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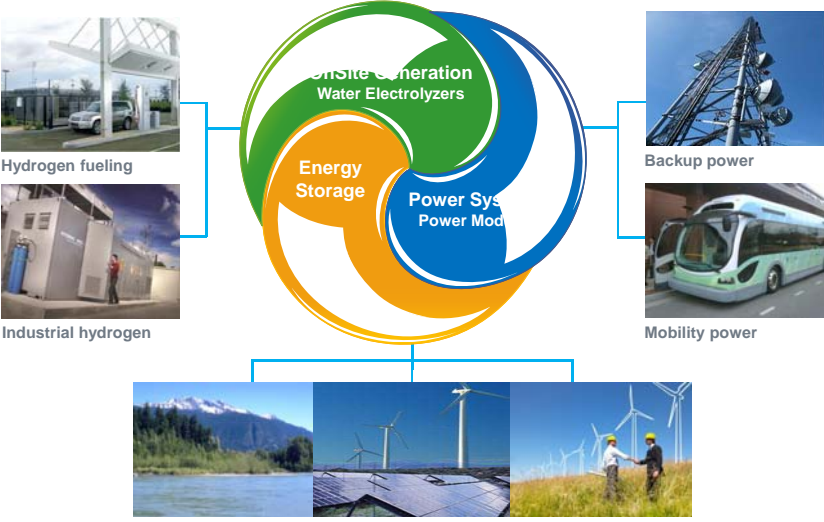
HyPM HD Fuel Cell Systems for Heavy Duty Green Mining

MDEC Conference 2014, Toronto
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MDEC Conference 2014
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Business Overview



The diagram illustrates a business overview with a central circular flow of three overlapping loops: a green loop for "OnSite Generation Water Electrolyzers", an orange loop for "Energy Storage", and a blue loop for "Power Systems Power Mod".

- Hydrogen fueling:** Represented by an image of a hydrogen fueling station.
- Industrial hydrogen:** Represented by an image of industrial hydrogen storage tanks.
- Backup power:** Represented by an image of a telecommunications tower.
- Mobility power:** Represented by an image of a hydrogen fuel cell bus.
- Load Control, Smart Grid & Remote Communities:** Represented by a collage of images including wind turbines, solar panels, and a hydroelectric dam.

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Green Mining



Green Mining Tree Hugger

- Improved workplace health
- Lower emissions
- Little Noise
- Advancing with clean tech
- Reduced OpEX
- Reduced ventilation
- Greater system efficiency
- Enhanced design scalability
- Power system flexibility









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Hydrogen Safety





- Fuel Leakage Simulation conducted by Dr. M. Swain, University of Miami
- Hydrogen Fuel Cell vehicle shown on left side, Gasoline powered vehicle shown on right side
- The Hydrogen powered vehicle was undamaged; the Gasoline powered vehicle had severe damage





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Hydrogen Fuel Cell Safety Standards


- IEC 62282-2 – EU Standard for Mobility fuel cell
- IEC 62282-3 – EU Standard for Stationary fuel cell
- ANSI/CSA America FC1-2004, Stationary Fuel Cell Power Systems
- NFPA 853 – Standard for Installation of Stationary Fuel Cell Power Plants, 2003
- NFPA 55 – Standard for Storage, Use, and Handling of Compressed Gases and Cryogenic Fluids in Portable and Stationary Container, Cylinders, and Tanks, 2005
- NFPA 496 – Standard for Purged & Pressurized Enclosures for Electrical Equipment, 1998
- CGA E-11 – Standard for Stationary Compressed Gas Cylinder Discharging Manifolds for Working Pressures up to 3000 PSI
- CGA – G-5.4 – Standard for Hydrogen Piping Systems at Consumer Locations
- ASME/ANSI B31.3 – Process Piping Code

