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DOE Hydrogen Program

# Development of Highly Efficient Solid State Electrochemical Hydrogen Compressor (EHC)

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Project ID #
pdp_22_lipp

# Overview

## Timeline: Phase II

- Start: August 2008
- End: August 2010
- 38% complete

## Budget

- Total project funding
  - **DOE share $750k**
  - **Contractor share $218k**
- Funding received in FY08: $8.1k
- Funding for FY09: $375k

## Barriers

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

## Partners

- Sustainable Innovations, LLC
- University of Connecticut

# Relevance

## Objectives:

- **Pressure Capability:** Develop designs and materials to increase EHC pressure capability from 2,000 to 6,000 psi
- **Operating Cost:** Improve the cell performance to reduce power consumption (compression efficiency)
- **Capital Cost:** Reduce the EHC cell cost by increasing operating current density
- **Life:** Study thermal and water management options to increase system reliability and life

# 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

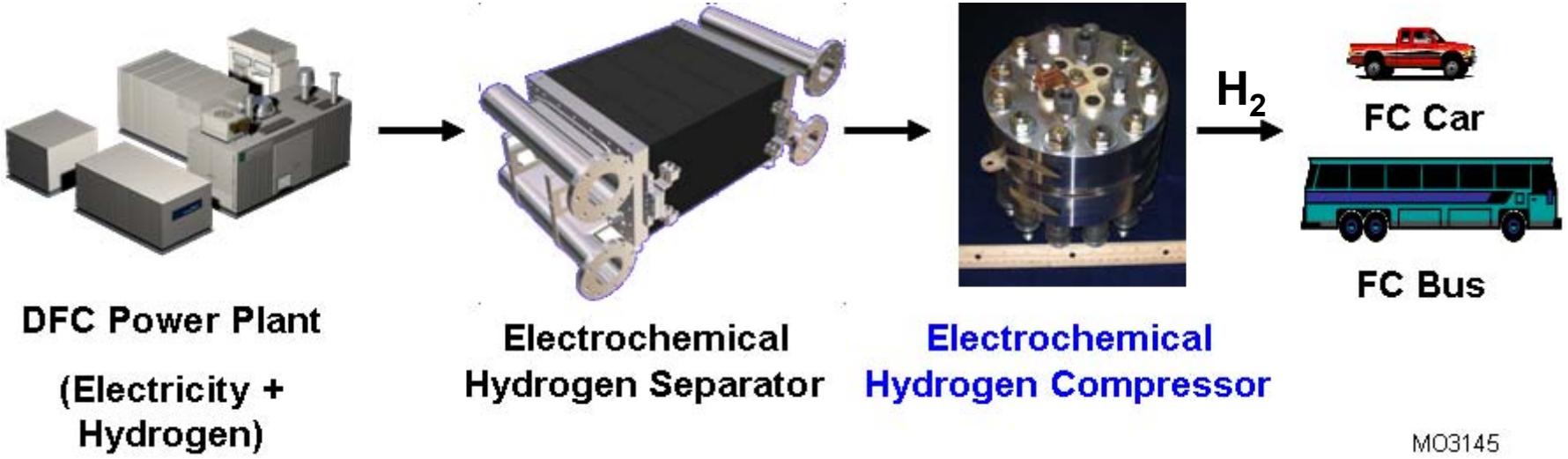
- **Use high-pressure electrolyzer experience for mechanically robust cell design**
- **Higher current density operation to minimize capital and operating costs**
- **Improved flow field design to increase $H_2$ recovery efficiency**
- **Simple system: Reduce capital cost by reducing catalyst loading and humidification requirements**

# Milestones

| Parameter | FY08 Goals | FY09 Goals | Current Status |
|---|---|---|---|
| Hydrogen Product Pressure | 2,000 psi | Up to 6,000 psi | 4,500 psi |
| Minimize Hydrogen Inlet Pressure | 30 psig | 5 psig | **< 5 psig** ✓ |
| Compression Ratio | 40:1 | Up to 300:1 | **300:1** ✓ |
| Hydrogen Recovery Efficiency | 90% | 96% | Up to 95% |
| Pressure Cycling | 10 cycles to 2,000 psi | 50 cycles to 4,500 psi | >1,000 cycles to 3,000 psi |
| Life Testing | 50 hrs at 2,000 psi | 500 hrs at 4,500 psi | ~3,000 hrs at 3,000 psi |
| No. of Cells in Stack | 1 | 3 | **3** ✓ |

