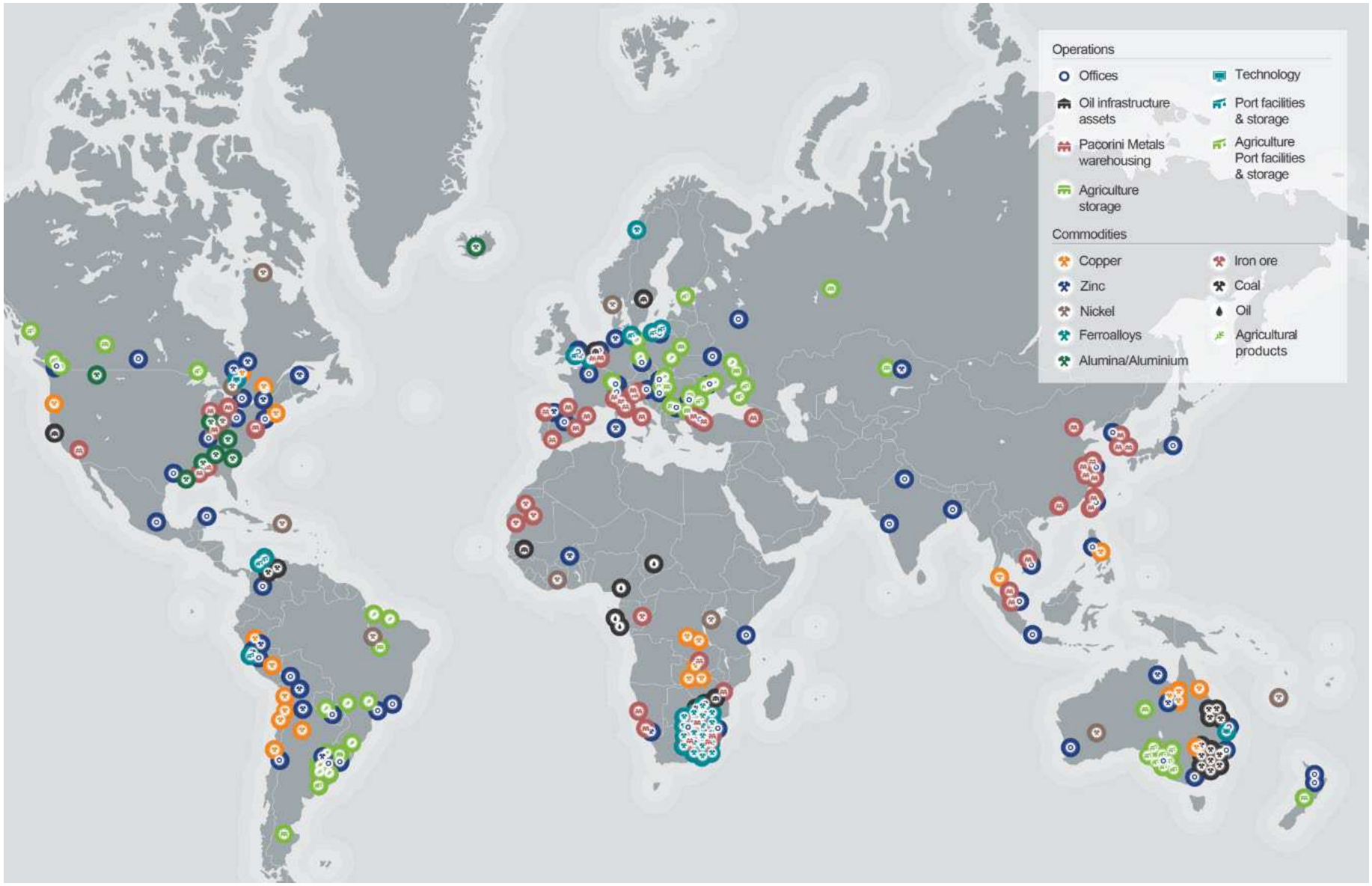
Technology Innovation in the Mining Sector

