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AusIMM Sydney Branch Tech Talk: Mine electrification – what technology is available now, and how do the costs stack up?

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Presenter: Sarah de Vries,
Principal Consultant

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WHY ELECTRIFY MINING?

Why electrify mining? Decarbonisation

> *"Mining contributes approximately 8% of global GHG emissions, with 40–50% of this from diesel combustion in mobile equipment."*
> **Source**: McKinsey & Company, "*Creating the zero-carbon mine*", July 2021
> https://www.mckinsey.com/industries/metals-and-mining/our-insights/creating-the-zero-carbon-mine

How to reduce fossil fuel usage?

- Global use of fossil fuels:
  - Power generation
  - Heating / Cooling
  - Transportation (Road, Air and Sea)
  - Industrial processes
- Alternative fuels to fossil fuels:
  - Renewable electricity generation (solar, wind, hydro, nuclear)
  - Renewable electricity storage (lithium-ion batteries, sodium, vanadium etc)
  - Hydrogen
  - Ammonia
  - Various Technology Readiness Levels (TRL), costs and availability

Bellevue Gold Solar Farm and BESS
Source – Zenith Energy (zenithenergy.com.au)

Kathleen Valley Wind Farm
Source – Zenith Energy (zenithenergy.com.au)

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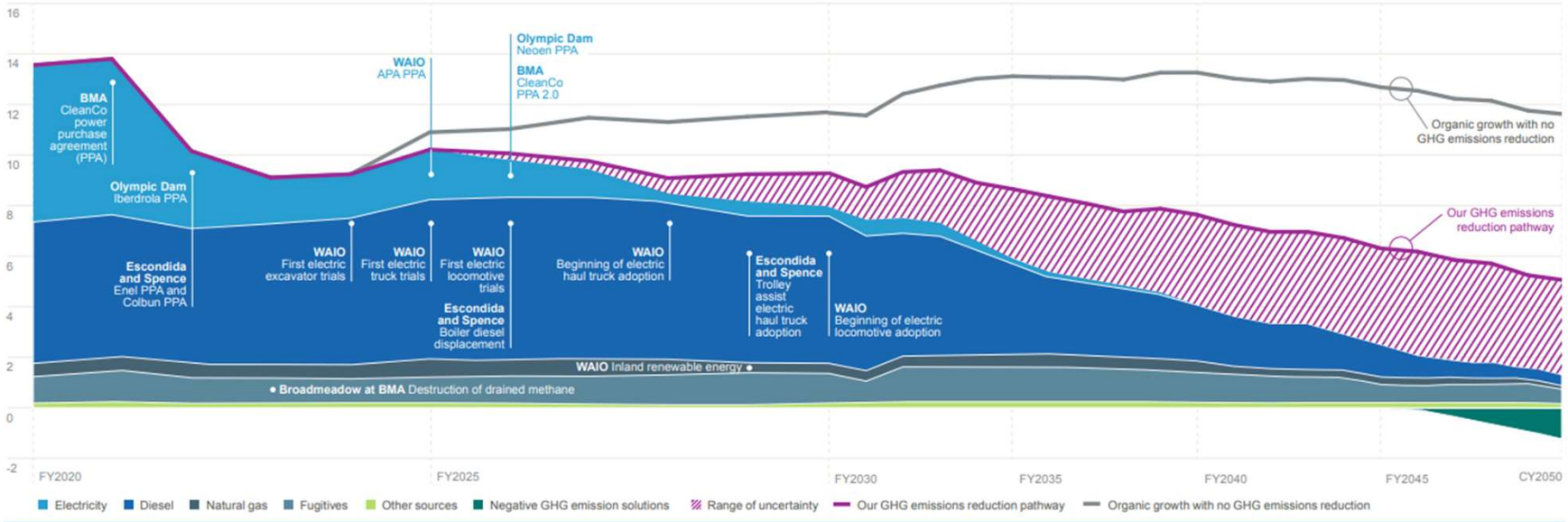
How to reduce fossil fuel usage in mining?

