Minimising Risks for Hydrogen in Mining

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Power 2 Gas, Electrical Safety, Quality

Hydrogen & Mines, Oct. 2020

Financing Demands for H_2 Projects in Mines

1 The technical challenge

2 The financial challenge

3 Requirements to minimise risks - technical

4 Requirements to minimise risks - financial

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Technical Challenges

Extremely variable loads

- Mills
- Flotation
- Ventilation
- Compressed Air

Different Demands (Electricity, Fuel)

Harsh Environment

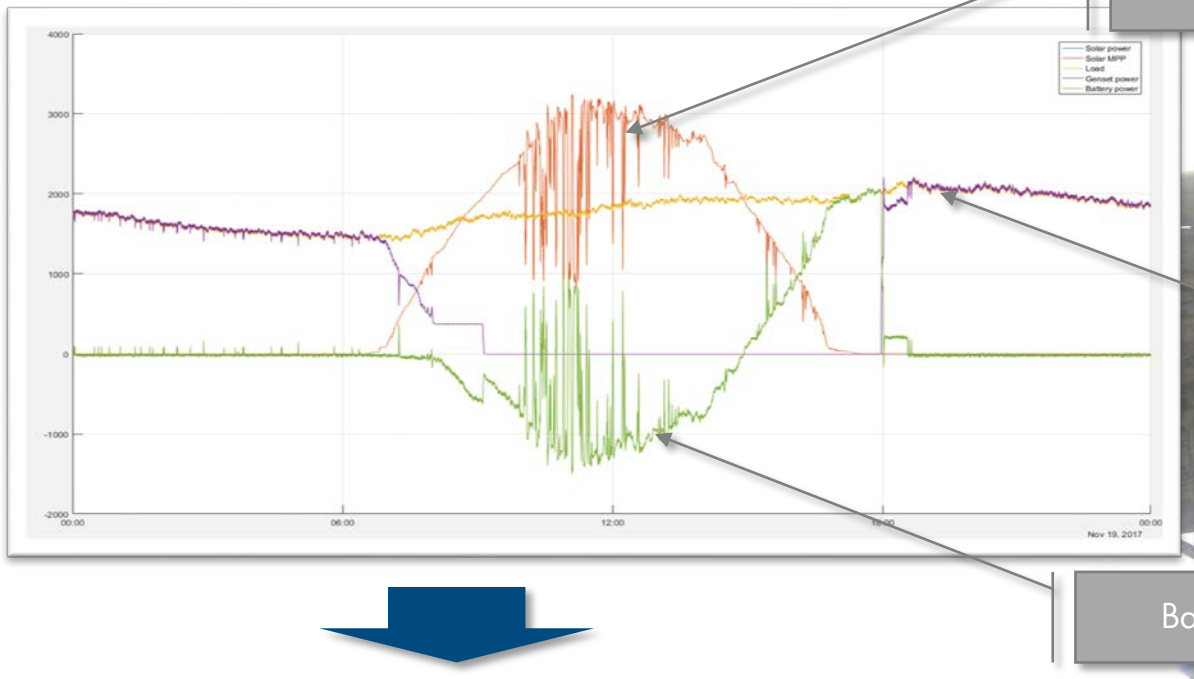
- Temperatures
- Dust

Remote Locations

- Reliability
- Maintenance

The Solar Yield does not match the load

- Highly fluctuating solar yield does not match mine load



Solar

Load

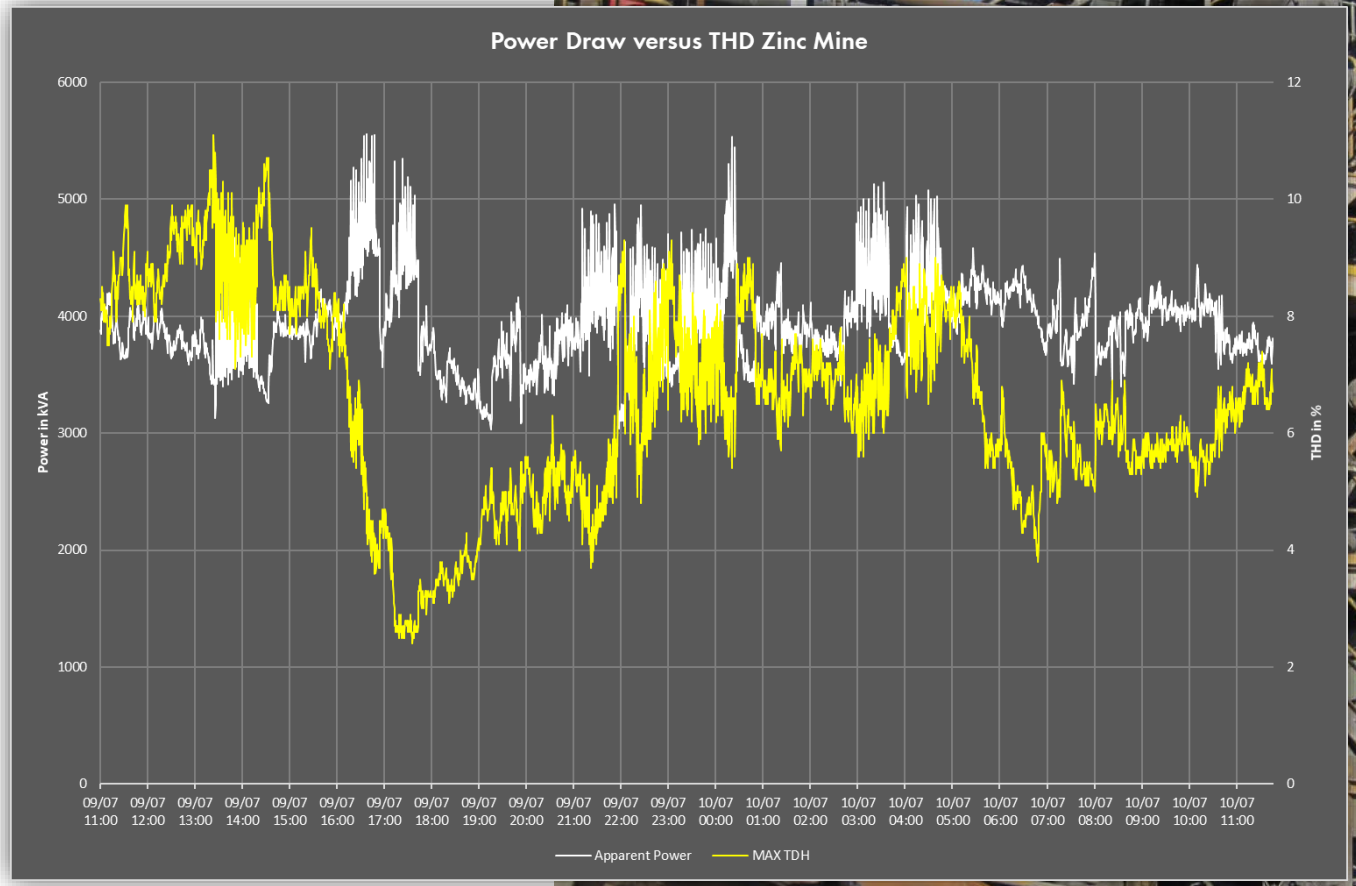
Battery

- Batteries for short term variations (intra-minute to intra day)
- Hydrogen for long term variations (intra-day to seasonal)

