



Artisan Vehicles

Heat Generation in Battery Electric Underground Haul Trucks

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MDEC Toronto 2018

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Big Picture

- A diesel truck produces 7-1/2 times the heat of a battery electric truck
- 40 tonne diesel truck produces 3.75 kWh of heat per tonne per km
- Z40 battery electric truck produces 0.5 kWh of heat per tonne per km
- At 960 tonnes per day hauling 2 km on a 15% grade, a diesel truck produces 6.2 MWh more heat than a battery electric truck in one day
- Enough SURPLUS heat to heat an average home for one year. Every day!

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Calculating the Heat

Conventional Thinking

- Electric motors are **90% efficient**
- Diesel engines are **30% efficient**
- Therefore electric machines produce **1/3 the heat** of a diesel engine

THIS IS NOT THE WHOLE STORY

A Correct Model Includes Potential Energy

- $E_{\text{pot}} = m \cdot g \cdot h$ (mass x gravity x height)

Heat = Battery Energy - Potential Energy

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Calculating the Heat

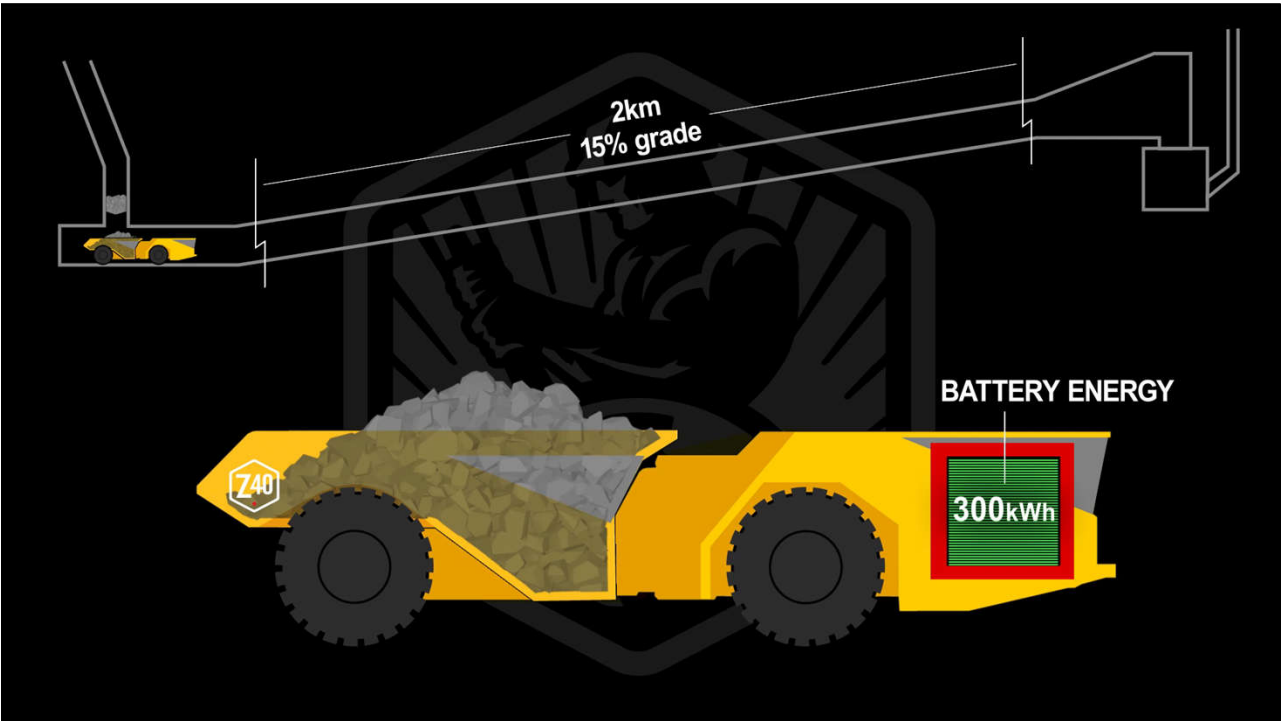
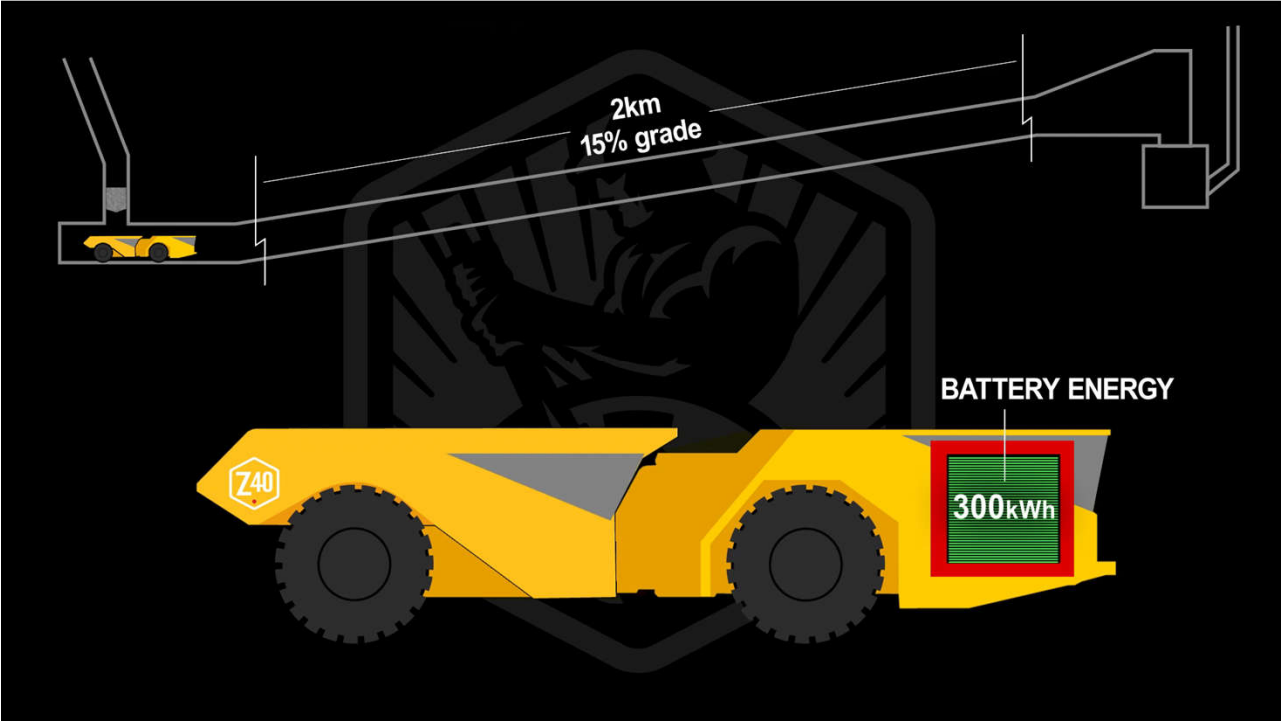
Climbing Loaded

