Implementing Trolley-assist at New and Existing Operations

Joy Mazumdar

Haulage and Loading 2023

April 3rd, 2023

"Mining is not a choice – the way we mine is."
Dr. B. Banerjee

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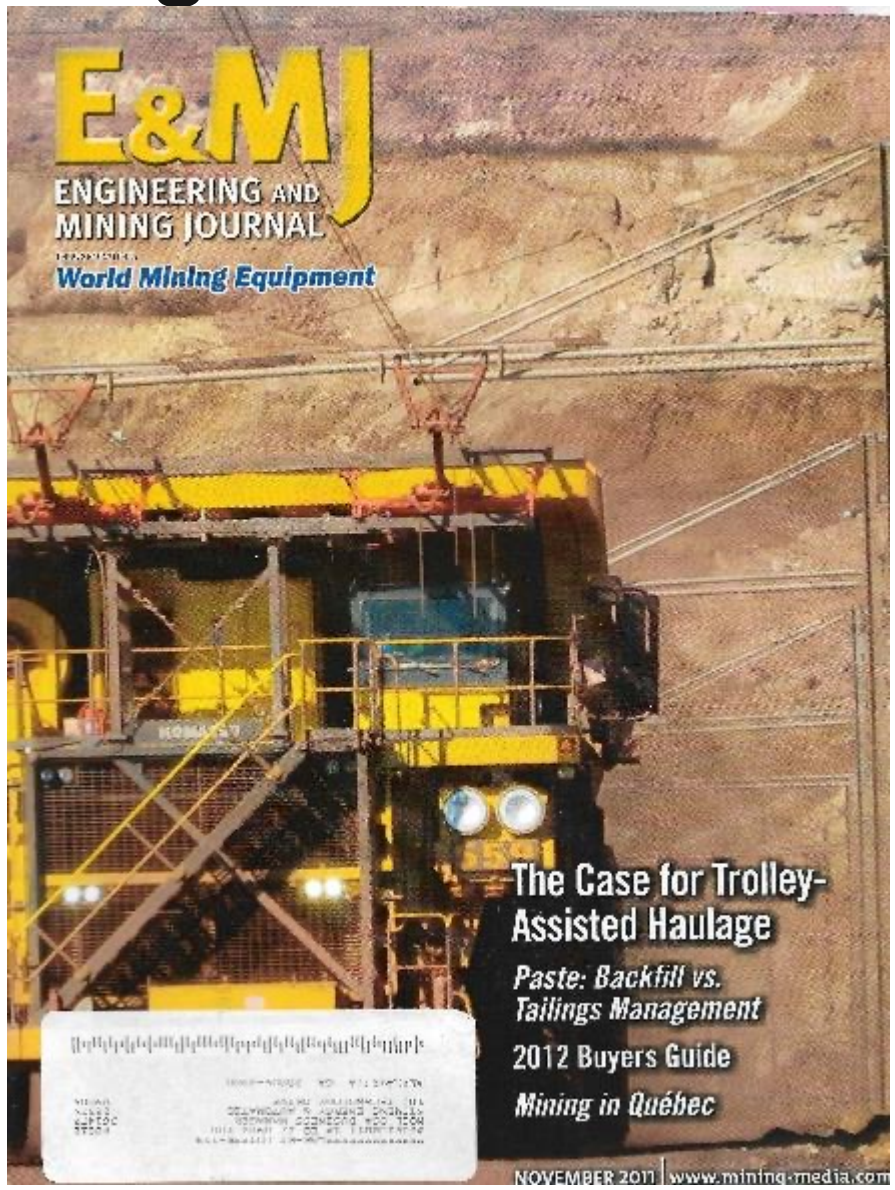
Looking back….



TROLLEY ASSIST

The Case for Trolley Assist

High fuel prices are the main reason mine operators consider trolley assist for haul trucks, but safety and sustainability are also important considerations

By Dr. Joy Mazumdar

Large haul and super-giant trucks are considered ideally suited for trolley assist haulage.

Advances in electric drive haul truck technology over the past 20 years have been remarkable. The drive systems for these trucks consist of two electric drive motors that are integrated through gears into the rear wheels of the trucks, an electric generator and a powerful diesel engine. The characteristics of the truck's drive system allow it to harness electrical power directly. In some parts of the world, electrical power can be generated inexpensively and with less emissions, depending on the fuel source. Trucks with trolley systems, which simply substitute electricity for diesel fuel, may offer another avenue for further advancement.

Instead of generating electricity from the diesel engine and the electric generator on the truck, it is sourced from a fixed based substation and transmitted via an overhead catenary to the drive motors on the truck.

Past experience has shown the best system to fulfill this function should be based on designs used in conventional catenary systems, such as those used for transit on-road or light railway infrastructure. A similar system has been optimized for mining operations, which have similar demands such as mechanical stability, operating reliability and low maintenance. The infrastructure for a complete trolley system includes a catenary system, traction substations, a trolley mast-mounted high voltage supply, a trolley box mounted on the truck deck, and illumination of the catenary system.

The overhead wires are fed from a transportable rectifier station via high speed DC circuit breakers. Masts are placed along the haul routes carrying two catenaries on a single cantilever. Each catenary comprises copper wire messenger wires and copper silver alloy contact wires. The messenger and contact wires are each tensioned via weight tensioning equipment. The mast and foundation poles are insulated, while all other fabricated steel work on the line is galvanized. The line equipment is assembled using galvanized copper alloys or stainless steel hardware.