- Replace fossil fuel **power generation** with solar, wind, hydropower etc, with short term and long term Battery Energy Storage Systems (BESS)
- Remove / reduce diesel consumption from **truck haulage** by utilizing current **electrification** technologies (ie IPCC, EPCC, rope-con, railveyor, trolley-assist truck haulage)
- Remove / reduce diesel consumption from **loading equipment** by replacing with **cable-electric** face shovels, excavators, tethered underground loaders
- Reduce diesel consumption by replacing diesel **trucks and loaders** with **diesel-electric trucks and loaders** (up to 30% reduction in fuel consumption)
- Remove / reduce diesel consumption by replacing **diesel drills** with **electric drills**
- Reduce diesel consumption by replacing **diesel** with **biofuel / renewable diesel**
- Reduce diesel consumption by utilising **remote health monitoring, fleet management systems, mine planning systems**, AI to minimize inefficiencies (decrease queuing and idle time, reduce rehandle)

BHP's Decarbonisation pathway (Scope 1 and 2)

Figure 1.2: Projected (to FY2030) and potential (beyond FY2030) pathways to our operational GHG emissions long-term net zero goal[6]
Scopes 1 and 2 emissions ($MtCO_2$-e) (adjusted for acquisitions, divestments and methodology changes)



Source – BHP Climate Action Plan 2024.pdf

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An alternative approach – Rio Tinto

Renewable diesel:

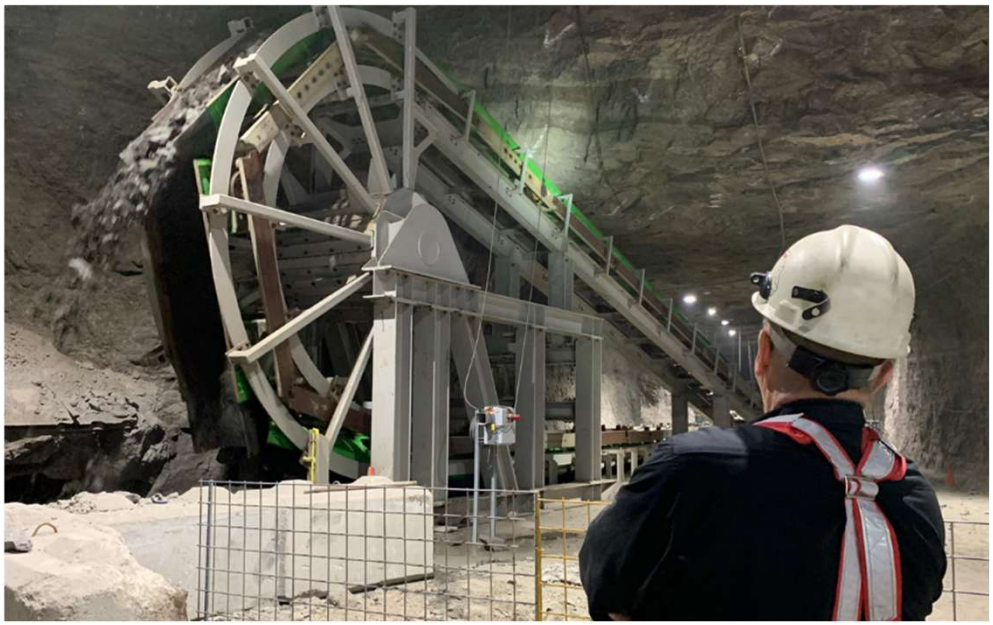
- 90% soybean, remainder animal fat and used cooking oil
- Boron 2023
- Kennecott 2024
- Trialled for 4 weeks in Pilbara in 2025 – 20% renewable (used cooking oil) and 80% fossil diesel
- Pongamia seed farms in Australia

Another alternative - Fortescue

- Real Zero by 2030 (no offsets)
- Renewable power
- Replacing diesel with battery-electric or cabled electric
- Also testing ammonia power shipping and hydrogen fuel cell trucks

Source – Fortescue.com

Why electrify mining? Cost and Productivity



Source – Railveyor.com

- Electricity is cheaper than diesel
- Electricity is more efficient than diesel (diesel ~30% efficient, electric motors ~90% efficient)
- Speed increase, particularly on ramp / incline
- Reduced maintenance costs

- Underground – reduced ventilation and cooling costs

Why electrify mining? Safety and health benefits

Minetruck MT42 SG Trolley
Source – Epiroc (www.epiroc.com)

