

Advanced Alkaline Electrolysis

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imagination at work

Project #PDP16

Acknowledgements

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Overview

Timeline

Start: 30 September 2006

End: 30 December 2008

20% complete

Budget

Total Funding: \$1,239,479

DOE Share: \$ 973,783

Contractor: \$ 265,696

*funded by both the DOE Nuclear
Hydrogen Initiative and DOE
HFCIT programs*

Received in 2006: \$542,546

2007 Funding (to date) : \$ 92,478

Barriers Addressed

G. Capital Cost of Electrolysis Systems

I. Grid Electricity Emissions

Partners

GE Global Research

GE Energy Nuclear

Entergy Nuclear

National Renewable Energy Laboratory

Objectives

Study the feasibility of using alkaline electrolysis technology with current-generation nuclear power for large scale hydrogen production:

Economic Feasibility : Market study of existing industrial H2 users

Technical Feasibility : Developing pressurized low cost electrolyzer

Codes and Safety: Environmental and regulatory impact assessment

	Units	DOE 2012 Target
Cell Efficiency	%	69% (1.8V)
System Cost	\$/kg H2	\$0.70 (\$400/kW)
Electricity Cost	\$/kg H2	\$2.00
O&M Cost	\$/kg H2	\$0.60

Approach

80% complete	Task 1: Define market and requirements <ul style="list-style-type: none">• Industrial users survey• Technical and pricing requirements• Nuclear regulatory and environmental impact issues
10% complete	Task 2: Design and build pressurized electrolyzer stack <ul style="list-style-type: none">• Develop plastic stack technology• Low cost electrode methods
5% complete	Task 3: Plastics oxidation lifing <ul style="list-style-type: none">• Creep resistance• Oxidation
	Task 4: Demonstrate electrolyzer performance and capital costs
	Task 5: System operation testing <ul style="list-style-type: none">• O&M cost assessment
	Task 6: Create industrial-scale system conceptual design
	Task 7: Create 1-kg-per-second demonstration system conceptual design

Global Hydrogen Market

Ammonia Production



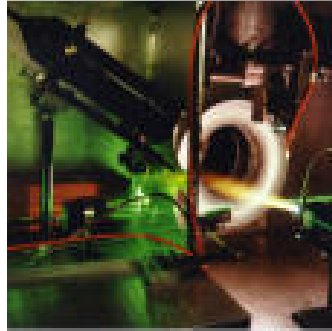
Size: • \$ 17 B
Growth: • 1.5 % CAGR

Refineries



• \$ 15.5 B
 • 10 % CAGR

Metals Fab. & Treatment



• >\$0.5 B
 • 5% CAGR

Chemical Mfr'g



• \$ 1 B
 • 1.5% CAGR

Food & Personal Care



• >\$0.5 B
 • 5% CAGR



- Flat Demand
- Key Use: Fertilizer
- Captive H2 Production Facilities

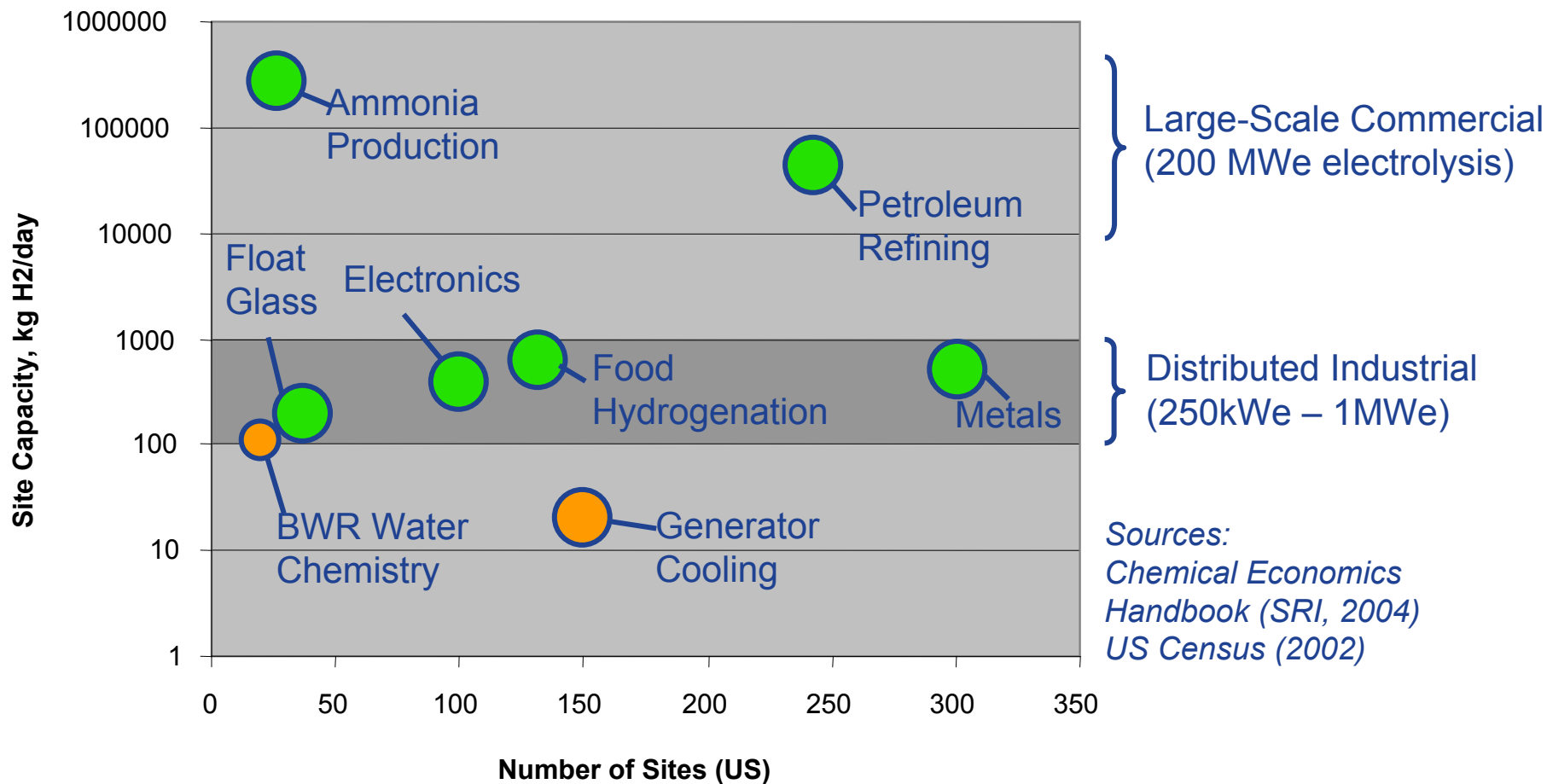
- Hydrogen Used to Remove Sulfur
- EU & US Regulations Mandating Lower Sulfur Content in Gas, Diesel
- Captive H2 Production Facilities

