

**HYDROGENICS**  
SHIFT POWER | ENERGIZE YOUR WORLD


POWER TO FUEL TO GAS

POWER TO MOVE TO PROTECT

**HyPM HD Fuel Cell Systems for Heavy Duty Green Mining**

**MDEC Conference 2012, Toronto**  
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There is a power shift happening worldwide:

- From fossil fuels to renewable alternatives
- From sufficient generation capacity to sufficient energy
- From single-purpose energy silos to multi-purpose energy infrastructure—power, gas, and transport
- From national energy security concerns to rebuilding confidence in the future

**Hydrogenics provides a link to a cleaner energy future**

2

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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

**under WATER**



**in SPACE**



**in the AIR**



**on LAND**



3

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## Hydrogenics' Lines of Business

**Onsite Generation**  
Water Electrolyzers




Industrial hydrogen

**Power Systems**  
Power Modules



Hydrogen fueling

**Power Systems**  
Power Modules



Backup power

**Power Systems**  
Power Modules




Mobility power


**Energy Storage**  
Load Control, Smart Grid and Remote Communities



**under WATER**



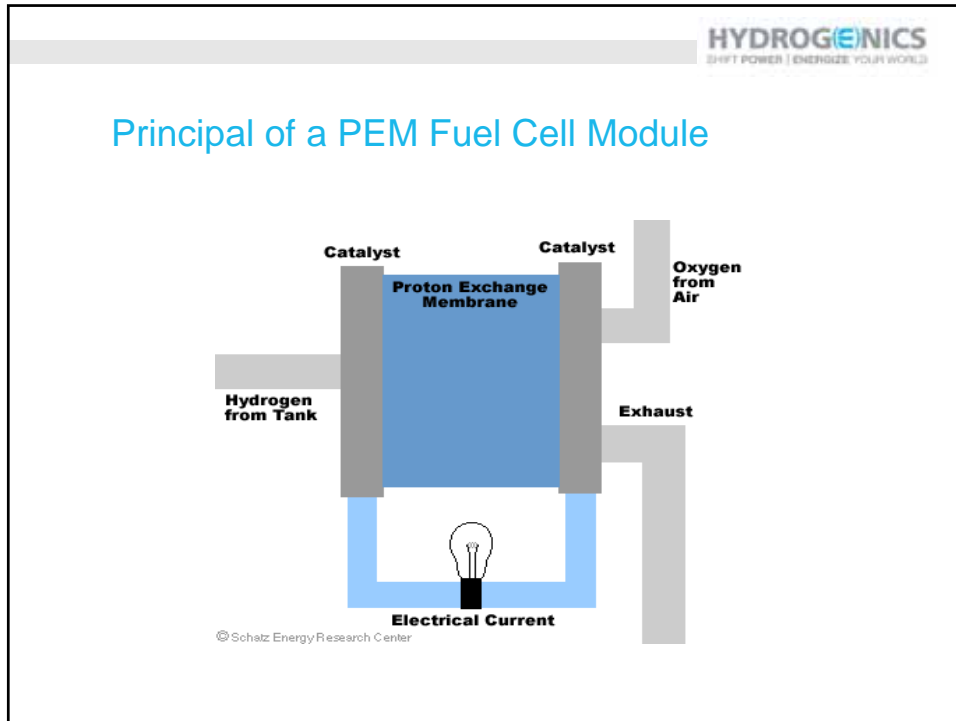
**in the AIR**



**in SPACE**



4



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



## We provide Fuel Solution: 350bar Fueling Station

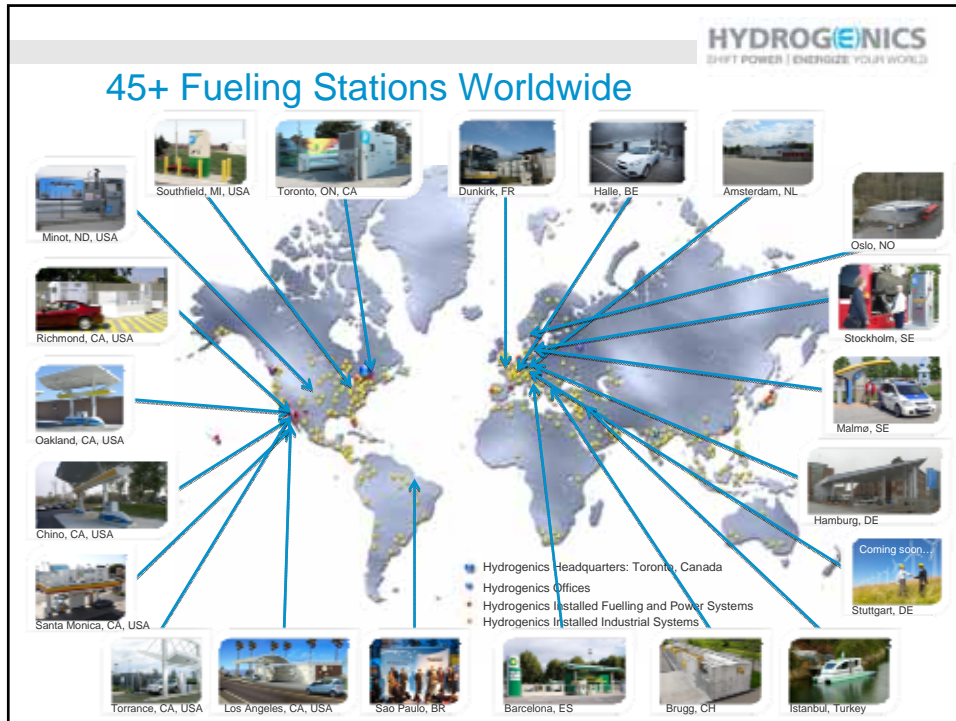
**Module 1: Electrolyser**  
(21,32, 65, 97 or 130kg/day)

**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

8



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### Experience in Advanced Technology Development

Performance		<p><b>DLR (Deutsches Zentrum für Luft-und Raumfahrt) – German Aerospace Center</b> Antares H3 – Hydrogenics to develop fuel cell system for next generation of fuel cell-powered aircraft</p> <p><b>Challenge</b></p> <ul style="list-style-type: none"> <li>• High Efficiency</li> <li>• Mass &amp; Performance Targets</li> <li>• Variation of oxygen content</li> </ul> <p><b>Strengths</b></p> <ul style="list-style-type: none"> <li>• Direct hybridization experience</li> <li>• Leading product technology</li> <li>• Extensive product validation</li> </ul> <p><b>Opportunities</b></p> <ul style="list-style-type: none"> <li>• First Transatlantic flight</li> <li>• Delivering critical Apps</li> <li>• Technology transfer</li> </ul>
