FACT SHEET: EMERGING ENERGY-EFFICIENT TECHNOLOGIES IN MINING

This fact sheet provides an overview of six different emerging[1] energy-efficient technologies in mining: battery electric mine vehicles, hybrid electric haul trucks, continuous mining, ventilation on demand, in-pit crushing and conveyance, and alternative milling technologies. For an overview of the mining sector and established energy-efficient technologies, please refer to the Industrial Energy Efficiency Best Practice Guide.

[1] A technology is considered emerging if it is not widely adopted in Ontario.

EMERGING TECHNOLOGIES TO REDUCE ENERGY CONSUMPTION AND GREENHOUSE GAS (GHG) EMISSIONS IN MINING

- Battery electric mine vehicles (BEVs)
- Hybrid electric haul trucks (diesel-battery or diesel-trolley assist)
- Continuous miner
- Ventilation on demand (VOD)
- In-pit crushing and conveyance (IPCC)
- Alternative milling technologies

BATTERY ELECTRIC MINE VEHICLES

Battery electric mine vehicles (BEVs) have no internal combustion engine and are powered by an electric drive train using rechargeable batteries (mainly lithium-ion currently). They offer the mobility of conventional diesel engine-powered equipment, zero local emissions and better traction at low speed. Depleted batteries can be charged on the vehicle, but are often swapped out for a charged battery in the garage, like changing batteries or propane tanks on a forklift (although much larger).

ADVANTAGES

Zero tailpipe emissions – eliminates odours, heat and fumes for nearby personnel, improving worker health.

Zero tailpipe emissions – reduces the need for underground ventilation (fan motors) and heated make-up air, generating significant energy savings.

Electric motors are quieter than diesel engines, which improves working conditions.

Improved low-speed traction.

Longer drive train life.

Lower maintenance requirements, lower operating costs, and improved operational energy efficiency.

Reduces or eliminates the need for diesel or propane fuel transportation, storage, dispensing and conventional fire safety equipment.

CONSIDERATIONS

- Purchase price (without incentive) is about 1.5x to 2x that of conventional diesel for all vehicle types.
- Availability, battery life, battery end of life disposal.
- Range is less than diesel or hybrid, difficult to recharge remotely if charge runs too low.
- Cold weather limitations.
- Cost of charging infrastructure.
- Requires different and sometimes more complex fire safety equipment.

ADOPTION

While battery electric mining vehicles have been tested experimentally for many years, the technology really accelerated and began to be field-proven and commercially accepted in 2019, and Ontario mines have been enthusiastic early adopters. Like diesel mining equipment, most battery mining equipment is manufactured in Europe, the U.S. and Japan, but there are also world-class, competitive Ontario-based suppliers. Currently, the technology and economics for BEVs are best suited to underground operations, where battery range, temperature ranges and proximity to charging stations are less challenging than open-pit mining.

Emerging BEV applications include testing and adoption of larger-capacity underground equipment and open-pit equipment that must travel longer distances and operate in much colder conditions. There is an active international industry working on battery technology advancements for mining vehicles.

HYBRID ELECTRIC HAUL TRUCKS (DIESEL-BATTERY OR DIESEL-TROLLEY ASSIST)

Hybrid haul trucks combine a diesel engine and electric drivetrain (like a hybrid car) to reduce diesel fuel consumption and emissions and provide excellent low-speed traction. In hybrid diesel-battery systems, the comparatively small onboard battery is charged when braking or with any surplus diesel engine power not used when the vehicle is moving, so external charging is not required. The range of a diesel-battery vehicle is much greater than that of a fully electric vehicle and is better suited to the long distances of open-pit mining. An alternative type of hybrid haul truck is a diesel-trolley assist system that uses overhead wires (like a streetcar) to provide power to the electric drive motors on common road sections, especially on long ramp climbs where fuel consumption is greatest. A trolley assist system can also be used to power a 100% electric battery vehicle.

ADVANTAGES

Overall tailpipe emissions reduction of 40–50%.

Reduction of engine noise when diesel engine not running.

Improved low-speed traction and higher uphill speeds when operating on electric drive, improving productivity.

Less diesel system maintenance (fewer running hours on engine).

Generally lower operating costs (depends on local electricity and diesel prices).

Not affected by the cold temperature or range limitations of battery-only vehicles, well suited for open pit and long distance operation.

In some cases, existing diesel equipment can be converted to hybrid.

CONSIDERATIONS

- Price (without incentive) is about 1.5x cost of conventional diesel for all vehicle types.
- Possibly greater and different type of fire risks for battery vehicles.
- Trolley assist requires a relatively large capital investment of $8–10K per metre for infrastructure that cannot be relocated.
- Trolley assist may not be practical for sites that experience frequent icing conditions as ice or frost may accumulate on wires/busbars.

ADOPTION

While smaller hybrid electric vehicles (pickup trucks, vans, etc.) are commercially well adopted and common, the development, field-testing and adoption of larger vehicles such as haul trucks is still in the early stages. One example is a 220-metric-ton payload diesel battery hybrid mining truck being tested at an iron mine in China.

Basic trolley assist vehicles have been used in Sweden for underground mining since the 1950s, but the technology has more recently being significantly adapted and implemented at an open-pit copper mine in Sweden (2018) and an open-pit copper mine in British Columbia (2022).

