ADVANCED REACTOR, FUEL CYCLE, AND ENERGY PRODUCTS WORKSHOP FOR UNIVERSITIES

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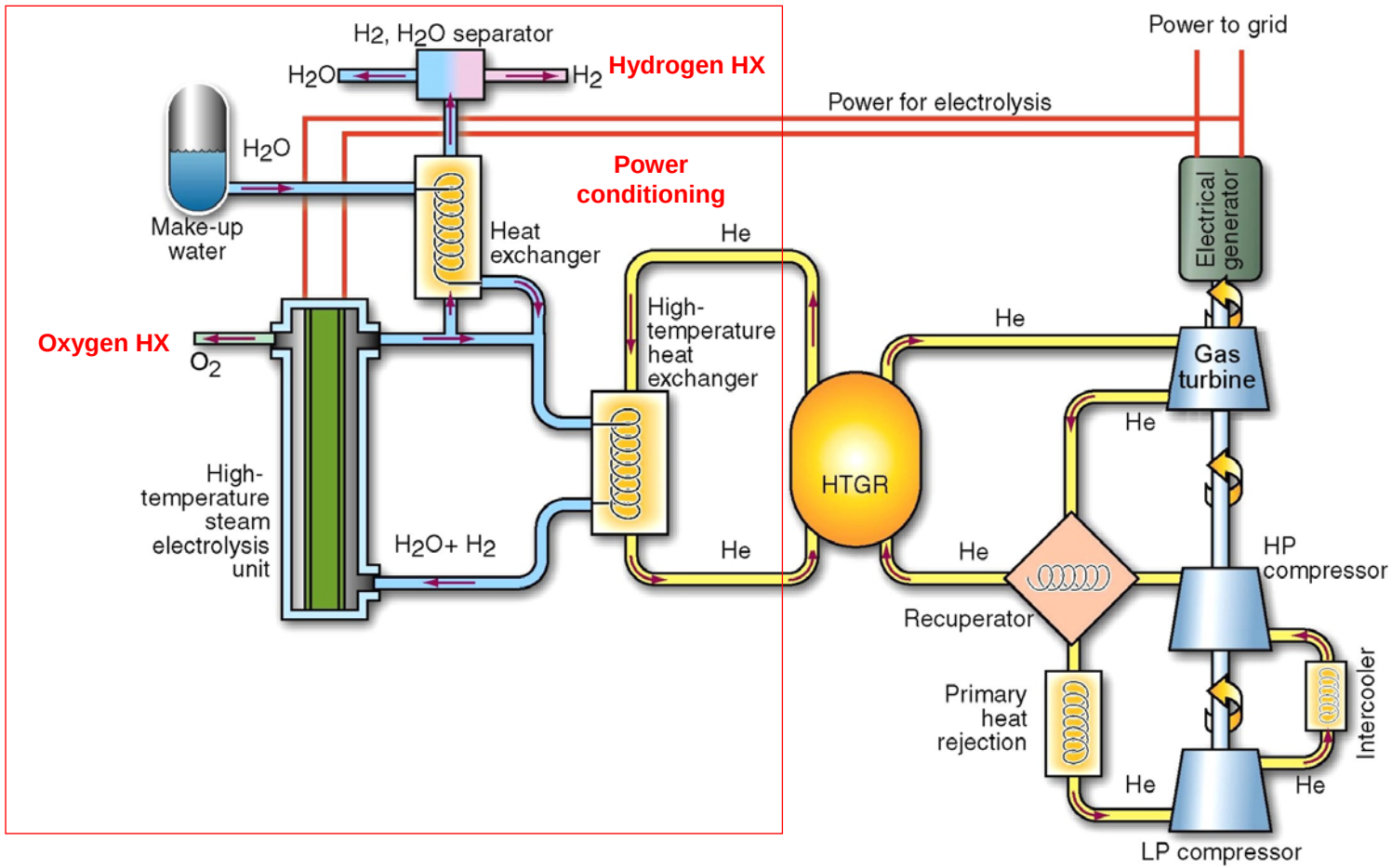
High Temperature Electrolysis

