Methods of Estimating Mobile Equipment Heat Loads for Battery Power

Sudbury – October 17, 2016

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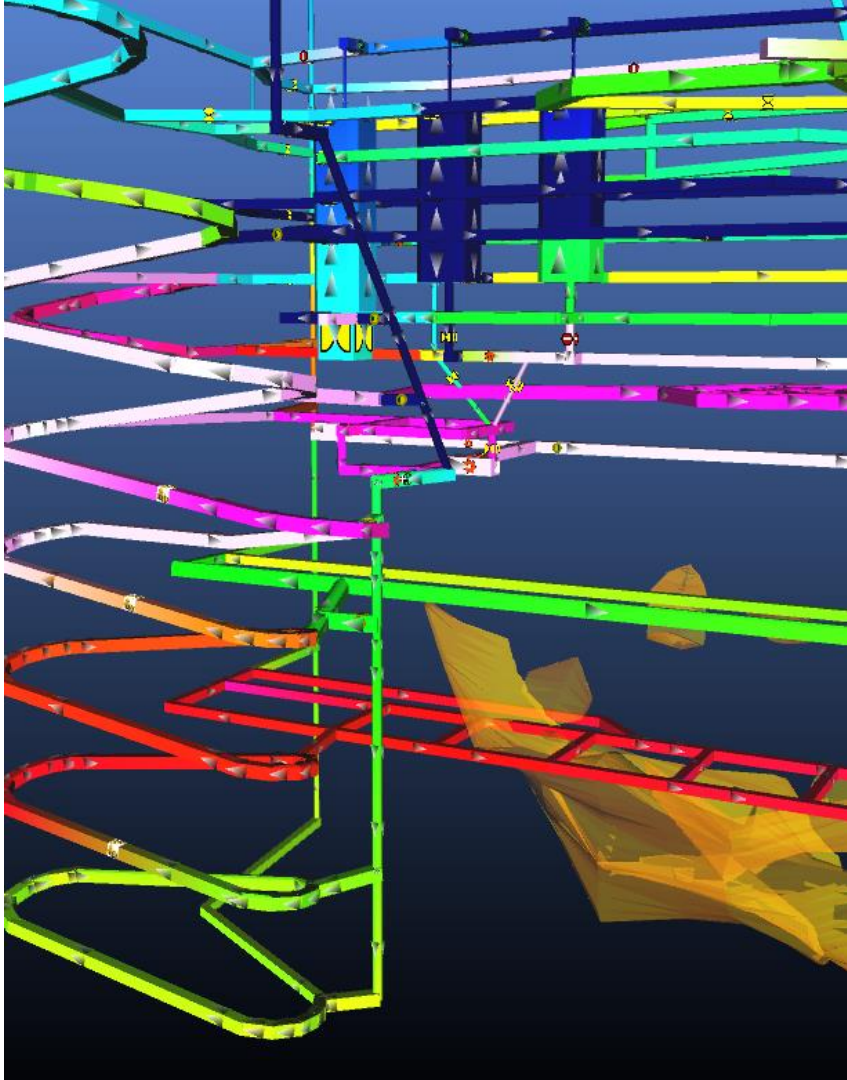
Driver

- Looking at non-diesel equipment
- Deeper mining / need savings for NPV
- Ventilation and cooling system design
  - No longer have 100 cfm/hp to define flow
  - Heat from equipment is critical for heat analysis

Parameter of Interest

- Sustained heat output while equipment is working
- Input for modeling
- Understand how much cooler workings will be



Sensible Heat from Battery Equipment

- Battery charger & charging losses

- Battery heat during discharge
- Electric motors & electronics
- Mechanical & tire losses
  - At the work site

Interest

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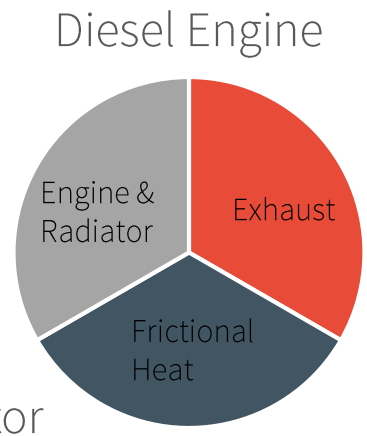
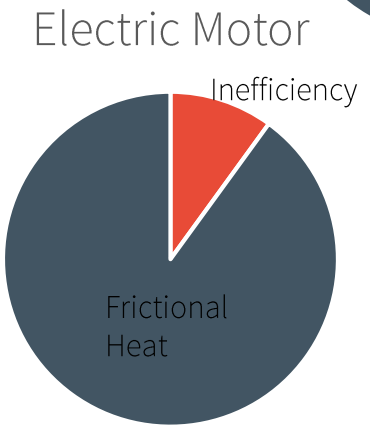
Methods

