

Transitioning Towards Diesel Free Mines

An Exposure Reduction Strategy for Diesel Exhaust

CIM 2018

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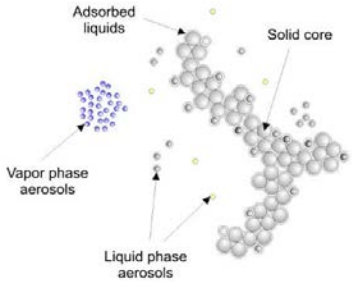
GOLDCORP

DIESEL EXHAUST EXPOSURE REDUCTION STRATEGY

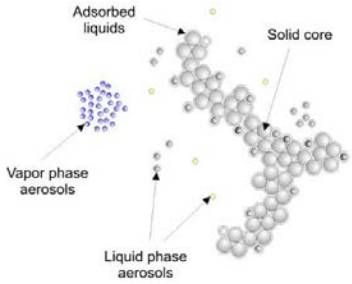
The case for an exposure reduction strategy for diesel exhaust.



COMPONENTS OF DIESEL ENGINE EXHAUST

Diesel exhaust can contain:

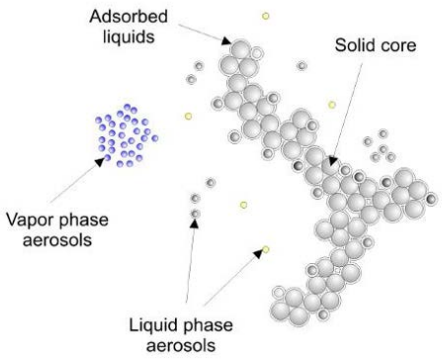
Alcohols
Aldehydes
Carbon (soot)
Carbon monoxide
Carbon dioxide
Diesel particulate matter (DPM)
Ketones
Hydrocarbons
Oxygen
Water vapour
Nitrogen
Oxides of nitrogen
Oxides of sulphur
Polycyclic aromatic hydrocarbons (PAHs)



HEALTH EFFECT OF DIESEL EXHAUST

Acute Health Effects

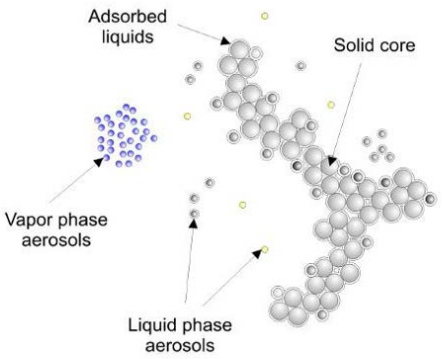
- coughing
- irritation of the eyes, nose, throat,
- lung irritation and/or an allergic reaction causing asthma
- asphyxiation from carbon monoxide poisoning.



HEALTH EFFECT OF DIESEL EXHAUST

Chronic Health Effects

The International Agency for Research on Cancer (IARC), part of the World Health Organization (WHO), classified diesel engine exhaust as carcinogenic to humans (Group 1), determining that exposure to diesel exhaust emissions increases the risk for lung cancer and possibly bladder cancer.



BURDEN OF OCCUPATIONAL CANCER IN ONTARIO

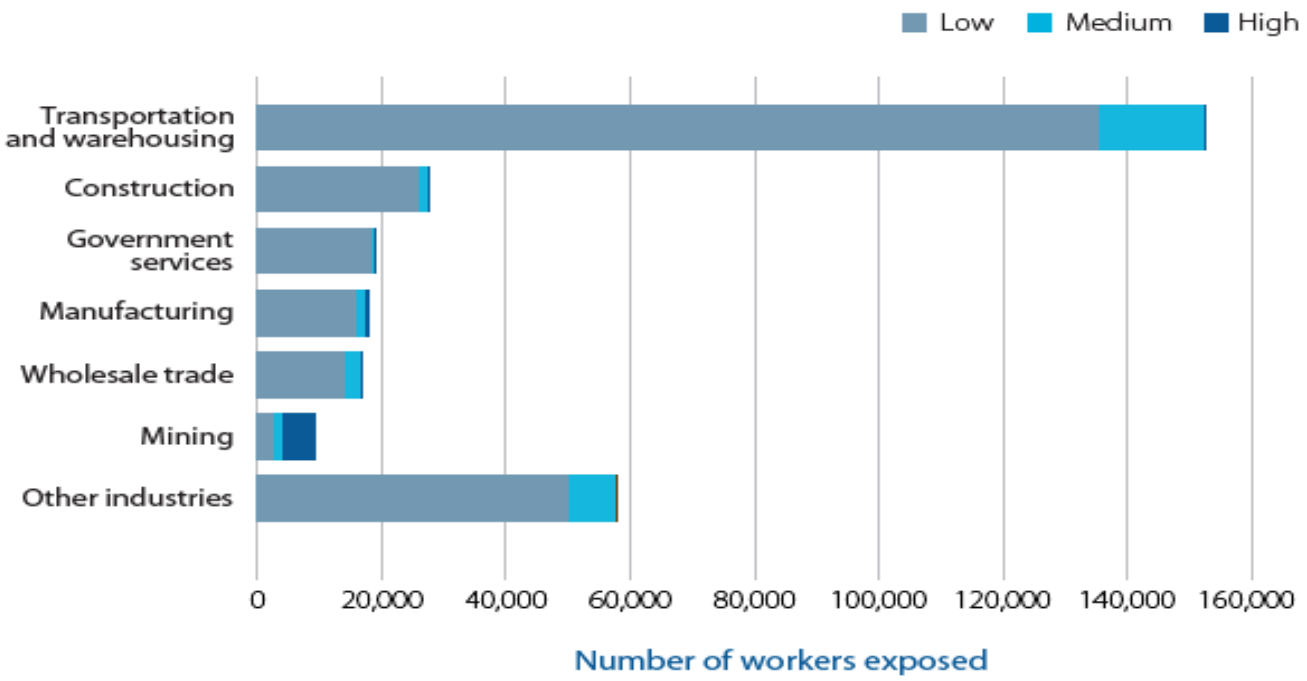
Diesel Engine Exhaust (DEE) (OCRC, 2017)

- 301,000 workers exposed to diesel engine exhaust (DEE) in Ontario
- Annual burden - 170 lung cancer cases, 45 bladder cancer cases
- DEE is the 3rd of 11 priority carcinogens
- Approximately 2.1 % of lung cancer cases diagnosed annually are from occupational exposure to DEE

1. Cancer Care Ontario, Occupational Cancer Research Centre. *Burden of occupational cancer in Ontario: Major workplace carcinogens and prevention of exposure.*Toronto: Queen's Printer for Ontario; 2017.

