Low Cost, High Efficiency Reversible Fuel Cell Systems

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Outline

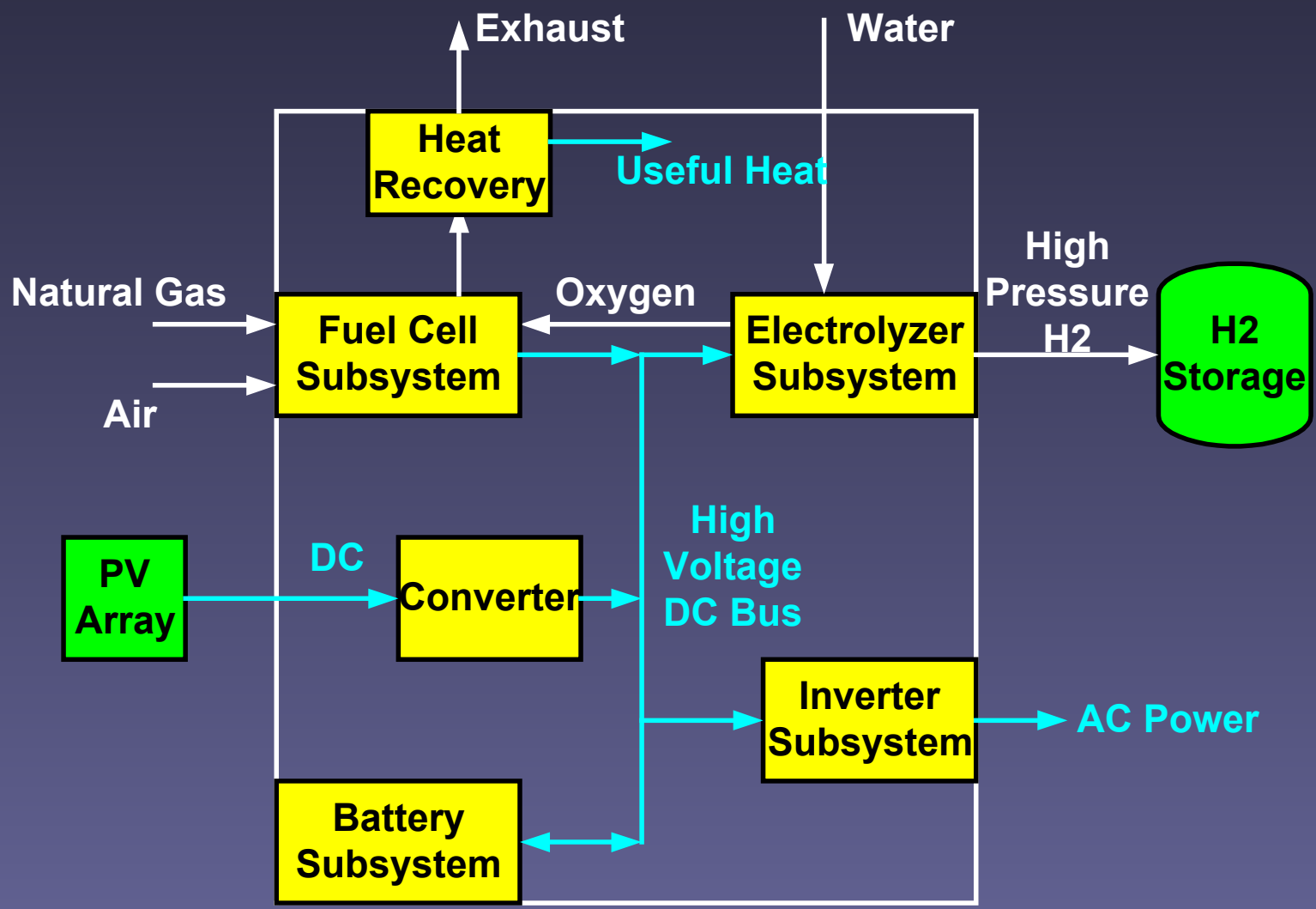
- Objectives
- Approach
- Time Line
- Accomplishments
- Interactions
- Plans

