Development of a Hydrogen Home Fueling System

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Project ID#: PD069

Overview

Timeline

- Project started: 07/20/2009
- Project ends: 04/19/2010
- Percent completed: 100%

Budget

- Total budget funding
  - DOE $100k
  - Contractor $ 0
- Funding received in FY09
  - $ 84k
- Funding for FY10
  - $ 16k

Barriers

Hydrogen generation by water electrolysis

- G – Capital cost
- H – System efficiency

Fuel Cell

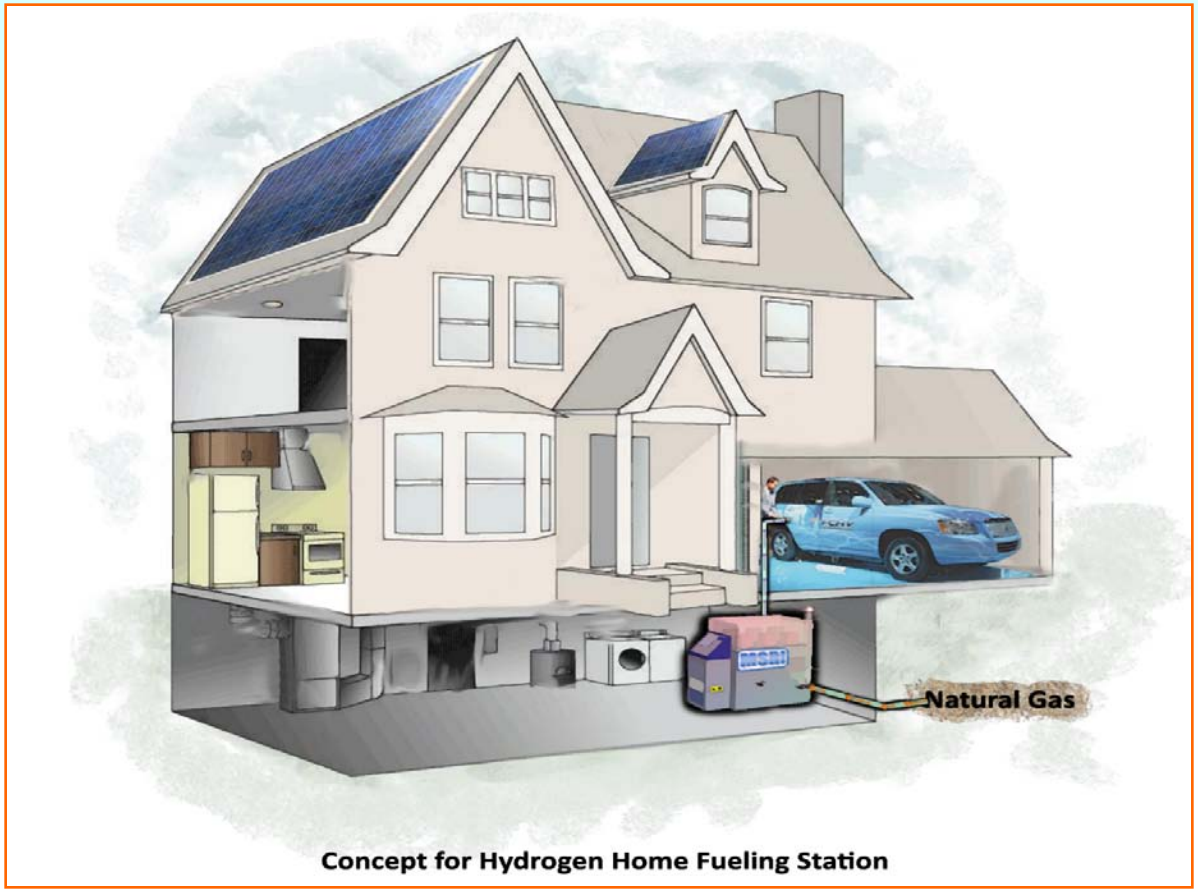
- A – Durability
- C – Performance

Partners

- Materials and Systems Research Inc. – advanced H_2 production technology and system development (G. Tao)
- National Renewable Energy Laboratory – techno-economic analysis (M. Penev)

Objective/Relevance

Overall Objective	• To investigate the development of a hydrogen home fueling system that tri-generates hydrogen, power, and heat directly using distributed natural gas