A robust transportable traction substation has been designed to cope with rough environmental and operational conditions, including the repeated cold that is so typical in traction applications, along with dust, abrasive elements, high temperatures and 24 hour operation. The substation equipment is modularly designed and mounted on skids that allow it to be easily moved from site to site as mining progresses.

Benefits of Trolley

Longer hauls and steeper grades present an opportunity for trolley assisted haulage. Typical truck payload requires a huge power source (around 2,200 kW) that has to be efficiently used. Keeping the gross vehicle weight for haul trucks as low as possible is also important, so power consumption is limited to just one horsepower. Every ton added to the truck itself is one less ton of ore the truck can haul. Most mines are located in remote areas (deserts, high mountains, etc.) and the trucks have to operate with extreme environmental conditions. These parameters make electrical packaging a fundamental component in haul truck design because of the small space left to place adequate power source covers.

The energy crisis in the US led to the development of a trolley system for mines. Today Siemens is a leading supplier of trolley technology and infrastructure and the company has seen a lot of renewed interest, mainly due to diesel fuel consumption. Aside from the obvious reduction in fuel cost, further advantages have been realized with modern systems, including

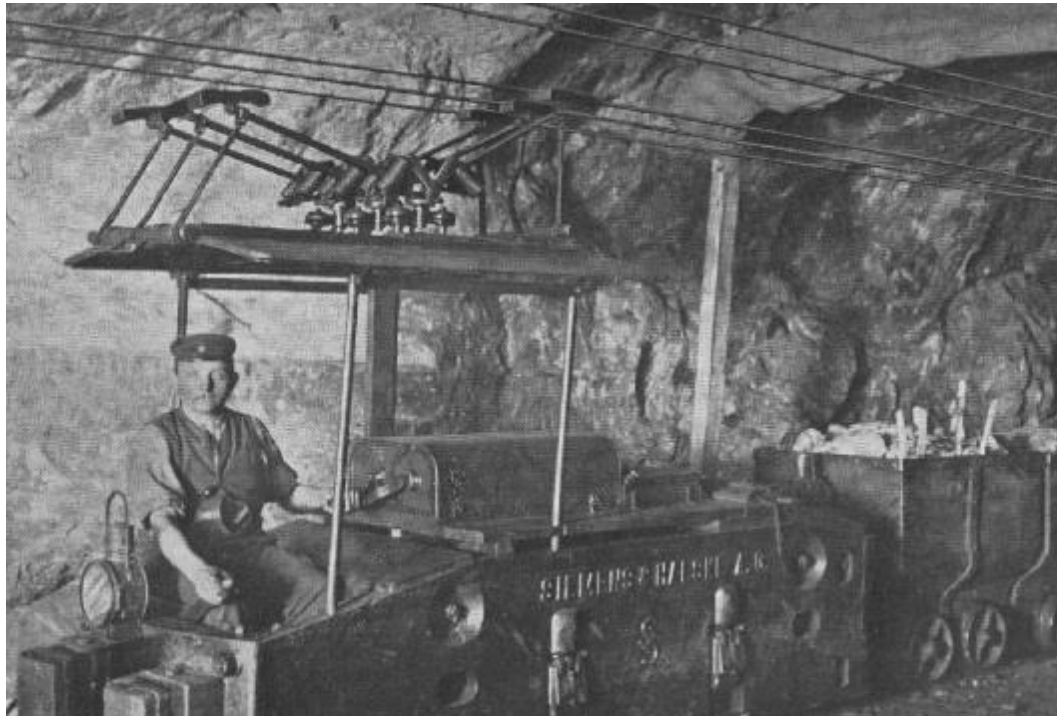
A bit of history…..

Electrified Haulage

- The idea of running a mining vehicle drawing power from overhead lines has been around ~1900's

Power Transfer

- As technology advanced, trolley systems with pantographs were used for mining trucks in the late 1970's

