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HyPM HD Fuel Cell Systems for Heavy Duty Green Mining

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Hydrogenics in a Nutshell

- Global provider of hydrogen power systems and water electrolysis products
- Founded in 1996
- Listed on NASDAQ (HYGS) and TSX (HYG)
- Offices in Toronto (HQ), Belgium and Germany
- 120 employees worldwide
- Over 1,800 projects deployed in > 100 countries

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Hydrogenics' Lines of Business

Onsite Generation
Water Electrolyzers

Power Systems
Power Modules




Industrial hydrogen | Hydrogen fueling | Backup power | Mobility power

Energy Storage
Load Control, Smart Grid and Remote Communities



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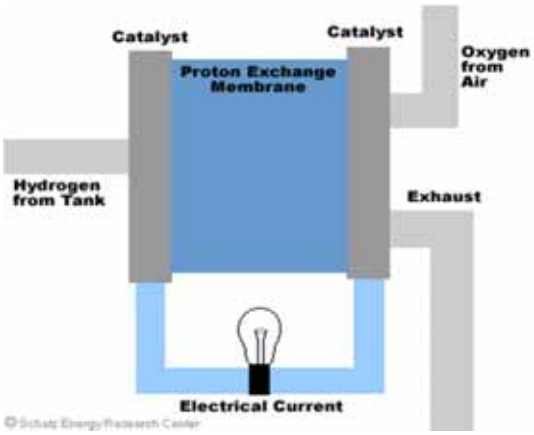
Principal of a PEM Fuel Cell Module



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FC Development History – Hydrogenics Gen2.0 HyPM™ Power Module

Gen2.0

Hydrogenics HyPM Power Modules (mobility)

	2001	2002	2003	2009	2011
Stack Pressure	High	High	Low	Low	Low
Power	25 kW	25 kW	20 kW	16.5 kW	33 kW
System Mass **Power Density**	290 kg **86 W/kg**	200 kg **125 W/kg**	170 kg **117 W/kg**	92 kg **180 W/kg** >2x	65 kg **507 W/kg**
System Volume **Power Density**	365 L **68 W/L**	340 L **73 W/L**	180 L **111 W/L**	133 L **124 W/L** >2x	125 L **264 W/L**
System Efficiency	45…38%	45…38%	54…40%	**54…48%**	**55…48%**
Major Components	25	19	8	6	6
Onboard water	Required	Required	Not required. With Ca and An saturators.	**Not required** **No saturators**	**Not required** **No saturators**

Application Examples: > 20 buses and 40 mobility applications in service

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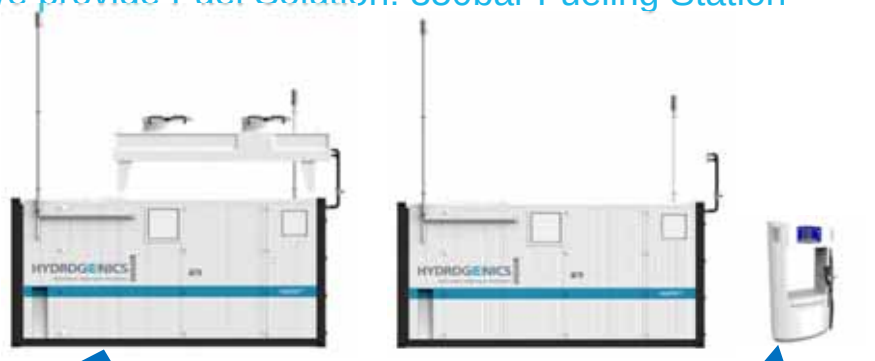
We provide Fuel Solution: 350bar Fueling Station



Module 1: Electrolyser (21,32, 65, 97 or 130kg/day)

Module 2: Compression (cooling), (storage) and Storage management system

350 bar Dispenser

- Hydrogen quality: **Fuel Cell Grade (99,998%)**
- Fill type: **According to SAEJ 2601 requirements**
- Consumption: **65 kWh/kg H2 produced**
- **Fully interconnected and centrally controlled**

