VIRENT
Energy Systems, Inc.

3591 Anderson Street, Suite 209
Madison, WI 53704
www.virent.com
608-663-0228

Virent will efficiently supply hydrogen "on-demand" using liquid phase reforming of renewable compounds like sugar. Virent will enable the hydrogen economy by dramatically increasing energy density and eliminating hydrogen storage issues from fuel cell systems.

Virent Energy Systems Overview

- Virent was founded in 2002 by Dr. Jim Dumesic and Dr. Randy Cortright of the UW Department of Chemical Engineering.
- Virent is developing patented Aqueous Phase Reforming (APR) technology for the conversion of liquid hydrocarbons, like sugar, to hydrogen gas.
- Virent Currently has 12 employees and occupies 3,000 square feet of lab and office on the TEC campus in Madison, WI
- Virent has attracted over $2.2 million in Federal funding, $550k in State funding, and raised $300k of private equity seed money.
- Virent has the only cost effective, carbon neutral source of hydrogen from renewable fuels.

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Virent's Value Propositions

- Virent is one of the only technologies that can efficiently produce H2 from a renewable/Carbon neutral source.
  - Can we beat Wind, Solar, nuclear, and other biomass solutions in cost?
- Virent solves energy density and safety problems with H2 on-demand and on/board reforming.
  - Cost?

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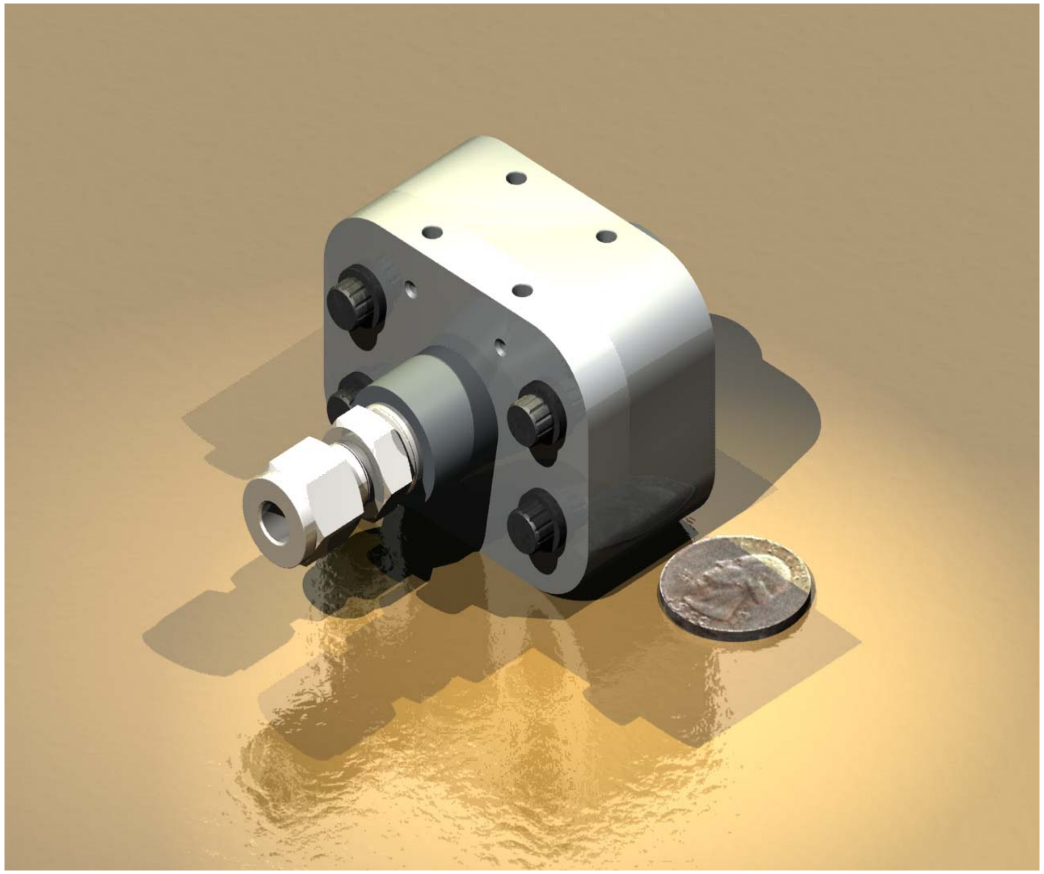
Aqueous Phase Reforming

- Ultra Efficient liquid phase reactor design.
- Generates 100 cc/min of H_2 from a small reactor volume and 1 gram of catalyst.
- Less than 240 °C operating temperature.
- Glycerol, Sorbitol, Ethylene Glycol and Glucose fuels



