

SOLID

GROUND

#1 2023

A MAGAZINE FROM
SANDVIK MINING AND ROCK SOLUTIONS

Norway:
**Creating an
emission-free
mine**

Technology:
**Powering the
next generation
of electrification**

The Expert:
Battery recycling

Newcrest Brucejack Gold Mine

An electrified journey

SANDVIK

Dear reader,

ELECTRIFICATION, DIGITALIZATION, AUTOMATION: important focus areas for Sandvik, and for the mining industry as a whole. That's why we are continuing to expand our competence and offering – for example, by recently acquiring a company that specializes in battery analytics.

We are proud to be leading the industry in the development of BEV technology, with Sandvik TH665B, our largest-capacity battery-electric truck yet, set for trials in Australia. More and more customers are finding that now is the time to start thinking about making the shift to electrification. Don't take our word for it? Read about the benefits it has brought to Newcrest's mine in British Columbia, Canada, in improving both productivity and the working environment.

We are continuing to push the boundaries in mining automation too, and want to give our customers an insight into the technological advancements they can expect to see from us moving forward. That's why we developed our fully autonomous concept drill rig, designed to help us make automation more accessible and usable in the mining industry.

TECHNOLOGY IS JUST part of the story: it's our people who are leading the way in a changing industry. They are the ones behind the development, and they are also the ones who can help our customers understand the economic and technical feasibility of implementing battery-electric vehicle fleets. They have a real passion for what they do and share our organization's commitment to helping customers improve their safety, productivity and sustainability. One of those customers is Rana Gruber in Norway, where Sandvik is playing an important part in their goal to become the world's first CO₂ emission-free mine by the end of 2025.

We understand the challenges facing our industry and want to help our customers face those challenges. Our rock tool 'opt-out' recycling program, the first of its kind in the industry, makes it easy for customers to improve their own sustainability impact, knowing that their old tools are entering into a circular economy.

Wherever you are on the journey, we're here to help you improve your organization's safety, productivity and sustainability.

MATS ERIKSSON,
PRESIDENT SANDVIK
MINING AND ROCK SOLUTIONS



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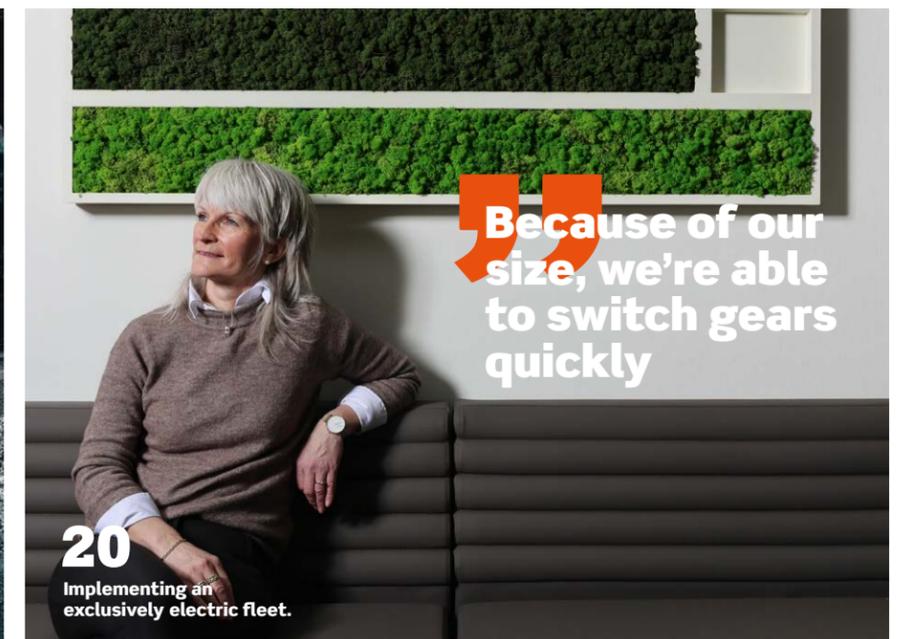
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Next evolutionary step in electric automation.



“Because of our size, we're able to switch gears quickly”

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Implementing an exclusively electric fleet.

New factory in Malaysia

▶ Sandvik is establishing a new production unit in Malaysia for manufacturing underground loaders and trucks, which is expected to be operational by late 2023. Its primary focus will be meeting the growing global demand for battery-electric vehicles (BEVs), but it will also manufacture conventional loaders and trucks.

“Demand for our loaders and trucks is exceeding our current production capacity at our existing factories,” says Patricio Apablaza, President of Sandvik Mining and Rock Solutions’ Load and Haul division. “The establishment of our new production unit in Malaysia will enable flexible manufacturing of both conventional diesel and battery-electric mining equipment.”

The newly constructed factory, situated 70 kilometers south of Kuala Lumpur, will cover an area of over 8000 square meters. Its annual capacity will gradually increase to 300 loaders and trucks, and 500 battery cages by 2030.



Concept drill rig advances electric shift

▶ A new electric concept surface drill rig has been developed in Tampere, Finland, to support sustainable and energy-efficient drilling. Operated fully by electricity, it reduces particulate and CO₂ emissions of tramming and drilling.

What the concept drill rig has been able to do is transfer highly advanced sustainability technologies into the surface drilling world for the first time. This means it is bringing new solutions together on an actual machine.

Sandvik aims to be the go-to provider for customers looking for zero-emissions solutions, implementing these new drilling innovations throughout Sandvik’s product range. Furthermore, a continued dialogue with customers and partners is very important.

“We could make the selections ourselves,” says Lauri Laihanen, Vice President, R&D and Product Management, Surface Drilling Division, “but we want to do it together with our customers. It’s about customer orientation, rather than



The concept rig has the possibility of operating on direct electric power or battery power, as well as hybrid power supply using a small diesel generator.

Sandvik unveils biggest battery-electric mining truck yet

▶ With a payload capacity of 65 metric tons, the Sandvik TH665B is the largest-capacity battery-electric truck for underground mining yet from Sandvik. The prototype has completed factory testing in California and has been showcased at trade shows both in Australia and South Africa.

The truck will be trialed in Australia, where the purpose is to prove Sandvik TH665B’s performance in

long ramp haulage applications. When fully loaded it is expected to be up to 30 percent faster on a 1:7 ramp than a comparable conventional diesel underground truck, thanks to an electric drivetrain that can deliver 640kW of continuous power. It is also equipped with Sandvik’s patented self-swapping system, which enables its batteries to be exchanged in just a few minutes.



TH665B battery electric truck from Sandvik is the largest battery-powered dump truck made for underground mining conditions.

technology orientation. Technology for us is only a tool to meet customer needs. With this surface concept drill rig, the primary role of technology is to support a zero-emissions approach.”

As the ideal platform for the surface

concept drill rig, Sandvik selected the Commando™ DC300Ri top hammer drill rig, known for its excellence in urban surface drilling, underground secondary breaking, and support applications.

AN INDUSTRY LEADER GOES NEXT LEVEL

▶ Ever since its launch in 2004, the Sandvik Alpha 330 has been hugely popular in the drilling industry due to its short, robust thread. The concept has evolved into an even more advanced solution: the new Sandvik Alpha 340.

The key innovation is its unique asymmetric thread profile, which lowers stress levels in critical areas and makes it easier to uncouple. In addition, an increased thread diameter allows for higher fatigue strength, and a larger flushing hole reduces the risk of jamming. As a result of these improvements, service life is now up to 30 percent longer compared to the Sandvik Alpha 330.

“The difference between the asymmetric thread and a standard thread is that we have different flank angles,” explains John Hammargren, R&D Senior Development Engineer. “We have improved

the thread profile where we have contact while drilling, so there we have lower stresses where most of the fatigue breakage starts.”

The development of the Sandvik Alpha 340 has been made possible by Sandvik’s expanded research and development capabilities. Extensive computer simulations have helped perfect the design while digital control in machining has enabled more advanced geometries. It has been subjected to extensive field tests at 17 different sites across the world, where it has been trialed in different operating conditions and rock types.

With the launch of the Sandvik Alpha 340, the Sandvik Alpha 330 will no longer be available on the market. The Sandvik Rock Tools team is contacting all current users with information on how to convert to the new updated product.



FOR THE LONG HAUL

KITIMAT-STIKINE, BRITISH COLUMBIA. With more than 18,000 operating hours, underground mining's largest battery-electric haul truck fleet is delivering marked productivity and environmental improvements for Newcrest's Brucejack gold mine.

TEXT: ERIC GOURLEY PHOTO: ADAM LACH

Sandvik Z50 has one of the smallest envelopes in the 50-metric-ton-capacity truck class and generates twice the peak horsepower and 1/8th the heat of diesel equivalents.



Brucejack mine superintendent Ahsan Chaudhary looks after all underground operations at the remote site in north-western British Columbia's Golden Triangle.

THE FINAL 11 kilometers of the access road to Brucejack mine, spanning a total distance of 76 kilometers from the nearest highway, passes through the Knipple Glacier. The glacier road – which all employees, contractors, equipment, parts, consumables and supplies must cross to reach the mine in the mountainous north-western British Columbia – requires year-round maintenance, from grading in summer to grooming in winter.