Concept for Hydrogen Home Fueling Station

Approach

H_2 Home Fueling System Development

A. Fueling system requirement identification

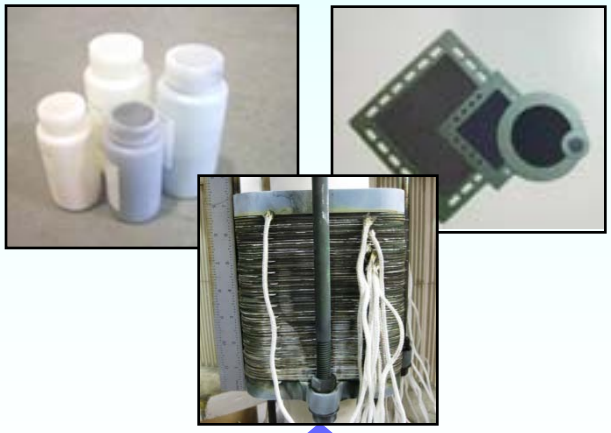
B. H_2 home fueling system design

C. Stack stability evaluation

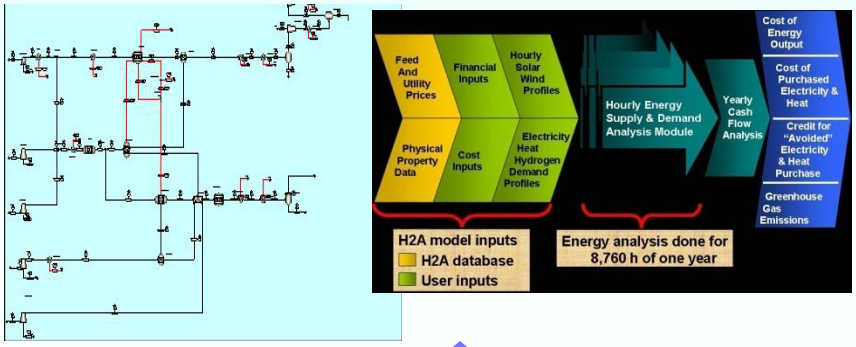
Techno-economic Evaluation

A. H2A analysis implementation

B. Technology development plan construction



MSRI, NREL



NREL, MSRI

Milestones

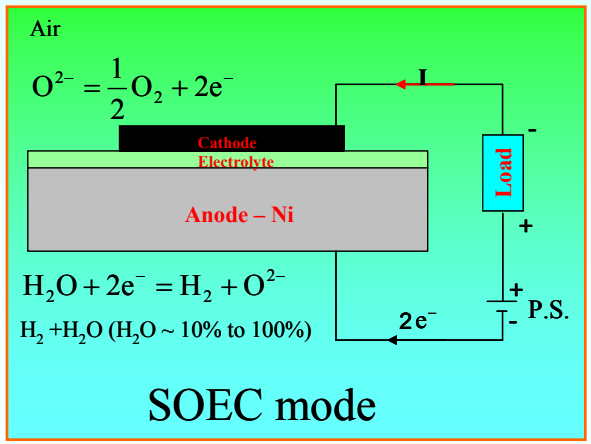
Milestones	Progress Notes	Comments	% Completed
H_2 home fueling system design goal	Achieved the design goal of system efficiency > 55% for an optimum system configuration	System performance analyses were carried out with the ASPEN model for a H_2 home fueling system with different conceptual configurations.	100%
H2A model implementation	Implemented the H2A model with MSRI's unique H2 production technology	H_2 home fueling system would be treated as one type of home appliances. Government incentive is extremely important in the early stage of market penetration. Costs of stacks and BOP components should be reduced.	100%
Degradation rate less than 5%/1000 hrs	Demonstrated a degradation rate < 3%/1000 hrs over a 500 hrs test	Built short stacks and tested them in hybrid mode fueled with line natural gas. 500 hrs long-term test was performed in the electrolyzer mode.	100%

