Mobile Equipment Power Source Impact on Ventilation Design

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Agenda

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2. Design Criteria
3. Heat and Dust
4. Case Study Scenarios
5. Comparison of Results
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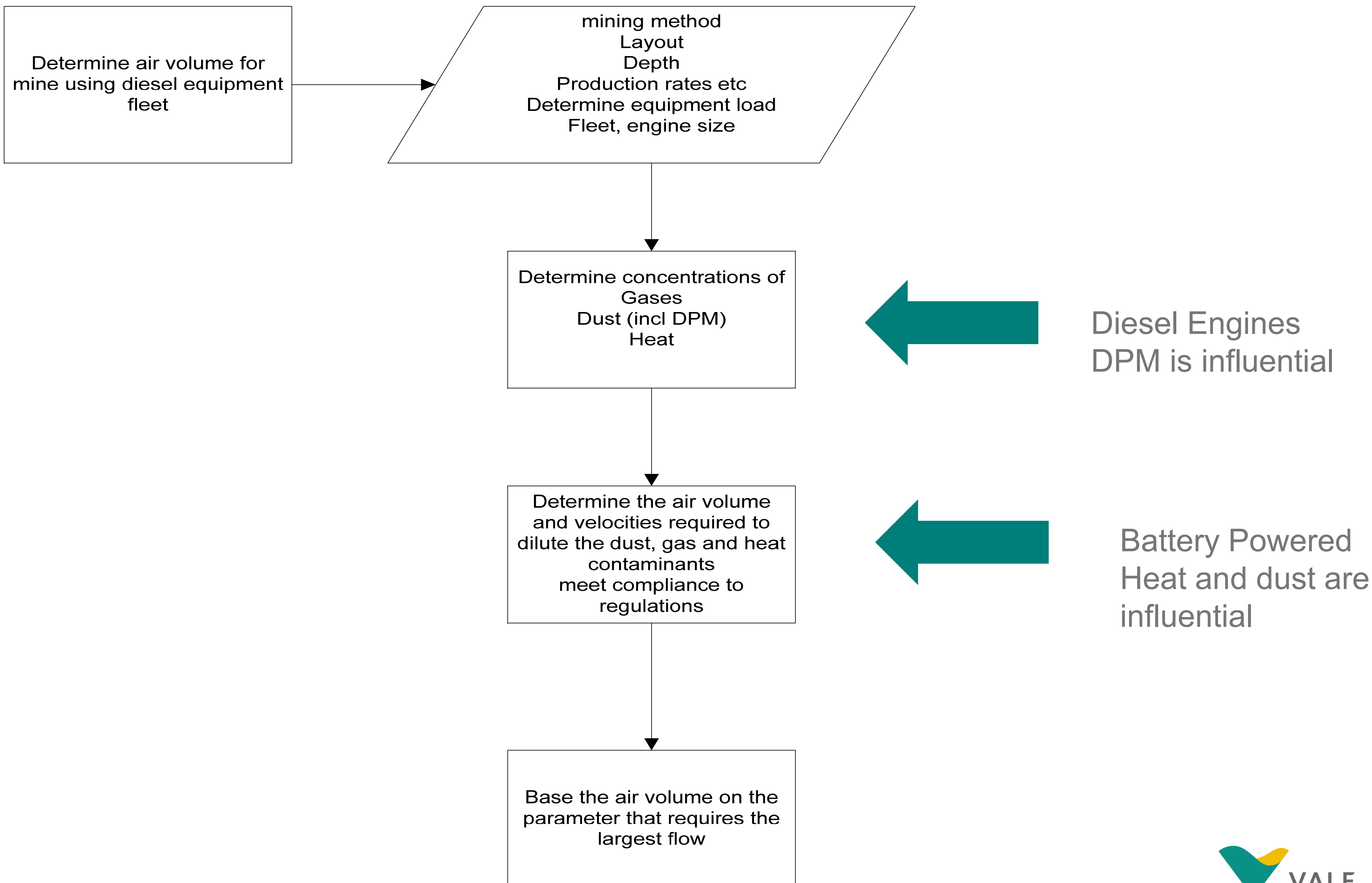
Design Approach