Tanker trucks transporting thousands of liters of diesel to the site must also traverse the glacier, but their trips are not nearly as frequent since Brucejack became the first brownfield operation to convert its entire haulage fleet to battery-electric.

Mike Gagnon is Principal of Business Improvement at Newcrest. He served as Brucejack's superintendent from November 2020 to June 2022 and has been intimately involved throughout an electrification

journey that began with a tradeoff study and a single-truck trial to establish a business case, and has since resulted in underground mining's first full haulage fleet BEV conversion.

Beyond the expected productivity advantages of faster cycle times and lower unit costs, and environmental improvements including reduced heat, noise and green-

We saw noticeable improvements compared to the existing diesel fleet.

house gas emissions, Gagnon says de-risking a substantial amount of diesel hauling is an undervalued benefit of the transition.

“Our first priority was to improve the air, the atmosphere underground for our mining team,” Gagnon said. “However, we also realized an additional important benefit. By replacing our diesel trucks underground at the Brucejack mine, we were able to save the hauling of almost 5,000 liters of diesel fuel per day up over the glacier, which is a significant safety improvement for us.”

BRUCEJACK BEGAN A four-month trial of a Sandvik Z50 in October 2020. Ahsan Chaudhary, who took over as superintendent when Gagnon assumed his business improvement role, says the mine established a range of productivity KPIs, including payload, speed, cycle times and availability, to assess performance against the existing diesel fleet.

“Even though the environmental benefits are fairly well-known with the reduction of heat and noise and removing diesel from the equation, we wanted to be sure that the business case was solid for proceeding with the Z50 truck fleet,” Chaudhary says.

Over the four-month trial period, Brucejack saw a 22 percent reduction in cycle time for the average haul cycle.

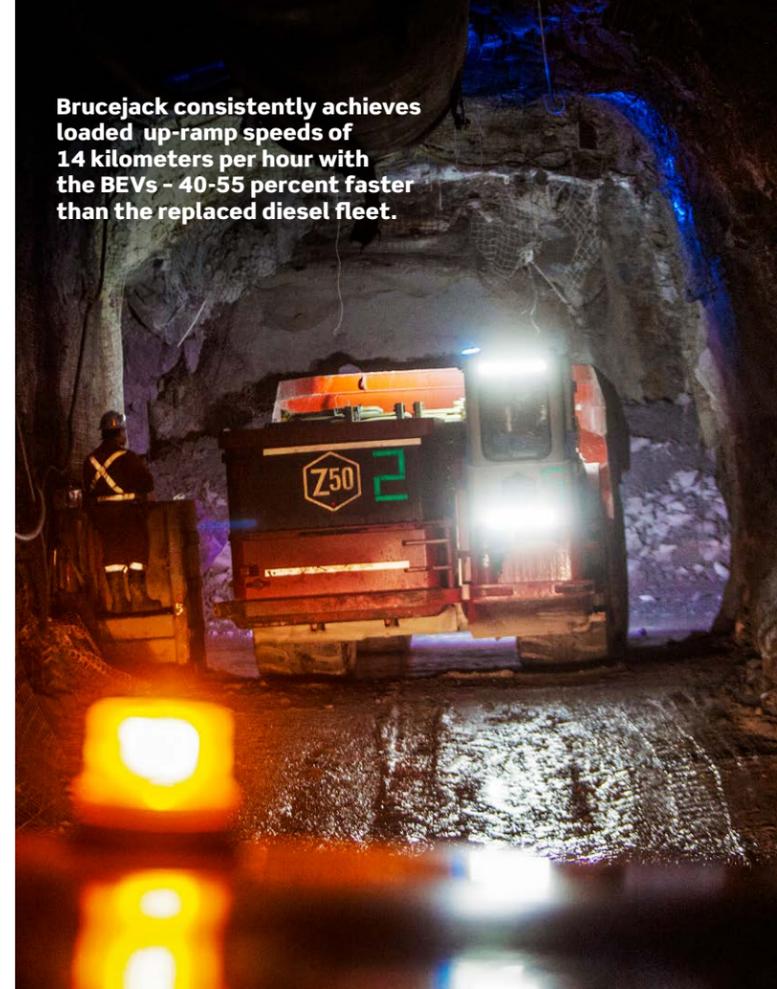
“In each of the key KPI areas that we were looking at, we saw noticeable improvements compared to the existing diesel fleet,” Chaudhary says.

Having confirmed the truck's production benefits, and with partial funding from the CleanBC Industry Fund, Brucejack embarked on a full fleet replacement. The mine invested in eight Sandvik Z50 50-metric-ton BEVs to replace its 12 30-metric-ton diesel haul trucks.

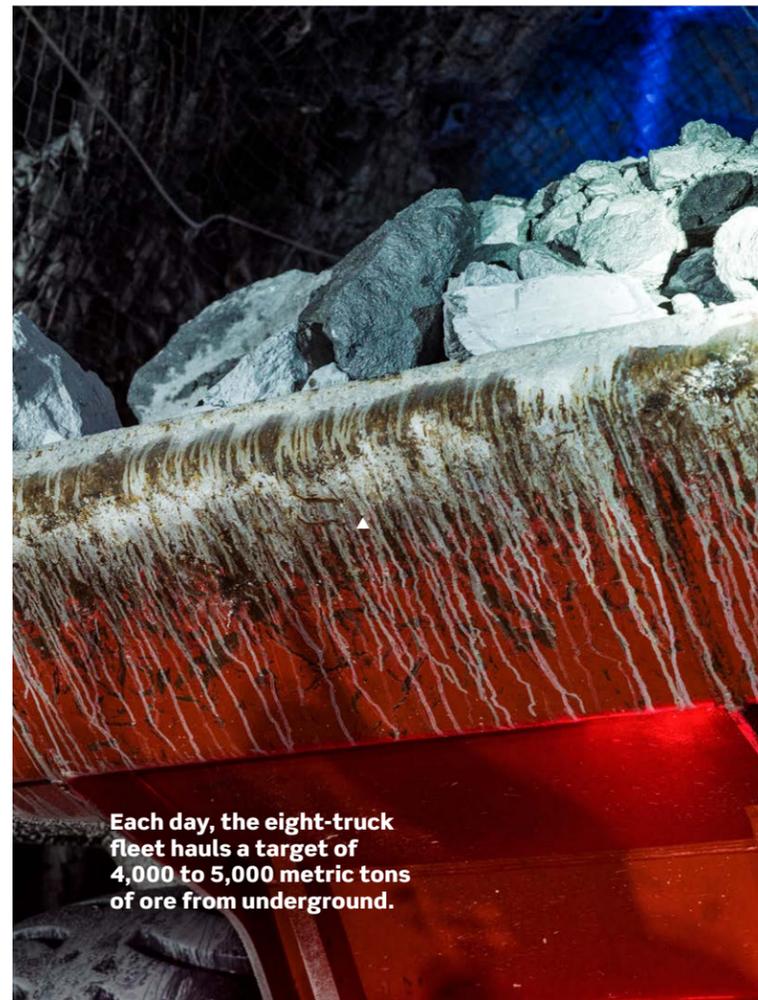
The predecessor of Sandvik TH550B, Sandvik Z50 has one of the smallest envelopes in the 50-metric-ton capacity



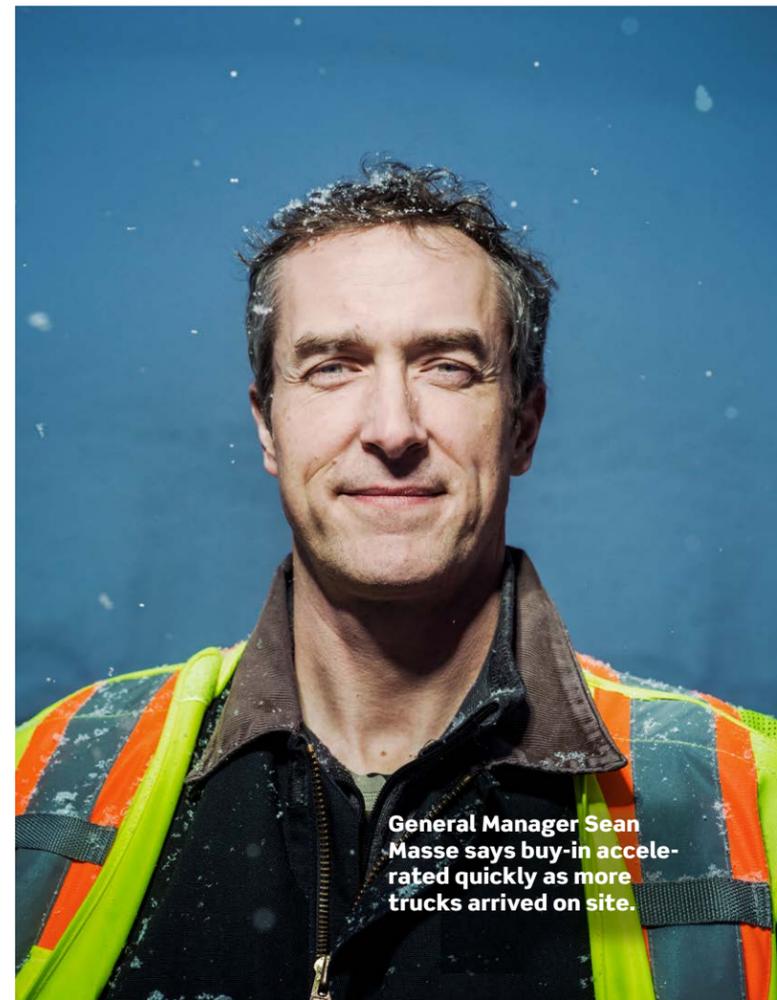
Mike Gagnon, Principal of Business Improvement at Newcrest, has been intimately involved throughout the mine's electrification journey.