DIESEL ENGINE EXHAUST EXPOSURE IN ONTARIO

FIGURE 6 Number of workers occupationally exposed to diesel engine exhaust (DEE) by level of exposure and industry in Ontario



Cancer Care Ontario, Occupational Cancer Research Centre. *Burden of occupational cancer in Ontario: Major workplace carcinogens and prevention of exposure.*Toronto: Queen's Printer for Ontario; 2017.

PROGRESSION TO LOWER EXPOSURE LIMITS

The health risk estimates have continued to evolve and the setting of protective occupational exposure limits have struggled to keep pace.

Challenge of technological feasibility versus health impact.

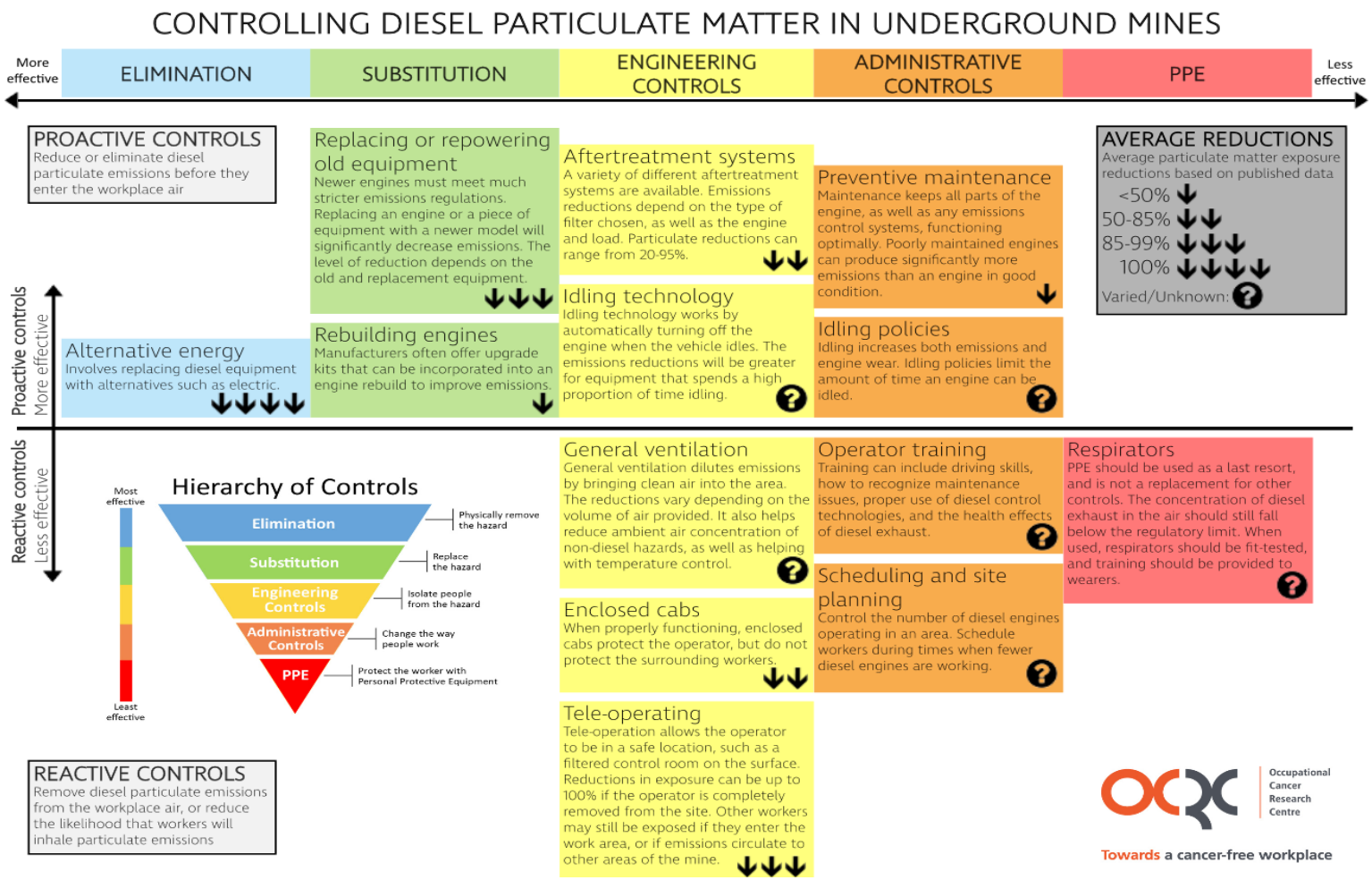
OCCUPATIONAL EXPOSURE LIMIT IN ONTARIO Total Carbon	
Agent	**µg/m³**
Respirable Combustible Dust (RCD)	1500
Total Carbon (TC) (2012)	400
Total Carbon (TC) (2018 - Proposed)	**160**

STRATEGY FOR DIESEL EXHAUST REDUCTION

Elements of a Diesel Exhaust Management Program

- Equipment purchasing policies
- Replacement and repowering of old equipment
- Low sulfur fuels
- Biodiesel
- Performance-based maintenance
- After-treatment systems (Diesel Particulate Filters / Selective Catalytic Reduction)
- Equipment management
- Idling Policy/Idling Technology
- Driving policies
- Prescribed ventilation rates
- Enclosed cab integrity
- Tele-remote and remote vehicle operation
- Operator training

HIERACHY OF CONTROLS



OCRC. Controlling Diesel Particulate Matter in Underground Mines
http://www.occupationalcancer.ca/2017/controlling-dpm-in-mining/

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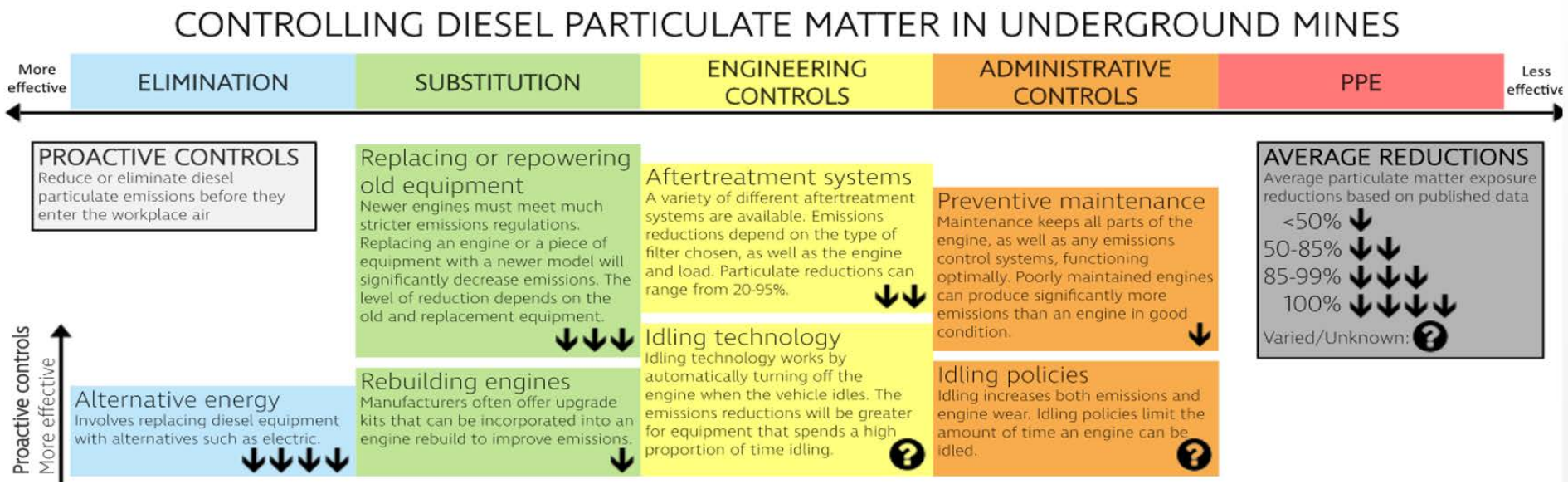

