The Parker Bay Co.) are, in one way or another, powered by diesel engines. The power density and flexibility that these units offer, as well as the widespread availability of hardware, fuel and service capabilities create a combination that's extremely hard to beat.

These advantages, coupled with the fact that haul trucks and diesel engines are relatively long-life assets, plus mining companies' general aversion to risk associated with "new" technologies, mean that the bulk of new trucks joining the global fleet over the next three to five years are also likely to feature engines capable of running, partly or exclusively, on diesel. However, the tide is slowly starting to show signs of turning.

This is evident, both in the number of new technologies released over the past year — MINExpo 2021 was awash with announcements of electrified and low-carbon haulage solutions — and, in the partnerships that vendors, OEMs and miners have signed to jointly develop and deploy next-generation trucks in a step toward their large-scale decarbonization targets.

According to McKinsey & Co., around 40%-50% of CO_2 emissions from mining today come from diesel used in mobile equipment, with another 30%-35% from non-renewable electricity. Emissions intensity varies widely across sites, with commodities like copper and iron-ore at the upper end of the spectrum. At an average 25-million-ton-per-year (t/y) Western Australian iron-ore mine, haul trucks are the biggest source of carbon emissions on site, ahead of even comminution, accounting for 20%-25% of the total.

Naturally, these miners are at the forefront of haulage technology development and deployment today, and more are joining their ranks. Operators are leaning more heavily than ever on OEMs, technology and engine providers to broaden their power options for different applications and, where options do not yet exist, some pioneers are even creating their own — see Anglo American's hydrogen-powered truck program.

To better understand the scope of power options available today and get a peek at future truck developments, *E&MJ* invited six companies to share their thoughts and solutions with its readers.

Bringing Sustainable Fuels and Hybrid Into the Mix

Through its mtu brand, Rolls-Royce offers diesel engines for haul trucks with payloads from 100-500 short tons. The Series 2000 and Series 4000 models cover the full power range from 783-3,000 kilowatts (kW).

"These engines have always featured pioneering new technologies," explained Cobus van Schalkwyk, director of global mining at Rolls-Royce Business Unit Power Systems. "For example, the mtu Series 4000 engine was the first commercially available engine with common rail injection when it launched around 25 years ago. Our current mining engine lineup fulfills the latest emission regulations through its optimized combustion process. In other words, we minimize emissions at the source instead of reducing them through exhaust aftertreatment, even for the strictest regulations such as U.S. Environmental Protection Agency (EPA) Tier 4. Our key technologies to achieve this are our patented donor-cylinder exhaust gas recirculation (EGR) system, dual-stage turbocharging, common-rail injection and our in-house developed engine control system."

mtu engines are now available for all relevant emissions regulations, including the strictest in the EU, U.S. and China, and with CO_2-optimized calibrations.

"Depending on the different markets and applications, internal combustion engines will continue to play an important role for years to come," van Schalkwyk said. "They are not only contributing to keeping current operations running but will

also play a major role in market transformation over the coming years and in the net-zero future. This may sound counterintuitive at first, but our engineers have made mtu engines much more efficient and environmentally friendly over the past decades and continue to optimize them for less fuel consumption and lower emissions. Coupled with hybrid technology and sustainable fuels, internal combustion engines, including diesel engines, are an important part of our roadmap toward net zero."

Starting in 2023, Rolls-Royce will release mtu Series 2000 and 4000 engines for use with sustainable fuels, such as e-diesel and second-generation biofuels, thus enabling climate-neutral operation in almost all applications. Electrification will also play an important role.

"The mining industry aims for fully battery-electric trucks to achieve net-zero GHG emissions," van Schalkwyk explained. "But, to maintain the current autonomy of diesel-powered trucks with more than 12 hours before refueling, batteries need to be continuously recharged during operation. The only proven technology for dynamic external charging is trolley assist. However, these systems are not always easy to deploy economically."

Rolls-Royce hopes to solve this challenge through technology, which it is exploring with its Hybrid Haul Truck Concept. This is the first in a number of developments that will lead toward the creation of fully-electric trucks. The concept foresees a vehicle that is battery powered and carries a dynamic charger to avoid the limitations described above. To keep things affordable and simple, it would initially feature a downsized diesel engine that, when paired with sustainable fuels, is GHG-neutral.