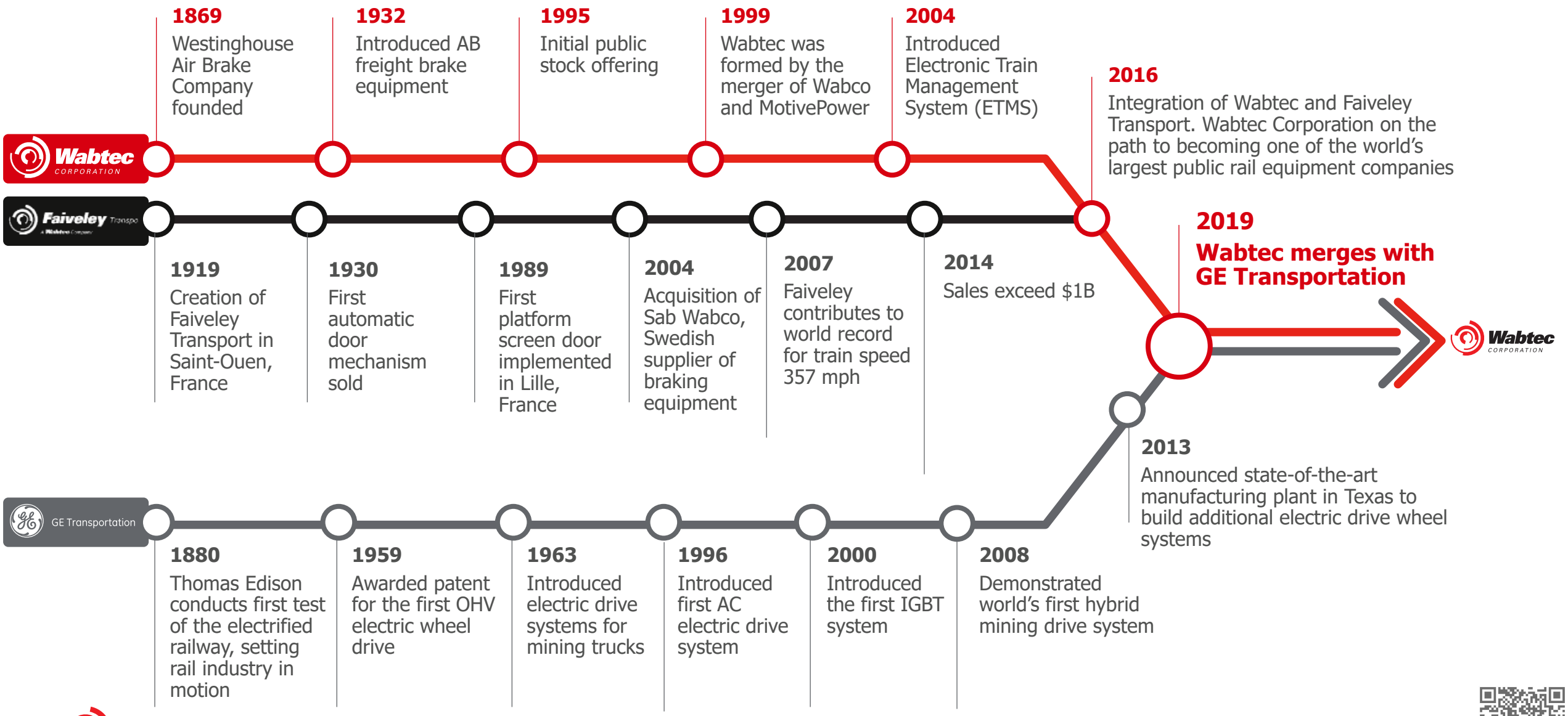


* Image HL 2011

Overview

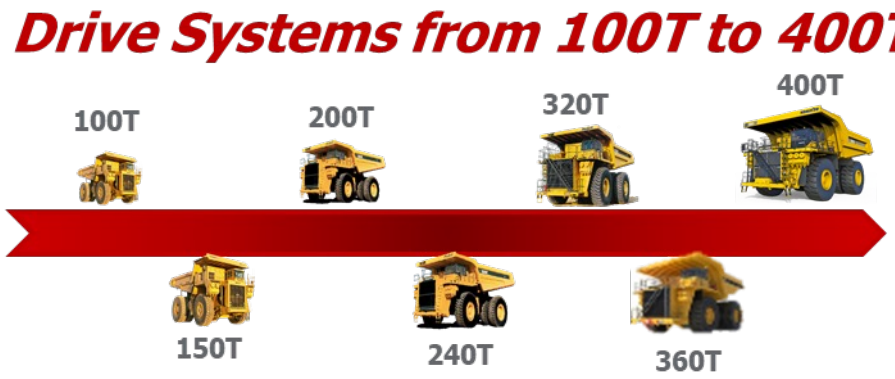
- **History Wabtec Corporation**
- **Bridge to Electrification - Trolley**
  - Trolley Overview and History
  - Trolley Kit
  - Integration of all electric system
- **Simulation Results**
  - Trolley Benefit Analysis
  - Trolley Use Cases
  - Pantographs and Charging
- **Conclusions**

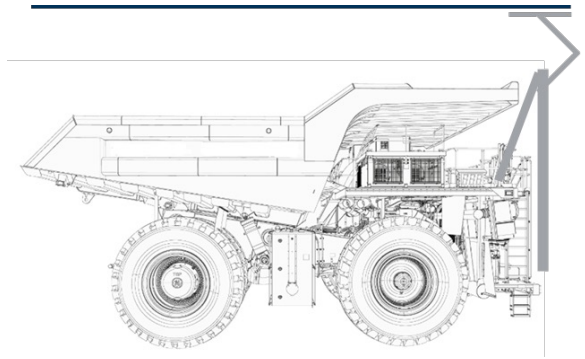
Nearly four centuries of collective innovation

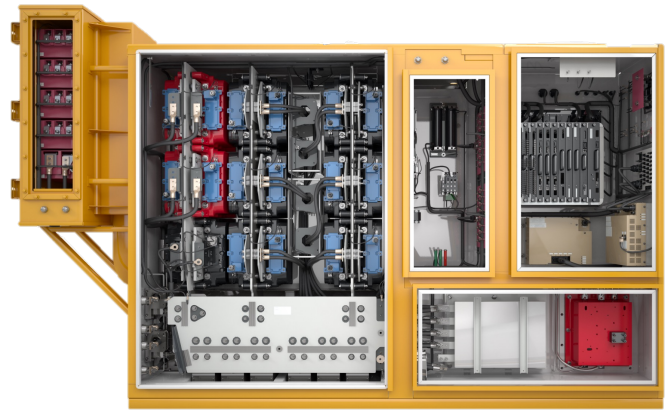


Wabtec (former GE Transportation) Electric Drives

65 years later







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One Wabtec Mining

Mining Equipment

Electric Drive Systems for OHV Trucks

Digital Mining

Collision Awareness System
Drill Guidance System
Digital Mine Software, including asset performance and process optimization technologies