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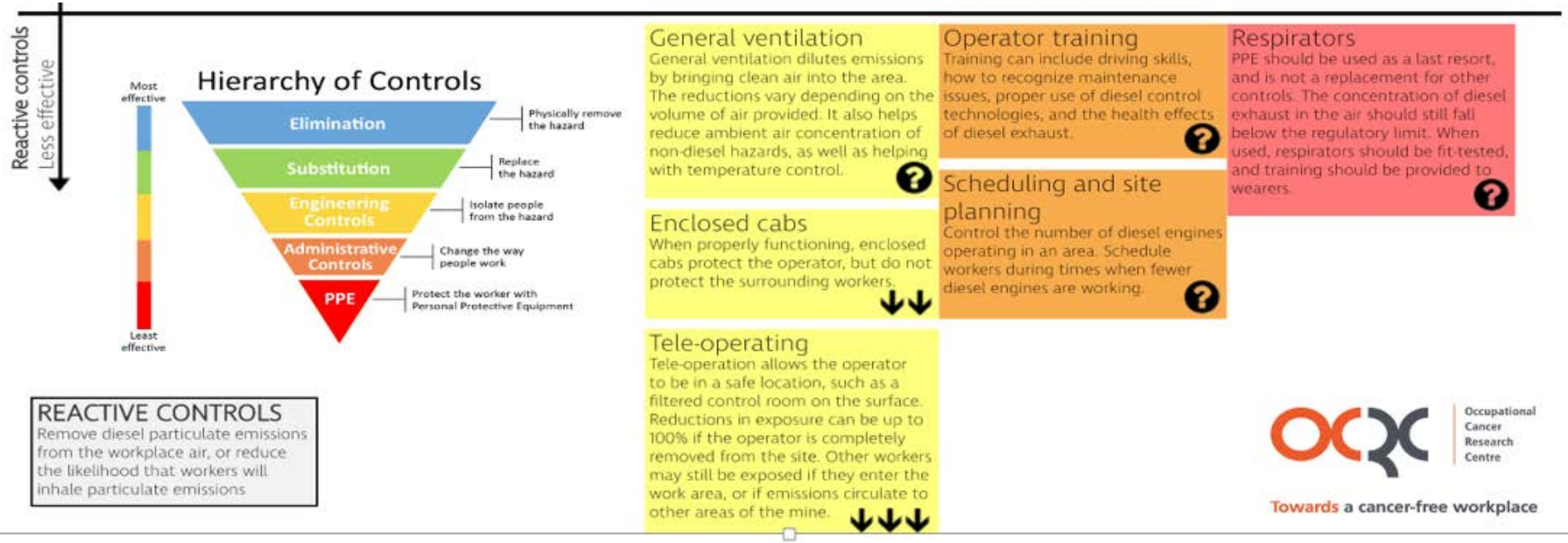

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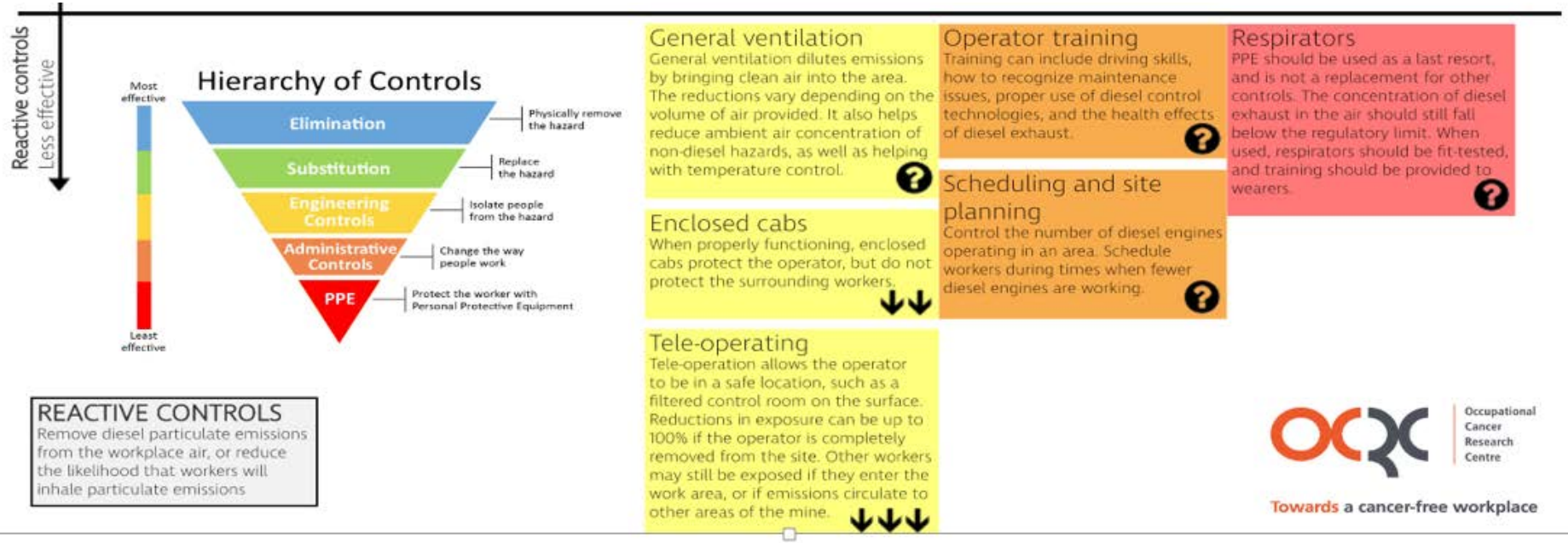