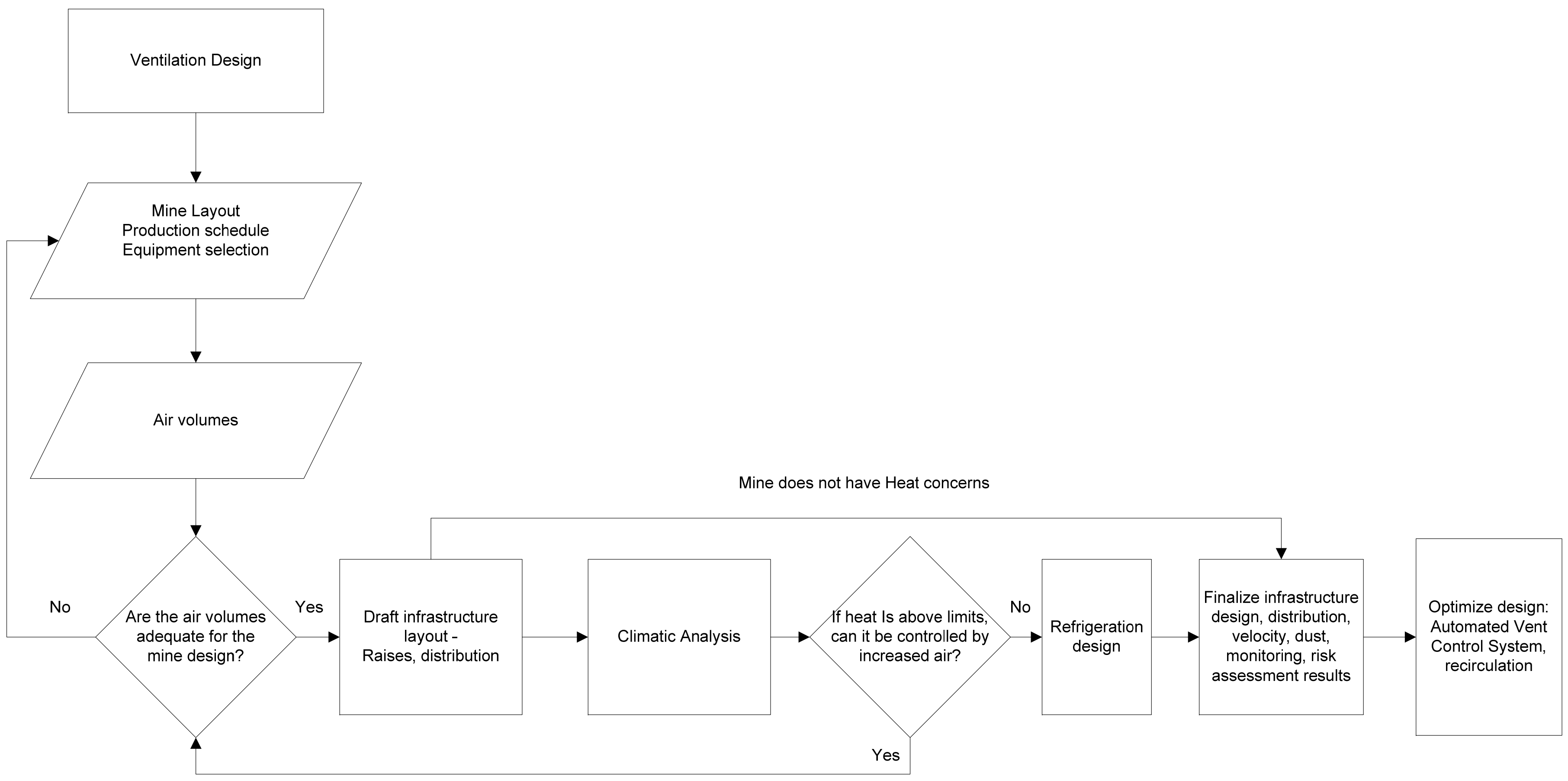
Design Principles

- In mechanized mines, ventilation design is mainly based on dilution of diesel exhaust contaminants.
  - This volume is generally adequate to cover all other factors that are part of ventilation design (ie 0.06 m^3/s per kW)
- When considering alternative power sources for mobile equipment (ie battery), the design basis must consider other factors such as dust, gas, heat and air velocity.
- Designing to minimum regulations does not guarantee an acceptable design, but a design must be sure to meet any regulations.
- Start the design process with robust and good practice principles
  - A weak starting process can only degrade and create restrictions
  - Work to a “fit-for-purpose” design

Air Volume - Design Process



Ventilation Design Process



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Design Criteria

Volume and Distribution

Air Volume

- Ensure volumes meet any jurisdictional regulations.
- Establish a consistent method to determine the equipment allocation to suit the mining activity.
- Establish what allowances will be made for leakage, equipment fleet changes, study level of confidence, garages etc
- If heat is a concern, will increased volume maintain temperature limits

Ventilation Plan

- Create a conceptual distribution and infrastructure based on established criteria for air velocity, temperature work limits, pressure differential limits, garage exhaust, escapeway, ramp direction.
- Determine if automation for vent control will be incorporated
- Determine if mechanical refrigeration or mine air heating is required

Environment, Economics, Hazards

Environment

- Conduct climatic modeling with established input parameters specific to site rock properties and local ambient average temperature conditions.
- Ensure temperatures are maintained within established limits.
- Determine potential dust sources and that air velocities are adequate for dilution and removal.
- Complete noise modeling to ensure surface noise levels are within regulated and internal limits

Economics

- Use economic analysis to optimize the size of airways .

Hazards

- A risk assessment should be conducted to highlight any critical issues that may be inherent within the design.
- If the design deviates from the established criteria, a risk assessment would identify controls that may be necessary to reduce any associated risk.

