Electrochemical Hydrogen Compressor

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Overview

Timeline

- Project start date: 7/15/10
- Project end date: 7/14/13
- Percent complete: *61%*

Budget

- Total project funding
  - DOE share: $1993k
  - Contractor share: $629k
- Funding received in FY11: $500k
- Funding for FY12: $748k

Barriers

- Barriers addressed for gaseous hydrogen compression:
  - Improve reliability
  - Eliminate contamination
  - Improve energy efficiency
  - Reduce cost

Partners

- Collaborations: Sustainable Innovations, LLC
- Project lead: FuelCell Energy

Relevance

Impact of EHC:

- **Increases reliability/availability over current mechanical compressors**
- **Ensures "no possibility of lubricant contamination" (No moving parts) → Fuel Cell Quality H_2**
- **Increases Compression Efficiency to 95% (DOE 2015 Target)**
- **Potentially reduces cost of H_2 delivery to <$1/gge (DOE Long Term Target)**

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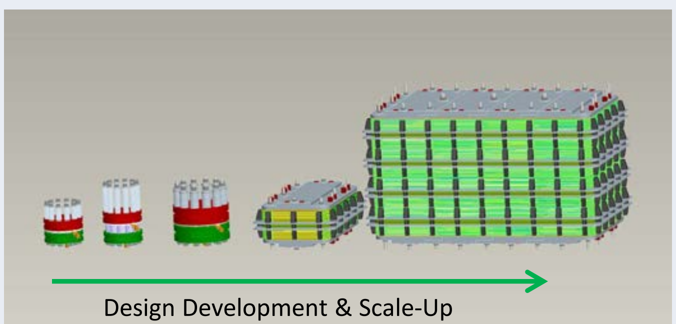
Approach

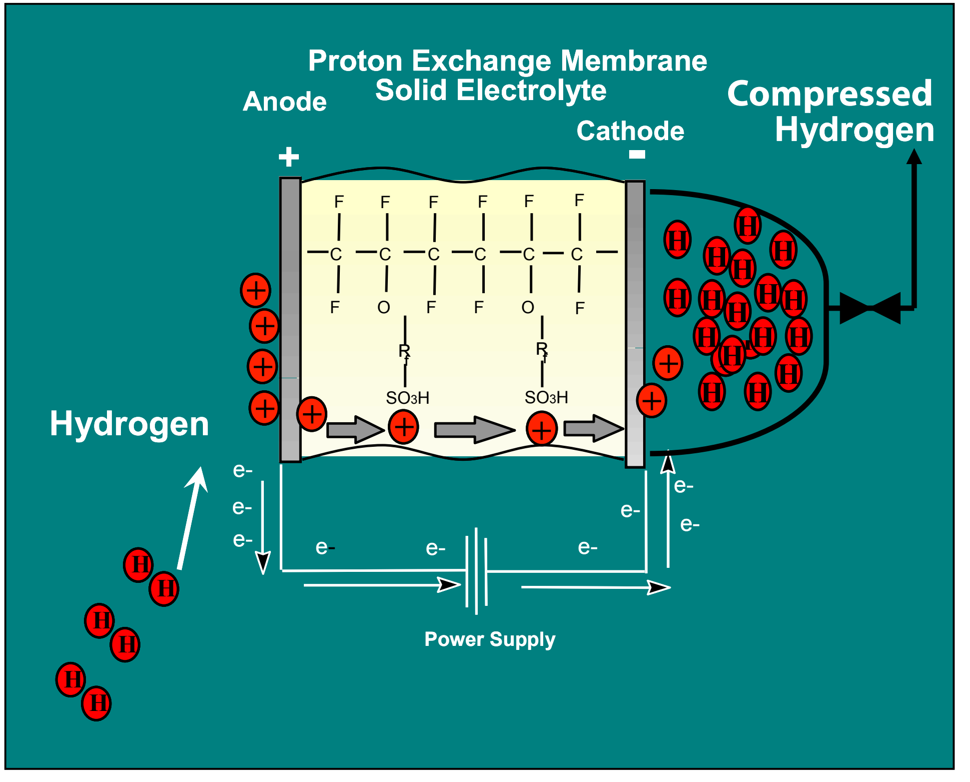
- **Use high-pressure electrolyzer experience for mechanically robust cell design**
- **Higher current density operation to minimize capital and operating costs**
- **Improved flow field design to increase H_2 recovery efficiency**
- **Simple system: Reduce capital cost by increasing cell size and reducing number of parts**

Approach

ITEM	APPROACH
Increase Pressure, Life, Efficiency	-Cell & Stack Design Enhancements -MEA Improvements -Multi-Stage Operation -Very High Single Stage Compression
Lower System Cost	-Cell & Stack Design Enhancements -Increase Current Density -Increased Durability/Life -Increase Single-Stage Pressure Capability -Design for Mfg & Assembly -Lower Labor Rates -Lower Cost Materials of Construction -Lower Part Count -Leverage Economies of Scale -Increase Cell Active Area