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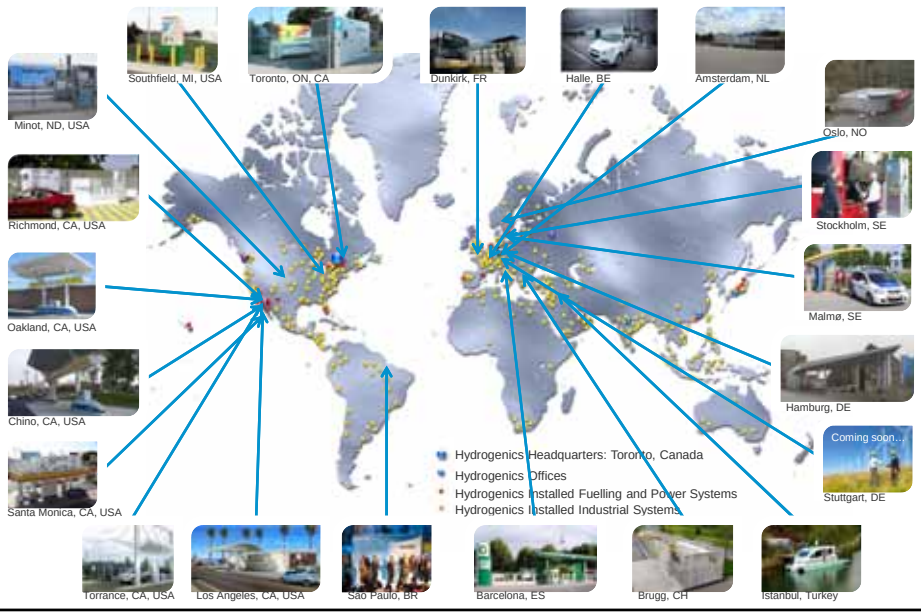
45+ Fueling Stations Worldwide



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Experience in Advanced Technology Development

Performance

DLR (Deutsches Zentrum für Luft-und Raumfahrt) – German Aerospace Center
Antares H3 – Hydrogenics to develop fuel cell system for next generation of fuel cell-powered aircraft

Challenge	Strengths	Opportunities
• High Efficiency	• Direct hybridization experience	• First Transatlantic flight
• Mass & Performance Targets	• Leading product technology	• Delivering critical Apps
• Variation of oxygen content	• Extensive product validation	• Technology transfer

High Power

World Leader in Naval Defense
AIP (Air Independent Propulsion) – Hydrogenics supplies 250kW fuel cell systems

Challenges	Strengths	Opportunities
• Fuel Consumption Targets	• Leading product technology	• Mission critical Apps, UUVs
• Oxygen Feed	• Strong domain expertise	• System Integration & Consulting
• Noise signature	• Deep subject matter expertise	• Solutions for high power systems

APU

Airbus – Leading Aircraft Manufacturer
Multi-function APU for RAT replacement, fuel cell powered electric nose wheel for commercial aircraft

Challenges	Strengths	Opportunities
• RTCA DO 160E Vibration Test	• Leading product technology	• Delivering commercial Apps
• Variation of oxygen content	• Strong domain expertise	• System Integration & Consulting
• Rapid start, dynamic loads	• Strong product validation	• Technology transfer

Space

CSA – Canadian Space Agency
Hydrogenics picked to supply next generation fuel cell power system for Lunar Rover to be built in Canada

Challenges	Strengths	Opportunities
• Hydrogen-Oxygen	• Leading product technology	• Technology transfer
• Extreme Environmental	• Direct hybridization experience	• Platform for advanced development
• Critical Mass Targets	• Deep subject matter expertise	• Hydrogen-Oxygen Generation

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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!
- Heat emissions!
- Noise emissions
- Vibrations - rock overhead
- Ventilation costs
- Increasing mine depth

Courtesy Altas Copco

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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 Applications?

Fueling:
- Production on site
- Refuel in minutes
- Increase productivity

Emissions:
- No PM. PM directly impacts health.
- Heat reduced to 10's of kW
- Noise reduced – fuel cells are quiet!
- Increased productivity

Vibrations
- Reduced

Ventilation costs
- Reduced

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In a remote mining application, an electrolyser would be used to capture surplus RE power and a fuel cell to generate power

