FuelCell Energy

DOE Hydrogen Program

Electrochemical Hydrogen Compressor

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Project ID #PD048

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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

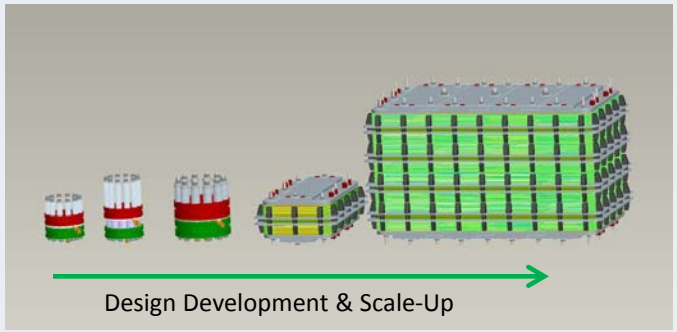
Impact of EHC:

- **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)**

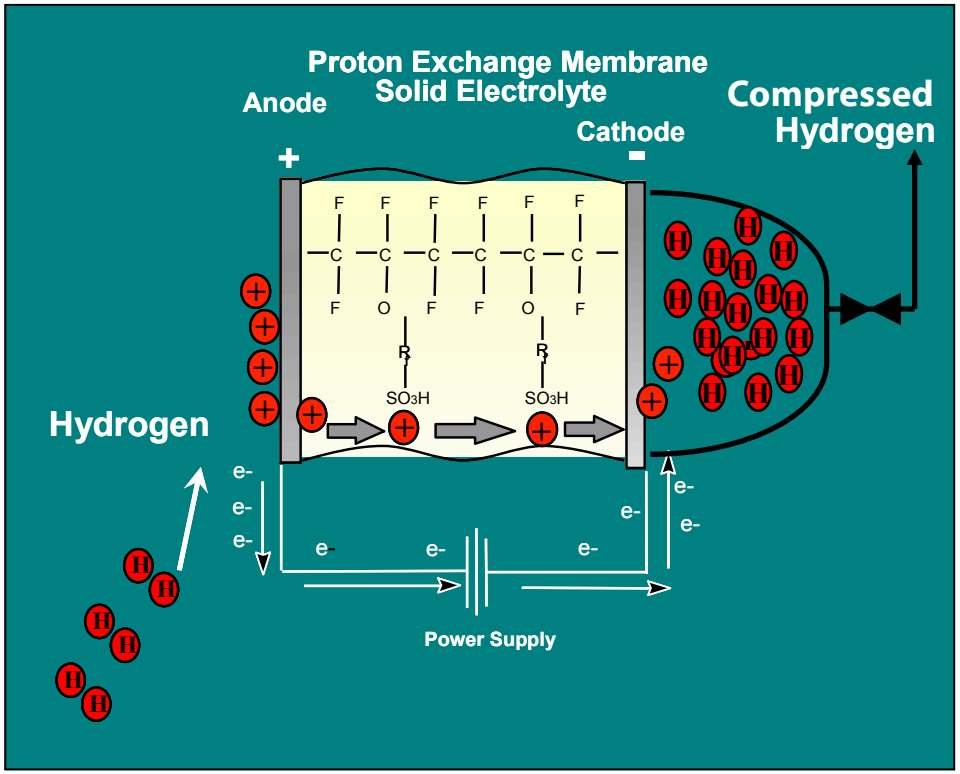
Approach

- **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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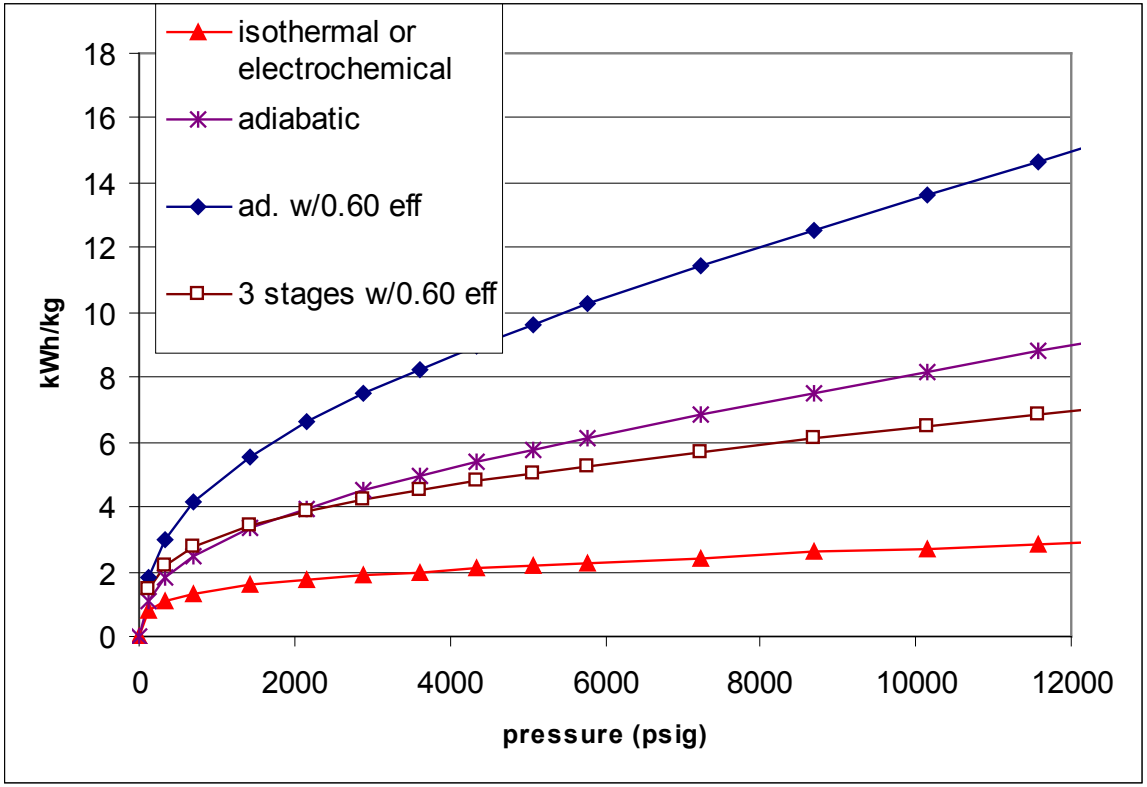
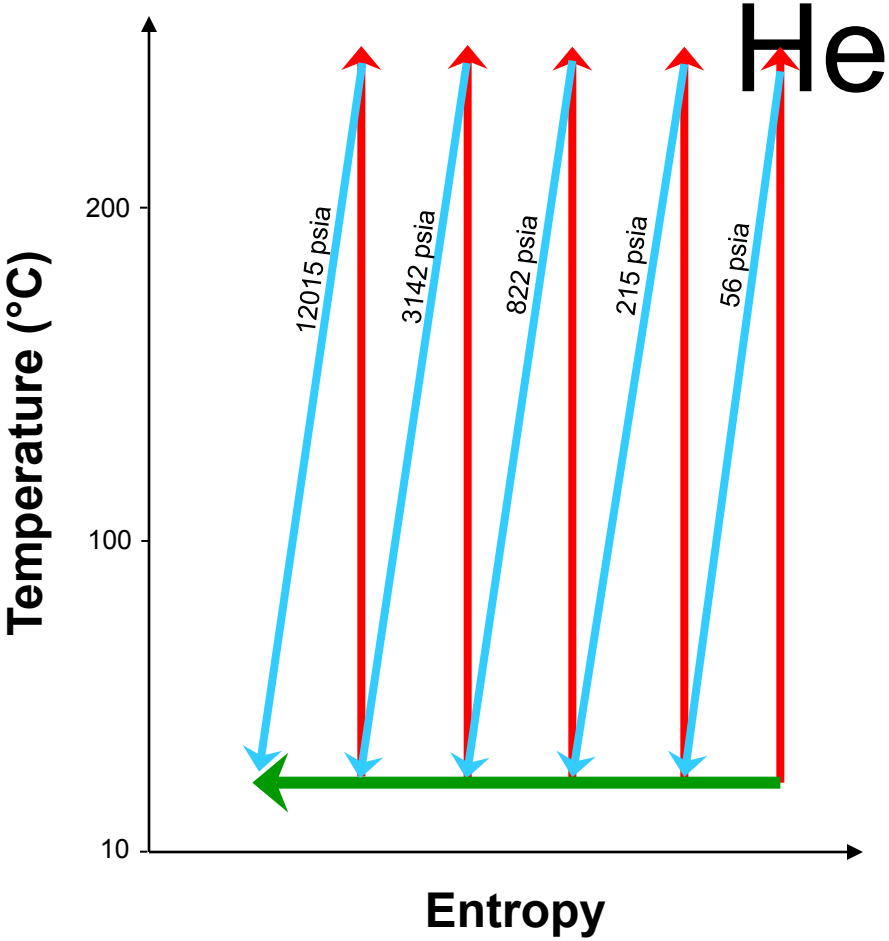
Calculated Compressor Performance Values