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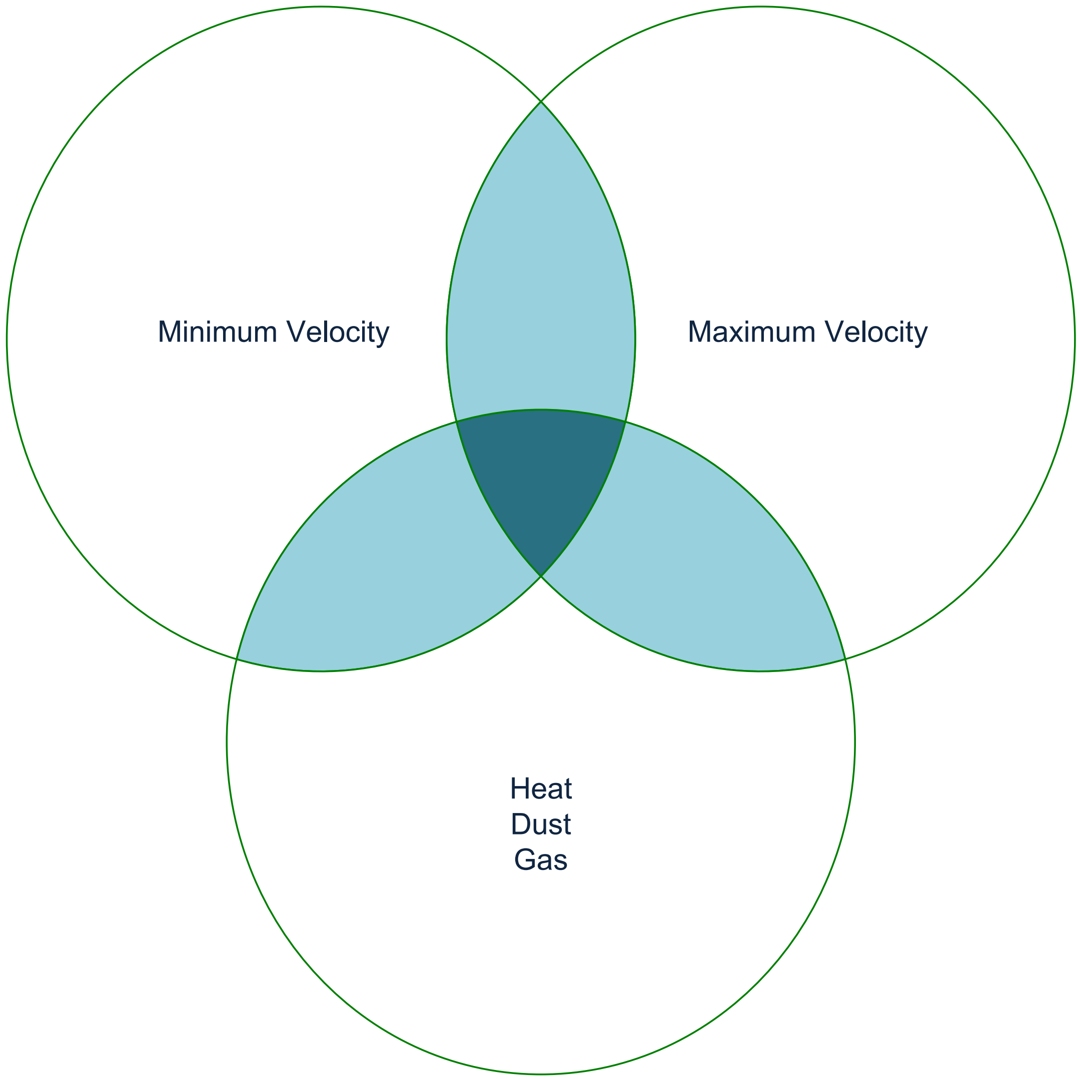
Contaminants

Design Balance



- Air velocity must be considered once the air volume requirements have been met for the other parameters
- The velocity balance is necessary for safety
  - Max velocity for Submicron size to dilute
  - Min velocity to not create dust and discomfort

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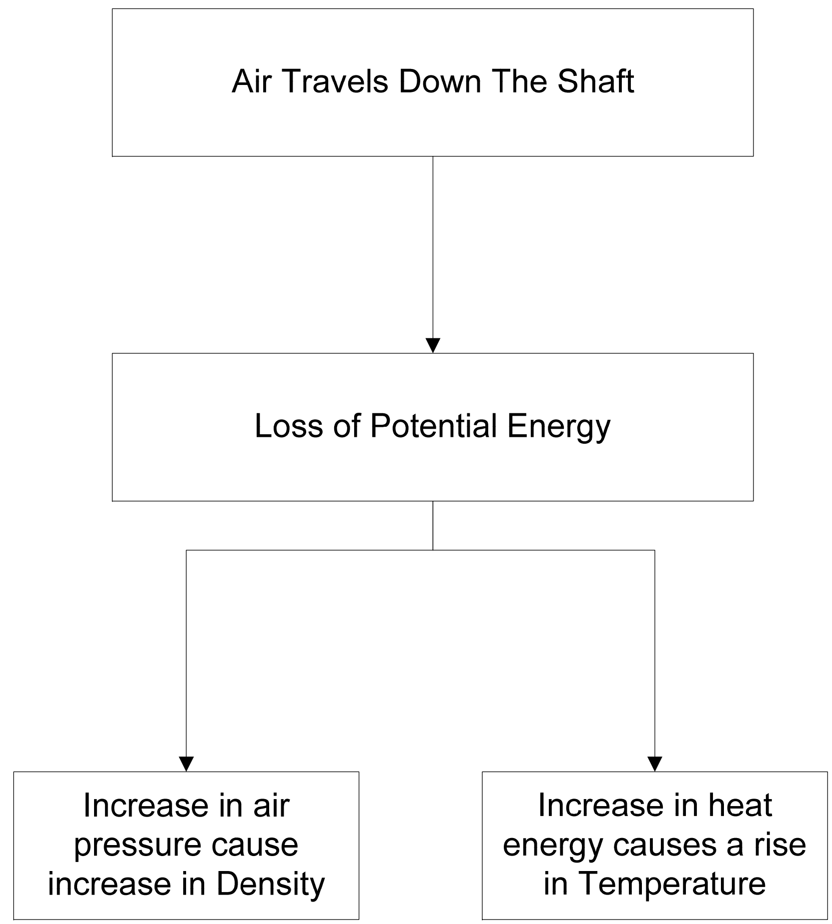
Sources of Heat