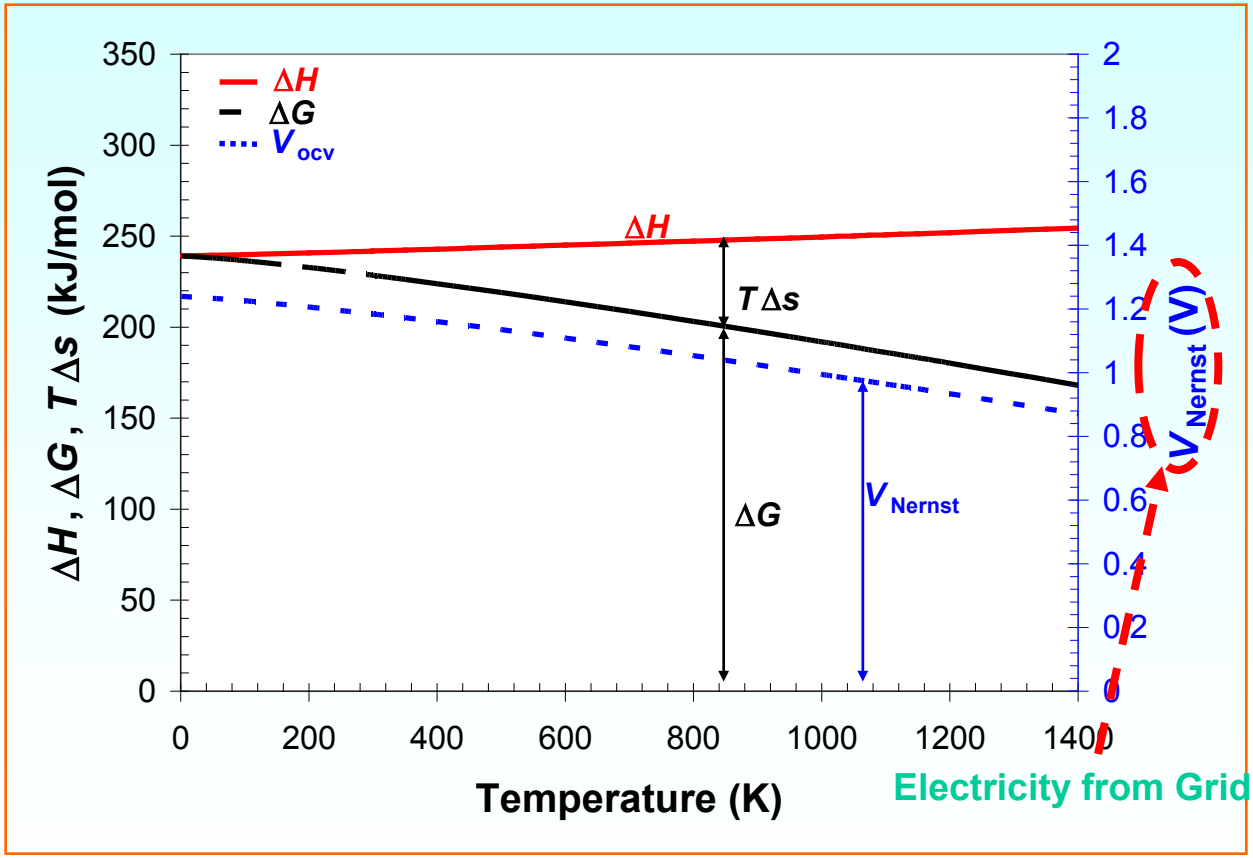
H_2 Production via Electrolysis Technologies

Conventional electrolysis technologies: KOH & PEM (low temperature), SOEC (high temperature)

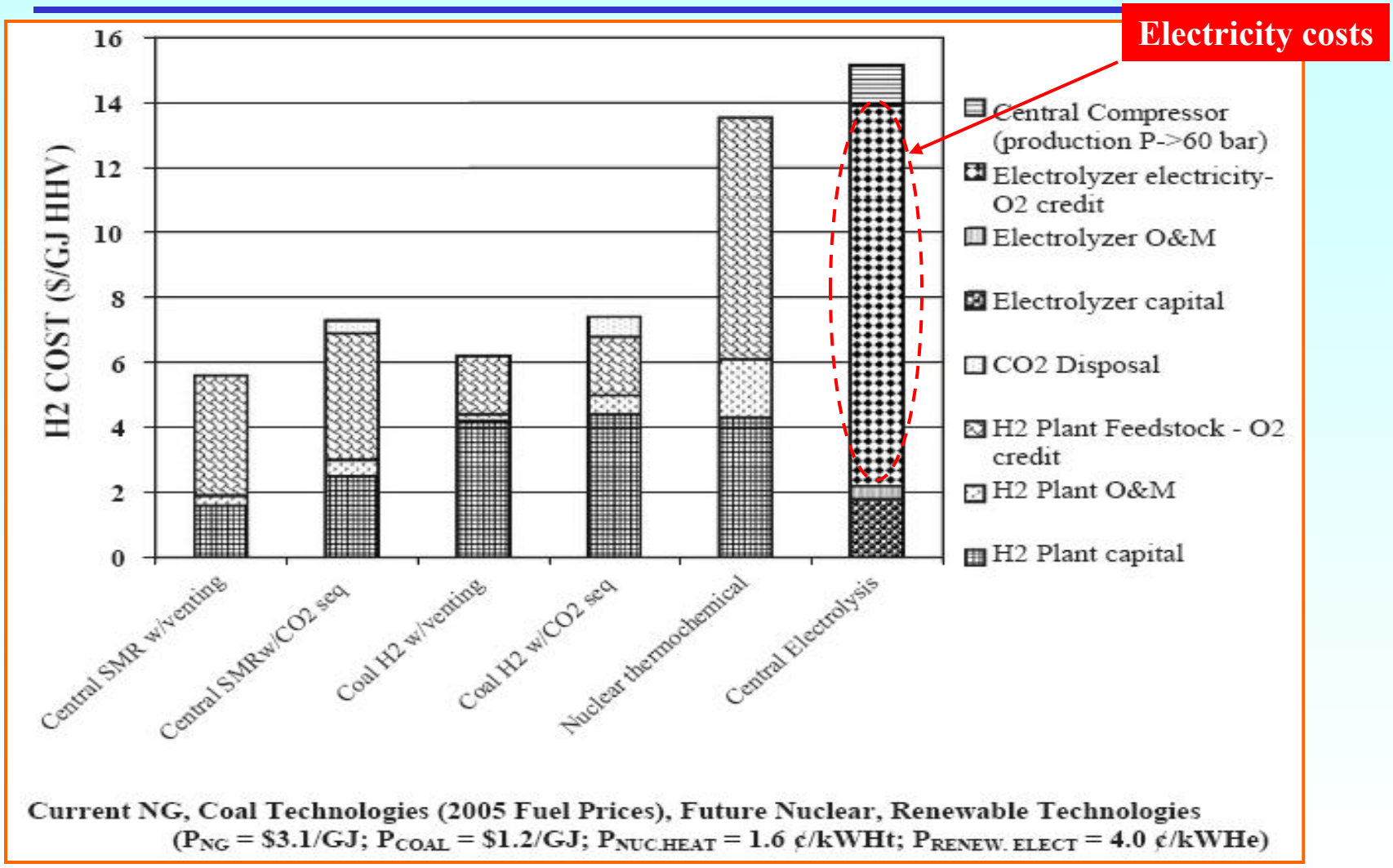
Input: H_2O, and electricity ($$)
Output: H_2 and O_2 (by-product)

