Electric Mine Operational Knowledge Sharing Platform
Summary of Survey Results and Workshop Outcomes

Executive Summary

A survey that was open between April and June 2020 with 95 respondents (as of June 9) and workshops held on May 7 and May 20 aimed to define priorities for the GMG Electric Mine Operational Knowledge Sharing Platform project. This project aims to create a neutral platform to capture performance data for electric surface and underground equipment based on the industry's knowledge and experience.

Types of information that will provide value
In the survey, performance was the highest priority in terms of types of information that will provide value.

However, the results of the workshops identified that there would be certain types of information that can be used to provide value in overlapping areas (e.g. they may help operations make performance comparisons and also identify operational or maintenance needs). Highlights include:

- Information about the daily cycle and time usage in comparison to diesel
- Identifying what information should available in real time
- Information or metrics for comparing charging strategies
- Information for assessing and updating charging infrastructure
- Training information for operators, safety personnel and maintenance technicians
- Information on heat generation

Uses of information:
The following priorities were identified in the survey and workshops:

- Understanding capital and operating costs
- Developing the business case
- Developing a charging philosophy and strategy
- Understanding safety requirements and improving safety
- Understanding infrastructure, design, and planning requirements

Equipment types:
Survey respondents were asked about what types of equipment to prioritize, the results are as follows.

- General: Haul trucks and LHD trucks
- Electric equipment types**:** Battery electric vehicles (BEVs)

These results may be influenced by the higher representation of underground mining professionals and that 64% of respondents are North American and similar representation at the workshops.

Demographics

Out of a total of 95 survey respondents, there was a relatively even split between stakeholder types (Figure 1). Underground mining was more heavily represented than surface, but many respondents specialize in both (Figure 2). Professionals (engineers, geologists, metallurgists, etc.) were the most highly represented (26%) while corporate senior management (17%) and corporate technology leaders (17%) were also well-represented. 65% of respondents are North American, while 16% are Australian and 11% are European. The demographics of the workshop participants are consistent with those of the survey.

Figure 1. Stakeholder group

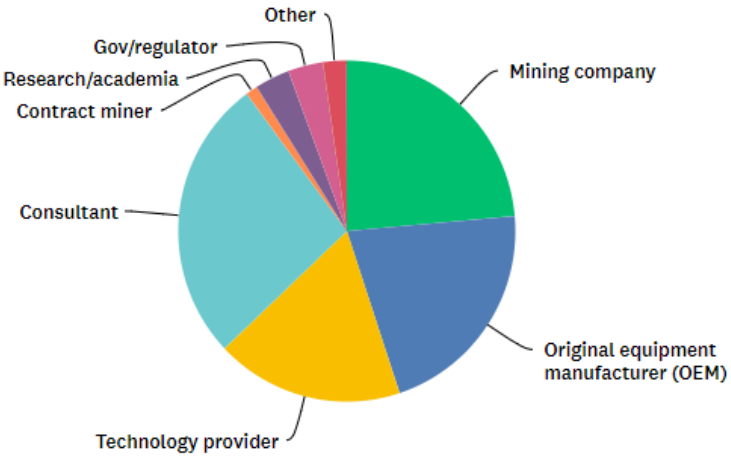
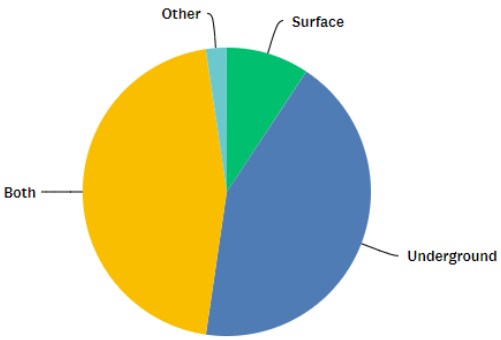


Figure 2. Type of operation



Information providing the greatest value

The survey respondents identified information about performance as the highest priority (50 votes). The next four – layout, infrastructure and design; charging; utilization and availability; and maintenance – all received between 31 and 35 votes (Figure 3).

Workshop participants worked on identifying what information that would be a priority within these categories. The results (Table 2) reflect that there is some information that will overlap between sections. Highlights that came up in multiple categories include:

- Information about the daily cycle and time usage in comparison to diesel
- Identifying what information should available in real time
- Information or metrics for comparing charging strategies
- Information for assessing and updating charging infrastructure
- Training information for operators, safety personnel and maintenance technicians
- Information on heat generation

Figure 3. Survey results (survey respondents chose their top three)