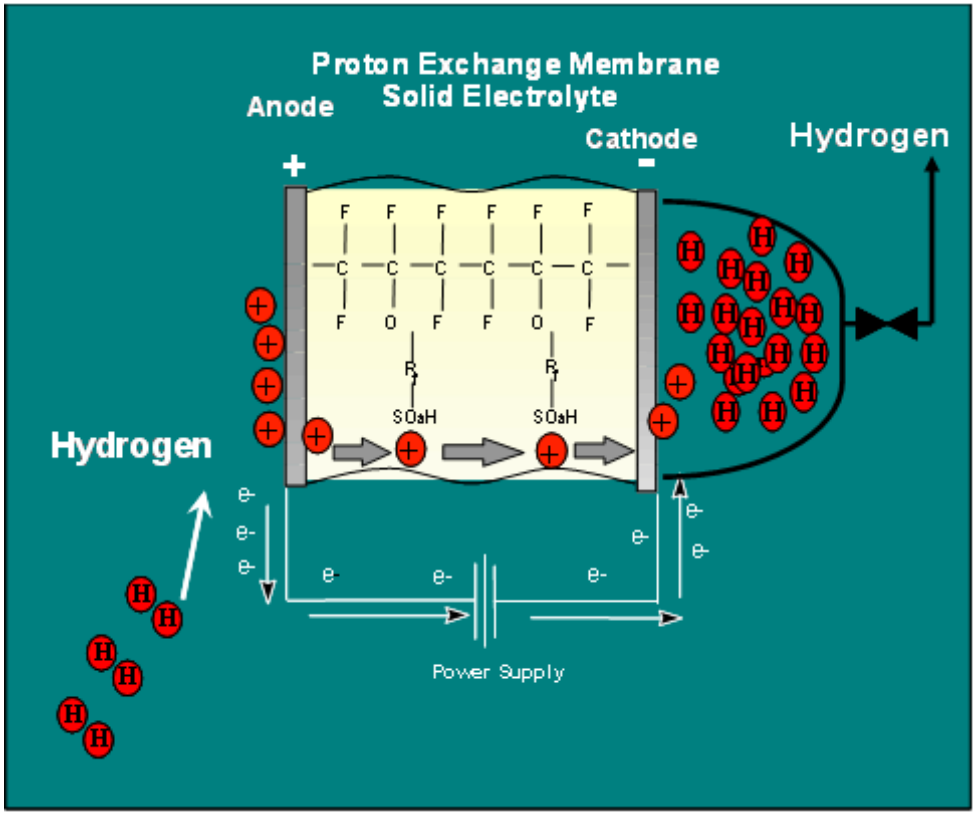
- **All FY08 Milestones Exceeded**
- **Three FY09 Milestones Met already, on Track to Meet all FY09 Goals**

# Enabler for Hydrogen Infrastructure




**The EHC Technology has Unique Synergy to the Hydrogen Energy Stations**

# Principle of an Electrochemical Hydrogen Compressor




- Simple Operating Principle with No Moving Parts – Solid State !
- Use of Hydrogen Electrode for High Compression Efficiency



