EPRI Hydrogen Briefing to DOE

May 27, 2008

Dan Rastler

drastler@epri.com

650-855-2521

Agenda

- Industrial Hydrogen Market Study
- Home Hydrogen Electrolyzer Study
- Discussion

H2 Market Study Project Objectives

Objectives

- Explore the near-term opportunity for serving hydrogen industrial markets via electrolysis systems and the opportunity for synergy between electricity providers and the hydrogen equipment providers.
- Determine if there is an opportunity for electrolysis to compete in existing industrial hydrogen markets
- Quantify the benefits to energy companies and electrolyzer vendors.
- Assess the current and emerging markets for hydrogen and help quantify the business case for electrolysis today and in the coming years.
- Detailed business case analysis were done for: Entergy, Xcel, and Southern Company

Objectives and Scope, continued

- Provide utilities and electrolyzer vendors with insights on the market status for small hydrogen users
- Characterization of the current supply method, and the prospects for using electrolysis to meet their hydrogen needs.
- The study focused on small hydrogen users (up to 0.5 million SCF/day) that currently purchase delivered hydrogen or generate the hydrogen onsite.
- Large users that generate their own hydrogen, like petroleum refineries, ammonia plants, and methanol producers will not be included in this market assessment.

Captive hydrogen users produce their own hydrogen at the plant where it is consumed. Merchant users consume hydrogen produced by other entities. U.S. Hydrogen consumption totaled 7.74 billion kg/year in 2003.

U.S. Hydrogen Consumption

Sector	2003 Consumption	
	billion kg/yr	kg/day
Captive Users		
Ammonia	2.59	7,100,000
Refineries	3.19	8,740,000
Methanol	0.39	1,070,000
Other	0.35	960,000
Merchant Users		
Pipeline or on-site	1.16	3,180,000
Cylinder or bulk (e.g., gaseous tube trailer, liquid tanker truck)	0.05	137,000
Total	7.74	21,200,000

EPRI

The industrial market for hydrogen is about 300,000 kg/day and could represent almost 6,000 million kWh of electric sales annually. There are numerous business segments that consume hydrogen on a daily basis and purchase their supply rather than produce it themselves.

Small Hydrogen End-User Consumption in the U. S.

Small End-User Sector	2006 (projected) Merchant Consumption	
	1,000 kg/yr	kg/day
Fats and Oils	11,200	30,700
Metals	43,100	118,100
Electronics	23,900	65,500
Aerospace	19,100	52,300
Utilities	3,200	8,800
Float Glass	4,800	13,200
Miscellaneous (labs, instruments, etc.)	6,400	17,500
Total	111,700	306,100

utility customers from these SIC codes were targeted for the survey and economic analysis

Sector	SIC	NAICS
Fats, Oils, other Food, other Hydrogenation		
Fats and Oils	2074, 2075, 2076, 2077, 2079	311223 & 311225
Sorbitol	2834	325199
Soaps and detergents	2841	325611
Metals		
Refining of other metals	3339	331419
Metal heat treating	3398	332811
Nonferrous foundries of other metals	3369	331528
Steel and Iron Foundries	3321, 3322, 3324, 3325	331511, 331512, 331513
Primary Metal, NEC	3399	331111, 331221, 331314, 331423, 331492, 332618, 332813
Electronics		
Semiconduction Fabrication	3674	334413
Aerospace		
Rocket production or launch facilities (NASA, Air Force)	3761, 3764, 3769	336412, 336414, 336419, 332995
Electric Utilities		
Electric Utilities, Independent Power Producers	4911	221111, 221112, 221113, 221119, 221121, 221122
Float Glass		
Flat Glass	3211	327211
Miscellaneous		
Chemical		
Inrogranic NEC	2819	211112, 325131, 325188, 325998, 331311
Organic Chemicals	2821, 2822, 2823, 2824	
Pharmaceuticals	2833, 2834, 2835, 2836	
Cyclic Organic Crude Products	2865	325110, 325132, 325192
Organic NEC	2869	325110, 325120, 325188, 325192, 325193, 325998
Laboratory	8734	541380
Universities	8221	611310
Merchant Power Plants	49119902	221119

Current Product offerings

Sample Product Offerings from Industrial Gas Supplier (Source: Airgas, Inc.)

Product Description	Unit	Min. Quantity
Hydrogen Industrial Size 400 Customer Owned	Cylinder	1
Hydrogen Industrial Size 4k Customer Owned	Cylinder	1
Hydrogen Industrial Size 125	Cylinder	1
Hydrogen Industrial Size 150	Cylinder	1
Hydrogen Industrial Size 200	Cylinder	1
Hydrogen Industrial Size 200 Customer Owned	Cylinder	1
Hydrogen Industrial Size 250	Cylinder	1
Hydrogen Industrial Size 60	Cylinder	1
Hydrogen Industrial Size 80 Customer Owned	Cylinder	1
Hydrogen Industrial 18 Pack Size 200	Each	1
Hydrogen Industrial 15 Pack Size 300	Each	1
Hydrogen Industrial 12 Pack Size 200	Each	1
Hydrogen Industrial 6 Pack Size 200	Each	1
Hydrogen Industrial 6 Pack Size 300	Each	1
Hydrogen High Purity Size Tube Trailer	Hundred Cu ft	1
Hydrogen Tube Trailer	Hundred Cu ft	1

Purity Levels (units in ppm (v/v) unless otherwise stated) (Source: CGA G-5.3, Table 1)

Quality Verification Levels							
Limiting Characteristics	Gaseous (Type I)				Liquid (Type II)		
	B[1]	D	F[1]	L	A	C	B
Hydrogen minimum %	99.95	99.99	99.995	99.999	99.995[2]	99.999	99.9997[2]
Ar					1		1
CO_2	110	0.5		2	1	2	
CO	10	1					
He					39		
O	400	25	2	2		2	2
Para content minimum %					95		95
Permanent particulates				3)	Filtering required	3)	
Total HC content	10	5	0.05	1	9[4]	1	
Water	34	3.5	1.5	3.5		3.5	
Dew Point F	-60	-91	-101	-91		-91	

Notes
1) If hydrogen is produced by mercury brine cell, then analysis for mercury vapor is required.
2) Can include up to 50 ppm neon plus helium.
3) To be determined between supplier and user.
4) Includes water.

Historical Hydrogen Prices 1997-2002 (Source: The Innovation Group, 2003 and university contracts)

Delivery Option	High		Low	
	$/100 SCF	$/kg	$/100 SCF	$/kg
Pipeline, delivered	0.80	3.60	0.18	0.80
Cryogenic TT, f.o.b. origin[1]	1.80	8.10	1.15	5.16
Compressed, TT, f.o.b. origin	2.60	11.70	1.25	5.60
Cylinder, delivered, industrial grade	12.00	53.80	2.75	12.30
Cylinder, delivered, pre-purified grade	27.50	123.40	19.20	86.10

The hydrogen market prices exhibit great variation based on quantity purchased, natural gas costs, delivery distance, and purity level.

Hydrogen End-users in NM

Estimated Small End-User Hydrogen Consumption for New Mexico

Small End-User Sector	U.S. Consumption (1,000 kg/yr)	New Mexico Consumption (1,000 kg/yr)	Percentage of U.S. Total	Number of Facilities
Fats and Oils	11,200	41	0.37%	3
Metals	43,100	6	0.01%	10
Electronics	23,900	650	2.72%	11
Aerospace	19,100	157	0.82%	3
Utilities	3,200	23	0.72%	49
Float Glass	4,800	0	0.00%	0
Miscellaneous (labs, instruments, etc.)	6,400	14	0.22%	111
Total	111,700	891	0.80%	187

Hydrogen End-Users in NY

Estimated Small End-User Hydrogen Consumption for New York

Small End-User Sector	U.S. Consumption (1,000 kg/yr)	New York Consumption (1,000 kg/yr)	Percentage of U.S. Total	Number of Facilities
Fats and Oils	11,200	304	2.71%	46
Metals	43,100	1,050	2.44%	294
Electronics	23,900	1,623	6.79%	37
Aerospace	19,100	665	3.48%	22
Utilities	3,200	129	4.02%	361
Float Glass	4,800	172	3.58%	1
Miscellaneous (labs, instruments, etc.)	6,400	803	12.55%	606
Total	111,700	4,746	4.25%	1367

EPRI

Hydrogen End-Users in Entergy Region

Estimated Small End-User Hydrogen Consumption for Entergy Region

Small End-User Sector	U.S. Consumption (1,000 kg/yr)	Entergy Consumption (1,000 kg/yr)	Percentage of U.S. Total	Number of Facilities
Fats and Oils	11,200	1,592	14.22%	65
Metals	43,100	679	1.58%	105
Electronics	23,900	1	0.00%	2
Aerospace	19,100	1,148	6.01%	7
Utilities	3,200	172	5.36%	198
Float Glass	4,800	2	0.05%	2
Miscellaneous (labs, instruments, etc.)	6,400	216	3.37%	463
Total	111,700	3,810	3.41%	

Source: RDC estimates based on data from U. S. County Business Patterns and The Innovation Group[1], except for the utility segment, which is based on data from the Energy Information Administration[2]

Hydrogen End-Users in Southern Co Region

Estimated Small End-User Hydrogen Consumption for Southern Company Region

Small End-User Sector	U.S. Consumption (1,000 kg/yr)	S.C. Consumption (1,000 kg/yr)	Percentage of U.S. Total	Number of Facilities
Fats and Oils	11,200	442	3.95%	75
Metals	43,100	2,490	5.78%	185
Electronics	23,900	23	0.09%	6
Aerospace	19,100	763	4.00%	19
Utilities	3,200	205	6.41%	223
Float Glass	4,800	1	0.03%	1
Miscellaneous (labs, instruments, etc.)	6,400	282	4.41%	498
Total	111,700	4,207	3.77%	

Hydrogen End-Users in Xcel Energy Region

Estimated Small End-User Hydrogen Consumption for Xcel Energy Region

Small End-User Sector	U.S. Consumption (1,000 kg/yr)	Xcel Consumption (1,000 kg/yr)	Percentage of U.S. Total	Number of Facilities
Fats and Oils	11,200	182	1.63%	46
Metals	43,100	887	2.06%	200
Electronics	23,900	485	2.03%	37
Aerospace	19,100	2,582	13.52%	10
Utilities	3,200	45	1.41%	71
Float Glass	4,800	80	1.67%	1
Miscellaneous (labs, instruments, etc.)	6,400	325	5.08%	491
Total	111,700	4,586	4.11%	856

EPRI

Summary of Small End User Hydrogen Markets

- For the three utilities evaluated, if the entire hydrogen use were served by electrolyzers within their service area, it would require 20-30 MW of capacity to serve for each utility.