Principle of Electrochemical Hydrogen Compressor



- Simple operating principle with no moving parts – **Solid State !**
- Use of hydrogen electrode for high compression efficiency

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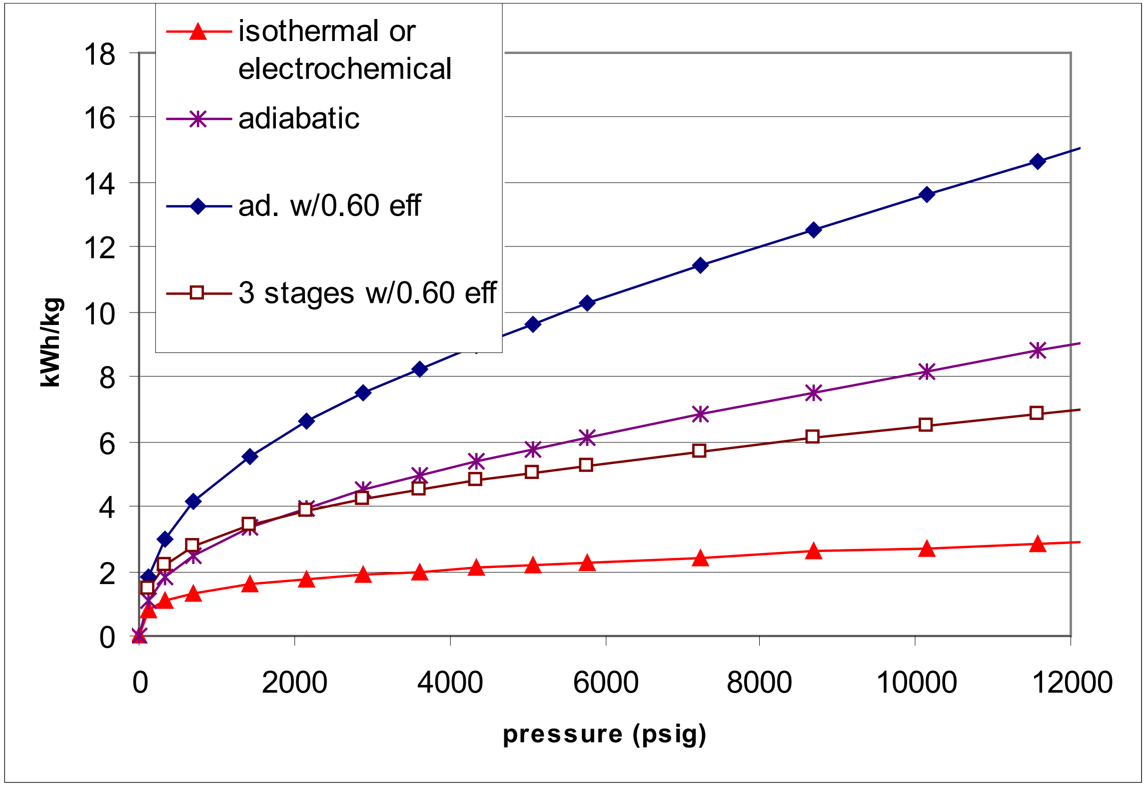
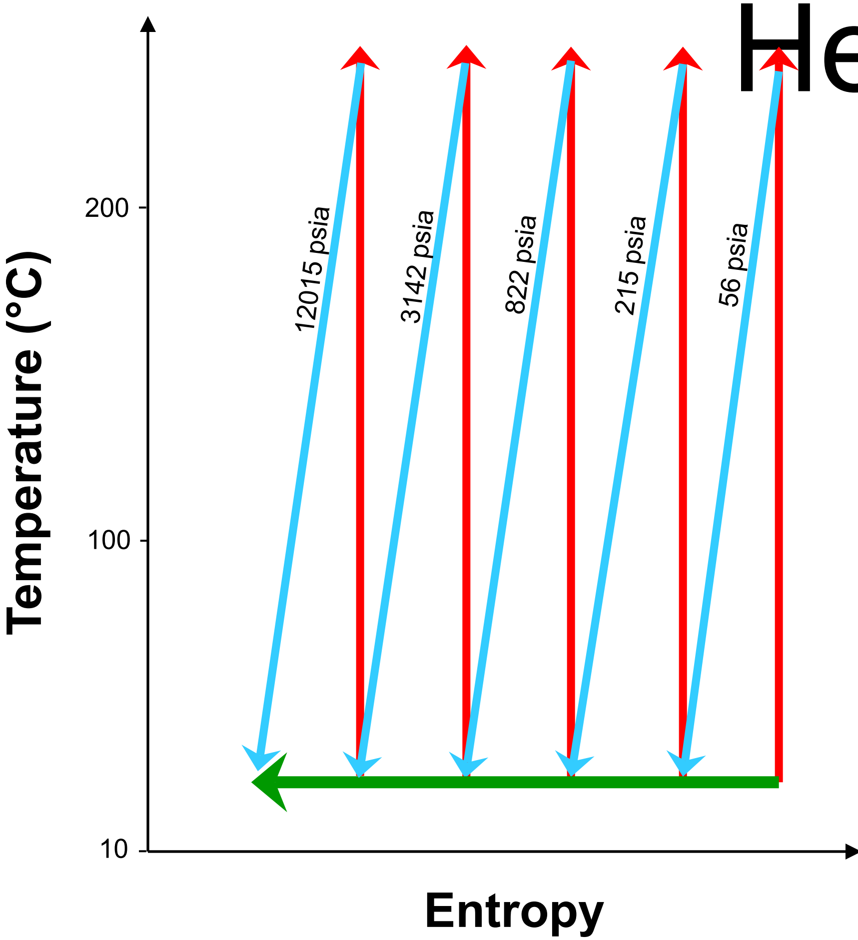
Calculated Compressor Performance Values



