# Holistic Overview of Cost Impacts in Battery Electric versus Diesel-powered Equipment Selection

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## Introduction

- Ian Loomis
  - Technical Director and Principal Consultant with Worley
  - Experience includes Operations, Consulting, Education and Research
  - Includes work in – United States, Canada, Indonesia, Mongolia, Morocco, Portugal, Spain and Turkey
  - Studies of projects in several other countries also

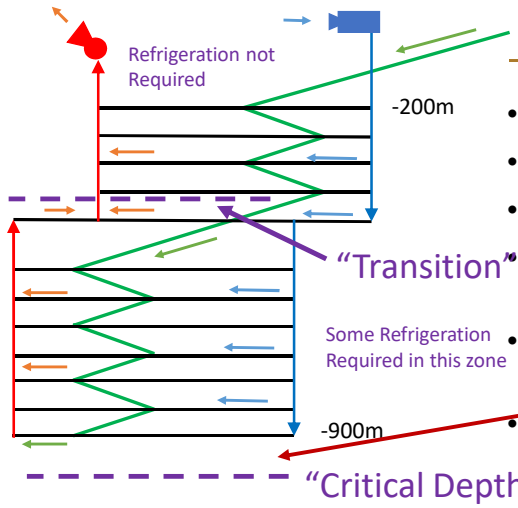
*Disclaimer – The work discussed in this presentation was conducted prior to my engagement with Worley. It represents the views and opinions solely of the author.*

# Trade-Off Study

- Focused or limited in scope
- Support the transition from Pre-feasibility options to the Preferred Alternative carried to the Feasibility Study
- Consider the cost estimate range at ±25%

# Trade-Off Study

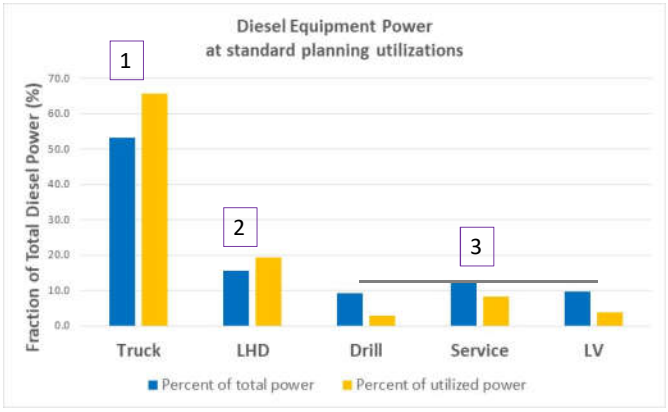
- Key question – Diesel versus Battery Electric?
  - Relative impact by class
  - Differences in size, capacity and performance
  - Matching the analogues
  - Capital, operating and maintenance costs
- Extended Impacts
  - Ramp and drift profiles
  - Raise diameters
  - Ventilation and refrigeration demands
  - Ventilation and refrigeration infrastructure
  - Power transmission/distribution
- Energy Balance
- Less-than-Tangible




# "Goldilocks Mine"

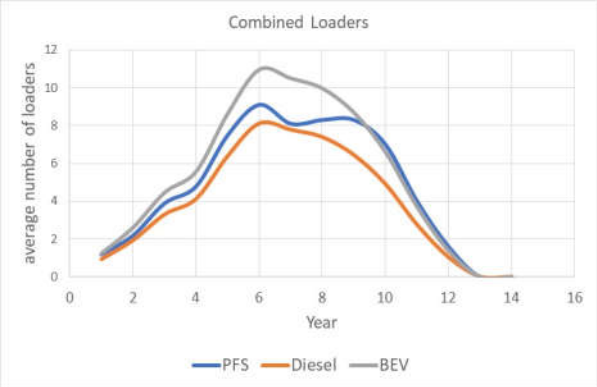
- New mine at brownfield site (~4,000 tpd)
- Haulage lift from 200m to 900m
- Existing LoM production and equipment profiles
- Trucks limited to hauling in ramp
  - Segregation of intake airflow
- Within depth limit of BEV truck haul out
  - Surface battery facility for haul trucks
- "Critical Depth" is just below the lowest level
  - Delay of refrigeration components/modules