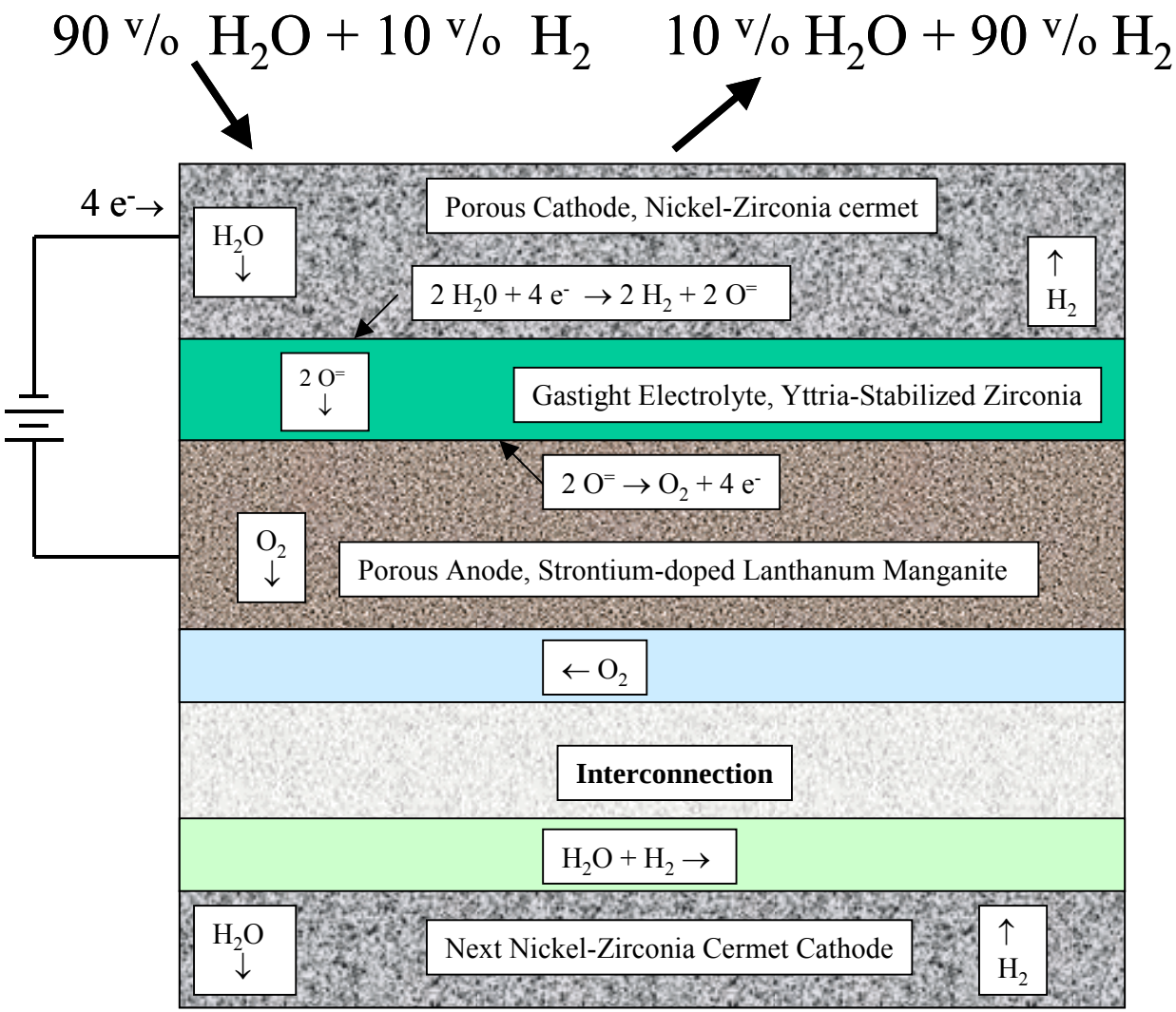
Idaho National Engineering and Environmental Laboratory