Responses to last year's reviewer comments are included throughout this presentation

Objectives

- Develop Enabling Technology for Low Cost Production of Hydrogen for Vehicles
  - natural gas
  - photovoltaic or wind power utilized when available
  - up to 80 MPa (11,600 psi)
  - residential or filling station sites
  - negligible CO and H_2O
  - negligible emissions of NO_x and other pollutants
  - cost < $1.50/kg

Approach: System Concept



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Approach: Challenges

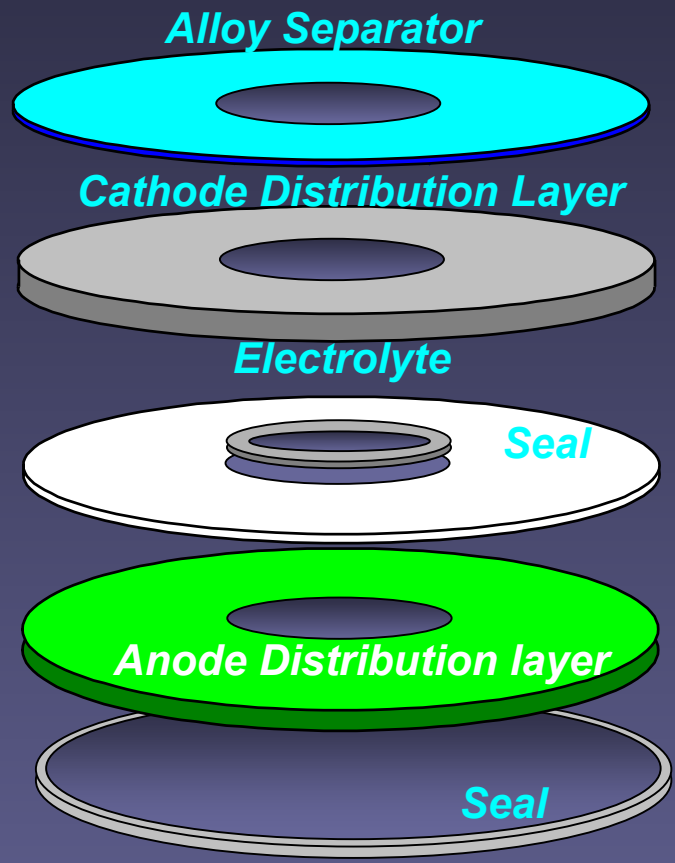
- Electrolyzer Subsystem Efficiency
- Fuel Cell Subsystem Efficiency
- Moderate Installed Capital Cost
- Other