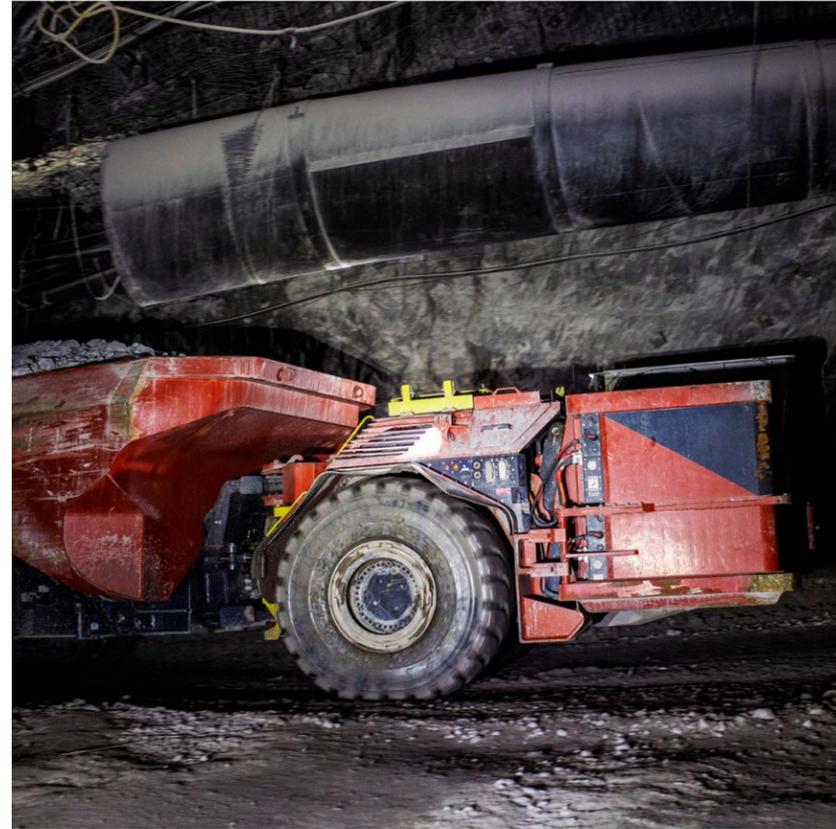
Brucejack consistently achieves loaded up-ramp speeds of 14 kilometers per hour with the BEVs – 40-55 percent faster than the replaced diesel fleet.



Each day, the eight-truck fleet hauls a target of 4,000 to 5,000 metric tons of ore from underground.



General Manager Sean Masse says buy-in accelerated quickly as more trucks arrived on site.



Operator Andrena Moore started at Brucejack in 2015 working snow removal before moving to surface operations a few years later and transitioning underground in 2021. She has more than 1,100 hours operating Sandvik Z50s.

We are reducing thousands of metric tons of carbon from our operation

“The emissions and heat difference is significant compared to the diesel trucks,” she says. “I enjoy the quiet in the cab, for sure, way, way more. Although I do use earplugs still, I’m less tired, less fatigued by the end of the day because that background sound is gone. For such a large machine, they’re quite precise. They articulate very smoothly. They can get in and out of tight spaces. They just move smoother, more gracefully.”

Each day, the eight-truck fleet hauls a target of 4,000 to 5,000 metric tons of ore from underground in addition to approximately 2,500 metric tons of development waste. During a typical shift, each Sandvik Z50 is responsible for 10-15 loads and covers a total

travel distance of 30-40 kilometers. The trucks swap batteries two or three times per shift, with each swap requiring manual battery disconnection and reconnection and taking as little as seven minutes, depending on charge bay efficiency. The same swap can be completed in as little as three minutes on successor Sandvik TH550B, which features Sandvik’s next-generation AutoConnect feature.

Brucejack adapted existing infrastructure for its first charge bay for the trial truck. As the mine has grown its fleet and progressed on its electrification journey, its charge bays have become more purpose-built with increasingly refined and optimized designs. Early setups include chargers on pads of

crushed material followed by poured concrete pads that provide better footing for operators doing swaps.

“After that we created an elevated platform for the charging equipment that made the segregation between the mobile equipment and the fixed infrastructure more robust and gave our operators a larger working area to complete swaps,” Chaudhary says.

THE LATEST ITERATION utilizes the same bench concept to remove the electrical equipment from the roadway, but with the addition of a drive-through system.

“Operators no longer have to drive in and back out,” Chaudhary says. “You drive in, drop your battery and then you continue driving forward to pick up the second battery and then to leave the charge bay, you continue to drive straight through and back to the ramp.”

Sandvik supports the fleet of eight trucks and 21 battery cages under a Battery as a Service by Sandvik contract, a turnkey solution for Brucejack under which Sandvik takes full responsibility for battery maintenance, renewal and disposal. Sandvik provides a fleet manager and four onsite technicians to

truck class and generates twice the peak horsepower and 1/8th the heat of diesel equivalents.

With operators needing to take turns on the trial truck and getting only limited experience with the BEV technology until Brucejack commissioned the second unit in February 2022, some initially resisted the shift from conventional haulage. General Manager Sean Masse says buy-in accelerated quickly as more trucks arrived on site.

“As we started to have a bigger fleet, then more and more employees were like, ‘oh yeah, this thing is way faster, it’s way quieter. I feel a lot more comfortable at the end of the day,’” Masse says. “And it also has a really good ESG aspect to it. We are reducing thousands of metric tons of carbon from our operation.”

Brucejack has now removed more than 3,200 diesel horsepower from underground through a battery-electric migration that Newcrest expects will eliminate around 65,000 metric tons of CO₂ emissions by the end of the decade – the equivalent emissions of 14,000 gasoline-powered passenger vehicles driven for one year. Brucejack is

grid-connected, enabling the use of renewable power despite the mine’s remoteness. It predominantly operates on low-cost, low-carbon hydroelectric power, broadening the benefits of BEVs even further.

BRUCEJACK COMMISSIONED ITS eighth and final Sandvik Z50 in March 2023. The trial truck has amassed more than 6,000 operating hours since October 2020 while the second unit recently reached 4,000. Average fleet availability has hovered around 92 percent, and Brucejack consistently achieves loaded up-ramp speeds of 14 kilometers per hour with the BEVs – 40-55 percent faster than the replaced diesel fleet.

“We’re seeing added value across the board



Reid Simpson

when it comes to our production, the speed of those trucks, the cycle times on them,” says Reid Simpson, Mine Engineer, Projects, who worked on the initial tradeoff study before the trial. “You’re providing your workers a cleaner environment to work in and a more productive environment, so why not, right? It’s a no-brainer for us.”

Operator Andrena Moore started at Brucejack in 2015 working snow removal before moving to surface operations a few years later and transitioning underground in 2021. She has more than 1,100 hours operating Sandvik Z50s.

BRUCEJACK MINE

Brucejack is located in north-western British Columbia’s Golden Triangle, approximately 950 kilometers north of Vancouver and 140 kilometers south of Newcrest’s majority-owned and operated Red Chris mine. One of the world’s highest-grade gold operations, Brucejack reached commercial production in July 2017 under Pretium Resources. Newcrest acquired Pretium and the Brucejack operation in March 2022.



Brucejack’s battery-electric migration is expected to eliminate around 65,000 metric tons of CO₂ emissions by the end of the decade.



Sandvik Z50 battery swaps at Brucejack take as little as seven minutes, depending on charge bay efficiency.



Sandvik supports the fleet of eight trucks and 21 battery cages under a Battery as a Service by Sandvik contract.

“I think everyone’s going to want to say they had swapped over sooner

support the batteries and BEVs.

The haulage transition success has delivered so much value that the mine commissioned a Sandvik LH518B battery-electric loader for a six-month trial in March 2023.

“Other mines have trialed the BEV loaders and we want to understand the same learnings and mimic the same benefits to understand if there’s a business case for Brucejack by implementing a battery-electric fleet for our loaders as well,” Chaudhary says.

Mine Planning Engineer Evan Robson, who alongside Simpson spearheaded the initial tradeoff study, is excited about the potential more battery-electricity has to improve productivity and working conditions at Brucejack.

“There’s a capital cost that comes with making the switch, but looking three to five years down the road, I think everyone’s going to want to say they had swapped over sooner,” Robson says. “And I think the time’s now to do so.”

Gagnon agrees.

“For companies that are interested in battery-electric technology, I highly recommend that they reach out to Sandvik and start the discussion now, to get in line and start their own battery-electric journey,” he says. “Sandvik for us has been a great partner to work with and helped us along the design, implementation and execution of the battery-electric project at the Brucejack mine.”

NEWCREST

Newcrest is Australia’s largest gold producer and one of the world’s leading gold miners. The company operates gold and copper mines in Australia, Canada and Papua New Guinea. Newcrest produced 1.96 million ounces of gold and 121,000 metric tons of copper in FY 2022.