"At the core of the concept are the energy storage solution and a sophisticated power and energy management system for multiple sources of power, i.e., the battery plus the source of recharging," van Schalkwyk said. "With improving energy density of batteries and the advent of advanced dynamic charging solutions, the concept allows for gradual downsizing and eventual elimination of the combustion engine and scaling up of the battery to arrive at full electrification."

van Schalkwyk was clear that the route to electrified haul truck solutions is a journey — potentially, a long one.

"These vehicles won't just arrive and take over from diesel one day to the next,"

Anglo Rolls Out Hydrogen-powered Haul Truck

Anglo American recently unveiled a prototype of the world's largest hydrogen-powered haul truck designed to operate in everyday mining conditions at its Mogalakwena platinum group metals (PGM) mine in South Africa. The 2-MW hydrogen-battery hybrid truck, generating more power than its diesel predecessor and capable of carrying a 290-metric-ton (mt) payload, is part of Anglo American's nuGen Zero Emission Haulage Solution (ZEHS).

This is the first time a truck of this size and weight (510 mt laden, which includes a 220-mt gross vehicle weight and a payload capacity of 290 mt) has been converted to run on hydrogen that will be produced on-site in hybrid combination with a battery.

The nuGen truck uses a hybrid hydrogen fuel cell providing roughly half of the power and a battery pack for the other half, to allow energy recovery from braking. Hydrogen enters the fuel cell from the tank and mixes with oxygen to create water in a chemical reaction catalyzed by platinum. This generates electricity that is used to power the motors that drive the wheels. The only emission from the vehicle is water vapor.

The 2-MW hybrid battery/hydrogen fuel cell powerplant, which replaces the diesel engine installed, has been designed by Anglo American and First Mode in Seattle, USA. The power management and battery systems in the truck have been developed to improve overall efficiency by recovering energy when the haul trucks travel downhill, through regenerative braking. By harvesting the regenerative energy created when driving downhill, it reduces the need for external energy. This energy, stored in the battery, together with the hydrogen, extends the truck's range and reduces the out of cycle time for the trucks, since hydrogen refueling is significantly faster than recharging batteries.

As part of the integrated nuGen solution, Anglo has also built a hydrogen production, storage, and refueling complex at Mogalakwena that incorporates the largest electrolyzer in Africa and a solar PV field to support the operation of the haul truck. nuGen is part of FutureSmart Mining, Anglo's innovation-led approach to sustainable mining, which brings together technology and digitalization to drive sustainability outcomes, including its commitment to carbon-neutrality across its operations by 2040.

"nuGen is a tangible demonstration of our FutureSmart Mining program changing the future of our industry," Anglo American CEO Duncan Wanblad said. "With diesel emissions from our haul truck fleet accounting for about 10%-15% of our total Scope 1 emissions, this is an important step on our pathway to carbon neutral operations by 2040. The mining industry is playing a considerable role in helping the world decarbonize, both through our own emissions footprint and the metals and minerals that we produce that are critical to low carbon energy and transport systems."

Over the next several years, Anglo plans to convert or replace its current fleet of diesel-powered trucks with this zero-emission haulage system, fueled with green hydrogen. If this pilot is successful, the company could remove up to 80% of diesel emissions at its open-pit mines.

This is the first time a 290-mt haul truck has been converted to run on hydrogen. (Photo: Anglo American)

he said. "We are convinced that our evolutionary approach makes CO_2-saving technology for mining trucks available in the fastest possible way. It also offers the best protection of valuable assets as it can be retrofitted to existing machines."

The concept was presented for the first time at the MINExpo 2021 tradeshow in Las Vegas, U.S., and, according to van Schalkwyk, it garnered much positive feedback. The team is currently engaged in dialogue with customers to analyze their needs and refine the concept.

"We have many years of experience with hybrid drive systems," added van Schalkwyk. "The first train powered by mtu Hybrid PowerPacks has recently entered passenger service in the U.K. after thorough development. Our hybrid rail-drive system enables fuel and thus CO_2 savings of up to 25% while also offering improved train performance."

From Diesel and Digital to Hydrogen

Another area that offers both immediate and future reductions in engine emissions is digitalization. Rolls-Royce is currently working on digital systems that will bring benefits to both mine operators and the environment.

van Schalkwyk explained: "By capturing drive system data and analyzing it in real time, we will be able to optimize the operation of our engines, increase uptime and availability, and reduce fuel consumption. We have already developed self-learning algorithms for engine control, which will help us to optimize the operation of our engines.