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

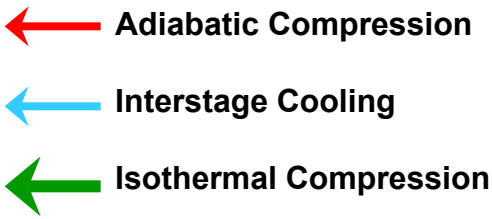
Compression Heat



Multistage Adiabatic Compression with Interstage Cooling

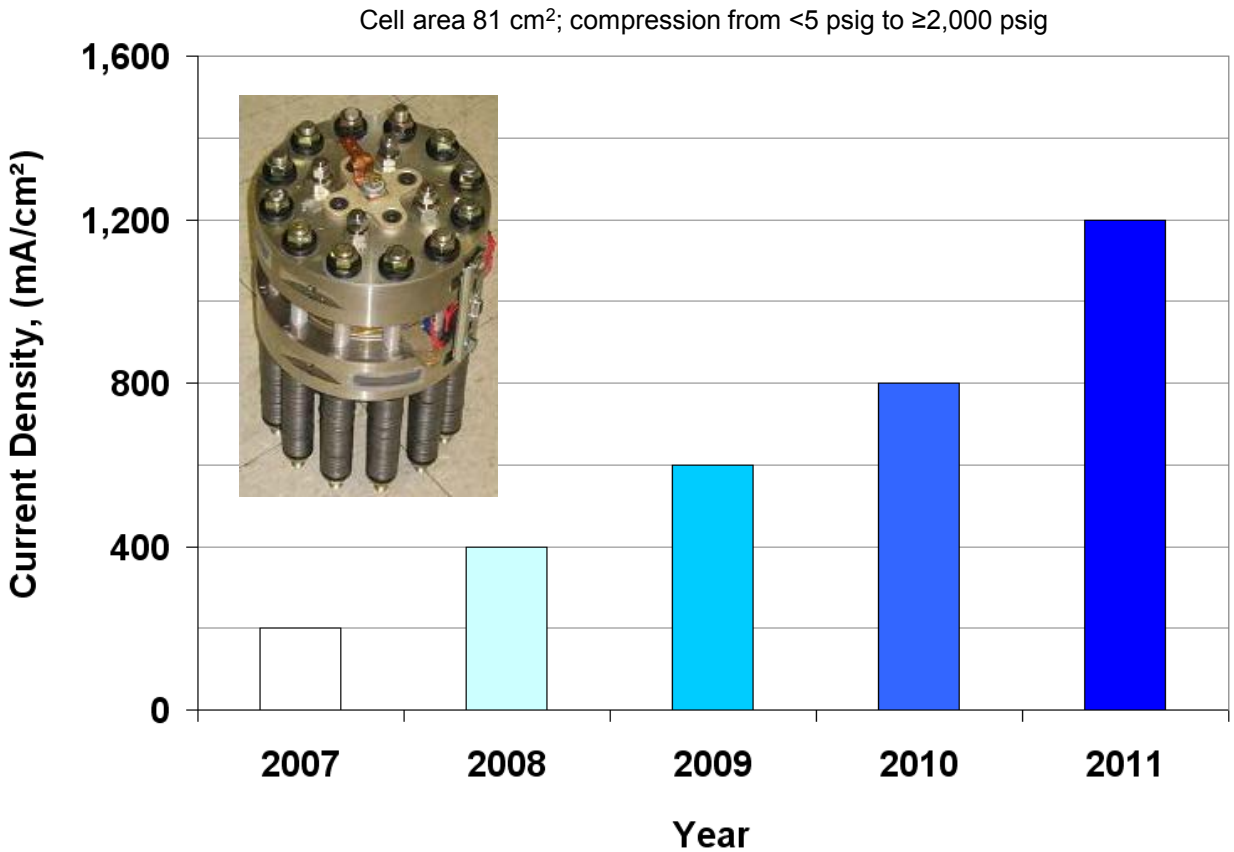
vs.