# Analogue Selection

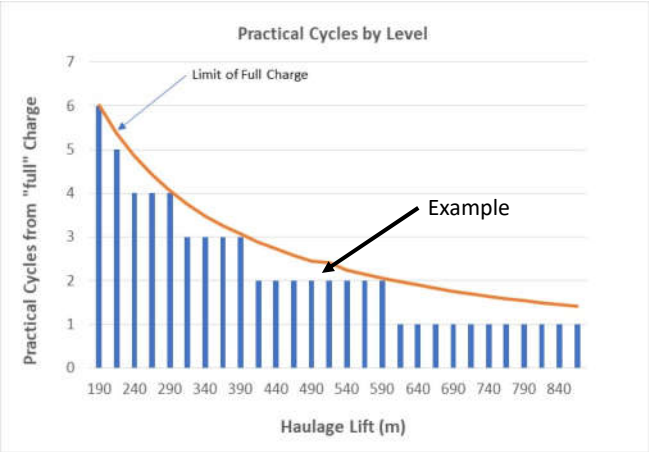


- Trucks
  - Diesel –
    - higher payload
    - Single Fueling
  - BEV –
    - Faster (?)
    - Battery Swapping/Regen
- Loaders
  - Diesel –
    - Larger
    - Cycle Match for Diesel Truck
    - Production/Development Share
  - BEV –
    - Smaller
    - Cycle mis-match
    - Need for two loaders on a production level

# Analogue Selection




# Haulage Characteristics

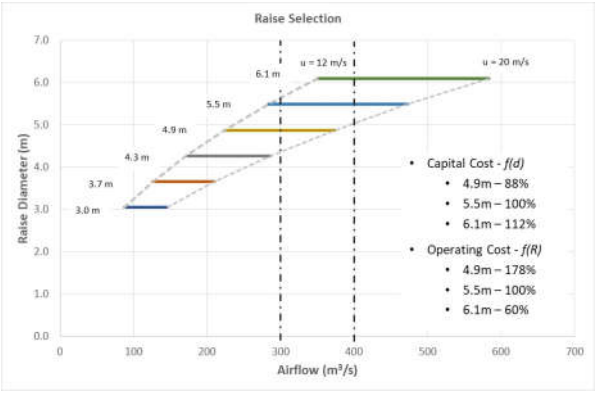


# Ventilation Loads

| Requirement Basis | Diesel | Battery Electric |
|---|---|---|
| MSHA/Canmet/local | ✓ | |
| "Consensus" Flow Rate | ✓ | ~?~ |
| EPA Tier/Euro Spec Class | ✓ | |
| Heat Management | ✓ | ✓ |
| Minimum Velocity – Dust | ✓ | ✓ |
| Minimum Velocity – Mixing | ✓ | ✓ |

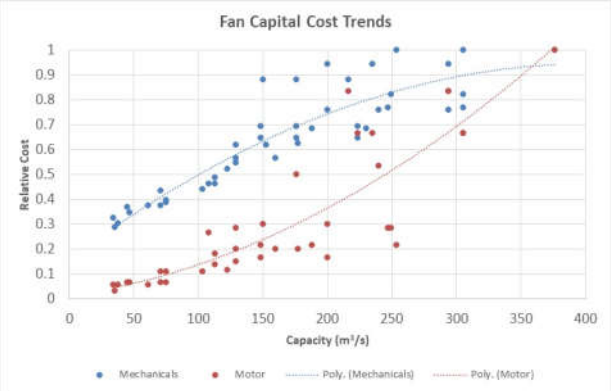
# Ventilation Raises

- Capital Cost
  - Fairly low impact on project cost
  - In this case: <2% total cost
  - Step changes with reamer diameter
  - Tendency to select as large as technically viable
- Operating Cost
  - At fixed flow larger diameter has lower fan pressure and lower operating cost
  - In this case:
    - ~26% of Elec cost of full Diesel
    - ~17% of Elec cost of full BEV



# Main Ventilation Fans

- Mechanicals Cost
  - Step Changes as Fan Specs Change
  - Differential cost tends to flatten has capacity increases
- Motor Cost
  - Differential cost tends to increase as capacity increases
- Fan Equipment Cost
  - Roughly 1/3 of the total installed cost