October, 2018

Glencore Global Operations



Battery Electric Vehicle

GLENCORE

Sudbury Operations

Fraser Mine

Mining Operation

Plant

Strathcona Mill

Craig Mine
Onaping Depth Project

Ni Rim
South Mine

Smelter

City of
Sudbury

10km

Sudbury Igneous Complex

Properties

Joint Venture Properties

Ore Zones

N
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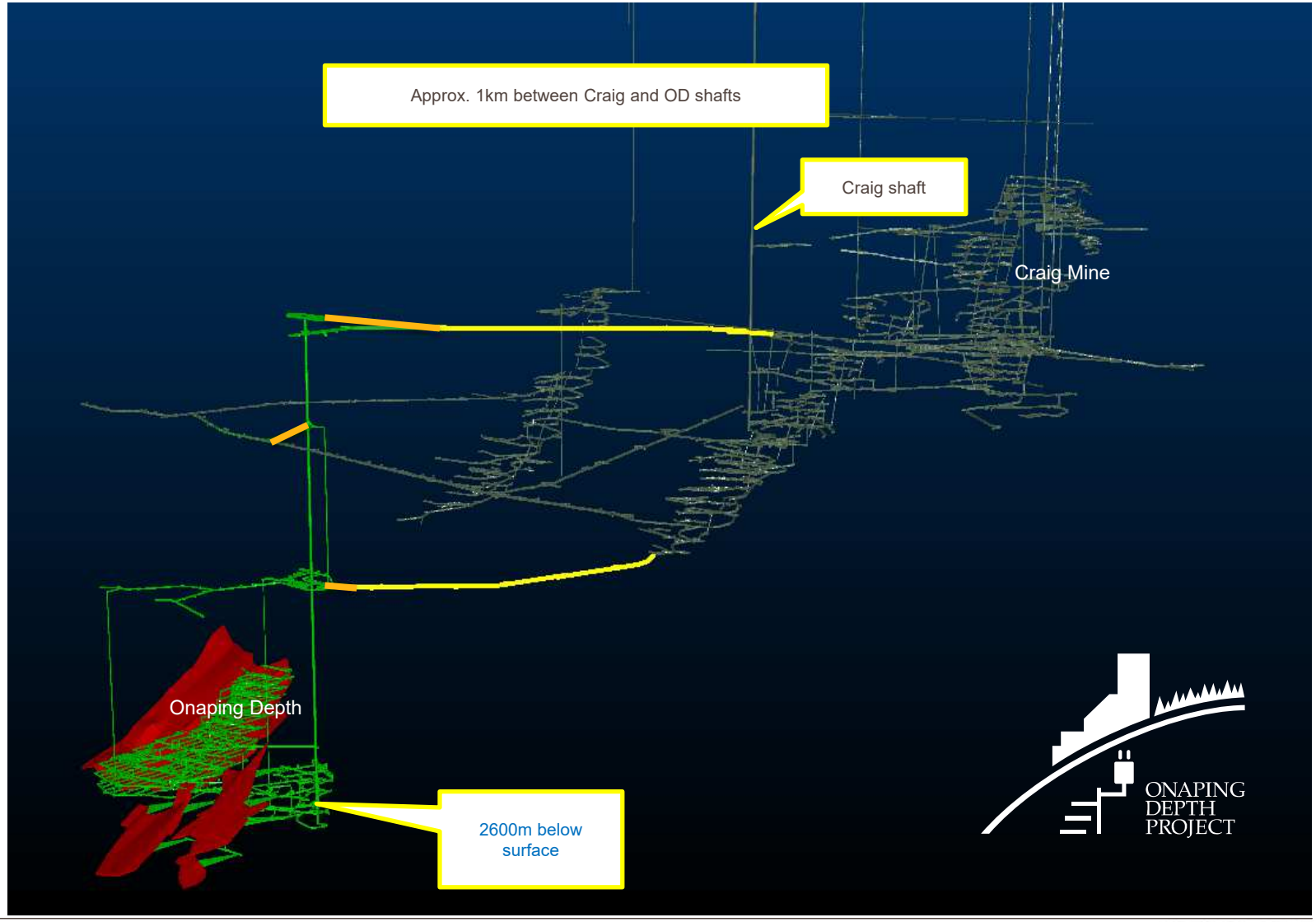
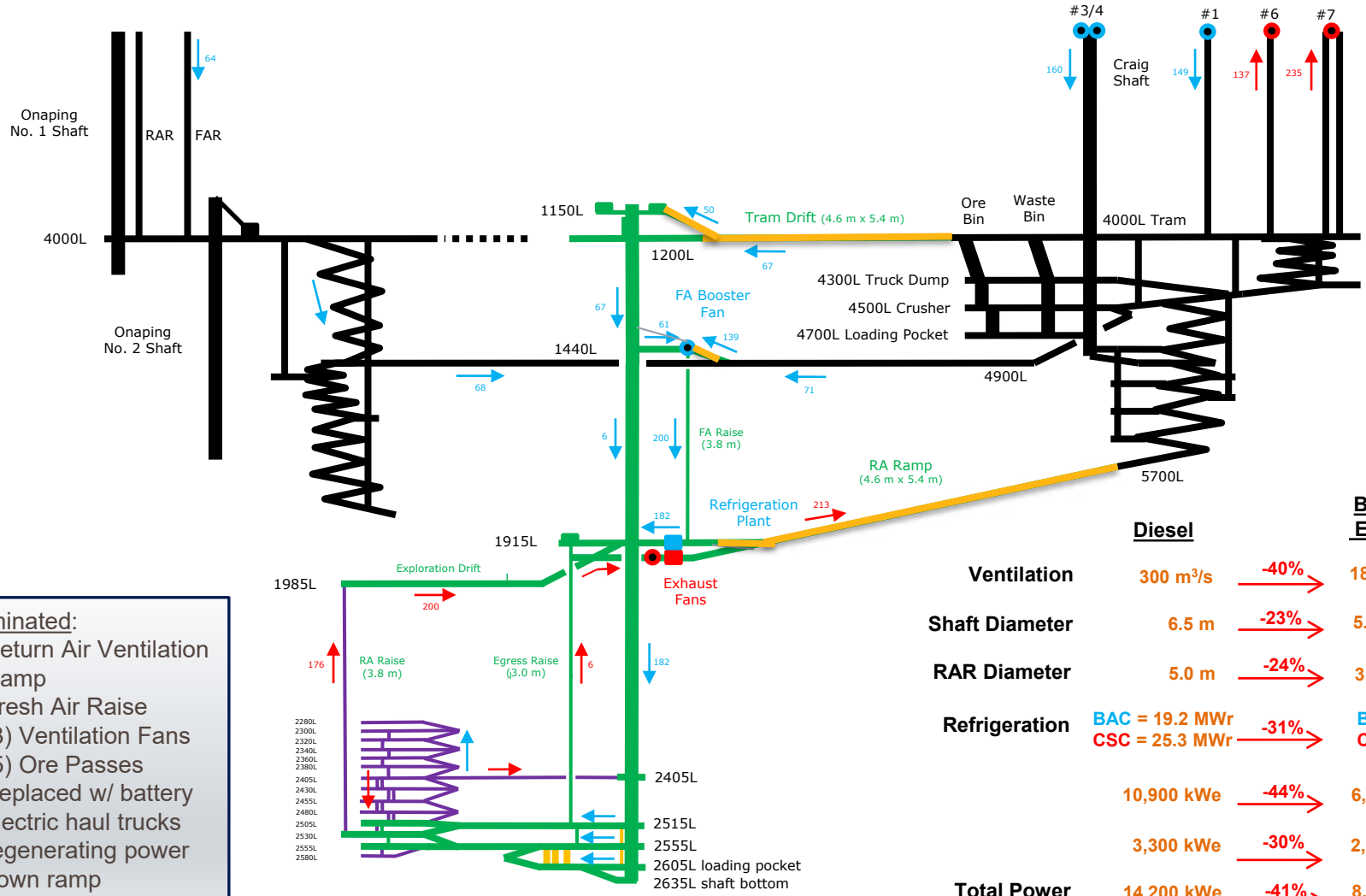
Onaping Depth Project