CONTINUOUS MINER

These electrically powered vehicles have rotary cutters that advance with wheels or tracks into the working face of the mine and directly dislodge or excavate rock and ore. Excavated material is typically collected with mechanical arms or guides and fed to the rear of the machine via conveyor. These systems are commonly used in soft-rock underground operations, but more recent advances are being made to support their use in hard-rock conditions. When conditions allow, they significantly reduce the need for drilling, blasting and mucking/loading, and can be operated remotely or autonomously, and integrated to conveyor systems.

ADVANTAGES

All electric, no tailpipe emissions, diesel engine fumes or engine noise.

Well-suited to softer rock and ore types.

Significantly reduces need for drilling machines, blasting processes and use of explosives.

Less labour-intensive and less hazardous than drilling and blasting process.

Can reduce or eliminate need to evacuate work area for blasting processes.

When combined with conveying systems, can significantly reduce need for conveying vehicles (scoops, haul trucks).

CONSIDERATIONS

- Requires high power electrical delivery at working face.
- Requires more ventilation and dust control while cutting compared to drill and blast.
- Difficult to move or reverse the system other than in the working direction, repairs can be challenging to do in place, tight working areas.
- Cutting teeth and wheels may require frequent replacement, high cost.
- Roof control may be more challenging with tight working areas.

ADOPTION

Continuous miners are standard equipment in most Canadian coal, gypsum, salt and potash mines, including several in Ontario. They are used to drive development tunnels but can also be used as production machines. Hard-rock continuous mining technology is still in the development stage, including trials in Australia in 2020 and in Sudbury in 2021–22.

VENTILATION ON DEMAND (VOD)

A VOD system uses sensors to monitor the air quality and control ventilation in an underground mine. Ventilation is typically the largest electrical load in an underground mine. VOD can reduce energy consumption by directing adequate conditioned and fresh air ventilation to active areas with personnel, reduce flow where not required, and manage air and dust control during blast operations, allowing work to resume faster.

ADVANTAGES

Up to 50% electrical savings.

Up to 45% heating and related GHG savings.

Productivity improvement.

Enhanced air quality control, fan control requires less time and labour compared to adjusting mechanical doors and dampers, better control of dust after blasting.

CONSIDERATIONS

- Initial cost for sensors and controls and software.
- Inspection costs.
- Requirement for robust wireless infrastructure underground to enable higher levels of automated VOD.

ADOPTION

VOD is enabled by improved and more affordable sensors, software, controls, wireless communication and variable frequency drive technologies. These systems have been widely adopted in mines across Canada and worldwide over the last 15 years, but there are still many opportunities to implement in Ontario. There are varying levels of sophistication of implementation, so more basic VOD systems can be upgraded to fully automatic and sensor-based systems. The rapid adoption of electricity-powered, zero-exhaust mining vehicles and remote-operated vehicles in Ontario has greatly changed the air quality and worker exposure in many mines, providing even more opportunities to manage safety and cost of ventilation.

The amendment to *O. Reg. 854, Mines and mining plants* and the ventilation requirements for diesel-powered equipment in underground mines from 2023 stipulates that ventilation is based on diesel-powered equipment (no longer generic "horsepower") and a general oxygen requirement, so ventilation requirements can possibly be reduced for BEVs.

IN-PIT CRUSHING AND CONVEYANCE (IPCC)

An alternative to using conventional haul trucks for transporting ore and waste material from surface operations. Permanent, semi-mobile and fully mobile IPCC systems can be combined to suit site requirements over the life of the mine, and can significantly reduce or eliminate the need for haul trucks and associated costs and emissions. Conveyors can be many kilometres long and replace dozens of vehicles and associated labour costs.

ADVANTAGES

Reduction or elimination of need for large-haul vehicles and operators, and heavy road maintenance.

Fully electric, reduction or elimination of in fuel costs and emissions associated with diesel hauling.

Operating costs 45–65% lower than conventional truck and shovel methods.

Conveyors can traverse rugged areas not suitable for haul roads.

CONSIDERATIONS

- In most cases, higher initial costs than truck hauling and significant custom engineering design required.
- Selection of suitable conveying components is critical.
- Significant failure or accident involving conveyors can shut down operations for extended periods.
- The physical constraints of many existing mining operations may not support IPCC.

ADOPTION

A large iron mine in Brazil used IPCC to reduce the need for 100 trucks. A mobile crushing system and 37 kilometres of conveyor belts reduced diesel consumption by 70%. There are other installations in Chile, South Africa, Peru and Thailand.

ALTERNATIVE MILLING TECHNOLOGIES

Several technological advancements provide energy-saving alternatives to the conventional rod mills, ball mills and semi-autogenous grinding (SAG) processes used to reduce particle sizes of ore. High pressure grinding rolls (HPGR) use two large rollers with the same dimensions, rotated against each other at the same speed to crush and compact material. Vertical mills use a large screw mounted vertically to lift and grind material. Vertical mills are better suited to smaller particle sizes and are sometimes used in the secondary stage after a primary grinder.

ADVANTAGES

HPGR can completely replace conventional SAG, rod and ball mills with ~35% reduction in electricity consumption.

Vertical mills provide ~40% reduction in electricity consumption compared to conventional ball mills at smaller particle sizes.

Both technologies also provide improvements in process control, maintenance and cost.

CONSIDERATIONS

- Cost of replacing existing systems if still in good condition.
- Significantly increased mechanical complexity and the potential for failure if not well maintained.

ADOPTION

These technologies are being well adopted. For example, a Canadian iron ore producer awarded an order for two powerful vertical mills to be delivered in 2024 and an Ontario gold mine uses HPGR and a ball mill followed by two vertical mills.