- Hydrogen Used for High Heat Processes i.e. Plasma Spray
- Batch type process

- Manufacture of Specialty Chemicals for a Variety of Industries
- Methanol

- Hydrogenating Oils for a range of applications:

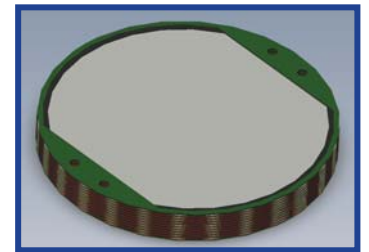
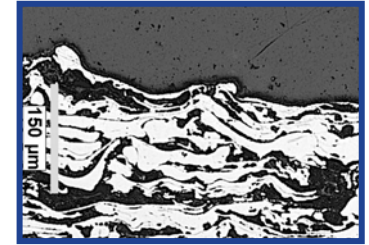
Industrial Hydrogen Market Segments



Industrial market infrastructure can lead fueling infrastructure

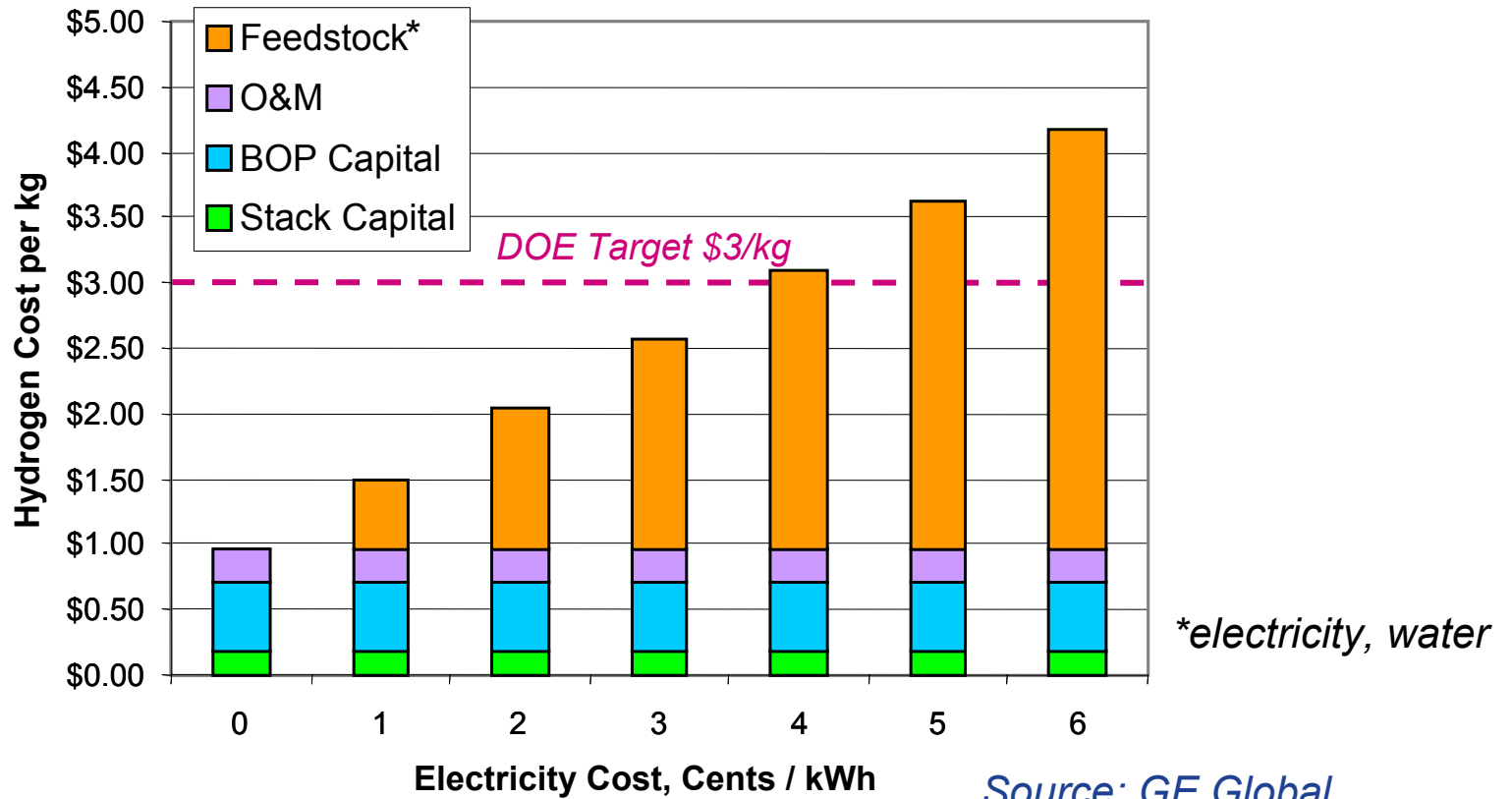
GE Technology Capital Costs

Projected CapEx, 5 kg/hr stack :	Per kg/hr	Per Nm ³ /hr
Prototype	\$16,000	\$1,426
Production	\$5,000	\$446