Battery Electric Vehicles – Onaping Depth



	Diesel		Battery Electric
Ventilation	300 m³/s	-40%	180 m³/s
Shaft Diameter	6.5 m	-23%	5.0 m
RAR Diameter	5.0 m	-24%	3.8 m
Refrigeration	BAC = 19.2 MWr CSC = 25.3 MWr	-31%	BAC = 13.3 MWr CSC = 17.5 MWr
	10,900 kWe	-44%	6,100 kWe
	3,300 kWe	-30%	2,300 kWe
Total Power	14,200 kWe	-41%	8,400 kWe

Eliminated:

- Return Air Ventilation Ramp
- Fresh Air Raise
- (3) Ventilation Fans
- (5) Ore Passes (replaced w/ battery electric haul trucks regenerating power down ramp

Things to Overcome – BEV Mine Design

- **Regulations – Ontario Air Quality**
  - Requires 96 cfm/hp – based on diesel equipment underground.
- **Uncertainty of Supply, Performance and Cost of BEV fleet**
  - Supply
  - *Stay in regular contact with OEM's on their technology roadmaps*
  - *Create a network of Mining Companies and organizations to share experiences.*
  - Performance
  - *Buy units and get first hand experience- we started with a personnel carrier in 2015*
  - *Get OEM's to perform duty cycle simulations of proposed equipment.*
  - *Run tests at sites to validate performance claims.*
  - *Create a network of Mining Companies and organizations to share experiences.*
  - Cost
  - *Have appropriate premium allowance in the project budget based on vehicle class and size.*
- **Mine Design**
  - Must design the mine around the BEVs capabilities and needs.

Things to Consider – BEV Mine design

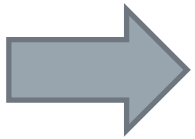
- **Take advantage of re-generation**
  - Limitation – method for releasing energy when fully charged.
- **On board vs off board chargers**
- **Battery swapping vs batteries stay in vehicles**
- **Battery chemistries**
  - Safety considerations
  - How to maximise life
  - Opportunity charging capacity
  - How many different chemistries can your mine handle
- **Parking and charging locations**
- **Charging management systems – individual vehicles and for fleet**
- **Rent or buy batteries**
- **Battery disposal**
- **Power quality**

Battery Electric Vehicles

ONAPING DEPTH PROJECT

Improved Vehicle Characteristics

- **No emissions**
- **Improved performance**
- **Less heat from vehicles (5x)**
- **Less noise**
- **Simpler machinery**
- **Less wear and tear**
- **Less maintenance**



Benefit to Mining

- **Health benefits**
  - Less particulates – DPM elimination
  - Quieter
  - Less vibration
  - Less heat from equipment
- **Less ventilation**
  - Reduce size & number of ventilation openings
  - Less auxiliary fans
  - Reduce size of refrigeration plant
  - Less heating of mine air in winter (if required)
- **Overall lower energy usage and cost**
- **Improved productivity**
  - Subjective at present – but mostly due to air quality, vibration, noise and heat benefits

Operating Mining Equipment in the Future

Autonomous Mining Operations

+40% Productivity Improvement

Safety

- WMSD – Travel/Mount/Dismount
- Hygiene – Ergonomic Stations
- Fatigue / Distraction
- FHP – Seatbelt Compliance
- Collision avoidance

Productivity

- Hot Seat Change Overs
- Mucking between shifts (surface)
- Gas clearing / seismic operation
- Multiple machines per operator
- Reduced fleet & faster stope cycling

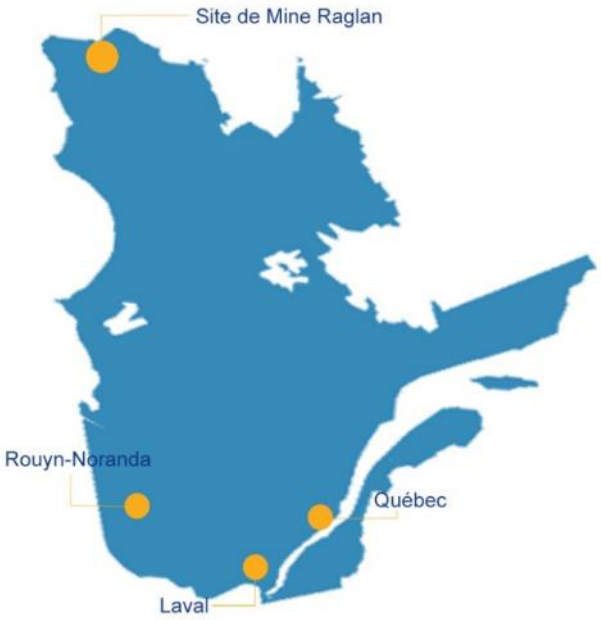
Equipment

- Reduced component damage
- Reduced tire wear
- Faster tram times (scoop controlled)
- Real time operating data

