HYDROGENICS
Advanced Hydrogen Solutions

Staff Workshop for the 2010-2011 Investment Plan Hydrogen Technology for Transportation

September 29, 2009
Kevin Harris

Overview

- A leading manufacturer of electrolysers and fuel cells

- Canadian-based company with offices in Toronto, Belgium, Germany, and California:
  - On Site Generation Systems: HySTAT™ Electrolysers for industrial hydrogen and energy applications
  - Power Systems: HyPM™ Fuel cells for backup power and mobility applications
  - Renewable Energy Systems: Hydrogen system applications for community energy storage and smart grid

- 1,700 + hydrogen products deployed worldwide since 1948

Worldwide Hydrogen Refueling Stations

- Richmond, Torrance, Diamond Bar, Chino, Chula Vista, Oakland, Rosemead, West Los Angeles (Santa Monica)

- Ford, APG, Arizona

- Detroit, Michigan

- Minot, North Dakota

- Toronto (4) and Vancouver, Canada

- Malmo & Stockholm in Sweden

- Porto, Portugal

- Amsterdam, Netherlands

- Barcelona, Spain

- Hong Kong

Product Lines

HySTAT™
IMET Electrolyzer Stations
and
HyLYZER™
PEM Electrolyzer Modules
for OnSite hydrogen generation

HyPM™ XR
Fuel Cell Power Module extended run data centre and telecom UPS power

HyPM™ HD
Fuel Cell Power Module for mobility applications

HyPX™
Fuel Cell Power Pack for material handling

HyUPS™
Backup Power System

For Hydrogen; Against Nothing

- There is a great marriage between electricity/batteries and hydrogen/fuel cells
- We endorse the battery dominant, smaller fuel cell, plug-in hybrid powertrain architecture

Hydrogen as an Energy Storage and Energy Transfer Medium, and Renewable Energy Enabler