Mine Planning Engineer Evan Robson is excited about the potential more battery-electricity has to improve productivity and working conditions at Brucejack.



Second in line for Sandvik's autonomous vision, the AutoMine Concept Underground Drill is a fully autonomous, fully electric and cabinless underground drill.

THE FUTURE OF AUTONOMOUS MINING

The AutoMine Concept Underground Drill is the next generation of autonomous drilling. The cabinless battery-electric machine is the company's next evolutionary step in automation.

TEXT: ASA BUTCHER PHOTO: SANDVIK

ONLY THE SOUND of stone crunching beneath four vast tires comes from the consuming darkness of the mine. The tunnel is suddenly illuminated by a bank of blinding bright lights, revealing a massive twin-boom development drill rig in orange and black but with no driver. You are standing face-to-face with the future of underground mining.

"Every drilling rig and drilling jumbo in the world must have a name. We affectionately chose 'Amelia' because it means 'industrious'— an adjective that neatly describes Sandvik's AutoMine Concept Underground Drill. This is the second technology demonstrator for our autonomous mining vision, following the AutoMine Concept Loader we introduced two years ago," says Jussi Puura, Digitalization Research Lead at Sandvik Mining and Rock Solutions.

The Concept Loader was the world's first fully autonomous underground mining machine explicitly built for automation. Now, Sandvik has expanded its vision from autonomous mucking to designing the next generation of autonomous drilling and



Elen Toodu is the Director of Global Automation Product Line & Projects at Sandvik Mining and Rock Solutions.

continuing to push the boundaries of mining automation.

Sandvik selected the development drill as its next Concept Vehicle to demonstrate that autonomy can work effectively in a mine's development phase and constantly changing environments.

"We had to design a drill rig that would be fully autonomous, cabinless, battery electric, and be able to plan and execute the entire drilling cycle. So, it had to tram to the location, drill the pattern, and return home to



Mikko Valtee, Electrification Technologies and Machinery Systems Manager at Sandvik Mining and Rock Solutions.

charge for the next cycle. It was a challenge," he laughs, adding, "We also wanted to make communication with the machine as easy as chatting with a co-worker."

MIKKO VALTEE, ELECTRIFICATION Technologies and Machinery Systems Manager at Sandvik Mining and Rock Solutions, explains that the project demanded much to be accomplished quickly, which meant that systems had to be developed in parallel and brought together as a fully functional concept. To achieve that, they had to completely create the autonomy software before the physical unit was even constructed using simulator environments.

He adds, "While the base machine was being built, we were already fine-tuning all the autonomy in detail using the simulator. We tested the drilling, navigation, route planning and all the new features, such as extreme cornering and auto-leveling. It was much more cost-efficient, faster and safer to test everything in the virtual environment first."

Sandvik also has a state-of-the-art test mine at its production unit in the Finnish city of Tampere. It provides real mine conditions for rapid prototype testing and underground equipment quality assurance verification. Valtee likens it to a playground, saying, "We can trial, test, and we have our assembling people here, so this is a luxury. But this is what it takes to get these unique projects done."

Puura agrees, noting that it's been a long

journey from the beginning to this point. "I couldn't be happier with how the Concept Drill has turned out. We've had a great team working on this since 2021. They have come from all divisions of Sandvik Mining and Rock Solutions, are all truly dedicated professionals in their area, and have a passion to win."

UNVEILED AND DEMONSTRATED for the first time at a customer event in Tampere in September 2022, the fully functional AutoMine Concept Underground Drill is not being introduced by Sandvik as a commercial product.

Elen Toodu, Director of Global Automation Product Line & Projects at Sandvik Mining and Rock Solutions, states, "We intend to showcase what next-generation intelligent innovations are coming over the next few years. The Concept Drill will act as an in-house platform for testing and developing new technologies our customers identify as crucial to their operations, which will then be introduced for current and future Sandvik offerings."

While not initially for sale, she underscores that this concept is designed to show Sandvik's customers that incorporating new automation and high-end technology in actual underground mining operations can be effortless.

"We are working hard to make automation more accessible and usable in the mining industry. Some features will be available as standalone products and others as upgrades or options for existing products or equipment."

Due to being fully autonomous, the AutoMine Concept Underground Drill does not possess an operator cabin. This has created extra space for onboard water and battery storage, eliminating the need for supply cables or water hoses during operation. In addition, the onboard battery supply has a longer duration because the self-contained drill uses and optimizes power and electricity based on need.

According to Puura, "Once the drill rig knows to which tunnel and face it should work on, it can plan the rest of its mission autonomously using data from mine planning software like iSURE and Deswik. For example, drilling and blasting patterns, tunnel lines, and profiles are designed in iSURE for optimal hole placement, detona-



The cabinless battery-electric drill can plan and execute the entire drilling cycle from tramping to the face, setting up for drilling, drilling the pattern and returning home to charge for the next cycle.

tion and profile quality. The machine executes and adapts them in the real environment as it works."

During drilling, it uses an AI-guided automatic drill bit changer to identify when bits are worn and change them automatically. There is also a lifter tube installer that



Jussi Puura, Digitalization Research Lead at Sandvik Mining and Rock Solutions.

simplifies the face charging procedure. Compatible with traditional safety gate systems or working without area isolation, it will only ask for assistance when refilling consumables and recharging. However, if it is unsure of environmental changes, it can request intervention from an operator in the control room via the mine's 5G or Wi-Fi network."

Since the AutoMine Concept Underground Drill has instant access to 3D models of a site, which are automatically merged from survey and mapping results, the drill rig can update and optimize the 3D model of the mine in real time based on feedback from its onboard cameras and scanners. "From entry to exit, it is continuously learning and adapting to the ever-changing environment so it can safely complete entire missions," says Puura.

For Toodu, its self-planning of the route is one of the fascinating features on board the AutoMine Concept Underground Drill. "The effective use of a large machine underground is enabled by our automatic boom collision avoidance system, which assists in the agile navigation of tight spaces. Once at its destination, it uses the automatic drill plan adjustment to optimize and adapt the drilling

pattern and drill the full round."

Thanks to the rapid advancement of battery technologies, Puura envisages equipment like this to one day execute the entire drilling cycle on battery power, eliminating the need to plug into a grid. He adds that modules like mapping kits, 3D positioning and obstacle detection are coming to the market soon as separate products and features in the Sandvik offering.

WITH THE FUTURE of underground mining rapidly evolving, Sandvik recognizes that one of the most significant changes will be the adoption of autonomous technologies. The increasing demand for minerals and resources and the need to optimize productivity means mining companies must recognize autonomous technologies and revolutionize operations.

For Toodu, the future will see an increasing number of autonomous machines and systems that will perform tasks traditionally done by human workers: "From drilling and blasting to hauling and loading, as these technologies evolve and become more sophisticated, the potential for increased efficiency, safety and profitability in the mining industry is immense."



Haley-Anna Blinn initially worked for the company Artisan, later acquired by Sandvik because of their advancements in the BEV field.

HALEY-ANNA BLINN

Working as a young, female BEV applications engineer for Sandvik has provided Haley-Anna Blinn with extensive knowledge and experience, going forward into the battery-dominated mining industry.

TEXT: DAVID JOHANSSON PHOTO: PRIVATE

HALEY-ANNA BLINN IS based in Ontario, Canada, but works out of the Sandvik Mining and Rock Solutions facilities in Camarillo, California. Her work is currently focused on helping mines understand the economic and technical feasibility of implementing battery-electric vehicle fleets. She also recognizes that there's no one-solution-fits-all, and welcomes creative electrification ideas.

"We're seeing lots of other creative solutions outside of BEV-centered electrification as well," Blinn says. "One example is Glencore's Raglan Mine in Canada, where they've built a hydrogen loop for long-term energy storage paired with a 3 MW wind turbine for energy generation. This was built in an effort to reduce the remote site's dependence on diesel-based power generation."

Blinn never thought she would be working in the mining industry. Her education is in astrophysics and math. "I began working at Artisan while I was a student, as a research and development intern. That allowed me to

do research on electrochemical cells and their degradation mechanisms."

She then transferred to a customer site in Kirkland Lake, Ontario, that operated the largest BEV fleet at the time, mostly utilizing Sandvik equipment.

"That enabled me to develop a lot of working knowledge on the technology itself, specifically Sandvik technology. Then, in 2022, I decided that I wanted to pursue working for Sandvik as I felt the battery world was what interested me the most, and I wanted to stay in it," Blinn says.

Working with BEV applications and having experience from customer mine sites has enabled her to understand why mine sites have different needs and concerns when it comes to adopting a BEV fleet.

Is there a certain skepticism connected to making the shift to BEV fleets?

"With the introduction of new technologies, the mining industry is rightfully a bit appre-

We're going to be seeing a lot more of diversified clean energy solutions in the industry

hensive to adopt it quickly. In my experience, mining is very stringent on safety, and being able to quantify the risks associated with any task in the operation is critical. Batteries are not so simple and the industry does not possess the working knowledge to feel as comfortable as they do with more traditional technologies. Batteries are electrochemical objects that complete chemical reactions to deliver and store energy. The storage and distribution of energy, when you're referring to traditional electrical systems outside the battery, is something that mines have strict regulations on and standards to follow. Thus, companies are not very eager to adopt it right away, without understanding every facet of that technology."