At 50 kWh/kg H₂ , production stack cost is
\$100/kW

Projected H2 Cost with GE Electrolyzer: 1000 kg/day, 30 bar pressure

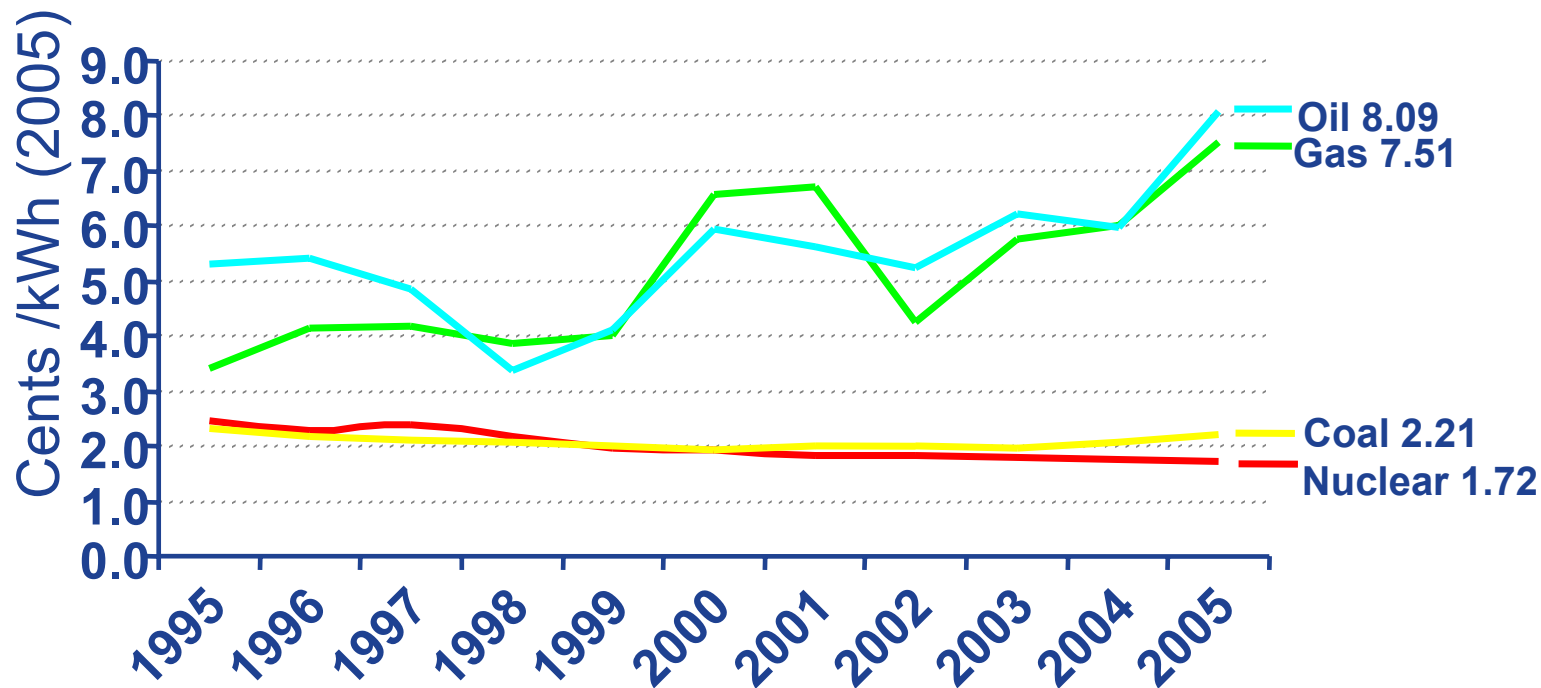


Source: GE Global
Research, NREL H2A Model

Low-cost electricity still key to meeting targets.

Electricity Production Costs

existing fleet - US 1995-2005

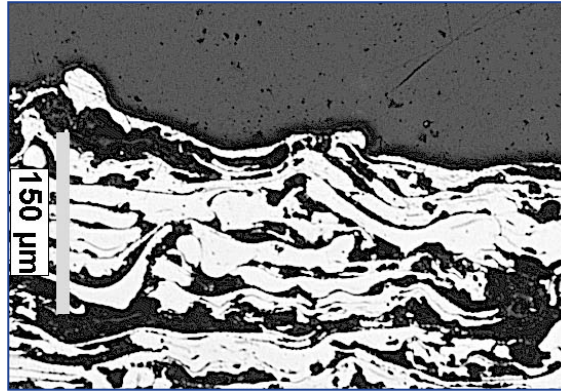


Source: NEI, 2006

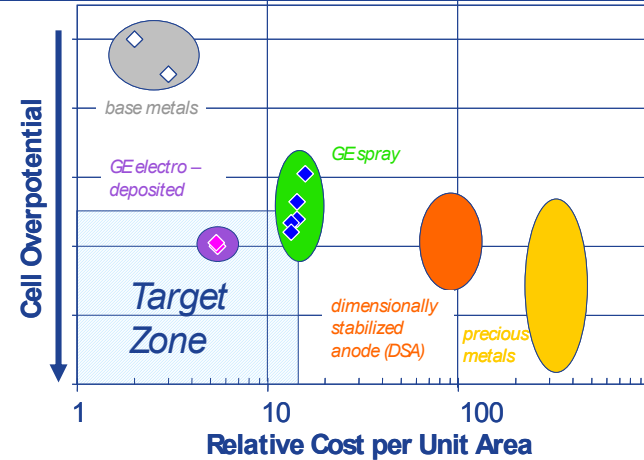
Lowest **cost** electricity available from existing nuclear
Electricity market demands set actual **price**