Electrochemical compression is by far the most efficient way to compress hydrogen

Compression Heat



Multistage Adiabatic Compression with Interstage Cooling

vs.

Isothermal Compression of EHC

- **Adiabatic Compression** (red)
- **Interstage Cooling** (light blue)
- **Isothermal Compression** (green)

Hydrogen does not significantly heat up during compression in EHC

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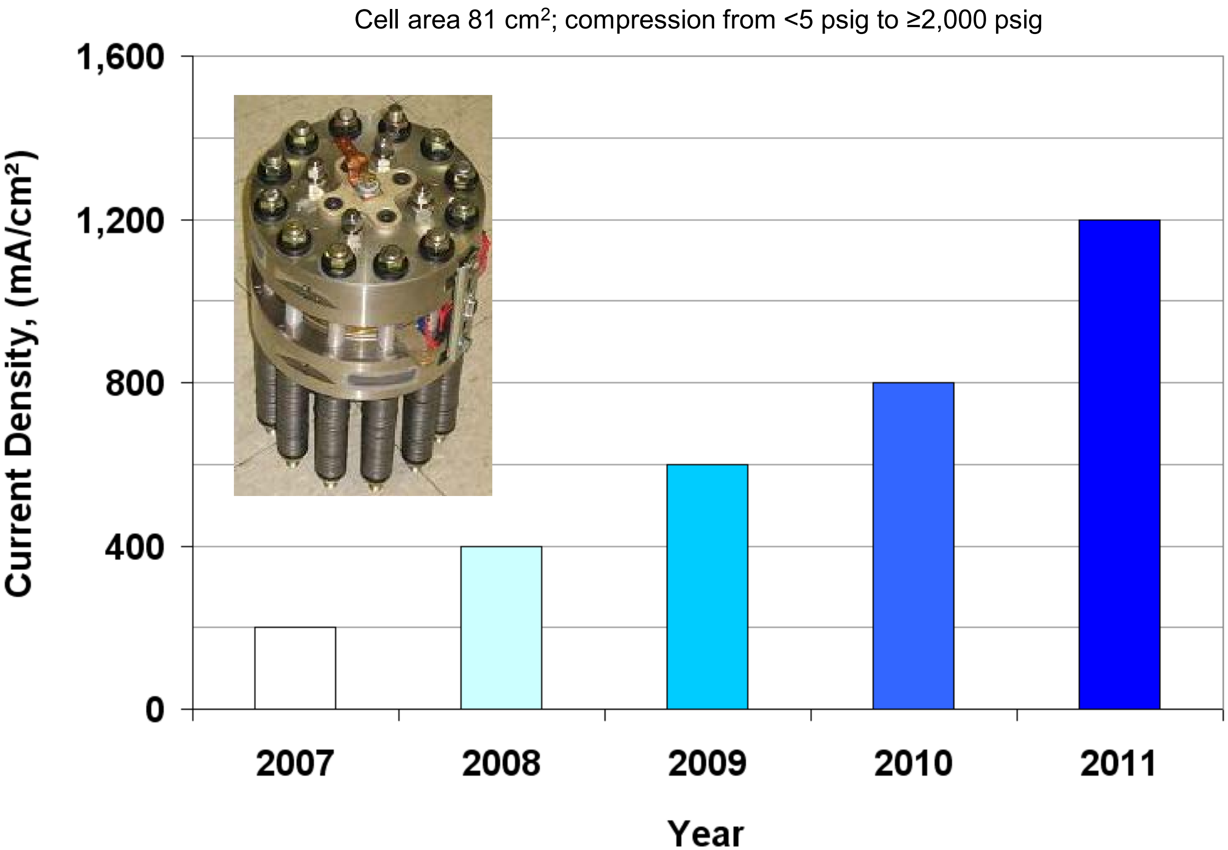
EHC Cost Reduction