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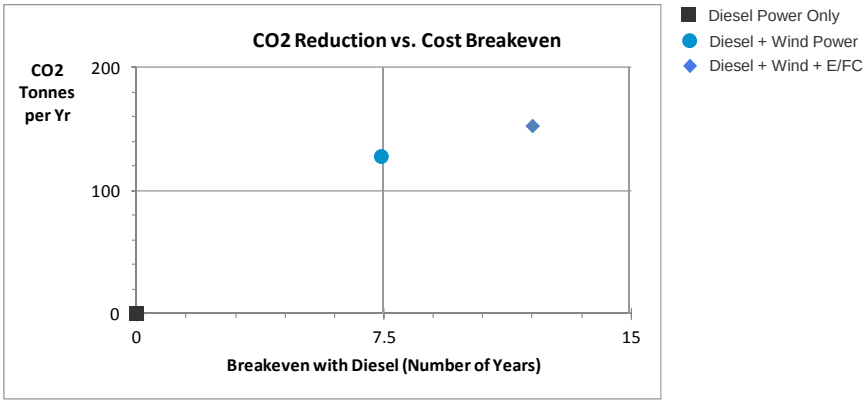
The RE alternatives provide a significant GHG dividend compared with the default Diesel Only, but at a higher cost

Scenario A: Arctic Diesel at Current Cost

Illustrative



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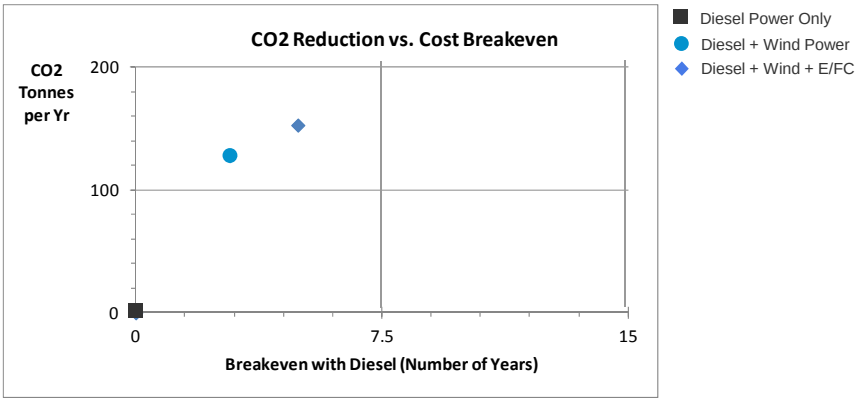
However if the cost of diesel increased by 50%, the hybrid options provide both a GHG dividend and attractive economics

Scenario B: Arctic Diesel at 150% Cost

Illustrative



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Technology: HyPM™ HD Fuel Cell Power Systems

- *Advanced onboard controls and diagnostics*
- *Integral Balance of Plant*
- *Rapid start-up and dynamic response*
- *Liquid-cooled advanced-MEA PEM stack*
- *Complete with Cathode Air delivery unit*

HyPM™ HD 30
High Durability – Heavy Duty

- *-46°C sub-zero shutdown capability*
- *No water for humidification required*
- *Unlimited start-stop cycling*
- *No nitrogen required for shutdown*

HyPM™ HD 2.0 Products

Technical Data	Unit	HD 30	HD 90	HD 180
Continuous Power	kW	33[b]	99[b]	198[b]
Dimensions (L x W x H)	mm	605x410x265[a]	955x1525x345	955x1525x690
Volume[a]	L	66[a]	502[b]	1002[b]
Mass	kg	58[a]	327[b]	654[b]
Operating Current	A_{dc}	0 to 500	0 to 500	0 to 500
Operating Voltage	V_{dc}	60…120	180…360	(2x) 180…360 or 360…720
Peak Efficiency	$\%_{LHV}$	55	55	55
Stack Operating Pressure	kPa	< 120	< 120	< 120

a) Air blower and coolant pump excluded (add 8.5 kg for air delivery and coolant pump.)
b) Includes air blower and coolant pump

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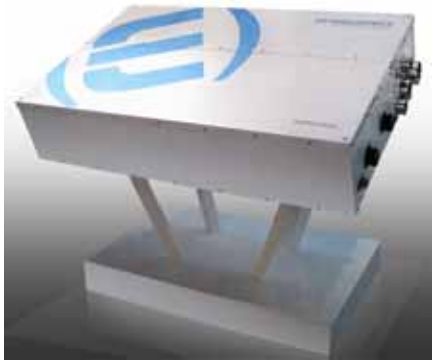
HyPM HD 90



1469 x 935 x 320 mm

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HyPM™ and HyPX™ in Mobile Certifications