$$2H_2O \rightarrow 2H_2 + O_2$$





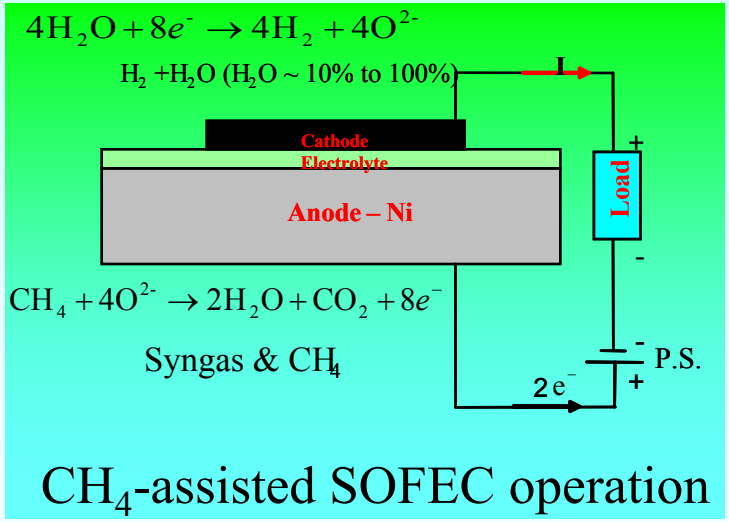
Cost of Hydrogen*



* R.H. Williams, "Alternative Technologies and Strategies for Hydrogen Production", Workshop on future energy issues – future energy resources national defense university, Washington DC, May 2003

Fuel-assisted Electrolyzer for H_2 Production

A Solid Oxide Fuel-Assisted Electrolysis Cell (SOFEC) directly applies the energy of a chemical fuel to replace the external electrical energy required to produce hydrogen from water/steam; thus decreasing the costs of energy relative to a traditional electrolysis process.