Workshop for Universities
Hilton Hotel, Gaithersburg, MD
March 4-5, 2004

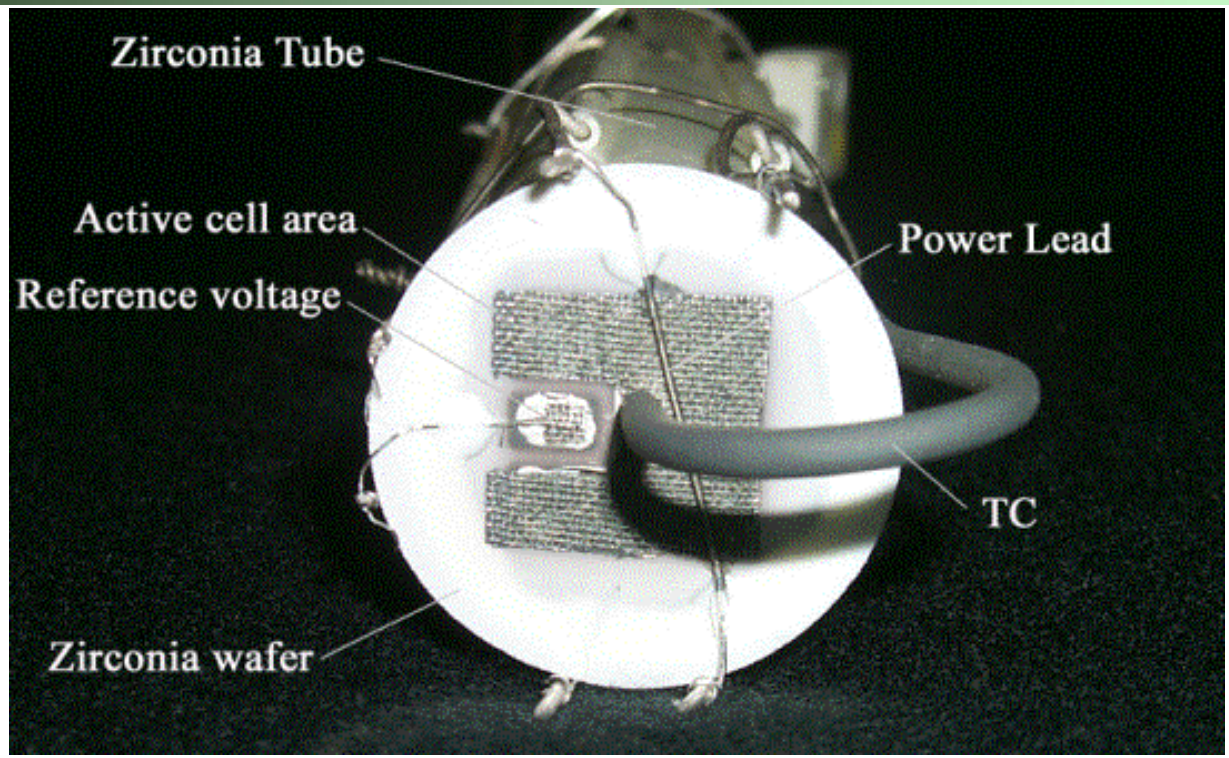
This research area includes components within boundary