Improvements made:

- Higher performance MEA
- Resistance at higher pressure
- Improved manufacturing tolerances
- Increased output
- Reduced part count

Six-fold increase in current density

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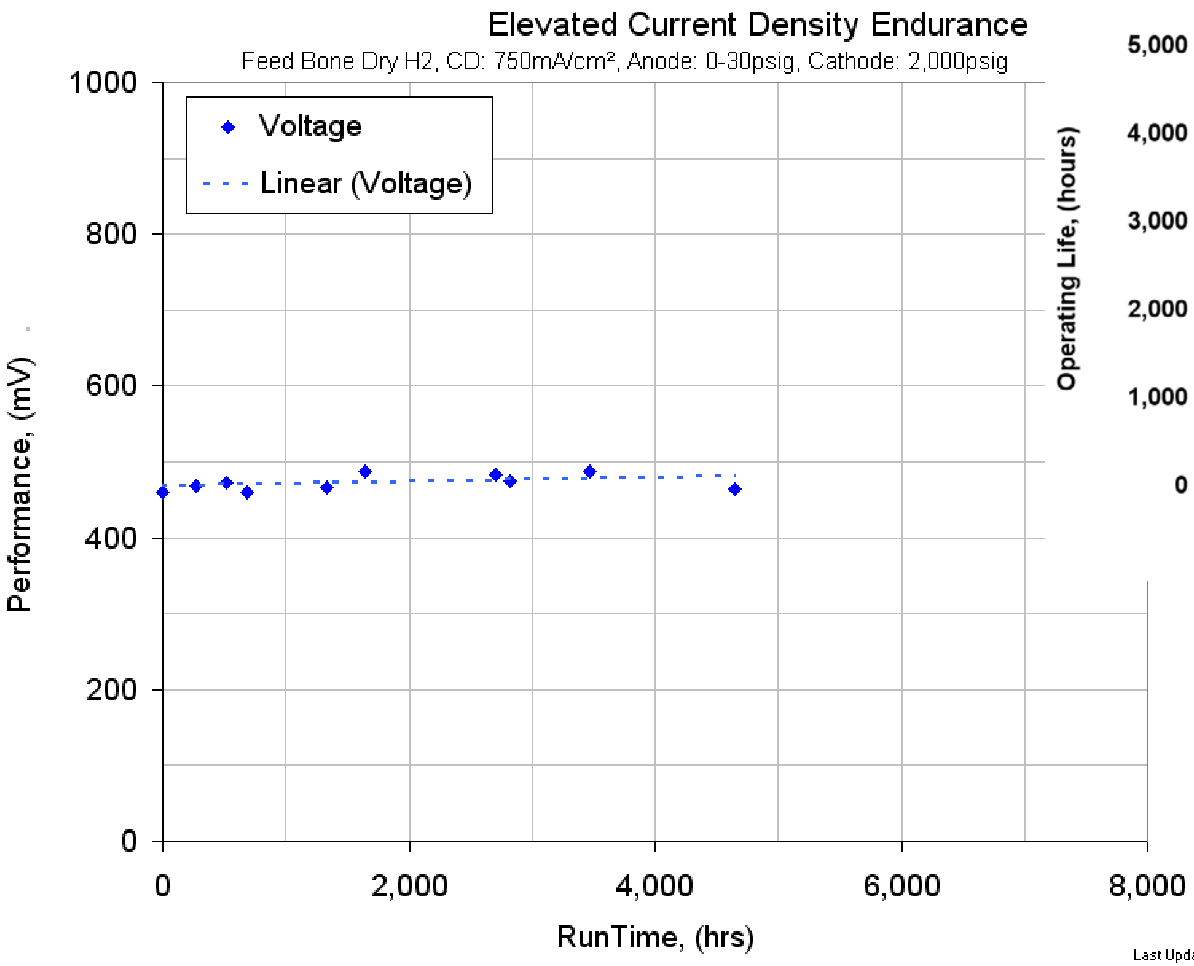
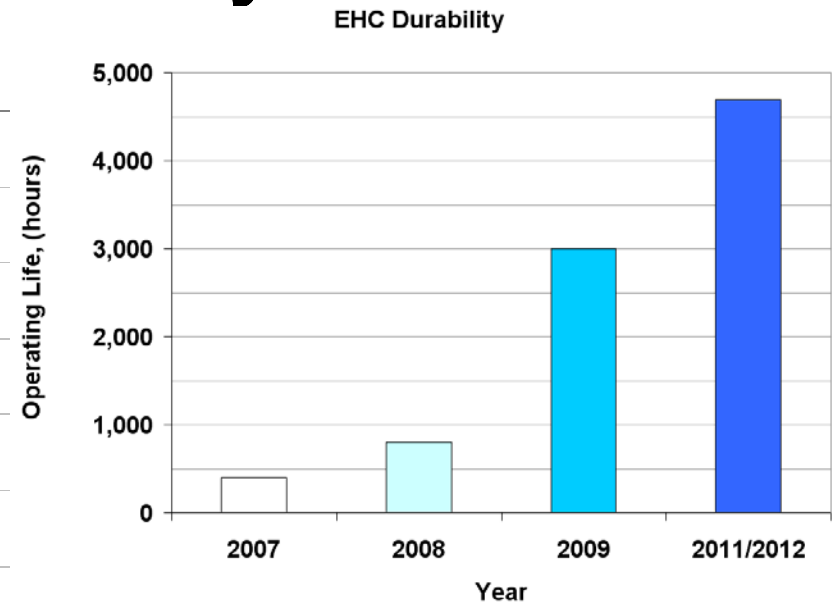
EHC Durability