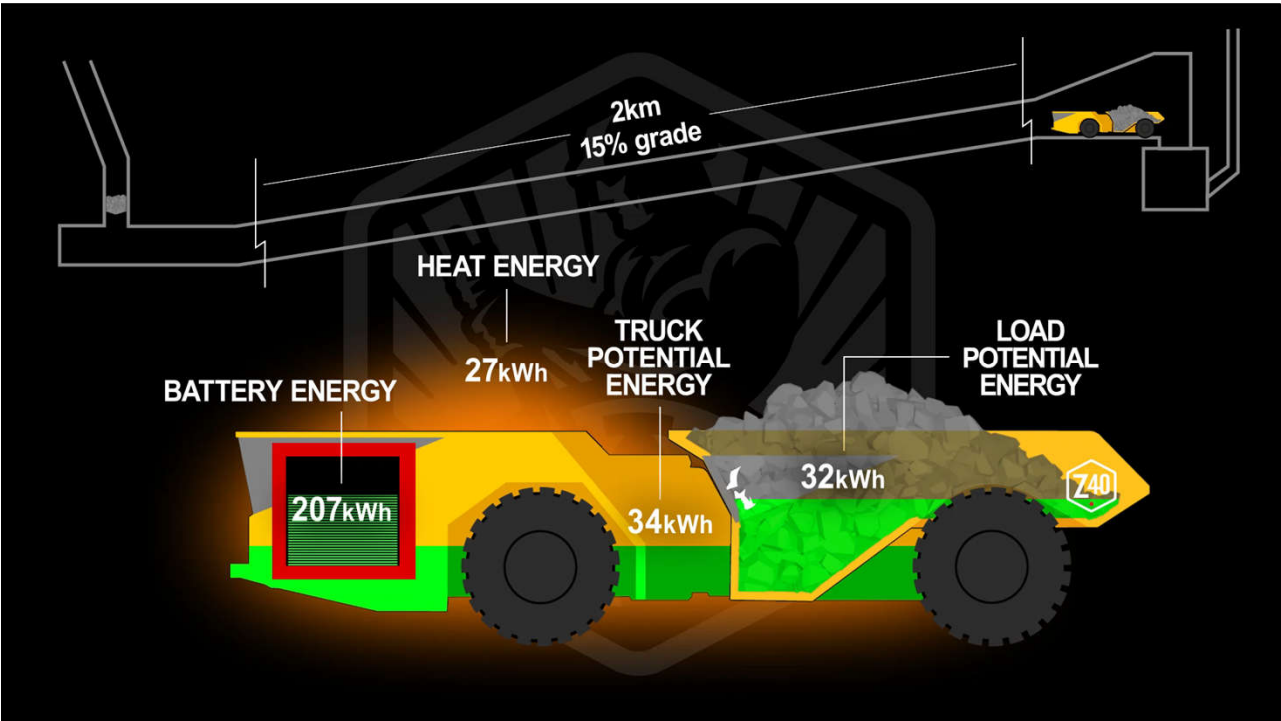
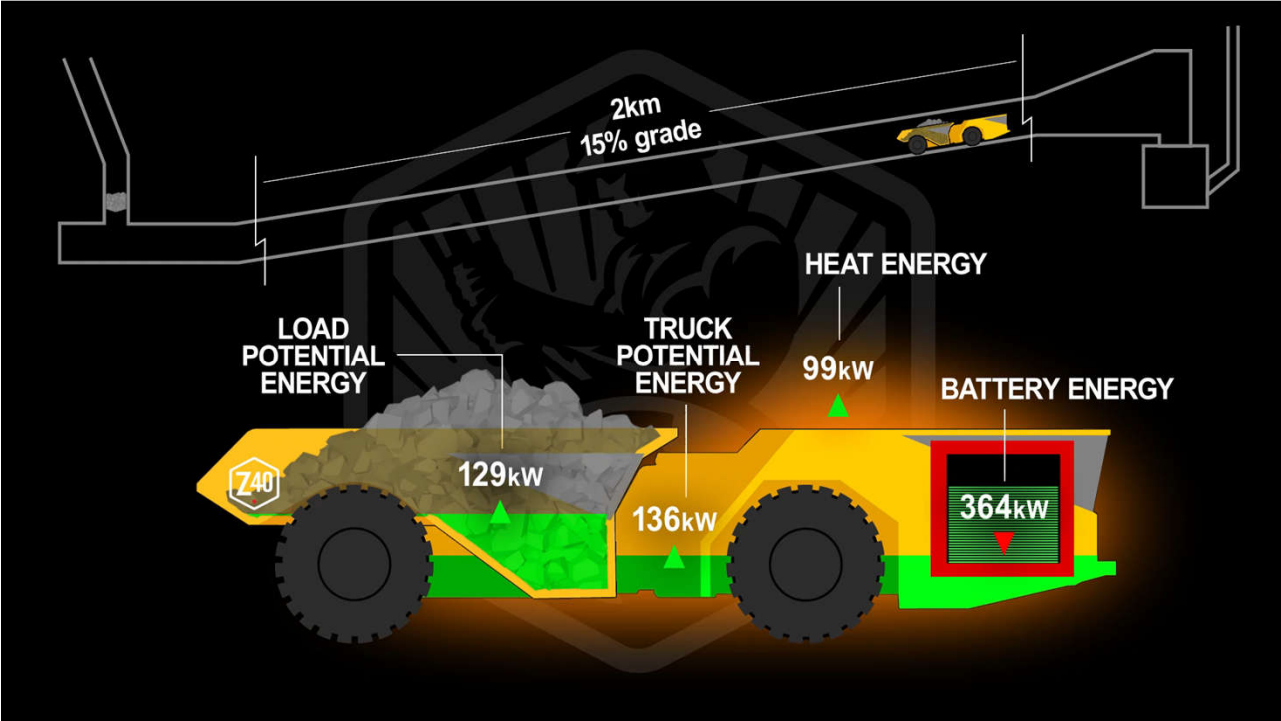
- Power Source?
 - battery
- Where does it go?
 - potential energy of the truck
 - potential energy of the load
 - losses in driveline and propulsion components - **heat**
 - accessory hydraulic and electric functions - **heat**