"In fact, we are currently implementing Engine Health Monitoring technology as part of a pilot project with several customers in the mining industry. The technology will enable mines to take preventive measures before engine component failures and thus minimize downtime. The system allows the monitoring of entire fleets down to the level of single parts. The final product which we will offer will be fully scalable to exactly fulfill our customer's needs."

As hinted earlier, Rolls-Royce is currently transforming itself from an engine manufacturer to a provider of integrated, sustainable power solutions. As part of this, the company has founded a new Sustainable Power Solutions business unit, which focuses exclusively on developing sustainable and climate-friendly solutions across all applications.

"The mining application is a good example of a field for which our whole ecosystem of future technologies is relevant, from sustainable fuels to hybrids, digital solutions to energy storage systems and hydrogen," van Schalkwyk said. "Hydrogen-related technologies include fuel cells and hydrolyzers. We have taken significant first steps on this path: the mtu fuel cell element for climate-neutral energy supply had its world premiere at the UN Climate Conference COP 26 in Glasgow at the end of 2021. A fuel cell demonstrator is operational at our plant in Friedrichshafen, Germany, and, from 2025, we plan to deliver series-manufactured fuel cell systems in the megawatt range.

"We are also working on internal combustion engines, which can run on hydrogen. From 2023, mtu engines and conversion kits could become available for use with up to 100% hydrogen. All of these technologies will be relevant for mining applications in the future."

Rolls Royce unveils its mtu Hybrid Truck Concept at MINExpo 2021. (Image: Rolls Royce)

Making Battery Technology Work for Heavy Haulage

Diesel engines, hybrid solutions and alternative power options all require specialized vehicle platforms, but this hasn't phased the OEMs. John Schellenberg, mining product manager for trucks at Hitachi Construction Machinery, joined *E&MJ* to discuss the challenges and opportunities.

"Diesel engines will have a place in mining for some time," he said. "Not all regions have the local infrastructure requirements to adopt zero-emission solutions. Modernized regions that have well developed infrastructure or the ability to invest in infrastructure will drive the adoption of greener solutions. But globally, there are many places that are still developing and don't have that foundation yet. Some developing nations will be able to bypass current diesel technology and transition directly to a zero-emission solution, because their local geography or resources are aligned to take advantage of the new technology. However, other nations will not have this luxury, and will need to rely on carbon-based technologies to grow and develop."

Hitachi Construction Machinery has a strong background in all things electrical. As such, the company's current lineup of mining trucks is built for diesel-electric operation, with the choice of either Cummins or mtu engines. Trolley and trolley-assist technologies have also been part of Hitachi's truck solution package since the 1980s, and so this is a natural option on all of the company's mining truck models.

"Battery solutions have been part of Hitachi's rail portfolio for more than 10 years, so transitioning rail/battery technology to the truck lineup is a natural progression," Schellenberg said. "This is the direction Hitachi Construction Machinery is pursuing; utilizing our current technology and adapting it to new applications. This limits development risk, and helps our customers have confidence in our approach."

Schellenberg explained that, since Hitachi Construction Machinery's mining truck product line already uses an electric drive system, the biggest challenge of adopting new power sources for the existing platform is energy storage and management; there are onboard space and weight limitations, due to the energy density of battery and/or hydrogen solutions.

"Current diesel trucks usually carry enough fuel for 24 hours of operation," he said. "Depending on the battery technology a mine selects, they are looking at a maximum of 1-3 hours of operation using today's solutions. This means that it's critical to utilize the energy as efficiently as possible. They also need to consider how to resupply that onboard energy. Current refueling for diesel units is a 10- to 20-minute process, once a day. If you need to recharge a battery 10 or more times in a day, you need to figure out how to do it quickly and safely. So, energy storage and transfer are very high on our 'challenge' list."

Hitachi Construction Machinery is working with both suppliers and end users to help provide boundaries for its R&D in this area. The company is collaborating with battery suppliers to understand the limitations of different battery technologies available today and is also actively supporting other business units that are working on the charging challenge.

"Through these collaborations, we gain a better understanding of the overall technical possibilities for onboard energy storage and energy transfer," Schellenberg said. "We then have detailed discussions with end users to determine how to modify operational practices so that the new technology can be leveraged to meet their needs."

Schellenberg added that the company is watching a number of future technologies too, including hydrogen.