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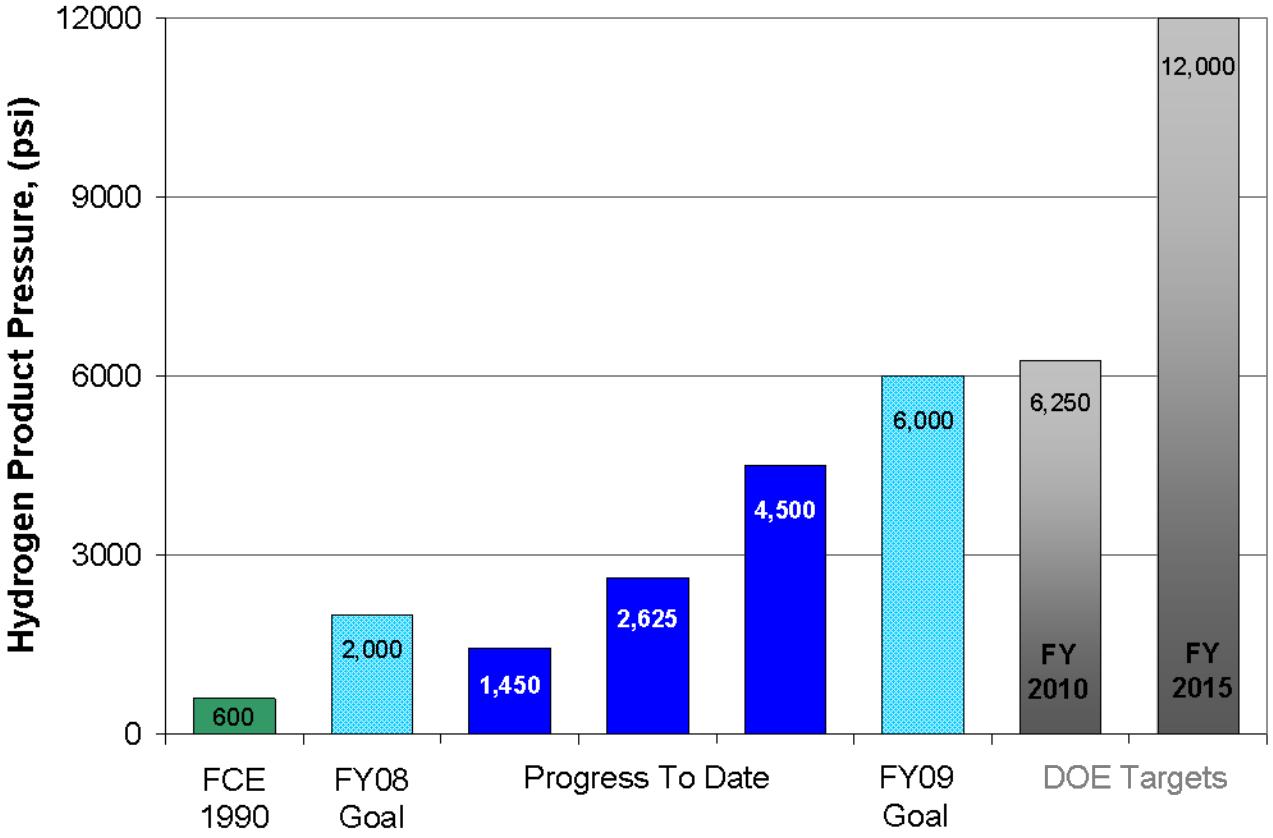
# Technical Accomplishments