Freight Equipment and Services

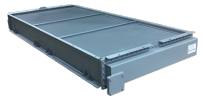
23,000+ Locomotives Worldwide

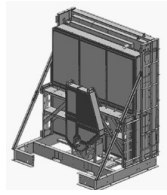
1,700+ Service personnel in 65 Global sites

Charging and Power Transfer

Mining Pantographs
Cable Reels, Sliprings for Excavators,
Cable Reels, Conductor bars for Underground mining equipment,
Charging Systems for multiple machines

Heat Transfer Solutions





High performance heat transfer systems and components for the rail, power generation, oil and gas, and mining markets.

Shuttlewagon Railcar Movers

Tier 4 Diesel to Full EV Railcar Movers

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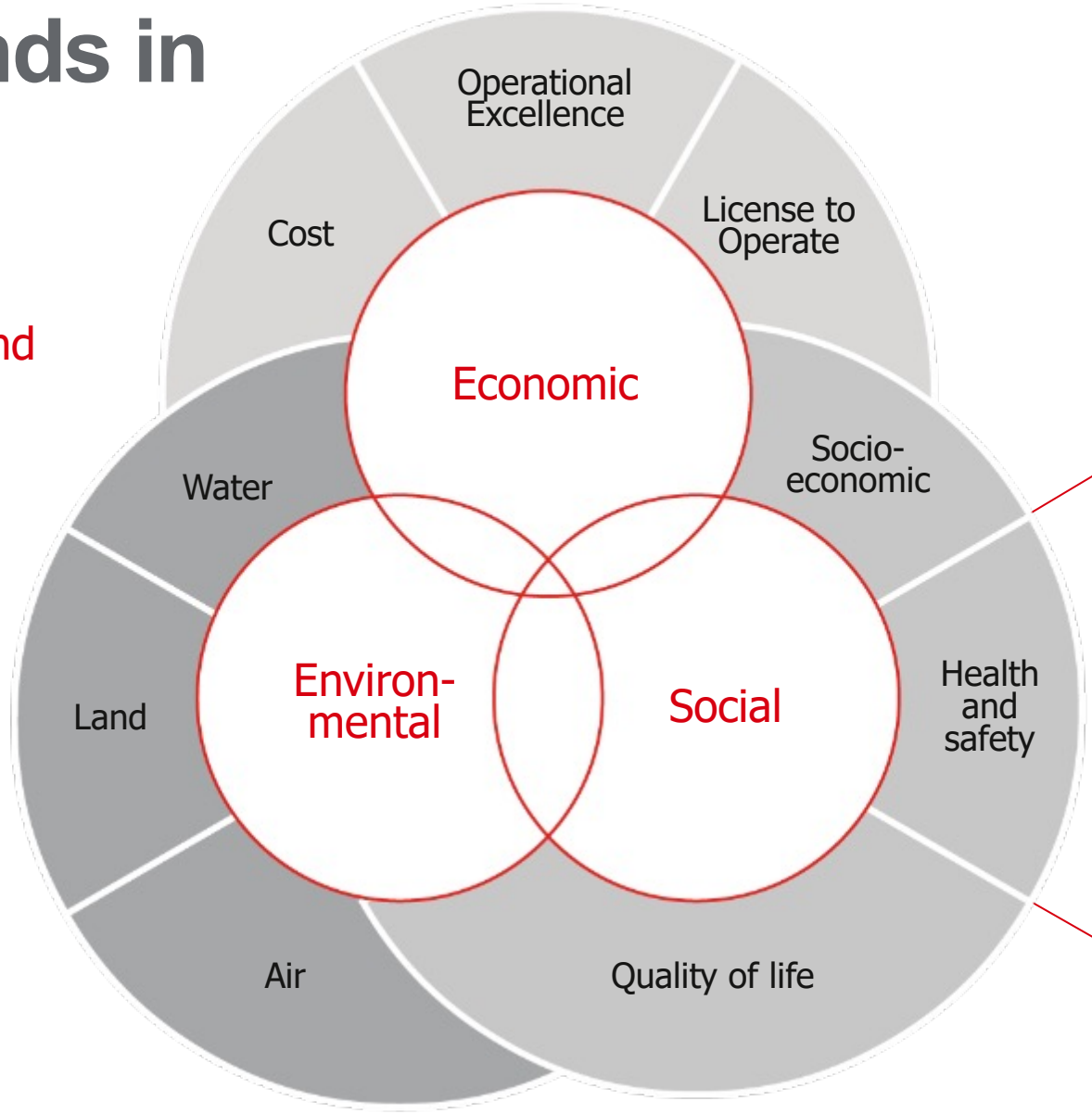
Key Trends in Mining

The economic, environmental, and social benefits of sustainability



Automation

- Safety
- Utilization
- Throughput
- Asset life

Connection

- Safety
- System efficiency
- Optimization

Electrification

- Emissions
- TCO
- Productivity

Source: A.T. Kearney analysis

Bridge to Electrification – Trolley

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Trolley

What is Trolley Assist

System that delivers electric power to a haul truck from an overhead line. The electric power supplements power from the engine to increase speed on grade.