GE Alkaline Electrolysis Technology

High Surface Electrode



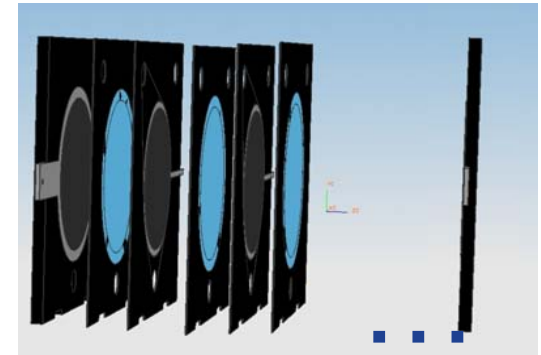
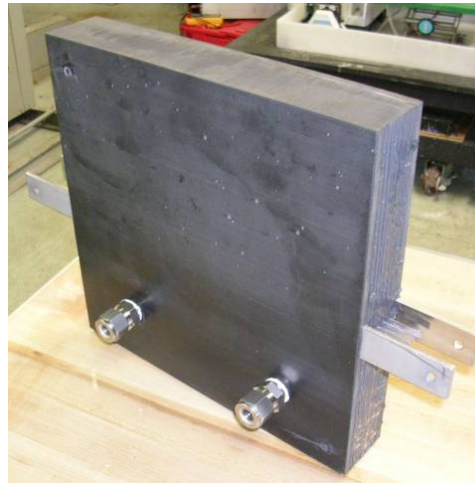
- Wire arc electrode system
- Electrodeposition



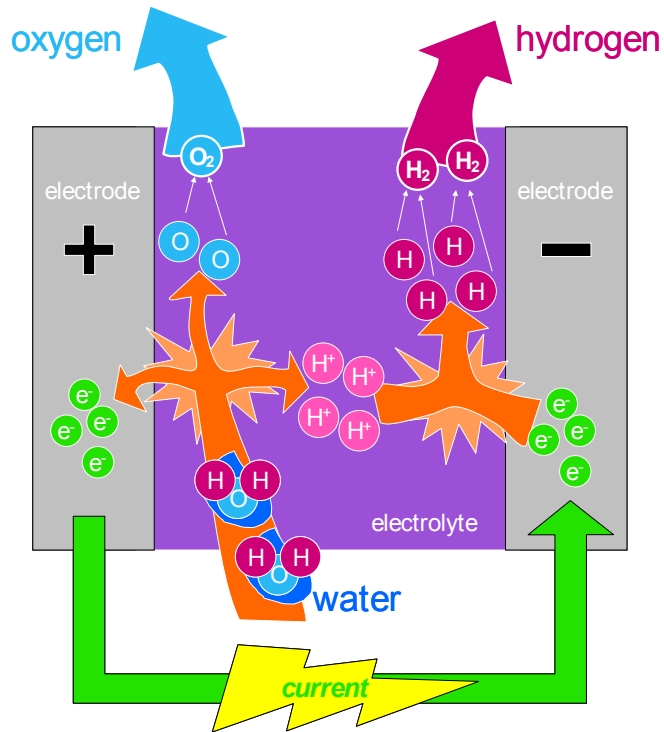
1000x electrode surface: performance at 1/10 traditional electrode cost