Safety

Improved working conditions

Social license to operate

Savings in ventilation/cooling

CURRENT TECHNOLOGIES

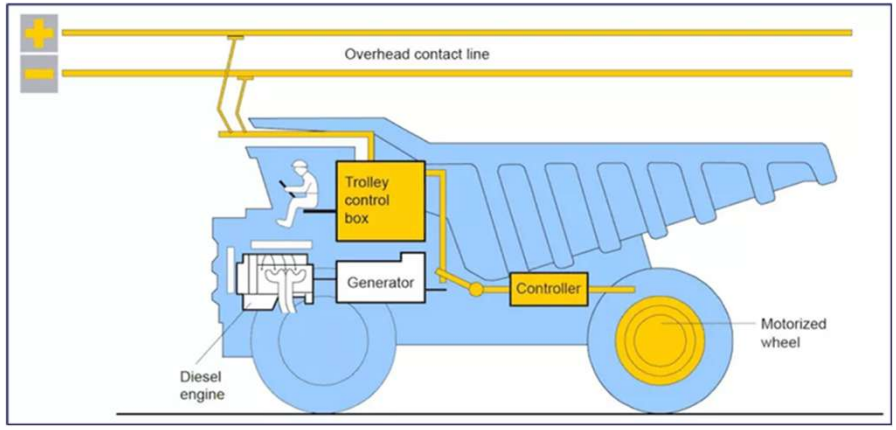
Open Pit – In Pit Crushing and Conveying (IPCC), Rope Con, Railveyor etc

RopeCon at Media Luna
Source – ResourceWorld.com

IPCC at Sentinel Mine, Zambia
Source – First Quantum Minerals

Open Pit – Diesel-Electric Trucks and / or Trolley Assist

- Diesel-electric trucks reduce fuel consumption by up to 30%
- These trucks can also be used with trolley assist systems



Source – Global Road Technology and Siemens

Hitachi 3500AC at Kansanshi Mine
Source – Hitachi Construction Machinery

Open Pit – Plug-in Electric Equipment

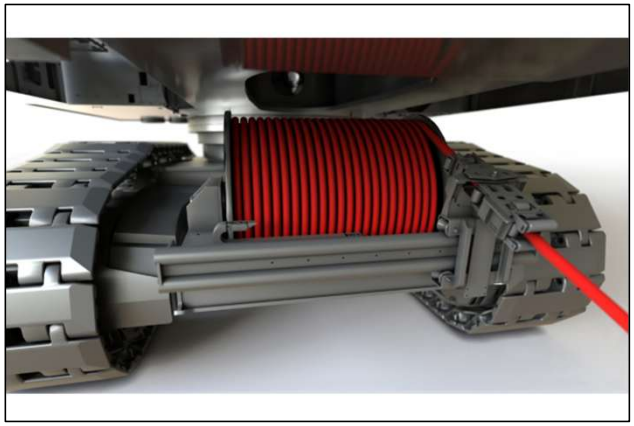
Electric Loading Equipment

- Draglines (Coal)
- Electric face shovels
- Electric excavators

Electric Production Drills

Operational Implications

- Cable handling (automatic reelers)
- Cable handling for blasts
- Cable damage due to being run over



Source – Liebherr.com

Underground – Crushing and Shaft Hoisting / Conveying

- Crushing and Shaft Hoisting or Conveying
- Battery electric locomotives (lead acid)
- Tethered electric loaders
- Trolley assist haulage (Kiruna trucks)

Source – Sandvik

Source – Mount Isa City Council Library

EMERGING TECHNOLOGIES

Why are lithium-ion BEVs are now an option?