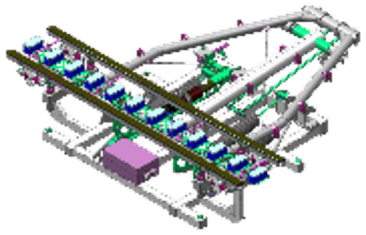
Benefits of Trolley Assist

- Increase speed on grade
- Decrease fuel consumption
- Charge while running
- Extend diesel overhaul schedule
- Reduce emissions

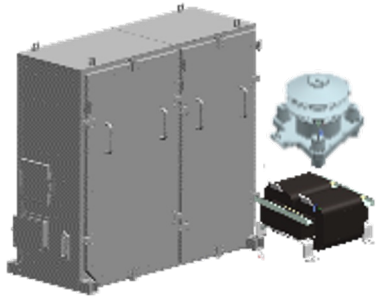
Integrated System – Trolley solution is a kit

- Single supplier/integrator for entire on-truck system – pantograph to wheel

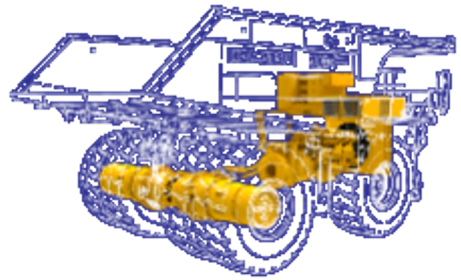
Pantograph & Monitoring Unit



Trolley Kit



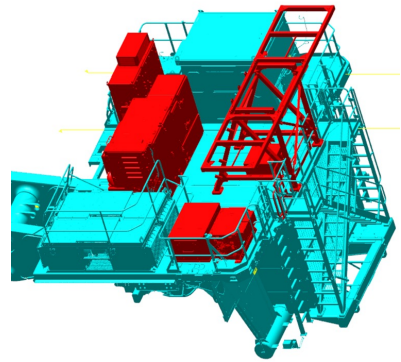
Trolley Ready Drive System



Voltage-flexible

- 1400V ~ 2600V line

Trolley Stepdown System



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Wabtec Trolley Innovation – History and Installed Base

QCM, Lac Jeannine
Quebec, Canada
- Unit Rig M85
- Unit Rig M100
- GE772 w/SEPEX Control

Barrick Goldstrike
Nevada, USA
- 74 x Komatsu 630E
- GE788
- Statex II/III

Kevitsa, Finland
- 13 x Komatsu 830E

Copper Mt., Canada
- 7 x Komatsu 830E

Historic Oil Prices

1960 **1970** **1980** **1990** **2000** **2010** **2021**

Riverside Cement, California, USA
- Dart 27 Trucks
- GE762 traction motors
- Full electric – no diesel

Southern Africa Mines

• Palabora	100 x 170T (GE776)	
• Sishen	74 x 170T (GE776)	
• Grootegeluk*	20 x 170T (GE776),	10 x 200T
• Rossing* (GE788)	31 x 170T (GE776),	10 x 190T
• N'Changa	33 x 120T (GE776)	
• Gecamines	22 x 170T (GE776)	

Trolley Opportunities
- Reliance India
- Grootegeluk
- VALE
- Antafogasta
- Chucquicomata

* Trolley still in operation

Data and image sources: GE Internal & http://hut[illegible]

AC Drive Trolley Upgrade Kit

240T Kit Example

Performance

2.96 MW, 1700V operating line

80% speed on grade increase @ 12% EG max

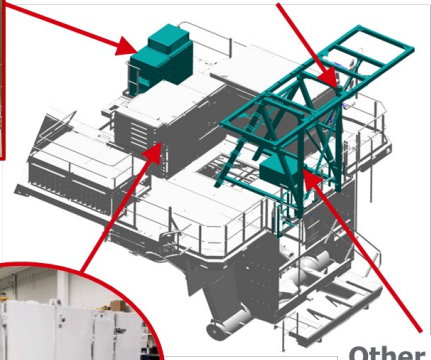
Reduced fuel cost and emissions

Pantograph

- Developed with Faiveley Stemmann-Technik
- Includes guidance system; in-cab display helps operator stay under line