"Hydrogen has a lot of potential, but there are both onboard and off-board challenges associated with the technology," he said. "As a truck and excavator supplier, we have ideas on how to solve the onboard issues, but we need to watch how other parts of the industry solve the off-board issues too. As of today, we are monitoring what is happening with this technology, including infrastructure development commitments made by end users and governments.

"Overall, I think that powering mine haul trucks in different ways offers a great opportunity for the mining industry as a whole to look at new ways of doing business. Based on a number of reviews by Hitachi Construction Machinery and clients, I believe that electrification is not only possible with today's technology, but it can also achieve a better commercial rate of return than conventional techniques in a number of applications.

The Hitachi EH4000AC3 in action. The company has a strong background in all things electric. (Photo: Hitachi)

"From an equipment development point of view, the diesel engine has been a constant in mobile equipment design for almost 100 years now. Now we need to change this 'constant,' which has not only influenced the overall shape and capacity of mobile equipment, but mine design as well. This means equipment that will not focus on a rotating mass at its center, and power outputs will be broader to allow for steeper haul profiles. How will end users leverage these changes and apply them to mine design?"

Developing the Power Agnostic Truck

It's a good question. One which hints at the potential gains that could potentially be achieved if a sea-change is affected, encompassing the entire mine design and planning process. The tricky thing with mine design is that every site has unique challenges and opportunities. Not all companies will be immediately ready to overhaul their plans and processes to take advantage of green power sources, while others may race ahead.

To reflect this and provide greater optionality, Komatsu has several concurrent development programs focused on GHG reduction and zero-emission platforms for surface mining. The company's recently announced power agnostic truck design effort runs parallel with the development of unique power modules for its trucks.

"The three basic types of Komatsu power modules are: power supply, power storage and hybrid supply," Don Lindell, director for the GHG Alliance and sustainability, at Komatsu, said. "A power supply module generates power from sources like a diesel engine and may be combined with overhead trolley power for additional savings. A power storage module collects power from off-board sources, like trolley or a static charging station, and stores it in batteries for use while the truck is untethered from a power source. Hybrid supply modules generate and store power using a combination of technologies, like hydrogen fuel cells coupled with lithium batteries. Engagement with Komatsu GHG Alliance members shows clear benefit from all three power modules depending on a mine's transition strategy and deployment timing."

The Komatsu GHG Alliance saw its launch in August 2021. It was formed by Komatsu and several of its customers, including Rio Tinto, BHP, Codelco and Boliden, to rapidly innovate in support of carbon reduction targets. Through its framework, the partners are working with Komatsu to collaborate on product planning, development, testing and deployment of next-generation zero-emission mining equipment and infrastructure.

The alliance's initial target is advancing Komatsu's power agnostic truck concept, which debuted at MINExpo 2021. The ultimate aim is to develop a series of haulage vehicles that can run on a variety of power sources, including diesel-electric, electric, trolley (wired), battery power and even hydrogen fuel cells.

As part of this, Komatsu has an aggressive trolley development and testing schedule starting in the second half of this year for both standard and autonomous trucks.

"The order or priority of these platforms is in part determined by the market and the GHG Alliance members," Lindell said. "The Komatsu power agnostic platform will be released on several models and size classes traditionally supplied with electric drives.

"Members of the GHG Alliance provide guidance on demand and timing through engagement on zero-emission strategy planning, which helps drive priorities," Lindell said. "Early planning and collaboration are key to developing a successful long-term transition to the zero-emission economy."

Trolley's Place in the Electric Mine

Trolley assist is a proven technology in mining; one that has seen a renewal of interest over the past five years. ABB has been at the forefront of this revival. It's trolley installation at Boliden's Aitik operation (and now Kevitsa) in Sweden has attracted a lot of industry attention and, such was the project's success, the companies have now signed an agreement with Epiroc to adapt the technology for use underground at the Kristineberg mine too.

Mehrzad Ashnagaran, global product line manager for electrification and composite plant at ABB, spoke to *E&MJ* about the benefits and considerations required for success with trolley-assist.

"The transition to all-electric mines is being driven by the need for the industry to decarbonize and commit to net-zero emissions in line with evolving environmental legislation, chiefly by eliminating diesel from haulage trucks, a significant source of CO_2 in many open-pit mines," he said.

"This can only be achieved if digital, automation and electrification solutions like trolley assist and automated charging systems for hybrid haul trucks are cost-competitive compared with existing fossil fuel alternatives. For specialist technology providers like ABB, that means collaborating with OEMs to provide open-standard, vendor-agnostic solutions that evolve as clients' needs change."