- Wall Rock
- Broken Rock
- Electrical Load from fixed equipment, fans, pumps
- Mobile equipment - Diesel and Electric Load,
- Autocompression (not an external heat source)
- Metabolism
- Curing, sandfill and concrete
- Oxidation

Autocompression



Heat from Equipment

Diesel

- Heat from diesel is in the form of sensible and latent when added together is the total heat
- Total Heat can be determined from:
  - Fuel consumption rate
  - Efficiency of the diesel engine –
- The rise in enthalpy (total heat) from the engine drives the ventilation rate to meet a target temperature

Battery

- Heat from electric equipment is in the form of sensible heat
- The electric motor is efficient, therefore the power consumption is equal to the heat generated plus a small inefficiency.

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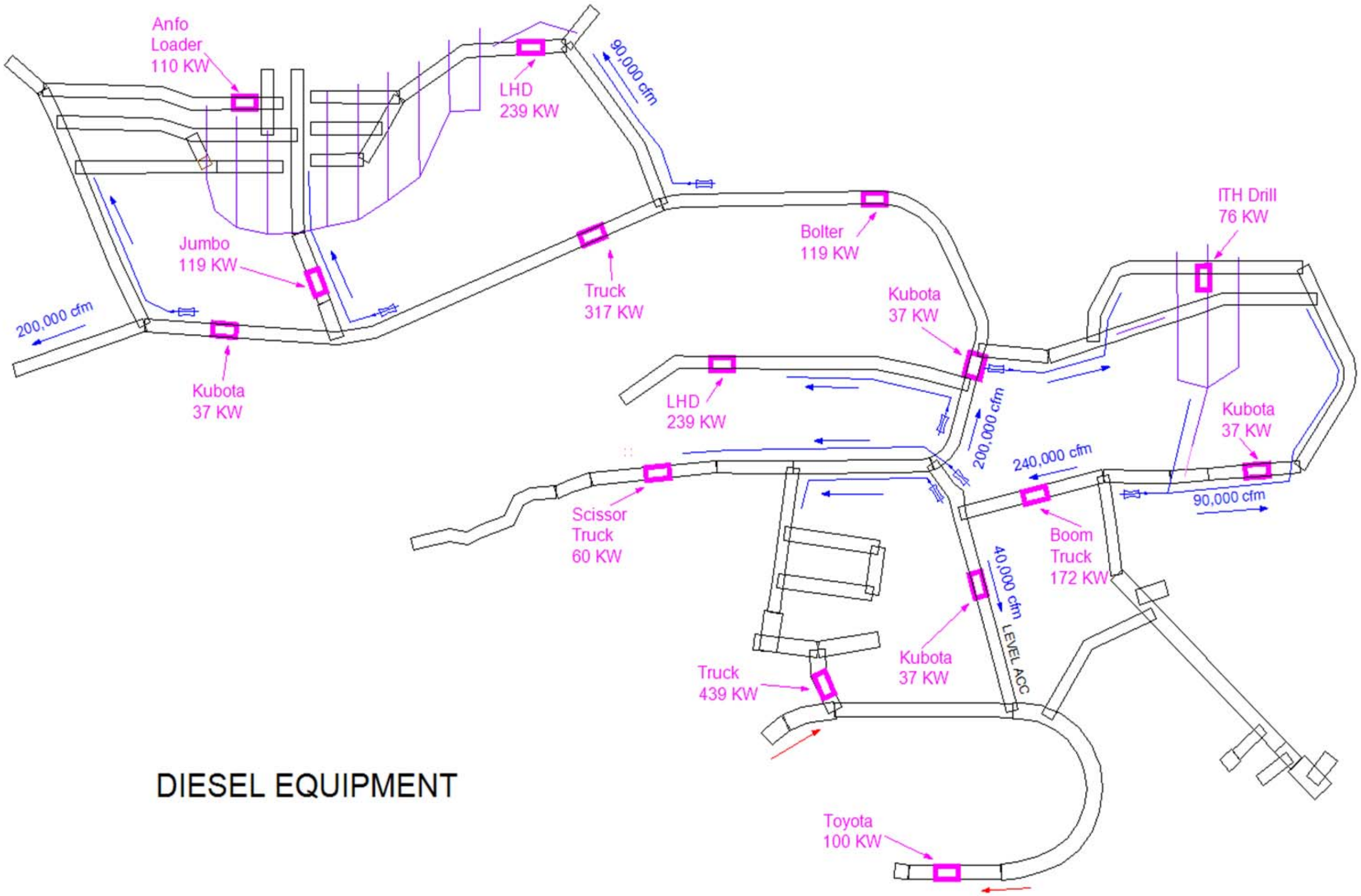
Case Study Scenarios