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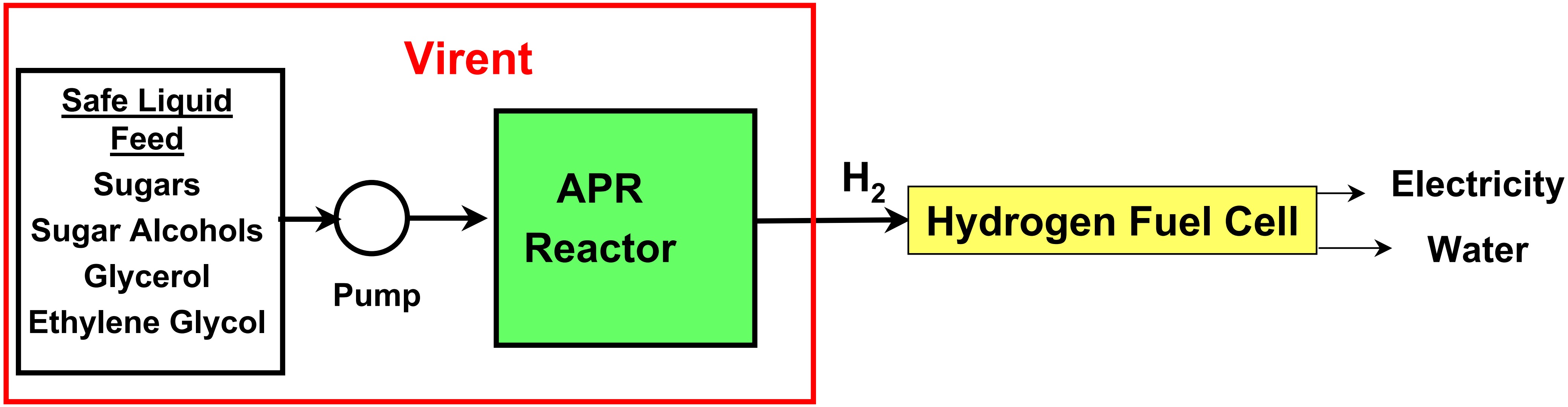
Virent's Solution
Aqueous-Phase Reforming Process (APR)



- **Liquid-Phase Reforming**
  - Generates Fuel Cell Grade Hydrogen in a Simple One Reaction Step Process
  - Generates 15 times more hydrogen per mass of catalyst than existing steam reforming process.
  - Solves Hydrogen Storage Problem and Generates "On-Demand" Hydrogen for Fuel Cells

Intellectual Property

- Virent is the <u>Only</u> Company in the World that can Develop the APR Technology

- Three Patents Applied for through the Wisconsin Alumni Research Foundation (WARF)
  - Inventors: Randy D. Cortright and James A. Dumesic (Co-Founders of Virent)
  - Claims allowed for first patent application
  - Covers all probable compositions and conditions needed for liquid phase reforming

- Virent: *Sole Technology Licensee*
  - Exclusive worldwide license
  - Right to sublicense

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Features, Advantages , Benefits

Feature	Advantage	Benefit
Liquid phase reforming	Steam generation not required.	Higher efficiency. Lower operating costs.
Single reactor vessel	Simple, compact design.	Lower equipment cost, higher reliability, easier system integration.
Low operating temperature (200 °C)	Low carbon monoxide (CO). Lower thermal losses.	Hydrogen directly usable by advanced PEM fuel cells. Higher efficiency.
Broad range of liquid feedstocks	Renewable, non-flammable, indigenous feedstocks available.	Safety, public acceptance, environmental impact, energy security.