End-user Survey

Facilities Responding to Survey

Company Name	Industry SIC	Process / Products Requiring Hydrogen	Annual Hydrogen Use (kg)
Archer - Daniels Midland	2075	Vegetable oil hydrogenation	240,000
CHS Inc.	2075	Soybean oil hydrogenation	53,000
Hospira	2834	Quality control laboratory	7.1
Tru Vue, Inc.	3211	Sputter deposition in vacuum process	30
ME Global	3321	Heat treating furnace	240
Polar Semiconductor	3674	Oxidation, annealing, pollution abatement	33,000
Wilbrecht Electronics	3674	Reducing, brazing, decarburizing	850
Fort Collins Utility	4911	Hydrogen vehicle fueling	310
Colorado Energy Management	4911	Generator cooling	560
Minnesota State University	8221	Gas chromatography	0.47
St. Cloud State University	8221	Laboratory classroom	0.35
Bethel University	8221	Laboratory classroom	0.24
Reservoirs Environmental	8734	Gas chromatography	3
Braun Intertech	8734	Analysis	18

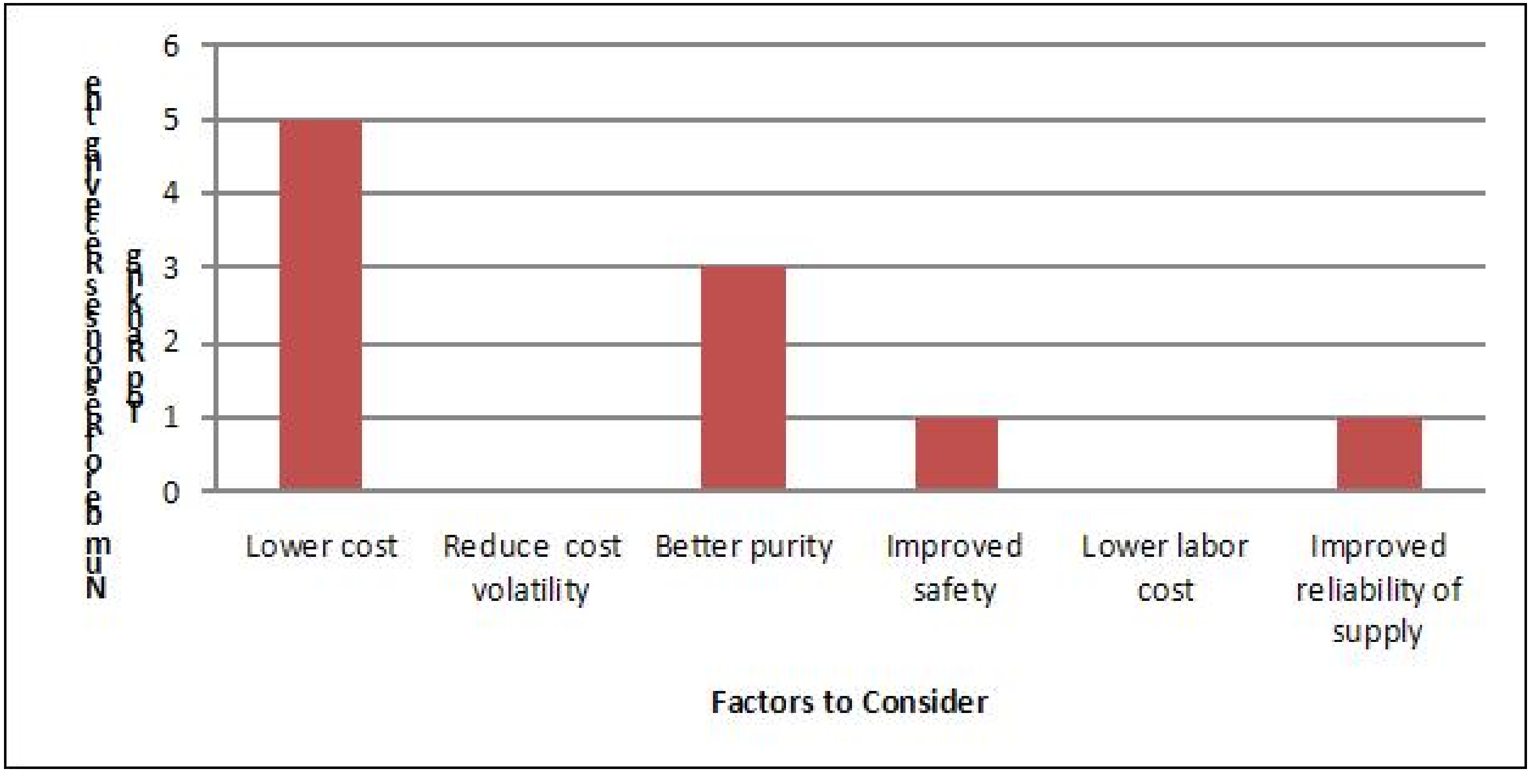
EPRI

Pricing Levels by Purity Requirements

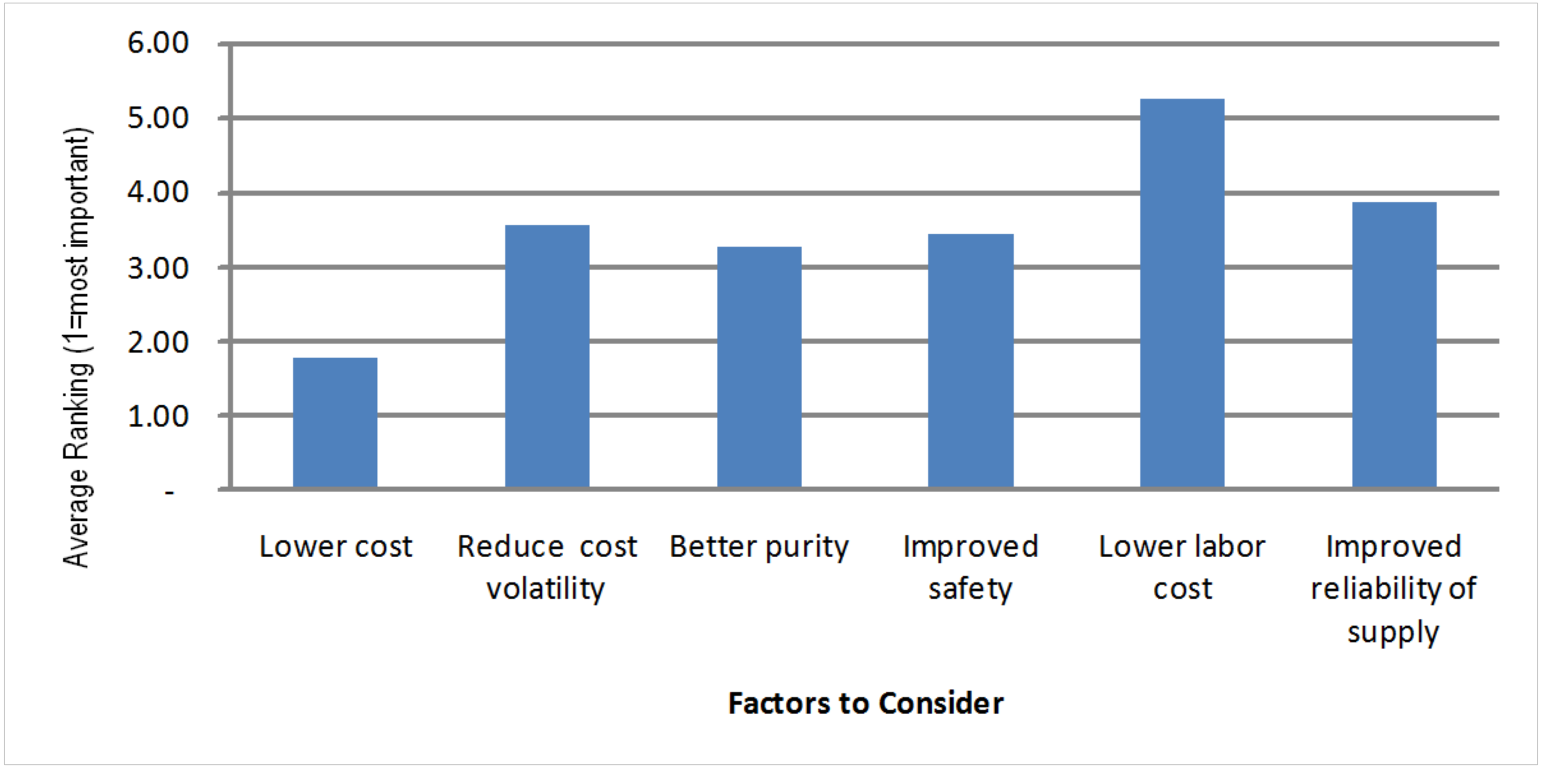
Purity Requirements	Number of responses	Range of Pricing ($/kg)	
		Low	High
90.0-99.0% pure	5	12.7	16.9
99.5-99.99% pure	3	2.1	17.8
99.995-99.999% pure	2	21.1	126.9
99.9995%+ purity	2	7.4	18.6
Not specified	2	0	0

Factors to Consider when Investing in an Electrolyzer

Number of Responses receiving top Rating



Top Ranked Factors, by Number of Responses



Economic Analysis of Electrolyzers in Three Utility Regions

Survey Results: Three Typical Hydrogen Consuming Facilities

Facility Type	Employees	H2 use (kg/day)	Average kW/employee	Estimated Facility Size (kW)	Load Factor
Metal Production	35	0.7	13.0	456	0.8
Semiconductors	500	89	13.1	6,570	0.7
Vegetable Oils	89	650	42.6	3,790	0.76

Economic Analysis of Electrolyzers in Three Utility Regions

Example Facilities to be used in H2A Model, with Electrolyzer Data

Facility Type	H2 use (kg/day)	Facility Size (kW)	Electrolyzer Size (kg/day)	Electrolyzer Demand (kW)	Load Factor w/Electrolyzer
Metal Production	0.7	6,000	10	20	0.8
Semiconductors	89	7,000	100	218	0.71
Vegetable Oils	650	5,000	1,000	1,960	0.82