Extreme network conditions require high quality components

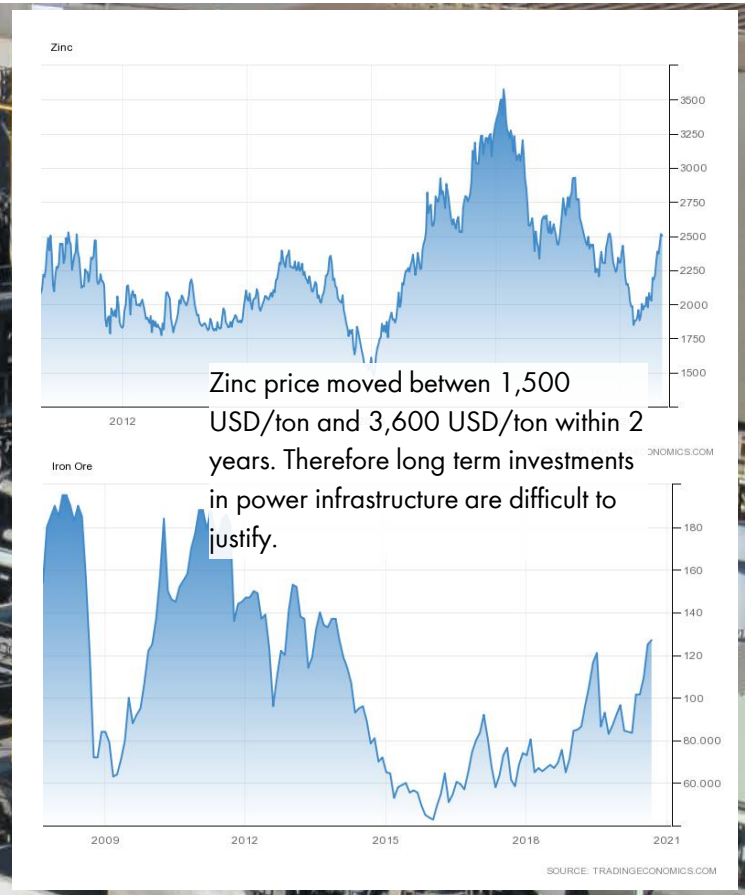
Mine operations are usually a high harmonics environment due to the operation of high power variable speed drives (Mills, Cyclones etc.).

Rugged outdoor environment represents a challenge for sensitive components.