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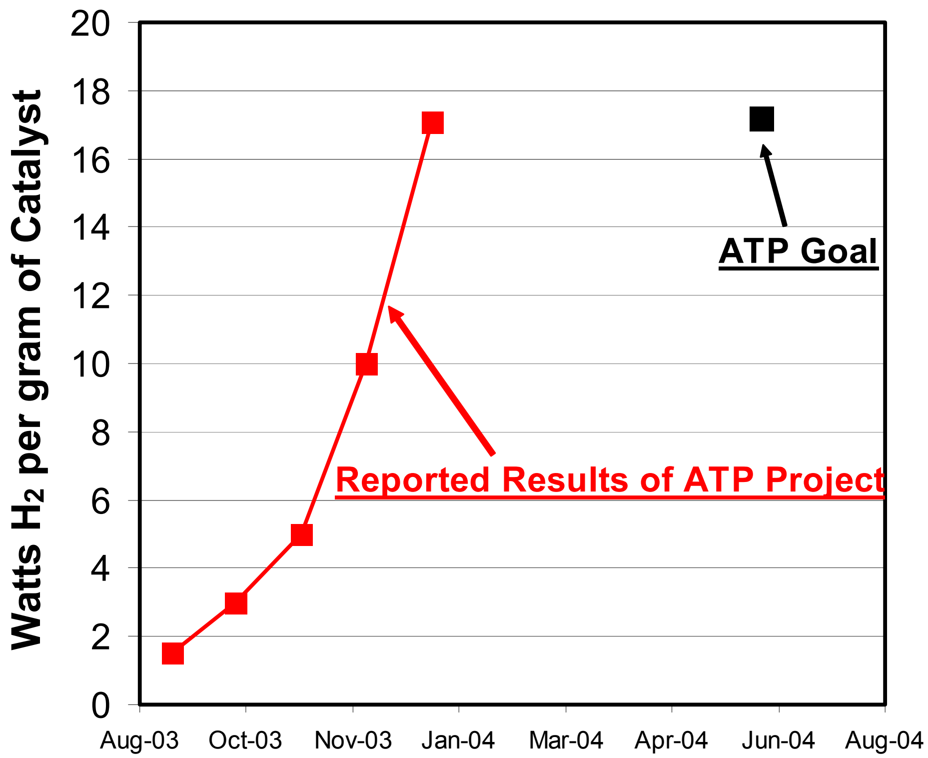
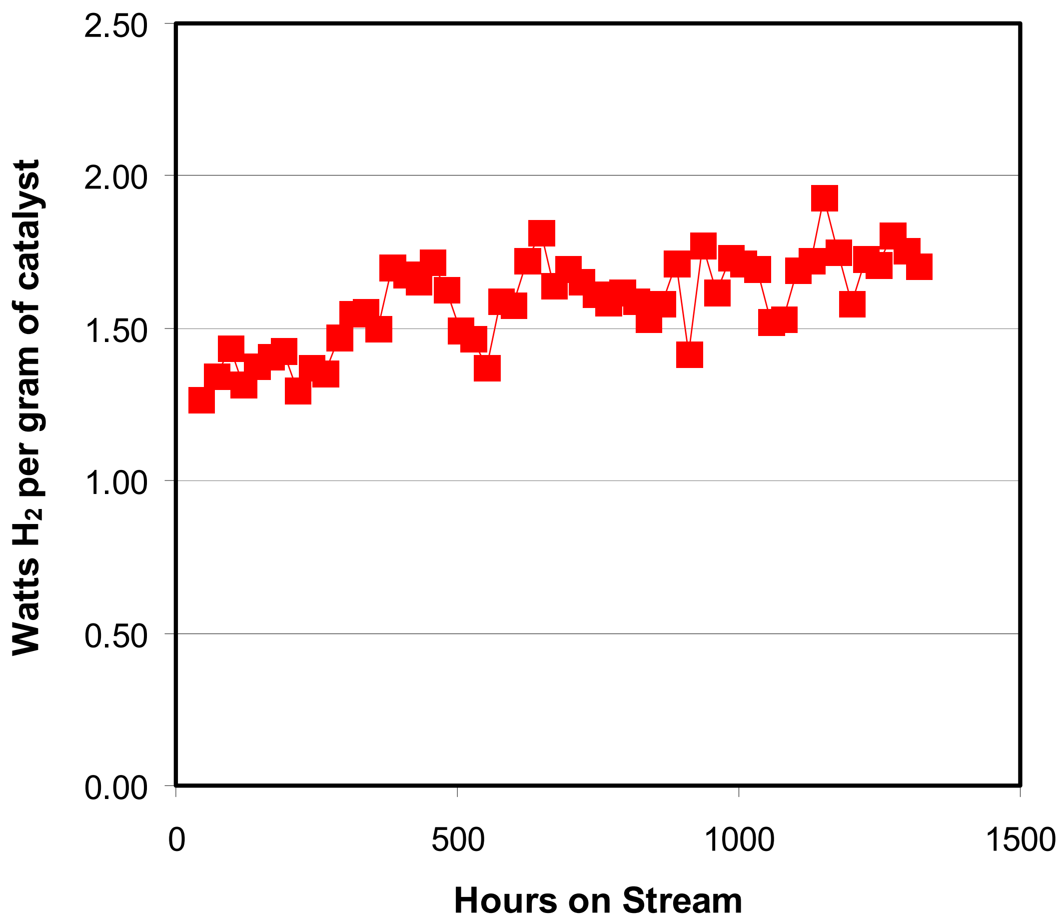
Catalyst Activity Studies



- NIST/ATP Funded Project
- Increased Activity due to Catalyst Composition, Reactor Design, and Reaction Conditions
- Ethylene Glycol Feed
- 70 vol% H_2 in reactor Effluent