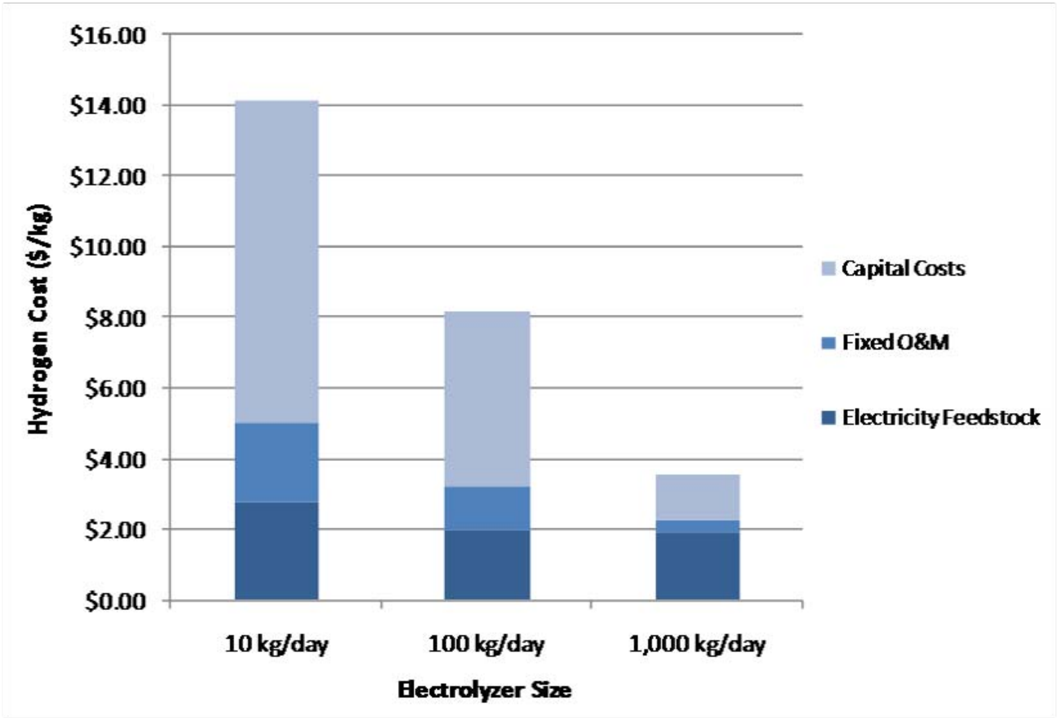
These three example facilities are used to estimate the effective cost of hydrogen using an electrolyzer for typical industrial applications in three utility service territories, including Entergy, Southern Company, and Xcel Energy.

Cost of Electricity for Example Facilities using Entergy Arkansas and Entergy Louisiana's Rates

Facility Type	Size (kW) w/ Electrolyzer	Energy Usage (kWh/ month)	Facility Electricity Cost (cents per kWh)	Incremental Electricity Cost (cents/kWh)				
				AR - LPS	AR – LPS (w/TOU)	AR – LPS Interruptible	LA - LIS	LA – LIS (w/TOU)
Metal Production	6,000	3,470,000	5.55	5.15	6.54	n/a	6.77	6.01
Semiconductors	7,220	3,680,000	5.79	5.15	4.10	3.70	6.77	6.01
Vegetable Oils	6,960	4,104,000	5.57	5.15	3.86	3.62	6.77	6.01

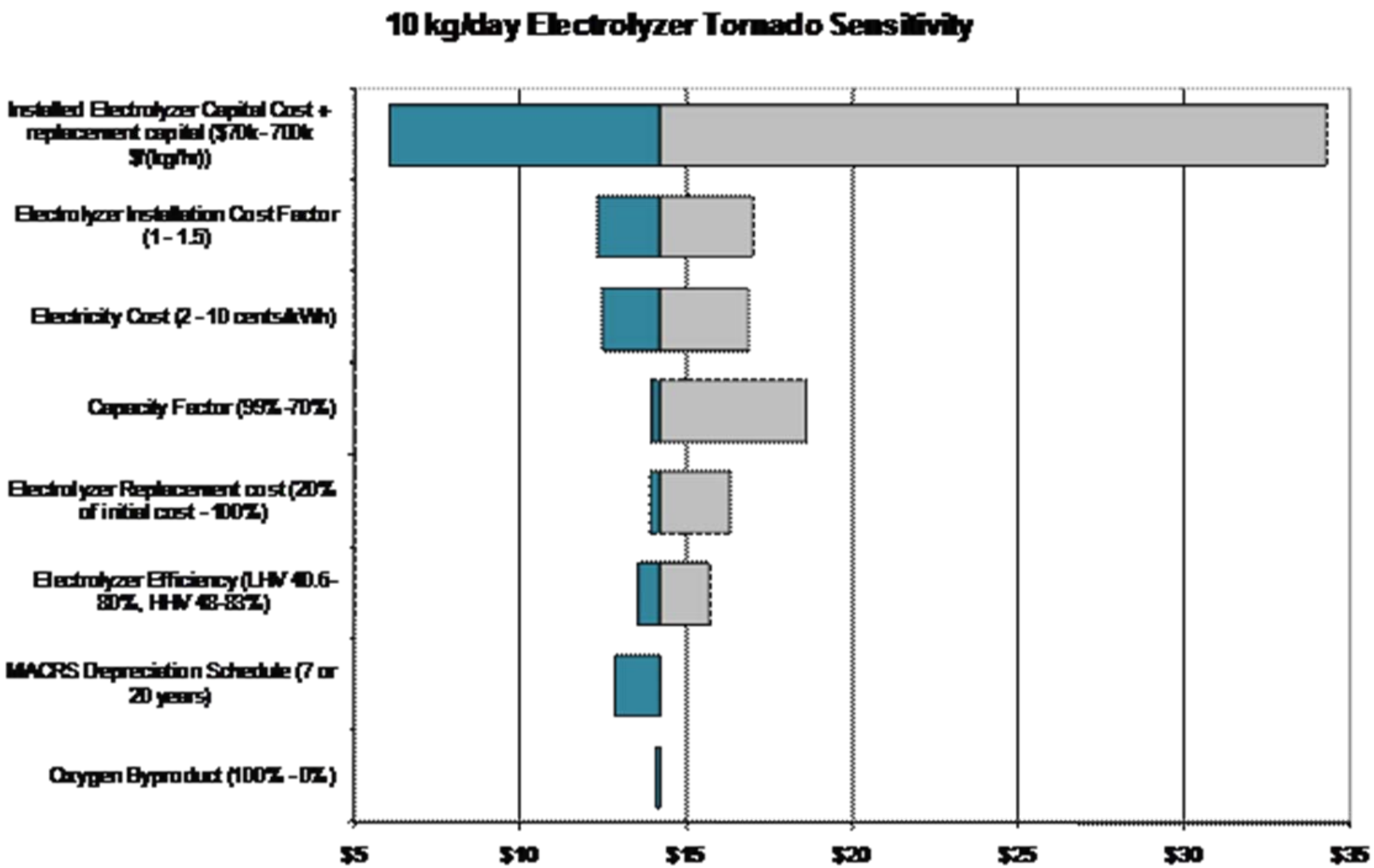
Rate code notes: AR-LPS=Arkansas Large Power Service, AR LPS w/TOU=Arkansas Large Power Service with Time of Use, AR-LPS Interruptible=Arkansas Large Power Service with Interruptible Rider, LA-LIS = Louisiana Large Industrial Service, LA-LIS w/TOU = Louisiana Large Industrial Service with Time of Use