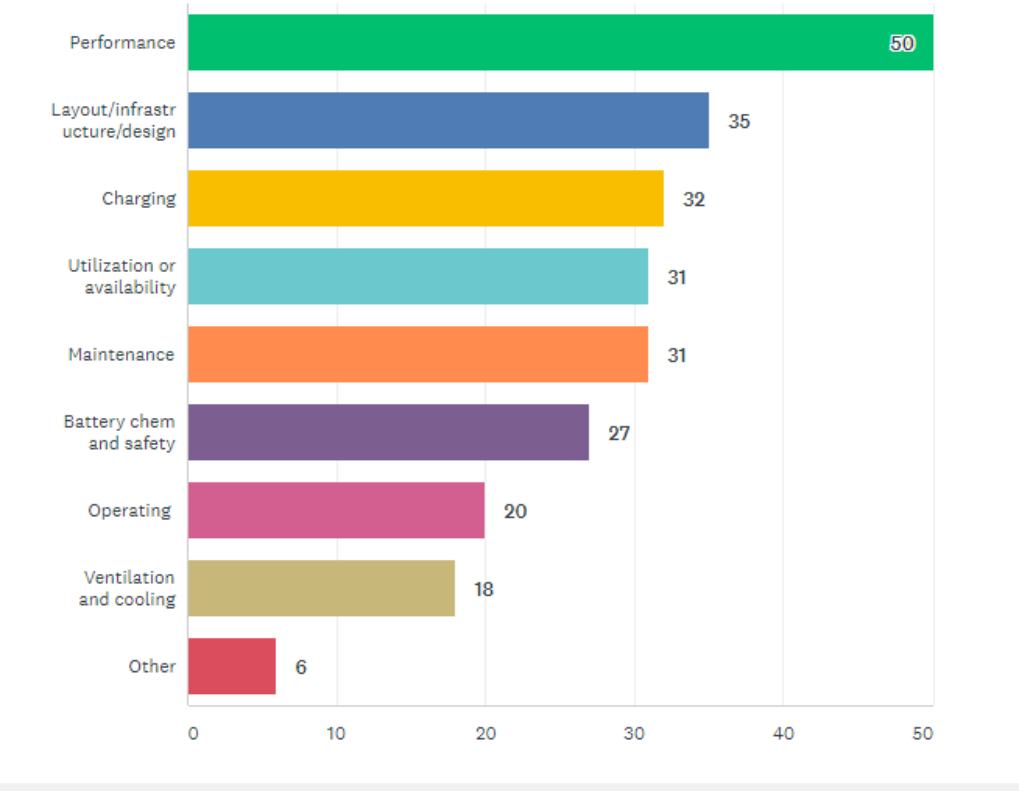


Table 1. Workshop highlights

Topic	Information that would provide value
Performance	• Information about operational performance (e.g., cycle time, how uptime and downtime affect productivity, and impact of grade and payload in range) – *Some of this also relevant to availability and utilization (see below)** • Information on data / metrics that can be used to set a baseline • Information about access to real-time performance data • Equipment component performance information (e.g., battery lifetime, braking performance, speed)
Layout, Infrastructure and Design	• Information to help understand energy storage requirements, if the current electric infrastructure is sufficient, or if there needs to be additions. • Energy forecasting information • Information for assessing / updating charging infrastructure (e.g., where to place chargers, adding charging stations, number of EVs per charger, optimal amount of charging/swapping stations compared to number of vehicles) – *also identified as a priority under charging**
Charging	• Information / metrics for comparing charging strategies (e.g. in/out cycle, deep charge, top ups, on-board/off board, trolley systems) and how the strategy affects battery life – *charging strategies also identified as a key area in availability and utilization** • Information on smart charging philosophy • Information on how charging time, swap time affects operations (compared to diesel machines) • Heat generation information • Information to help make sure charging can be done safely
Utilization and availability	• Information to help develop a time usage model relevant to electric vehicles • Information on the overall daily cycle and comparisons with diesel, including maintenance schedules and procedures, PM schedule implications and how they affect availability and utilization • Information that can be used to evaluation between charging strategies and their impact on availability and utilization – *see also note under charging**
Maintenance	• Information that can be used to train maintenance personnel • Comparisons with diesel maintenance programs (e.g., isolation systems, tooling requirements, spare parts, scheduling, costs) – *many of these considerations will also play into availability and utilization* • Information on when maintenance should be onsite versus when it should be done by the OEM
Battery chemistry and safety	• Information about risks (e.g., fire risk, thermal runaway, fast charging risks) to prevent incidents • Information about battery management system (BMS) data storage ability for second life usage • Cost information (Wh/$) • High energy density information (Wh/kg) • Information about structural and vibration integrity and dust protection
Ventilation and cooling	• Battery heating requirements in open pit mines – *see also battery chemistry and safety* • Information to educate the industry about ventilation factors beyond equipment to prevent reducing ventilation more than it should be and the implications of ventilation in terms of fire safety • Comparison between diesel and electric vehicles on heat loads and cooling requirements
Operating	• Identifying information that needs to be measured in real-time – *also relevant to performance* • Human factors (e.g., information about noise levels and interactions between equipment and humans, operational interface, information for training personnel) • Information about material movement in comparison to diesel
Other	• Information about interoperability and standardization (e.g. standardized charging protocols, if / when it is possible to combine chargers when operating mixed fleets) • Information about how BEV regulations are applied

Uses of information

Understanding capital and operating costs and **developing and understanding the business case** were identified as the highest priorities in the survey, although all options had many rankings as very high or high priority (Table 2).