Plastic Stack

- One piece stack assembly: minimal part count
- Molded passages, not machined



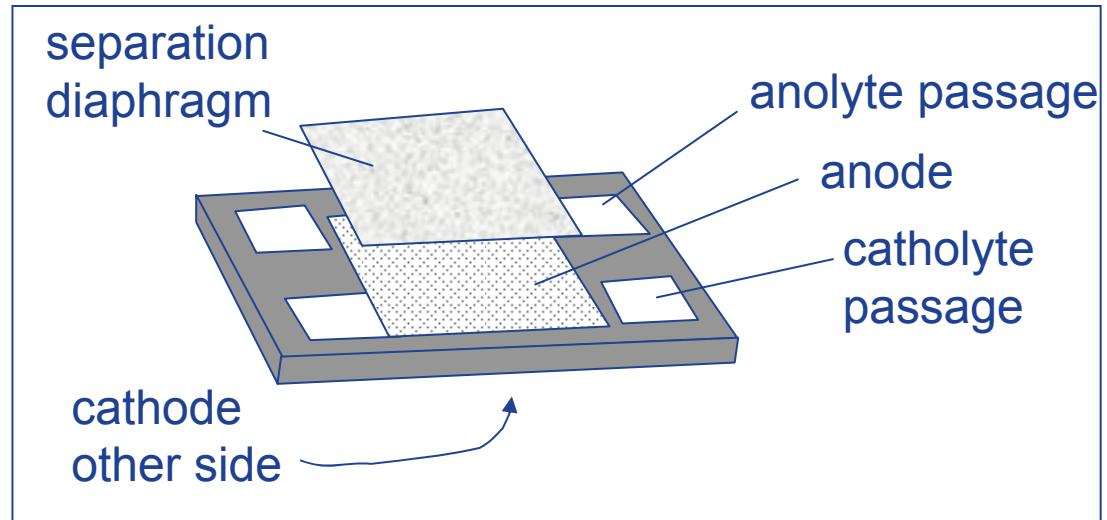
Electrolysis Cell Basics



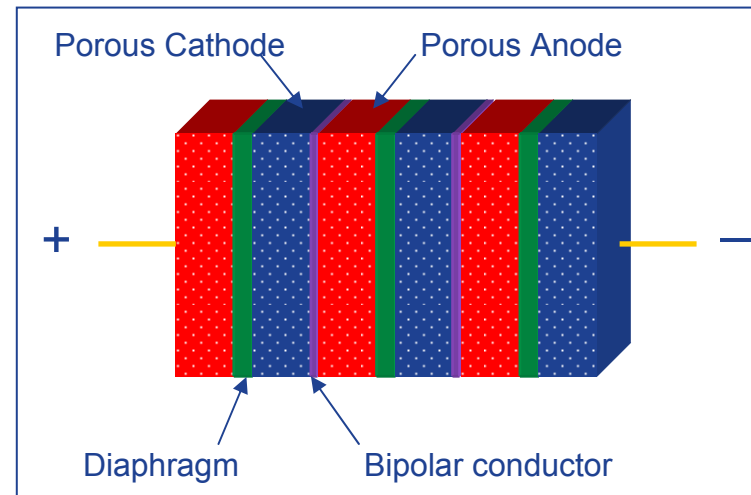
Cathode (-):



Anode (+):



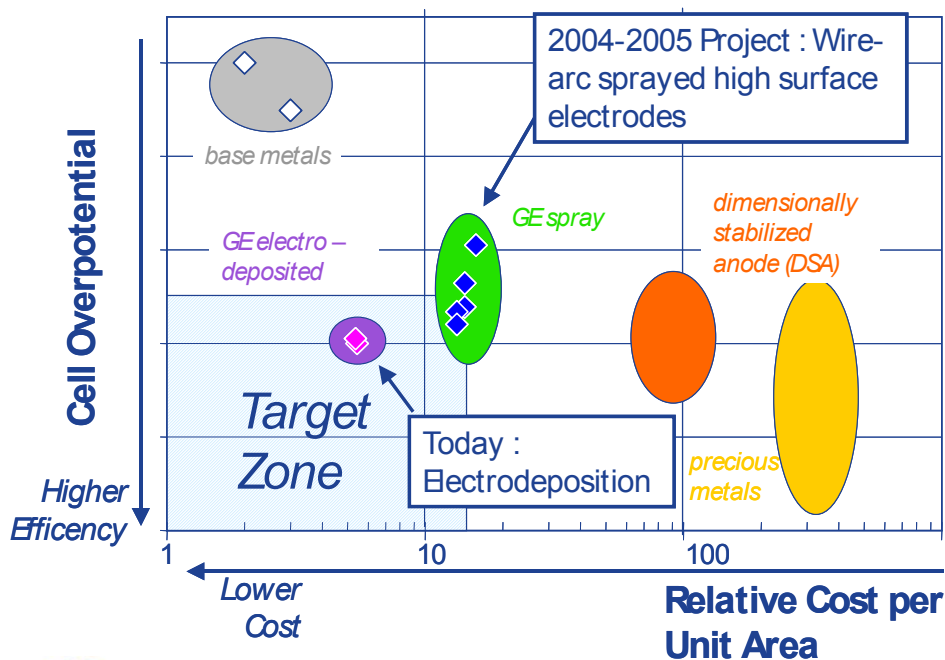
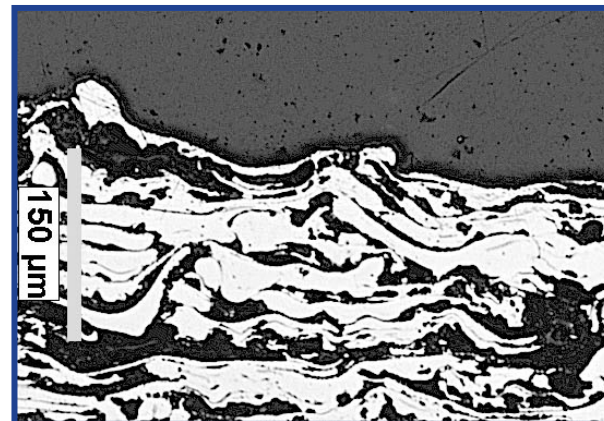
Bipolar type half-cells



Multicell
Bipolar
Stack

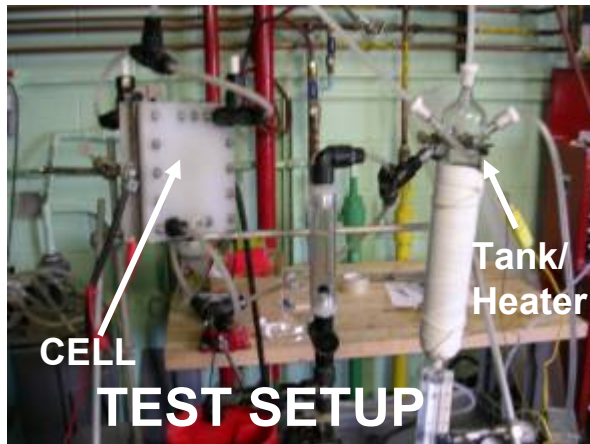
Technical Details - Electrode

GE electrode technology applies a high effective surface area, nickel-based coating to the base metal bipolar plate for high performance at low cost.