So how does Sandvik work to ensure that the batteries coming from you are safer than only a couple of years ago?

"It's taken a long time to educate and provide materials in order to understand what we've done. One of the most significant choices we've made to mitigate safety hazards is the choice of chemistry in our batteries. Our cells are lithium-iron phosphate, which is a subset of lithium-ion batteries. Not many people are familiar with subsets of lithium-ion batteries, but we chose lithium-iron phosphate as our particular chemistry because it is very stable. It has a relatively high tolerance for thermal runaway, and low heat release rate (HRR), as compared to other lithium-ion cells. Thermal runaway is the uncontrolled release of heat and energy from the cell, caused by the cell internal temperature exceeding critical limits. Other types of lithium-ion chemistries engage in thermal runaway at lower temperatures than ours, which would lead to issues in the hot and humid underground environments our vehicles are deployed in. Furthermore, lithium-iron phosphate chemistry has a low heat release rate compared to most chemistries, meaning that if a cell were to undergo thermal runaway, it wouldn't ignite as easily and it wouldn't release the stored energy as violently as other chemistries. A chemistry with a higher

heat release rate would more readily experience cell off-gassing, bursting or ignition – things you wouldn't want happening in your battery, and certainly not within the confines of an underground environment."

What is the biggest challenge for you and your team right now?

"My role right now involves aiding mine sites in the pre-sale stage, understanding the economic and technical feasibility of implementing a battery fleet at their operation. So, I'd say the biggest challenge is that every mine site has different parameters that would make battery operation more or less feasible. For instance, we see mine sites who are more willing to adopt because their local governing body has imposed regulations that have made it economically unfeasible to operate diesel, so BEVs are a prudent choice. In British Columbia, Canada, there's existing regulation, and suspected to be more coming, that would really restrict the use of diesel engines in underground mines. Also, in many regions diesel prices are very high, which makes the argument for BEVs a lot easier. We also look at the mine design, as BEVs may unlock potential production areas in some cases, or may require extra infrastructure in others. In terms of supply, a lot of companies are recognizing that this is a new technology to the mining industry and our factory production levels aren't yet at peak, so they're going to have to get involved early if they want to have a fleet in the next five years available to them. However, the hardest part of these projects is definitely assessing the mine site and all of the micro and macroeconomic factors that affect it, and trying to model how feasible the fleet implementation will be from an economic standpoint since it's different every time."

What about the concern of diminishing raw materials?

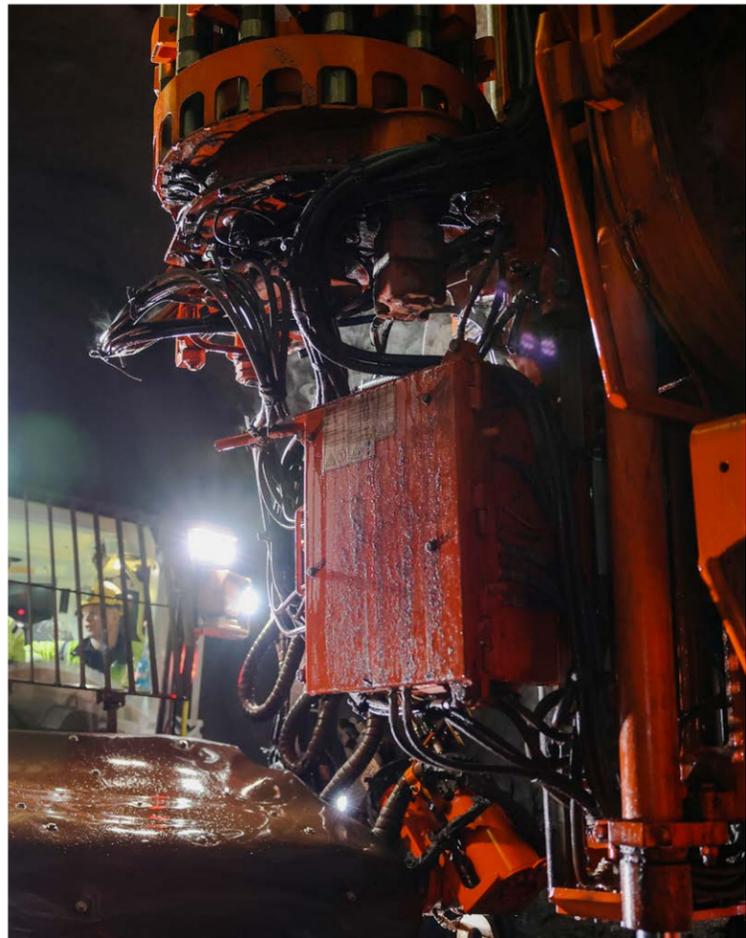
"I genuinely believe things like asteroid mining might become a feasible endeavor in the future, even though it may not be taken very seriously by most people at the moment."



The mining town of Mo i Rana is located in northern Norway, about 960 kilometers north of Oslo.



The fully automated battery-electric DL422iE is a topammer longhole drill designed for underground mass mining in 4 x 4 m or larger production drifts.



DECARBONIZING THE MINE

MO I RANA, DUNDERLAND VALLEY. Eyeing the future of mining, Rana Gruber is making a gear switch and replacing its entire underground diesel fleet with battery electric vehicles from Sandvik. The goal? Becoming the world's first CO₂ emission-free mine by the end of 2025.

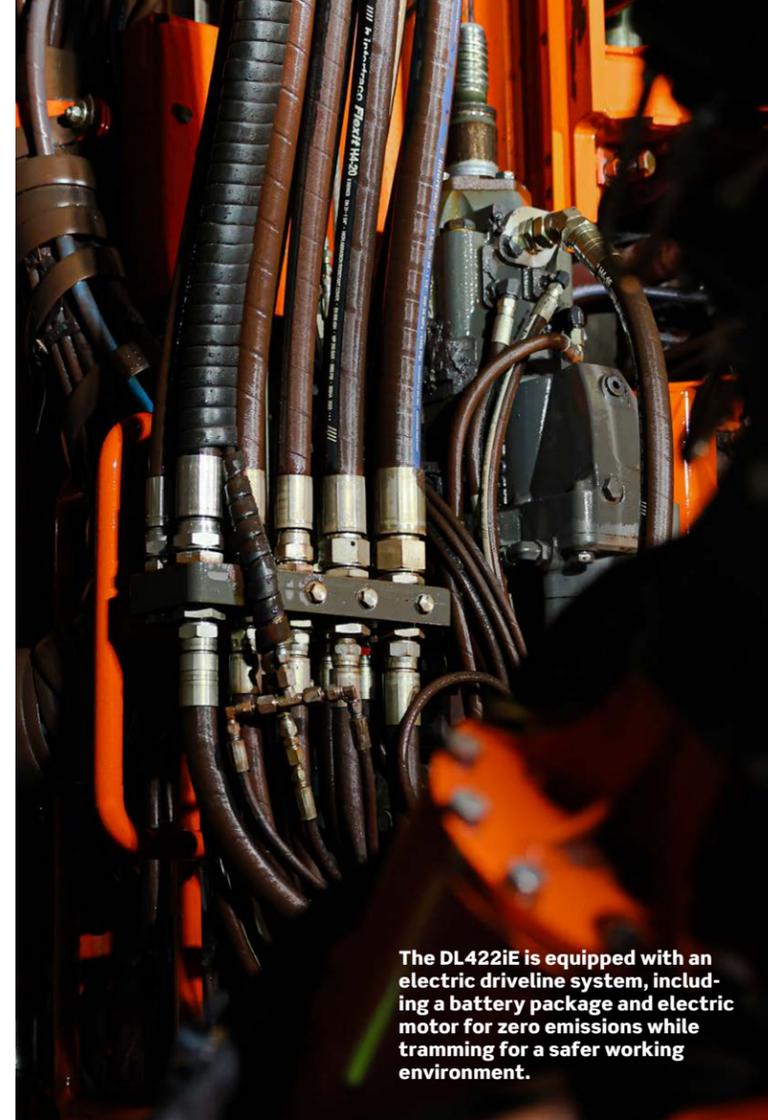
TEXT: DAVID JOHANSSON PHOTO: KAJSA KEGEN LORENTZON



Nancy Stien Schreiner,
Sustainability Manager
at Rana Gruber.

SANDVIK FLEET AND SERVICES

As of May 2023, Sandvik has delivered two DL422iE production drills and two more will be delivered in 2024. During 2023 and 2024 Sandvik will deliver four LH518iB loaders, seven TH550B trucks, three DD422iE development drills, and two DS412iE bolters. Rock tools, parts, services and Battery as a Service (BaaS) are also included in the agreement.



The DL422iE is equipped with an electric driveline system, including a battery package and electric motor for zero emissions while tramming for a safer working environment.



Gunnar Moe,
CEO Rana Gruber.



We wanted to provide a sustainable and environmental product

SITUATED IN THE dreamy Norwegian mountains, far away from urban cityscapes, is Mo i Rana, a small mining town close to the Dunderland Valley known for its picturesque surroundings and the local iron ore deposit run by Rana Gruber.