The "all-electric" mine market is gradually taking shape and the ecosystem of electric solutions, such as connectors, batteries and charging capabilities is steadily evolving and maturing. However, the need to run continuously in demanding industrial conditions imposes additional challenges, and there is a parallel market shift toward renewable energy, implementation of energy storage solutions, and more smart energy management.

Trolley assist, automated charging systems for hybrid haul trucks and OEM collaboration are already helping operators to achieve net-zero targets, but Ashnagaran said it's important to note that they are all interconnected. For this reason, solutions such as trolley assist should not be viewed in isolation, but rather as one component in the industry's journey to carbon neutrality.

ABB provides technologies with open, OEM-agnostic standards that provide a complete solution and avoid customers from being locked-in with a single specific vendor.

Ashnagaran explained: "ABB's eMine solution is backboned by ABB Ability MineOptimize, a unique approach to digital transformation that unifies electrification, automation and digital systems in a single system that is fully vertically and horizontally integrated, from pit to port. MineOptimize is the culmination of 40 years of ABB experience in providing large-scale integrated electrical power and control solutions.

"ABB has extended this unique approach to its trolley system. Here again, we integrate electrification, automation and digital technologies within an ecosystem that includes other OEMs and technology partners. No one can make this journey alone; instead, this unique, triangular model allows ABB and its project partners to accompany customers during their transition to all-electric motors and mines."

According to Ashnagaran, it can take time for customers to understand that integrating a trolley assist system requires a mine redesign and there are operational implications around strategy, scheduling and skill sets.

Integrating a trolley system and charging infrastructure also changes the mine's energy load requirements, often making them more volatile. It's therefore important that mining operations undergoing electrification also optimize their grid connection to manage fluctuations in supply and demand, combined with accurate production forecasting and energy storage. Again, this will increase in importance as mines become more automated too.

LNG: Benefits for Today and Tomorrow

For mines that have high diesel burn rates, converting haul truck engines to accept a percentage of liquified natural gas (LNG) is another way that mines can reduce their operating costs today, while also reducing their total GHG emissions.

GFS Corp.'s EVO MT System for haul trucks (and other mining machinery) has been designed to allow for the relatively simple retrofit of existing machinery with minimal downtime and no risk to production relative to LNG operation.

"Our design philosophy is to maximize cost savings for the customer while simultaneously ensuring that the trucks are always able to operate on 100% diesel fuel should the need arise," Jason Green, president at GFS Corp., said. "Although LNG availability is improving on a global basis, the distribution and supply chain is not as robust and competitive compared to distillate fuels and we believe it's important that operators have the ability to switch back to 100% diesel mode in the event that the LNG supply is disrupted."

LNG is an attractive option for mines that see fuel costs as one of their biggest operating expenses, alongside things like tires and explosives.

"To make natural gas conversions worthwhile, mines need to have a certain level of diesel fuel consumption," explained Green. "We find that midsized and larger mines with a lot of machinery and a high fuel load see the most benefit because, when building a business case, mines need to factor in, not just the retrofit costs, but also the investment in LNG infrastructure for on-site fuel storage and refueling."

A local source of LNG is also important. At first glance, some projects may look viable, but if the closest LNG terminal is 1,000 kilometers away, then ongoing transportation and logistics costs can be significant. Aftermarket conversions can also affect OEM and engine warranties.

Depending on the technology that's being retrofitted, a percentage of the truck's diesel consumption is substituted

with LNG; Green explained that the maximum ratio GFS recommends is 70% LNG to 30% diesel, although in reality, the mix is usually in the range of 40%-50% LNG with the balance made up by diesel.

"It depends on the duty cycle of the haul truck and its operating mode," he explained. "Whenever the engine is operating under mid- to high-load, that's when it's possible to optimize LNG substitution. When the truck is operating at light loads, idling or going down into the pit, those modes are much less effective for diesel substitution."

LNG has a lower energy density than diesel so, on a volume basis, it takes about 1.6-1.7 gallons of LNG to provide the same amount of energy as 1 gallon of diesel fuel. Because of this, more LNG must be stored onboard the truck to provide the same performance as diesel. LNG storage also requires specialized cryogenic tanks, which can limit their location.

Scheduling fleet activities to allow for refueling of both diesel and LNG is another consideration.

"That adds another layer of complexity," Green said. "It would be much simpler if mines could deal exclusively with LNG but, to my knowledge, nobody offers 100% gas-fired engines for haul trucks yet; there are too many technological and logistical limitations."