Catalyst Lifetime Study



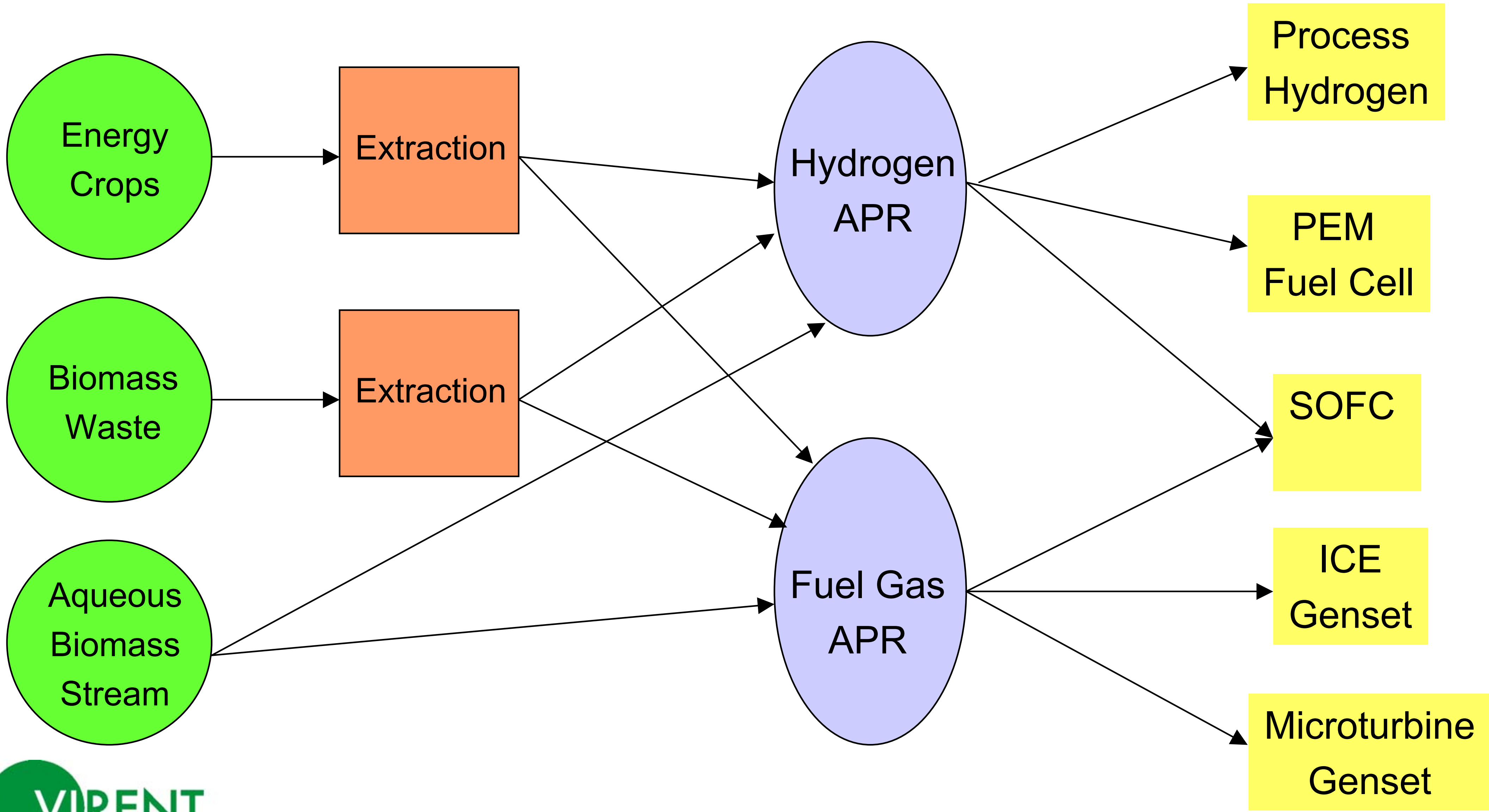
Results from NSF STTR Phase I Project

Platinum-Based Catalyst

10% Glycerol Feed

Two Month Run from September 2003 to November 2003

Applications of the APR Process Utilizing Biomass Streams



Product drivers for Hydrogen Fixed Applications

	Industrial -float glass -annealing	Laboratory GC	Home Energy Center (FC)	Auto/Bus Filling Station	Grid Power
Power Range	NA	20-100 W	5-10kW	NA	NA
Flow rate - H2 needed		0.1-0.5 l/min	300-600g/hr	10 kg/hr	
Product Needs 1.	Cost	Safety	Cost	Cost	Cost
2.	Cost	Cost	Reliability	Renewable	Emissions
3.	Reliability	Reliability	Emissions	Carbon Neutral	Renewable
4.			Noise level	logistics	Carbon Neutral

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Product drivers for Hydrogen Mobil Applications

	Battery Replacement	Portable Recharger	Small on-board generator	On-board Reforming for PEM FC	On-board reforming for ICE
Power Range	10-50 W	20-100 W	500-2kW	35kW	35kW
Flow rate - H2 needed	0.15-0.7 l/min	0.3-1.5 l/min	30g/hr-120g/hr	2.1 kg/hr	2.1kg/hr
Product Needs 1.	Energy Density	Energy Density	Cost	Emissions	Emissions
2.	Cost	Cost	Reliability	Energy Density	Energy Density
3.	Reliability	Reliability	Emissions	Cost	Cost
4.			Noise level	Renewable	Renewable