High Power		<p><b>World Leader in Naval Defense</b> AIP (Air Independent Propulsion) – Hydrogenics supplies 250kW fuel cell systems</p> <p><b>Challenges</b></p> <ul style="list-style-type: none"> <li>• Fuel Consumption Targets</li> <li>• Oxygen Feed</li> <li>• Noise signature</li> </ul> <p><b>Strengths</b></p> <ul style="list-style-type: none"> <li>• Leading product technology</li> <li>• Strong domain expertise</li> <li>• Deep subject matter expertise</li> </ul> <p><b>Opportunities</b></p> <ul style="list-style-type: none"> <li>• Mission critical Apps, UAVs</li> <li>• System Integration &amp; Consulting</li> <li>• Solutions for high power systems</li> </ul>
APU		<p><b>Airbus – Leading Aircraft Manufacturer</b> Multi-function APU for RAT replacement, fuel cell powered electric nose wheel for commercial aircraft</p> <p><b>Challenges</b></p> <ul style="list-style-type: none"> <li>• RTCA DO 160E Vibration Test</li> <li>• Variation of oxygen content</li> <li>• Rapid start, dynamic loads</li> </ul> <p><b>Strengths</b></p> <ul style="list-style-type: none"> <li>• Leading product technology</li> <li>• Strong domain expertise</li> <li>• Strong product validation</li> </ul> <p><b>Opportunities</b></p> <ul style="list-style-type: none"> <li>• Delivering commercial Apps</li> <li>• System Integration &amp; Consulting</li> <li>• Technology transfer</li> </ul>
Space		<p><b>CSA – Canadian Space Agency</b> Hydrogenics picked to supply next generation fuel cell power system for Lunar Rover to be built in Canada</p> <p><b>Challenges</b></p> <ul style="list-style-type: none"> <li>• Hydrogen-Oxygen</li> <li>• Extreme Environmental</li> <li>• Critical Mass Targets</li> </ul> <p><b>Strengths</b></p> <ul style="list-style-type: none"> <li>• Leading product technology</li> <li>• Direct hybridization experience</li> <li>• Deep subject matter expertise</li> </ul> <p><b>Opportunities</b></p> <ul style="list-style-type: none"> <li>• Technology transfer</li> <li>• Platform for advanced development</li> <li>• Hydrogen-Oxygen Generation</li> </ul>