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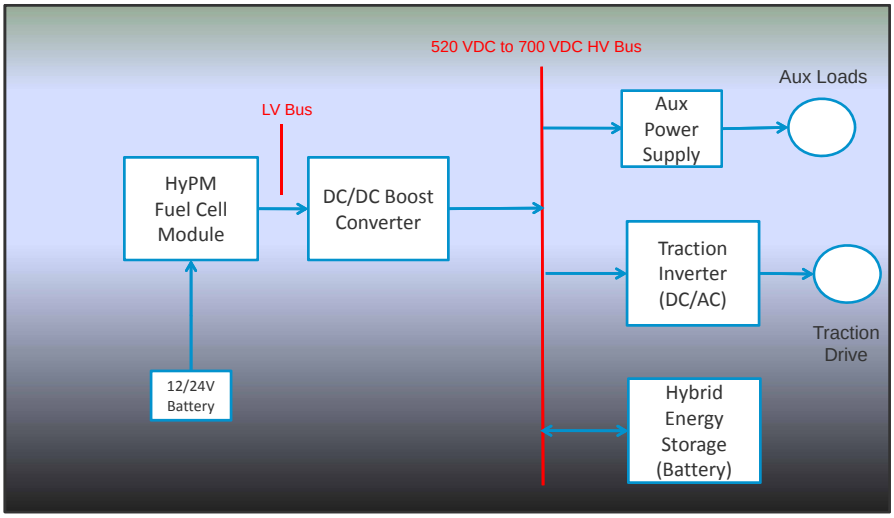
Fuel Cell Module in Vehicle
High Voltage Systems Architecture



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Adding a hydrogen energy system to a mining site provides additional benefits

- Electrolyzer/Fuel Cell system improves efficiency of other RE so that a higher percentage of energy produced is captured
  - Modular design which can be scaled over time
  - Oxygen available for waste water treatment
  - Turnkey solution
  - Are competitive for powering mining equipment
  - Offer zero emissions, high safety, fuel efficiency, productivity, long range and operating life
- Opens door to future options
  - Eliminate diesel generation in future if conditions permit

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Energy Storage: Remote Communities

Ramea Island (Newfoundland, Canada)

Customer: Newfoundland and Labrador Hydro (NLH)

OBJECTIVE OF THE PROJECT

- 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.

SOLUTION

- HySTAT-30/10 Outdoor solution to produce 30Nm³/h H_2.
- Hydrogen compression and storage system to provide 24/7 power from wind.
- Hydrogen power provided by H_2 gensets (HEC).

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Energy Storage: Remote Communities

HARP (Bella Coola, BC, Canada)

Customer: BC Hydro, HARP: Hydrogen assisted renewable power

OBJECTIVE OF THE PROJECT

- Government funded project to understand the benefit of connecting H2 energy storage to hydro power projects in small communities.
- Reduce diesel consumption by 200'000 L annually (= 600 tons of GHG).

SOLUTION

- HySTAT-60/10 Outdoor solution to produce 60Nm³/h H_2 from run-of-river hydro power.
- Hydrogen compression and storage system to store H_2.
- Fuel cells system to produce electricity when required.

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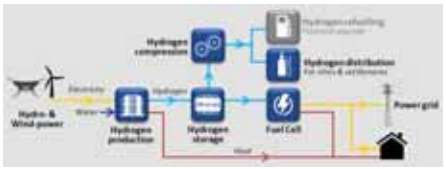
Hydrogenics' systems have been deployed in the Arctic for the H2KT Project in Nuuk, Greenland

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



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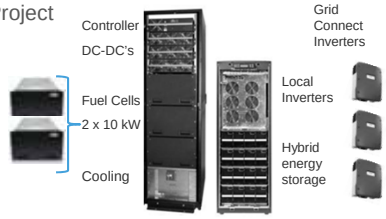
H2 Logic

Hydrogenics Scope:



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WHy Hydrogenics HyPM

- Hydrogenics has developed the HyPM™HD power module family
  - specifically designed for heavy duty commercial vehicle market
- Hydrogenics' proven HyPM™HD architecture makes integration into existing electric drive platforms simple and straightforward
  - fully integrated, many competitive advantages
- Over **10** years of development and deployment experience
  - **5 Generations**
  - **$ 100 000 000** invested
  - Lessons from broad range of applications and conditions worldwide fed back into development improvements
- Standard product, with flexibility on size - **15** variants in portfolio
- Proven durability > **12 000** hours and increasing!
- Competitive warranty and service support

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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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