- Achieved target performance with hot spray technique in 2005.
- Researching electrodeposition for additional cost and performance advantage:
 - Thinner bipolar plate
 - Eliminates warping
 - Coats 3D electrode surface

Technical Details – Electrode



- Single flow cell
- Ambient pressure, 80°C



- Some oxide left – leaching blocked by plastic mesh

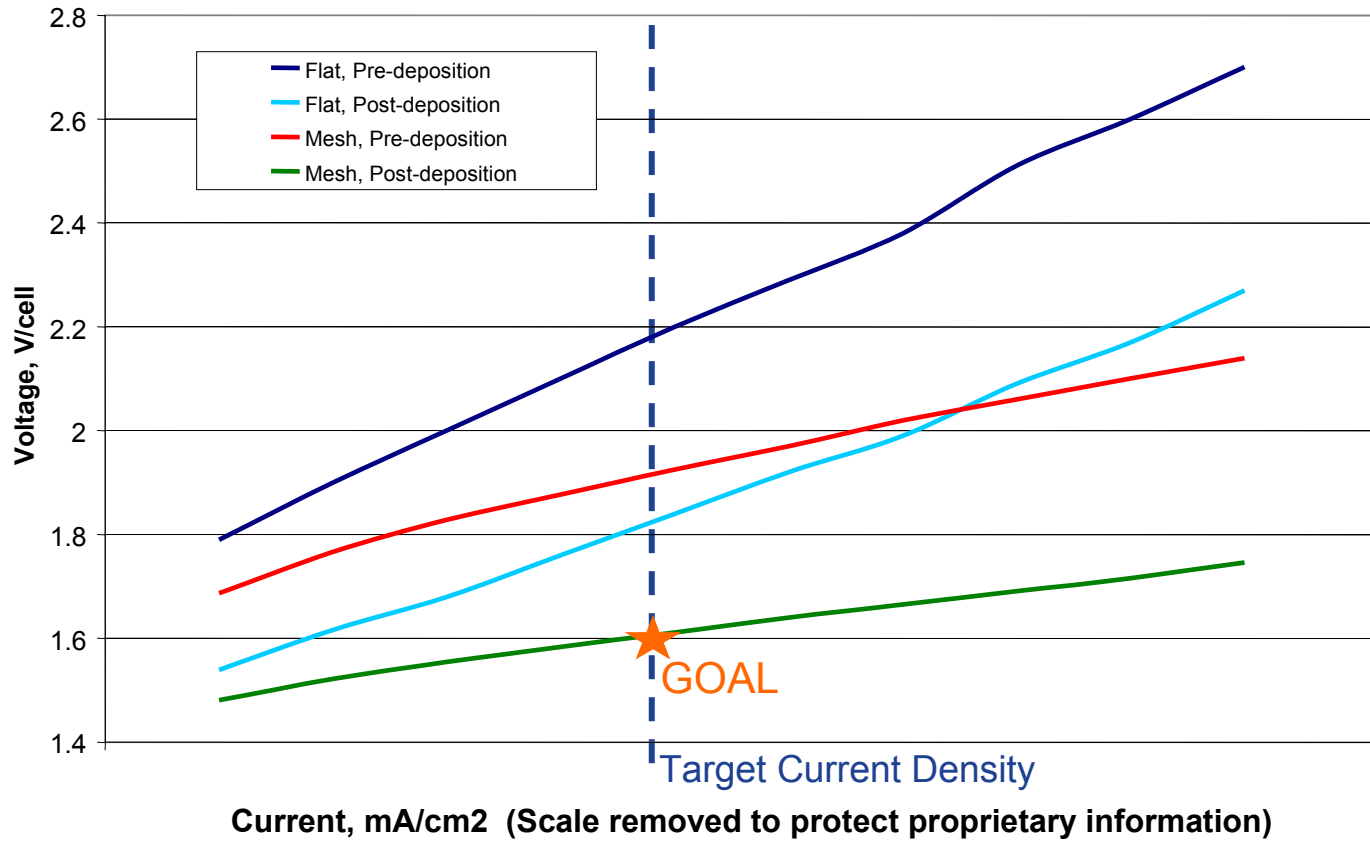


- Plastic mesh for flow distribution



- Cathode mesh applied
- Higher coated surface area

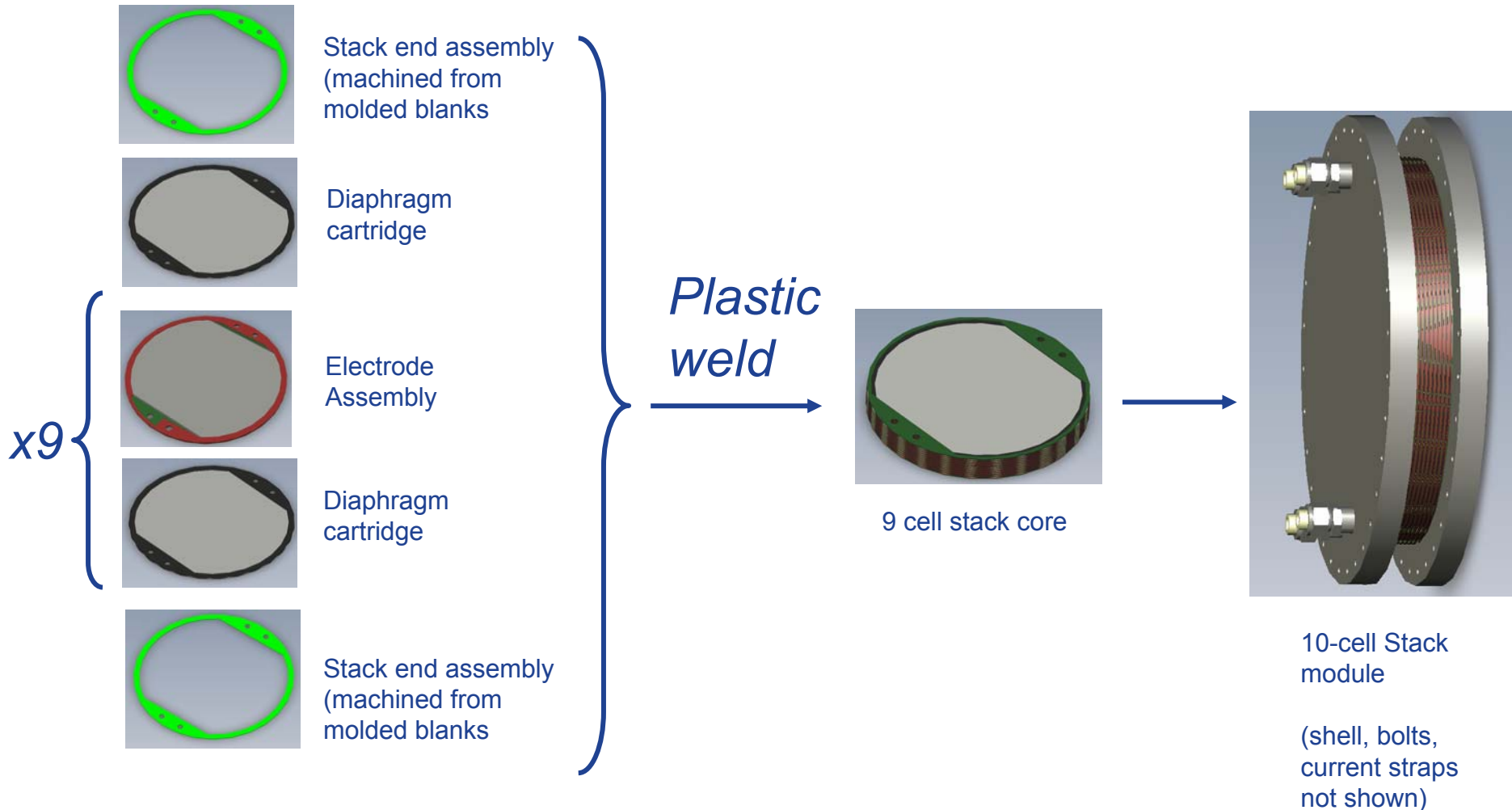
Single Cell Performance



Electrode Results- First Quarter

- Test results meeting target current density for single cell.
- Additional performance margin needed: large cell and multi-cell stack voltages are typically higher than small single cell.
