The Electric Mine Virtual Forum: Workshop Outcomes

At the Electric Mine virtual forum, participants collaborated on considerations for developing the business case for BEVs in greenfield, brownfield, and expansion/new mine in a brownfield project. The outcomes from this breakout session, while not a final form of guidance, will be used to support the guideline that is currently in development, which is the 3rd edition of the Battery Electric Vehicle guideline. Included below the outcomes are some questions and answers from the forum's panelists and speakers.

Things to consider when developing the business case for BEVs in:	Greenfield	Brownfield	Expansion /new mine in a brownfield project
Evaluation, change management, and decision-making			
Addressing stakeholder concerns to get buy-in for the change		✓	✓
What is the required change management to support the introduction/transition?	✓	✓	✓
Training strategy for workers		✓	✓
Address challenges around limited track record and public data around electric equipment	✓	✓	✓
Evaluation of all-electric technology landscape to review options beyond just BEVs	✓		
Risk that regulations may change during the life of mine cycle in its jurisdiction	✓		
Funding opportunities from external sources need to be well-charted early on	✓	✓	✓
BEVs as a solution for environmental permits and policies limiting the amount of air emissions, as well as corporate commitments to GHG reduction	✓	✓	✓
Access to transitional finance		✓	
Consideration of alternative business models (e.g battery as a service)	✓	✓	✓
Risk sharing between the mine and OEM could potentially reduce costs		✓	
Benchmark and baseline data	✓	✓	✓
Current and future carbon pricing	✓	✓	✓
Mine design and planning, and equipment selection considerations			
Energy management opportunities (e.g. regenerative braking on downhill runs with trolley assist cabling to feed power back into the mine grid to charge site batteries, regenerative braking, hybrid grids, intermittent use of EV chargers)	✓	✓	✓
Electric reticulation, design, and safety systems that support BEVs in underground mines			✓
The source of energy to charge the batteries (with renewable energy sources as the best option) and supplying the required quantity	✓	✓	✓
Optimal number of chargers and battery swapping stations throughout the life of mine	✓		
Potential "off the shelf" charging stations		✓	
Determine which activities BEVs can be used for and the impact on mine layout, mine services, and drive sizes	✓		
Haulage requirements and limitations on equipment	✓		
In development of mine layout and const prediction, incorporate estimates that consider BEVs and their impact on systems such as ventilation, power, and cooling	✓		
Combination of BEV with automation	✓	✓	✓
Alignment between IT and OEM with regards to data collection and cybersecurity risks		✓	
Integration with existing operations and systems		✓	✓
OEM product roadmap horizons	✓		

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Questions and Answers

Panel:
Ron Miller, Director – Asset Management, Energy, Newmont
Steve Holmik, Mobile Equipment Specialist, Sudbury Integrated Nickel Operations, A Glencore Company
Peter Wan, Lead, Technology & Innovation, Teck Resources Limited

1. **Ron:** What about the BEV infrastructure and potential power grid infrastructure cost?
   Peter: Transitioning to BEV's could significantly increase electrical demand at a mine site – so there could be significant upgrades required to both generating and transmission assets. Another big consideration will be how to smooth demand from charging infrastructure – with energy storage likely to a critical investment.
   Ron: For underground mines, you may see a net zero effect of electrification of the mine, replacing diesel LHD with BEV as this incremental energy demand may be offset by ventilation/cooling electrical load. With regards to the electrical grid, we may see more energy storage technology employed at the mine to accept energy from the grid in periods of low demand on the grid to relieve demand on the grid from increased mine electrification during the peak grid demand period.

2. **Steve:** do you see the major components in BEV lasting significantly longer than the diesel counterparts to assist in the TCO reduction?
   Steve: In general I would say yes and it once again, depends on the drive train configuration. If you can remove the transmission, drive lines & axles, then you've effectively removed most of your traditional drive train and the typical failures and maintenance associated with those. Electric motors require virtually Zero maintenance and are traditionally far more reliable than Diesel engines. Even with some traditional drive train components, due to the reduced vibrations and shock loadings, modelling and forecasts that I've seen has shown they will las longer. Hydraulically driven pumps can be utilized as required and in some cases, turned off while not in use so the wear on these components is reduced as well.
   Peter: BEV's have substantially less moving parts than ICE vehicles, so there will be a reduction in maintenance costs in that area. However, the biggest unknown (in my opinion) is the battery replacement cycle given that many factors will impact battery life (e.g. depth of discharge, charge rate, operating temperatures, etc.)
   Ron: The useful life of a battery pack will be contingent upon the number of charge/re-charges required to do the necessary work at the mine. This, in turn is contingent upon the length of haul, height of haul to destination, and the payload moved by the truck. Frequent charge cycles will take its toll on the battery with eventual degradation so that the work energy per recharge declines toward replacement.

3. **Panel:** Do we have enough experience to know enough about how the sustainability drivers stand up in the business case at a remote operation where power is generated from diesel?
   Peter: From a purely GHG accounting perspective, BEV's will still deliver a reduction in carbon emissions due to the increased efficiency of electric motors vs ICE (less energy consumed) and the lower emissions factor associated with diesel generation plants vs ICE. And for Underground operations, the BEV's will still result in a reduction in ventilation requirements (emissions will be from the generating plants on surface and not in the mine) – so operating costs will still be reduced.
   Ron: I don't see a lot of values for BEV's at a mine site that is powered by diesel gensets. The inefficiencies of generation of power from diesel (different fuel efficiencies and different load factors on engine generators) will then be compounded by inefficiencies in converting that energy generated in AC to battery energy in DC. BEV's should only be employed where there is an alternative energy source other than diesel gensets – the mine is only replacing diesel haul trucks with diesel gensets with all of its inherent combined inefficiencies. Only energy sources from natural gas, nuclear, solar, hydro, wind will make a substantive impact on GHG by using BEV's.

