



HYDROGENICS

SHIFT POWER | ENERGIZE YOUR WORLD

Hydrogen for Energy Storage and Transportation at Scale

H2@Scale Workshop

August 1, 2018

**Rob Del Core
Hydrogenics USA, Inc.**

Hydrogenics is based in Mississauga with operations around the world

Hydrogenics Corporation

- **Headquarters**
- Mississauga, Ontario
- Incorporated in 1996 [NASDAQ: HYGS; TSX: HYG]
- 175 employees worldwide
- Fuel Cells, PEM electrolyser stacks, Power-to-Gas, H₂ refueling and mobility products / projects

Hydrogenics Europe

- Oevel, Belgium
- Since 1987
- Power-to-Gas, industrial onsite hydrogen production, and H₂ refueling station projects

Hydrogenics USA

- Carlsbad, California
- Fuel Cell power module integration and sales office

Hydrogenics

- Gladbeck, Germany
- Since 2002
- Fuel Cells, mobility projects

- Production Facility
- Sales Office

Hydrogenics – Hydrogen Technology Company

We build Electrolyser Systems and Fuel Cell Power Modules

Electrolysers



Uniper 2MW P2G, Germany



P2G H₂ Fueling, California



5MW Power-to-Gas, Ontario

Fuel Cells



Fuel Cell Bus Integrators, China



Alstom Coradia iLint, Germany



UPS Delivery Van, US

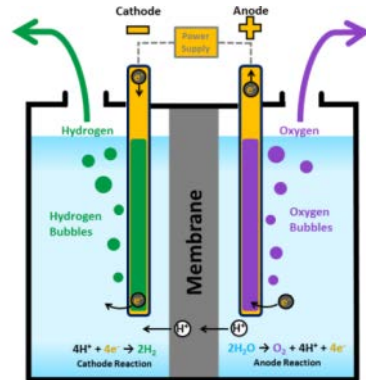
Electrolysers and Fuel Cells are electrochemical energy conversion devices

Electrolysers

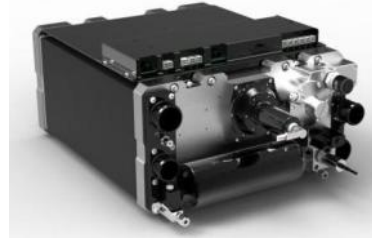


HyLYZER PEMWE Stack

Power Input: 1.25 MW
Hydrogen Output: 22.5 kg/h
Output Pressure: 35 bar

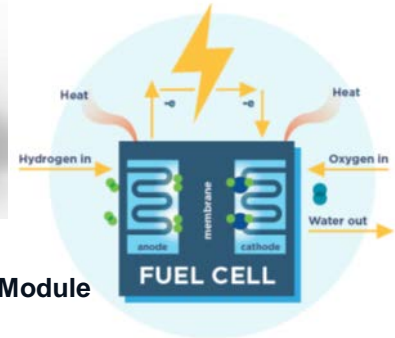


Fuel Cells



HyPM HD30 Fuel Cell Power Module

Power Output: 30kW
Integrated Balance of Plant
Low Pressure Design
Cold Temperature Operation