10

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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 require 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

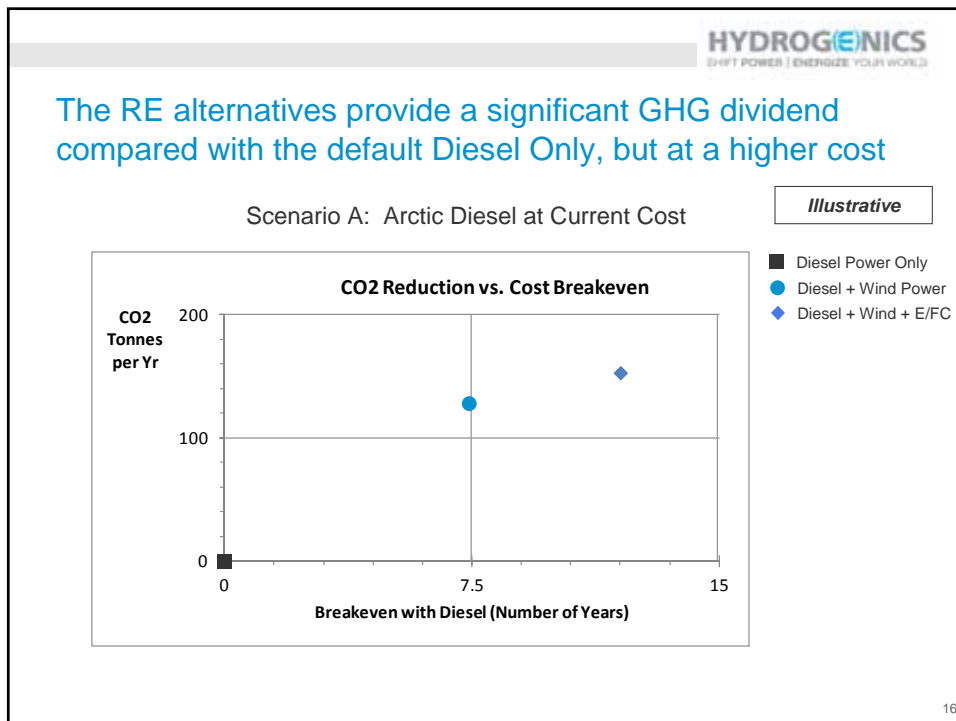
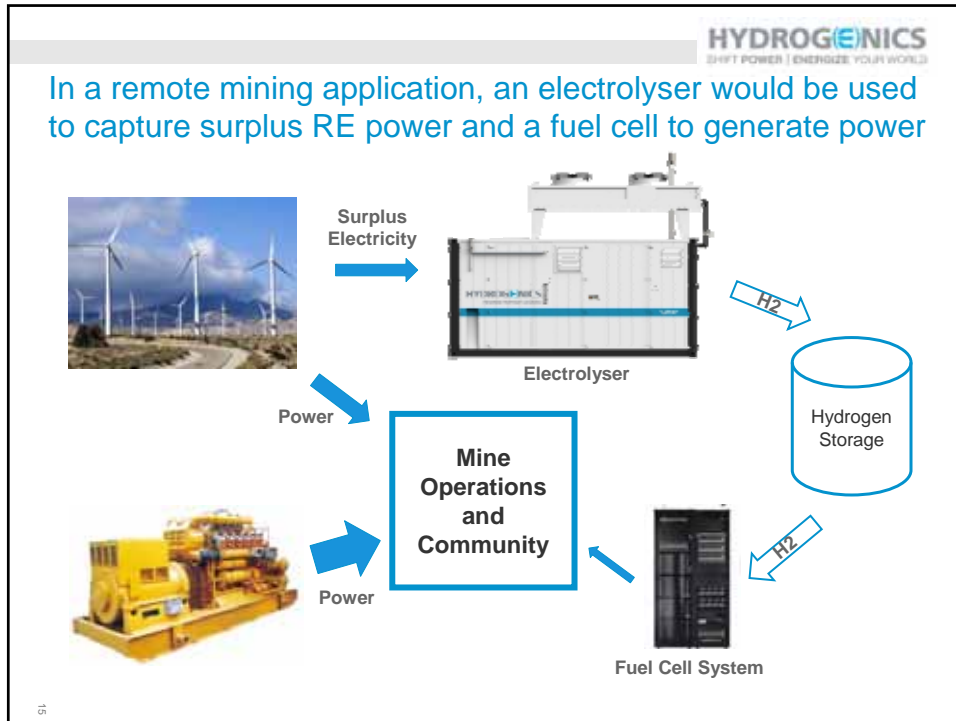
**Vibrations**