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Industrial Hydrogen Markets

- Float glass production
- Ammonia production
- Co-gen turbine blade cooling
- Heat treating/Annealing
- GC carrier gas
- Semiconductor manufacturing

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Fuel Cell Market Segments

Market Segment	Applications	Power Range	Projected Year to Market
Portable Power	"Soldier Power"	10 – 200 watts	2005
	Portable Recharger	1 – 200 watts	2005
	Laptop Computer	20 – 50 watts	2006
	Cell Phones	1 – 10 watts	2006
Transportation	Mopeds	100 – 500 watts	2005
	Forklifts	10 – 25 kW	2005
	Automotive	25 – 75 kW	2017
Stationary	Backup Power	1 – 25 kW	2004
	Home Power	5 – 10 kW	2008
	Remote Power	10 – 100 kW	2006
	Grid Power	1 – 1000 MW	2006

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Current Problems with Fuel Cells

- Hydrogen gas is expensive to distribute and store.
- Energy densities are still too low for portable power applications.
- Competing methanol fuel cell technology requires expensive catalyst and utilize toxic/flammable fuel.

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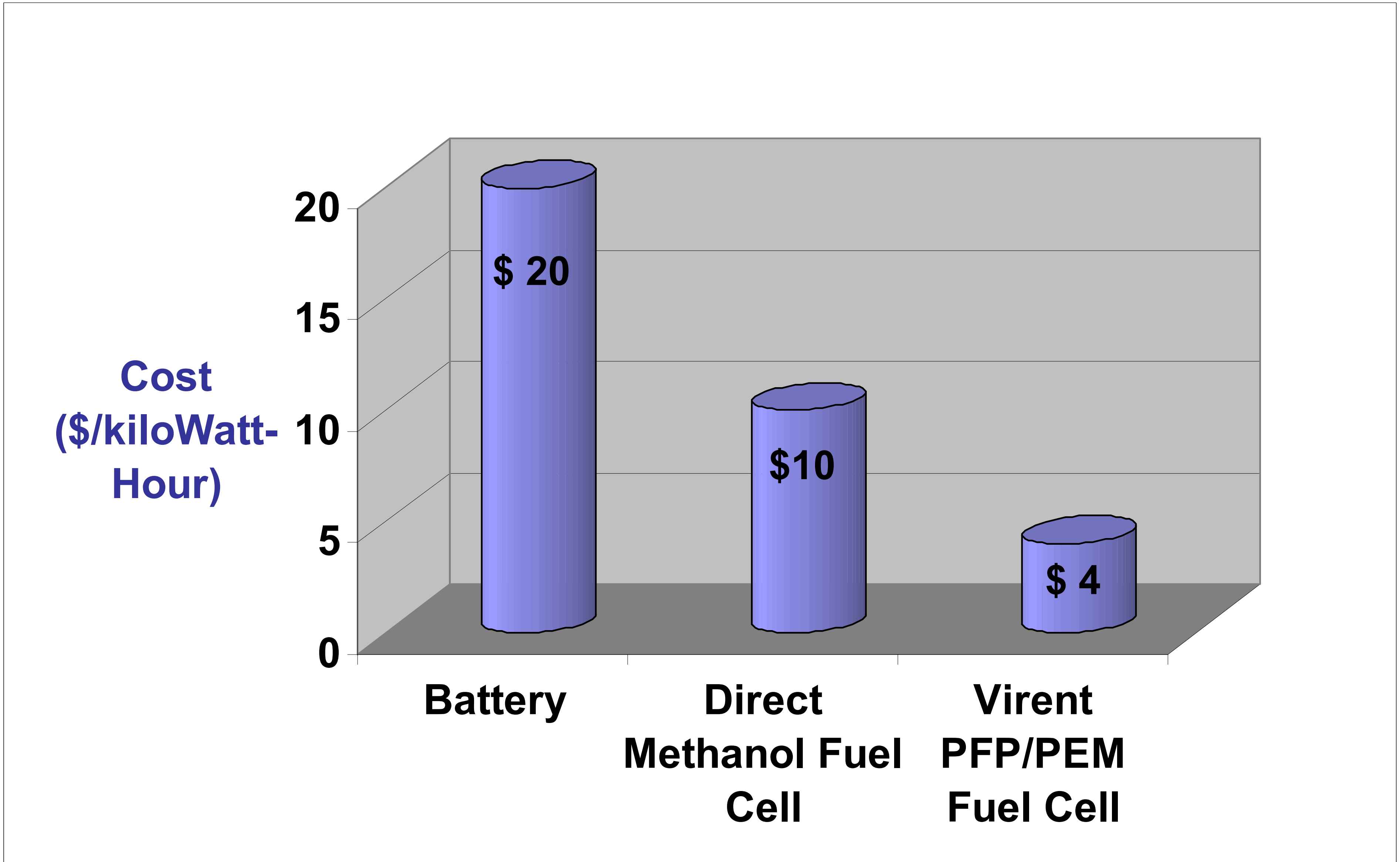
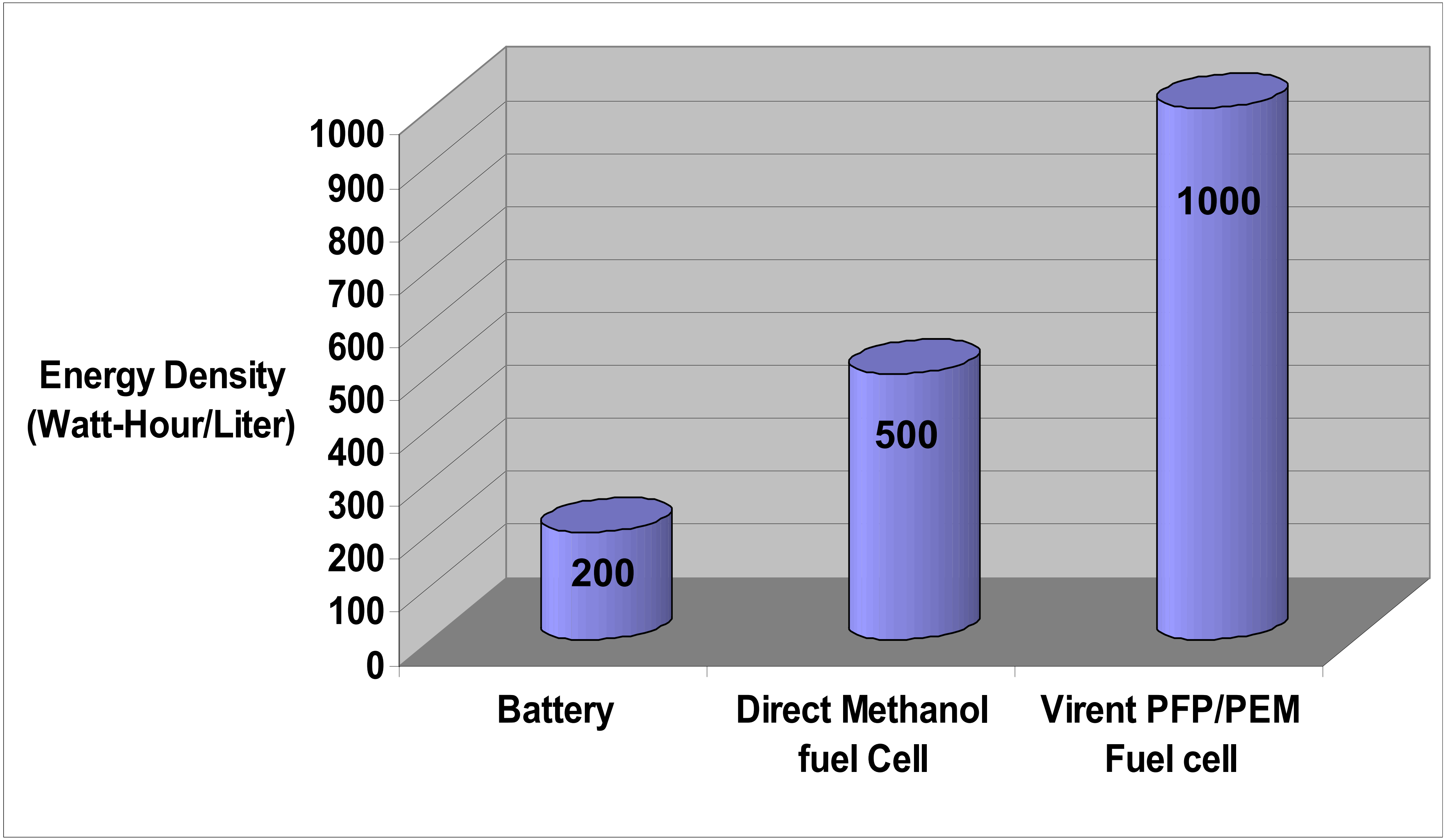
Cost of Portable Electrical Power



Energy Density of Portable Power Sources



Potential Application for APR (Premium Power)

- Integration with Fuel Cell
- Portable Devices
  - Utilizes non-flammable, non-toxic feedstocks
    - Ethylene glycol, glycerol
  - Battery Replacement
    - Laptop Computer
  - Soldier Power
    - Require high energy density fuels
- Uninterruptible Power Supply
- Remote Location Power