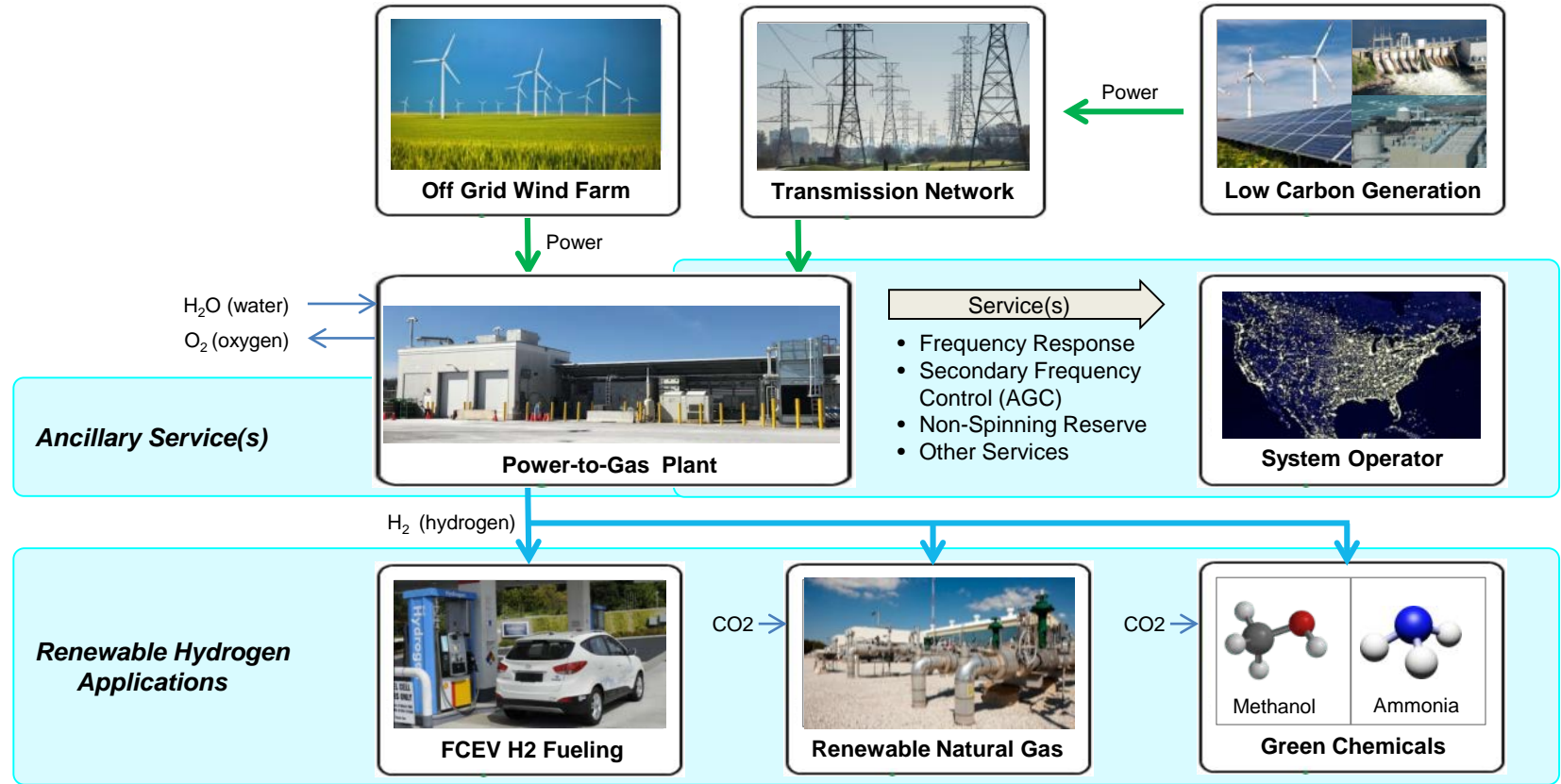
WATER (H₂O) + **POWER**

Electrolyser

Fuel Cell

HYDROGEN (H₂) + OXYGEN (O₂)

Power-to-Gas, Hydrogen as Energy Storage and Consumption



Hydrogen at Scale for Energy Storage

Over 35 Power-to-Gas projects operating in Europe

- Hydrogen Applications
 - FCEV H2 Fueling
 - Renewable Natural Gas
 - Direct Injection into NG Grid
 - Biogas Methanation
 - Catalytic Methanation
 - Industrial H2 Feed
- Projects range in size from 500kW to 6MW
- Commercial Scale projects will be 20MW to 50MW scale

Source: DNV KEMA . “Systems analyses Power to Gas: A technology review”.
June 20, 2013



Power-to-Gas is classified as Type 3 Energy Storage by the Independent Electricity System Operator in Ontario, Canada

