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Emerging Energy Efficient Technologies in Mining Information Session

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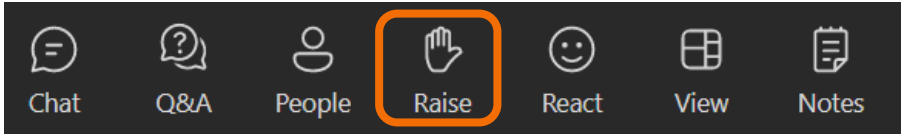

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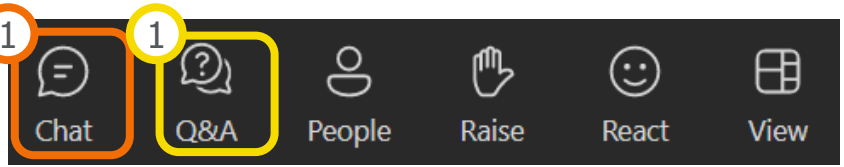

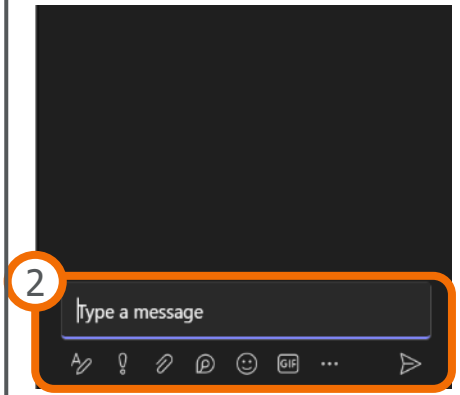

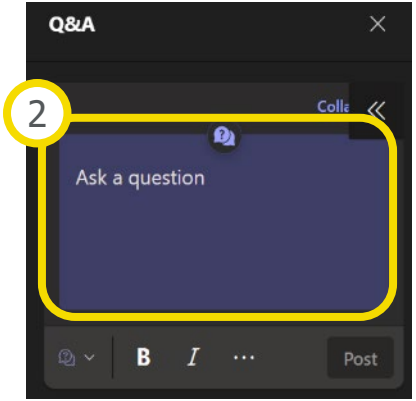

Introduction

Emily Thorn Corthay, MASc., P.Eng, CEM, CMVP, Founder and CEO of Thorn Associates

20-year career in industrial decarbonization and energy management, she has assisted her clients in achieving over $100 million in implemented energy savings and reduction in over 500,000 tonnes of CO_2e, acting as project manager, technical reviewer, and energy/sustainability engineer for over 80 energy & decarbonization projects in 15+ countries. Emily is a 2025 Clean50 award winner.

Robert Storey, P.Eng., CEM Energy Engineer, Associate at Thorn Associates

30 years of project and operations experience, specializing in energy since 2001, ISO 50001, codes and standards, over 300 Save on Energy projects with Toronto Hydro, client projects under the former Industrial Accelerator and Northern Industrial Electricity Rate programs.

Objectives and agenda

Introduction to emerging technologies in the mining sector that support energy efficiency and de-carbonization, with a focus on:

- Battery Electric Mine Vehicles
- Hybrid Electric Haul Trucks (Diesel-Battery and Diesel-Trolley Assist)
- Continuous Miners
- Ventilation on Demand (VOD)
- In-Pit Crushing and Conveyance (IPCC)
- Alternative Milling Technologies

Ontario mining sector – key statistics

- Ontario's mining sector is Canada's second largest (after Quebec), producing over $13.5B worth of minerals (2022) and employing 31,000 direct and 47,000 indirect workers
- 36 active mining operations in Ontario: 17 gold, 9 base metal, 1 iron, 1 platinum and 8 industrial mineral mines
- Ten of these mines also produce critical minerals, including cobalt, copper, indium, nickel, platinum group elements, selenium, tellurium, and zinc

Ontario mining sector – key statistics (cont'd)

- In 2021, the Ontario mining sector consumed 41 Petajoules of energy (about 47% of it is electricity) and emitted 1.5 Mtonnes CO2e (Scope 1 - direct)
- Traditional diesel mobile fleets account for the majority of the Scope 1 emissions in Ontario mining operations, followed by natural gas and propane heating (air and process heating)
- Scope 2 emissions are associated with offsite electricity generation, used to power underground ventilation, crushing, grinding, hoisting, conveying, pumping etc.
- Mining sector electricity use is expected to increase with adoption of electric vehicles and electric heating technologies

Battery electric mine vehicles

- No internal combustion engine
- Powered by an electric drive train using rechargeable batteries (mainly lithium-ion currently)
- Similar (or better) mobility vs conventional diesel engine-powered equipment, with better traction at low speed
- Zero local emissions
- Depleted batteries can be charged on the vehicle or swapped out for a charged battery in the garage