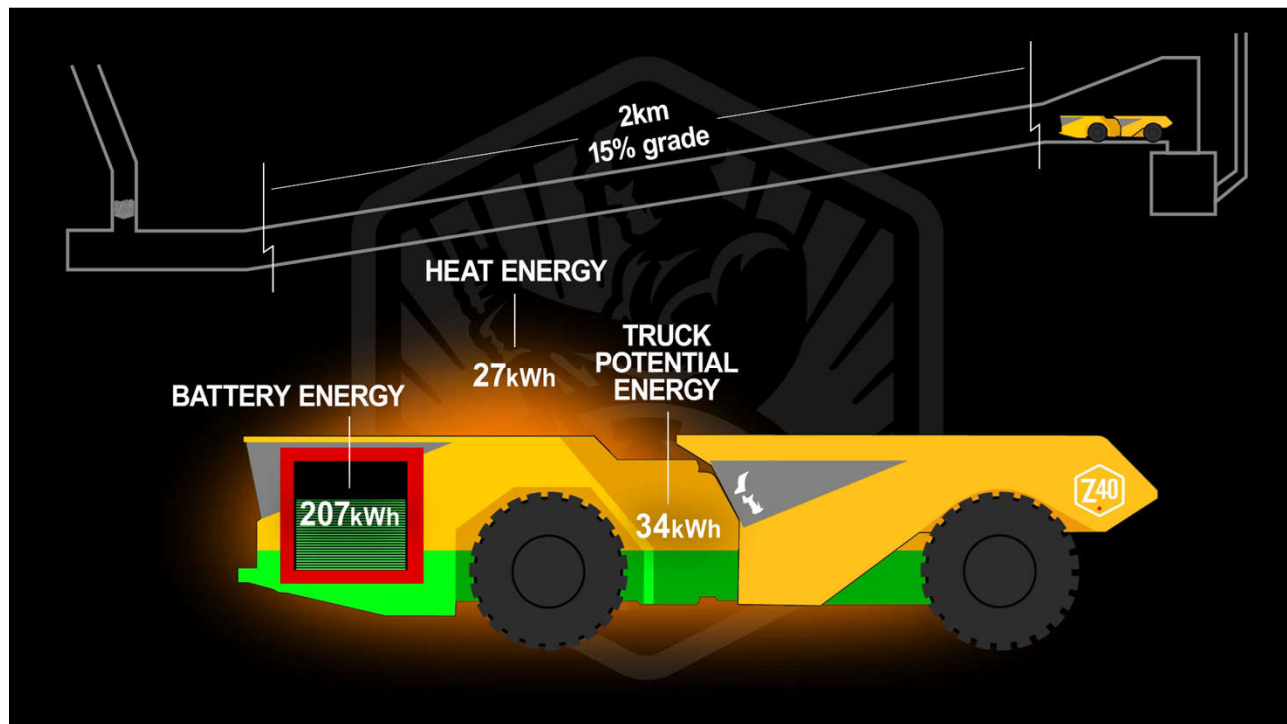
At the Top

- potential energy of load leaves the system
 - that energy does not end up as heat

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Calculating the Heat

Descending Empty

- Power Source?
 - potential energy of the truck
- Where does it go?
 - drivetrain losses and accessory loads - **heat**
 - remaining power is **returned to the battery pack**



Calculating the Heat

Diesel Machine

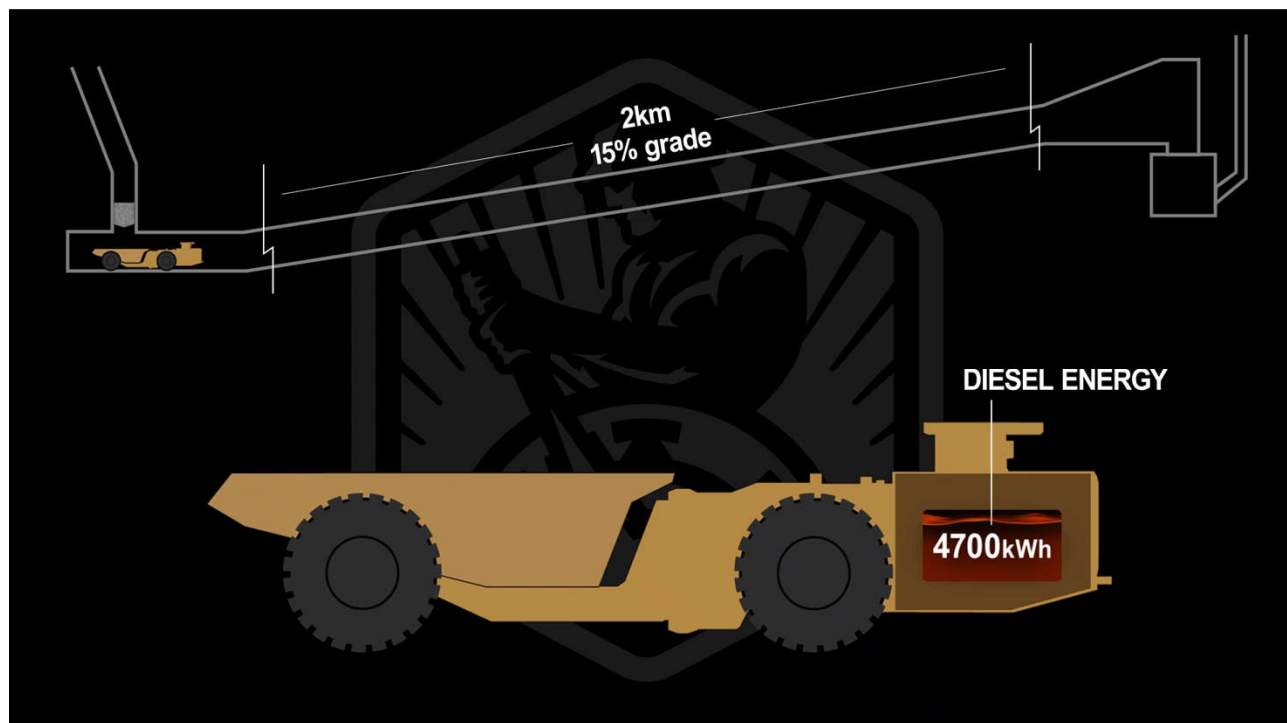
- Power Source?
 - diesel fuel
- Where does it go?
 - potential energy of the truck
 - potential energy of the load
 - losses in driveline and propulsion components - **heat ~3x higher**
 - accessory hydraulic and electric functions - **heat**