Trolley control cabinet

- High speed circuit breaker
- Contactors

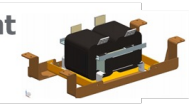


Control group kit

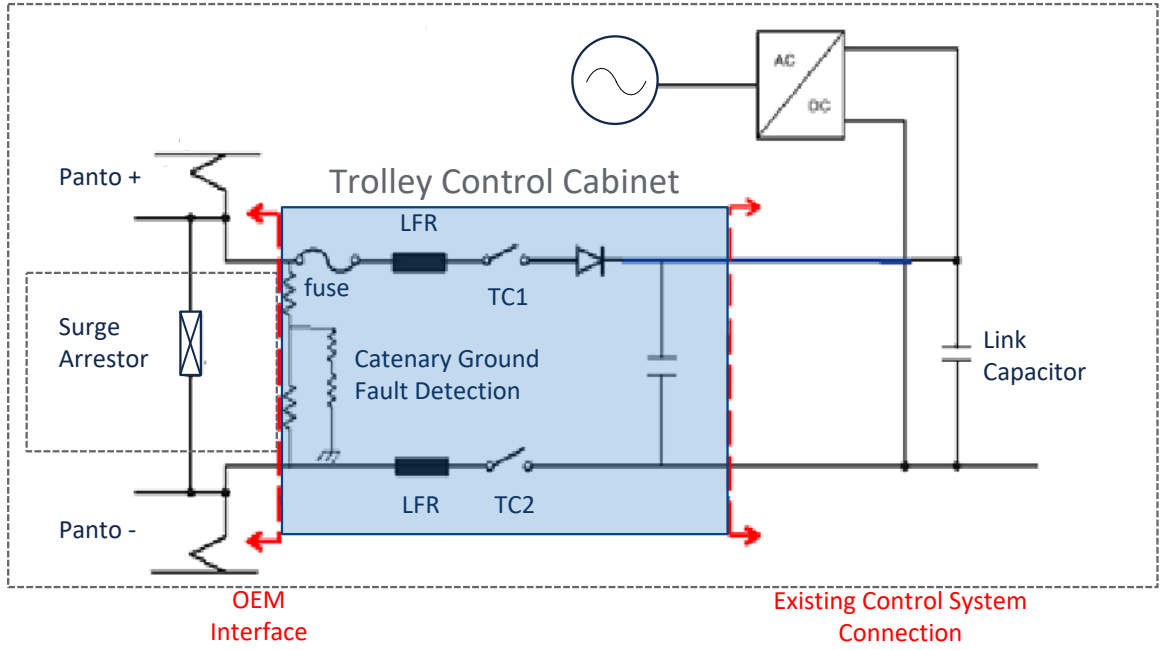
- Revised software
- Modification kit:
  - Capacitors
  - Phase modules w/ SGD
  - I/O handling
  - Bus bars
  - Panto control relays

Other equipment

- Air-cooled Inductor
- Surge Arrestor



Electrical Schematic



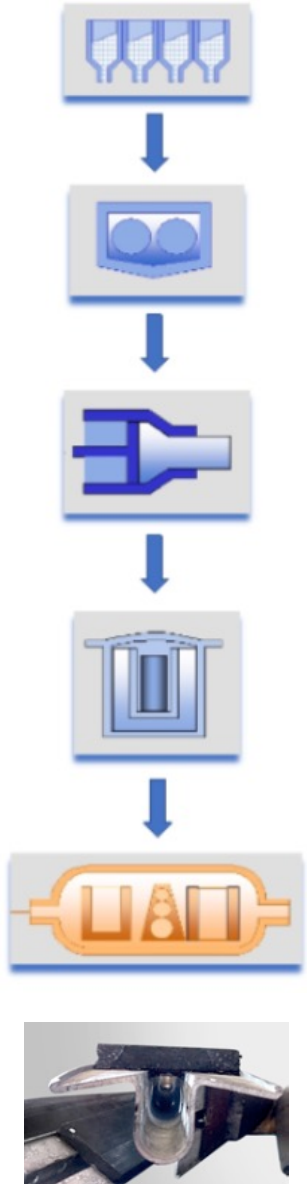
Pantograph Specifications

Parameter	Spec
Voltage	3000V DC
Current	2500A DC
Contact Force	Force 300N set, designed up to 350N
Features	Automated No-Power-Down function Guidance system
Cycles	6,000 Cycles per Year
Actuation	Electric Drive

Wabtec pantograph current: 2500 A

Available Trolley Power = Volts * Current
@1800V, available trolley power is 4.5MW
@2600V, available trolley power is 6.5MW

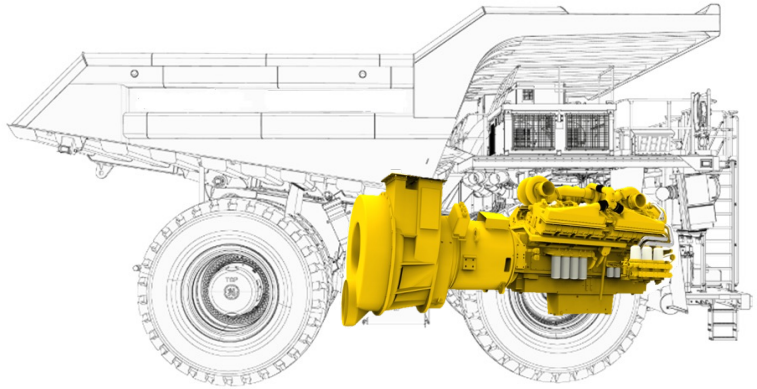
Carbon Manufacturing



Future Trend ….Integrating Battery and Trolley

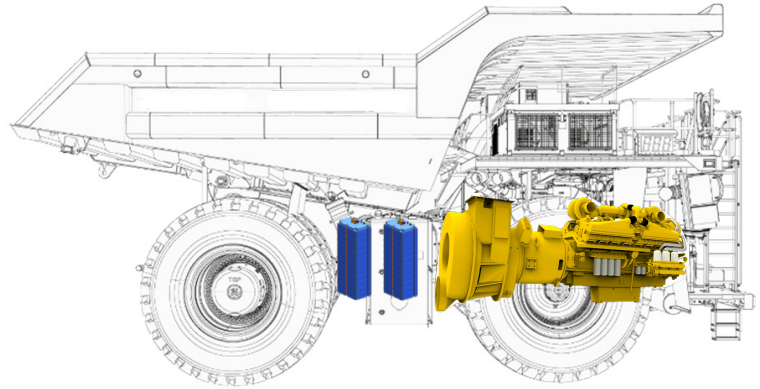
240t example… evolving toward power/voltage agnostic propulsion