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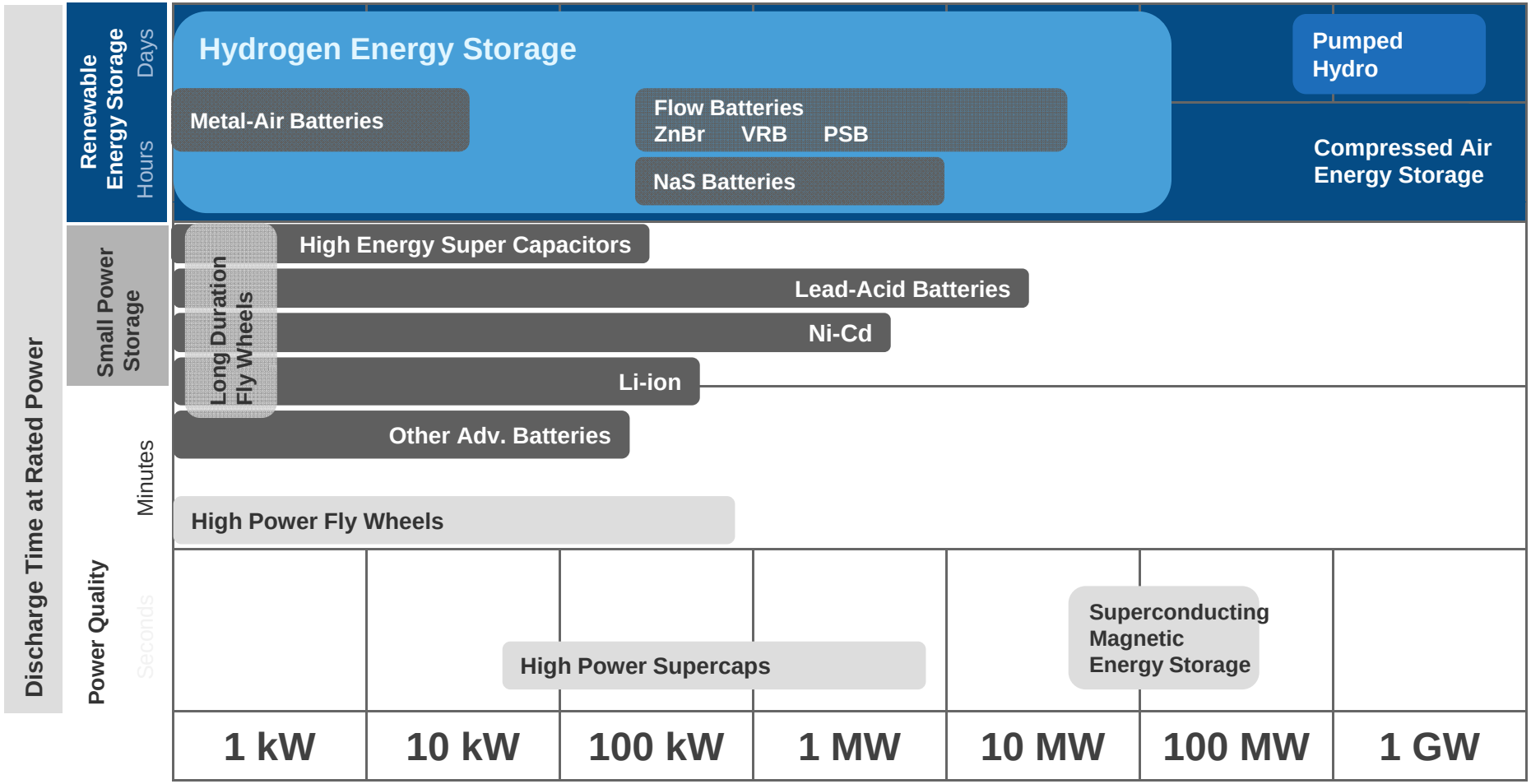
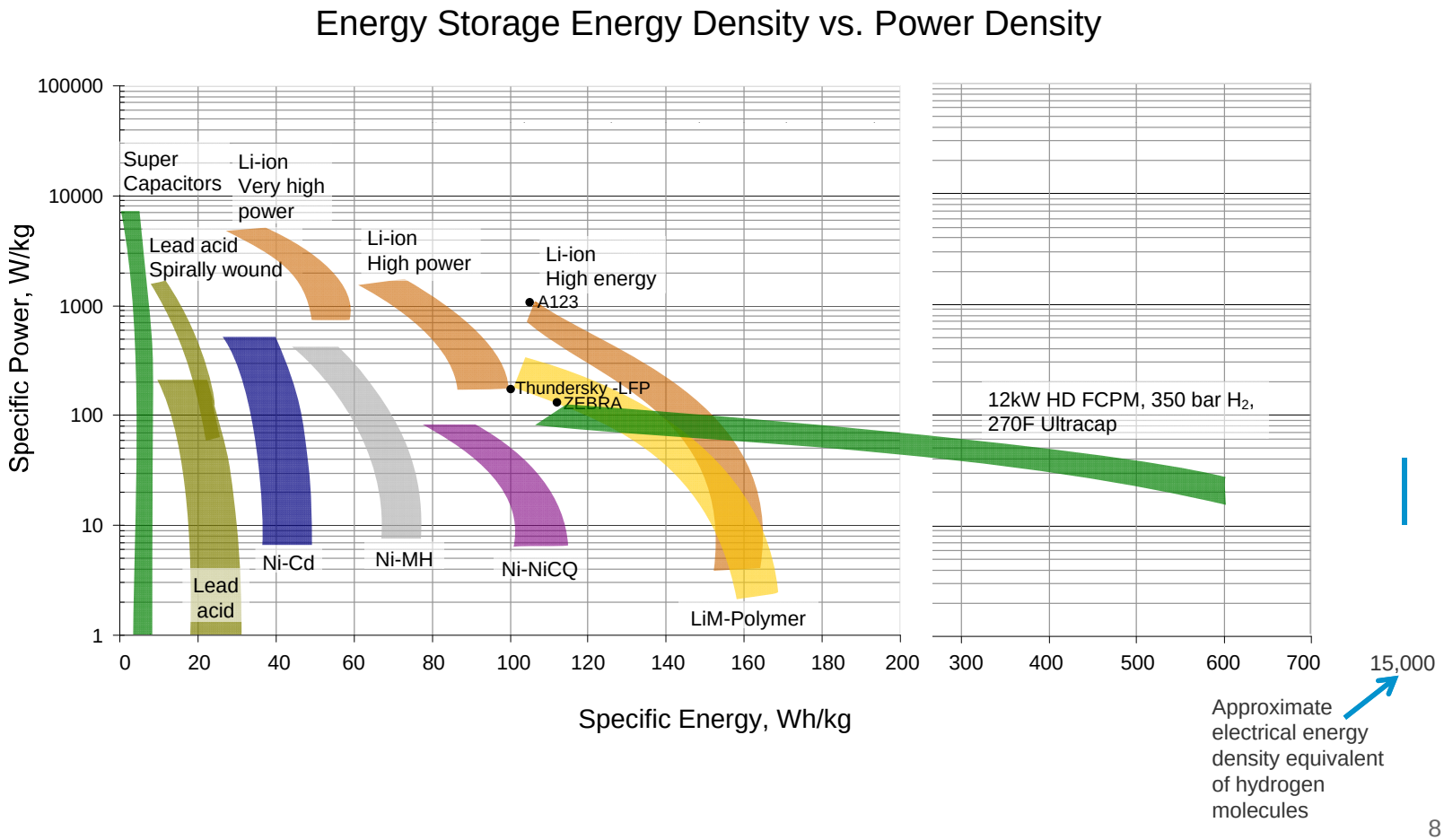
Wide Range of Complementary Solutions