The Norwegian mining company has set an official goal of becoming the world's first CO₂ emission-free mine, as early as 2025. A major step towards this goal has been to enter into a partnership with Sandvik, and by providing their experience, expertise and equipment for electric mine operations, Sandvik has become something more than a

supplier for Rana Gruber. They've become a partner.

For Rana Gruber, the partnership with Sandvik is what really makes the electric shift possible. It's a partnership that goes beyond providing BEV equipment. Sandvik also offers in-house consultation services to effectively plan the required infrastructure to support the transition to BEV, as well as aftermarket support, such as Battery as a Service.

The cooperation agreement between Rana Gruber and Sandvik was signed in November 2021 with the purpose of building a long-term development plan with clear targets. In

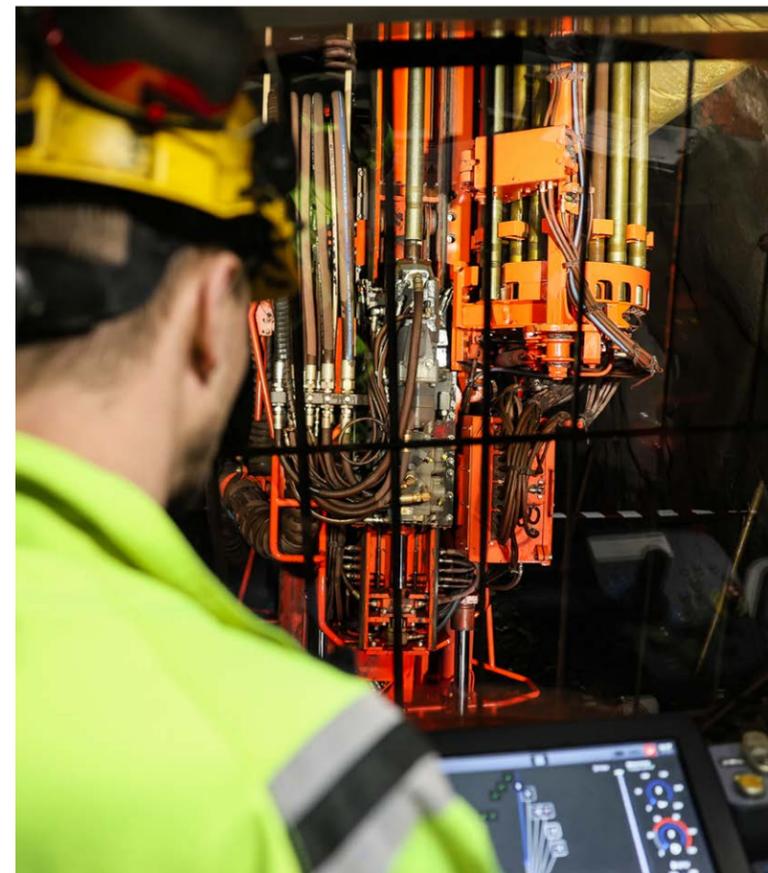
addition to implementing a full underground mining BEV fleet, the two companies are collaboratively developing strategies for operator and maintenance personnel training as well as future product development.

"Initially, the goal of becoming CO₂ emission free by the end of 2025 was connected to the steel industry," says Nancy Stien Schreiner, Sustainability Manager at Rana Gruber. "We wanted to provide a sustainable and environmental product."

RANA GRUBER IS a relatively small mining company, which makes them suitable for an ambitious goal like becoming CO₂ emission free within just a couple of years. Industry peers have set similar goals, but Schreiner knows Rana Gruber has this advantage.

"Because of our size, we're able to switch gears quickly."

Sandvik's Trans4Mine is an in-house service assisting customers to achieve best practice in sustainability, safety, productivity



RANA GRUBER

Based just outside of Mo i Rana in northern Norway, Rana Gruber has around 300 employees with an annual production capacity of 1.8 million metric tons of iron ore, coming from five deposits in the Dunderland Valley, most of which is hematite and magnetite. The company also offers specialized products traded under the flagship brand Colorana®. Rana exports almost all of their production to European buyers.



Left: drill operator Jonas Høgli. Above: Rana Gruber in Storforshei in the middle of the Dunderland Valley, north-east of Mo i Rana.

and performance via feasibility studies and customized fleet recommendations. In 2022, a Trans4Mine study was carried out by Sandvik and Rana Gruber, which resulted in the proposed underground BEV fleet, including drill rigs, loaders, trucks, roof bolters and longhole rigs.

Gunnar Moe is the CEO of Rana Gruber and points to assistance with mine planning from Sandvik as valued by Rana. “Locations where it is most suitable to establish charging stations and workshops is something Sandvik can advise on,” he says. “They have huge competence when it comes to their machines, maintenance and battery operation. This will continue to be important in our business; we know that Sandvik is only a phone call away, and they will provide us with whatever it is

that we need. We very much appreciate that.”

Jonas Høgli is a drill operator at Rana Gruber and is currently operating their first battery-electric drill, the Sandvik DL422iE.

“I liked how Sandvik traveled to Mo i Rana and taught us how to operate the drill,” Høgli says. “That way, we received a complete introduction before we placed the drill into production.” He also appreciates the benefits that come with an electric battery, as opposed to a diesel engine. “Removing all the fumes and the fact that the drill is so much more environmentally friendly are some of the most positive aspects to me.”

THE SANDVIK DL422IE is the first in a row of BEV machines to be delivered. It runs on four separate battery cells which can be re-

moved and replaced individually. This way, maintenance is made much easier, since the likelihood of all four battery cells malfunctioning at the same time is very low. The four cells run on 25 percent power each, which means the drill can still be used even without one or two cells.

In preparation for the arrival of the new BEV fleet, Rana Gruber and Sandvik have initiated a training program for new operator recruits. Ole Martin Røssvoll supervises the drill operators at Rana Gruber, and praises Sandvik’s range of Digital Driller training simulators for operator and maintenance training.

“We have an entirely new tool to bring us into this new era of digital learning,” says Røssvoll. “We can train employees to operate a series of machines, and simulating mine work like this will provide new operators with a fantastic starting point.”

He is quick to highlight Sandvik’s support quality and response time. “We don’t have to wait a very long to have a Sandvik technician on the line,” Røssvoll says. “They are very fast in proposing exactly what we need, and the support in general is great surrounding this whole process.”

DUNDERLAND VALLEY

The iron ore deposits of the Dunderland Valley, located just outside of the mine town Mo i Rana, have more than 200 years of mining history. Rana Gruber AS was founded in 1937 by A/S Sydvaranger and the German Vereinigte Stahlwerke AG, and the German-owned shares were acquired by the Norwegian state after World War II ended in 1945. At the end of the 1980s, the company transitioned to an export mine, mostly because of their specialty products, and became privately owned by LNS Eiendom in 1991. Since 2016 Rana Gruber has been listed on the Oslo Stock Market.



Ole Martin Røssvoll, supervisor at Rana Gruber.

We received a complete introduction before we placed the drill into production

SAFELY POWERING UP THE MINING INDUSTRY

Sandvik's AVS 4.0 battery module represents the cutting edge in electrification technology for the mining industry. Boasting increased power, unparalleled reliability and exceptional safety features, it is set to drive sustainability, efficiency and profitability for mining companies around the world.

TEXT: ASA BUTCHER PHOTO: SANDVIK

SAFETY, RELIABILITY AND increased performance are the core tenets behind Sandvik's new AVS 4.0 battery module set to power the next generation of electrification in the mining industry. But convincing new clients to take the leap demands extensive testing to fully establish confidence in adopting battery-powered technologies.

Brian Huff, VP of New Technology and Innovation at Sandvik's Load and Haul Division, concedes that getting customers comfortable with battery technology is one of the biggest hurdles. "They have valid safety concerns, especially when a burning EV appears on the news. They don't want fire hazards underground."

However, Sandvik's fourth-generation battery module has been purpose-built for the mining industry. "While some competitors use fragile automotive-style batteries, our design is rugged and we've made them

modular for safer and easier service in the field," Huff says. "We've also opted for lithium-iron phosphate chemistry that is safer and less volatile, allowing more passive protection features to be effective."

Huff adds that batteries designed for automotive use are just one monolithic thing: "If you put that into mining equipment and have a problem, you must replace the entire thing, which can be costly and difficult to manage. Our battery packs consist of 16 individual modules, so you can slide a module out and easily insert a replacement."

Underground mining is focused on uptime, with intense pressure to fix problems in situ. Huff says, "These batteries are designed to be serviced safely in the field. Arc flash has been addressed by having 40V modules and drawer-style connections to avoid contact with the conductors. The new module is robust and environmentally



Brian Huff

hardened, allowing safe and reliable underground transport."

The durability of the AVS 4.0 has been proven by its outstanding performance in the UL 2580 standard tests that evaluate batteries for electric vehicle use in

North America. The extreme tests included intense shock, mechanical vibration, thermal stress, environmental exposure and cell penetration.

The AVS 4.0 battery module has about 36 percent more energy capacity, a substantial increase compared to the previous generation. "From a performance perspective, machines can run longer before recharging. This is primarily thanks to utilizing the latest generation of battery cells. With this higher

energy density, we can run larger machines like the TH665B, TH550B and LH518B 36 percent longer between battery swaps. The increased capacity also increases the charge acceptance, allowing faster downhill speeds and improved efficiency," Huff says.