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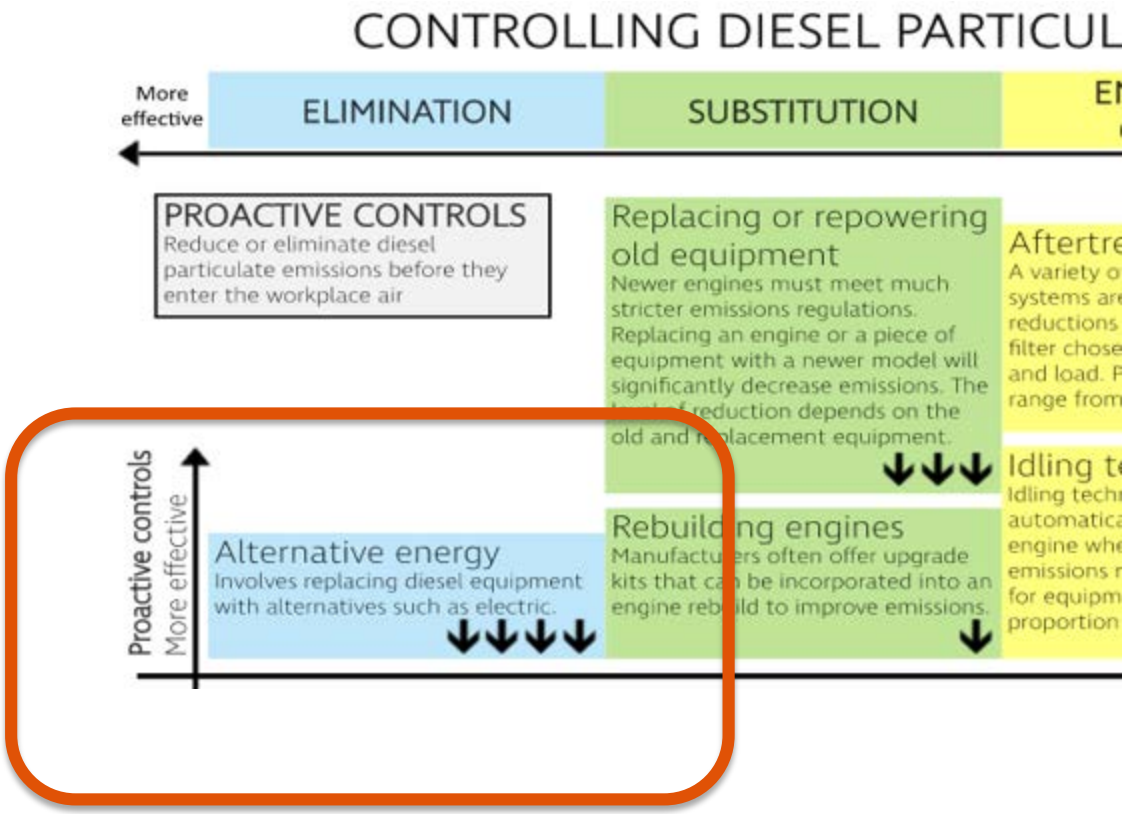
DIESEL EXHAUST ELIMINATION



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THE ELIMINAITON OF DIESEL EXHAUST

In underground mining, the introduction of alternative energy sources (battery electric vehicles (BEV)) offers the greatest opportunity for diesel exhaust exposure reduction.

GOLDCORP'S VISION AND STRATEGY

- At Goldcorp, safe, sustainable and responsible mining is a company-wide commitment rooted in the company's values as an organization.

- We are committed to making our mines and the working environments ***safe enough for our families***.

- **Together, Creating Sustainable Value**

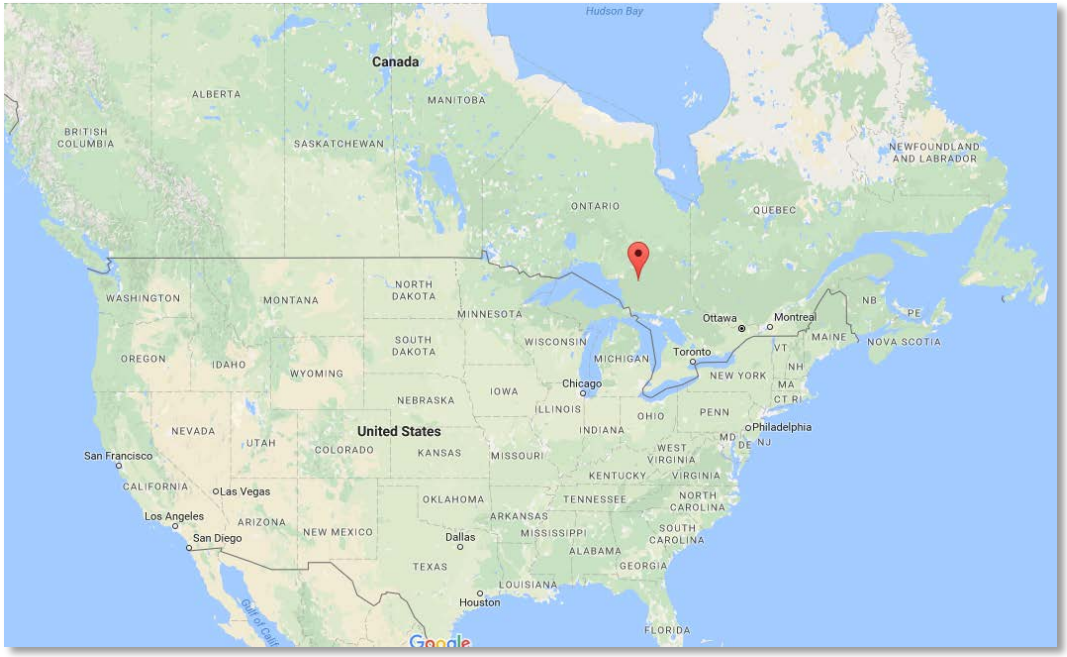
INNOVATION

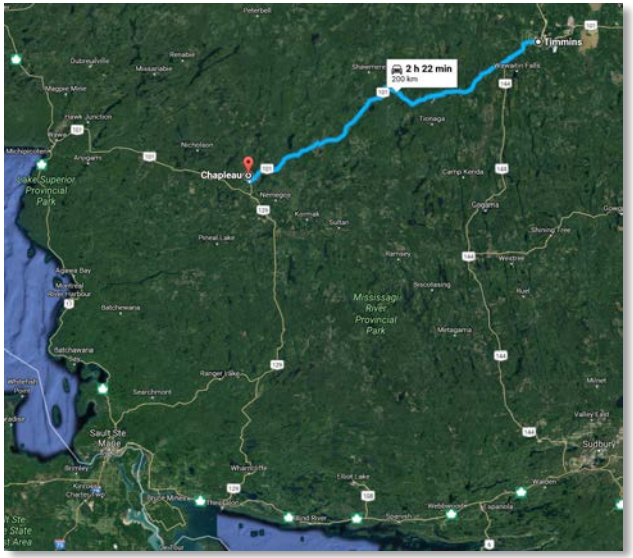
Innovation is key value underpinning the six pillars at the core of our business.