H2A Model Results - Entergy

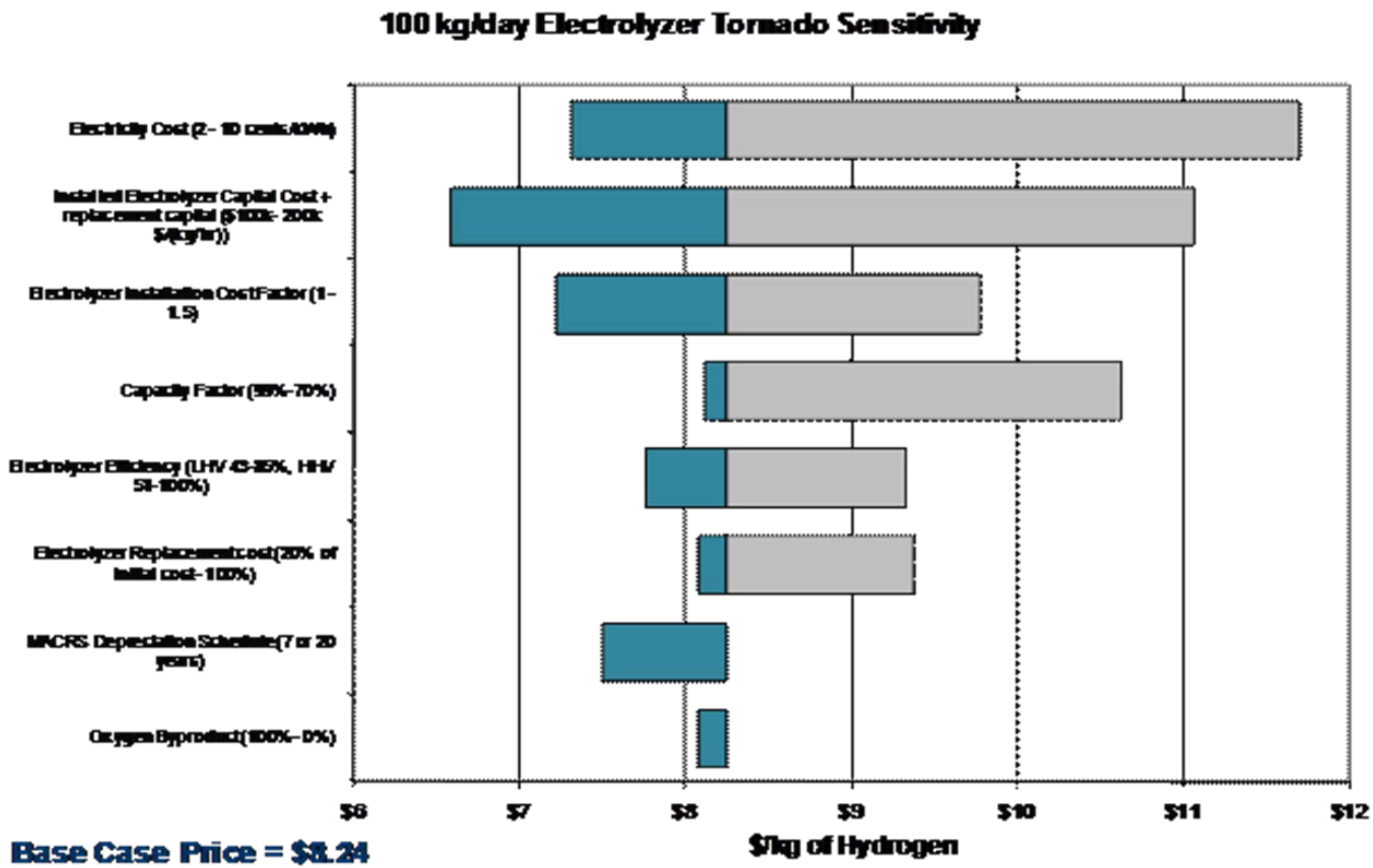


H2A Model Sensitivity Results – Entergy

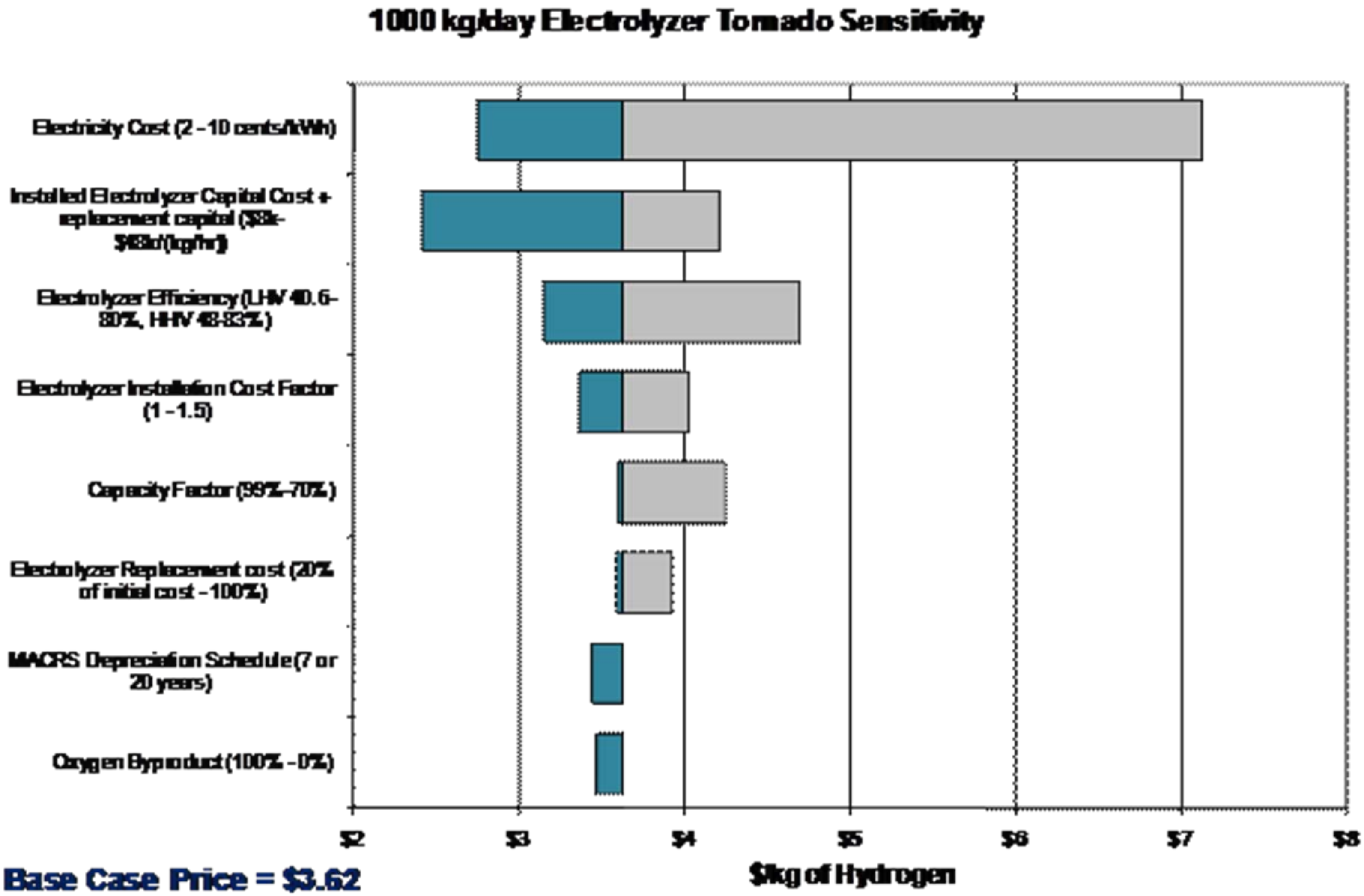
Tornado Sensitivity Chart for Metals Production Facility with 10 kg/day Electrolyzer



Base Case Price = $14.18



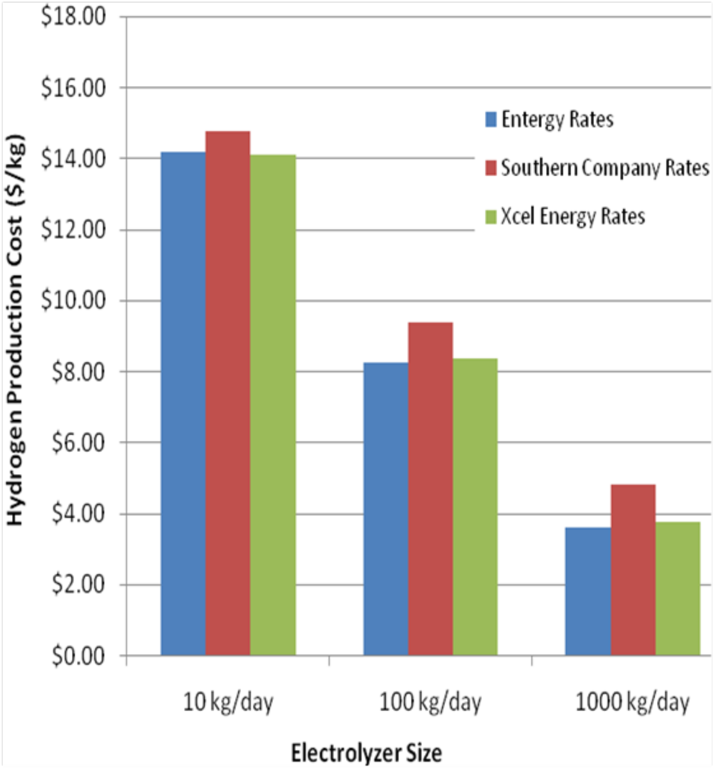
Base Case Price = $8.24



1000 kg/day Electrolyzer Tornado Sensitivity
Electricity Cost (2 - 10 cents/kWh)
Installed Electrolyzer Capital Cost + replacement capital
Electrolyzer Efficiency (LHV 40.6-80%, HHV 48-83%)
Electrolyzer Installation Cost Factor (1 - 1.5)
Capacity Factor (99%-70%)
Electrolyzer Replacement cost (20% of initial cost - 100%)
MACRS Depreciation Schedule (7 or 20 years)
Oxygen Byproduct (100% - 0%)
$2
$3
$4
$5
$6
$7
$8
$/kg of Hydrogen
Base Case Price = $3.62

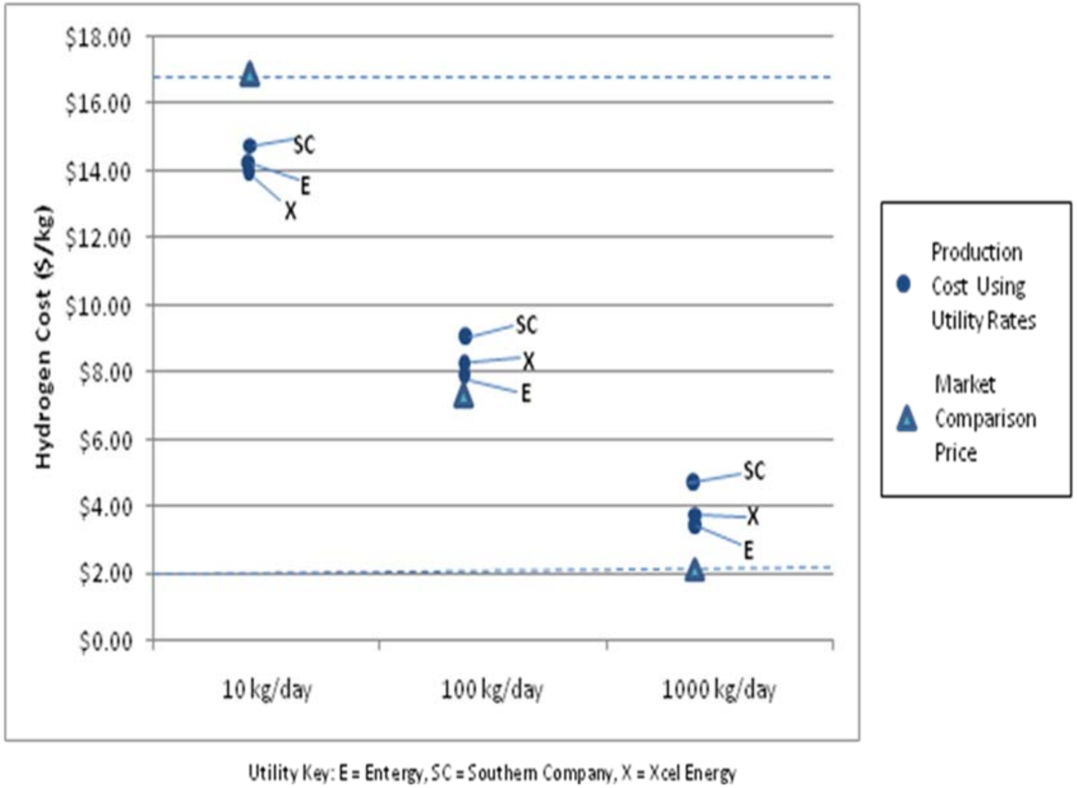
Industrial Hydrogen Market Study - Summary

- EPRI Report: Hydrogen Market Assessment and Opportunities for Electrolyzer Based Services (Report 1016244) Published
- Existing electrolyzers are competitive with current hydrogen supply options in most industrial market segment, and can produce hydrogen in the $3.6 to $4.8 per kilogram range when larger electrolyzers are employed.
- In many cases, hydrogen customers are paying several times what it would cost to produce hydrogen onsite by electrolysis.
- For larger hydrogen customers (1,000 kg/day) electrolyzers, specific utility rate structures, such as time-of-use or interruptible rates, could greatly improve the economic case for electrolysis.
- Report includes an analysis of the business case for electrolysis in each energy company territory, and provides the data needed to approach different types of hydrogen customers.