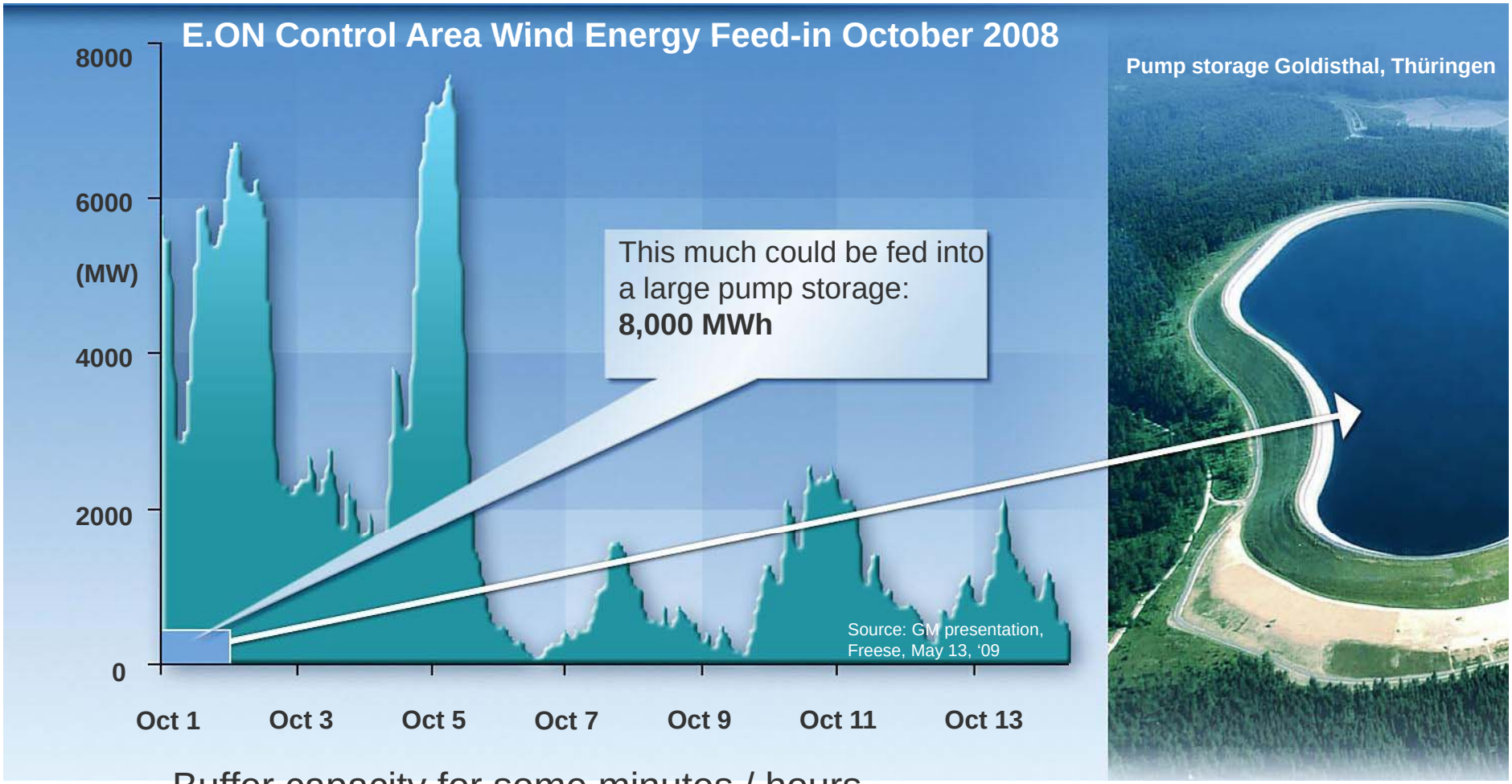


Source: Electricity Storage Association

Hydrogen Has Excellent Energy Density

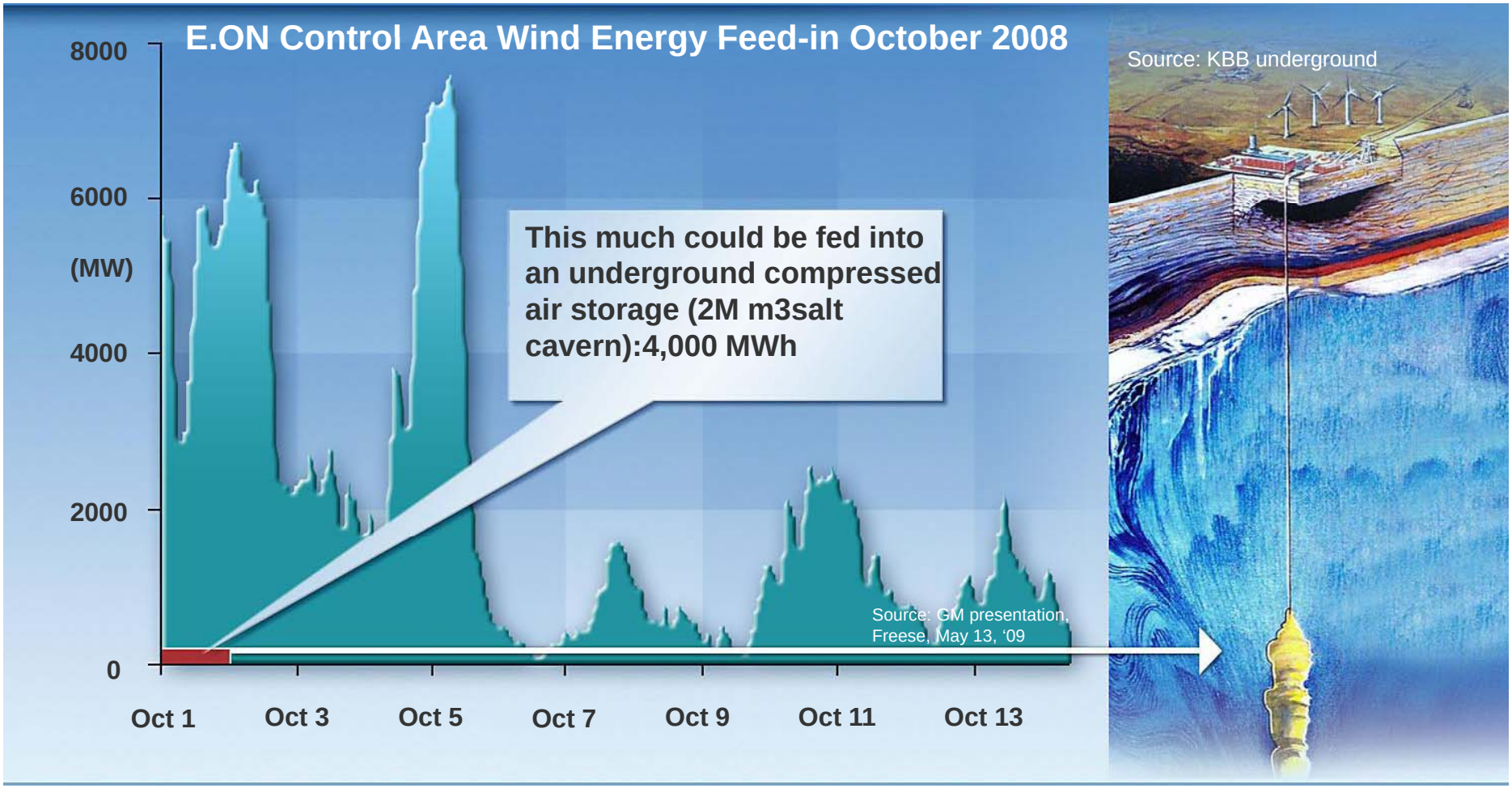


Energy Storage



Buffer capacity for some minutes / hours

Energy Storage



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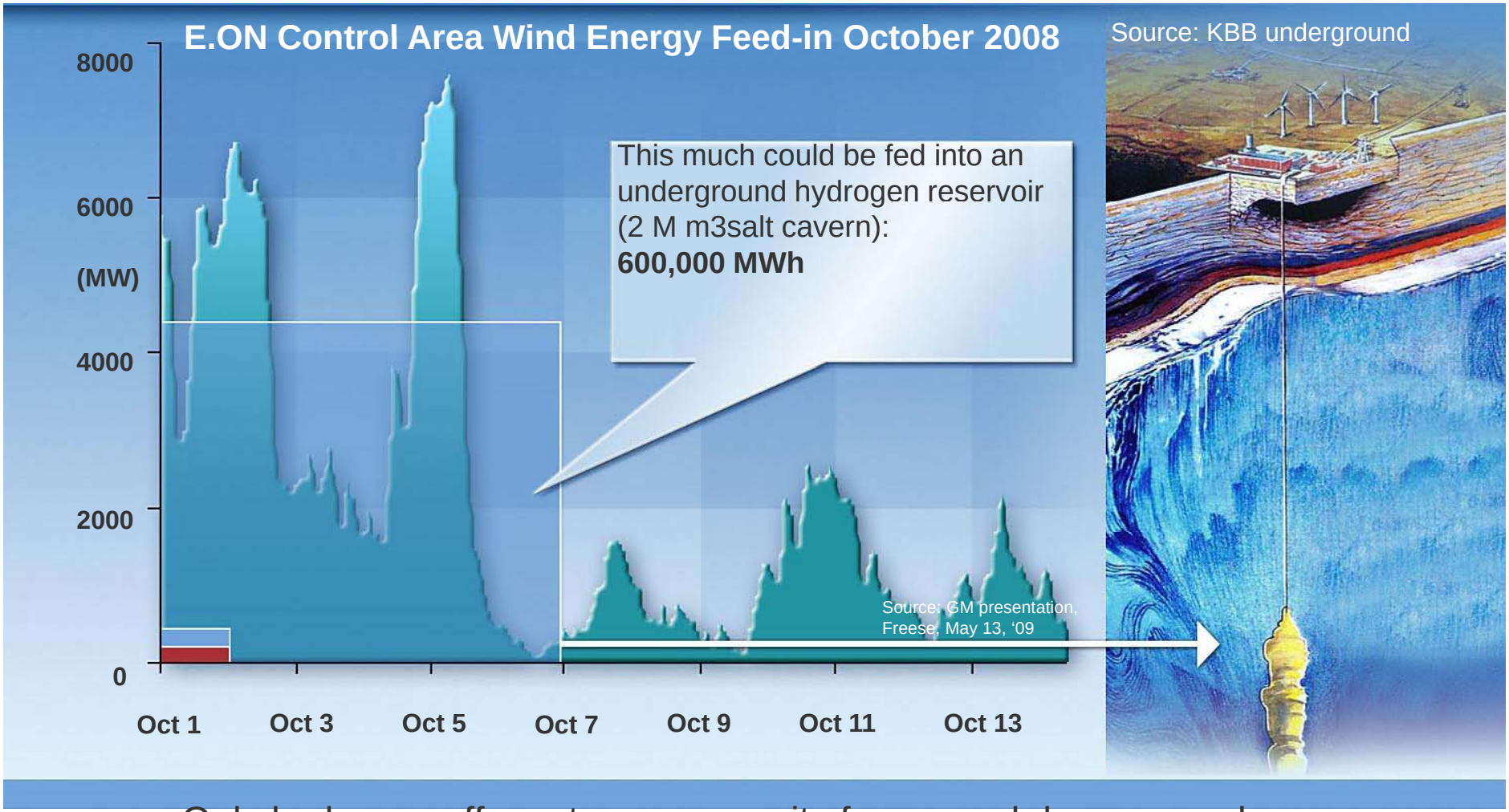


Only hydrogen offers storage capacity for several days or weeks

Unequalled Storage Density – Utility Scale

- Tube trailer can deliver 4 to 6 MWh when used with fuel cell
- No leakage and no parasitic losses over time
- Incremental storage capacity costs of less than $100/kWh