IESO Classes of Energy Storage

Type 1	Type 2	Type 3
Energy storage technologies that are capable of withdrawing electrical energy (electricity) from the grid, storing such energy for a period of time and then re-injecting this energy back into the grid (minus reasonable losses). Examples include, but are not limited to, flywheels, batteries, compressed air and pumped hydroelectric.	Energy storage technologies that withdraw electricity from the grid and store the energy for a period of time. However, instead of injecting it back into the grid, they use the stored energy to displace electricity consumption (demand) of their host facility at a later time. Examples include, but are not limited to, heat storage or ice production for space heating or cooling.	Energy storage technologies that only withdraw electricity from the grid like other loads but convert it into a storable form of energy or fuel that is subsequently used in an industrial, commercial or residential process or to displace a secondary form of energy. They're generally integrated with a host process that uses that secondary form of energy directly or are connected to a transmission or distribution network for their secondary form of energy (e.g., natural gas, steam or coolant). Examples include, but are not limited to, fuel production (hydrogen or methane), steam production and electric vehicles.

Source: IESO Energy Storage Report file:///C:/Users/rharvey/Downloads/IESO-Energy-Storage-Report_March-2016.pdf

Benefits of using hydrogen for Energy Storage

- No energy loss over time
- Relatively easier to scale up
- Environmental friendly
- Can be easily dispatched for emergency back up power
- Assist grid resiliency and stability

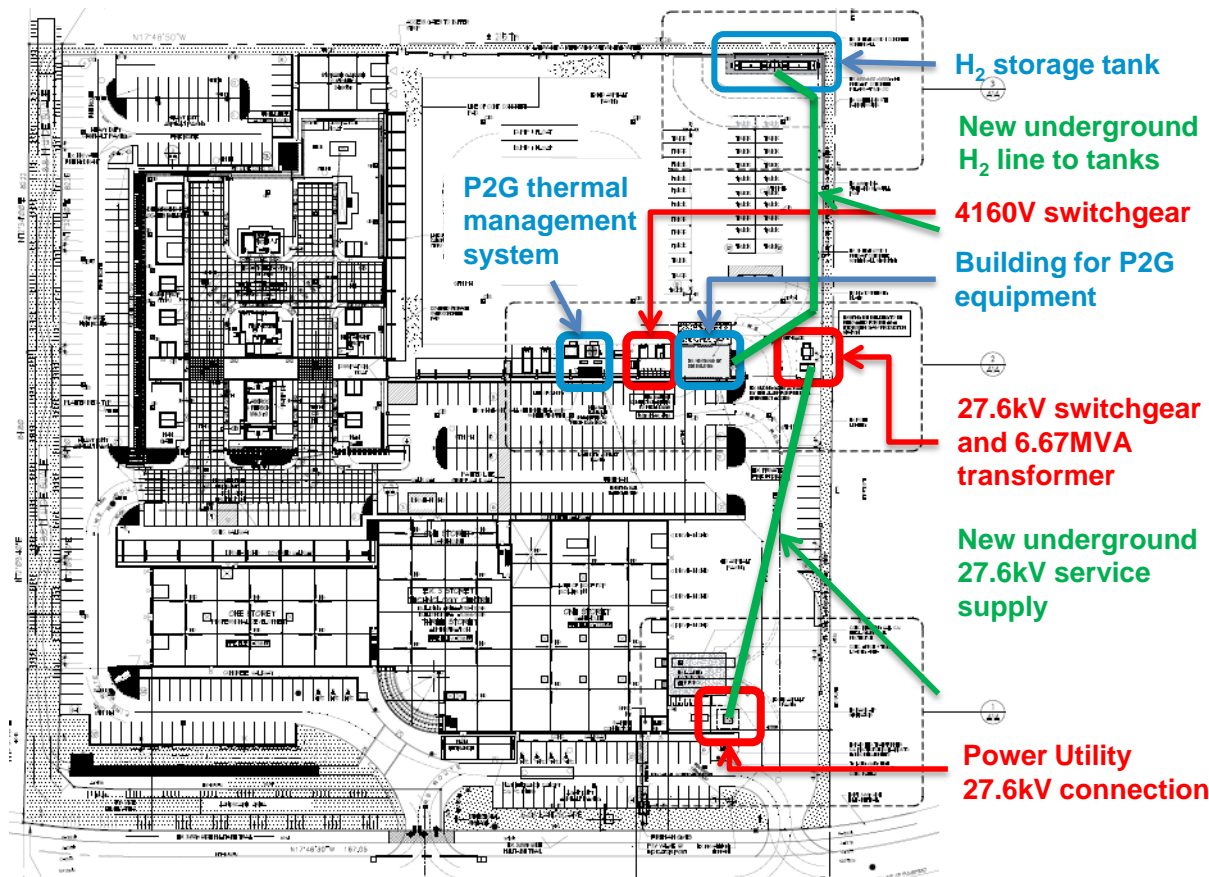
First and Largest Energy Storage Plant using Hydrogen in North America – Enbridge Energy Storage Facility in Canada