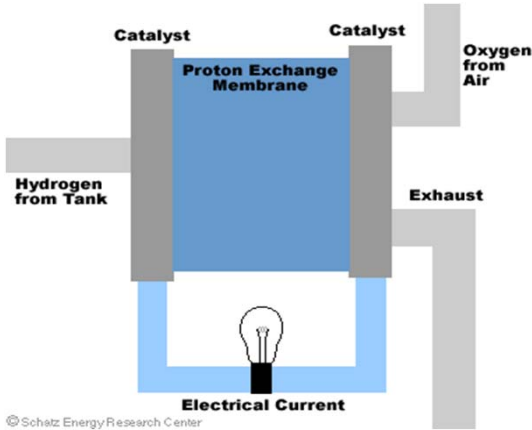


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Principal of a PEM Fuel Cell Module




© Schatz Energy Research Center




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Drivers for Clean Energy - Mining Industry

- Workplace health
 - New generation of diesel engines (EPA Tier 4 – in effect 2015)
 - 2012 WHO underground diesel power use health warning
 - Alternative energy to eliminate/reduce emissions - viable operational replacement
 - Fuel cells and batteries - significant reduction in noise generation and vehicle heat load in deep mines
- Rising oil prices
 - Replacing diesel
- Economic opportunity for the industry through cost reductions
 - Reducing required ventilation (savings in site electrical and energy bill)
 - Diesel equipment, maintenance, downtime, automation vs electric motor lower maintenance costs, higher reliability
 - Automation, tele-remote operation improved
- Keeping pace with surface vehicle clean energy drive
- Clean Energy - Changing climatic conditions
- Green House Gases (GHG) reduction from underground & open pit mining emissions




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Energy Storage: Remote Communities Ramea Island (Newfoundland, Canada)



Customer: Newfoundland and Labrador Hydro (NLH)

OBJECTIVE OF THE PROJECT	SOLUTION
<ul style="list-style-type: none"> • Solve the cost and storage issues associated with intermittent/ renewable energy generation. • Investigating the potential to combine wind turbines and hydrogen generation as an alternative to diesel power currently installed. • Provide continuous high quality power. 	<ul style="list-style-type: none"> • HySTAT-30/10 Outdoor solution to produce 30Nm³/h H₂. • Hydrogen compression and storage system to provide 24/7 power from wind. • Hydrogen power provided by H₂ gensets (HEC).



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Hydrogenics' systems have been deployed in the Arctic for the H₂KT Project in Nuuk, Greenland

- Nukissiorfiit: Energy Utility, End Client
- H2Logic: System Integration and Project Management
- Started up March 2010

Hydrogenics Scope:

- Controller
- DC-DC's
- Fuel Cells (2 x 10 kW)
- Cooling
- Grid Connect Inverters
- Local Inverters
- Hybrid energy storage

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Containerized Fuel Cell Power Plant

- Standard ISO container design offers versatility for system enclosure and transportation
- Features
 - Ambient (-40 to 50 °C)
 - Grid Tie or UPS
 - Scalable
- Benefits
 - Harsh environment operation
 - Built in redundancy
 - Thermal control system
 - Environmental conditioning
 - High durability
 - Improved reliability

Fuel Cell

+

DC/AC Inverter

kW

Fuel Cell Power Plant


MW


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Mobility




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Mining Applications


Equipment:

- Drag line excavators
- Electric Cable Shovels
- Wheel loaders and motor graders
- Motorized dump trucks
- Locomotives
- Underground Mining and tunneling equipment



Courtesy Altas Copco


OEMs have started to recognize the value of electrification to improve cycle efficiency and lower operating costs and reduce emissions


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Challenges for Conventional Powered Equipment