- Additional mV reductions possible from anode side mesh, method optimization, catalyst additives.

Plastic Stack Construction



15 bar pressure stack under construction for 2007 test

Resistance Wire Welding



- Robust method to join plates for test stack
- Wire path determines weld location
- Allows “blind” welds along passages
- Heat management, inspection method biggest challenges

Test plan to determine process parameters and abate risks:

- wire size, current, voltage
- weld spacing – in-plane and stacking of plates
- weld strength – tensile and crack opening
- clamping strategy
- wire placement and tacking
- weld closure

Welding – Experimental Setups

Coupon



Pressure Test



Full Plate with Manifolds



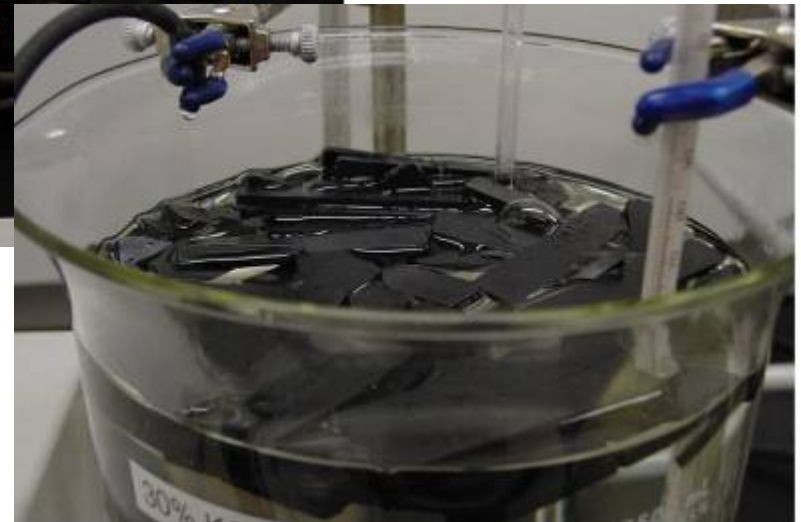
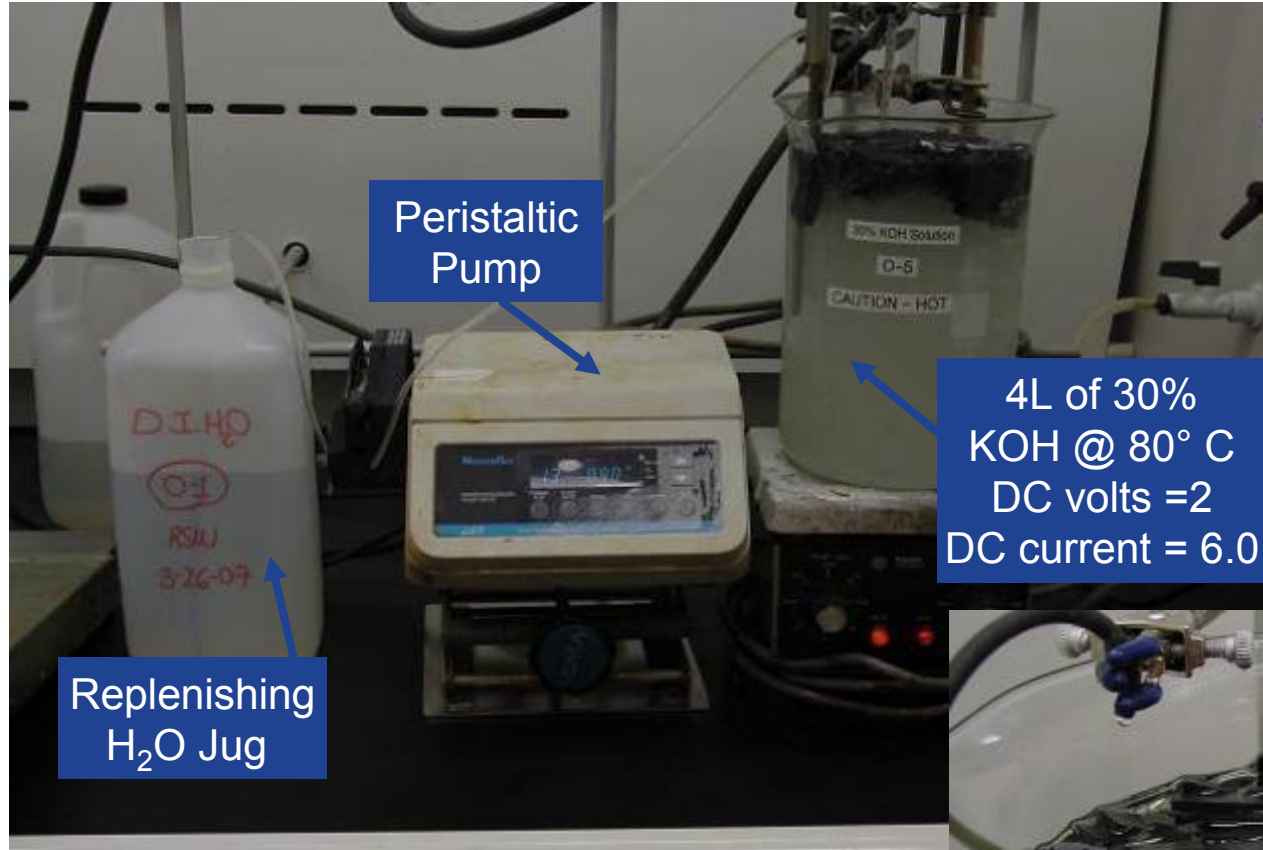
Plastic Oxidation Lifing