- Hydrogenics 1.25 MW electrolyzer has the **HIGHEST POWER DENSITY** and the **SMALLEST FOOTPRINT** for electrolyzer in the world
- First multi-MW power-to-gas energy storage plant in North America
- Joint Venture between Hydrogenics and Enbridge Gas Distribution
- 5MW plant design
- Electrolyser stack is the size of a bar fridge
- Power Input: 2.5MW



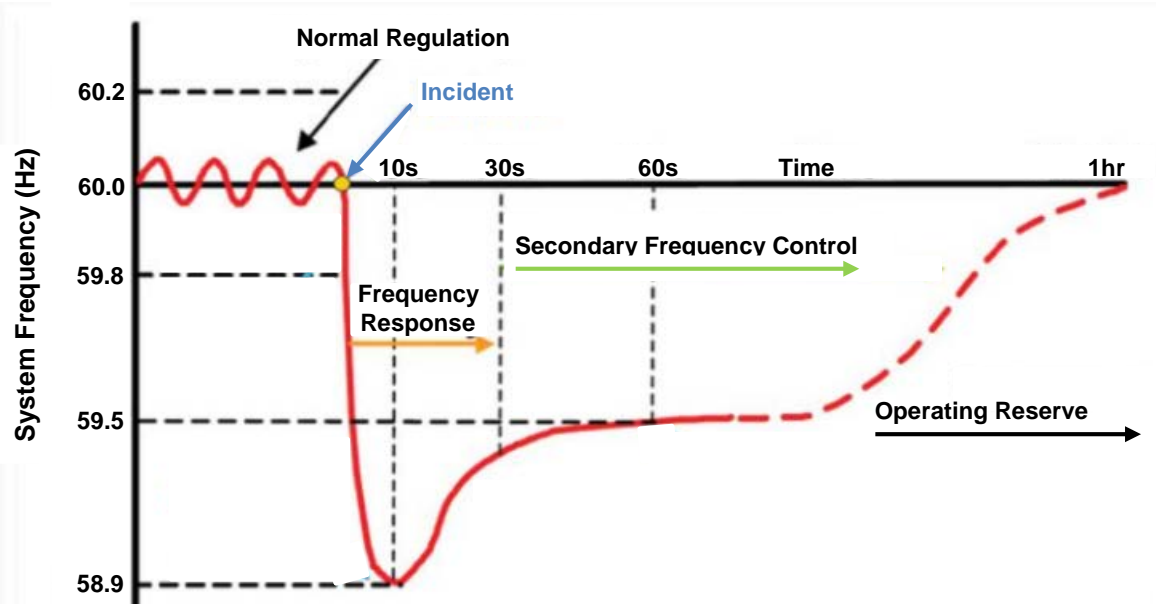
Markham Energy Storage Plant Site Layout



Power-to-Gas can provide the full range of regulation services for the System Operator