## EHC short stack operation demonstrated

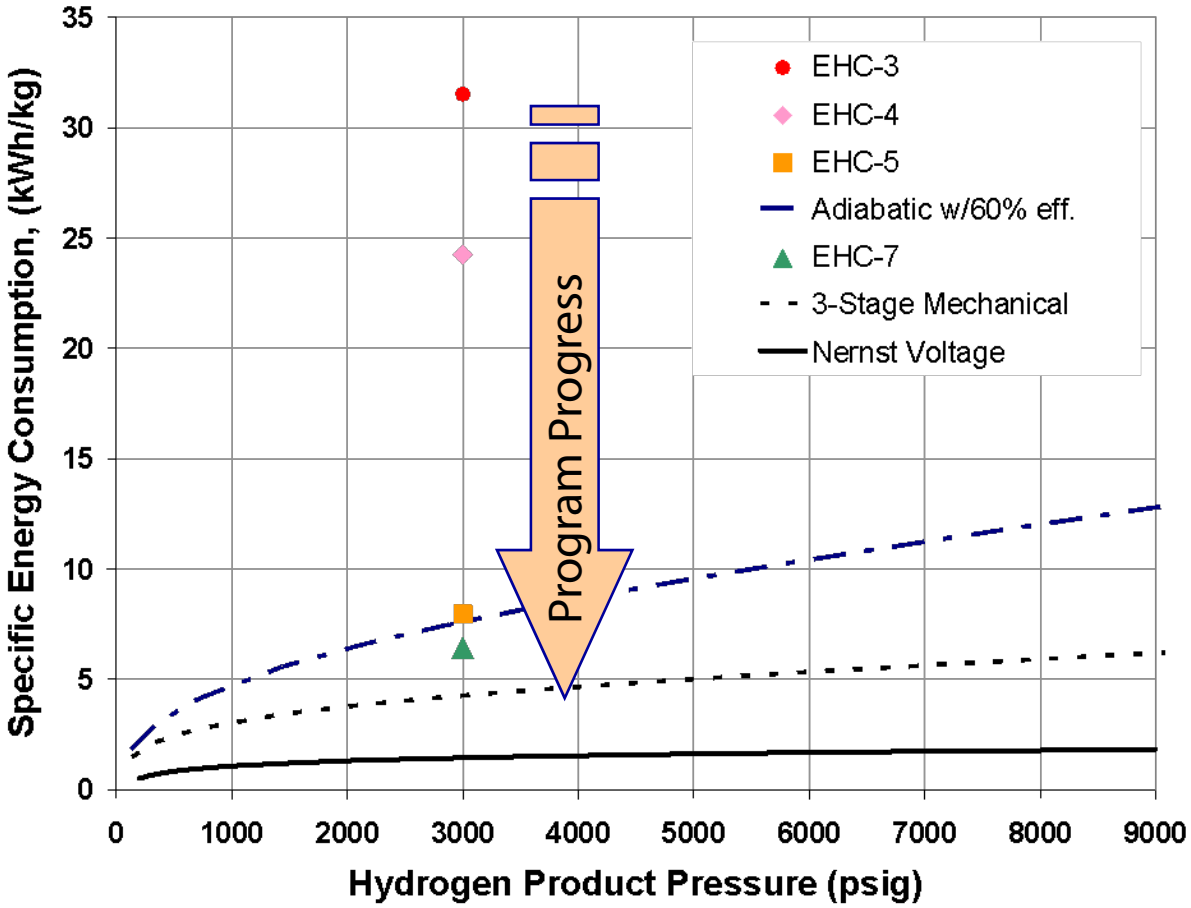
- **Compression Mode Operation:** Increased capability from 3,000 psi to 4,500 psi in a single stage EHC cell (300:1 compression ratio)
- **Compression Efficiency:** Reduced cell resistance by 70% → energy consumption comparable to mechanical compressors
- **Pressure Cycling:** Completed >1,000 pressure cycles from 100 to 3,000 psi without performance loss
- **Stack:** Scaled-up EHC technology from single cell to 3-cell stack (up to 3,000 psi)