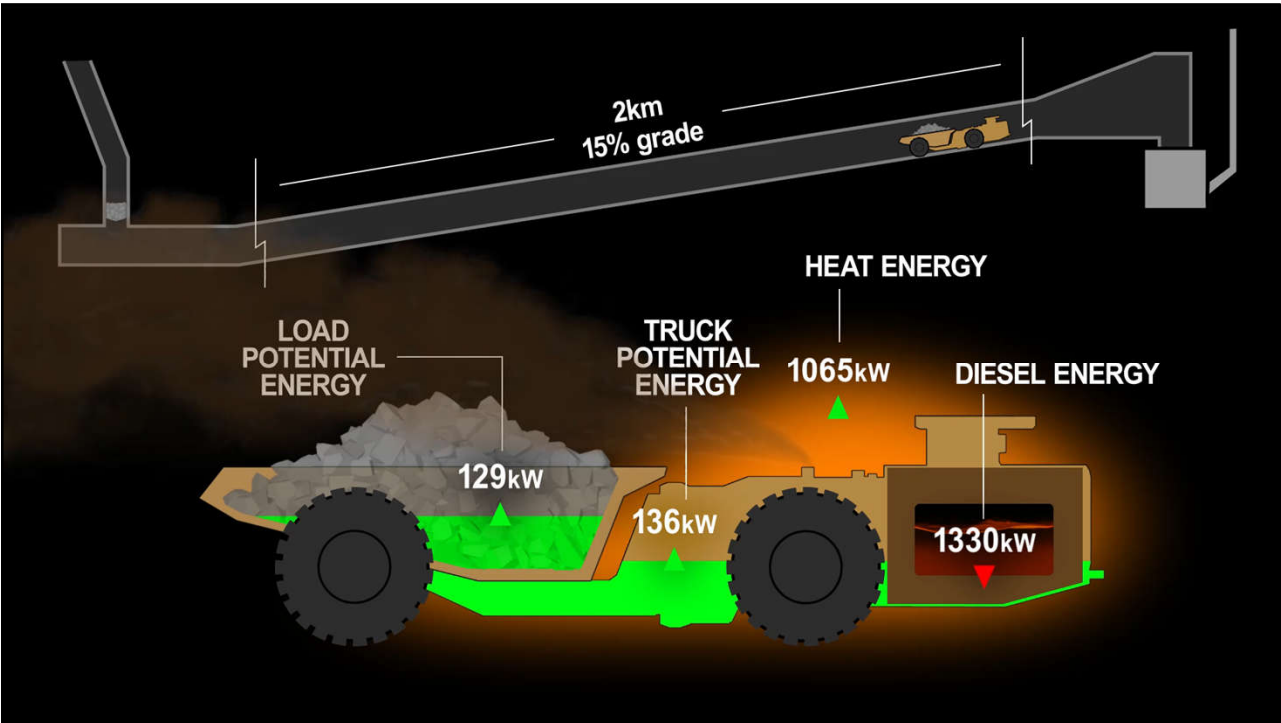
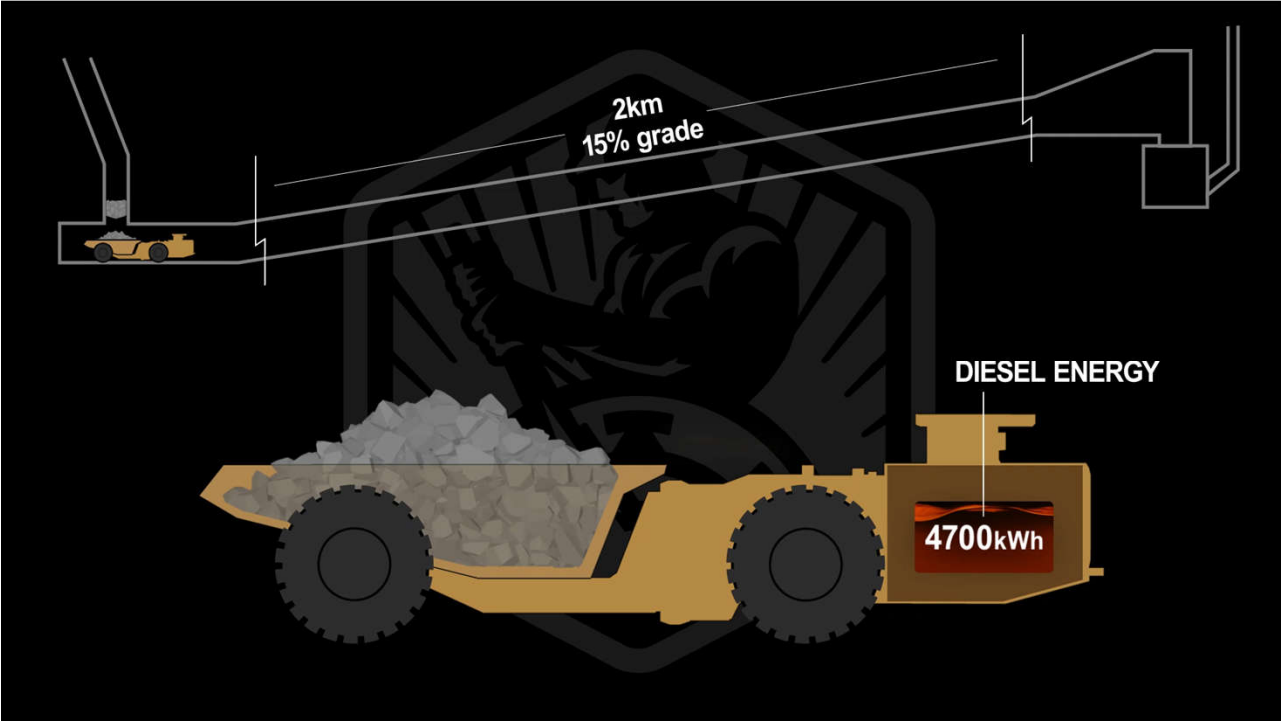
At the Top