Improvements made:

- **Membrane with higher proton conductivity**
- **Matching electrodes**
- **Lower cell resistance**
- **Lower applied voltage**

Demonstrated >5,000 hr life at elevated current density (750 mA/cm^2)

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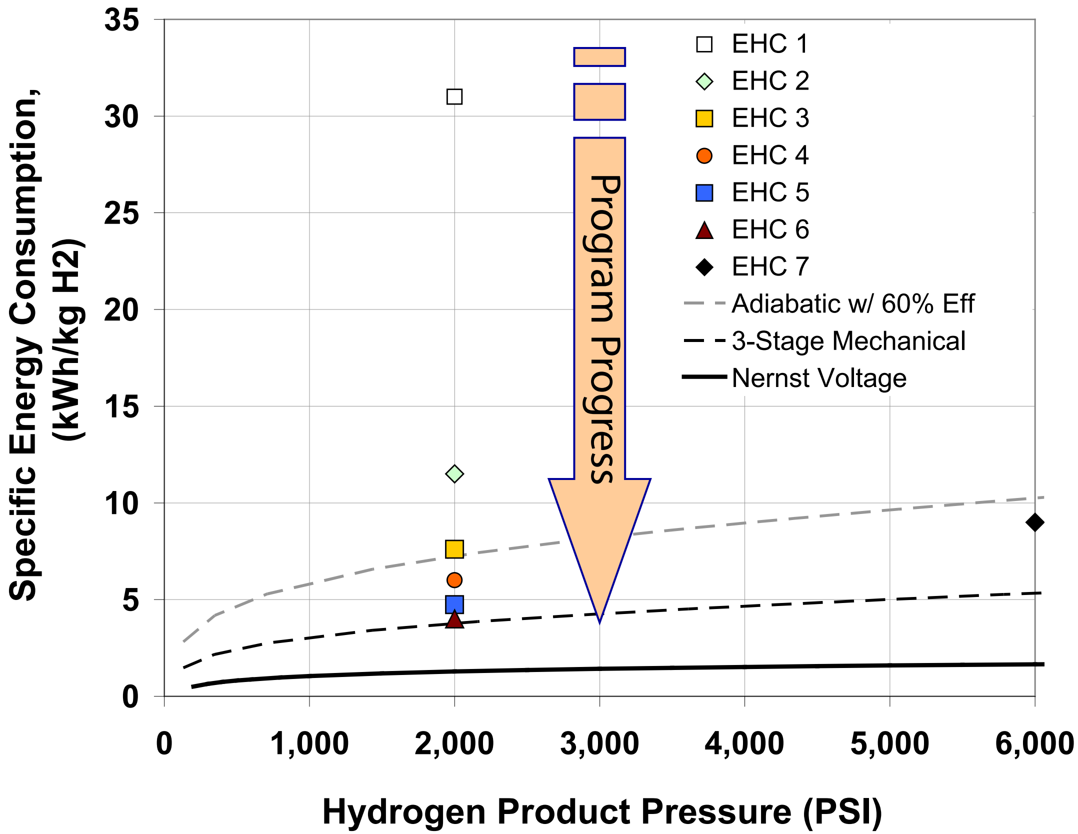
Reduction in the Energy Consumption of EHC