Approach: Novel Solid Oxide Technology

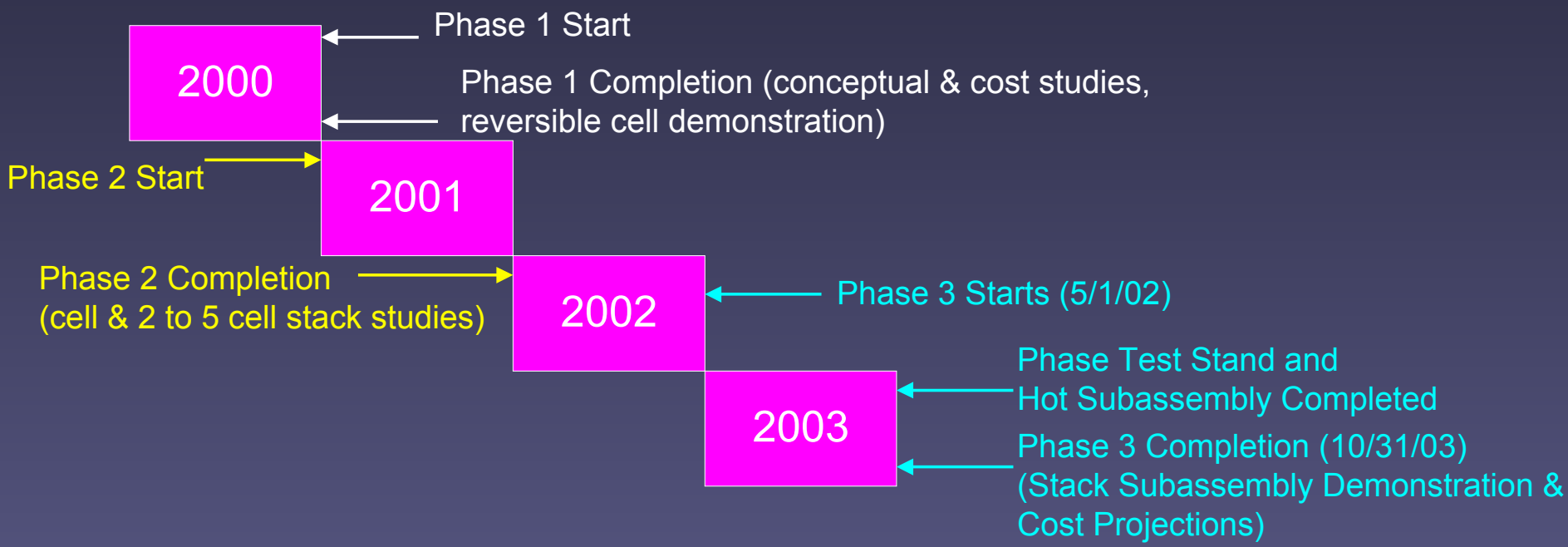
- Reversible Solid Oxide Stacks
  - target feed utilization: 100% (staged)
  - target average fuel cell voltage: 750 mV
  - target average electrolysis cell voltage: 1500 mV
- Stack Cost Target: $100./kW
- Stack Life Target: 5 years
- Integrated Subsystems