- **Together, Creating Sustainable Value**

BORDEN GOLD PROJECT

Goldcorp's Borden Gold Project (Borden Gold) located in northern Ontario represents the '***mine of the future***' where digitization and low carbon energy technologies underpin the viability, sustainability and profitability of the mine.





BORDEN GOLD

The design is centered on a concept of sustainable mining that improves safety performance, leverages technology and innovation, reduces greenhouse gas (GHG) emissions and eliminates diesel particulate matter.

- Borden will make use of emerging technologies, use far less energy, and produce emissions magnitudes less than a traditional mine similarly sized

- It will incorporate advanced and novel battery technology never used before in the underground mining industry in Canada.

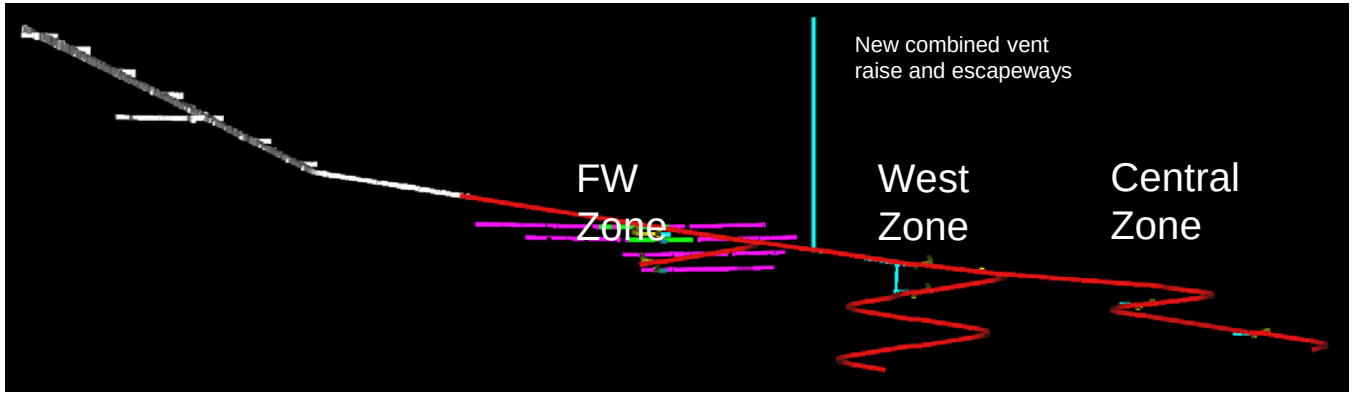
BORDEN GOLD

This project is the first underground mine in Canada to replace all diesel mobile equipment with Battery Electric Vehicles (BEVs)

- The mine is a model of efficiency and innovation, a low carbon footprint mine and cost effective.
- The impact of this project has the potential to transform Goldcorp, the industry and beyond.
- Co-benefits include environmental, health and safety, and economic.

BORDEN GOLD MINE

- The Borden Gold Mine will produce up to 2,000 TPD of ore at a capital cost of US250M$
- Mining will occur between 200m and 600m below surface and will be hauled to surface by truck
- The mining method is long hole sub level retreat with levels at every 15m vertically
- Commercial production is planned to start in 2019 and current LOM is projected until 2027
- Current reserve are estimated at app. 1M Oz with an average grade of reserve 6.85g/t – close to 4MT of reserve



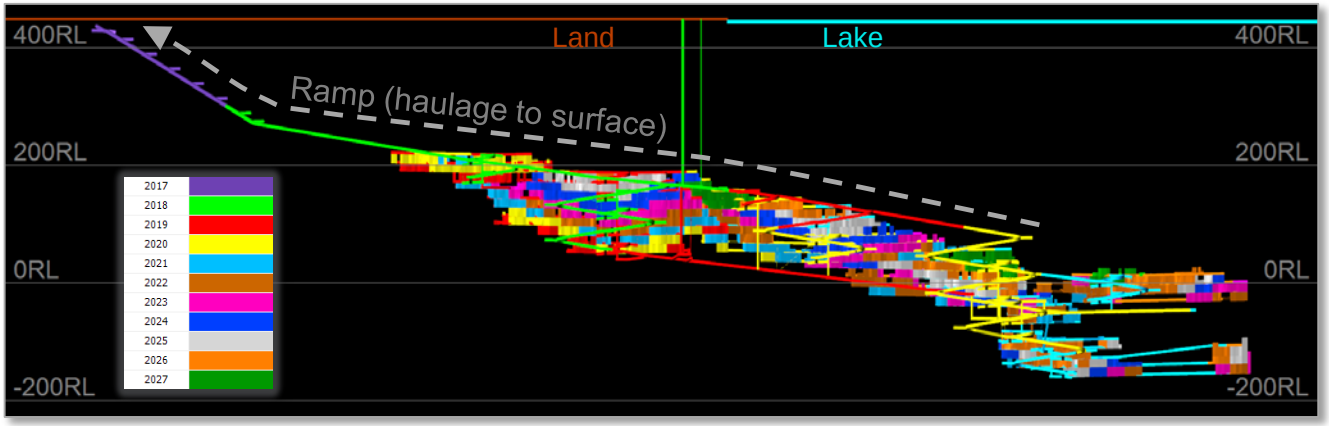
OCCUPATIONAL HEALTH BENEFITS

The elimination of diesel equipment at will also :

- Eliminate occupational exposure to diesel exhaust emissions (DEE), classified by IARC as a Group 1 carcinogen (carcinogenic to humans)
- Reduce underground noise levels
- Reduce underground thermal stress levels
- Reduce whole body vibration for equipment operators

- To date there has been little success in the introduction of BEVs in mining despite compelling environmental and health benefits.
- However, today the total cost of ownership (CAPEX +OPEX) are moving positively in favour of BEVs.
- BEVs are the solution to reducing DEE exposures, and ventilation requirements for gases and particulate in underground spaces

To support the vision of the Borden project, Goldcorp approached all of the major mining equipment suppliers with expanding Battery Electric programs.



The discussion focused on the best fit for Borden's MINING needs;

- 14 yd^3 scoops,
- 40 t trucks,
- state of the art drills - automation capability,
- robust bolters,
- utility vehicles
- grader

The business reasons supporting this decision included……

Safe Production

- On Board batteries - no swapping and proven technology

Technology

- Tele-remote scoops and automation-ready drills

Scale

- 14 yd3 scoops and 40 t trucks

Overall, the best fit for Borden was a fleet comprised of equipment from both Sandvik and MacLean.