Potential Application for APR
(Transportation Applications (50-75 kW)

- Mobile Applications
  - On-board hydrogen production
    - High Gravimetric and Volumetric Energy Densities
  - Fuel Cell or IC Engine
- Distributed Generation of Hydrogen
  - Filling Station Hydrogen

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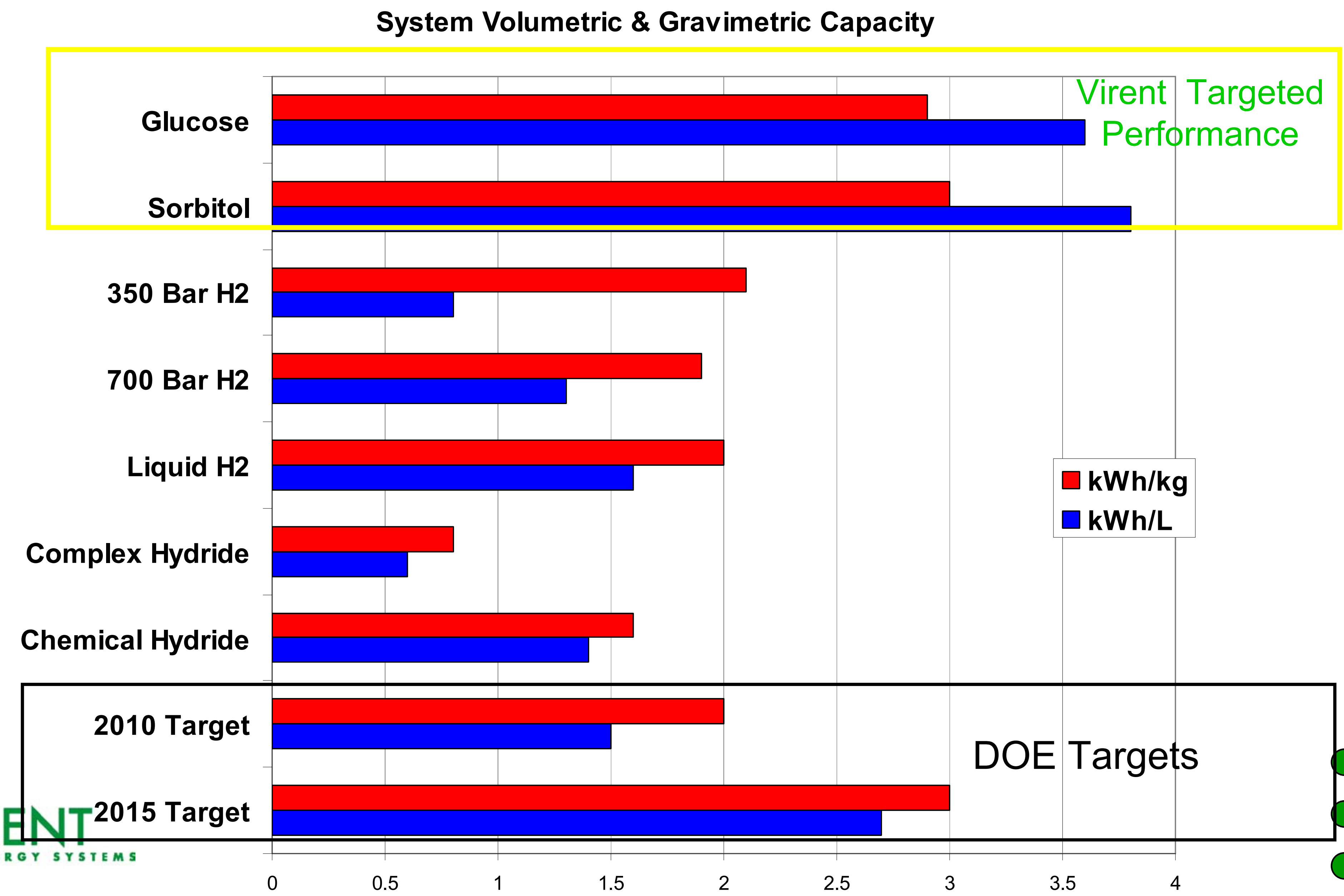
On-Board Hydrogen Storage