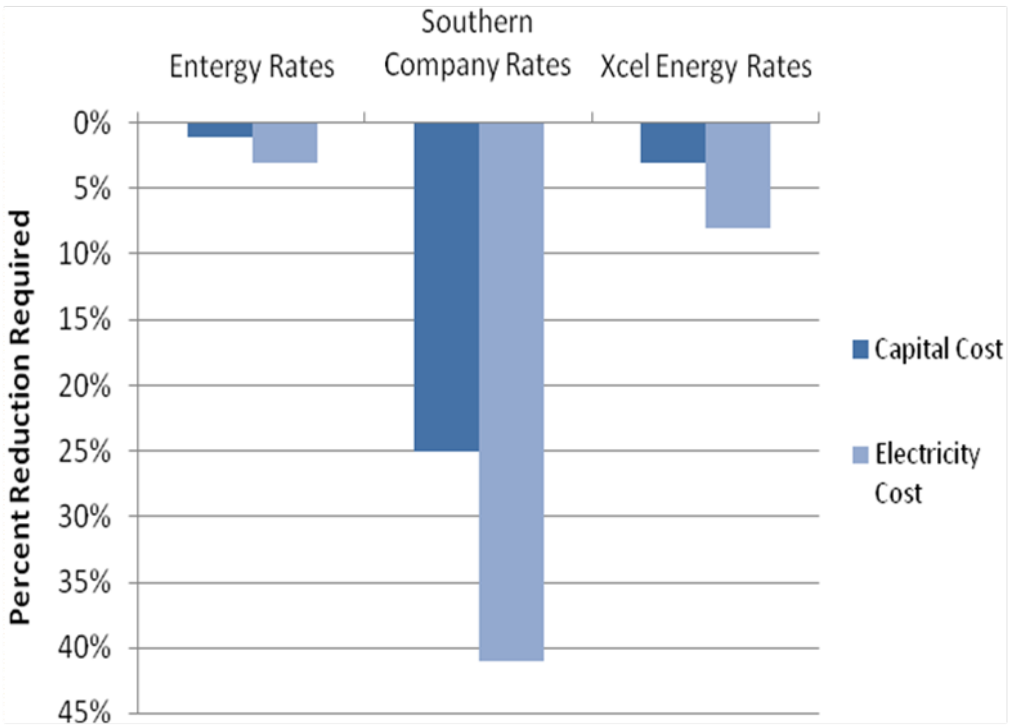
Industrial Hydrogen Market Study - Summary

- Utilities rates could be used to generate hydrogen at costs within the range of market comparison prices – see Figure
- In particular, the cost of generating hydrogen was below the market comparison price when used with a10 kg/day electrolyzer
- For the 100 kg/day and 1,000 kg/day applications, the hydrogen produced was above the market comparison price at that volume but was within the overall range of market comparison prices.

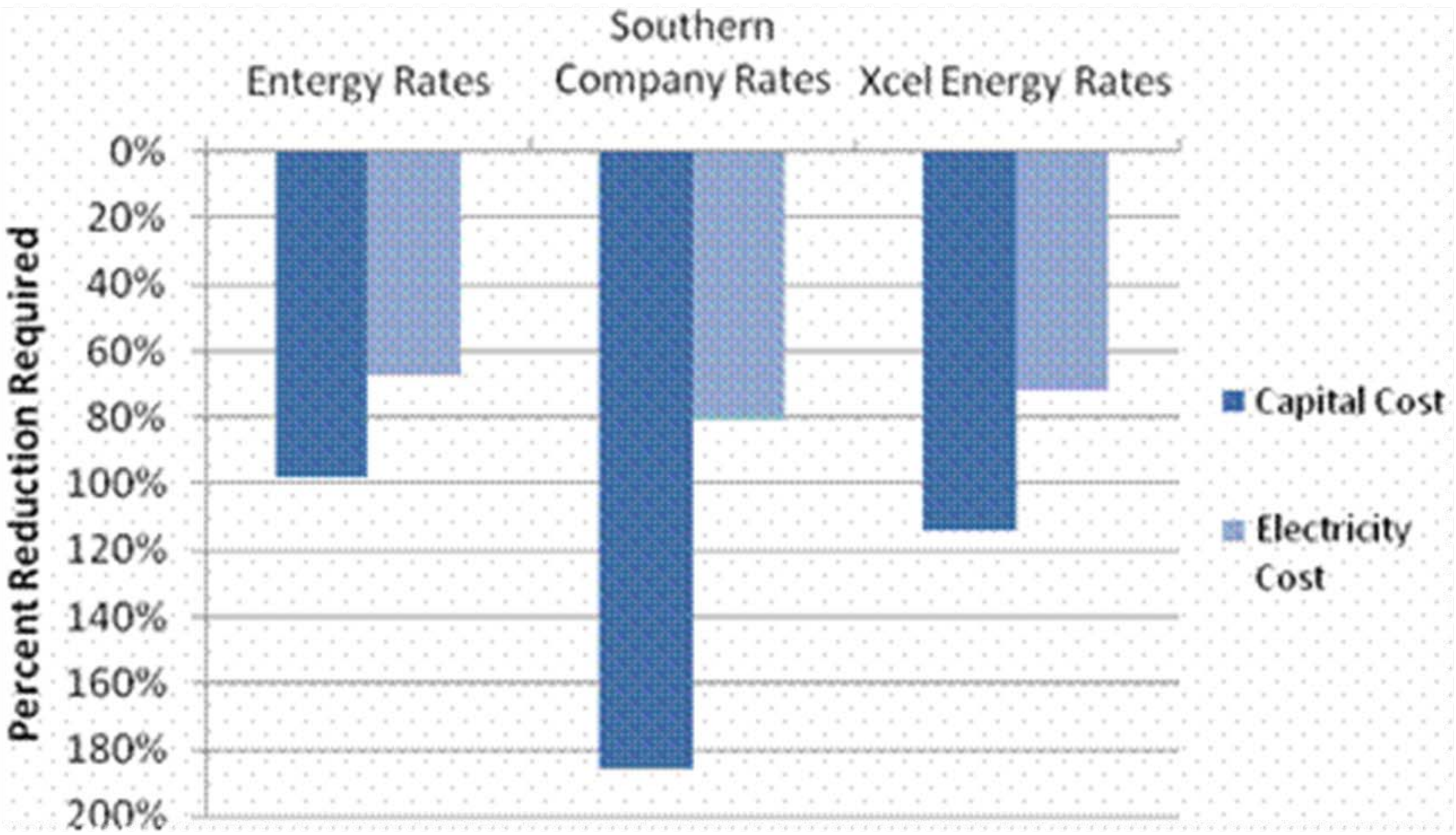


EPRI

Reduction in Capital Cost or Electricity Cost Necessary to Approach Market Comparison Prices, for 100 kg/day Electrolyzer



Reduction in Capital Cost or Electricity Cost Necessary to Approach Market Comparison Prices, for 1000 kg/day Electrolyzer



EPRI

Home Electrolyzer Technology Assessment

An EPRI Technology Innovation Funded Project

- The objectives of this project were to:
- Demonstrate Proof-of-Concept by successfully operating its unique PEM IFF Electrolyzer/Hydrogen Generator.
- Develop a specific electrolyzer system design and assess the technical and economic feasibility for a home automotive refueling (HHR appliance) sized to support the operation of a single passenger car.
- Develop an R&D action plan for the next steps.

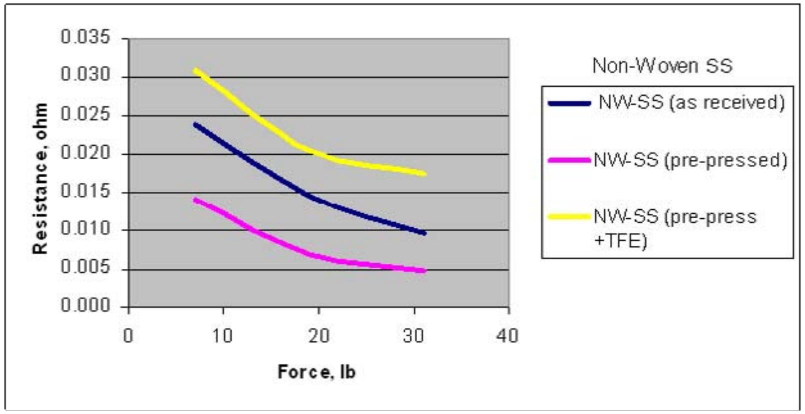
Assessment of the IFF concept

Results and Findings:

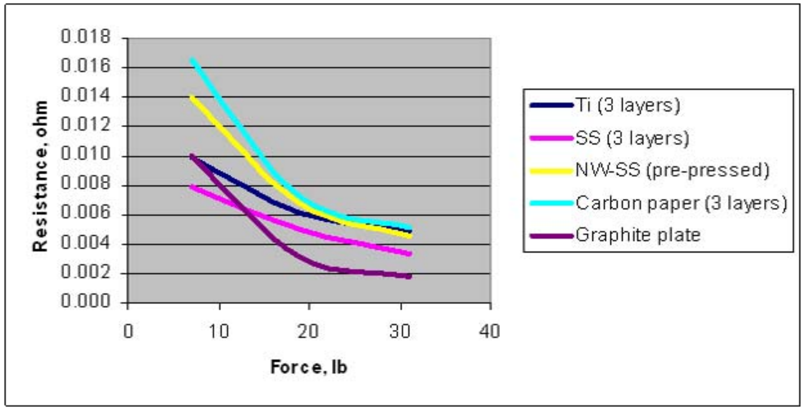
- ***Experimental:*** The advanced IFF Electrolyzer/Hydrogen Generator cell outperformed a conventional electrolyzer cell, in efficiency of hydrogen production as well as stability of operation.
- Long-term stable and efficient cell operation did not require water circulation or phase separators, proving viability under passive operating conditions.
- Passive operation is enabled by the unique IFF design that transports and separates water and gases inside each cell through its fundamental properties.

R&D

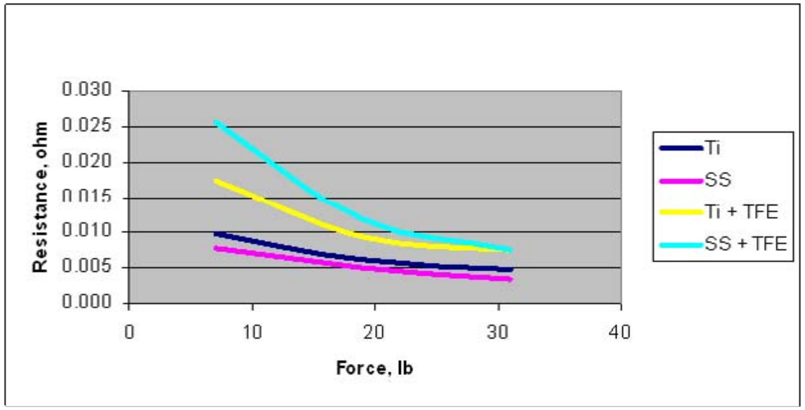
- The task was to develop an oxidation-resistant porous IFF material which has a structure similar to the existing porous carbon IFF material. Subtasks included (1) identifying material candidates and suppliers, (2) screening the candidate materials based upon (2a) potential to meet the electrolyzer IFF porous structure requirements, (2b) meeting the IFF material oxidation-resistance requirements, (2c) meeting contract delivery requirements, and (2d) meeting contract cost requirements, (3) conducting hydrophobic and hydrophilic treatment and evaluations, and (4) conducting electrical conductivity/contact resistance evaluations.   Candidate materials were selected from existing materials, such as titanium (Ti) or stainless steel (SS) screens, meshes, perforated sheets, and porous forms. In addition, the new non-woven metal sheet materials (which have structures similar to the existing carbon-based IFF structures) were also investigated.
- Candidate materials were screened based upon their potential to meet the IFF porous structure requirements. Three materials were selected for experimental testing: (1) Sponge-like Titanium (SLTi); (2) Sponge-like Stainless Steel (SLSS); and (3) Non-woven stainless steel (NWSS).
- The primary criterion and test results were as follows
- Electrical conductivity under pressure. All three candidate IFF non-carbon materials were good (as reflected by their lower resistances than carbon paper, which had been successfully used in ElectroChem’s IFF Fuel Cell
- Electrical conductivity after Teflon treatment. All three candidate IFF non-carbon materials were good.
- Corrosion resistance. Both the Sponge-like Ti and the Sponge-like SS corroded during the experiments. This may reflect the reactions of impurities in these particular materials and not that of pure Ti and SS.