Research Area also includes Materials of Cell Construction

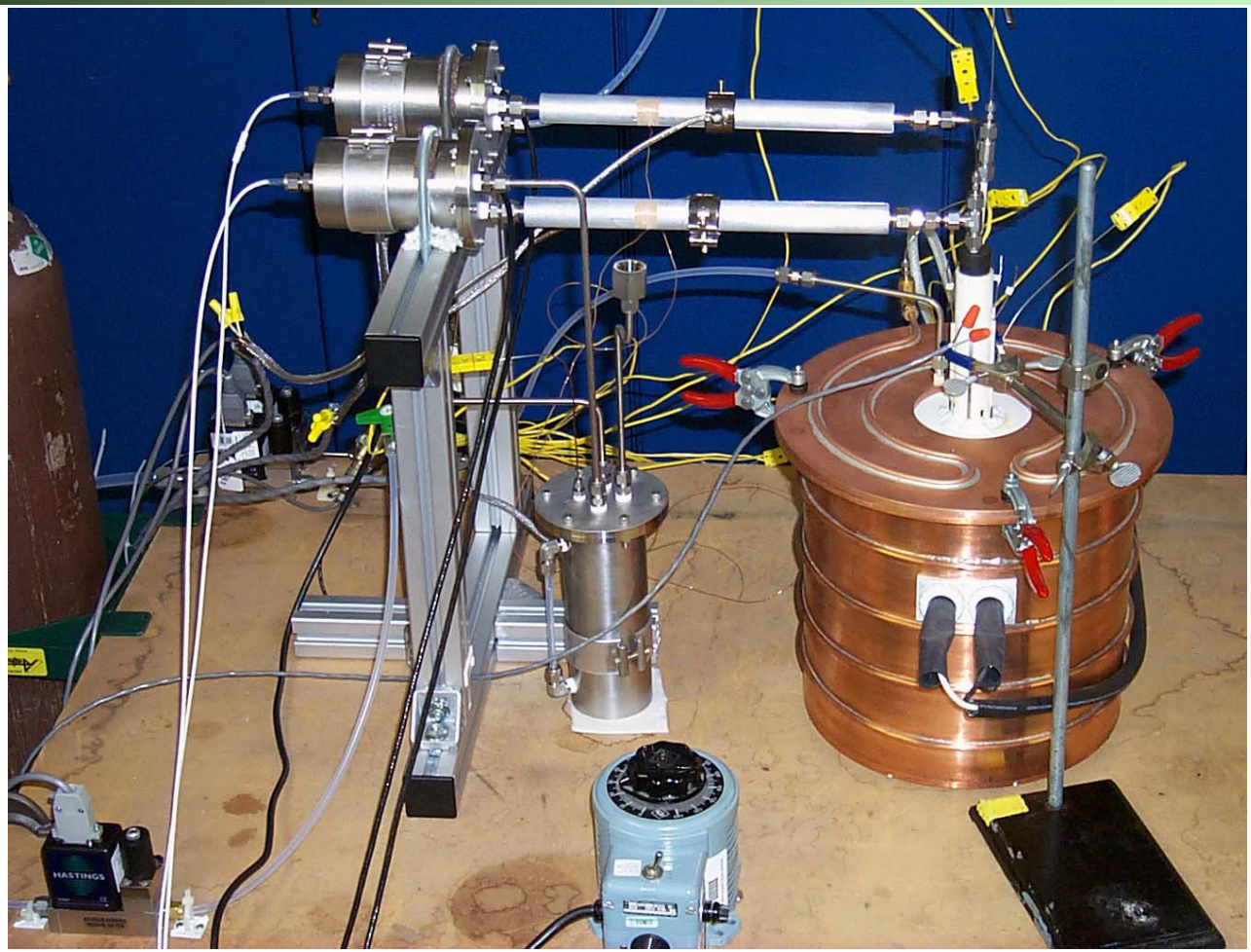


FY-03 Accomplishments - Button-cell Experiments