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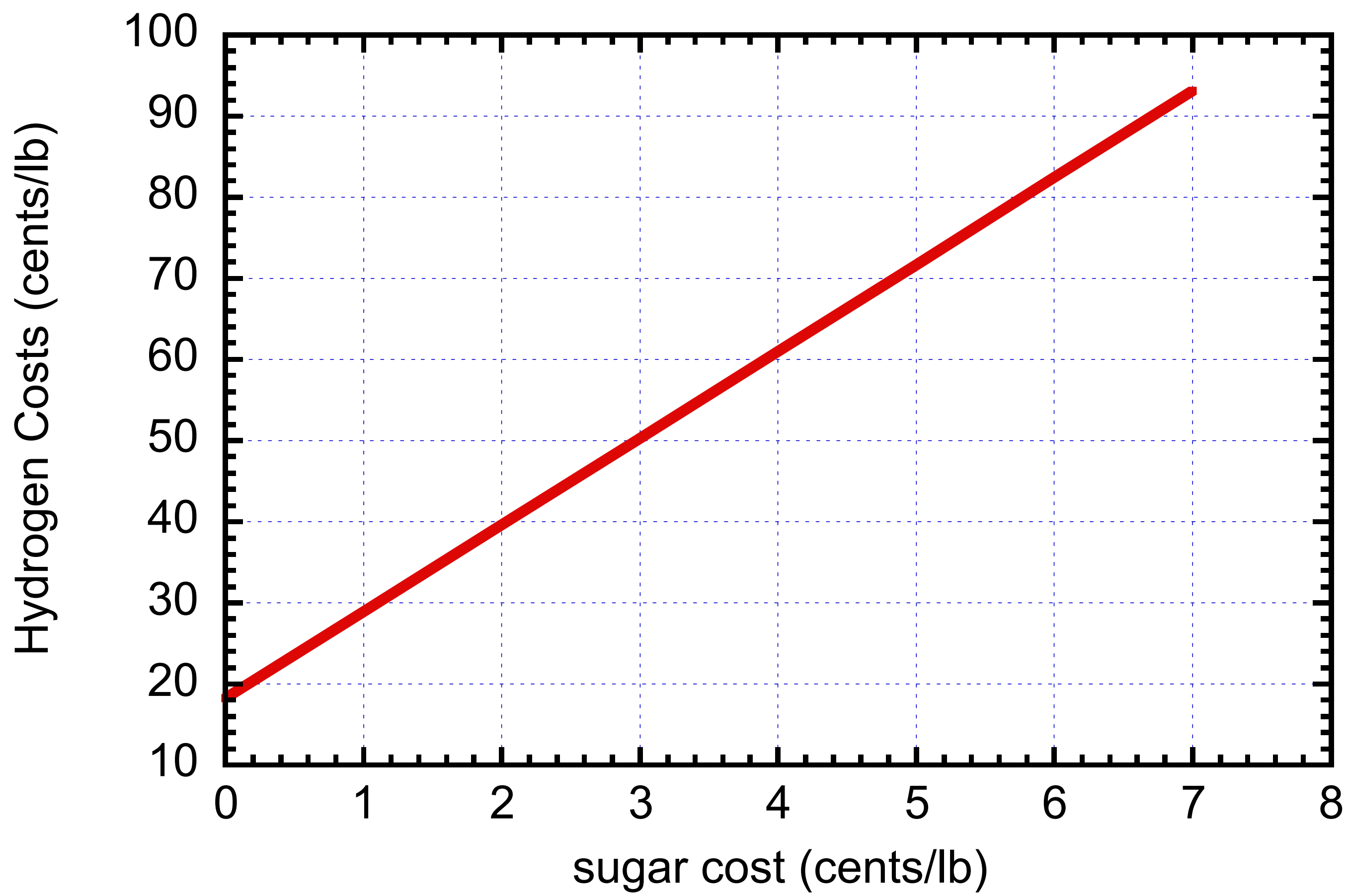
Energy Density of Oxygenated Fuels for Portable Power

Fuel	Energy Density (Wh/liter)
Ethylene Glycol (1:1 H_2O:C)	3700
Glycerol (1:1 H_2O:C)	3736
Sorbitol (1:1 H_2O:C)	3809
Glucose (1:1 H_2O:C)	3585
Methanol (1:1 H_2O:C)	3572
Li-Ion Battery	200 (Current)

- Energy densities based on hydrogen produced via APR process
- Ethylene Glycol, Glycerol, Sorbitol, and Glucose are non-flammable, non-toxic, and have higher energy densities than methanol
- Viable fuels for combined APR process and fuel cell technologies for future replacement of batteries

Cost of Hydrogen from Sugars Utilizing the APR Process



70 % Thermal Efficiency

Glucose from Corn

6 cents per lb

Corn to H_2 yields 70 % more net energy than corn to ethanol

Marketing/Sales Model

- Virent will form strategic partnerships with fuel cell system and hydrogen gas generator OEMS.
- Virent will manufacture a hydrogen generator and license its technology in the portable power markets.
- Virent will license technology for use in the fixed power applications.

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Contact Information

Eric Apfelbach
President & CEO
Virent Energy Systems
3591 Anderson St., Suite 209
Madison, WI 53704

E-Mail: eric_apfelbach@virent.com

Phone: 608-663-0228
Cell: 608-576-7549
Fax: 608-310-9579

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