- Reduced

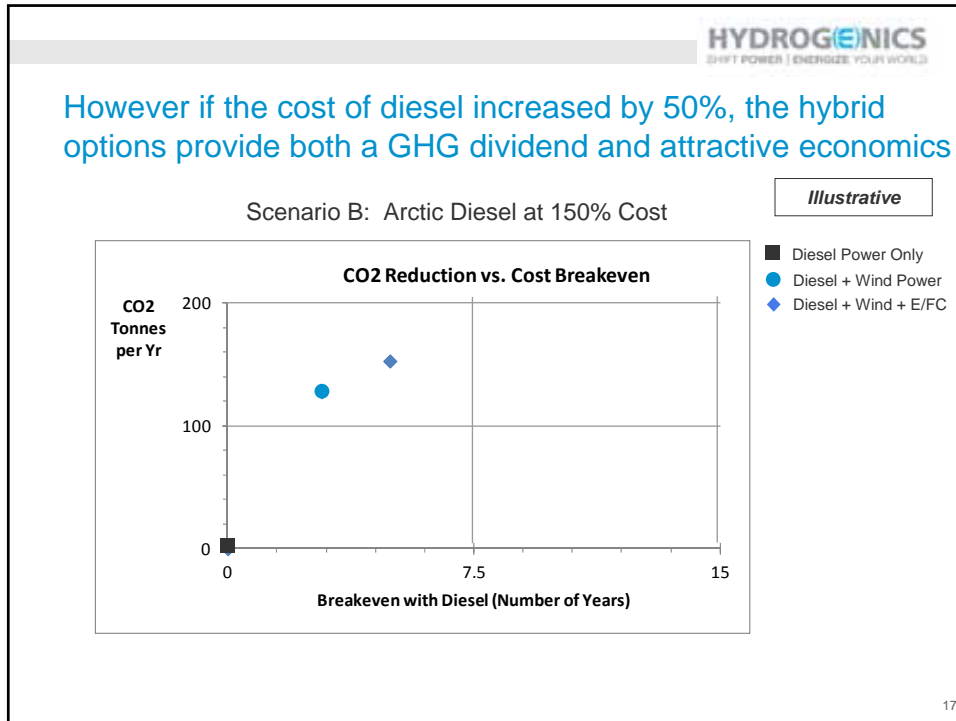
**Ventilation costs**

- Reduced







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### 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*
- *-46°C sub-zero shutdown capability*
- *Complete with Cathode Air delivery unit*
- *No water for humidification required*
- *Unlimited start-stop cycling*
- *No nitrogen required for shutdown*