Increased working time due to
+20% reduced operating delays

Renewable Energy in Mining Operations

The Raglan Mine – Mining in the Arctic



- Aerial or maritime access only
- No connexion to the electric grid or natural gas network
  - ✓ Largest diesel consumer in the Arctic : 100 % diesel
  - ✓ Largest GHG emitter in the Arctic : >100 000 tonnes of GHG
  - ✓ Diesel is the 2nd most significant cost center at Raglan Mine
- Mine Raglan Life of Mine : over 25 yrs as of today

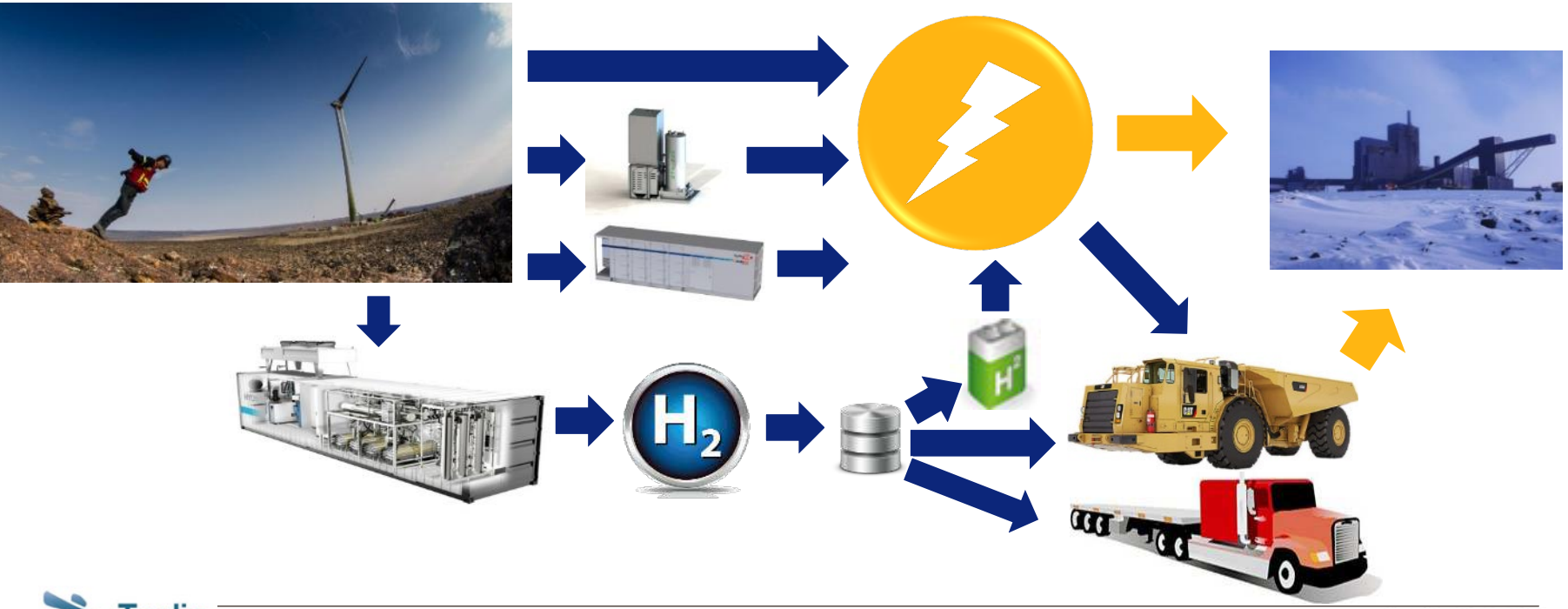
Renewable Energy in Action

3 MW Wind Turbine with cold weather package and fit-for-purpose foundation design

Coupled technologies has further increased fuel displacement

Additional diesel fuel displacement opportunities

- Replace diesel with natural gas
- Hydrogen can be used in other applications e.g. zero-emission transport fuel
- Electric vehicles for surface and underground mining trucks, further reducing ventilation needs