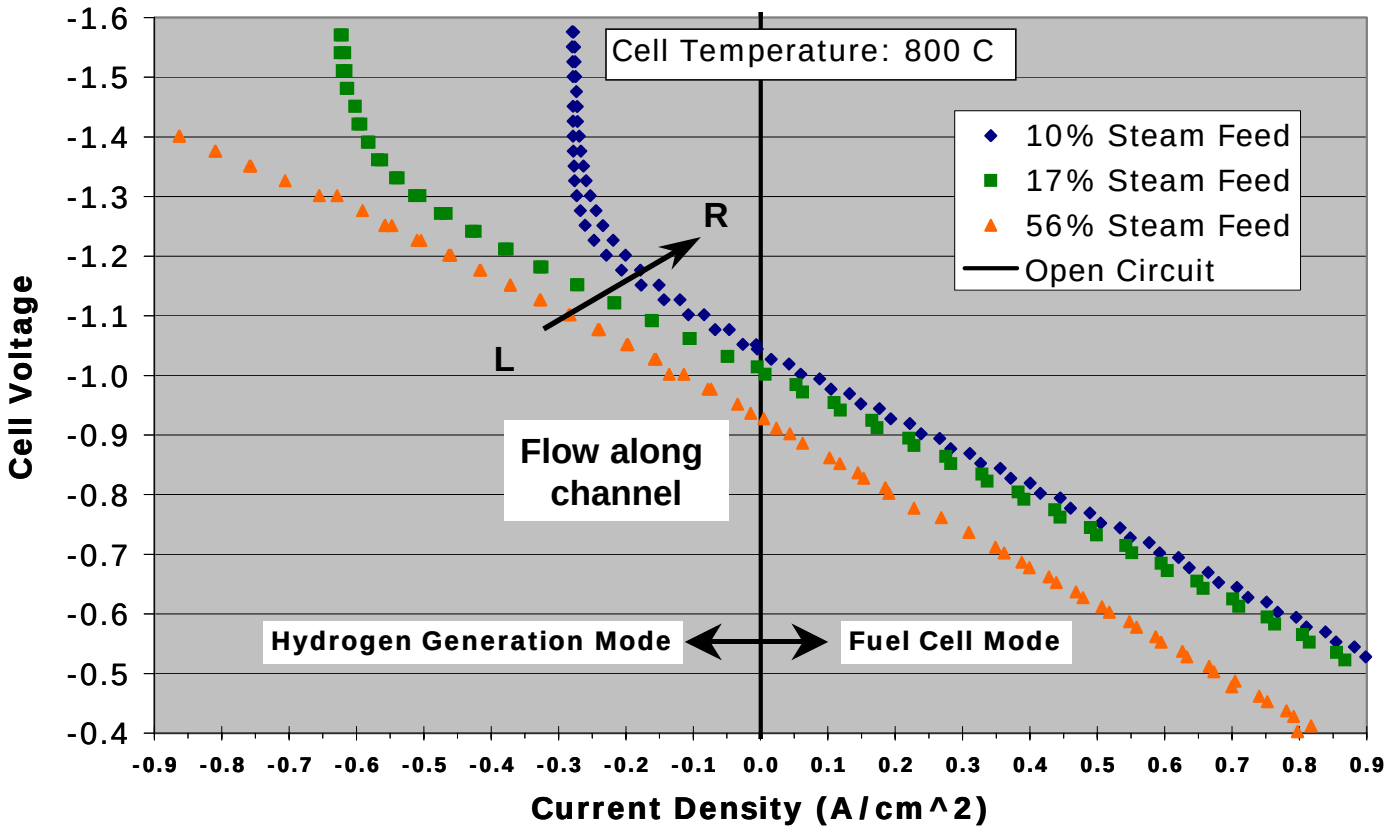


- ♦Began experiments Jan 2003
- ♦Button cell tests with yttria stabilized zirconia, LSM.
- ♦Various electrode materials