- Factor on Engine Duty (Gundersen)
- Engine Swap (US mines study)
- Empirical – Field Measurements (Halim)
- Conversion - Energy Consumption from Diesel
- First Principles Energy Analysis

Factor on Engine Duty

- Primitive estimation
- Peak diesel engine power rating
- Assume same electric motor power
- Consider that value the heat number
  - 145 kW diesel LHD → 145 kW motor
    - 90% efficient motor → 161 kW heat
- Simplistic, ignores duty factor





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Engine Swap

- Take diesel fleet or machine
- Assume engine replaced with motor
- Take 2.8 times less heat and apply as all-sensible
- Does consider the importance of duty factor

Empirical – Field Measurements

- Publication by Halim et al from Northparkes
- Took heat measurements
  - Tether LHDs
- Concluded heat similar to motor rating
- Question about other heat such as broken rock
- Doesn’t seem to align with energy balance
- Did not include duty factor

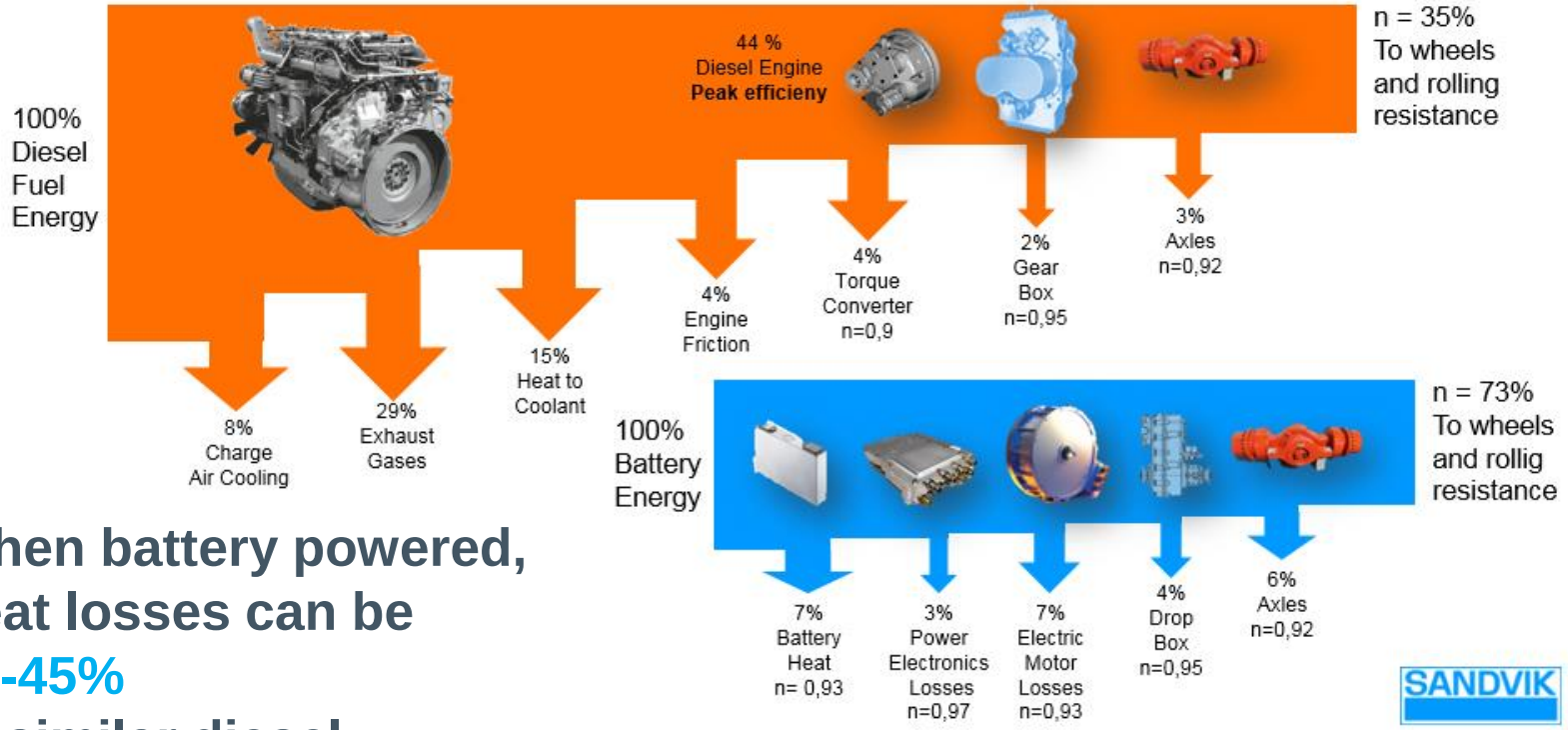
Conversion - Energy Consumption from Diesel