While most conversion projects are driven by cost savings, the emissions benefits that LNG offers are attracting more and more attention.

Green explained: "While some mining companies are now pushing ahead with alternative fuels and/or technologies, we believe that the vast majority of mining machines will continue to use diesel for the foreseeable future. Hybrid and battery solutions will become more commonplace as those technologies continue to develop."

Haulage as Part of the Bigger Picture

In conclusion, the future of haul truck power is a tale of two halves. In the short to midterm — at least for the next 10 to 15 years — the diesel engine will remain king of the global truck fleet, whether as the primary power option with accompanying emission reduction technologies and, where applicable, sustainable fuel substitutions, or accompanied by electric motors, trolley assist and energy storage as part of a hybrid solution.

However, in the mid-long term (20+ years), as miners begin to shrink their carbon footprint and take more radical steps toward net-zero, the makeup of the global fleet will gradually begin to tip in favor of electrified and fully-electric options and, eventually, future technologies such as hydrogen.

It's also worth remembering that, while trucks are a very visible source of GHG emissions, they are only one category of equipment on site that's responsible for them. Excavators, dozers, crushing and milling equipment… all of these items and more generate CO_2 emissions, whether directly or indirectly, and therefore an integrated approach to decarbonization encompassing a long-term, reliable and sustainable source of electricity, as well as the appropriate power distribution and control systems are also crucial. Together, these solutions offer a substantial opportunity to make a step change in reducing overall emissions from mining.

Caterpillar's Zero-emission Ambition

Over the past 12 months, Caterpillar and its customers have signed a series of agreements to develop and deploy zero-emissions mining equipment.

The company is supporting Nouveau Monde Graphite to reach its goal of powering the Matawinie graphite mine in Québec, Canada, with zero-emission machines by 2028. Caterpillar is the mine's exclusive equipment, technology and services provider — developing, testing and producing an all-electric fleet for the project.

In August 2021, following 12 months of discussions with BHP to analyze energy demands and possibilities for new technologies at the miner's sites, the companies announced a partnership to develop and deploy zero-emissions trucks to reduce operational GHG emissions.

And, in September 2021, Rio Tinto and Caterpillar signed a memorandum of understanding to develop zero-emissions autonomous haul trucks for Rio Tinto's Gudai-Darri site in Western Australian. The collaboration will see Rio Tinto and Caterpillar advance the development of the 220-metric-ton (mt) 793 autonomous haul truck, including validation of Caterpillar's emerging zero-emissions technology through a prototype pilot program, testing and pre-production trials. Following its success, 35 new 793 zero-emissions autonomous haul trucks will be introduced at Gudai-Darri in a world-first deployment.

Autonomous haulage offers many opportunities to create operational efficiencies, including in fuel and energy consumption. And this, in turn, can play an important role in reducing the carbon footprint of haulage. A recent five-year study by one of Caterpillar's mining customers that is autonomously hauling iron ore reported an 11% reduction in fuel usage — resulting in a 4,740-ton-per-year CO_2 emissions reduction — as well as an 11% increase in hourly production, 50% higher maximum truck travel speed, and 35% improved tire life.

Over 500 autonomous trucks equipped with MineStar Command for hauling are now operating at 18 mine sites by 10 companies, across three continents. Newmont recently joined the club, announcing it would introduce up to 16 autonomous Cat haul trucks through 2023 at the Cripple Creek and Victor mine in Colorado. In time, the miner plans to transition to an electrified fleet as part of its target to reduce its GHG emissions by more than 30%.

Teck Resources is also looking to electrification as a means to reduce its carbon intensity. The company signed an agreement with Caterpillar in February to introduce 30 zero-emissions haul trucks at its mining operations. The companies said that decarbonizing Teck's vehicle fleet "represents a significant reduction in Scope 1 emissions as Teck works toward its goals to reduce the carbon intensity of its operations by 33% by 2030 and be a carbon-neutral operator by 2050."

The companies plan to progress through a multiphased approach that includes early development, piloting and deployment of 30 zero-emission vehicles, including Cat 794 ultra-class trucks starting in 2027. Teck anticipates initially deploying zero-emissions trucks at its Elk Valley steelmaking coal operations in British Columbia, Canada. The operations are already powered by a 95% clean electricity grid, making it an ideal location to introduce one of Canada's first zero-emissions large haul truck fleets, with options for trolley-assist technology.