4. Question - I think GHG/lb or oz will be a key metric in the future. Besides the pure replacement of the diesel engine do you see other opportunities for reducing GHG/lb with BEVs?
   Ron: See my answer to question 3 above. We must move from diesel to natural gas, nuclear, solar, hydro, wind as an energy source for BEV's to move the needle toward GHG reduction. Down the road, using green liquid hydrogen may be another fuel source for mine vehicles that can reduce GHG, and that has a high production cost of H2 hurdle to overcome.

5. The industry definition of what total cost of ownership actually means needs to move on from stopping at doing the CAPEX and OPEX life cycle cost of just the equipment and expanded into the wider balance of what it means for mine design (development savings, etc.). One option that could be consider with high levels of consulting the industry is what we see on the consumer side of owning a BEV - road tax being determined by Emissions output, is that a mechanism related to the cost of Carbon that Nick talked about that should be included in the total cost of ownership model for an evaluation. Owning a vehicle versus leasing a vehicle can also have a significant impact as the market matures to battery as a service and other such models - it would be good to hear the panels view
   Peter: I agree that TCO calculations should take in savings from changes to mine design – however in the first phase of BEV deployments I don't expect we will be able to realize many of these savings as the BEV's will be operating in mixed fleets with existing diesel equipment. So, for example, we will not be able to increase ramp grades or reduce capital spend on fuelling infrastructure until we have 100% BEV fleets.
   Ron: I question the relevance of the consumer side of owning a BEV - road tax being determined by emissions output. The problem is roads don't deteriorate from emissions, they deteriorate from load placed upon them, that is why tractor trailer trucks pay the most road tax---they do the most damage. When doing an economic assessment all capex/opex costs of the internal combustion engine vs. BEV's must be taken into consideration. Fuel tanks, fuel logistics, engine maintenance, carbon tax, ventilation electricity on the diesel truck side. Charging stations, sub-station upgrades, downtime for charging and its unproductive haulage time for BEV's.

6. Has there ever been any significant studies in the industry of what the latent energy is inside a typical underground mines, given how much air we push at a consistent speed, or how much water we move up and down levels and looking at micro grid circuits to harness this level to level. seems like we could use the latent energy in those forms as a natural storage of energy?
   Ron: Since most of the ore in most mines is moved up in elevation in a loaded state, there is no latent energy to be captured, only the potential energy recovered as regenerative braking as the empty truck descends. Most of the water for mines below the water table is pumped up and out of the mine so no opportunity for hydro power production.

7. Do you think that switching to BEV will make mining as a more attractive workplace? Given that mining industry currently is having problem in getting new generation of mining engineers and number of students in mining school worldwide is declining.
   Ron: Using BEV's, autonomous and remote equipment will make the mines safer and allow a cost savings in ventilation capex/opex if done properly. This may see a change in the types of jobs required at a mine much as human labour has been replaced over centuries by machines. The opportunity to leverage different "information age" skill sets in the mining industry can have a positive effect on recruiting of younger and talented employees of the future.

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Questions for Maarten Van Koppen, Product Manager – Mine Operations, MacLean Engineering

1. What Battery Chemistries are you using?
   Maarten: Our EV products come with Lithium NMC batteries.
2. Do you use regen for braking?
   Maarten: Yes, all our EV products regenerate energy where applicable.
3. Do you have thermal management systems that monitor these batteries and does cell isolation in case of battery issues?
   Maarten: Yes, we have thermal management systems on board.
4. What is the cost of a battery, W/O delivery?
   Maarten: Feel free to reach out to us for pricing.
5. Any thoughts on the used batteries after their life at mining operations?
   Maarten: First and foremost the batteries we supply can be fully recycled. There could be all sorts of applications for batteries that reached the end of their life for mobile applications. At that point their condition, the effort required to integrate and the trade-off against buying new batteries that are designed for stationary storage are some of the things that need to be looked at.
6. What is MacLean using for Chargers and are the chargers part of the EV Series Data Collection?
   Maarten: Our current offering includes on-board chargers to make adoption as seamless as possible.
7. Is there an onboard fire suppression system?
   Maarten: Yes, there is.
8. What's the size of the Cement Mixer / Agicar in m3
   Maarten: We have several options available, please feel free to reach out to discuss the options.

Feel free to contact Maarten at mvankoppen@macleanengineering.com

Questions for Nick Gardner, Global Manager Mining Engineering & Technology, Vale Base Metals

1. Have you also thought about electric smaller vehicles for people transportation?
   Nick: We currently have a few Rokion's for transporting people (3 to 12 passengers).
2. Any statistic for electric powered vehicle fires caused by faulty batteries?
   Nick: There is a bit of information out there via consortiums and competitors. Nevertheless, Vale is putting in measures with regards to operational readiness to curtail fire hazards from faulty batteries.
3. Who is the best source for battery knowledge in the mining world to advise a mining company on chemistries as well as risk assessments?
   Nick: Currently, we rely on OEMs and ABB for battery knowledge.