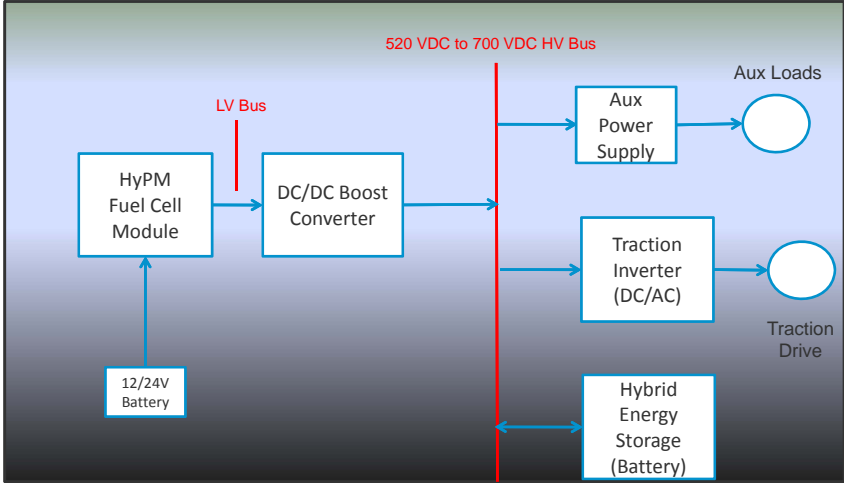
- Fueling and associated costs, including transport to site
- Particulate emissions in closed area – engine transients worse
- Workplace health
- Heat emissions
- Noise emissions
- Vibrations - rock overhead
- Ventilation costs
- Increasing mine depth




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Fuel Cell Module in Vehicle High Voltage Systems Architecture



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Hydrogen & Mines Initiatives

1. **Proof of Concept Projects:** Design and testing of mining surface & underground power plants, vehicles; cost-benefit, refueling, etc
2. **Applicable norms and standards, expertise, mining regulations**
3. **Risk management & safety for project**
4. **Hydrogen behaviour in confined areas, ventilation, ignition**
5. **Evaluation of results and best practices for mining**

The diagram illustrates the hydrogen delivery and site infrastructure for mining. It is divided into 'Surface' and 'Underground' sections. On the surface, hydrogen is produced (e.g., from electrolysis) and stored in tanks. It is then delivered to a 'fuel cell back-up power' unit and used to power 'MINING MATTERY TRUCKS'. On the underground level, hydrogen is delivered via a '300 psi' line to 'refueling' stations for 'mobile fuel cell power plant extraction equipment' (ventilators, pumps). A 'hydrogen sensor' and 'exhaust raise' system are also shown. The title 'Hydrogen Delivery and Site Infrastructure' is written in blue italics.

Source: CanmetMINING

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Partial Solutions

- Diesel hybrids**
 - Still have combustion
- Battery electric, limited by:**
 - Range
 - Cycle life
 - Long charge times
 - Aggressive thermal management needed
- Electric vehicle with tether**
 - Stationary diesel gensets with retractable tether
 - Tether length
 - Line voltage sag – may required energy storage (ultra-capacitors) to stabilize







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Why Fuel Cells for Mining

- Workplace health:**
 - Improved
- Fueling:**
 - Production on site
 - Refuel in minutes
 - Increase productivity
- Emissions:**
 - No PM. PM directly impacts health.
 - Heat reduction
 - Noise reduced – fuel cells are quiet!
 - Increased productivity
- Vibrations**
 - Reduced
- Ventilation costs**
 - Reduced






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Hydrogen & Mines Initiatives – Raglan Mine, Que

3 MW




Batteries Li-ion




200kW

Fuel Cells




200kW

Flywheel










250 kW

25kV



16MW



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Hydrogen & Mines Initiatives – Potential Next Steps

Sifto Salt Project (under discussion)

Task 1

- definition of diesel fleet
- operating baseline
- duty cycles
- ventilation criteria
- definition of utility vehicle power plant
- operation protocol
- underground hydrogen production, storage, refueling

>Go/no go

Task 2

- regulatory review, requirements (mining, installation code, best practices)
- operating protocols

>Go/no go

Task 3

- design and construction of utility vehicle prototype
- underground trials


Task 4

- comparison diesel vs hydrogen vehicle versions, energy, ventilation costs, safety, vehicle design




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“The world will not evolve past its current state of crisis by using the same thinking that created the situation.” - ALBERT EINSTEIN

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