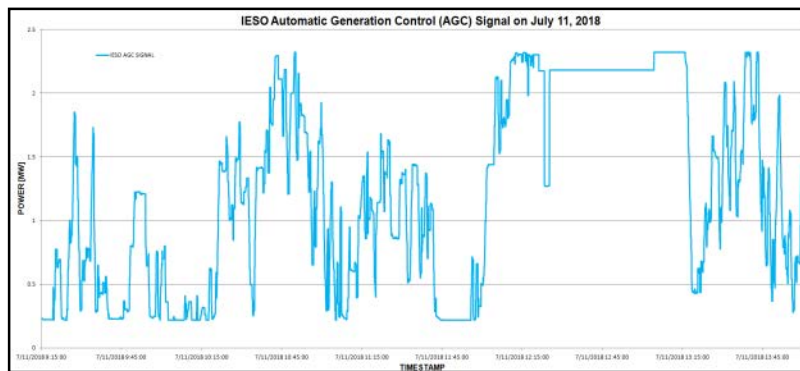
Illustrative

Regulation Services in Respond to Generation Loss

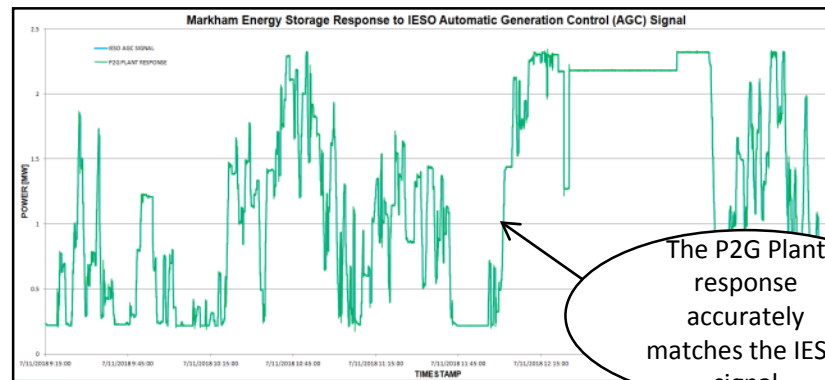


Adapted from EE Publishers article <http://www.ee.co.za/article/synthetic-inertia-grids-high-renewable-energy-content.html>

Electrolyzer fast acting response for grid stability



The IESO sends a AGC dispatch signal to the Markham Energy Storage Facility every 2 seconds



The Markham Energy Storage Facility adjusts its output in real time to match the IESO AGC Signal

Hydrogen at Scale for Transportation

Zero Emission Goods Movement & Transportation using Hydrogen Fuel in California

Fuel Cell Transit Bus and Port Truck, California

- Funded by CEC, to develop New Flyer fuel cell bus and Freightliner fuel cell trucks, Hydrogenics' Celerity bundled with Siemens ELFA



Fuel Cell Range Extend Drayage Truck, California

- Powered by Hydrogenics fuel cell



Fuel Cell Port Truck, California

- Funded by DOE ZECT, SCAQMD to develop hydrogen fuel cell Daimler class 8 freight truck using Hydrogenics' Celerity fuel cell power system for zero emission cargo transportation



Fuel Cell Range Extend UPS Medium Duty Delivery Van, California

- 17 UPS fuel cell delivery van powered by Hydrogenics fuel cell



Zero-emission hydrogen fuel cell regional train commercialization



- ~ 40% of rail network in Germany is not electrified (operated with diesel)
- Too expensive to electrify regional routes
- Increasingly stringent regulations (emission, noise)
- Expected future price increases for diesel

Date	NIP Project "BetHy" Schedule:
2014-09	LOI signed by 4 German States
2015-09	1 st Prototype FC System delivered
2016-09	Unveiled at Innotrans Exhibition, Berlin
2017-03	1 st two Pre-Series trains on test track
2018-1H	Completion of Type Approval testing
2018-2H	Pre-series validation in revenue service