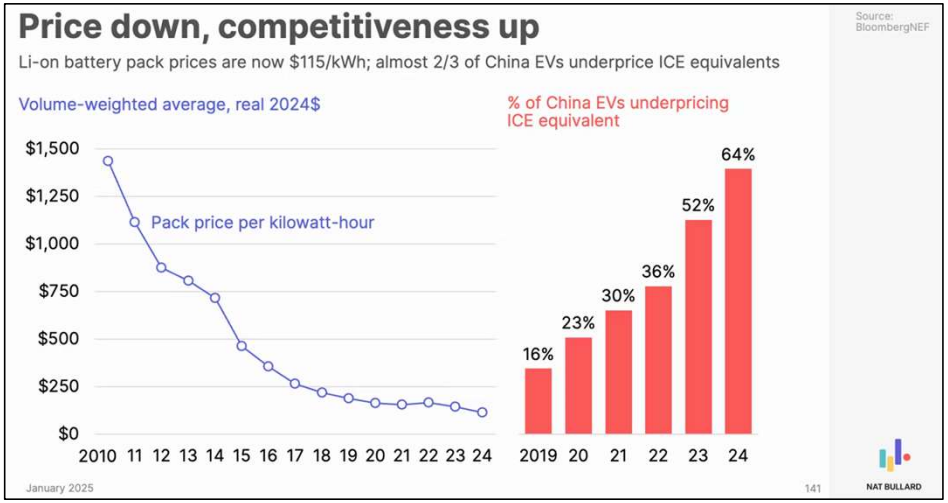
Capacity/range is increasing

Cost is reducing

Regenerative braking

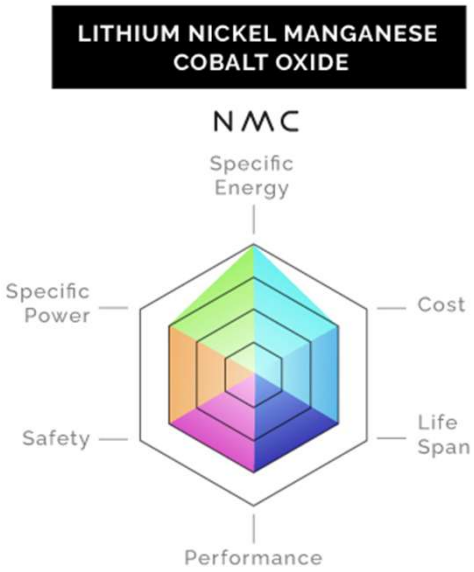
Battery swapping

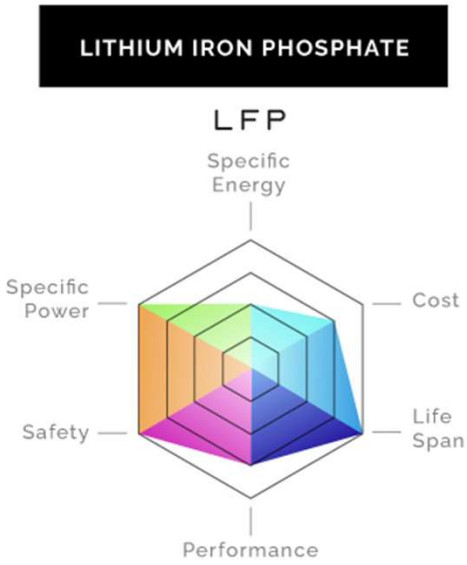
"By 2025, over 50 mines globally are expected to be piloting or operating battery-electric fleets."
"Borden Mine (Goldcorp, now Newmont) has eliminated all diesel equipment underground."
Source: Global Mining Review, 2023; Epiroc 2024 Report
https://www.globalminingreview.com/handling-processing/28032023/battery-electric-mining-market-on-the-rise/

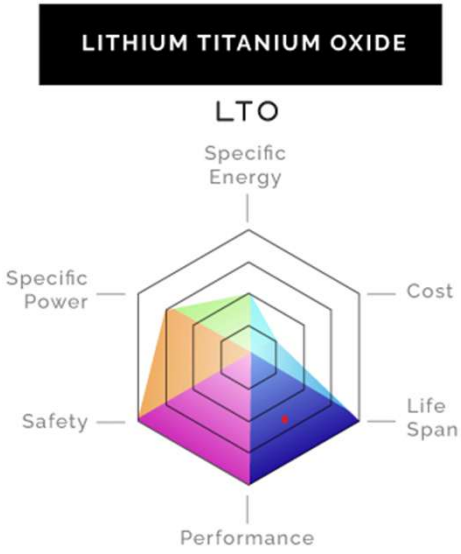


Li-ion battery pack prices
Source (www.nathanielbullard.com/presentations)

Lithium-ion battery chemistries (Underground BEVs)







Lithium Nickel Manganese Cobalt (NMC)
used by Epiroc and MacLean

Lithium Iron Phosphate (LiFePO4)
used by Sandvik

Lithium Titanium Oxide (LTO)
used by Normet

Image Source – Visual Capitalist (https://elements.visualcapitalist.com/the-six-major-types-of-lithium-ion-batteries/)

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Underground BEV trucks

Toro TH550B
Source – Sandvik (www.rocktechnology.sandvik.com)

- Increased speed on grade
- Faster dig speeds (loaders)
- Regenerative braking saves power to battery
- Reduced maintenance costs
- Current limitation – battery capacity not yet sufficient for deep mines to haul to surface