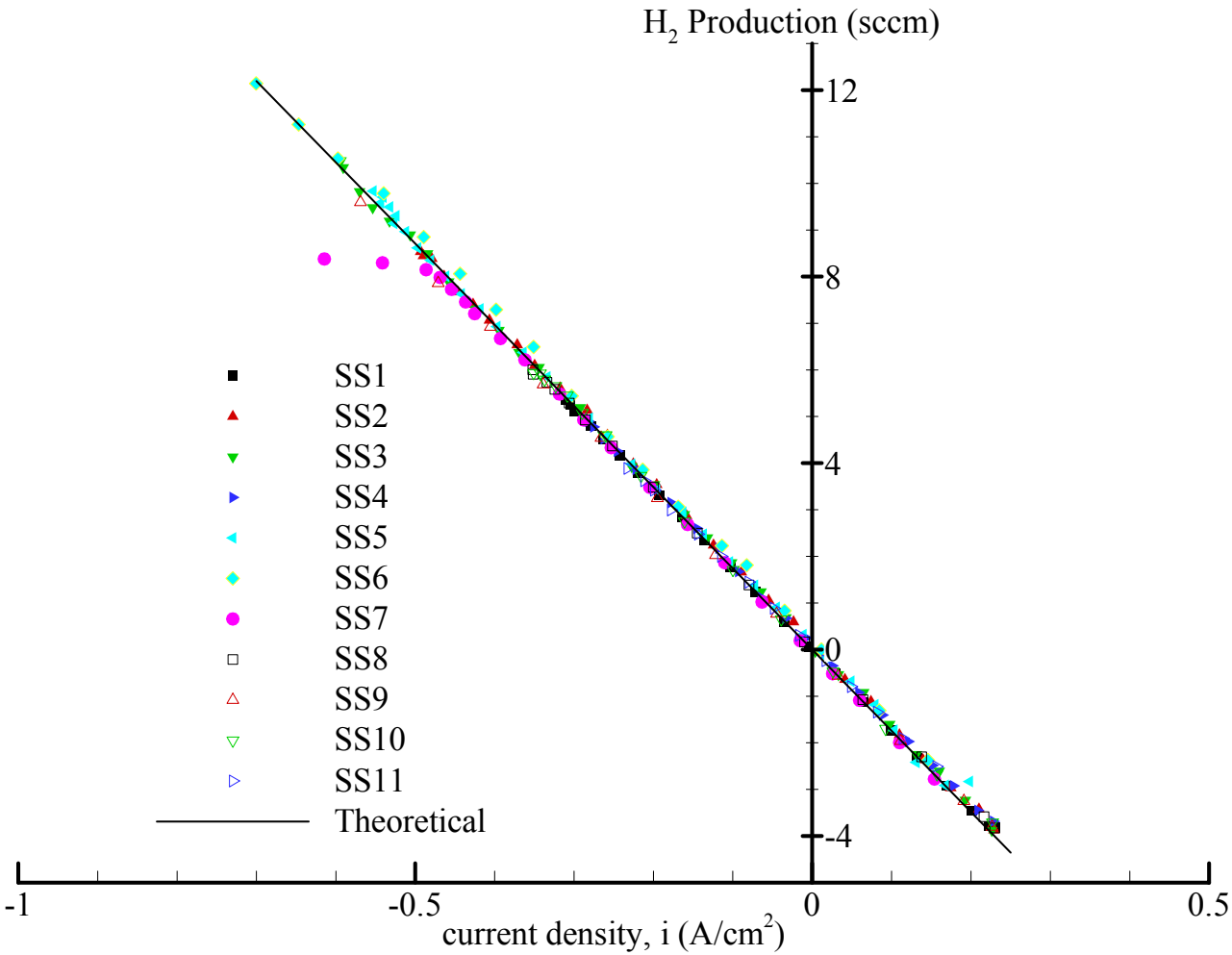
FY-03 Accomplishments: Experimental configuration



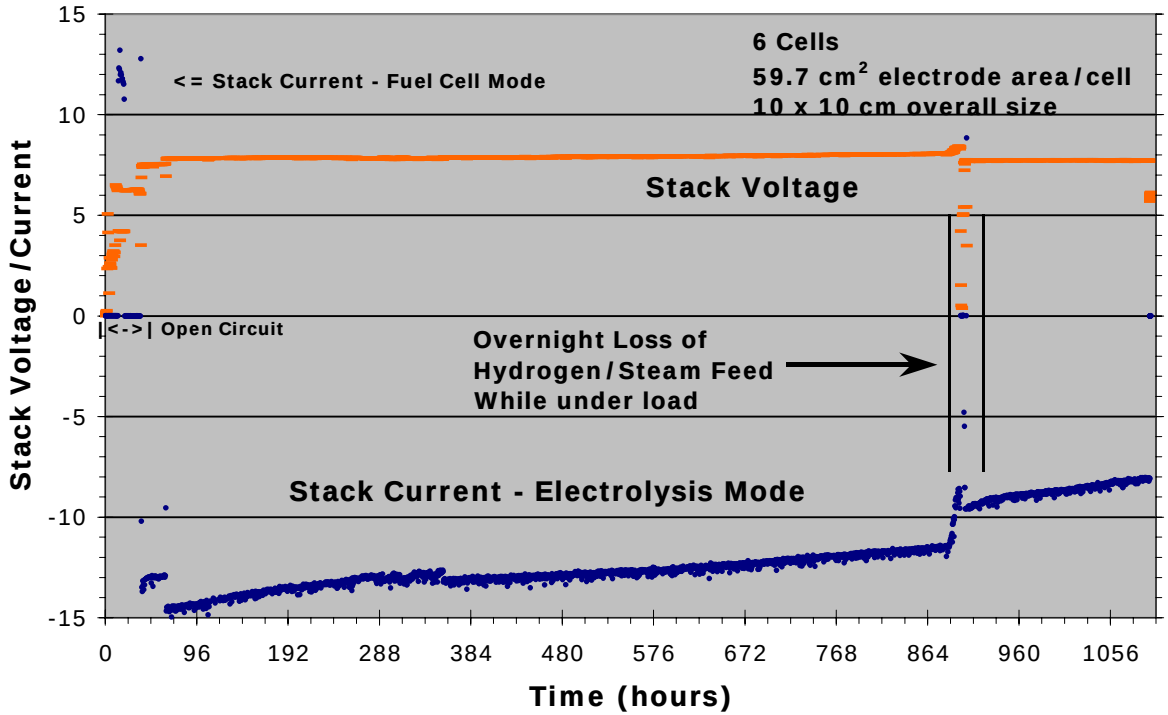
FY-03 Accomplishments: LSGM button cell Characteristics