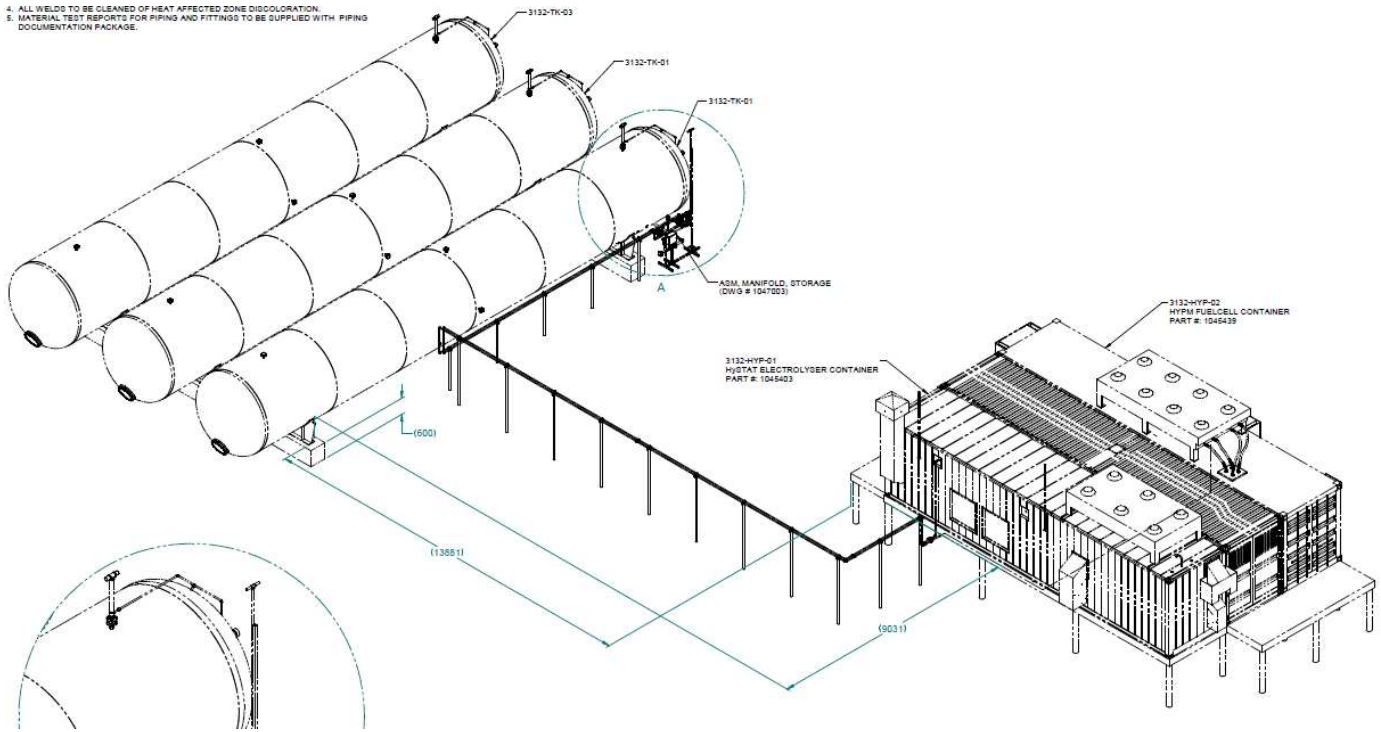
The Next Journey : Energy Storage

Hatch William's flywheel *GTR 200*:
- 200 kW of storage for up to 27 sec

Hydrogenic's *HySTAT 60* electrolyser and *HyPM R200* fuel cells :
- 200 kW of storage capacity for up to 20 hrs

Electrovaya's Li-Ion battery solution:
- 200 kW of storage for up to 74 mins

Controlled by **Hatch's** *HμGrid*
- Reduce power fluctuations on the grid and increase penetration level of wind energy

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