- **Scoops**: Sandvik LH 514 E – tethered electric
- **Trucks**: Sandvik TH 54-0 diesel - with a firm commitment to a 40 T battery truck
- **Drills**: Sandvik DD 422i
- **Bolters**: MacLean MEM 975 Scissor Bolter
- **Utility Vehicles**: MacLean Cassette Carries and Scissor Lift
- **Grader**: MacLean conversion of a Cat 12 M2 diesel grader
- **Personnel Carriers** Multiple options

SANDVIK EQUIPMENT

Scoops : Sandvik 14T LHD

- Teleoperated capable from surface via Wifi (100%)
- Tethered unit has no battery
- Will only perform when powered to the grid
- https://vimeo.com/162330918

Trucks: Sandvik 40T truck

- Sandvik committed to delivering a 40T BEV truck by 2020
- Challenge is duty cycle 17% ramp and 2 km without recharging
- We have alternatives to achieve an electric mine.

Drills Sandvik Drill

- On board charger, charges while drilling
- System has approx. 4 years of testing in Sandvik UG test mine
- Total tramming distance 14 km on flat ground 5 km on 1:7 ramp

MACLEAN ENGINNEERING EQUIPMENT

Currently purchased:

- Boom Truck
- Cassette Truck
- Scissor lift
- Emulsion loader
- Bolter

- Every unit has a on board charger
- Charge with conventional underground extension cord
- Limited autonomy compare to diesel
- Require to take advantage of opportunity charge

BATTERY CHEMISTRY: HIGH DENSITY / HIGH PERFORMANCE

Proven, best-in-class battery technology:

- Lithium Ion/Manganese/Nickel/Cobalt battery chemistry
- Sourced from Established European Battery Supplier
- Global leader in battery development and industrial integration
- 30.67 kw per module:
  - Stackable
  - Each module has stand-alone operational capability
- Capable of 6200 charge cycles
  - Charge rate 40 kw/h
  - Complete (80%) charge cycle 1.8 hours
- Battery management system:
  - internal cooling (liquid)
  - cell capacity
  - charge level

Represents annual reductions of:

- 7,000 tCO2e of GHG emissions
- 2 M liters of diesel and 1 M liters of propane
- 33,000 MWh per year because of huge reduction in ventilation requirements

Based on production requirement for the year 2022

- Battery equipment will offer a ventilation reduction of **40% over a diesel fleet (e**xcluding VOD)
- Battery fleet will require higher capital but will reduce OPEX requirement
- Electricity consumption will decrease with a fleet of electric equipment

Air Usage	Diesel Fleet Airflow (m^3/s)	Battery Fleet Airflow (m^3/s)
Development	65.7	36.0
Production	88.9	24.0
Backfill	59.5	24.0
Infrastructure	45.0	45.0
Inactive Levels	20.0	20.0
Distribution Factor	51.8 (20%)	15.7 (10%)
Safety Factor	38.9 (15%)	23.6 (15%)
Total Mine Air	**369.8**	**216.3**
CFM/Tonne Mined	0.97	0.57

NEW MINE DESIGN CONSIDERATIONS

The transition to BEVs allows for new mine design considerations.

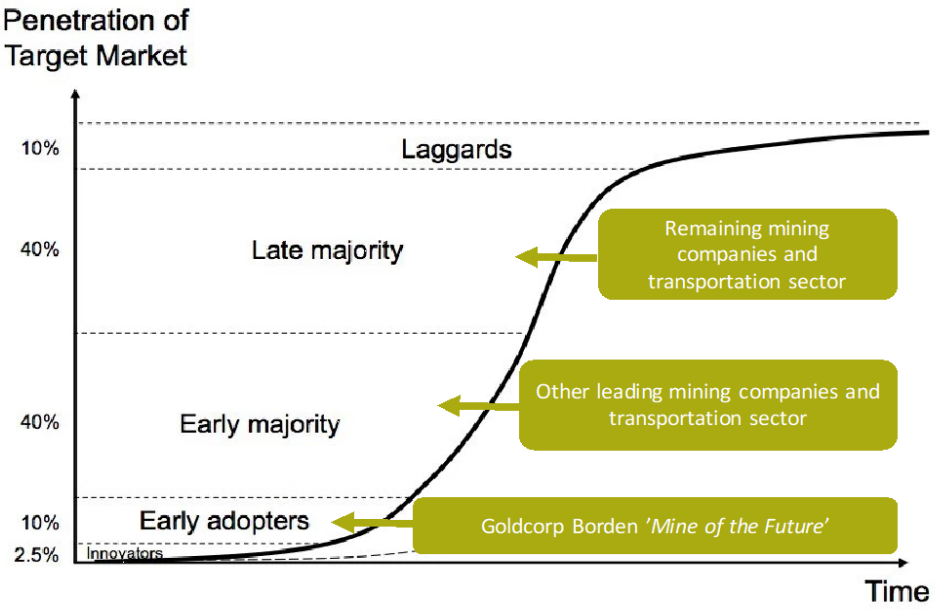
- New infrastructure and systems
- New geometry for drifts and ramps
- Ventilation rates (for efficient and appropriate air flow)
- Electrical vehicle charging stations
- Maintenance shops
- Battery managements systems
- Electricity load control
- Monitoring systems

Health and Safety Benefits

- Elimination of all DPM and all emissions associated with diesel engines
- Elimination of fuel distribution and storage issues
- Elimination of a potential source of ignition, as a result of no diesel exhaust components or shielding
- Elimination of noise, vibration and heat generation traditionally associated with diesel engines

PROJECT IMPACT AND SCALABILITY

- Completely scalable within the mining industry for existing and new mines.
- Applicable to on-road transportation vehicles, construction vehicles, and farming equipment.
- It is believe, conservatively, that at least 50% of new mines in Canada will be built with BEVs and that more than 50% of existing mines will replace their diesel powered vehicles with BEVs within 10 years.



Challenges

- Higher capital required to purchase equipment
- Tramming limitations
- Limited suppliers
- Limited supplier experience
- Unforeseen complications and unproven reliability of new equipment
- Cold weather & temperature changes vs batteries
- Design criteria for ventilation not prescriptive and introduces new ventilation drivers

Partnering

- Consortiums, Governments, OEMs, non-traditional suppliers, other industries.
- Partnering with other mining companies and CMIC to push development of high capacity BEVs (14-18 LHDs and 40 Tonne trucks)
- Exploring battery electric or hydrogen trucks to move ore from Borden to mill in Timmins.

Establishing Widely Accepted Standards

- Compatibility will further increase rate of adoption.