Renewable Energy and Energy Storage & Transfer

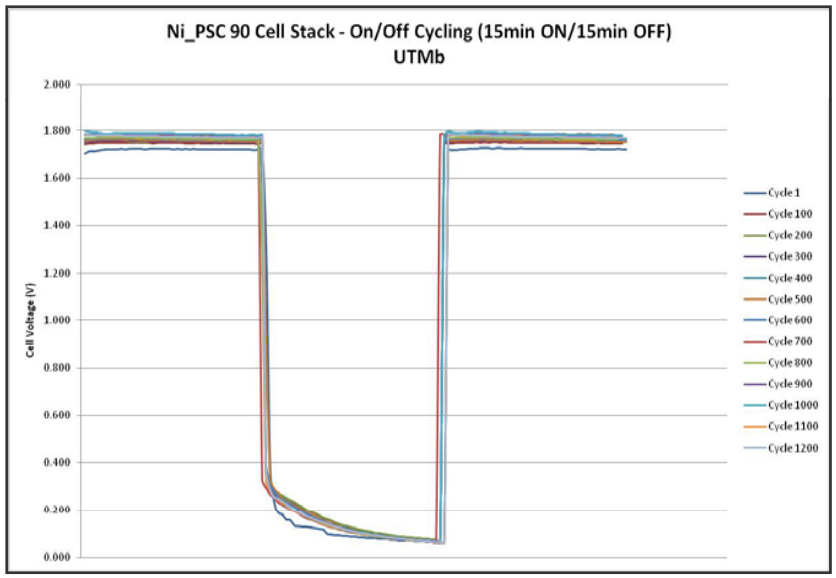
The Energy Storage Problem

- Renewable energy is driving the need for energy storage
  - Wind and solar are intermittent
  - Consumers and governments are pushing RE to higher proportions of grid mix
  - California Executive Order: 33% by 2020
- Problems occurring when RE provides >10% of the grid mix
  - Increased need for standby power and frequency regulation services
- Higher RE penetration raises the need for energy storage

Electrolysis Characteristics

- Ability to quickly cycle on and off
- High availability during periods of highest value
- Rapid response
- Distributed locations

- Allows operator to enter into grid ancillary services contract – giving temporary control of electrolyser to utility in exchange for lower rates or cash up front

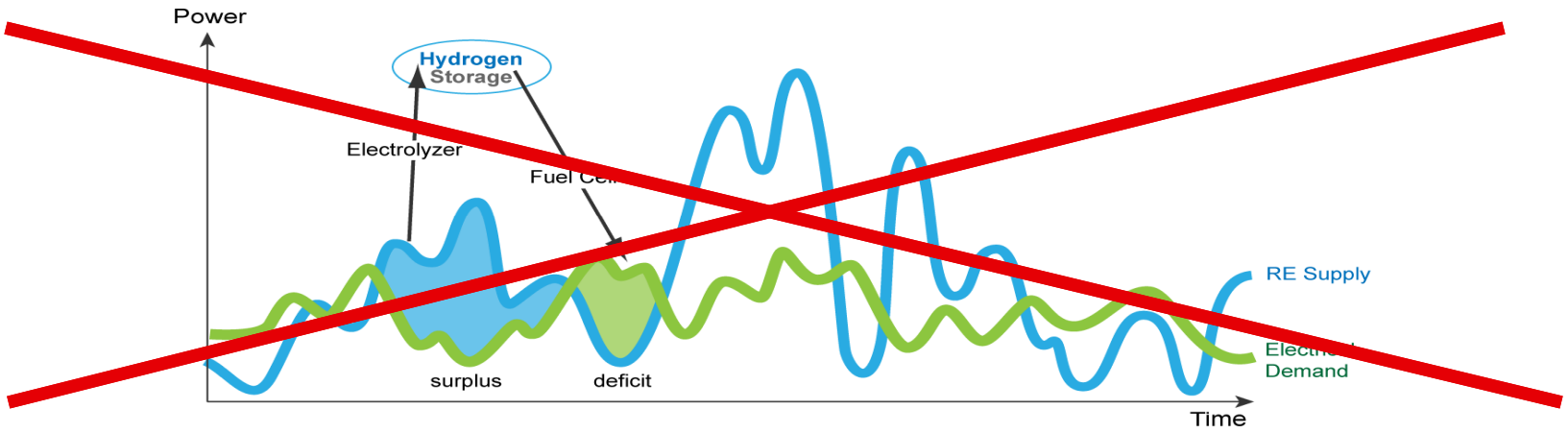


Commercial IMET On/Off Rapid Cycle Testing.