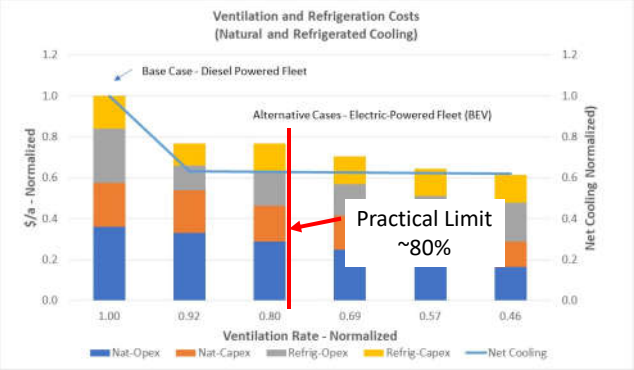


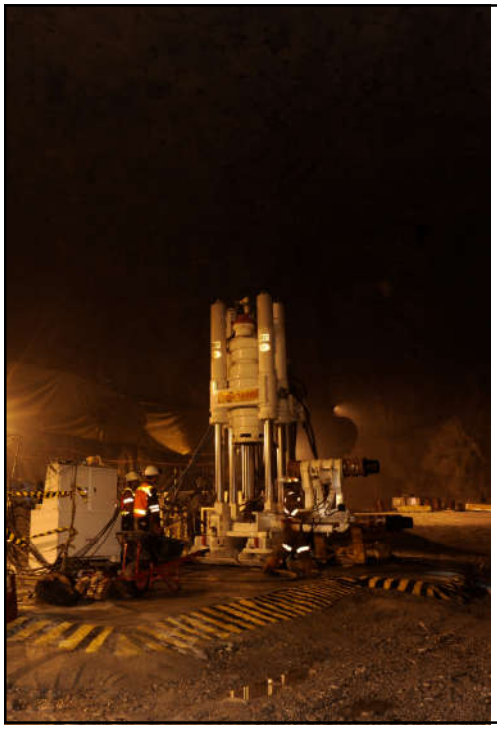

# Refrigeration Plant

- Refrigeration Plant
  - Step changes based on modular
- Bulk Air Cooler
  - Differential cost tends to increase as capacity increases
- Cold Storage
  - Cost of storage tanks

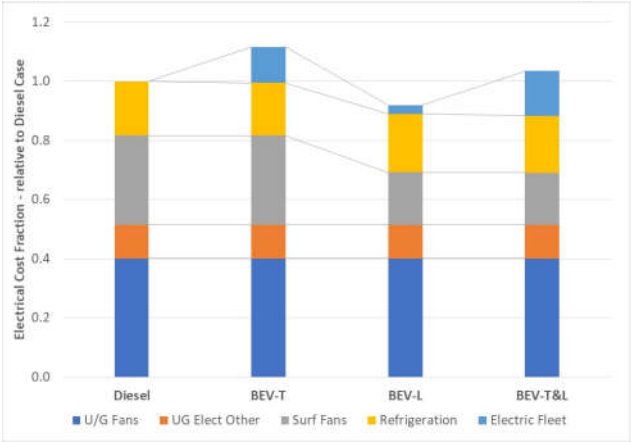
- "Managed Cooling"
  - Trade flow for refrigeration
- Airflow reduction
  - Lower capital cost
  - Lower operating cost
- Refrigeration increase
  - Step increase in capital cost
  - "Step" changes in operating costs
- Practical Limit
  - Change in the driver of the ventilation demand

# Combined Infrastructure



# LoM Cost Comparison



# Other Capital

- Battery Swapping
  - Distributed vs. centralized charging sites
  - 400 - 1,000+ kW capacity per unit
  - Transmission to underground
- On-board/Opportunity Charging
  - Extra “jumbo-boxes”
  - Load center capacity
  - Distribution
- “Carbon Credits” and “Tax Support”

# Observations

- Health impacts
  - Diesel Tier III- vs. Tier IV vs. BEV
  - Noise
  - Heat impacts
  - “Fueling” – manual vs. automated
- Emergency management
  - BEV vs. Diesel fires
  - Mine Rescue team support (training and equipment)

# Conclusions

- Currently, BEV implementation ~15-20% higher than Diesel – not immediately out of estimate window
- Larger BEV loaders are in the pipeline – improve cost profile?
- Expect that BEV performance will improve through the foreseeable future
- Cost convergence - ??
- BEV equipment appears to offer options to rather than replacement of Diesel equipment