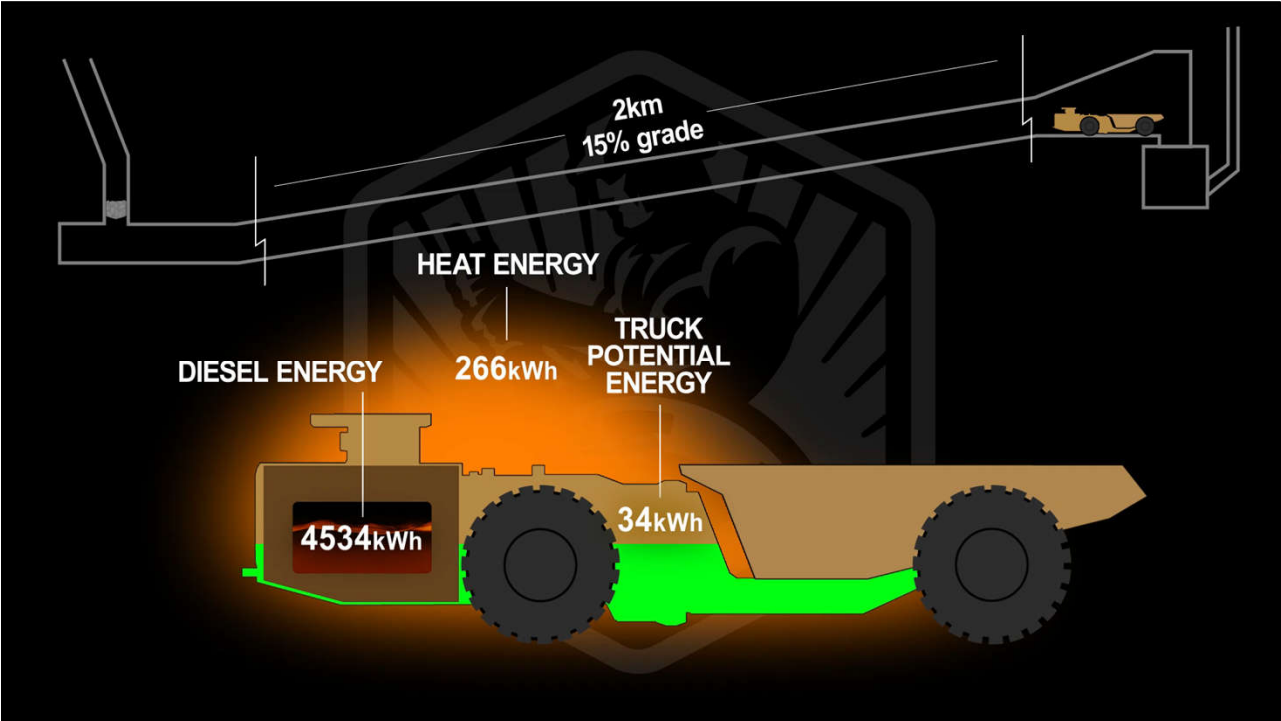
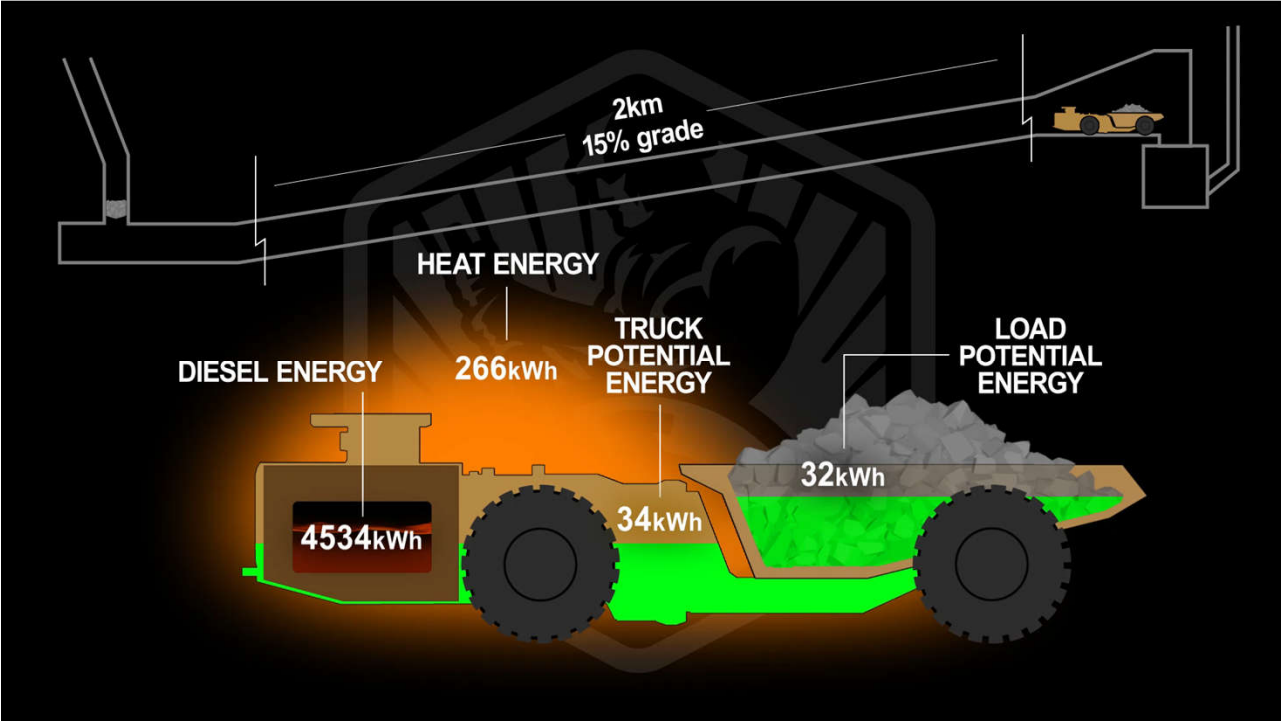
- Potential energy of load leaves the system
 - that energy does not end up as heat

Similar to a battery truck but lower efficiency

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Calculating the Heat

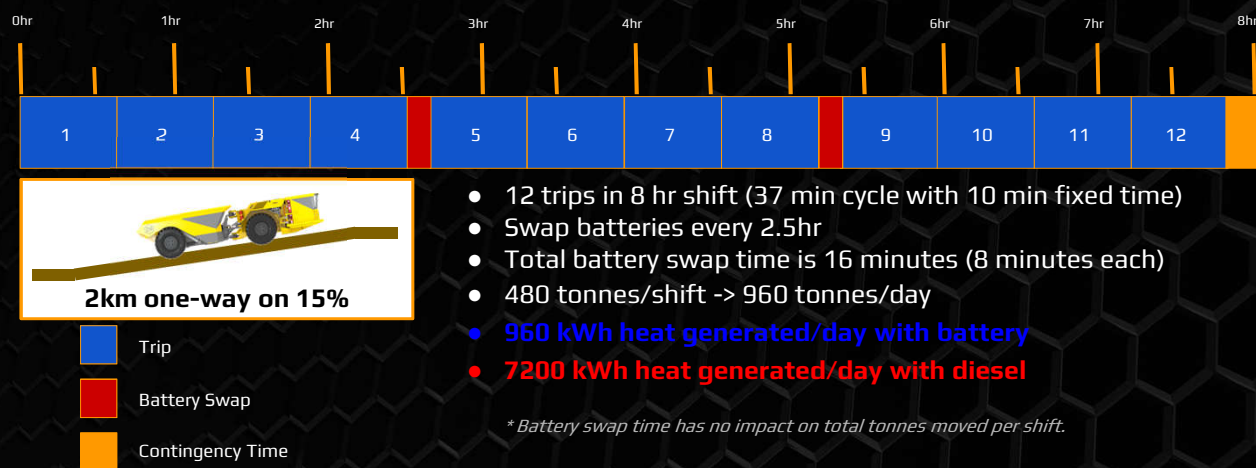
Descending Empty

- Power Source?
 - potential energy of the truck
- Where does it go?
 - all potential energy is **BURNED OFF AS HEAT**