DIESEL POWERED



Current configuration:
- 2500 HP engine
- AC alternator

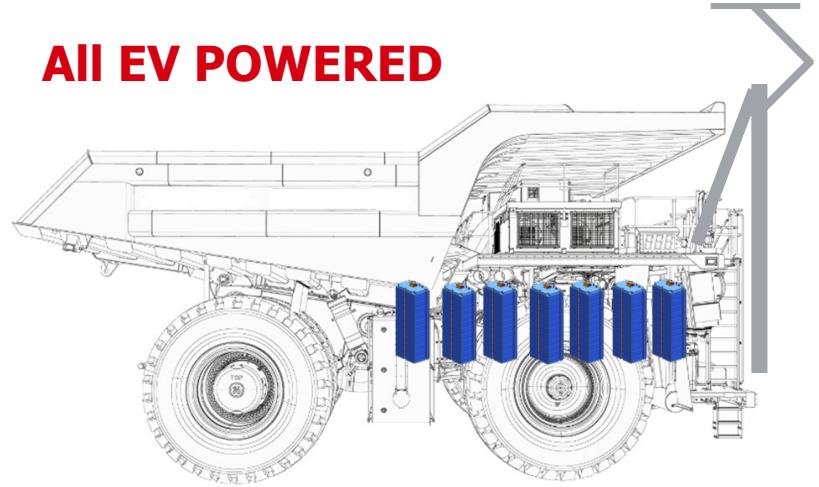
HYBRID POWERED



Configuration:
- 2500 HP engine
- AC alternator
- ES Boosts Performance
- ~200kWh

Benefits:
- ↓ emissions
- ↓ fuel
- ↑ productivity
- ↑ transient response

All EV POWERED



Configuration:
- Engine, alt, radiator eliminated
- 800 – 1200 kWh ES
- Trolley system or road

And/Or Stationary charging

And/Or Hydrogen Fuel Cell

Benefits:
- Zero emissions
- ↓ noise
- ↓ LCC
- ↑ productivity

Plus: Truck operation loads
- *Dump body hydraulics*
- *Steering*
- *Brakes*
- *Cab A/C*

Simulation Study – Trolley Benefits

Trolley Benefit Analysis

For a 1 km trolley ramp with 10% grade and 2% RR

Diesel Speed: 11.2 kph

Trolley Speed: 21.4 kph

Diesel fuel rate: 120.5 gph

Trolley fuel rate: 14.2 gph

Electricity Cost: ~ $6.5

Diesel Cost: ~$30

Diesel emissions: 80 kg CO2e

Increased productivity with reduced fuel consumption

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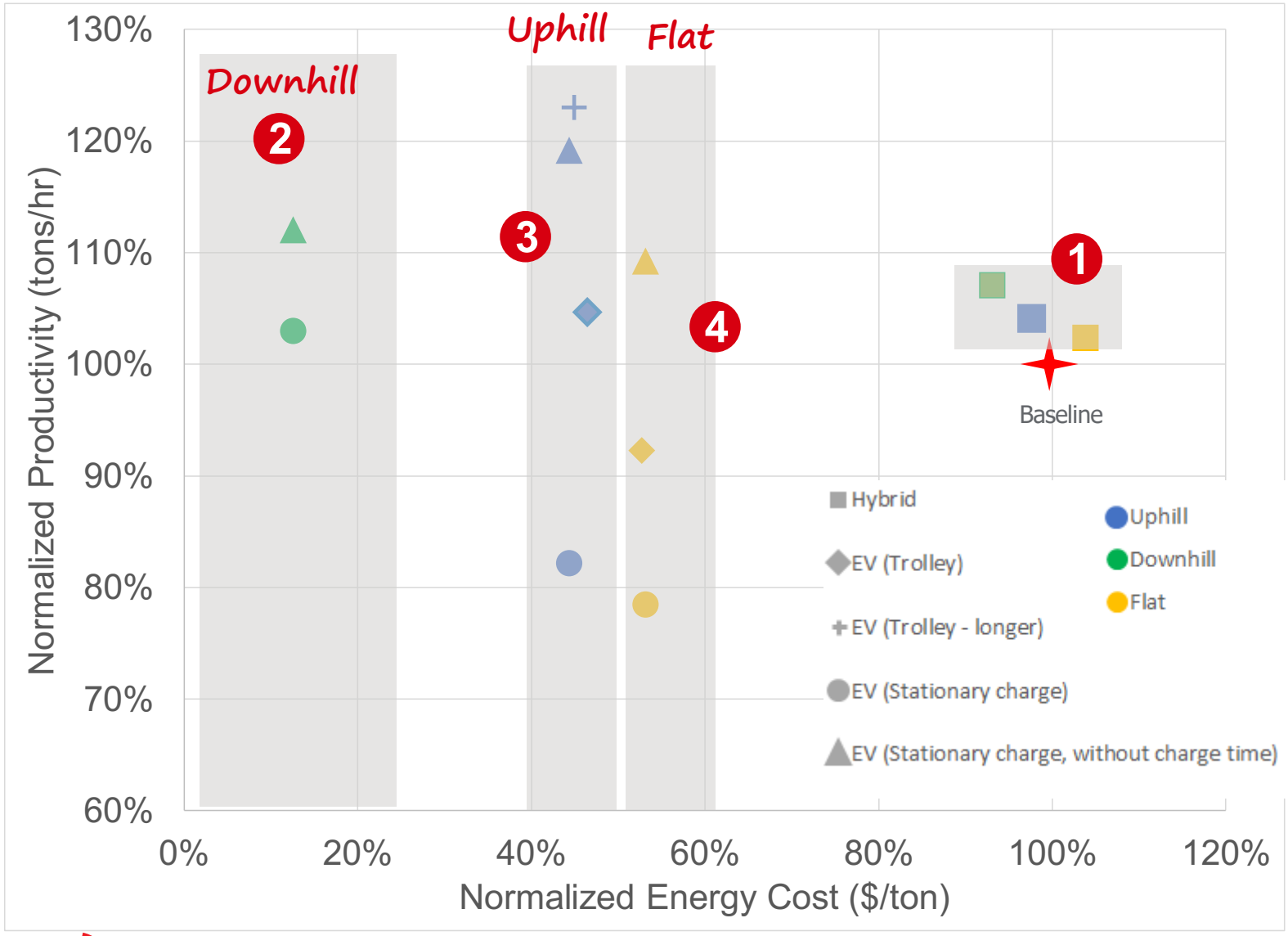
Energy Cost ($/ton) vs Productivity (ton/hr)