CH_4-assisted SOFEC Reaction: **Electrochemical Process**

$4H_2O_{(ca)} + 8e^- \rightarrow 4H_{2,(ca)} + 4O^{2-}$ at cathode

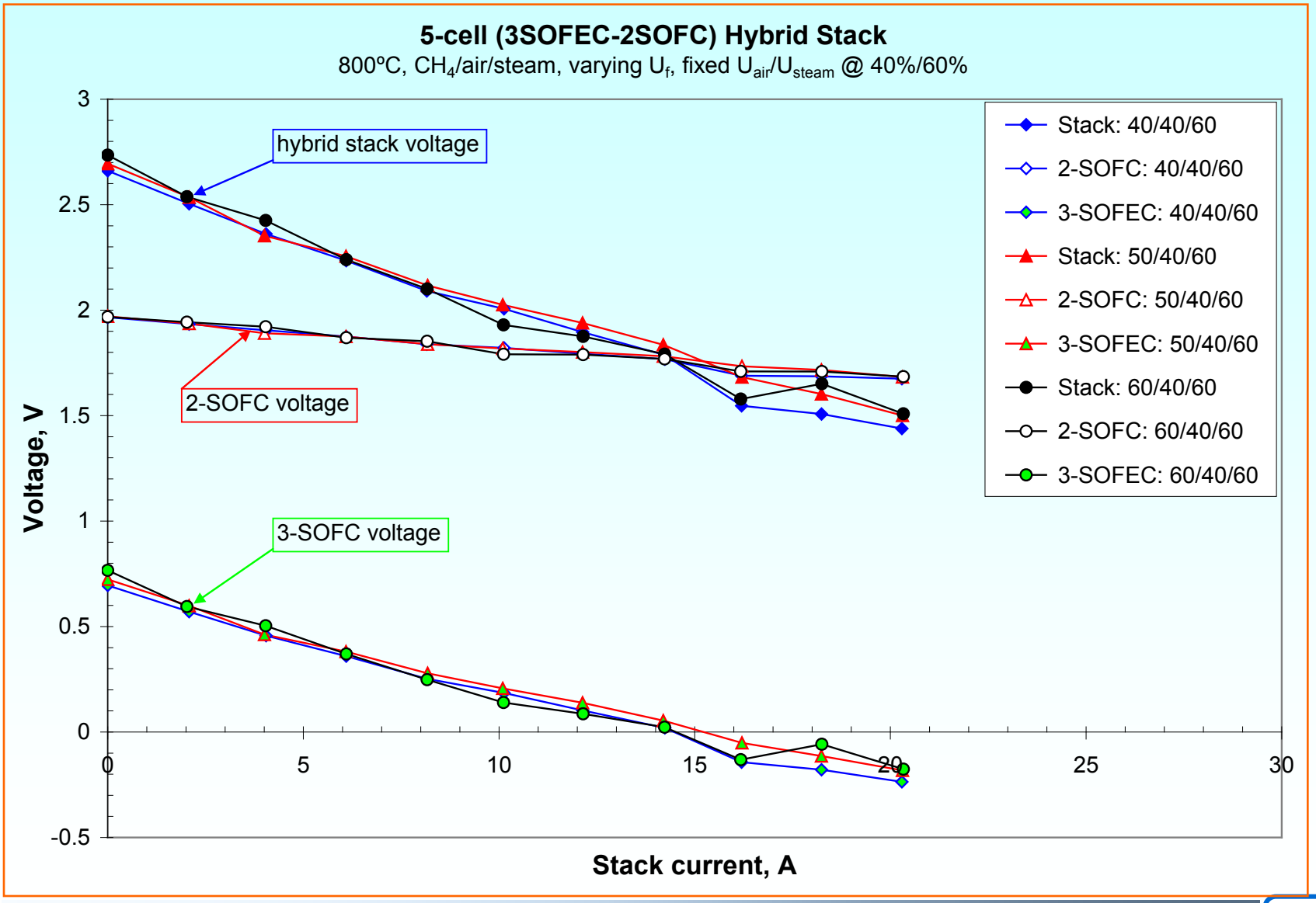
Electrolyte

$CH_{4,(an)} + 4O^{2-} \rightarrow CO_{2,(an)} + 2H_2O_{(an)} + 8e^-$ at anode