Approach - Cell Configuration

- Radial Flow
- Diffusional
- Small Diameter



Time Line

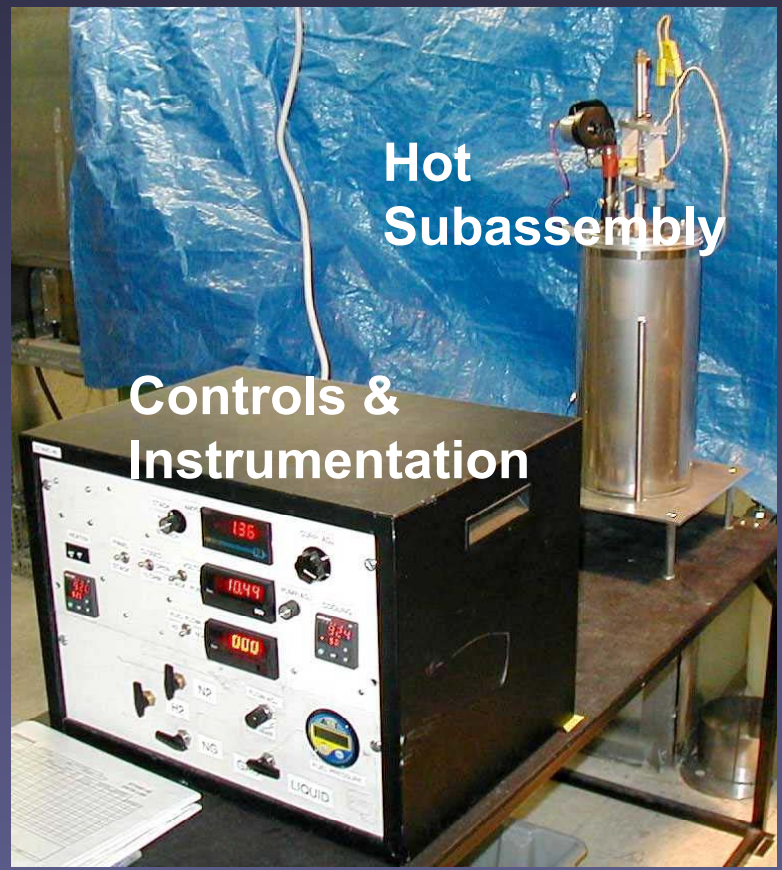

2000
Phase 1 Start
Phase 1 Completion (conceptual & cost studies, reversible cell demonstration)
2001
Phase 2 Start
Phase 2 Completion (cell & 2 to 5 cell stack studies)
2002
Phase 3 Starts (5/1/02)
2003
Phase Test Stand and Hot Subassembly Completed