Non-Woven SS
NW-SS (as received)
NW-SS (pre-pressed)
NW-SS (pre-press +TFE)
Resistance, ohm
Force, lb
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0
10
20
30
40

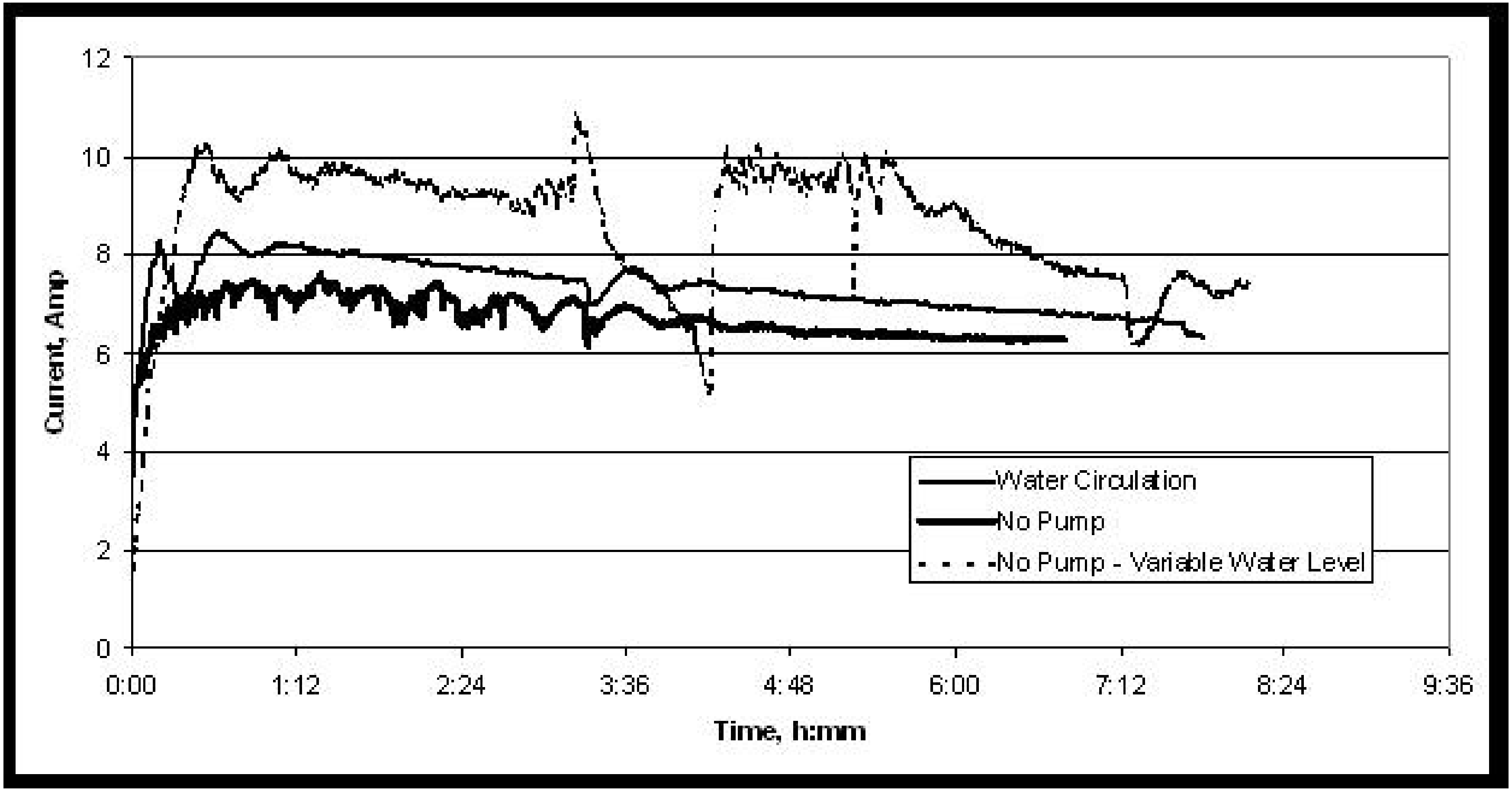


Ti (3 layers)
SS (3 layers)
NW-SS (pre-pressed)
Carbon paper (3 layers)
Graphite plate
Resistance, ohm
Force, lb
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
0
10
20
30
40

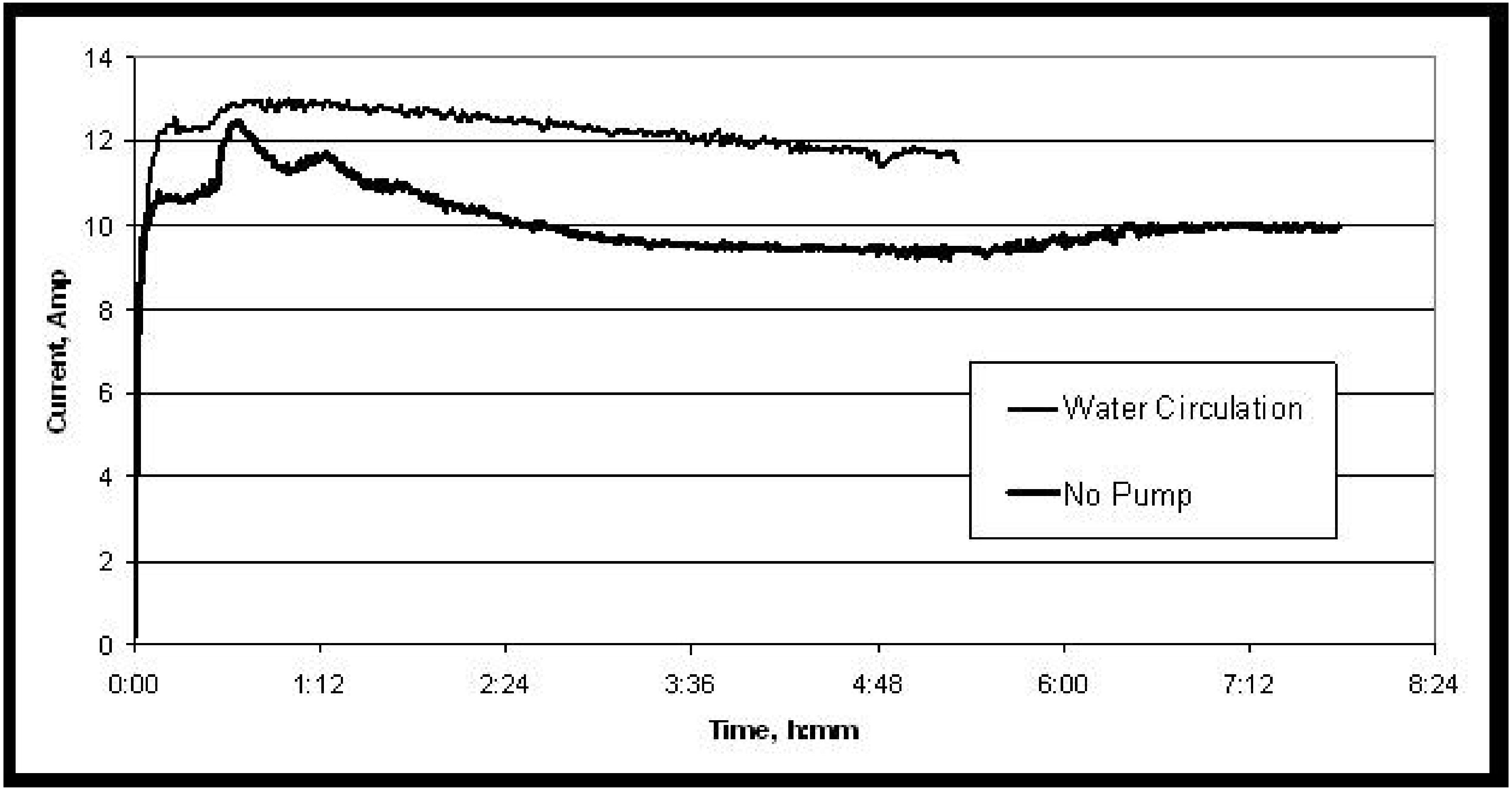


Ti
SS
Ti + TFE
SS + TFE
Resistance, ohm
Force, lb
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0
10
20
30
40

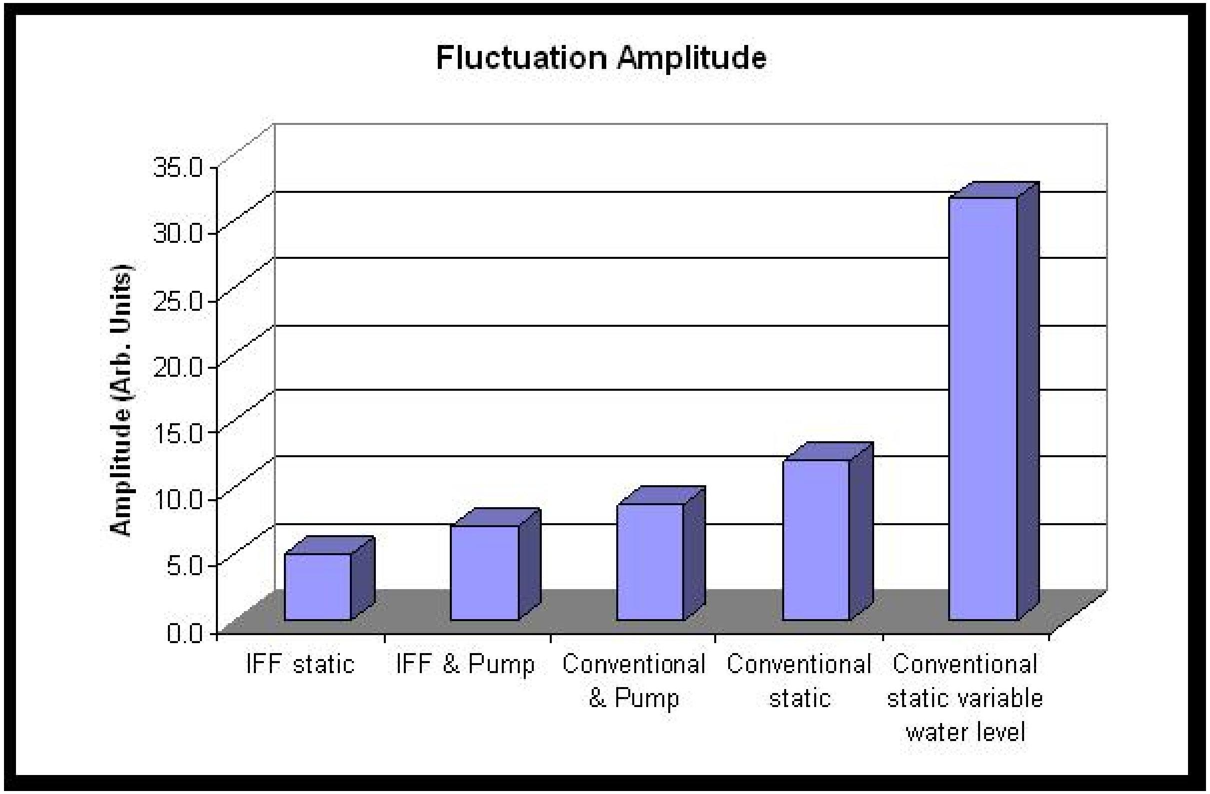
Comparison of the cell performance for the conventional flow field with and without water circulation. In addition, testing was done in which the water level within the cell was varied by altering the reservoir height.