DEPENDING ON THE mine, usage and other variables, the battery modules will last, on average, three years in a typical application. While that may initially sound low, the reality is that these batteries are continually in use, either charging or actively powering heavy machines—it is comparable to driving a car 250,000 miles in a year.

"A lot of our competition is chasing the idea of fast charging. This requires the infrastructure to provide a large underground power supply and 15-30 minutes of down-time. It also diminishes battery life and generates more heat. Our Sandvik machines can drop a battery off and pick up a fully charged one in less than five minutes, so the operator doesn't have to sit and wait," he says.

Because AVS 4.0 forgoes fast charging, the resulting benefit is that the battery lifespan increases through slower charging. Huff adds, "Charge time can be as short as one hour, but we encourage customers to charge as slowly as possible to meet the cycle. This slow-charge approach also means less power infrastructure is required at the mine."

Along with implementing the next generation of battery cells, Sandvik has redesigned its battery management system.

This safety feature monitors every cell's temperature and voltage to ensure everything is within operational range. "Because of the ongoing global semiconductor issue, we were driven to be more creative in the components selected to avoid possible supply chain problems. The outcome was a battery management system for improved reliability and function compared to previous designs," he says.

Coinciding with the official launch of the AVS 4.0 in late 2023, Sandvik will open its new state-of-the-art production line in Camarillo, California. Specifically designed to produce the new battery module, the factory will employ robotics and other automated processes to help increase production throughput and be more cost-effective. By the end of the year, a facility will also be built in Malaysia to help support

growth in Asia, Australia and other regions.

"Since 2015, we've been fully engaged in the mining market, developing battery-powered equipment from the ground up. We've always referred to what we were doing as 'making the market' because there wasn't a lot of battery electrification when we started Artisan Vehicles in 2010. We're at the forefront of getting the market to move in that direction and are now gaining traction," says Huff.

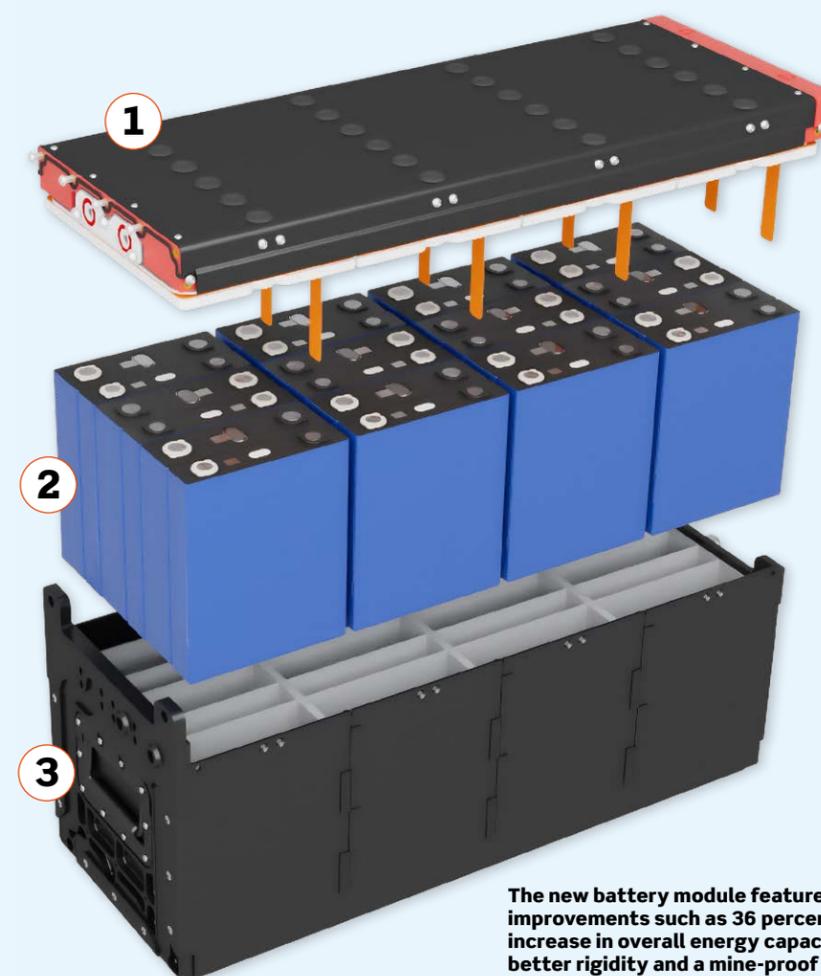
He concludes by saying that the new design and production line will grow the capacity in terms of meeting market demand: "Right now, battery equipment supply is outstripped by demand. Sandvik has the largest market share of battery equipment and machinery, so we must secure that advantage over our competitors. I'm confident that we will succeed."

SANDVIK 4.0 AVS BATTERY MODULE

Sandvik's new, improved battery module is designed to be even better for manufacturing and quality control, allowing usage of the advanced technologies.

Designed for mining:

1. Top assembly containing battery monitoring system, busbars, cooling plate and other components to complete the robust waterproof housing.
2. Latest technology in LFP cells which are fully encapsulated to dissipate heat and reduce vibration.
3. Rugged housing protects the cells, distributes coolant and allows for safe handling of the module.



The new battery module features improvements such as 36 percent increase in overall energy capacity, better rigidity and a mine-proof design with further enhanced cooling. It is also designed to be retrofitted to existing battery packs.

The Expert

As BEV Category Manager for Sandvik Mining and Rock Solutions' Parts & Services division, **Michael Roberts** deals with everything from battery logistics, the aftermarket business and battery data extraction.

MICHAEL ROBERTS JOINED

Sandvik in September 2022, after spending a decade working in the automotive battery industry. His experience in safety testing, whole pack design, technology management and investment is utilized for Parts & Services – particularly when it comes to identifying and capitalizing on new opportunities to generate revenue streams in the rapidly expanding field of BEVs.



development of new and viable businesses that utilize battery technology. This is a crucial aspect for us and the entire organization.

Q: COULD YOU PROVIDE SOME EXAMPLES OF POTENTIAL SECONDARY USE FOR BATTERIES?

A: We are actively exploring various secondary use applications for batteries.

One potential idea is to utilize the batteries themselves instead of generators underground in case of power quality issues. Another idea is to power underground drills for a shift, which could eliminate the need to extend the substation further down. Our goal is to find the right fit for the customer and design the product accordingly.

For instance, the Ajax Stadium in Amsterdam is powered by end-of-life automotive batteries that can no longer power a vehicle,

but can still provide energy for the stadium. Similarly, our battery packs could power a mine or a portion of it. As mining customers aim to reduce emissions and move away from traditional grid power, there could be a market for universal battery backup or a charge station for solar or wind to address the intermittency in renewables and aid in the transition for our customers. Our aim is to find innovative ways to extend the life of batteries beyond their end-of-life, thereby promoting circularity and sustainability.

Q: WHAT STEPS IS SANDVIK TAKING TO REDUCE THEIR CARBON FOOTPRINT AND PROMOTE SUSTAINABILITY IN THEIR BATTERY PRODUCTION?

A: Sandvik has committed to set targets in line with the Science Based Targets initiative (SBTi). We are committed to reducing our carbon footprint as much as possible, which is a key driver behind our shift towards BEVs. Being mindful of the chemistry we choose for our batteries is crucial and opting for lithium iron phosphate can have significant benefits in terms of safety, lifespan, environmental impact. Additionally, we are also constantly exploring ways to optimize our supply chain and become more efficient. For example, the opening of a new Load & Haul production facility in Malaysia, which will provide the additional production capacity needed to meet the rapid growth in demand for BEV technology, will also reduce the shipping distance of cells from China to California.

Q: WHAT IS YOUR CURRENT NUMBER ONE PRIORITY?

A: It's my role to make sure that we're putting forward the right activities so that our customers can be successful when they transition to BEV, and make it as seamless as possible for both the customer and for Sandvik.

Q: HOW DOES SANDVIK ENSURE THE RECYCLING OF BATTERIES?

A: At Sandvik, we are dedicated to achieving circularity in our products, and this includes our batteries. We are actively seeking recycling partnerships to achieve this goal. As the mining industry produces a relatively minor amount of battery cells compared to the automotive industry, we hope to leverage the recycling knowledge gained from the latter. Our focus is not only on recycling but also on exploring secondary use applications for batteries. By extending the lifespan of batteries through secondary use, we can delay the need for recycling and enable the

Our goal is to find the right fit for the customer and design the product accordingly

GIVING NEW LIFE TO OLD TOOLS

Having developed its own unique extraction technology, Sandvik Rock Tools can now offer an industry-leading recycling program for used drill bits. And by participating, customers can help generate significant reductions in CO₂ emissions and preserve scarce resources.

TEXT: NIC TOWNSEND PHOTO: SANDVIK

AT THE CURRENT rate of consumption, the world's supply of tungsten, a key component in cemented carbide, is expected to be depleted in as little as 40 to 100 years. At the same time, the whole mining industry is under increasing pressure to reduce waste and lower CO₂ emissions across the value chain.