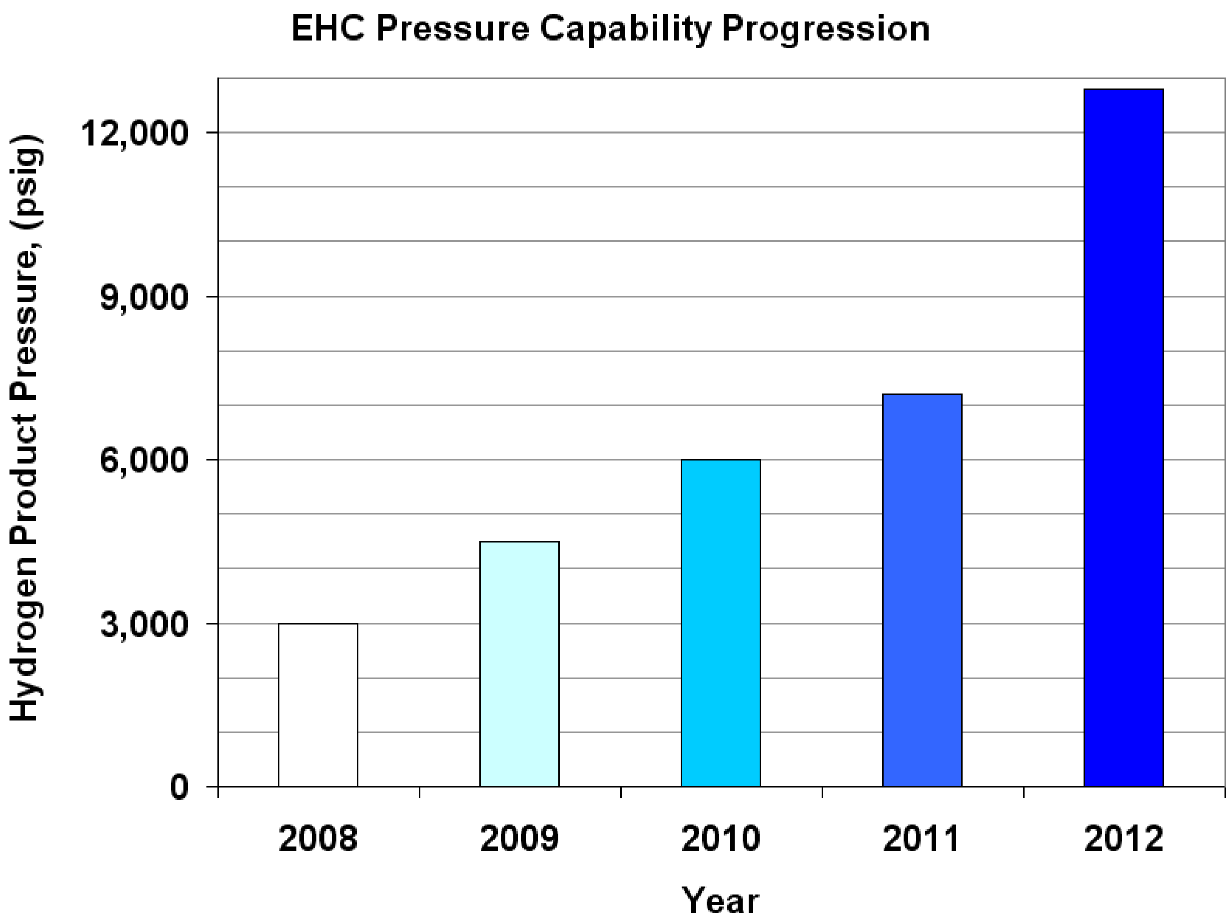


Improvements made:

- **Lower cell resistance**
- **Lower applied voltage**

Current EHC cell design provides low energy consumption for 0 → 2000 psig

EHC Pressure Capability



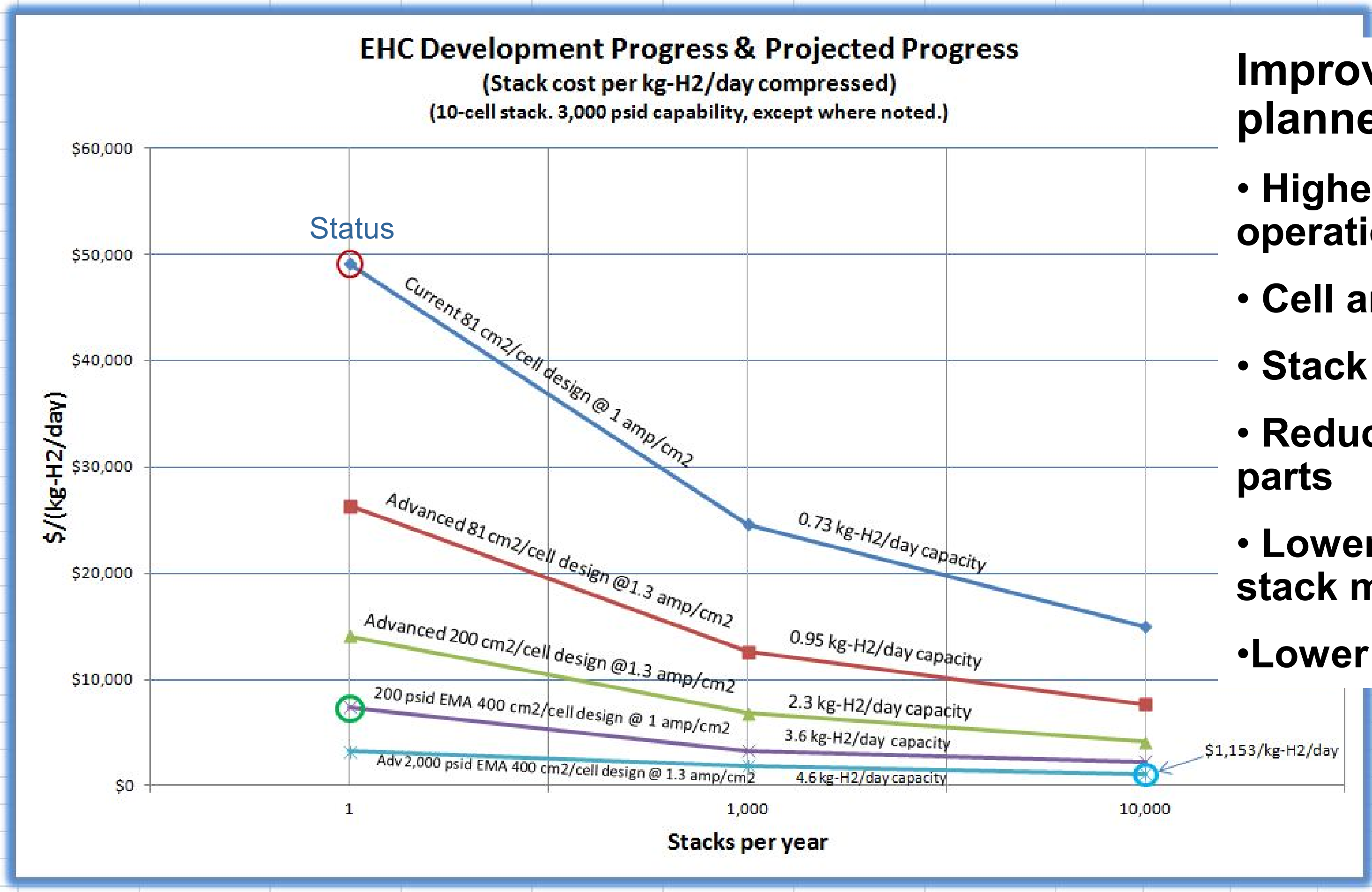
Improvements made:

- **Seals with higher pressure capability**
- **Improved MEA support**

Met DOE 2015 pressure target for forecourt compressors

Opportunities for Cost Reduction

(Stack Cost/H_2 Compression Capacity - $/kg-$H_2$/day)



Improvements planned:

- **Higher current density operation**
- **Cell area scale-up**
- **Stack scale-up**
- **Reduction in # of cell parts**
- **Lower cost cell and stack materials**
- **Lower cost fabrication**

Increase in current density and cell area are near-term focus

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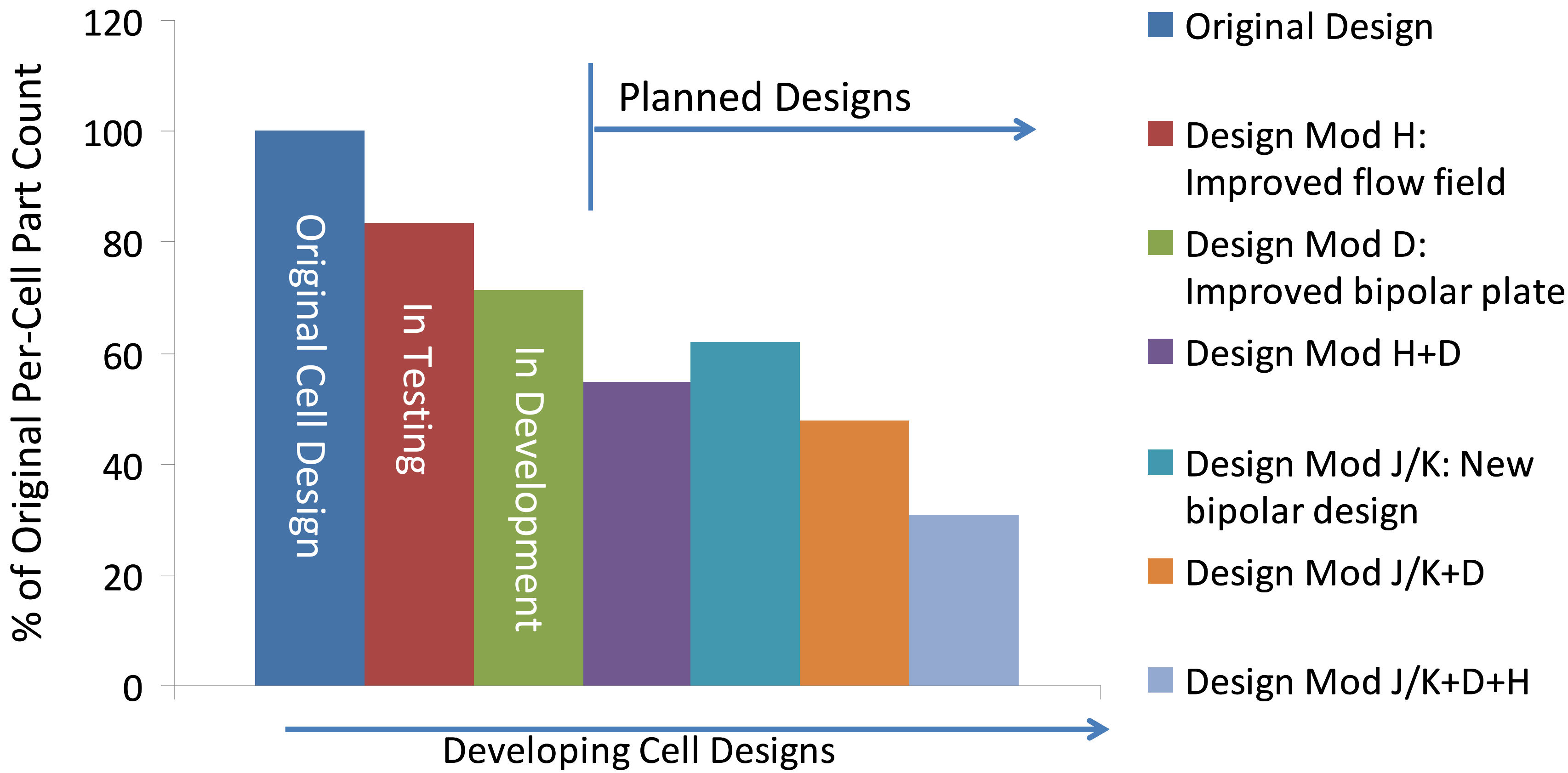
Reducing Cell Part Count