Scenario Assumptions

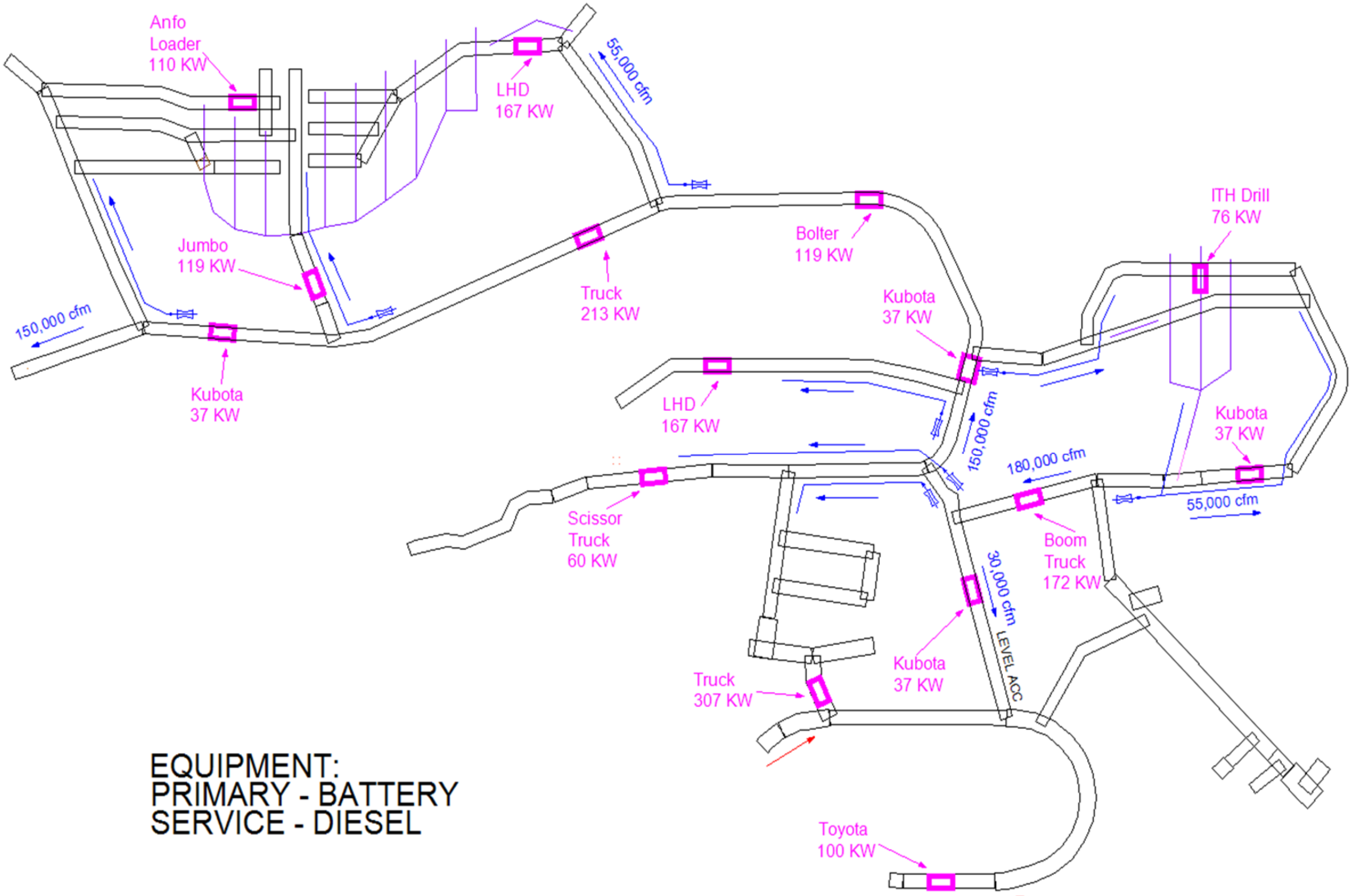
- 3 scenarios comparing diesel, diesel/battery hybrid, battery equipment
- Deep mine example
- Calculate the air volume per production level
- Parameters (mining method, depth, intake air temperature, target stope and reject temperatures) are kept constant except the type of mobile power source and the air volume to maintain the same temperature between scenarios