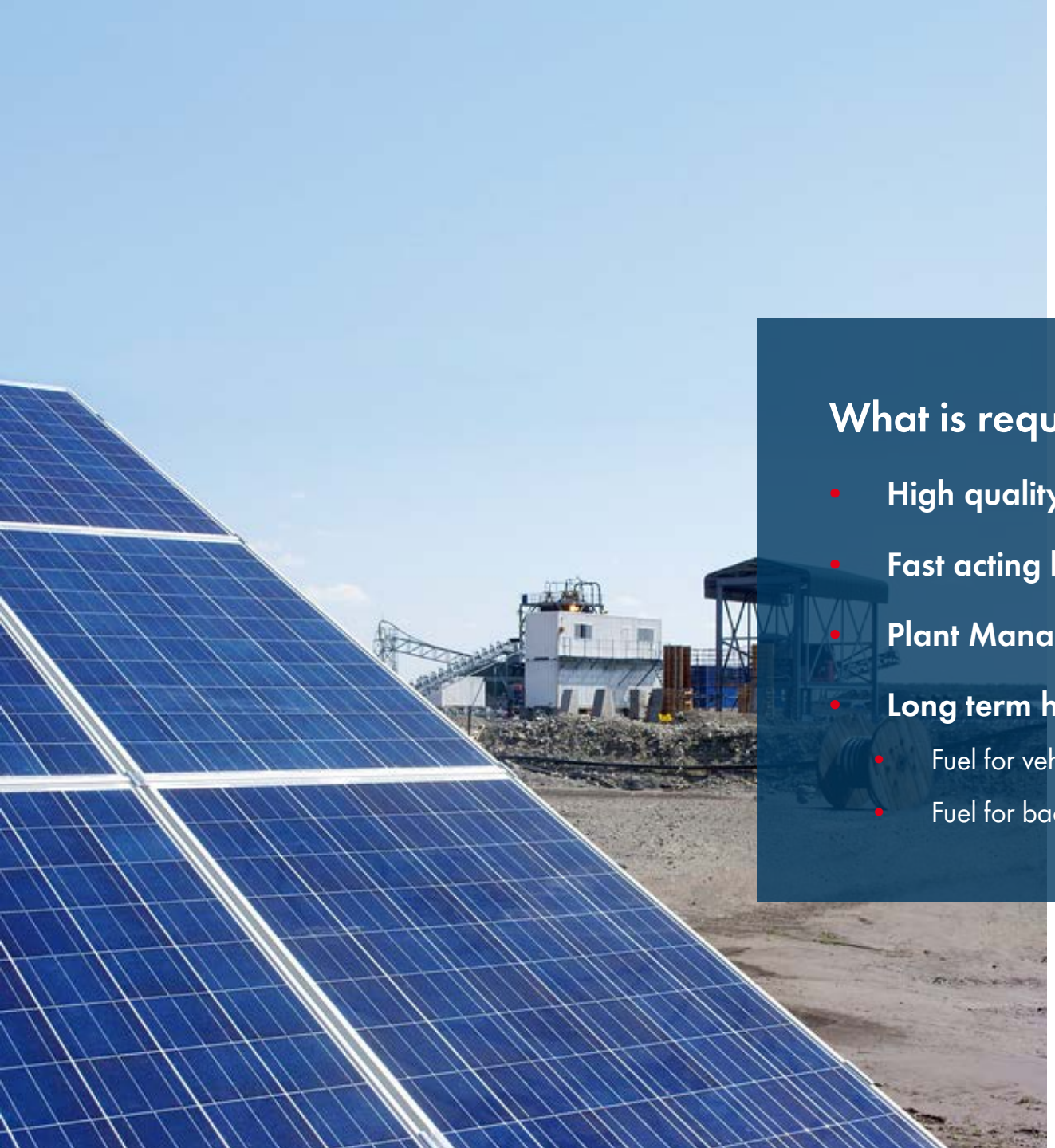
The financial challenges

- **Miners are not power companies, sometimes limited interest in complexities of power supply technology**
- **Short Mine Life, often less than 10 years**
- **Extremely volatile resource pricing**
- **Relatively high credit risk for smaller mining operations**
- **Extreme costs for power interruptions**



Zinc price moved betwen 1,500 USD/ton and 3,600 USD/ton within 2 years. Therefore long term investments in power infrastructure are difficult to justify.

⇨ A one hour power interruption for a typical coal mine (5 Mt/a @ 60 A$/t) costs AUD 35,000! ⇦



What is required to power a mine with green energy?

- **High quality oversized solar plant**
- **Fast acting battery system with grid forming inverters**
- **Plant Manager coordinating supplies, storage and loads**
- **Long term hydrogen storage for dual use**
  - Fuel for vehicles
  - Fuel for backup generators / backup fuel cells

And most importantly: Good Engineering!