FY-03 Accomplishments: Comparison of theoretical and experiment H_2 Production



Early FY-04 Accomplishment: Initial Stack tests



0 N liters/hr

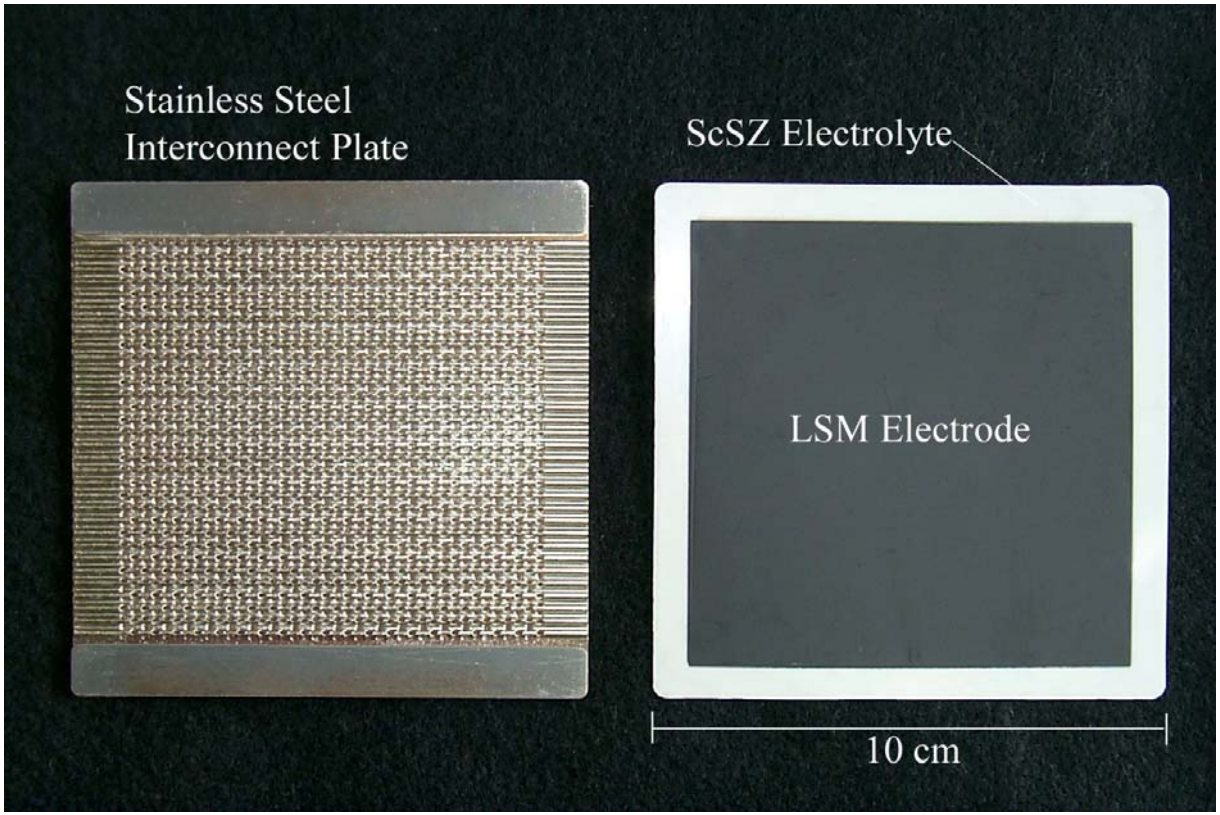
37.6 N liters/hr

6-cell stack test produced 32 normal liters/hr for ~ 800 hours, Oct-Nov. 2003 at Ceramatec facility in Salt Lake City