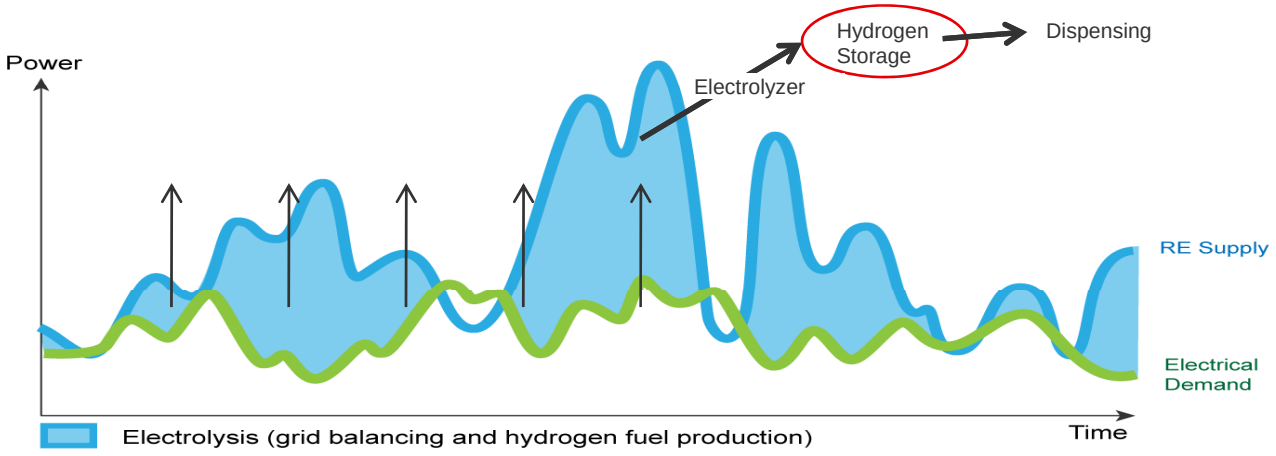
Ancillary Services Definitions

Service	Service Description		
	Response Speed	*Duration*	*Cycle Time*
Regulation	Power sources online, on automatic generation control, that can respond rapidly to system-operator requests for up and down movements; used to track the minute-to-minute fluctuations in system load and to correct for unintended fluctuations in generator output to comply with Control Performance Standards (CPSs) 1 and 2 of the North American Reliability Council (NERC 2002)		
	~1 min	*Minutes*	*Minutes*
Spinning reserve	Power sources online, synchronized to the grid, that can increase output immediately in response to a major generator or transmission outage and can reach full output within 10 min to comply with NERC's Disturbance Control Standard (DCS)		
	Seconds to <10 min	*10 to 120 min*	*Days*
Supplemental reserve	Same as spinning reserve, but need not respond immediately; units can be offline but still must be capable of reaching full output within the required 10 min		
	<10 min	*10 to 120 min*	*Days*
Replacement reserve	Same as supplemental reserve, but with a 30-min response time; used to restore spinning and supplemental reserves to their pre-contingency status		
	<30 min	*2 hours*	*Days*
Voltage control	The injection or absorption of reactive power to maintain transmission-system voltages within required ranges		
	Seconds	*Seconds*	*Continuous*

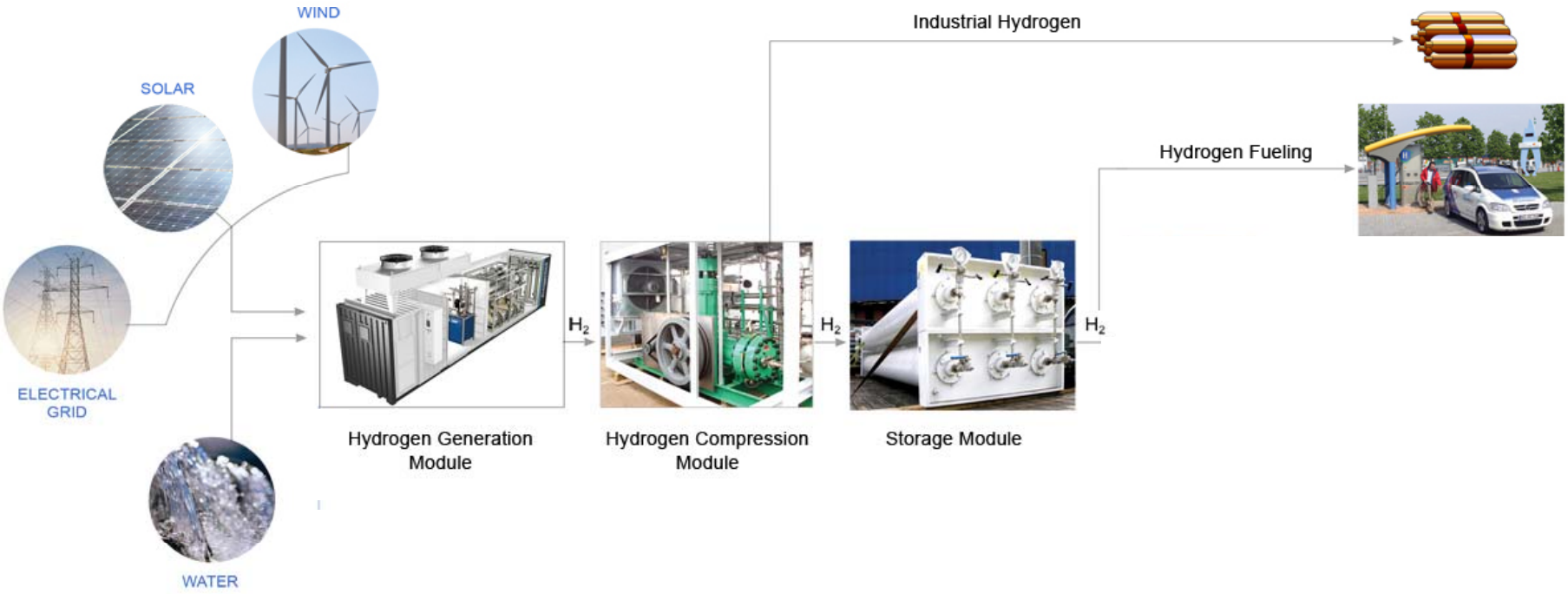
Intermittency and with Transportation Loads Added



Rebalance with H_2 Production for Transportation/Energy Storage



Hydrogen Energy Transfer System



Hydrogen Advantages

- Long term storage
  - Hydrogen storage costs are a fraction of batteries and flow batteries
  - Can store energy for days and weeks
  - No power dissipation