Stronger evidence and datasets

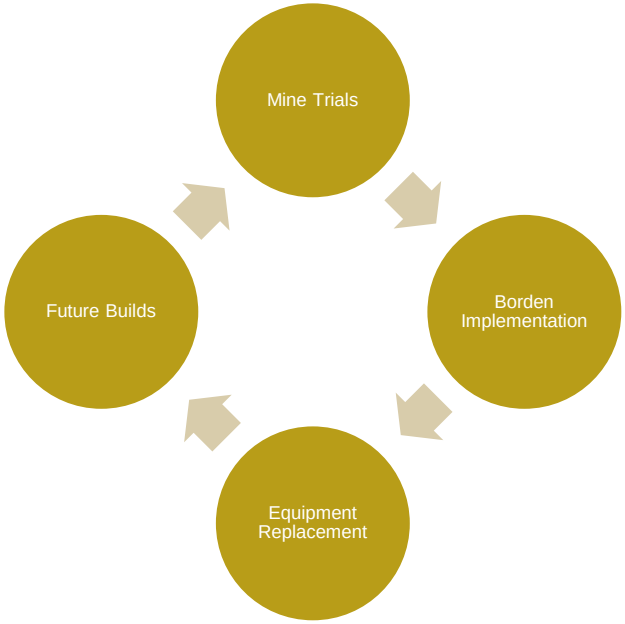
- Knowledge transfer, piloting, and data will push beyond tipping point and prove BEVs are equivalent or superior to diesel and remove the risk of adoption.

Leveraging technology at existing facilities

- Goldcorp is leveraging the technology and lessons learned to transition to BEV at existing operations

New Builds

- Will also leverage latest clean technologies



Societal Expectations

Recruitment and retention of the next generation of talent.

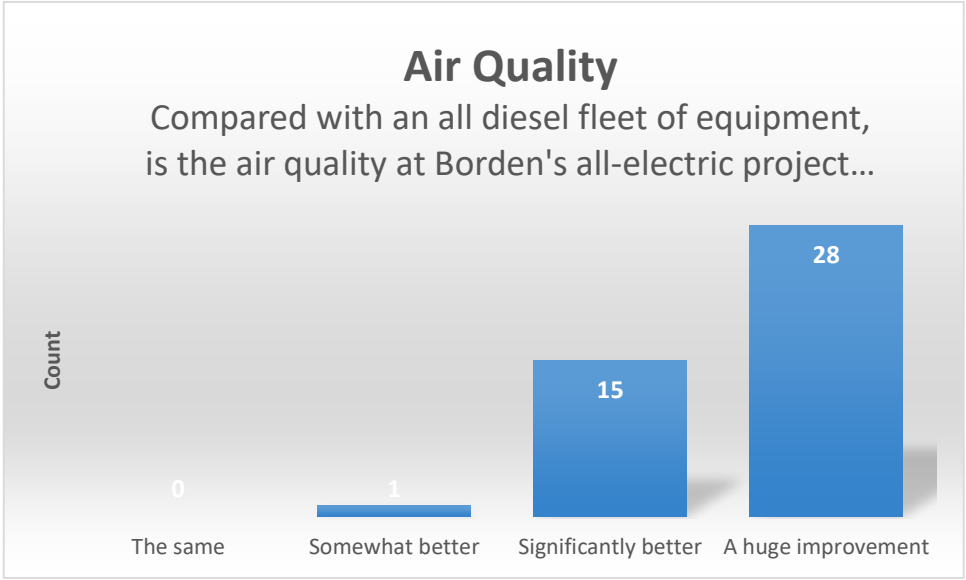
Improved Working Environment

A questionnaire was distributed to the Borden Gold workforce to gauge satisfaction with their working environment as it relates to:

- Air quality
- Noise
- Vibration
- Daily Impact
- Job Satisfaction
- Referrals

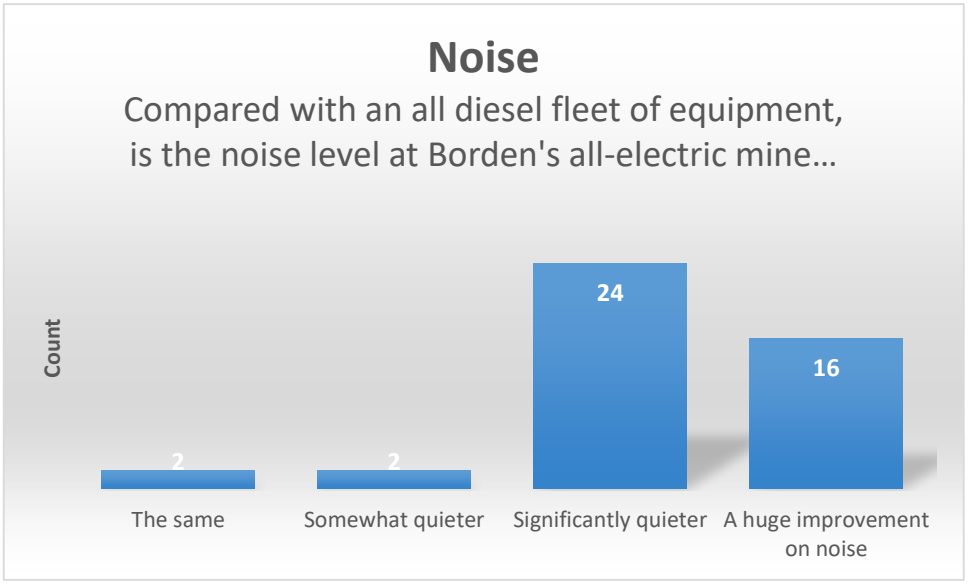
Air Quality

97% found air quality levels air quality levels at least significantly better than in a traditional diesel mine. 63% said it was a huge improvement.



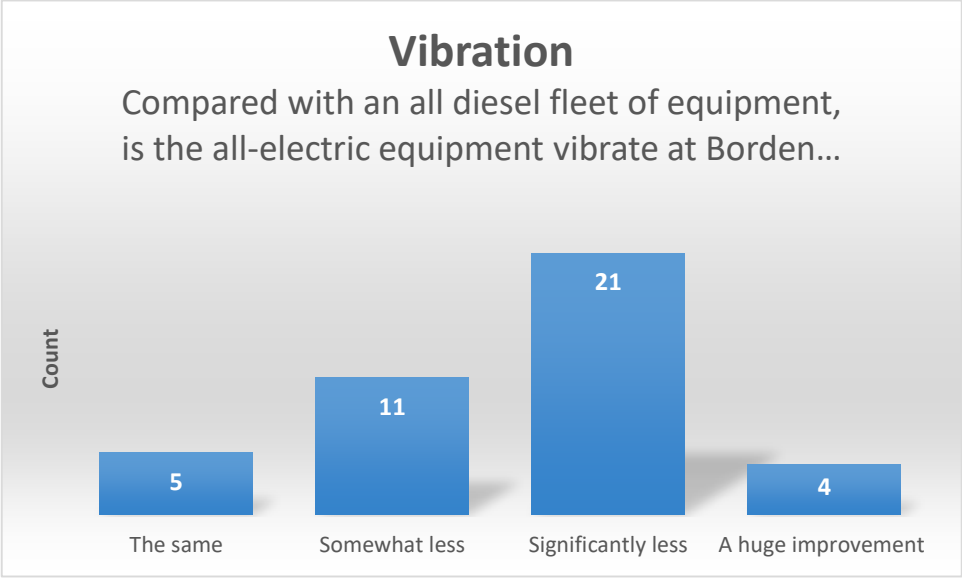
Noise

91% found noise levels at least significantly less than in a traditional diesel mine. 63% said it was a huge improvement. 36% said it was a huge improvement.