Level Layout for equipment placement Diesel



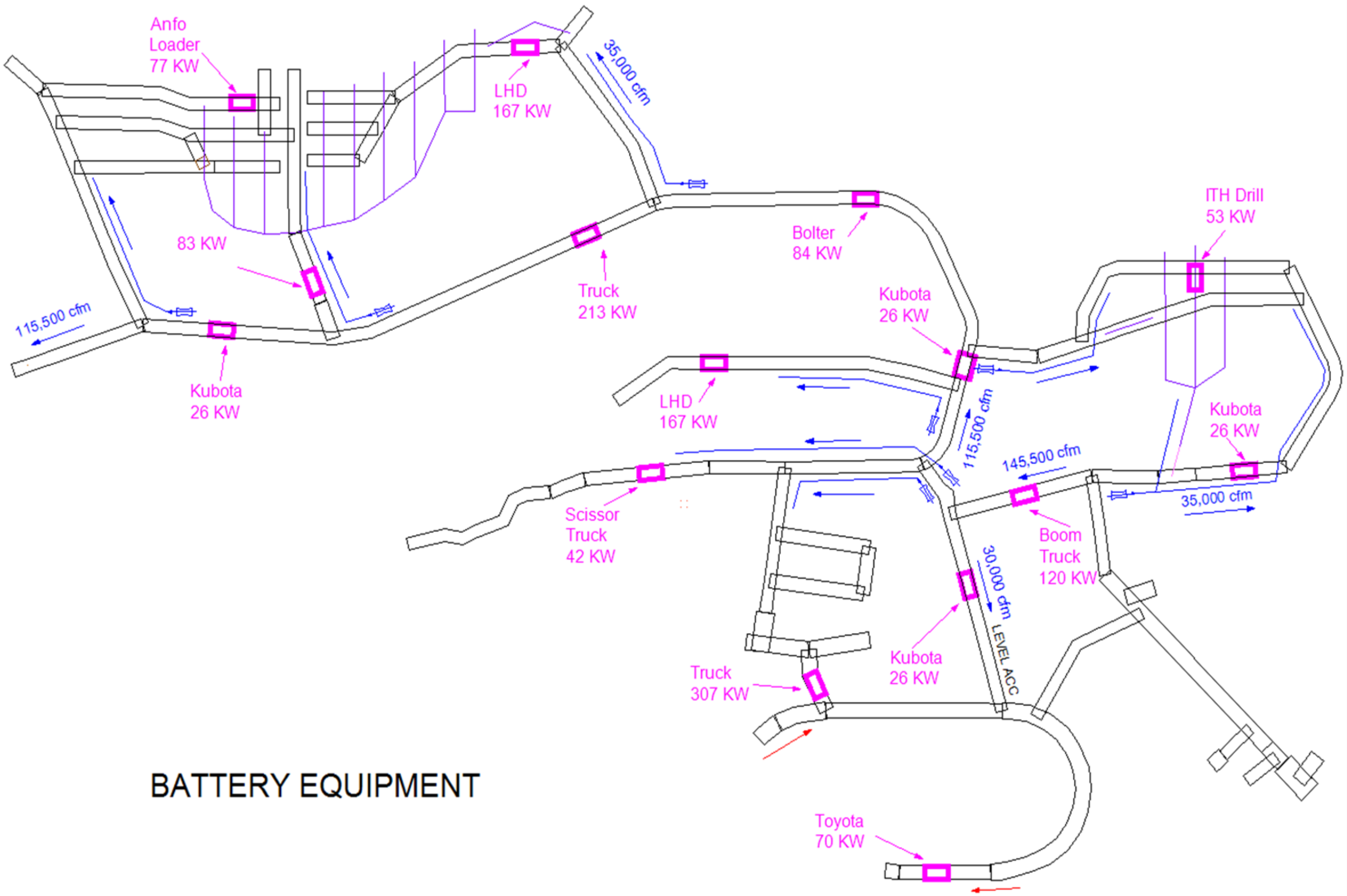
DIESEL EQUIPMENT

Level Layout for equipment placement Battery (primary movers), Diesel (service)



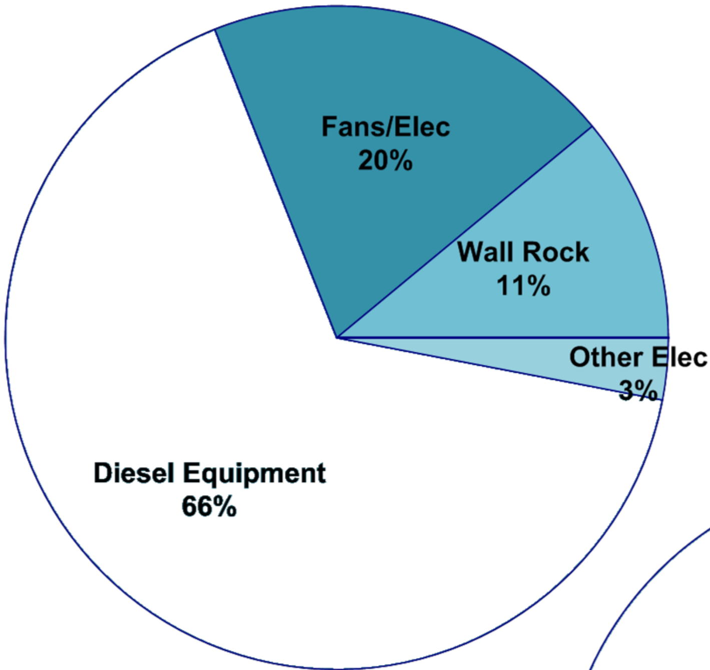
EQUIPMENT:
PRIMARY - BATTERY
SERVICE - DIESEL

Level Layout for equipment placement Battery (primary and secondary)