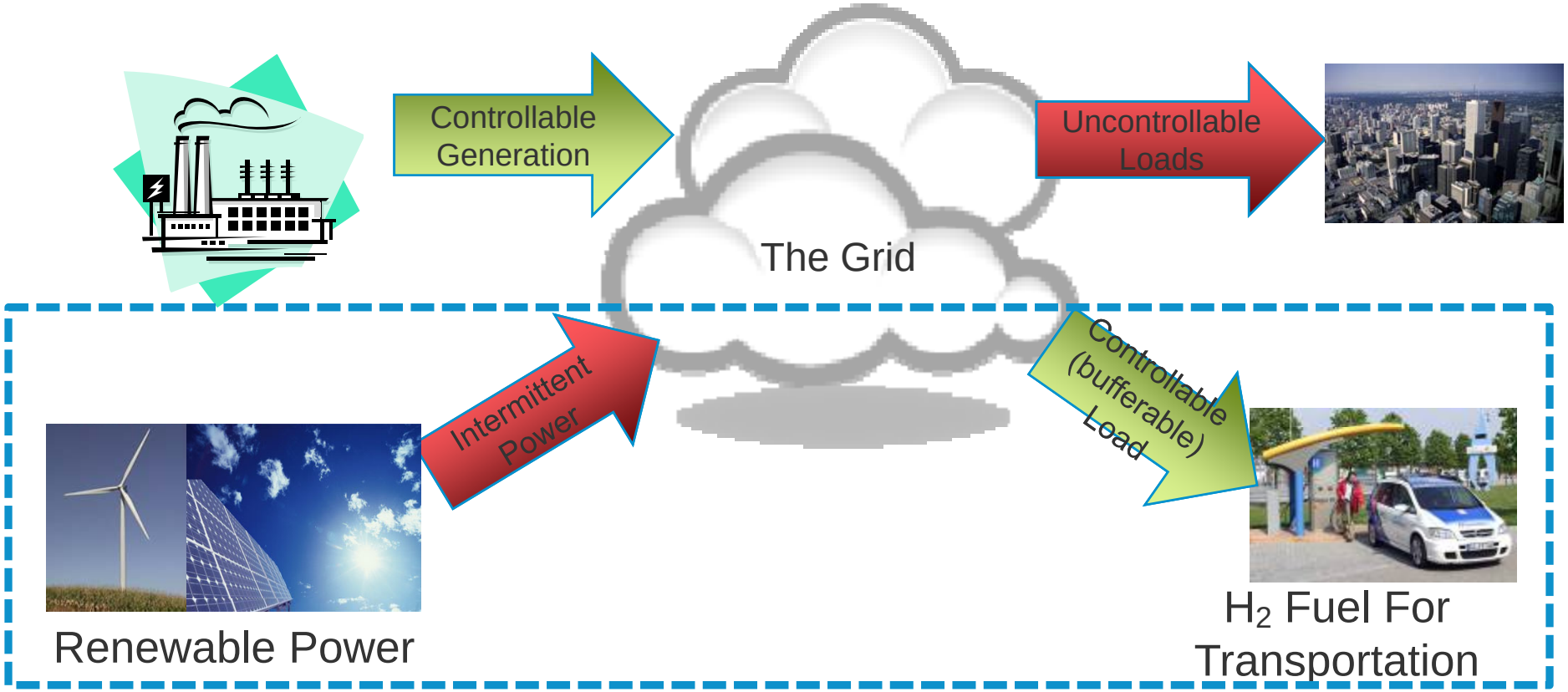
- Flexibility for use in many applications
  - Fueling for vehicles or other devices

- Zero emissions through entire system

- Hydrogen technology continuing to develop
  - Technical advances and cost reductions underway
  - Energy efficiency will be improved

Hydrogen Fueling Pathway

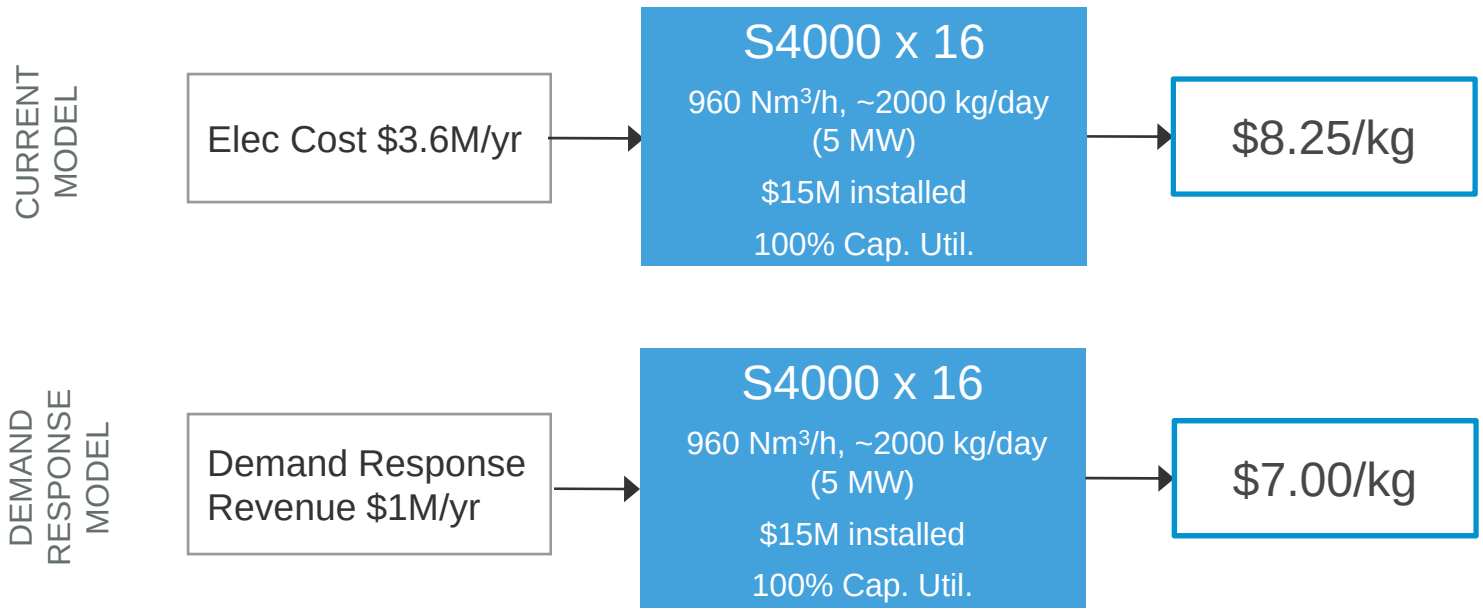
- Electrolysis hydrogen generation pathway to fueling
- Controllable load matches with intermittent renewable energy