Battery electric mine vehicles – advantages

- Zero tailpipe emissions, eliminates fuel combustion odours, heat and airborne particulate matter for nearby personnel (health benefit)
- May reduce needs for underground ventilation (fan motors) and conditioned make-up air, generating significant energy savings
- Electric motors are quieter than diesel engines, improves working conditions
- Improved low-speed traction
- Longer drive train life
- Lower maintenance requirements and lower operating costs
- Improved operational energy efficiency
- Reduces or eliminates the need for diesel or propane fuel transportation, storage, dispensing and conventional fire safety equipment

Battery electric mine vehicles – considerations

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

Battery electric mine vehicles – adoption

- Battery powered vehicles began to be field-proven and commercially accepted in 2019, and Ontario mines have been enthusiastic early adopters
- Like diesel mining equipment, most battery powered equipment is manufactured in Europe, USA and Japan, but there are competitive Ontario based suppliers of some equipment
- Available technology is best suited to underground operations, where battery range, temperature ranges and proximity to charging stations are less challenging than open-pit mining
- Future availability may include equipment suitable for open pit mining, with larger haul capacities, greater range and improved cold weather performance

Hybrid electric haul trucks

- Combine a diesel engine with an electric drivetrain (like a hybrid car) to reduce fuel consumption and emissions and provide excellent low-speed traction

Hybrid diesel-battery

- An onboard battery is charged with regenerative braking and surplus diesel engine power, so external charging is not required
- Range is much greater than battery alone, suitable for long distances of open-pit mining

Hybrid diesel-trolley assist

- Uses overhead wires (like a streetcar) to power the electric drive motors on the trucks on common roads and long ramp climbs where fuel consumption is greatest
- A trolley assist system can also be used to power a 100% electric battery vehicle

Hybrid electric haul trucks – 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, leading to significant productivity improvements
- 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

Hybrid electric haul trucks – 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 may accumulate on wires/busbars

Hybrid electric haul trucks – adoption

Hybrid diesel-battery

- Smaller vehicles (pickup trucks, vans, etc.) are commercially common
- Development, field-testing and adoption of large vehicles (e.g. haul trucks) is still in the early stages
- One example is a 220-metric-ton payload diesel battery hybrid haul truck being tested at an iron mine in China

Hybrid diesel-trolley assist

- Basic systems used in Sweden for underground mining since 1950s, 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

- Electrically powered vehicles with rotary cutters that advance with wheels or tracks into the working face and directly dislodge or excavate rock and ore
- Excavated material collected with mechanical arms or guides and fed to the rear of the machine via conveyor
- 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

Continuous miner – advantages

- All electric, no tailpipe emissions, nor 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)

Continuous miner – considerations

- Requires high power electrical delivery at working face
- Requires more ventilation and dust control while cutting versus 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

Continuous miner – adoption

- Continuous miners are standard equipment in most Canadian coal, gypsum, salt and potash mines, including several in Ontario
- They are most often 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 Sudbury in 2021–22

Ventilation on demand

- Ventilation on Demand (VOD) systems use sensors to monitor air quality and control ventilation in an underground mine
- Ventilation is typically the largest electricity consumer in an underground mine
- Air is conditioned and directed to active areas, reducing flow with variable frequency drives (VFD) where not required, major energy savings in fan loads and air heating/cooling
- Can improve air and dust control during blast operations, allowing work to resume faster

Ventilation on demand – advantages

- Up to 50% electrical savings
- Up to 45% heating and related GHG savings
- Productivity improvement, fan control requires less time and labour vs adjusting mechanical doors and dampers, better control of dust after blasting
- Enhanced air quality control
- Proven technology (even though it is still emerging in Ontario)

Ventilation on demand – considerations

- Initial cost for sensors and controls and software
- Inspection costs
- VFDs on large fan motors require engineering studies to avoid possible noise, vibration issues, harmonics etc. vs single speed operation
- Requirement for robust wireless infrastructure underground to enable higher levels of automated VOD

Ventilation on demand – 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 guidance from 2023 stipulates 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.

In-pit crushing and conveyance – advantages

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

In-pit crushing and conveyance – 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

In-pit crushing and conveyance – 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, which use a large screw mounted vertically to lift and grind material, are best suited to smaller particle sizes and are sometimes used in the secondary stage after a primary grinder

Alternative milling technologies

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

Alternative milling technologies – adoption

- These technologies are becoming well adopted in Ontario and other areas of Canada
- A Canadian iron ore producer awarded an order for two powerful vertical mills to be delivered in 2024
- An Ontario gold mine uses HPGR and a ball mill followed by two vertical mills

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Appendix – acronyms

- Greenhouse Gas (GHG)
- Carbon Dioxide Equivalent (CO2e)
- Battery Electric (Mine) Vehicles (BEV)
- Ventilation on Demand (VOD)
- In-Pit Crushing and Conveyance (IPCC)
- Variable frequency drive (VFD)
- Semi-autogenous grinding (SAG)
- High pressure grinding rolls (HPGR)