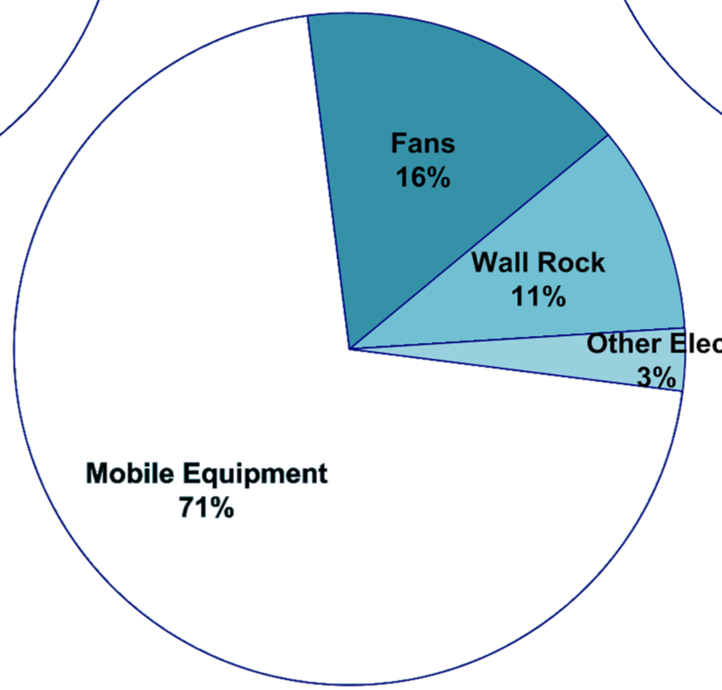


5 Comparison of Results

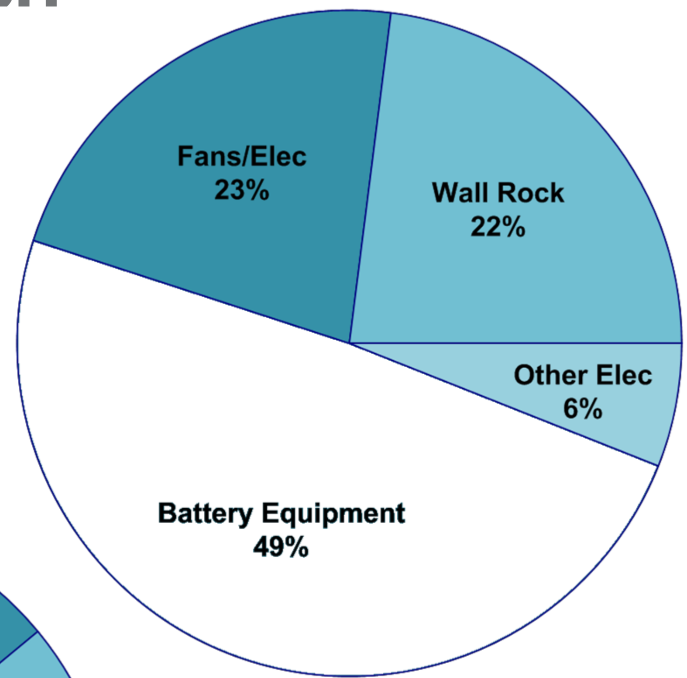
Heat Contribution



All Diesel
2962 kW Total Heat



Diesel/Battery
2301 kW Total Heat



All Battery
1380 kW Total Heat

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Heat Generation Comparison

Equipment Type	Wall Rock	Fans	Mobile Equipment	Other Electric Heat Source	Total Heat
All Electric	297 kW 22%	312 kW 23%	682 kW 49%	89 kW 6%	1380 kW 100%
All Diesel	320 kW 11%	602 kW 20%	1951 kW 66%	89 kW 3%	2962 kW 100%
Electric Primary Diesel Secondary	333 kW 11%	568kW 16%	1311 kW 71%	89 kW 3%	2301 kW 100%

Velocity

Equipment	Location	Volume (cfm)	Velocity (ft/min)
Diesel	Main Drift	200,000	735
	Stope Access	90,000	330
Battery	Main Drift	116,000	426
	Stope Access	35,000	128
Diesel/Electric	Main Drift	180,000	662
	Stope Access	55,000	202

Drift dimensions are 16ft x 17ft (272 ft^2)
Minimum velocity – 100 ft/min (0.5 m/s)
Optimum velocity – 200 ft/min (1.0 m/s)

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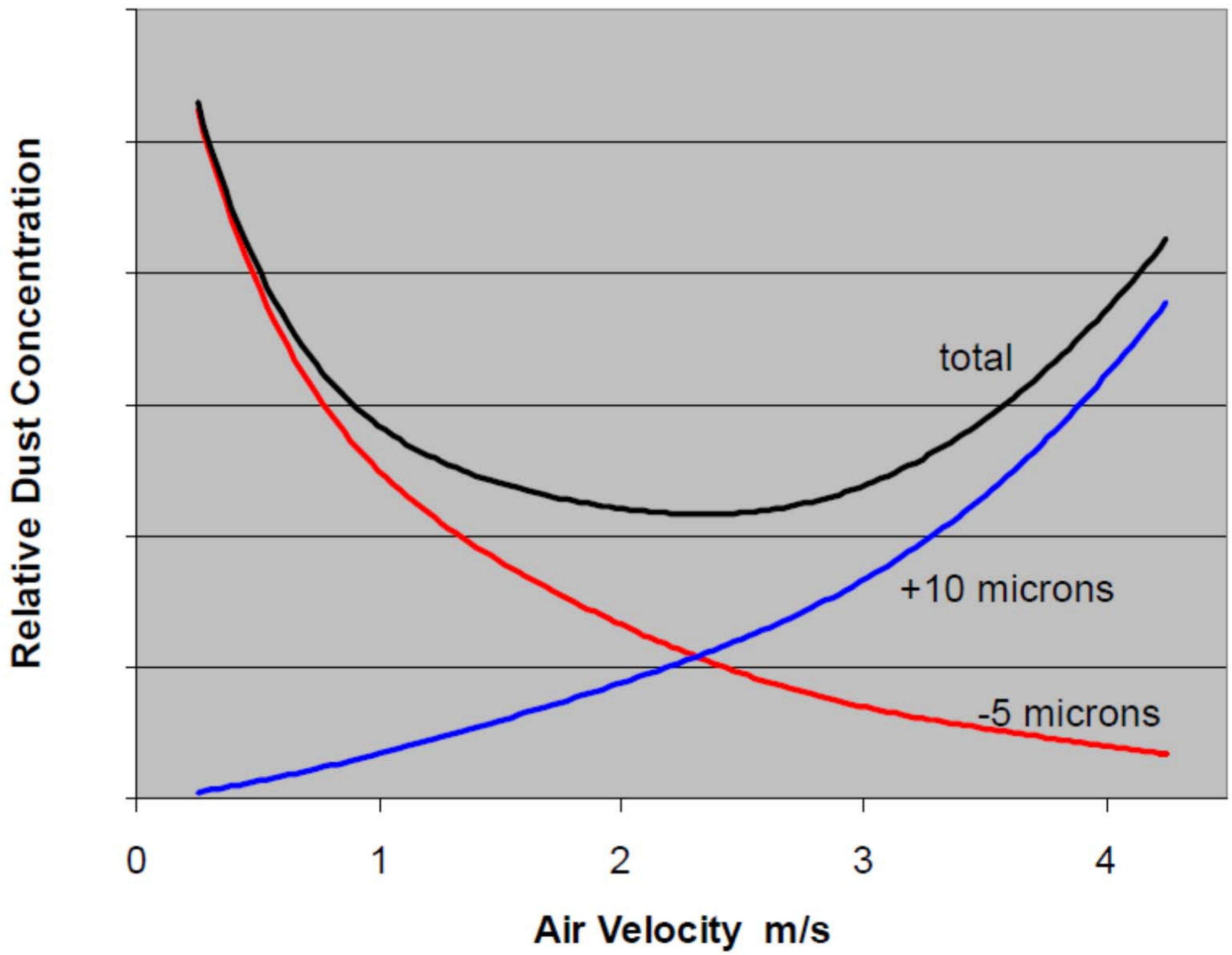
Dust Concentration vs Velocity