Underground - BEV availability

Category	Vehicle Types	Examples / Suppliers	Current Availability	Trends / Outlook
Drills & Ancillary	Face drills, bolters, utility/support units	Sandvik, Epiroc, Normet, MacLean	Commercially available	Widely deployed in Canada, Sweden, Finland; plug-in charging model standard
Loaders (LHDs)	14–18 t class	Sandvik, Epiroc	Commercially available (to 18t)	Limited to medium size; larger units in development
Trucks	42–50 t payload	Sandvik TH550B, Epiroc MT42 Battery	Commercially available (to 50t)	Sandvik TH665B (65t) completed trials, not yet commercial (2024)
Light Vehicles (BELVs)	Light-duty utes, people movers, supervisory vehicles	Toyota EV conversions, Ford F-150 Lightning, Rivian R1T, Rokion, Kovatera	Available via conversion or purpose-built platforms	Battery range 60–100 km per charge; ideal for short-range utility roles

Ventilation and cooling implications

Environmental and cost benefits:

- No exposure to DPM for workers
- Reduced primary and secondary ventilation requirements
    - Reduction in size or number of primary vent raises
    - Reduced development sizes due to reduced vent duct sizes
- Reduced heat generation
    - Reduced cooling requirements

Underground – Diesel-electric Loaders and Trucks

Loaders:

- Caterpillar 2900XE

Trucks:

- Sandvik 65t
- Epiroc 65t

Cat 2900XE XE
Source – Caterpillar

Open Pit BEV trucks

- Chinese OEMs are operating 70-90t BEVs in China and SE Asia
- Ultra class BEV trucks are not commercially available
    - Prototypes are being tested by Caterpillar (Cat 793 XE – Early Learner Program), Komatsu, Hitachi
    - Liebherr – Energy agnostic – Fortescue providing batteries for T264
    - Very big batteries and chargers required for these trucks!
    - OEMs developing dynamic charging systems to power truck and charge battery (Caterpillar, Liebherr, BluVein)

Cat 793 XE
Source – Caterpillar

Other emerging technologies

Bio-diesel

Hydrogen fuel cells

Ammonia

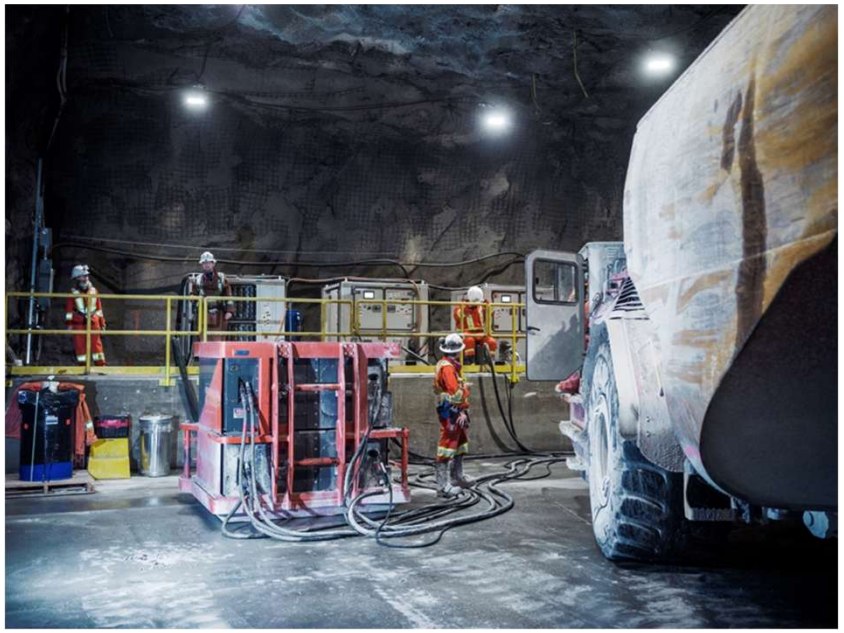
INFRASTRUCTURE REQUIREMENTS

Underground BEVs – Charging the battery

BEV trucks and loaders:

- Static battery charging vs battery swapping
- Loaders – 1-2x per shift
- Trucks – up to every cycle
- Trolley-assist possible

Source – Sandvik Mining and Rock Solutions



Brucejack Mine Battery Swap Bay
Source – Adam Lach, Sandvik Mining and Rock Solutions

Open Pit BEVs – Charging the battery

BEV trucks:

- Fortescue:
  - need to charge the batteries on their 240t trucks every ~4 hours
  - Charging will take ~35 minutes
  - Will increased speed offset the charging time required?
- Dynamic charging options:
  - Traditional trolley-assist with BEV
  - Dynamic charging (Caterpillar and Liebherr developing)
  - BluVein XL

Caterpillar Dynamic Energy Transfer
Source – www.caterpillar.com

Infrastructure considerations

Power availability

Electrical distribution

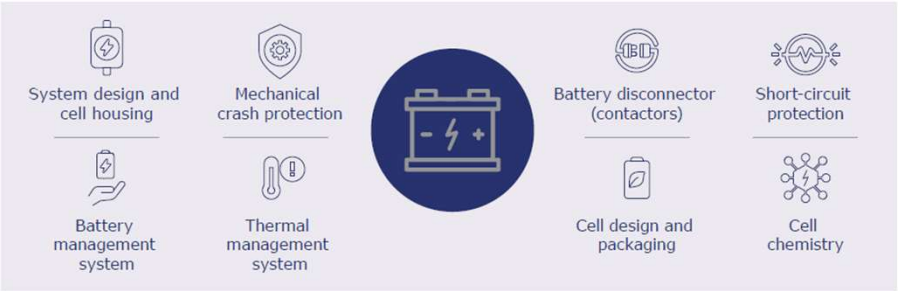
Charge / swap stations

Mine-wide connectivity (FMS / EMS)

Reduced ventilation and cooling

Safety

- Potential safety issues associated with BEVs underground:
  - Thermal run-away leading to fire or explosion
  - Fume generation during a fire (HF monitoring in battery charge bays)
  - Rupture causing toxic or flammable liquid / gas release
  - Electric shock risk
  - Manual handling risks
  - Burns due to heat



Components of battery safety
Source – IGO / Perenti / ABB, May 2024, Making Electrified Underground Mining a Reality

THE BOTTOM LINE – WHAT WILL IT COST?

BEVs are still more expensive upfront

Vehicle Type	Diesel Cost (USD)	BEV Cost (USD)	Capex Premium
LHD (18t)	$1.1M	$1.9M	~70%
Truck (42–50t)	$1.5M	$2.5M–2.8M	~75–90%
Light Vehicle (converted)	$80k	$130k–150k	~65–90%
Light Vehicle (purpose-built)	$90k	$200k+	>100%

But… Total Cost of Ownership is expected to be lower

Underground BEV versus diesel evaluation

- Equipment type: e.g. 50t truck
- Haul route and gradient
- Daily/annual utilization (hours, km, tonnes)
- Site layout and ventilation profile

- Truck purchase
- Workshop setup
- Ventilation
- Cooling
- Electrical infrastructure

- Fuel / energy
- Maintenance
- Downtime
- Ventilation power

- Track battery replacement cycles (usually 3–5 years)
- Include BaaS if using leased battery model (cost per cycle or kWh)
- Account for battery degradation, end-of-life disposal, or second-life reuse

- CAPEX
- Annual OPEX
- Sensitivity

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Summary

- Traditional mining electrification technologies are suited to low power cost, high production rate, long life mines; but are limited in flexibility
- BEVs combine the flexibility of diesel with the environmental and cost benefits of traditional electrification technologies
- Underground BEVs:
    - have been in use for 10+ years. BEVs are available to replace all diesel underground equipment. Truck BEVs are most suited to shallow decline, or shaft, greenfield mines
    - BEVs are well suited to hot mines with cooling constraints (ie Onaping Depth, Canada)
    - BEV capacity is expected to increase, and capital cost to decrease, over the next 5 years
- Open pit BEVs (trucks):
    - At an early TRL, site prototype trials being conducted. Likely 5+ years away from commercial production and availability

What can you do now?

- Utilise currently available to tools to run your mine efficiently and reduce diesel usage
- Be aware of Underground BEVs, particularly at the Study stage – new mine or mine extension
- Ventilation and cost savings, as well as reduction in DPM exposure, make underground BEVs a genuine option
- Large open pit BEV trucks are not yet available – but buying diesel-electric rather than diesel is possible now
- *Can we reduce our diesel consumption by not 'filling in the hole' at the end of mine life?*
- *Australia's contractor culture combined with a lack of government regulation and incentives means that Australia is lagging significantly behind Europe and North and South America - will we get left behind?*

Questions?

For more information:

Sarah de Vries | **Principal Consultant**

M +61 431 325 896

E sarah.devries@snowdenoptiro.com