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Typical Haulage Cycle

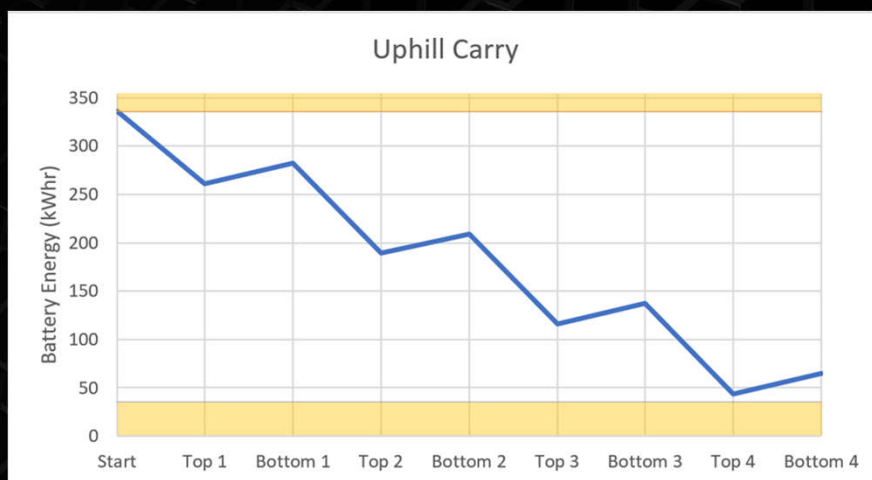


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Energy in the Battery Pack

- Climb loaded
 - - 93 kWh
- Descend Empty
 - + 21 kWh
- Net
 - - 72 kWh
- 4 round trips/charge