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Benefits

Infrastructure Reduction

Equipment	Air Volume (cfm)	Volume Reduction	Raise Bore Diameter (feet)	Size Reduction
Diesel	200,000	200,000→180,000 10%	11	11 → 10.5 5%
Diesel/Battery	180,000	180,000→116,000 35.5%	10.5	10.5 →8.7 17%
Battery	116,000	200,000→116,000 42%	8.7	11 → 8.7 21%

Raise size reduction per Level

Equipment	Air Volume (cfm)	Volume Reduction	Raise Bore Diameter (feet)	Size Reduction
Diesel	830,000	830,000→690,000 17%	19	19 → 17.5 8%
Diesel/Battery	690,000	690,000→570,000 17.4%	17.5	17.5 →16.5 4%
Battery	570,000	830,000→570,000 31%	16.5	19 → 16.5 13%

Raise size reduction per Area

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Energy – Fans

Equipment	Air Volume (cfm)	Volume Reduction	Fan Power (HP)	Power Reduction (6 fans/level)
Diesel	90,000	90,000→55,000 39%	180	1080 → 480 55.5%
Battery/Diesel	55,000	55,000→35,000 36%	80	480 →240 50%
Battery	35,000	90,000→35,000 61%	40	1080 → 240 78%

Power reduction for 6 **auxiliary** fans on one level

Equipment	Air Volume (cfm)	Volume Reduction	Fan Power (HP)	Power Reduction
Diesel	830,000	830,000→690,000 17%	2616	2616 → 2283 13%
Battery/Diesel	690,000	690,000→570,000 17.4%	2283	2283 →1719 25%
Battery	570,000	830,000→570,000 31%	1719	2616 → 1719 34%

Power reduction for **Primary** fans

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Energy – Fan Operating Cost

Equipment	Air Volume (cfm)	Fan Power 6 fans/level (HP)	Power Cost Per year
Diesel	90,000	1080	$529,000
Battery/Diesel	55,000	480	$235,000
Battery	35,000	240	$118,000

Power cost for **auxiliary** fans on one level

Equipment	Air Volume (cfm)	Fan Power (HP)	Power Cost Per year
Diesel	830,000	2616	$1,282,200
Battery/Diesel	690,000	2283	$1,118,900
Battery	570,000	1719	$842,500

Power cost for **Primary** fans

The power savings from Diesel to Battery/Diesel = $1,045,300/yr
The power savings from Diesel to Battery = $1,672,700/yr

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Energy – Heating and Cooling

Equipment	Air Volume (cfm)	Volume Reduction	Natural Gas (ft^3)	Natural Gas Reduction
Diesel	830,000	830,000→690,000 17%	57,558,948	57.6M ft^3 → 47.8M ft^3 17%
Battery/Diesel	690,000	690,000→570,000 17.4%	47,850,210	47.8M ft^3 → 39.5M ft^3 17.4%
Battery	570,000	830,000→570,000 31%	39,528,434	57.6M ft^3 → 39.5M ft^3 31%

Reduction of **Natural Gas**

Equipment	Air Volume (cfm)	Volume Reduction	Cooling (MW)	Cooling Reduction
Diesel	830,000	830,000→690,000 17%	13	13 MW → 10.8 MW 17%
Battery/Diesel	690,000	690,000→570,000 17.4%	10.8	10.8 MW → 8.9 MW 17.6%
Battery	570,000	830,000→570,000 31%	8.9	13 MW → 8.9 MW 31.5%

Reduction of **Refriger-ation**

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Summary

Summary

- The primary role of an underground ventilation system is to provide airflow to dilute and remove contaminants created in the mining process to safe levels where people are required to work or travel.
- Mine ventilation design can be complicated so a structured approach is required to ensure a robust and fit-for-purpose system.
- The electric or battery mine will require a more comprehensive design that considers the impact of velocity, heat and dust levels from air volume reductions that are possible as a result of zero emission engines.
- There are benefits to the mine design from replacing diesel engines with electric or battery powered equipment. These benefits consist of capital cost reductions from smaller raises and fans, and operating cost reductions from reducing power and natural gas demand.

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