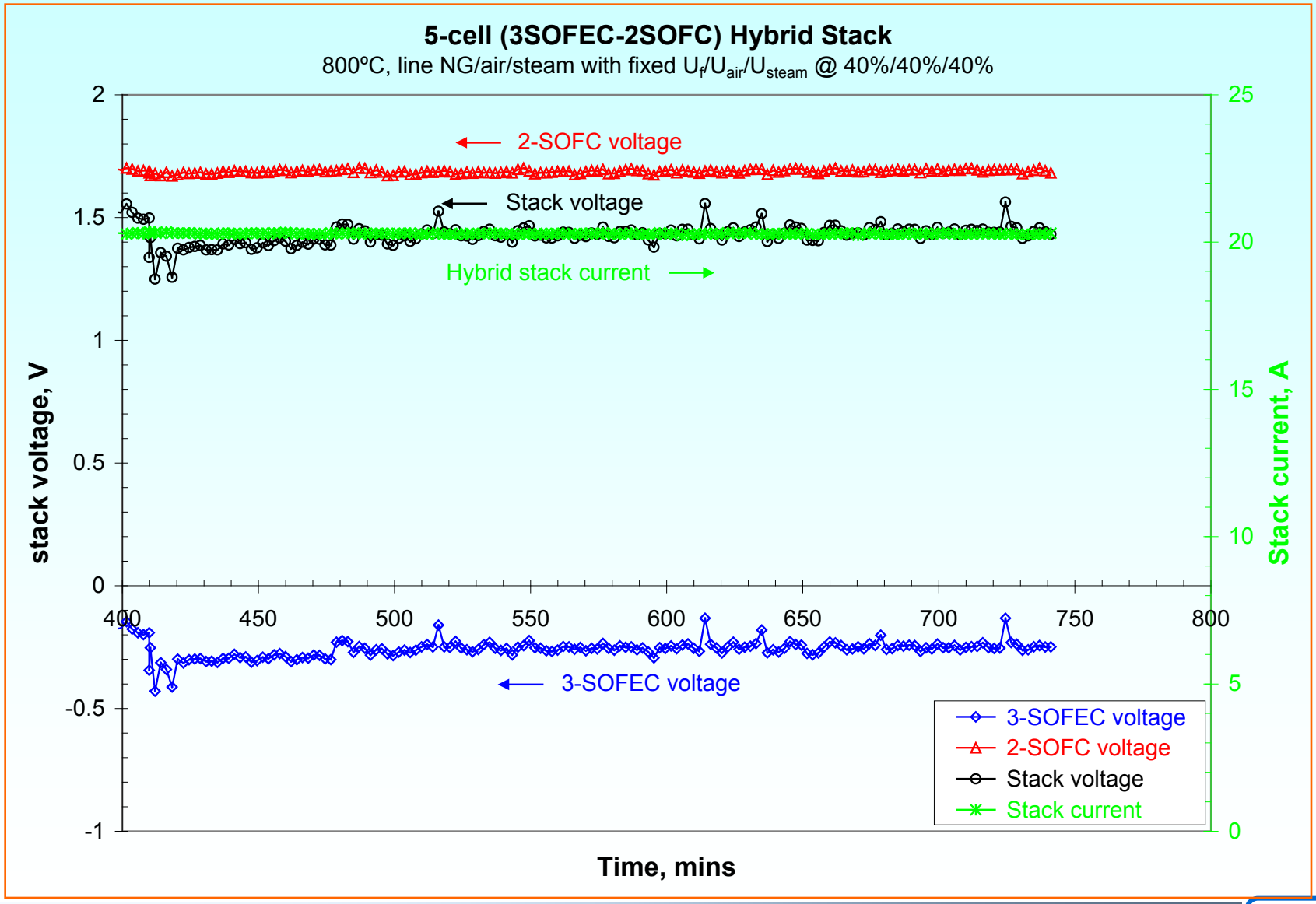
$CH_{4,(an)} + 2H_2O_{(ca)} \rightarrow CO_{2,(an)} + 4H_{2,(ca)}$ Overall

Pure H_2 formed. No need for H_2 separation membranes and have lower electricity requirement.