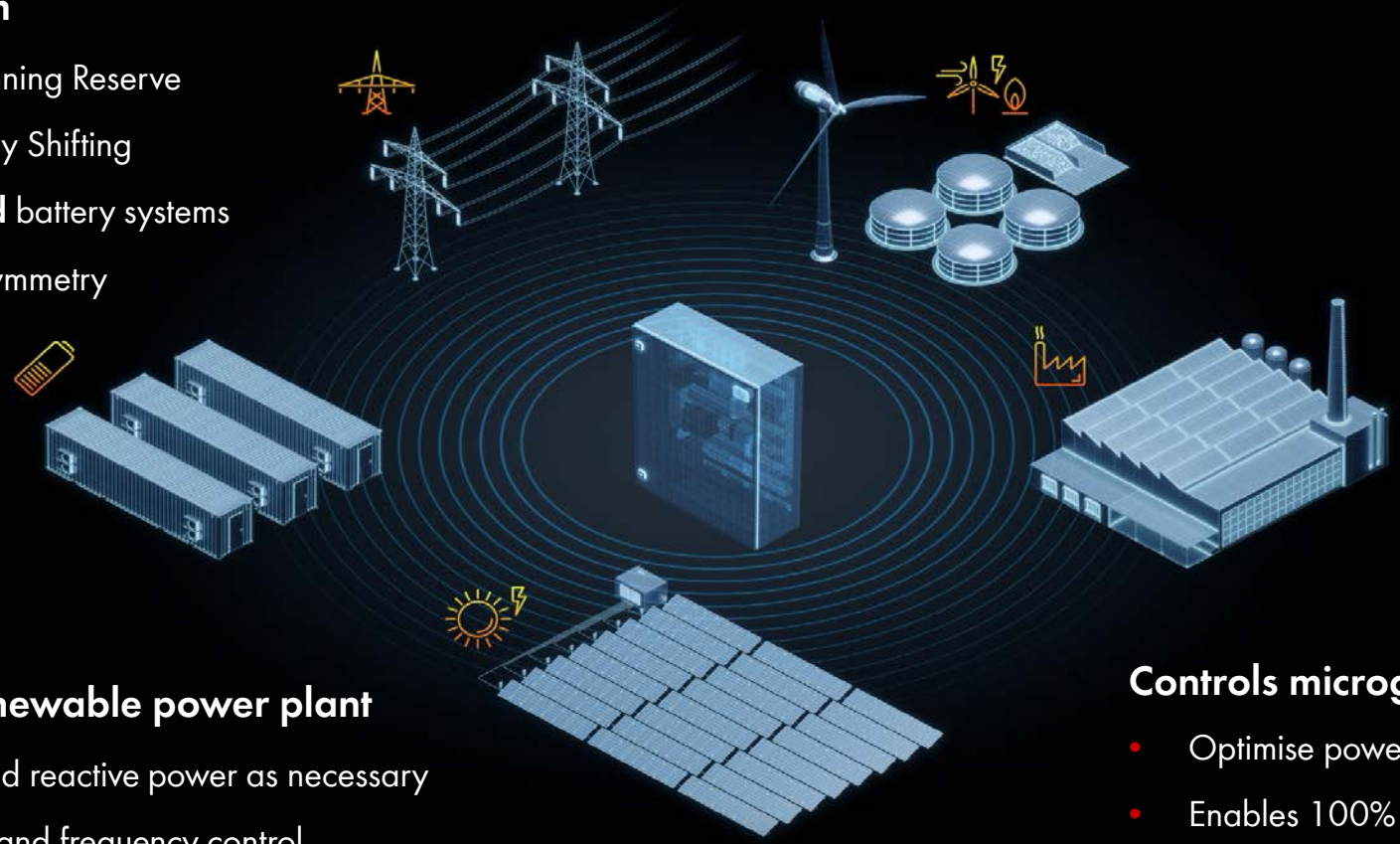
Componentry requirements

- All technology must be modular so it can be moved
- Containerised products for maximum modularity, compactness and building strength
- Design for harsh environments
- Standardised products so they can be reused
- Easy to maintain
- It's not just like "Lego", thorough systems engineering is required to ensure reliable and stable energy supply

Important for full Control – Power Plant Manager

Controls the battery system

- Primary Control Reserve / Spinning Reserve
- Rampe Rate Control and Energy Shifting
- Supports AC- and **DC-coupled** battery systems
- Controls state of charge and symmetry



Manages the renewable power plant

- Controls active and reactive power as necessary
- Supports voltage and frequency control
- Manage fault ride thru
- Manage curtailment when needed

Controls microgrids

- Optimise power and energy flow
- Enables 100% renewable energy supply by controlling Generators down to ZERO
- Secondary Frequency and Voltage Control

Key aspects for Financing:

- Energy is a necessity for mines not a business ⇨ separate energy & fuel supply from mining operation
- Long term PPAs won't work – this means short RoI or flexibility to move plant
- Holistic supply instead of simple component assembly required
- The more remote the easier for renewables
- Government needs to support with investment grants to get the costs down. Economies of scale can only be achieved at scale and for this we need a market first
- Balance sheet financing to reduce project risk should be considered for large scale operators
- Government provides market stimulus, industry delivers

A pilot project on an industrial scale would help!

Example:

5 MW Electrolyser
20 MW Solar
10 MW / 10 MWh Battery
Hydrogen Storage
Hydrogen Fuelling

Focus on requirements means success

Modularity

Holistic Supply

System Engineering

Summary

Financial Demands

- Lowest cost of energy does not mean lowest CAPEX – it is a combination of CAPEX, OPEX and reliability
- Relatively short mine lifespans may require a more modular approach to energy supply
- Mining Operation should be separated from Energy Operation
- Only holistic supply using a combination of solar, wind, battery, hydrogen provides the necessary RoI
- Government support as investment grants necessary to kick-start the industry

Technical Demands

- High quality equipment guarantees maximum reliability
- Containerised Systems improve system stability, operability, maintenance and movability
- Grid-forming components with high resilience against harmonics and instability in networks essential
- Designed for maximum reliability – a mine cannot afford to stop for energy outages

With good holistic financial and technical engineering focused on the mine's requirements, a viable and attractive solution can be developed - **NO DOUBT!**

Thank you!

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