The three most repeated topics in the workshops were **establishing a charging philosophy and strategy**; **understanding infrastructure, design and planning requirements**; and **understanding safety requirements and improving safety**. The first two were also highly rated in the survey (Table 2). Safety was not one of the options in the survey question but was something survey respondents commented as missing in the question.

Table 2. Survey Results

	VERY LOW PRIORITY	LOW PRIORITY	MODERATE PRIORITY	HIGH PRIORITY	VERY HIGH PRIORITY	N/A	TOTAL	WEIGHTED AVERAGE
Understanding capital and operating costs	0.00% 0	1.09% 1	13.04% 12	38.04% 35	47.83% 44	0.00% 0	92	4.33
Developing and understanding the business case	1.08% 1	5.38% 5	18.28% 17	38.71% 36	35.48% 33	1.08% 1	93	4.03
Understanding mine layout, infrastructure and design requirements	0.00% 0	4.30% 4	26.88% 25	41.94% 39	26.88% 25	0.00% 0	93	3.91
Establishing a charging philosophy	2.11% 2	3.16% 3	25.26% 24	41.05% 39	27.37% 26	1.05% 1	95	3.89
Developing a maintenance program	1.05% 1	6.32% 6	27.37% 26	37.89% 36	27.37% 26	0.00% 0	95	3.84
Understanding the comparison between electric and diesel equipment	2.13% 2	9.57% 9	20.21% 19	39.36% 37	28.72% 27	0.00% 0	94	3.83
Convincing the company to invest in electric equipment	3.19% 3	10.64% 10	21.28% 20	30.85% 29	30.85% 29	3.19% 3	94	3.78
Understanding ventilation and cooling requirements	1.08% 1	8.60% 8	29.03% 27	40.86% 38	18.28% 17	2.15% 2	93	3.68
Training operators	3.16% 3	13.68% 13	40.00% 38	20.00% 19	23.16% 22	0.00% 0	95	3.46

Workshop Highlights

When workshop participants were asked this question in an open-ended way, the following topics were the most frequently mentioned (the first three points were mentioned more than five times):

- Establishing a charging philosophy and strategy
- Understanding safety requirements and improving safety
- Understanding infrastructure, planning and design requirements
- Understanding performance and making comparisons
- Understanding maintenance requirements
- Achieving regulatory and community approval
- Making decisions around equipment based on the situation (e.g. retrofit requirements, vehicle selection, ownership models)
- Understanding energy consumption and implications

Equipment types

Haul trucks and load, haul dump machines were identified as the highest priority in terms of equipment type. Auxiliary vehicles, loaders and utility carriers were also identified as important (Figure 4).

BEVs were ranked the highest in terms of priority electric equipment (Figure 5). Some commenters noted that this will be different depending on underground or open pit (e.g., BEVs underground, trolley for open pit), so this result may be skewed due to the larger representation of underground mining in the survey.

Figure 4. Survey Results - Equipment Type

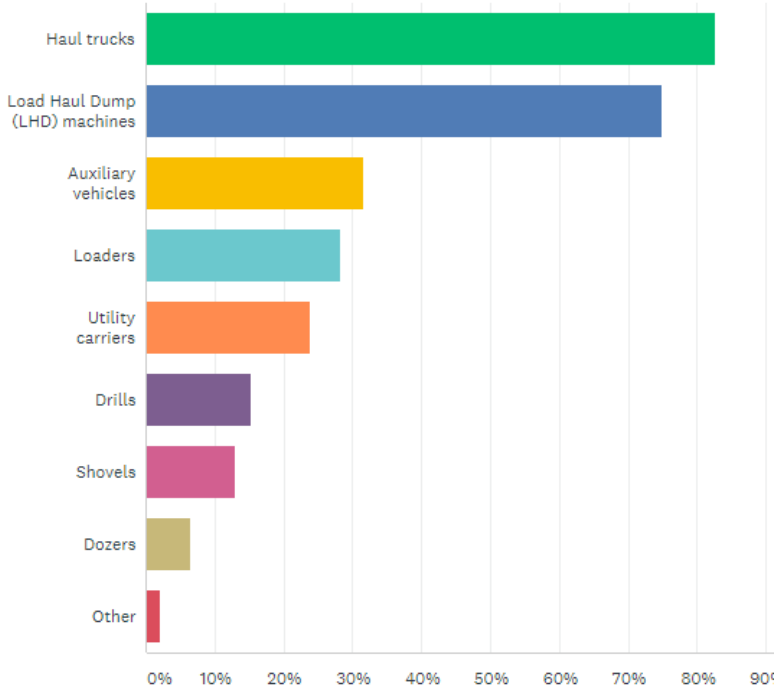


Figure 5. Survey Results - Electric Equipment Type