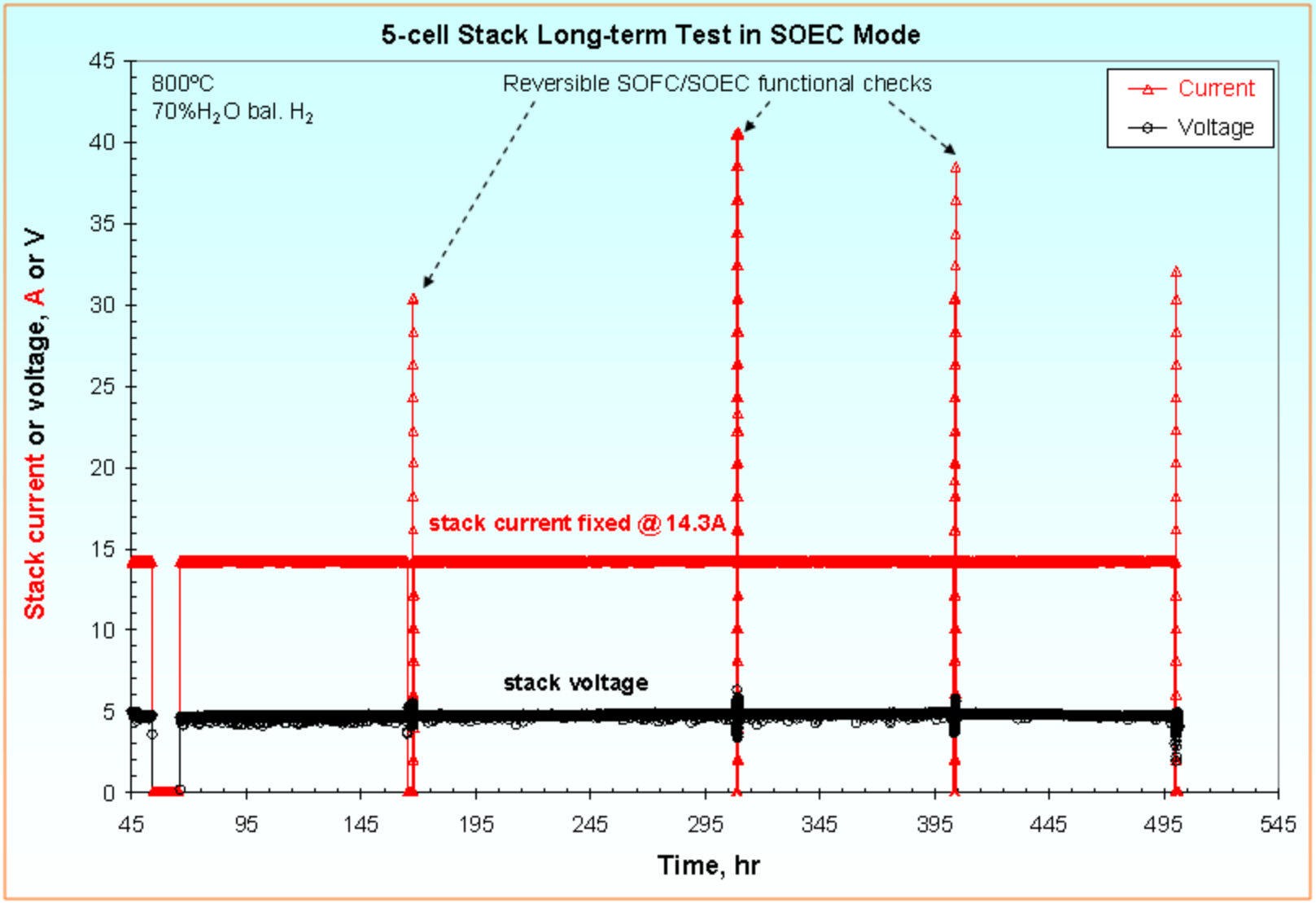
H_2 Production Using SOFEC-SOFC Hybrid Technology