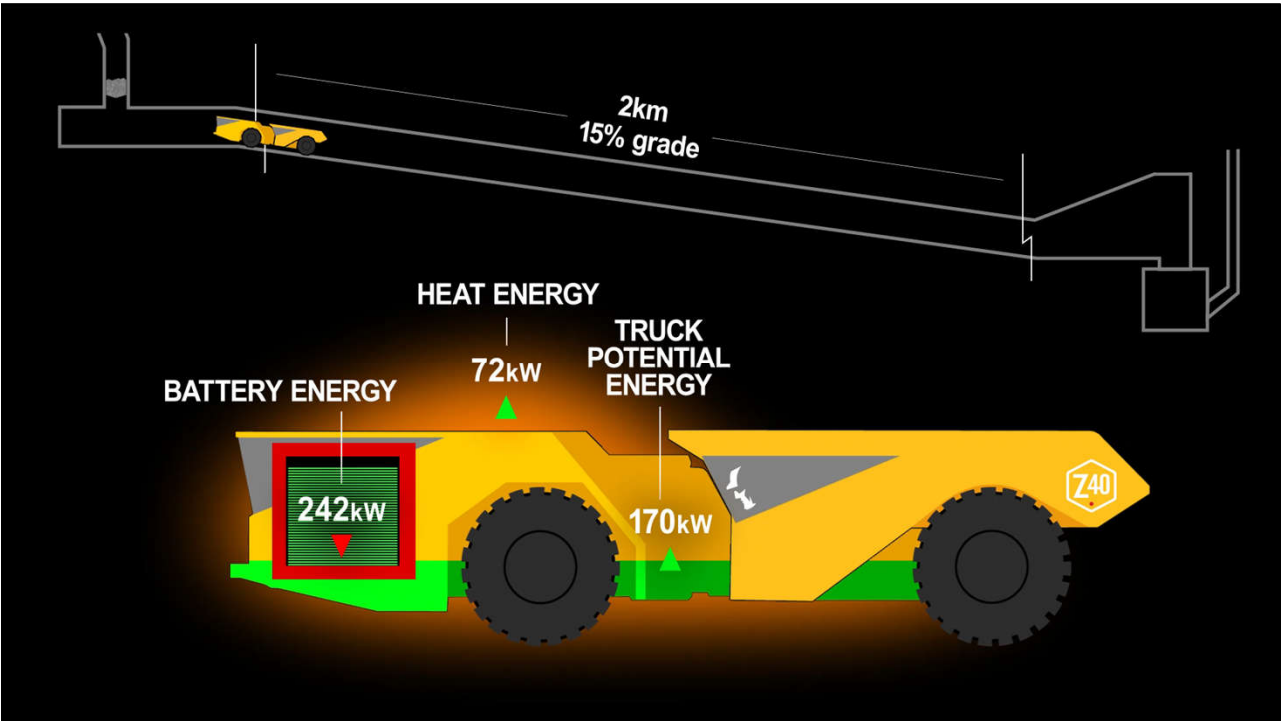
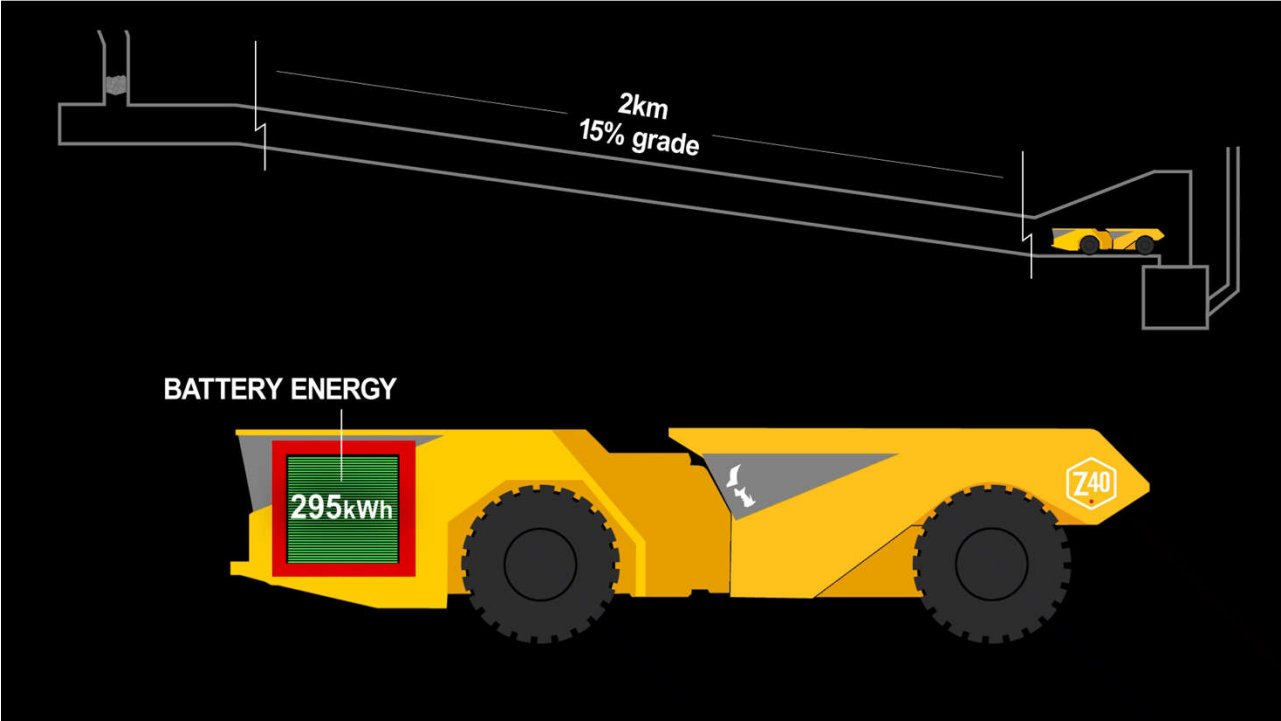
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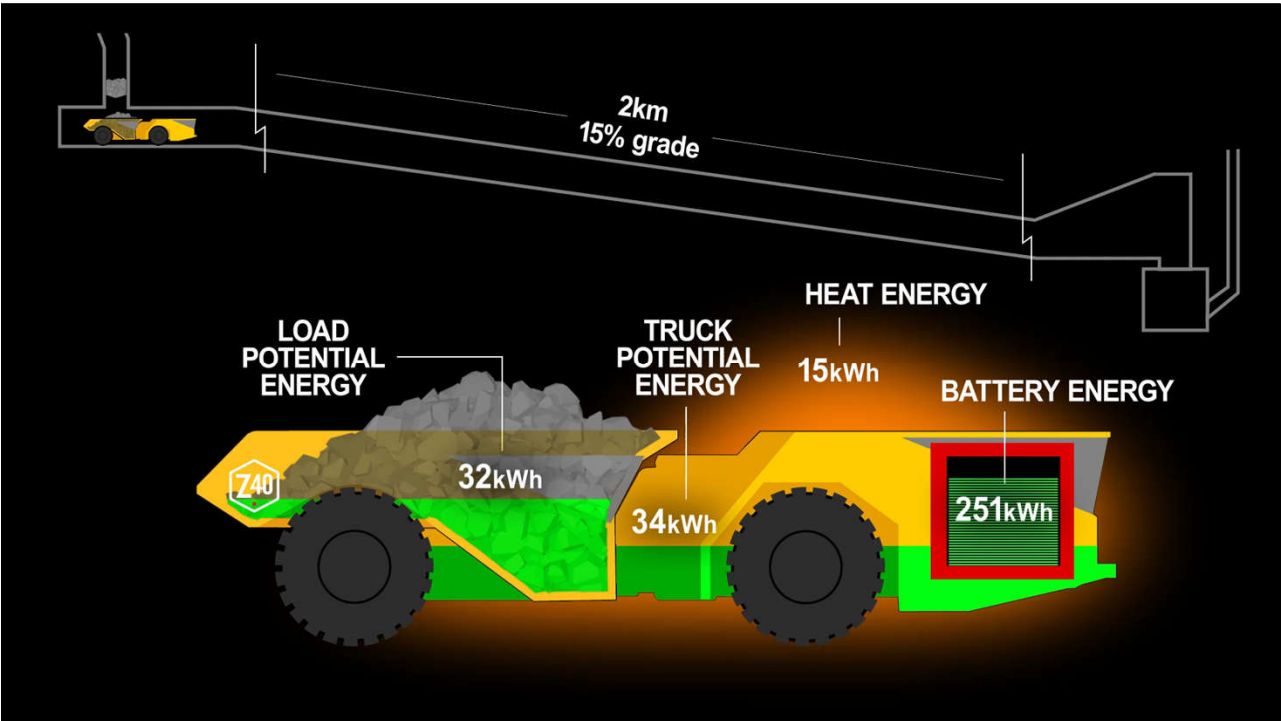
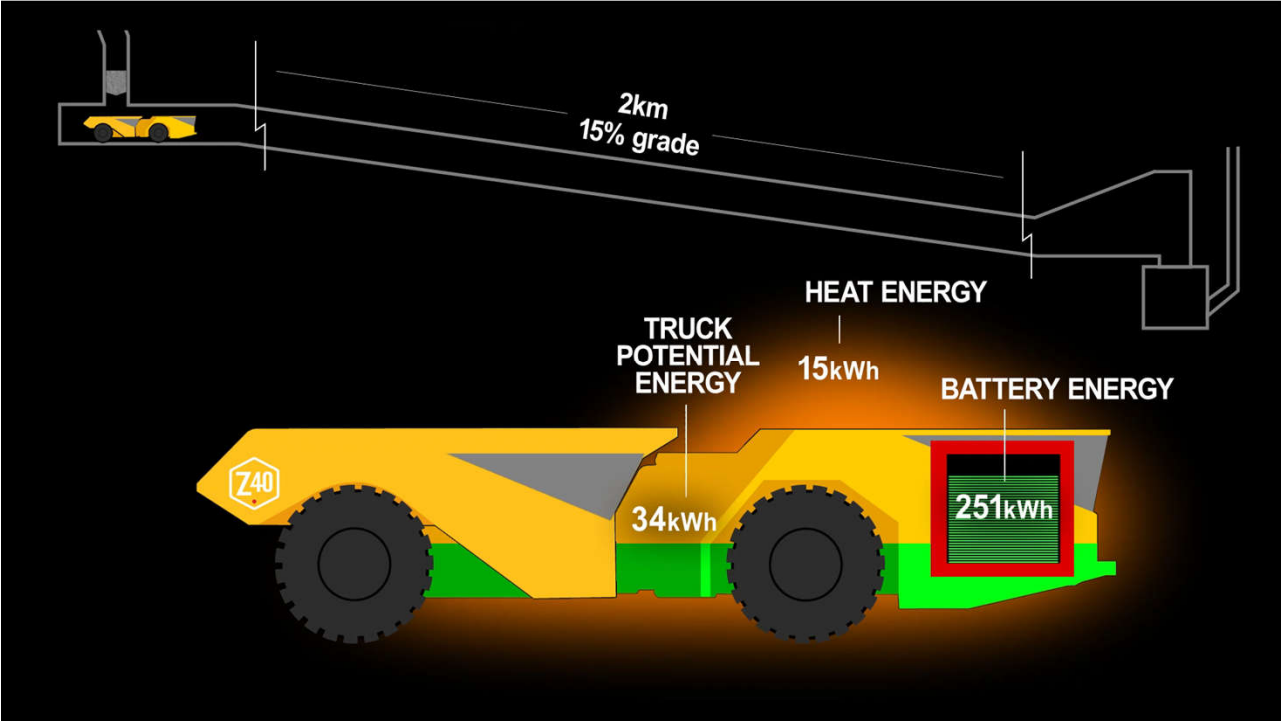