1. Hybrid
   - Incremental fuel and productivity improvement on Uphill and Downhill profiles
   - Highest operational flexibility
2. Downhill Hauls
   - No value to trolley
   - EV w/Stationary – high value even with time penalty
3. Uphill Hauls
   - Ideal EV + trolley… Flexibility impact
   - EV + Stationary… delivers flexibility… look at CAPEX
4. Flat Hauls
   - Trolley creates speed penalty…little value
   - EV + Stationary – best impact… look at CAPEX

Charging Infrastructure

Bus Charging

LV to 2.2 MW

Stemmann-Technik a Wabtec Company

Ferry Charging

LV to 5 MW
MV to 15 MW

Stemmann-Technik a Wabtec Company

- Required power transfer for trucks would exceed stationary systems developed for buses
- Power requirements more consistent with ferry (marine hybrid/electric ship) chargers
- **Chargers customized for mining duty, support opportunity fast charging and transportable**

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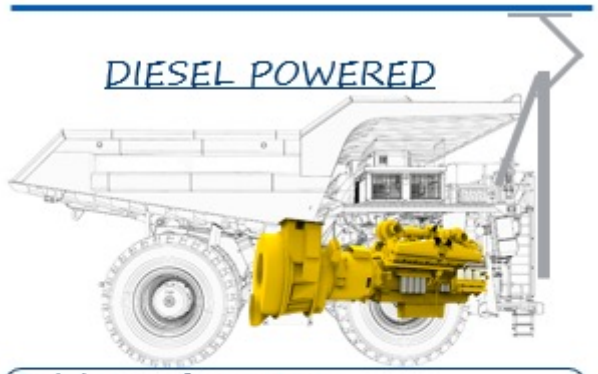
Conclusion

The Future is Electric ; Trolley is the bridge

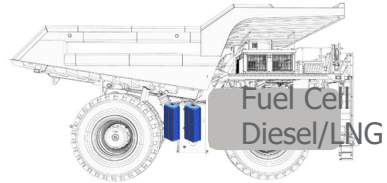
Trolley

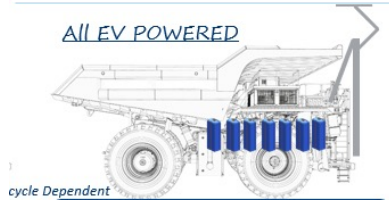


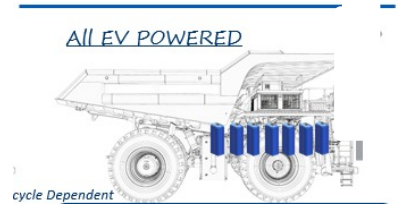
Boliden configuration:
- 2500/2700 HP engine
- GE AC alternator
- Secondary link hybrid compatible
- Traction link trolley compatible

Right Solution for Mine Application

- Flexible platform supports diverse power sources
- Enables alt fuels / EV
- Reduces noise
- Reduces GHG emissions







Hybrid:
- Low – Medium energy Hauls
- Dynamic Mine Plan
- Liquid Fuel Plan

Trolley-Battery:
- Uphill Hauls
- Stable Mine Plans

Battery – Stationary Charge:
- Low Energy Hauls
- High Speed
- Dynamic Mine Plans

- Substantial benefits
- Investments & Viability
- Technology trend

- No 'universal' cell
- Packaging is critical

- Application, Configuration and Value
- Flexibility vs. Benefit

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