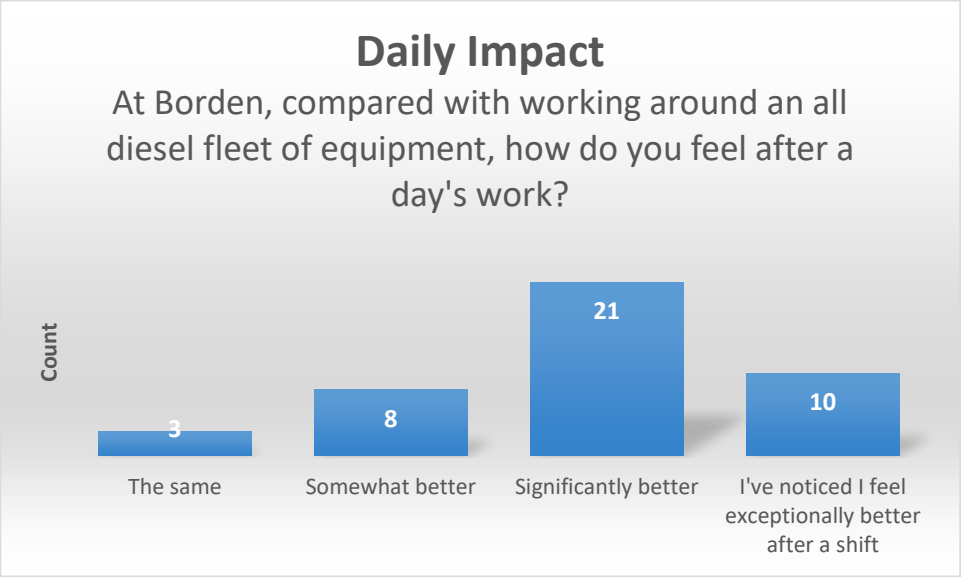
Vibration

61% found vibration levels at least significantly less than in a traditional diesel mine.



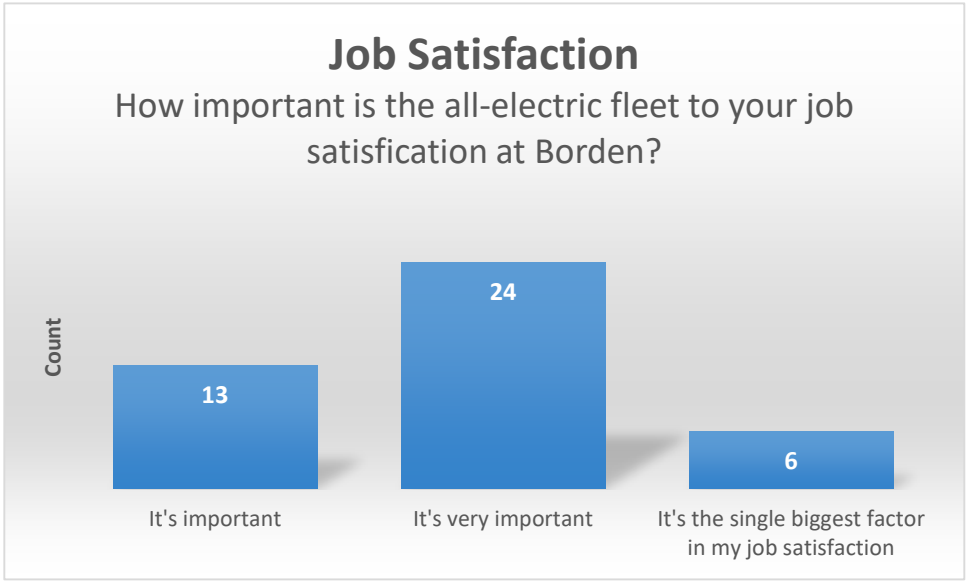
Wellbeing

76% found they felt significantly better at the end of the shift, compared to working with a diesel fleet.



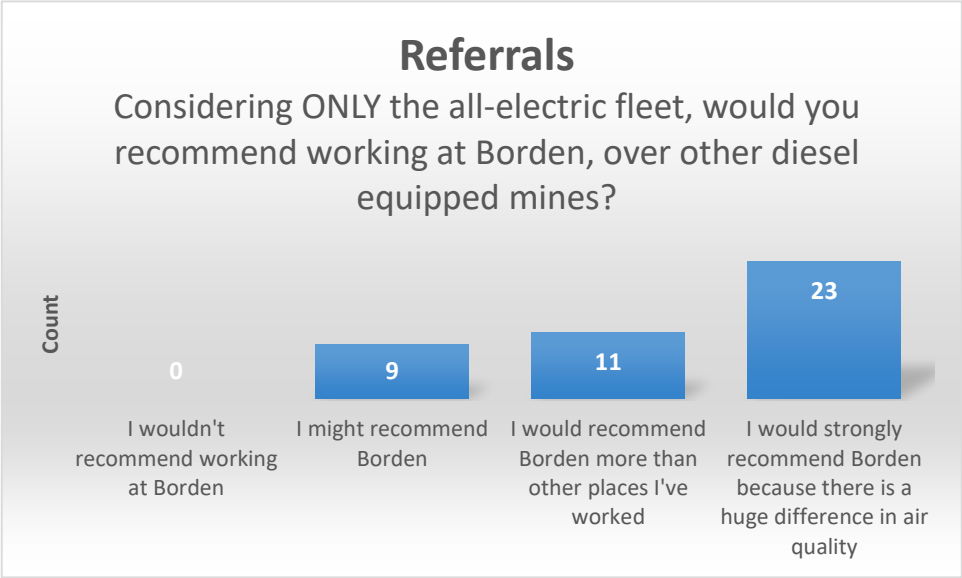
Job Satisfaction

70% felt that an all-electric fleet was very important to their overall job satisfaction. 14% said it was their biggest single factor.



Referrals

77% would recommend working at Borden Gold. 53% would strongly recommend Borden.



A DIESEL- FREE MINE OFFERS….

- Elimination of emissions associated with diesel engines
- Elimination of noise, vibration and heat generation traditionally associated with diesel engines
- Overall reduction of ventilation volumes underground
- Reduction in energy use and GHG footprint
- A significantly improved working environment
- Ability to potentially attract and retain talent



THANK YOU

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