Comparison of the cell performance for the non-woven stainless steel IFF with and without water circulation. Additional testing with variations in reservoir height showed no differences.



Comparisons of cell current fluctuations with different cell types and operating conditions. The static IFF cell clearly has superior stability over any other case, even the conventional cell with forced circulation. Even the circulated IFF cell has better cell stability.



The IFF cell without water circulation has the best stability of any of these test cases. The conventional cell is clearly very sensitive to water flow and variations in water level. While the IFF cell seems to have a modest hydrogen output gain by water circulation water circulation actually seems to marginally reduce its stability.
This implies that the IFF still allows forced water circulation, but is clearly designed for the greatest stability in passive operation.

Conclusions from Part I R&D

- The Integrated Flow Field design works well in the electrolyzer mode.
- As a water electrolyzer, it is capable of generating hydrogen gas continuously and in a very stable manner.
- The IFF electrolyzer generates hydrogen at a considerably higher rate than does a conventional water electrolyzer.
- The IFF electrolyzer is capable of the stable generation of hydrogen in a passive mode; conventional electrolyzers do not demonstrate this capability.
- Porous non-woven SS has the necessary oxidation-resistance and conductivity requirements for the oxygen-side IFF. It does not deteriorate when used at the high electrolyzer voltages.
- Although currently available Sponge-like Ti and Sponge-like SS exhibit attractive conductivity behavior, they can not be considered for use as IFF materials at present because they also contain impurities which quickly corrode. However, Ti has been successfully used in electrolyzers for many years. Therefore, Sponge-like Ti and SS materials that don't contain corrodible impurities should be sought for possible application in the IFF Electrolyzer/Hydrogen Generator.

Part II Assessment of a Home

Target System Parameters

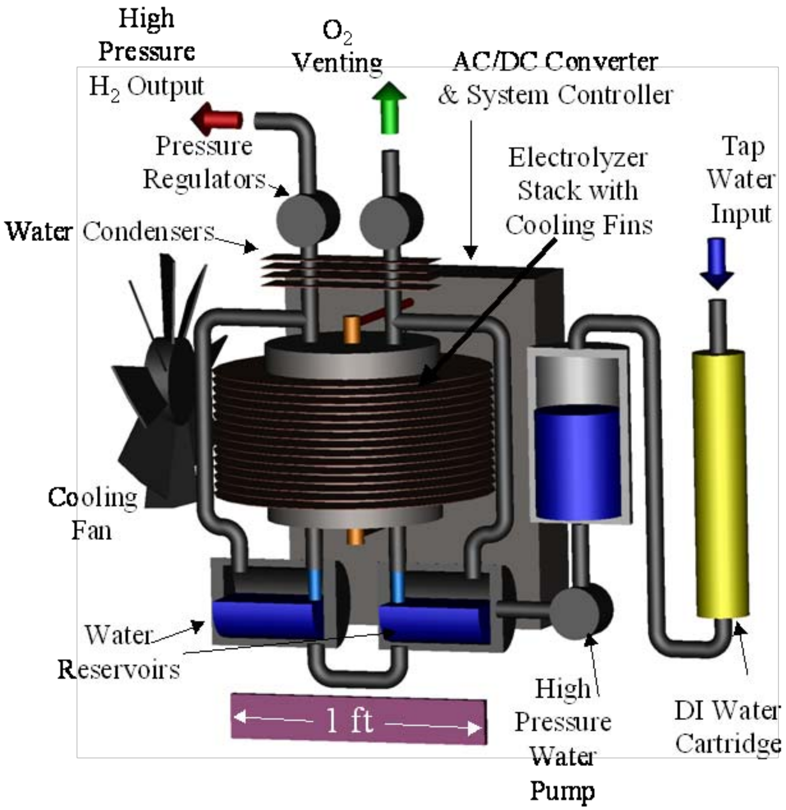
Parameter	Value	Units
Hydrogen Production Capacity	1	kg/day
Period of Operation	8	hrs
Operating Voltage	240	Volts (AC)
Power Use During Operation	6.3	kW
Physical Size	2 x 2 x 2	feet
Daily Commute	35	Miles
Mileage Efficiency of Vehicle	67.5	Miles per kg
Annual Mileage	12,000	Miles
Capacity Utilization	50%	
Product Life	10	Years

Vision: Fuel Cell is a Range Extender APU

in an advanced PHEV

Home Electrolyzer Technology Assessment
An EPRI Technology Innovation Funded Project

- System Design and Lay out developed
- 1 kg/day system sized for advanced PHEV hybrid
  - Operates 8 hr/day
  - 2' x 2' x 2'
  - 35 mi commute
  - 6.3 kW
  - 240 v AC
  - No H2 Storage



System design parameters.

Parameter	Value	Units
Operating Pressure	5000	Volts
Stack Voltage	48	Volts
Cell Voltage	1.85	Volts
Current Density	1.0	A/cm^2
Number of Cells	26	
Water Consumption	9	Liters / kg H_2