Continuous H_2 Production Assisted with NG Fuel

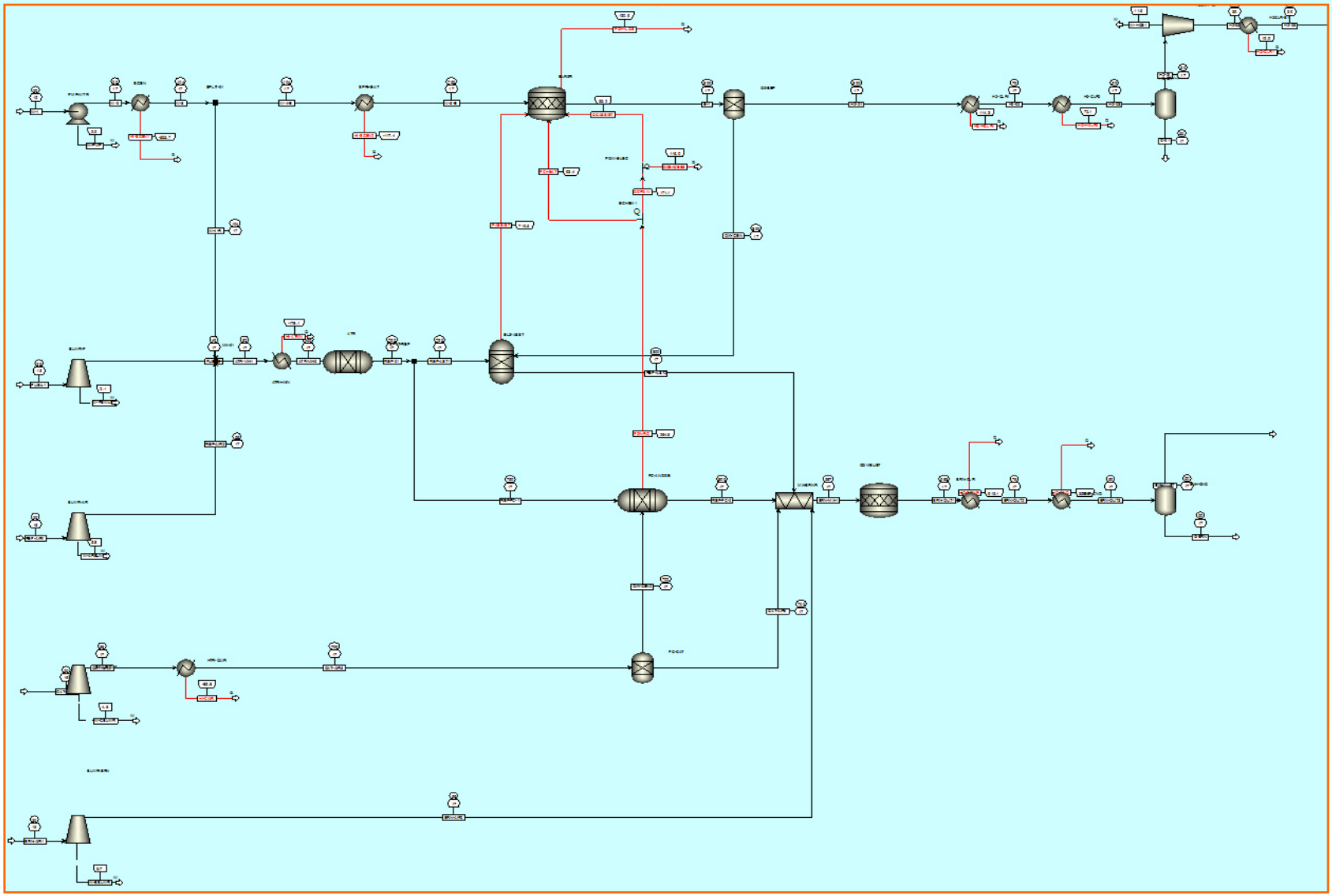


Solid-Oxide Electrolyzer Stability Test (SOEC Mode)



H_2 production rate: 32.63 standard liters of H_2 per hour, or 64.56 grams per day

System Performance Analysis



Cost of Hydrogen Analysis

- System configuration-1: Current technologies

Specific Item Cost Calculation		*Total Cost of Delivered Hydrogen*	$10.61
Cost Component	**Hydrogen Production Cost Contribution ($/kg)**	**Compression, Storage, and Dispensing Cost Contribution ($/kg)***	**Percentage of H_2 Cost**
Capital Costs	$6.14		57.9%
Decommissioning Costs	$0.00		0.0%
Fixed O&M	$1.70		16.0%
Feedstock Costs	$2.25		21.3%
Other Raw Material Costs	$0.00		0.0%
Byproduct Credits	$0.00		0.0%
Other Variable Costs (including utilities)	$0.51		4.8%
Total	**$10.61**	**$0.00**	

- System configuration-2: Improved technologies

Specific Item Cost Calculation		*Total Cost of Delivered Hydrogen*	$7.15
Cost Component	**Hydrogen Production Cost Contribution ($/kg)**	**Compression, Storage, and Dispensing Cost Contribution ($/kg)***	**Percentage of H_2 Cost**
Capital Costs	$2.84		39.8%
Decommissioning Costs	$0.00		0.0%
Fixed O&M	$1.77		24.7%
Feedstock Costs	$1.68		23.5%
Other Raw Material Costs	$0.00		0.0%
Byproduct Credits	$0.00		0.0%
Other Variable Costs (including utilities)	$0.86		12.0%
Total	**$7.15**	**$0.00**	

Collaboration

Partner:

- National Renewable Energy Laboratory
  - Performed a techno-economic analysis using the H2A model and ASPEN to provide an evaluation of a hydrogen home fueling system built upon the SOFEC-SOFC hybrid technology.

Future Work (FY 10 & beyond)

FY 10 & beyond

- Build and evaluation of a prototypal system at a smaller scale
  - Evaluate the SOFEC-SOFC technology for tri-generation
  - Investigate long-term degradation issues
  - Procure and evaluate key BOP components
  - Proof-of-concept demonstration
  - Identify key factors for cost reduction
  - Develop commercialization roadmap

Project Summary

Relevance:	Developing a hydrogen home fueling system for the tri-generation of hydrogen, power, and heat using distributed natural gas can reduce costs and the need for electrical input.
Approach:	Perform system analyses of a hydrogen home fueling system equipped with advanced SOFEC-SOFC technology, followed by an experimental evaluation of the technology on short hybrid stacks.
Project Accomplishments and Progresses:	Design specifications for a hydrogen home fueling system were defined, followed by a detailed system process design and system performance analysis. Process economics and merits of adopting the tri-generation technologies were analyzed. Short stacks were built and evaluated with different fuels to provide design parameters for system optimization.
Proposed future research:	A prototypal system at a smaller scale would be constructed and evaluated for proof-of-concept demonstration.