Isothermal Compression of EHC



Hydrogen does not significantly heat up during compression in EHC

EHC Cost Reduction

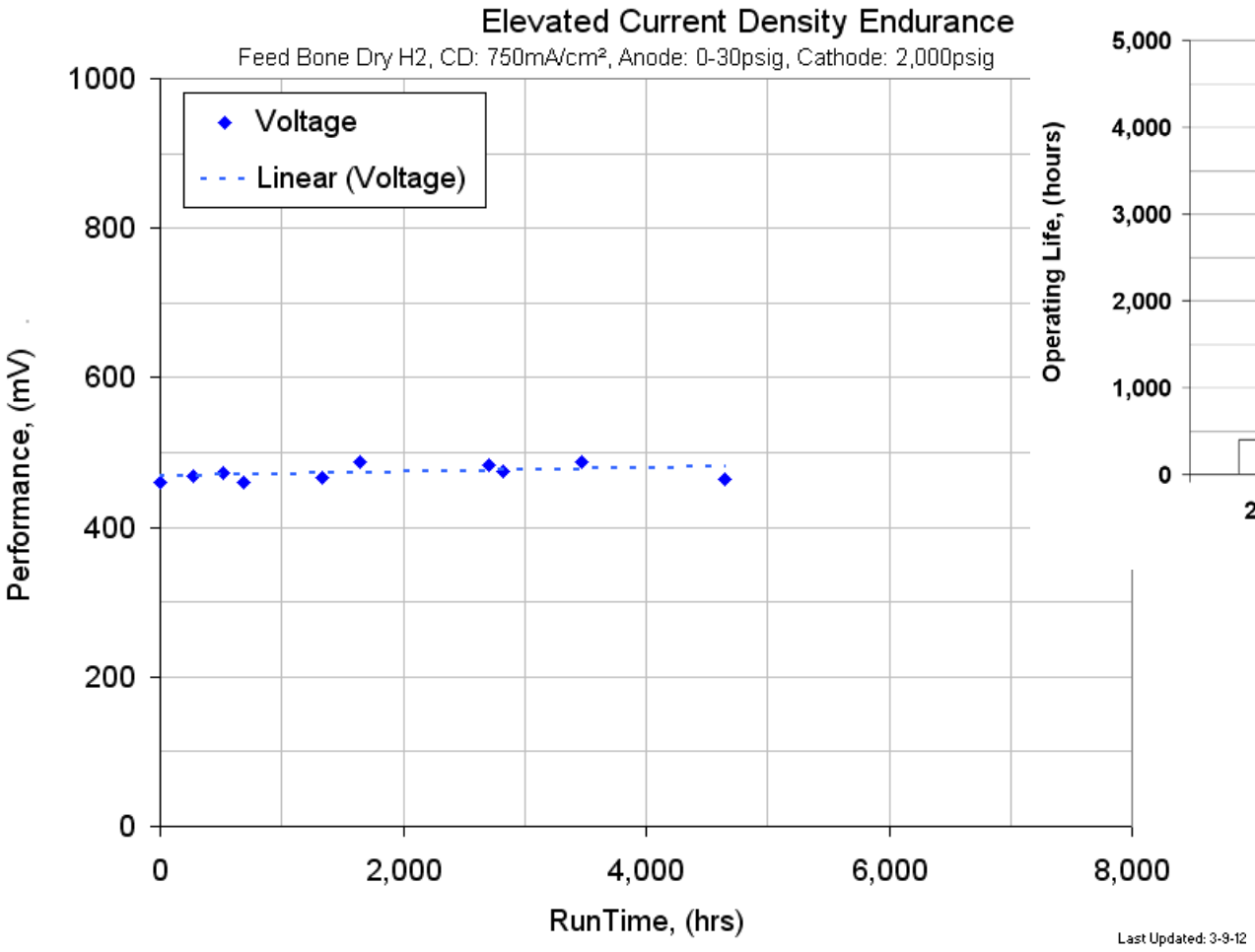


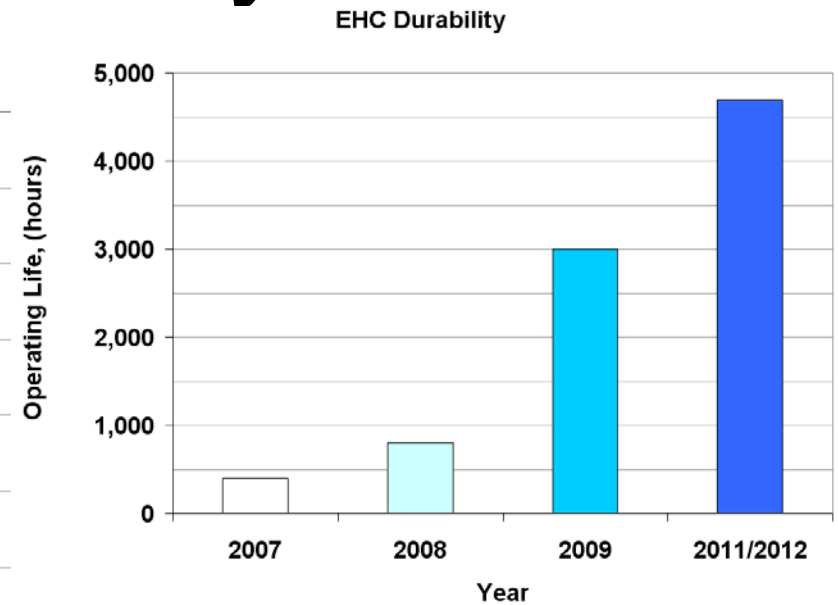
Improvements made:

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

Six-fold increase in current density

EHC Durability



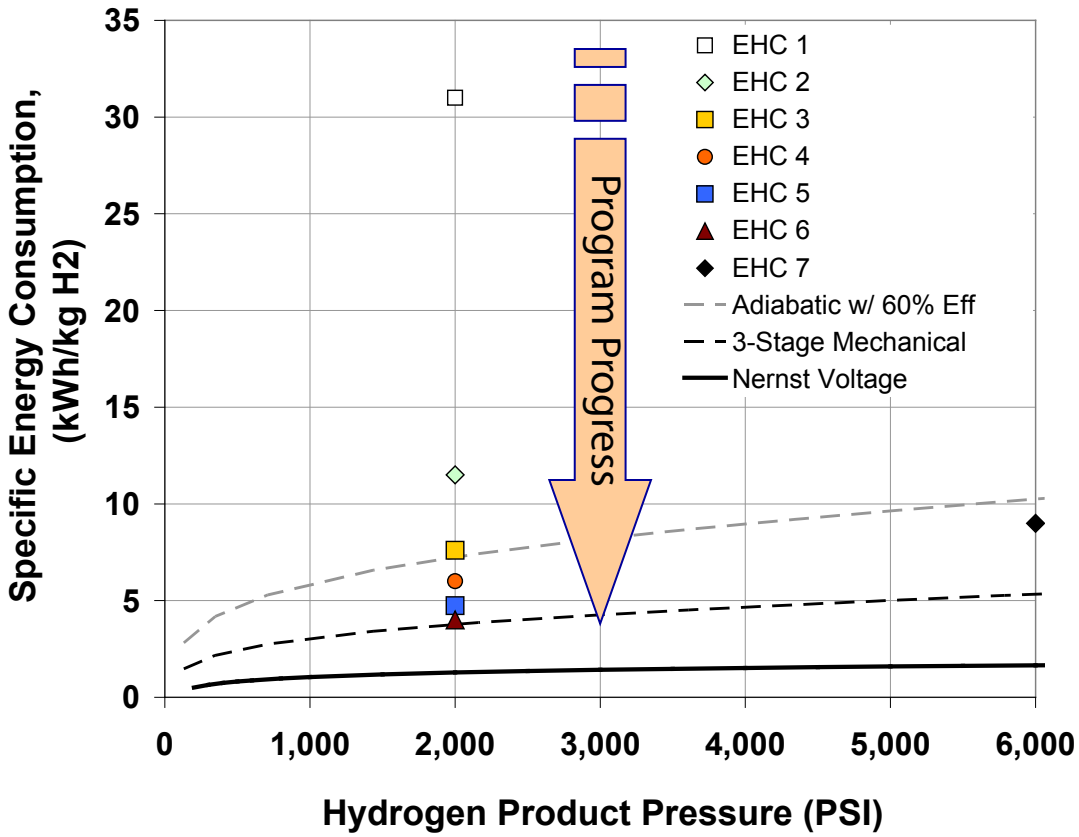


Improvements made:

- **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)