Controllable load matches intermittent power

Smart Grid Services to Lower Cost

Large-scale hydrogen fueling with demand response revenue



Demand Response = $200k/MW/yr; Electricity cost = .08/kWh

August 6th, 2009: DOE, NREL and SRNL Complete "Real World" Driving Evaluation

2009 Toyota Highlander Gasoline Hybrid

Full Tank Range: 710 km (440 miles)

Avg. Fuel Economy: 9.0 L /100km (26 mpg)

Cost to fill up @ $ 3.15/gal: $ 53.31

2009 Toyota Highlander H_2 Fuel Cell Hybrid Vehicle

Full Tank Range: 690 km (431 miles)

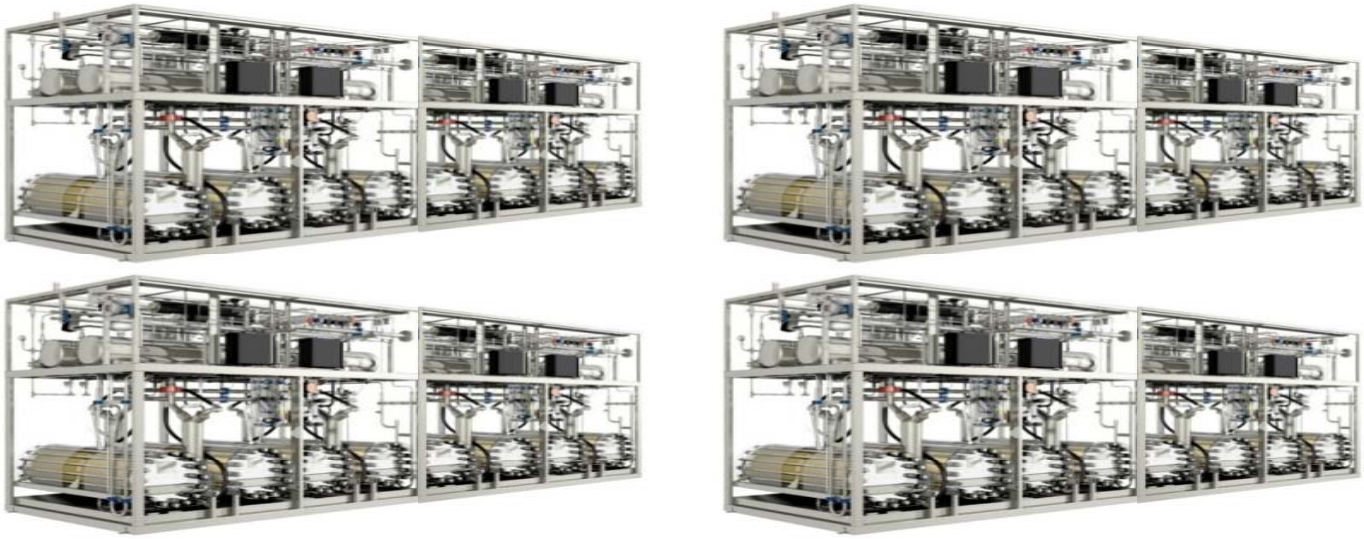
Avg. Fuel Economy[1]: 3.4 L /100km (68 mpg)

Cost to fill up @ $ 8/kg_{H2}: $ 50.71

Competitive fuel prices → Accelerating the transition to hydrogen

1. Converted from (kg) of hydrogen to litres of gasoline equivalent

Large Scale Electrolysis Accessible Today



2.5 MW (4 x 0.625MW) HYGS Module

- 32 stacks
- 485 Nm^3/h, 1000 kg/day Hydrogen
- 400 Amps
- 10 barg, 150 psig
- 32,000kg
- L 6.2m x H 1.8m x W 2.5m per module

Closing Remarks
Hydrogen = Energy Storage and Transfer

- Hydrogen can be considered a good form of energy storage
  - Particularly when large amounts of energy have to be stored
  - When the energy needs to be stored for long periods of time, e.g. days to months
- Hydrogen can be used as a energy *transfer* medium
  - to provide renewable-based fuel to the transportation market
    - At reasonable costs with the help of grid ancillary services contracts
- Hydrogen can help smooth out the intermittency of renewable energy sources (e.g. wind)
  - Enabling the further penetration of RE power sources into the grid mix
- End result:
  - lower petroleum consumption (increased energy independence and lower costs)
  - less air pollution
  - less greenhouse gases

Thank You