HyPM™ HD 30  
High Durability – Heavy Duty

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## HyPM™ HD 2.0 Products



Technical Data	Unit	HD 30	HD 90	HD 180
Continuous Power	kW	33 <sup>b</sup>	99 <sup>b</sup>	198 <sup>b</sup>
Dimensions (L x W x H)	mm	605x410x265 <sup>a</sup>	955x1525x345	955x1525x690
Volume <sup>a</sup>	L	66 <sup>a</sup>	502 <sup>b</sup>	1002 <sup>b</sup>
Mass	kg	58 <sup>a</sup>	327 <sup>b</sup>	654 <sup>b</sup>
Operating Current	A <sub>dc</sub>	0 to 500	0 to 500	0 to 500
Operating Voltage	V <sub>dc</sub>	60...120	180...360	(2x) 180...360 or 360...720
Peak Efficiency	% <sub>LHV</sub>	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



Integrated Air System

H2 Supply

HV Connections

Cooling

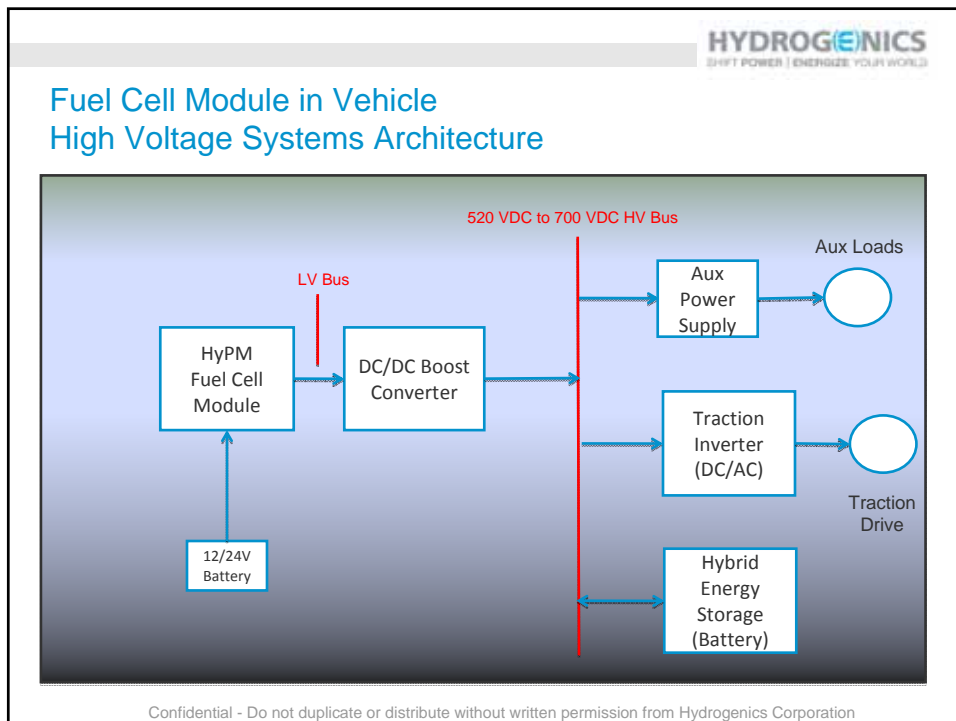
Exhaust


Air Inlet

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### HyPM™ and HyPX™ in Mobile Certifications


21






## 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






23



## 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"> <li>• Solve the cost and storage issues associated with intermittent/ renewable energy generation.</li> <li>• Investigating the potential to combine wind turbines and hydrogen generation as an alternative to diesel power currently installed.</li> <li>• Provide continuous high quality power.</li> </ul>	<ul style="list-style-type: none"> <li>• HySTAT-30/10 Outdoor solution to produce 30Nm<sup>3</sup>/h H<sub>2</sub>.</li> <li>• Hydrogen compression and storage system to provide 24/7 power from wind.</li> <li>• Hydrogen power provided by H<sub>2</sub> gensets (HEC).</li> </ul>

24



## Energy Storage: Remote Communities

### HARP (Bella Coola, BC, Canada)

Customer: BC Hydro, HARP: Hydrogen assisted renewable power

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#### OBJECTIVE OF THE PROJECT

- Government funded project to understand the benefit of connecting H<sub>2</sub> 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 60Nm<sup>3</sup>/h H<sub>2</sub> from run-of-river hydro power.
- Hydrogen compression and storage system to store H<sub>2</sub>.
- Fuel cells system to produce electricity when required.

25





## Hydrogenics' systems have been deployed in the Arctic for the H<sub>2</sub>KT 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




26

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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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