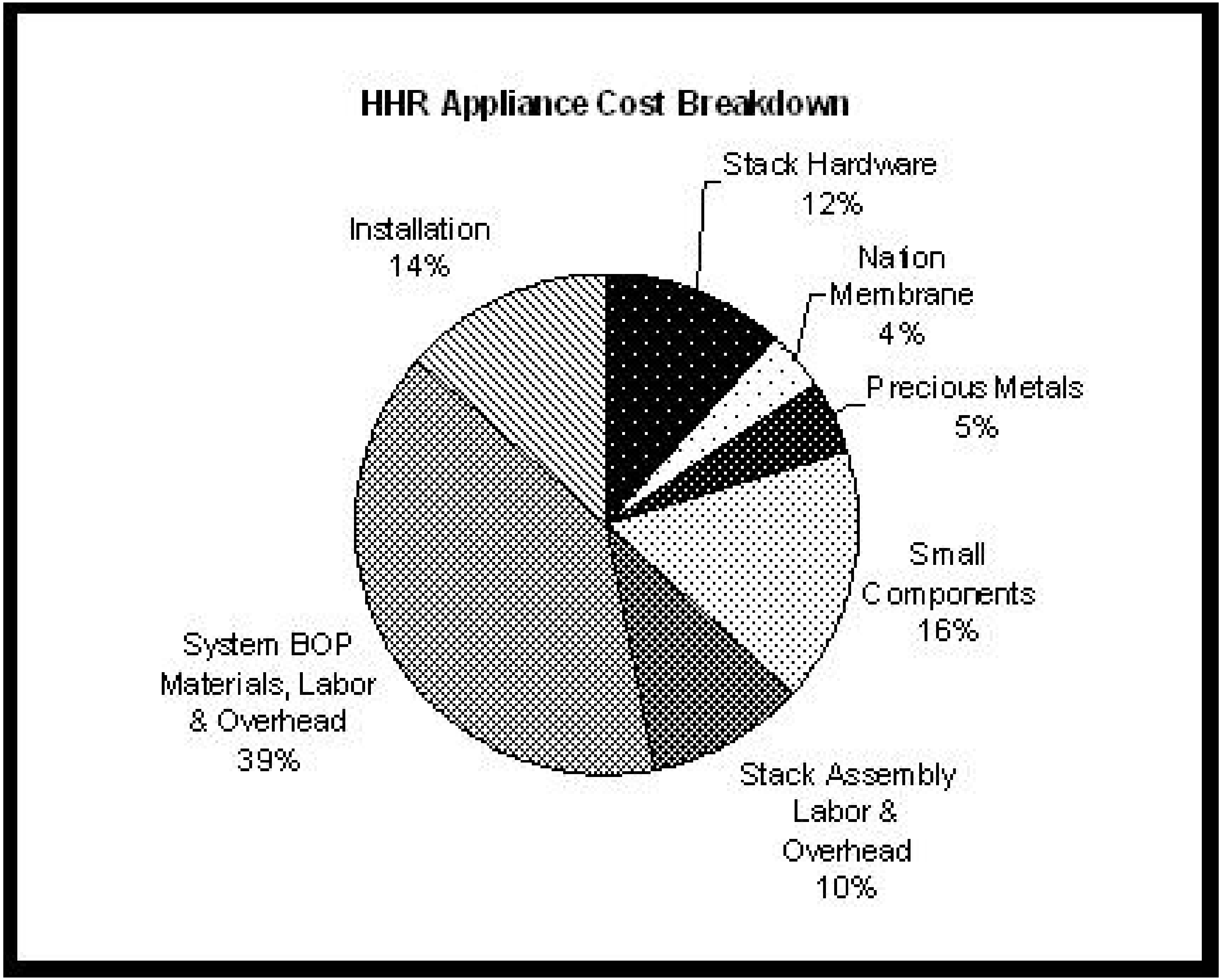
EPRI

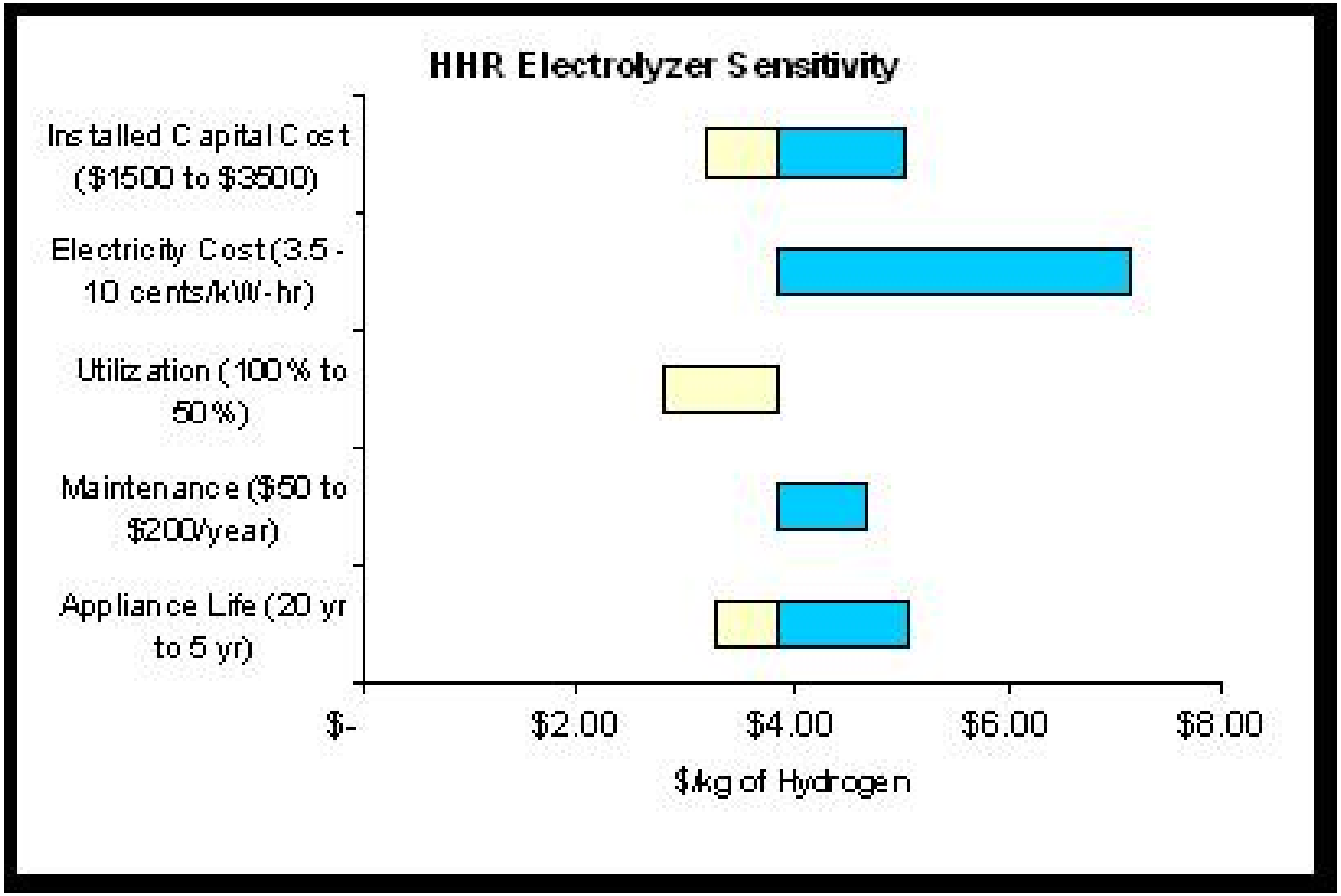
Estimation of Capital Costs

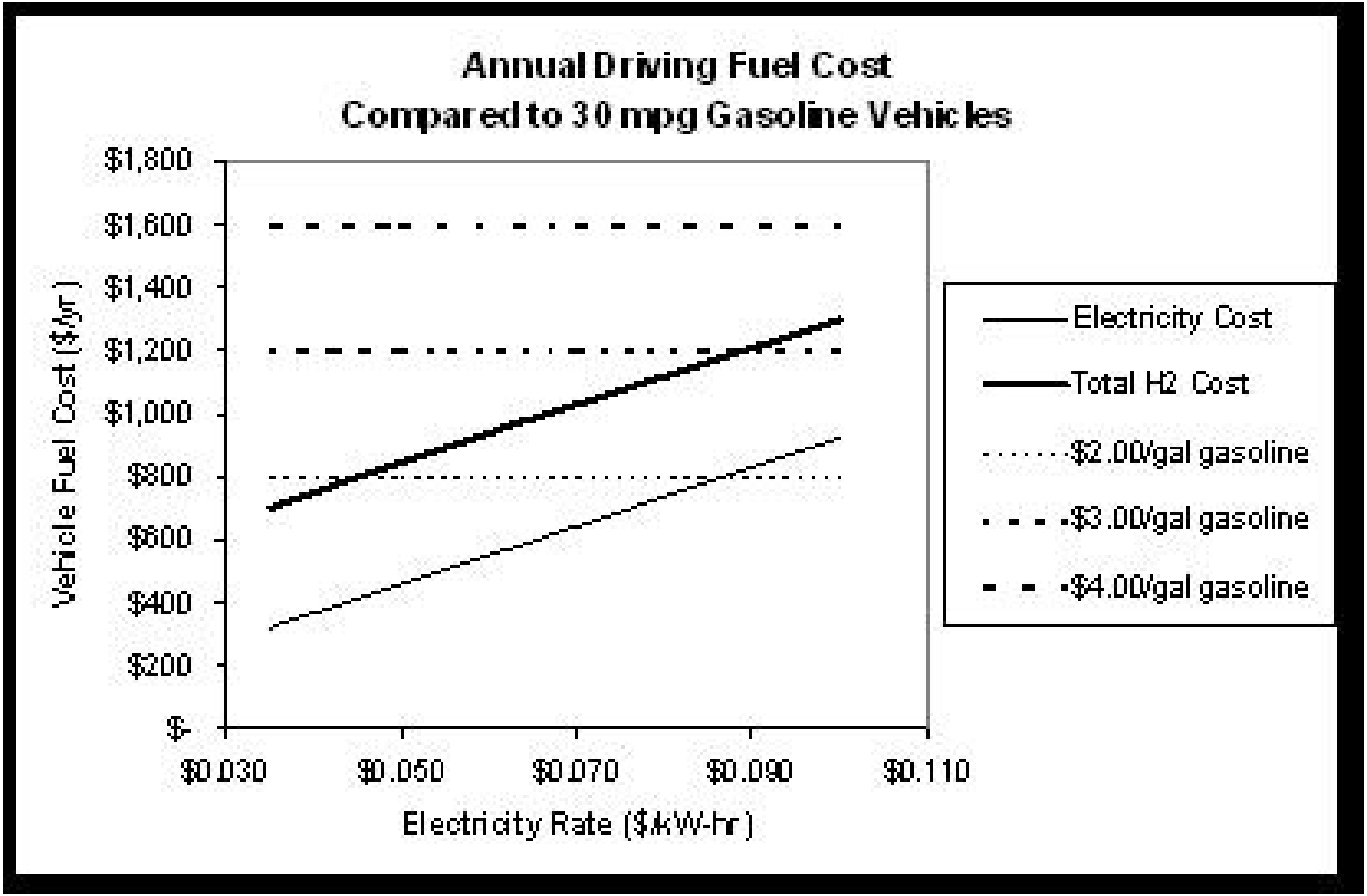
	Low Volume	Medium Volume	High Volume
Cost Summary	1,000 units per year	10,000 units per year	100,000 units per year
Stack Materials	$1,543.71	$816.91	$453.51
Stack Assembly Labor	$771.85	$408.45	$226.75
Stack Support Hardware	$1,456.00	$728.00	$364.00
System BOP	$3,510.77	$1,755.39	$877.69
Total Manufactured Cost	$7,282.33	$3,708.75	$1921.95
Installation Cost	$300.00	$300.00	$300.00
Total Installed Cost	**$7582.33**	**$4,008.45**	**$2,221.96**

A summary of operating costs for a typical use scenario are as follows for units produced at manufacturing volumes of 100,000 per year.

Installed Appliance Cost	$2221
Annual Mortgage Cost	$331
Annual Maintenance	$50
Power Cost	$0.035/kW-hr
Power Cost of H_2	$1.76/kg
Annual Power Cost @ 50% Utilization	$322
Total Annual Fuel Cost @ 50% Utilization	$703
H_2 cost @ 50% Utilization	$3.85/kg
H_2 cost @ 100% Utilization	$2.81/kg


HHR Appliance Cost Breakdown
Stack Hardware 12%
Installation 14%
Nafion Membrane 4%
Precious Metals 5%
Small Components 16%
System BOP Materials, Labor & Overhead 39%
Stack Assembly Labor & Overhead 10%


HHR Electrolyzer Sensitivity
Installed Capital Cost ($1500 to $3500)
Electricity Cost (3.5 - 10 cents/kW-hr)
Utilization (100% to 50%)
Maintenance ($50 to $200/year)
Appliance Life (20 yr to 5 yr)
$-
$2.00
$4.00
$6.00
$8.00
$/kg of Hydrogen


Annual Driving Fuel Cost
Compared to 30 mpg Gasoline Vehicles
Vehicle Fuel Cost ($/yr)
$1,800
$1,600
$1,400
$1,200
$1,000
$800
$600
$400
$200
$-
$0.030
$0.050
$0.070
$0.090
$0.110
Electricity Rate ($/kW-hr)
Electricity Cost
Total H2 Cost
$2.00/gal gasoline
$3.00/gal gasoline
$4.00/gal gasoline

Home Electrolyzer Technology Assessment

Results

- The IFF Electrolyzer cell outperformed the Conventional Electrolyzer in terms of generation of hydrogen gas and stability.
- Manufactured cost estimates range from $ 7600 to $ 2500 depending on volume production
- Additional Cost Assessments needed after 1st Prototype is designed and tested.
- At 3.5 cents per kWh; H2 production estimates ranged from $ 4 to $ 8 / per kg depending on volume production.
- EPRI TI Report to be published in May 2008

Summary and Recommendations

- The system simplifications allowed by this innovation enable the design of a small, efficient and low cost HHR appliance, targeting hydrogen vehicle refueling at home with off-peak electricity.
- The baseline technology is in the early stage of development and needs to be scaled-up.
- Research and development funds to produce a prototype HHR system are required.
- The major elements of the follow-on development work would be:
- Communicate the findings from this work to industry strategic partners and stakeholders.
- Development of Integrated Flow Field multi-cell stack hydrogen generator subsystem;
- Carry out performance and durability tests of the stack.
- Design, development, and construction of a full HHR Appliance Prototype; and
- Testing and evaluation of the appliance.
- The estimated development costs are $2 million over a two year period to advance the current technology to a 1 kg/day fully integrated prototype system.

Thanks!

- Visit www.epri.com for more information
  - ***More information on these topics is available from EPRI in the following reports:***
    - ***Hydrogen Market Assessment and Opportunities for Electrolyzer Based Services***. EPRI, Palo Alto, CA: 2007. 1016244.
    - ***Feasibility of Hydrogen Home Refueling Systems for Plug-in Hybrid Vehicle Applications,*** EPRI, Palo Alto, CA: 2008 1016169

- Please direct questions and inquiries to

Dan Rastler

Technical Leader, Energy Storage and Distributed Generation Program

Electric Power Research Institute

drastler@epri.com