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

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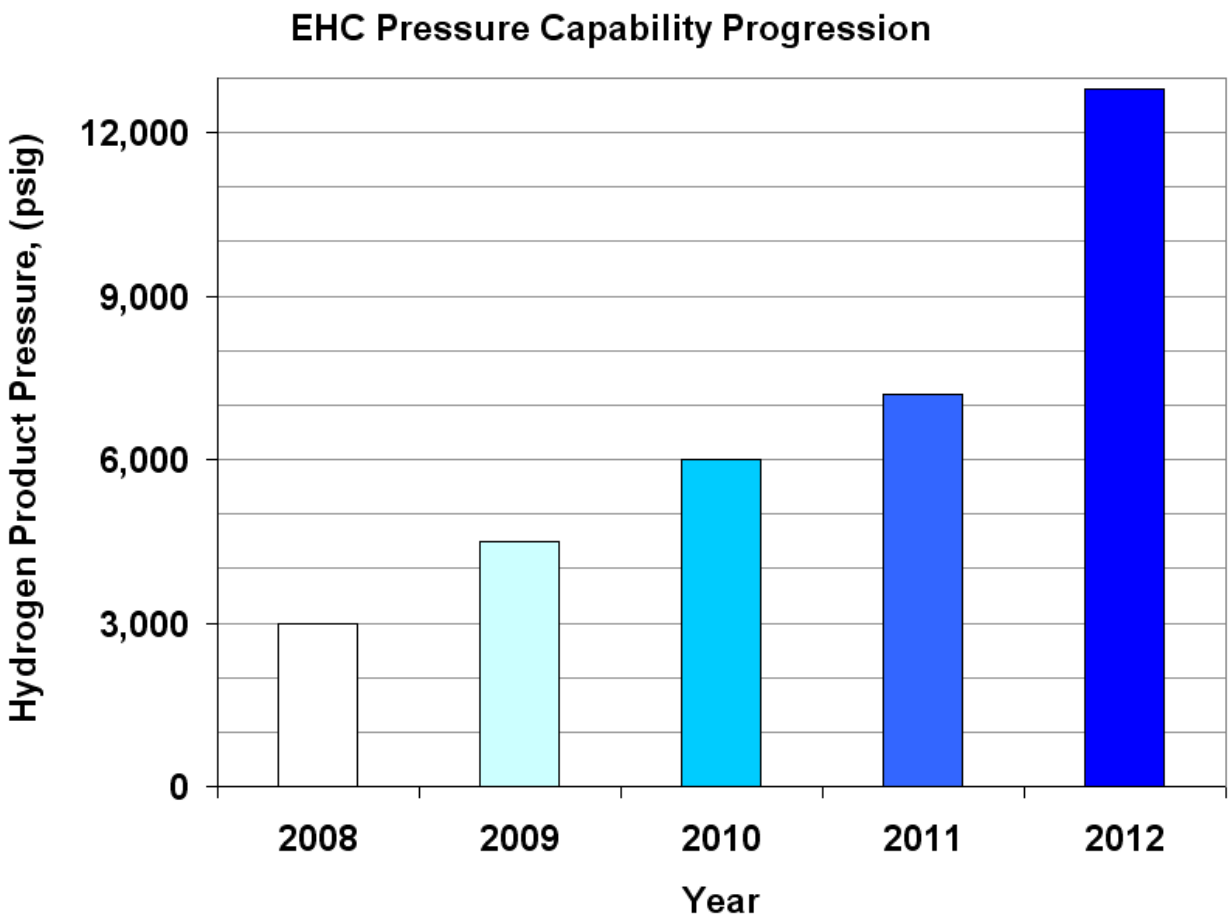
EHC Pressure Capability