(Reduction in Parts per EHC Cell)



- **Cells with up to 30% reduction in part count in progress**
  - **Current 81 cm^2 design – advanced design 200 cm^2**

Collaborations

Prime

- **FuelCell Energy, Inc. (Industry):**
  - **System development and application engineering**

Subcontractor

- **Sustainable Innovations, LLC (Small Business):**
  - **Cell and stack design and fabrication**
  - **Scale-up design and fabrication**
  - **EHC stack cost reduction and estimates**

Proposed Future Work

- **Fabricate and test at least two additional baseline cells to further increase current density and reduce cell part count by up to 30%**
- **Validate baseline stack design (up to 5 cells) - demonstrate 500 hr life at 2,000 - 3,000 psi**
- **Select promising advanced EHC cell design for scale-up**
- **Fabricate cell hardware for advanced design (200 cm^2 active area)**
- **Design stack test facility for compression up to 12,000 psi**

Scale-Up Plan to Reach 8 lb/day

Activity Covered
Under Current Funding

Single Cell
200 cm^2 Active Area
500 – 1000 mA/cm^2
Up to 0.4 lb/dy

3 - Cell
200 cm^2 Active Area
500 – 1000 mA/cm^2
Up to 1.2 lb/dy

10 - Cell
200 cm^2 Active Area
500 – 1000 mA/cm^2
Up to 4 lb/dy

Activity Not Covered
Under Current Funding

20 - Cell
200 cm^2 Active Area
500 – 1000 mA/cm^2
Up to 8 lb/dy

Achievements in EHC Technology Development

Parameter	Program Goals	Current Status
Hydrogen Product Pressure	Up to 3,000-12,000 psi	**12,000 psi** ✓ single stage **6,000 psi** ✓ 2-stage
Hydrogen Inlet Pressure	5 - 300 psig	**0 – 2,000 psig** ✓
Compression Ratio	Up to 600:1	**800:1** ✓
Hydrogen Recovery Efficiency	90 - 95%	**>95%** ✓
Hydrogen Flux	500 -1000 mA/cm^2	**750 mA/cm^2 for >5000 hrs**
Hydrogen Capacity	2-4 lb/day at 3,000 psi	**~0.1 lb/day**
Life Testing	1,000 hrs at 3,000 psi	**>500 hrs**

Project Summary

Relevance: **Provide highly efficient, reliable and cost-effective hydrogen compression (up to 6,000/12,000 psi)**

Approach: **Develop electrochemical compressor – solid state device**

Technical Accomplishments:

- **Reduced capital cost by almost 50% by increasing current density from 400 to 750 mA/cm^2**
- **Operated >5,000 hrs at elevated current density (750 mA/cm^2)**
- **Demonstrated single stage pressure capability to >12,000 psi**

Collaborations: **Active partnership with industry (Sustainable Innovations) on materials, design and fabrication**

Proposed Future Work: **Scale-up cell design to 200 cm^2 active area to increase throughput and lower the cost**

Acknowledgement

- FCE: Pinakin Patel, Ray Kopp, Jonathan Malwitz
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- DOE: Monterey Gardiner, Scott Weil, Dave Peterson, Paul Bakke