Phase 3 Completion (10/31/03) (Stack Subassembly Demonstration & Cost Projections)

Cell Development Accomplishments

Parameters	Goal	Status
Seal C_v	< 10^{-5}	< 10^{-6}
Power Decline (Watts/1000 hr)	< 5%	< 5%
Area Specific Resistance (Ω - cm^2)	< 1.0	1.1 to 2.3
Cells/Stack	up to 50	up to 20

Fuel Cell System Accomplishments

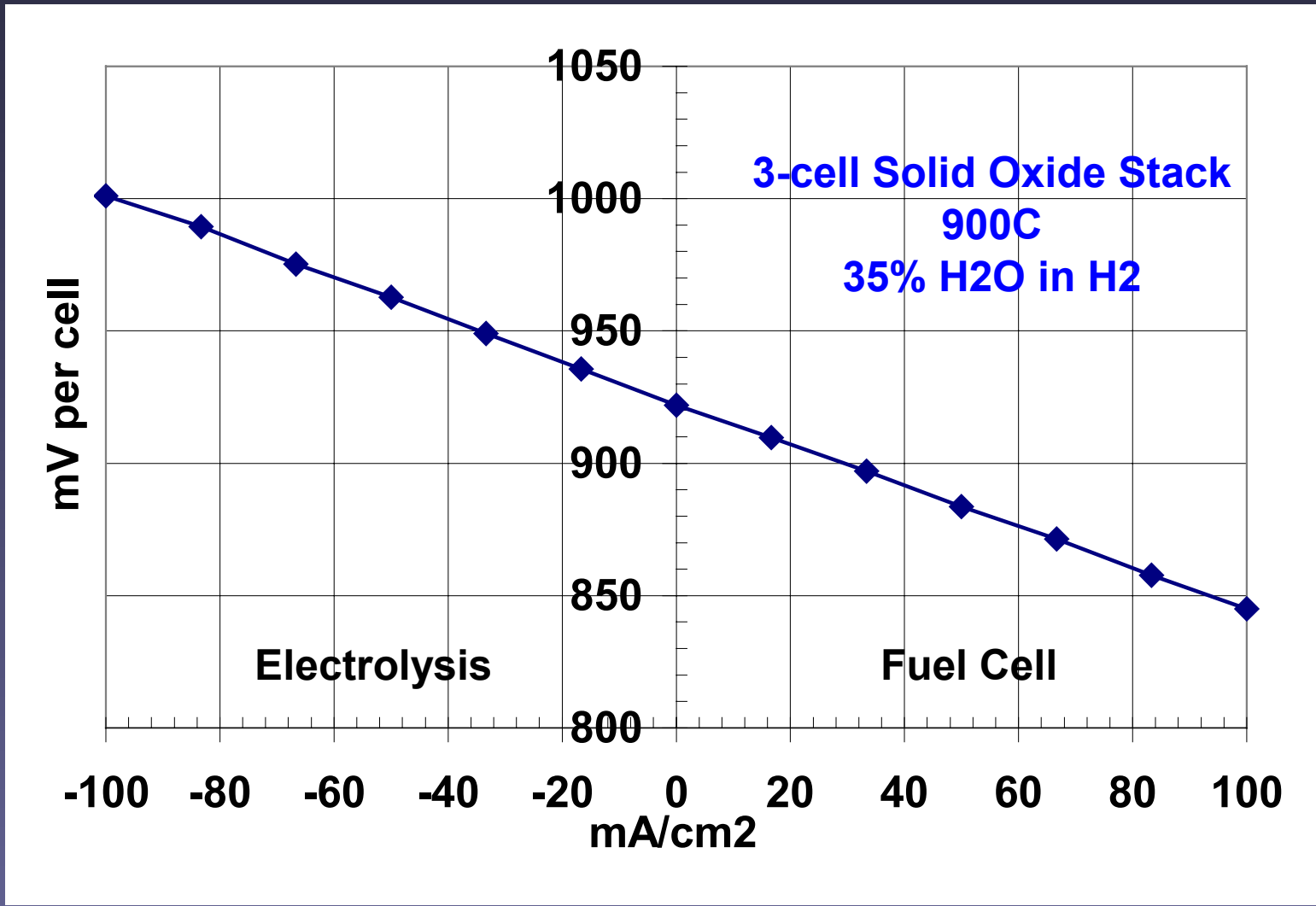
- 50 cell Reversible SOFC System Design
- Natural Gas or Water Feed