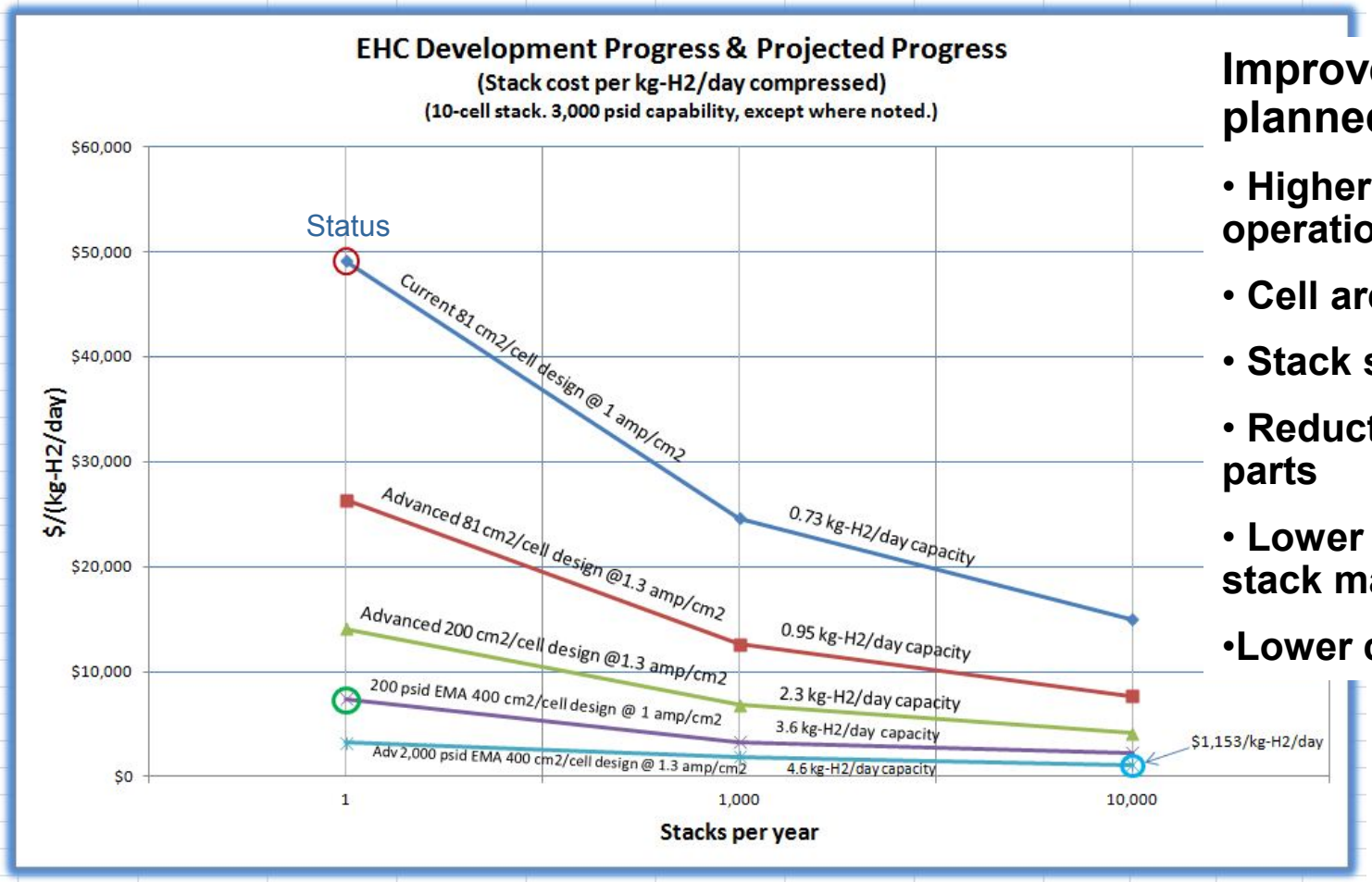
Improvements made:

- **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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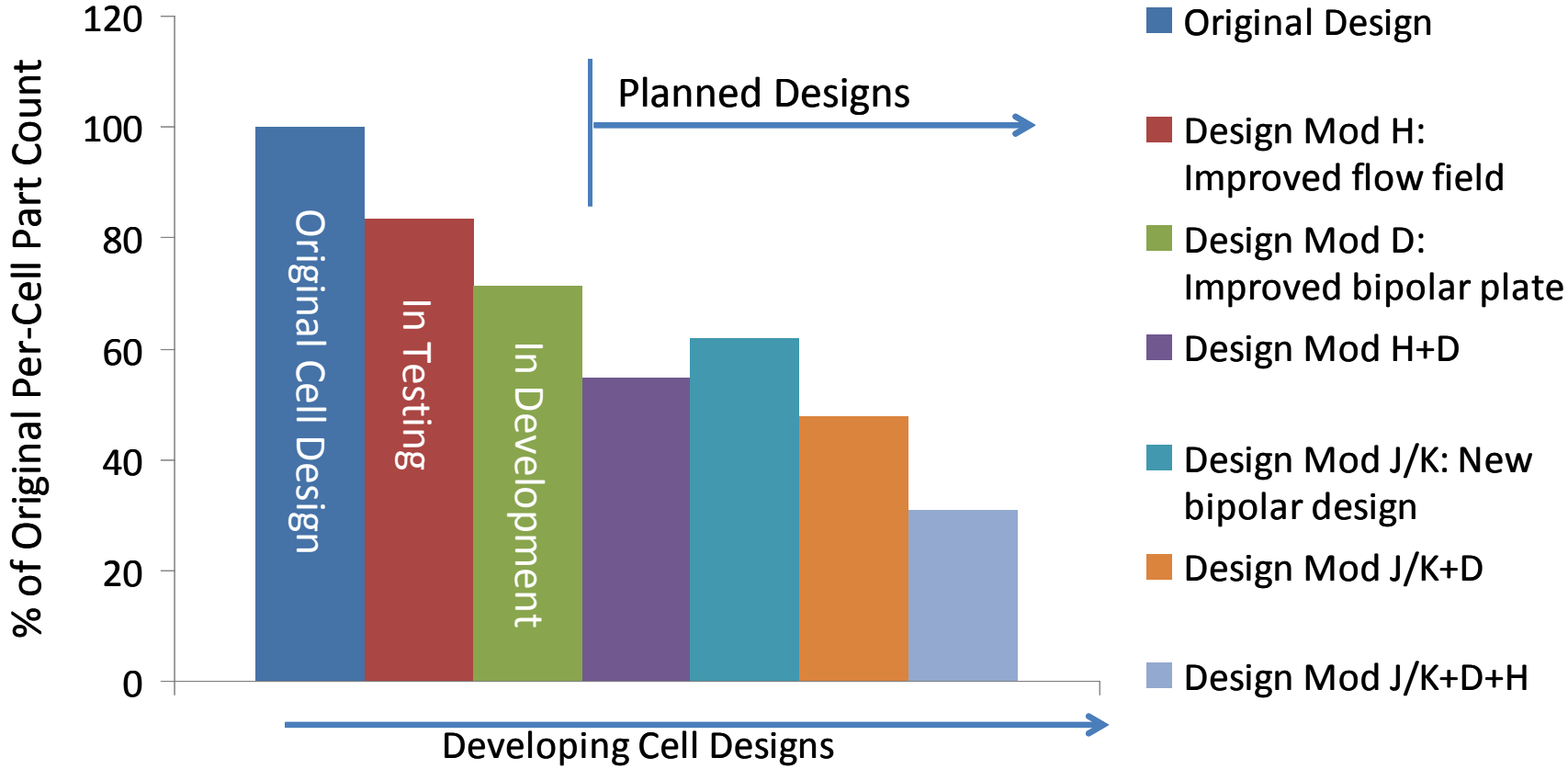
Reducing Cell Part Count

(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

Activity Not 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

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
- Sustainable Innovations, LLC: Trent Molter and team
- DOE: Monterey Gardiner, Scott Weil, Dave Peterson, Paul Bakke