# Hydrogen Product Pressure




- **Met FY08 Pressure Goal**
- **On Track to Meet FY09 Pressure Goal**

# Energy Consumption




**Significant Reduction in EHC Specific Energy Consumption Achieved**

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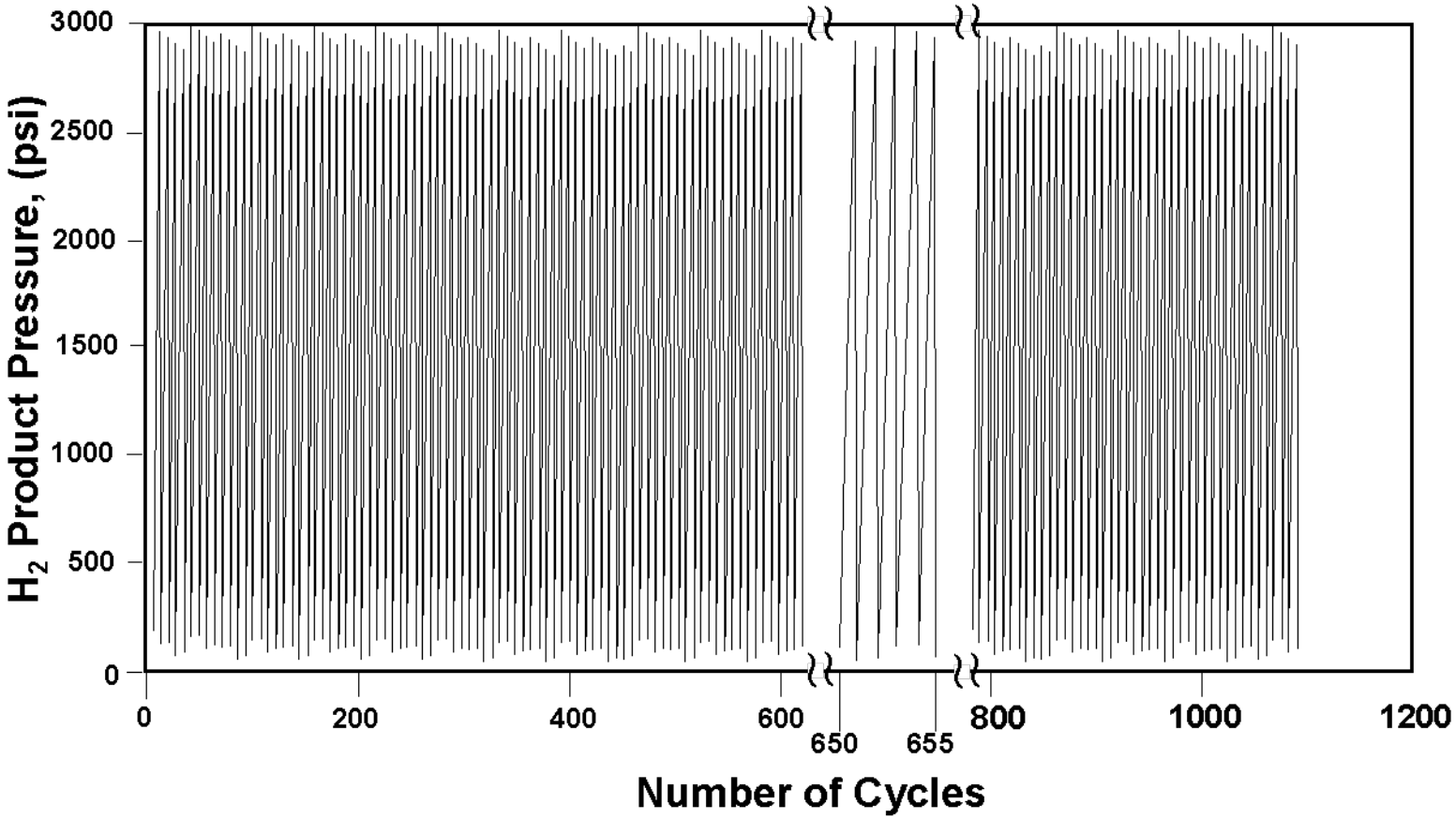
# Pressure Cycling




**> 1,000 Pressure Cycles to 3,000 psi Validates Robust Cell Design**

# Collaborations

## Prime

- **FuelCell Energy, Inc.* (Industry):**
  - **Leading fuel cell developer for over 30 years**

## Subcontractors

- **Sustainable Innovations, LLC* (Industry):**
  - **Cell and stack design and fabrication**
- **University of Connecticut* (Academic):**
  - **Identification and evaluation of low-cost materials**

*** Within DOE $H_2$ Program**

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# Proposed Future Work

- Increase pressure capability of single-stage EHC cell from 4,500 to 6,000 psi
- Further reduce power consumption of current design
- Develop and validate multi-cell stack design in a 10-cell stack
- Demonstrate 2 lb/day $H_2$ at 3,000 psi
- Increase hydrogen recovery to 98%
- Demonstrate 2,000 hr life at 6,000 psi in single cell
- Estimate capital and operating costs

# Project Summary

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

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

**Technical Accomplishments:** Demonstrated single-stage compression to 4,500 psi, operated 3-cell stack

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

**Proposed Future Work:** Further increase pressure, efficiency and throughput (2 lb/day $H_2$ at 3,000 psi)

# Acknowledgements


- **DOE: Monterey Gardiner, Richard Farmer, Tim Armstrong**
- **Sustainable Innovations, LLC: Trent Molter, Mark Dristy**
- **FCE: Jonathan Malwitz, Ray Kopp, Pinakin Patel**