Fuel Cell System Accomplishments

- 51% Stack LHV Efficiency on natural gas
  - 20-cell stack
- less than 5% per 1000 hr power decline
  - natural gas, 19-cell stack
- additional reversible stack tests

Fuel Cell System Accomplishments



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Engineering & Cost Studies Accomplishments

Example Residential System

- Annual Hydrogen 480 kg
- Annual AC 15000 kWh
- Annual Heat Recovery 18000 MJ
- Natural Gas LHV 925 BTU/scf

Engineering & Cost Studies Accomplishments

Example Residential System

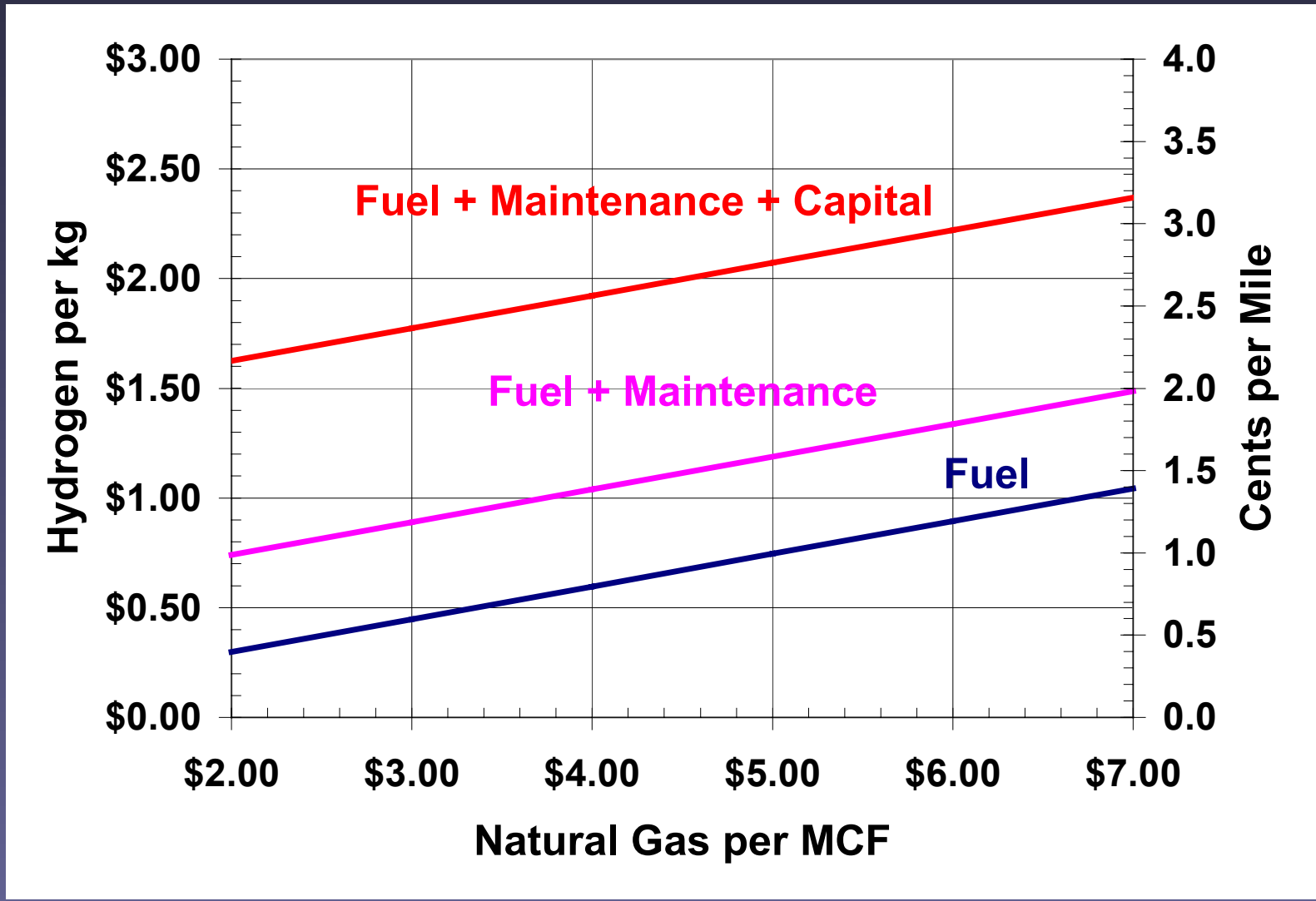
projections for large annual quantities

Fuel Cell Modules (2 x 3 kW)	$2281.
Electrolyzer Module (3 kW)	1178.
Inverter Subsystem (20 kVA surge)	317.
Battery Subsystem (20 kW surge)	388.
Photovoltaic Converter (3 kW)	49.
Heat Recovery (2 kW)	243.
Hydrogen Storage (10 kg)	261.
Total Manufacturing Costs	**$4717.**

Engineering & Cost Studies Accomplishments

Manufacturing Cost		$ 4717.
Manufacturing & Distribution Margins 75%		3538.
Installation Costs		1843.
Subtotal		$10098.
Sales Taxes 5%		505.
Total Installed Cost (end-user)		**$ 10603.**
Annual Rate (assumption)	8.0%	
Annual Capital		**$ 848.**
Annual Maintenance (20 yr. Avg.)		**$ 425.**

Engineering & Cost Studies Accomplishments



Engineering & Cost Studies Accomplishments

Example Residential System

AC Power (using Natural Gas @ $6.00/MCF)

	Cents/kWh
Fuel	2.2
Maintenance	1.4
Subtotal Cash	3.6
Capital	2.8
Total	6.4

Engineering & Cost Studies Accomplishments

H_2 and Electricity Cost Depend on:

- Fuel Cost
- Maintenance Costs
- Photovoltaic or Wind Inputs
- Sale and/or Purchase of Electricity
- Annual Capacity Factors
- Accounting Assumptions

Interactions

- NIST/ATP (Nat'l Institute of Standards & Technology - Advanced Technology) Program
  - Delco Remy International
- DoD/Air Force, Dual Use Science & Technology (DUS&T) Program
  - Electricore
  - Delco Remy International
  - NASA Glenn Research Center
- State of Ohio 3rd Frontier Action Fund
  - NASA Glenn Research Center
  - Boeing
  - Catacel

Plans

- Phase 3 completion: 10/31/03
- Cell and Stack Demonstration
  - Reduce ASR to 1.0 ohm-cm^2
  - Demonstrate Stacks up to 50 Cells
  - Preserve Power Loss < 5%/1000 hr
  - Preserve $C_v < 10^{-5}$
- Engineering and Cost Studies
  - Complete Work