Risk: Oxidation reduces strength of plastic over time. Electrolysis produces high-pressure oxygen and other oxidative species such as ozone.

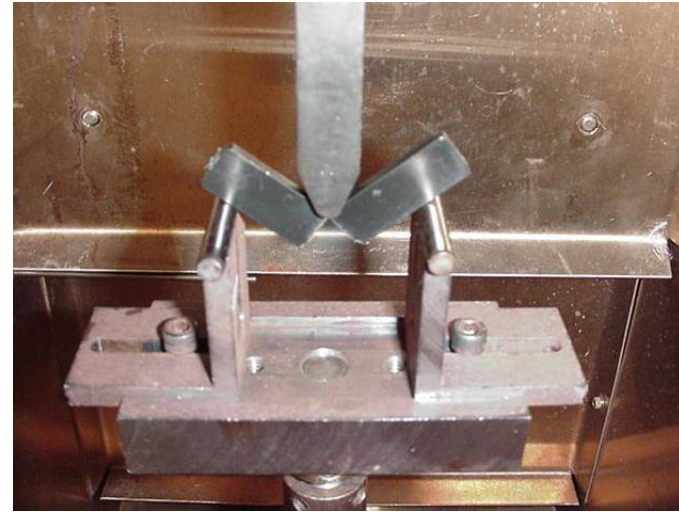
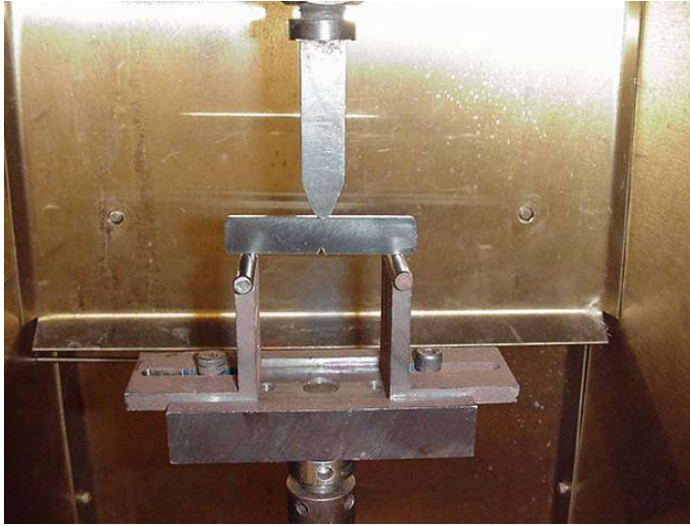
Approach: Exposing test samples to oxidant in three experiments:

- 1) Hot KOH and bubbling air at ambient pressure
- 2) Ambient pressure electrolysis
- 3) high pressure O₂ in reactor vessels

Oxidation Exposure Testing



Fracture Toughness Test



- 3-Point bend notched samples tested at 80C
- No difference between oxygen-only and electrolyzer-exposed samples after 5 days
- Continue sampling at 1 wk intervals

If there is no difference in strength between oxygen-only and electrolysis exposed samples, the high pressure oxygen-only experiment is validated.

Future Work

- 2007: Regulatory assessment
- Complete industrial market technical requirements
 - Complete electrolyzer stack technical development
 - Build and begin testing of 10-cell pressurized stack
- 2008: Conceptual design of reference plants

Summary

➤ **Relevance**

Technology for a sustainable hydrogen economy, built on current industrial markets with existing technology.

➤ **Approach**

Combine GE's low cost electrolyzer stack technology, Entergy's experience in nuclear electricity markets, and NREL's economic modeling expertise to evaluate the feasibility of nuclear electricity and electrolysis for large-scale hydrogen generation.

➤ **Technical Accomplishments and Progress**

Segmented industrial market and estimated hydrogen costs for developed product. Completed conceptual design for prototype electrolyzer stack.

➤ **Technology Transfer and Collaborations**

Completing market case and technology development for commercialization. Collaboration between electrolyzer developer and nuclear utility fosters a well-ordered approach to entering the industrial market.