- Example from recent study for LHDs
- Good for empirical study for existing operations
  - Look at actual fuel consumption
  - Convert to electric heat output
  - Difference represents reduction in mine heat/cooling

First Principles Energy Analysis

- Considers heat from each component
- Energy efficiency
- Still need to apply duty factors
- Valuable for diesel/electric comparison
- Can account for specific details:
  - Replacement of hydraulics
  - Driveline / power transmission
  - Battery type (discharge losses)

Heat Losses from Diesel and Battery



When battery powered, heat losses can be 25-45% of similar diesel equipment

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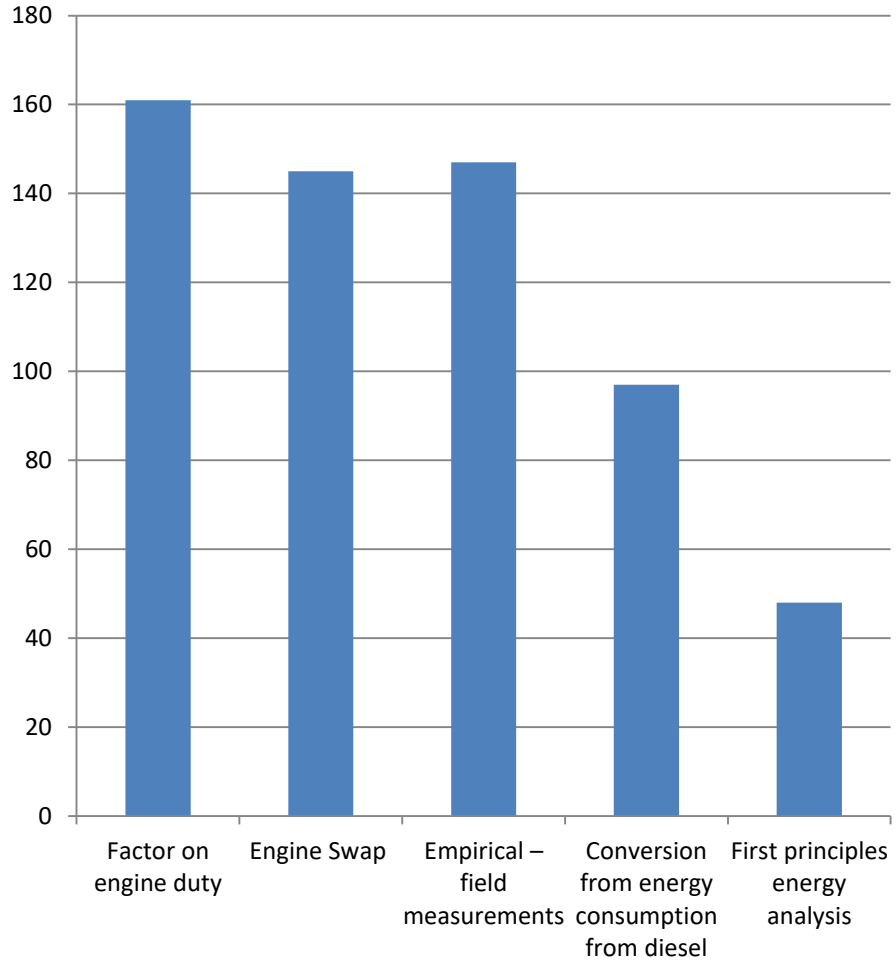
Comparison – 145 kW LHD

Method	Indicated Sensible Heat
Factor on engine duty :	161 kW
Engine Swap	145 kW
Empirical – field measurements	147 kW
Conversion from energy consumption from diesel	97 kW
First principles energy analysis	48 kW

Heat Comparison

- Up to 3x difference
- Similarities in first three
  - Sensible from energy balance only if duty factor of 100%



Findings & Recommendation

- Uncertainty remains
- Sensitivities
  - Duty factor
    - Haulage gradient & travel distance
    - Intensity of activity
  - Machine configuration
- Select method carefully for your project
- More testing

Thank you.