"We're serious about sustainability, and that means taking responsibility for our products through their life cycles and contributing to a more circular economy," says Dean Kangleas, Vice President, Rock Tools Services. "At the moment, we don't know how to drill without tungsten, so it's also important that we protect that source. For both these reasons, we've really stepped up our recycling efforts in recent years and can now recycle our drill bits to an extent that is unmatched by any other OEM in the mining industry."

Recycling carbide is not new, and Sandvik Rock Tools has been offering a recycling service for over a decade. However,



Dean Kangleas

the traditional process for extracting carbide from the steel drill bits is overly cumbersome and time consuming. For one, the entire drill bit has to be shipped to an extraction plant, and given that the carbide only accounts for around seven to ten percent of the drill bit's total weight, this means a lot of additional weight has to be shipped. Secondly, the extraction process itself is slow and hazardous, and the resulting carbide is generally of substandard quality when recycled with the old process.

"We realized that if recycling was to really gain traction, we needed to find an easier way to extract the carbide from the steel body, and we needed to bring the process closer to the source," says Dean. "If we could do this, it would" ▶



FIVE BENEFITS OF SANDVIK ROCK TOOLS' RECYCLING PROGRAM

- Manufacturing tools from recycled carbide consumes 70 percent less energy compared to mined carbide.
- The process emits 64 percent less CO₂.
- Recycling tools helps preserve scarce raw materials, most notably tungsten.
- Extracting carbide locally means a huge reduction in shipments and transportation, and by extension associated emissions.
- Local extraction generates employment opportunities and economic growth in local communities.

significantly reduce the weight of material that needed to be shipped. It would also help create employment opportunities in the local communities where our customers operate, which is also important to us.”

This challenge led Sandvik Rock Tools to design and develop its own extraction machine in-house, which could easily be relocated and installed on or near a customer’s site. It uses a combination of high-frequency induction heating and vibration to heat the drill bit before shaking out the carbide – a process that is far safer and more effective than the previous manual method.

Once the extraction is complete, the steel – which accounts for around 90-93 percent of the drill bit’s weight – can be sent to a local recycling facility, while the carbide is shipped to Austria for processing. In contrast to the previous extraction method, which saw the entire drill bit being shipped, this represents a significant reduction in the loads being shipped with corresponding reductions in emissions from transportation.

Concurrently, Sandvik Rock Tools has also been working closely with Wolfram Bergbau und Hütten AG, a Sandvik-owned company and supplier of tungsten powders, to develop a new chemical process for recycling the carbide

that can break it down to raw tungsten and cobalt in virtually virgin state. The resultant raw materials are 100 percent recyclable and can be returned to production to manufacture new drill bits and tools.

“Our extraction machines, and this new recycling process, are unique to Sandvik,” says Dean. “We are now the only OEM who can extract carbide locally at a customer’s site, and then recycle it back down to virgin material.”

HAVING DEVELOPED THE technology and the processes, the next innovation from Sandvik Rock Tools was to introduce the industry’s first ‘opt-out’ recycling program. While in the past, customers had to sign up for tool recycling, now it is automatically included in any sales agreement.

“Basically, all customers have to do is collect the old drill bits and deposit them in the bins that we provide – and we’ll take care of the rest,” explains Dean. “We collect them and we pay them for the scrap metal at market rates. We’re also happy to purchase competitors’ drill bits from them too. The customer is not required to do anything else but can rest easy knowing that they’re contributing to improving their own sustainability impact and that their old tools are entering into a circular economy.”

IT IS ESTIMATED that making tools from recycled carbide consumes 70 percent less energy compared to mined carbide, and that the process emits 64 percent less CO₂. Sandvik Rock Tools’ ambition is to collect 90 percent of its drill bits by 2025. If successful, this will save around 4500 metric tons of CO₂ per year as well as significantly reduce the amount of raw materials consumed in the production of new tools. It will also play an important role in helping Sandvik meet its ambition to reduce its CO₂ emissions by 50 percent by 2030.

Furthermore, for participating customers, the CO₂ savings generated by the recycling program can be used when calculating their own carbon footprints too.

“Recycling drill bits and bringing them back into the circular economy contributes to reducing customers’ emissions,” says Dean. “The message that we’re getting from our customers is that sustainability is just as important to them as it is to us, and a lot of them have ambitious targets of their own. They’re so excited by our program, and we expect to see it generate a lot of traction in the coming years.”

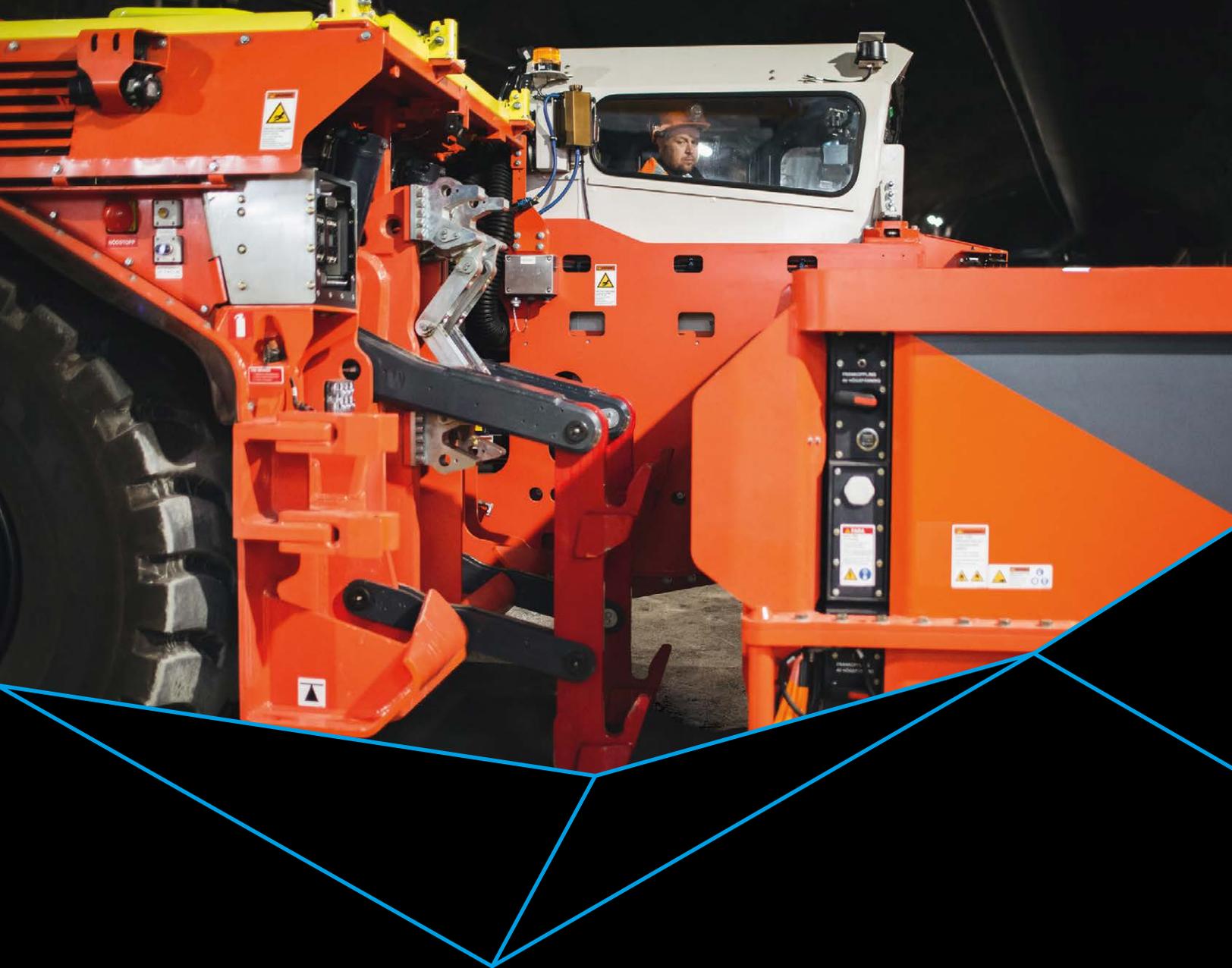
HOW IT WORKS

Sandvik Rock Tools’ recycling program is designed to make the process as simple as possible for the customer.

- Customers discard used drill bits in bins provided by Sandvik Rock Tools.
- Sandvik Rock Tools collects the drill bits and pays the customer for the scrap metal. This includes competitors’ drill bits too.
- The drill bits are taken to the closest extraction machine, which could potentially even be located on the customer’s site.
- The carbide is extracted from the drill bit’s steel body. The carbide is shipped to the recycling plant in Austria, while the steel is sent to a local recycling facility.
- The carbide is broken down into raw tungsten and cobalt. The quality of the raw material is virtually on par with virgin material.
- The tungsten and cobalt are returned to Sandvik Rock Tools’ production and used to manufacture new drill bits.
- The recycled drill bits are sold to customers, thus completing the circle.



Tungsten is a rare metal that’s almost exclusively found naturally occurring on Earth in compound with other materials.



FASTEST PIT STOP READY TO SWAP?

Sandvik Mining and Rock Solutions' third-generation loaders and trucks are designed from the ground up entirely around their battery system and electric driveline. Our patented self-swapping battery system enables the industry's fastest BEV "pit stop" – all without need for large infrastructure or power systems.

Ready to start your battery-electric transition? Join our journey towards emission-free mining.