Downhill Carry Opportunity

- With an uphill carry battery power is used to increase potential energy of load, then it leaves the mine
- With a downhill carry load potential energy helps fuel the truck
- Designing a mine around hauling down ramp could enable near continuous operation without charging
- Hauling waste rock or materials down ramp is another way to take advantage of potential energy and regenerative braking

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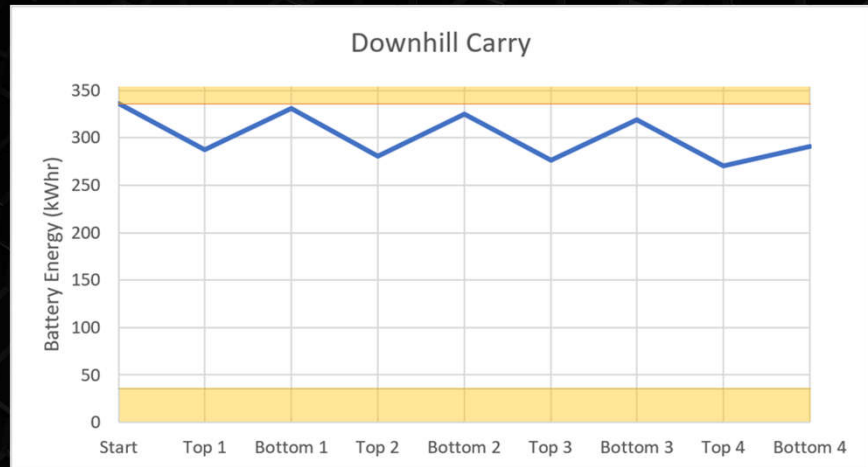






Battery Energy Chart - Downhill Carry

- 6 kWh/trip
- 50 trips/charge
- 2 kWh less heat/trip



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Real-World Data

- Z40 has >900 hours in operation at KL Gold's Macassa Mine
- Actual data was used to calibrate the mathematical model



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Artisan Products



- Battery-Electric
- 4 tonne LHD

ArtisanVehicles.com/A4



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Artisan Products



- Battery-Electric
- 40 tonne Truck

ArtisanVehicles.com/Z40



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Artisan Products



- Battery-Electric
- 40 tonne Truck

ArtisanVehicles.com/Z40



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ENTER CHARGE BAY
DISCONNECT BATTERY
02:00

DROP USED BATTERY
01:30

DRIVE TO NEW BATTERY
01:30

PICK UP NEW BATTERY
01:00

CONNECT BATTERY
LEAVE CHARGE BAY
02:35

TOTAL TIME
• 00:00





New Vehicle Announcement



A large yellow and red battery-electric haul truck, the A10, is shown in a dark, rocky underground mine environment. The truck is illuminated by its own headlights and the ambient light of the mine. A smaller yellow vehicle is visible in the background. The A10 logo is prominently displayed in the center of the image.

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Artisan Products



- Battery-Electric
- 10 tonne LHD

ArtisanVehicles.com/A10



A large yellow and red battery-electric haul truck, the A10, is shown in a dark, rocky underground mine environment. The truck is illuminated by its own headlights and the ambient light of the mine. The A10 logo is prominently displayed on the side of the truck.

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Artisan Products

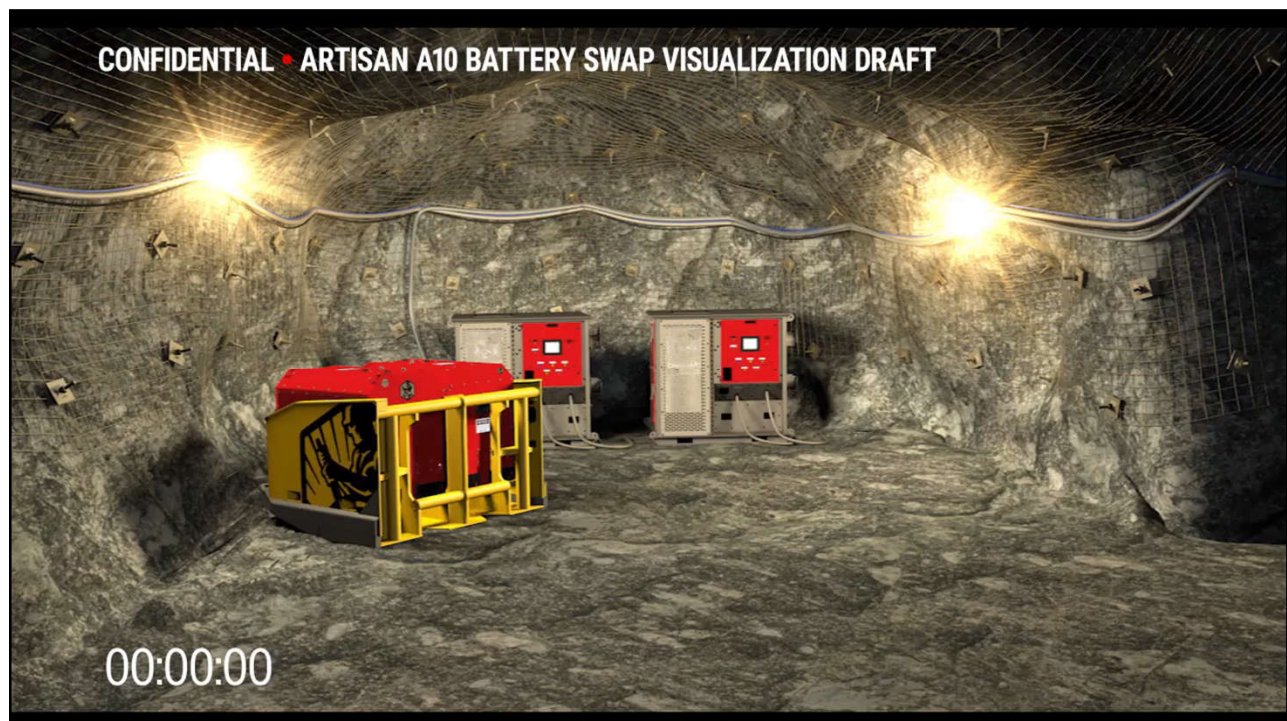


- Battery-Electric
- 10 tonne LHD

ArtisanVehicles.com/A10



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Thank You



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