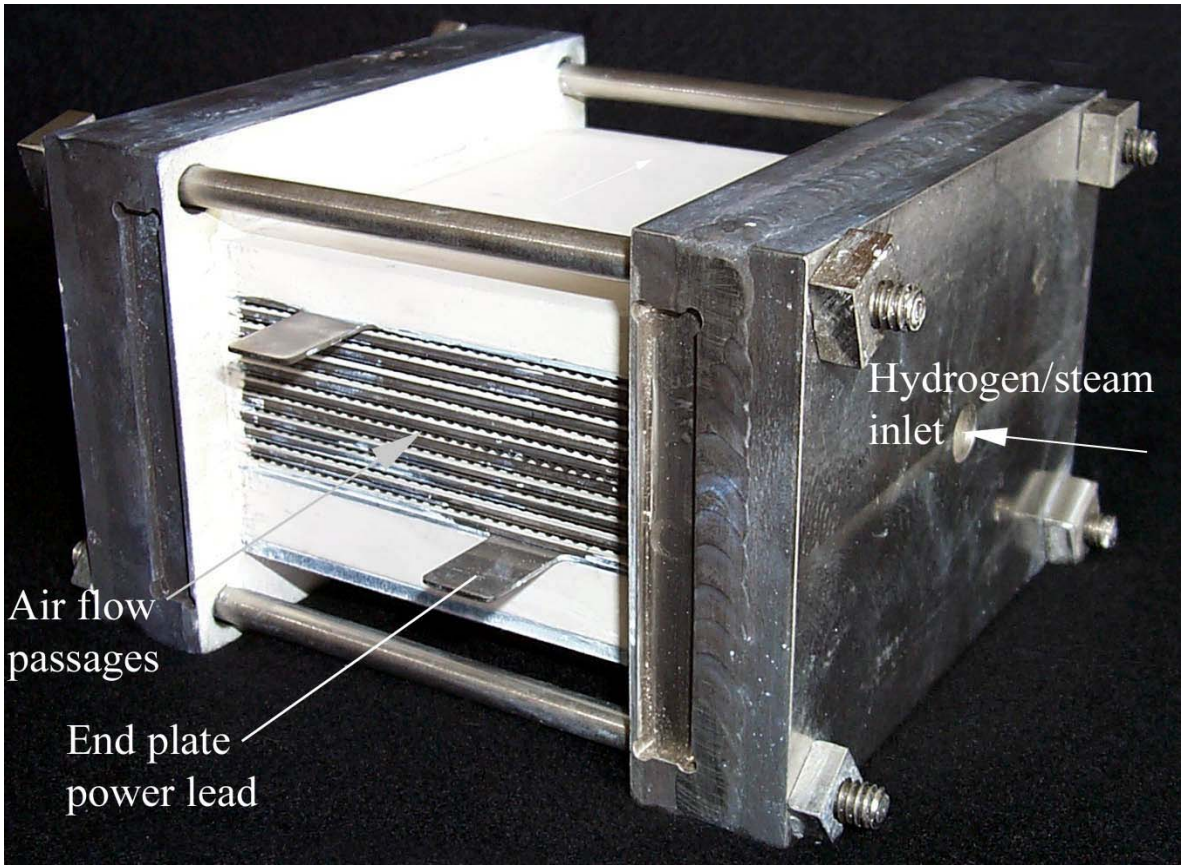
Work in Progress for FY-04:

- **HTE Experiment construction**
  - Fabrication of specialized hardware, stack fabrication, experiment assembly
- **HTE Cell/Stack Operation**
  - Complete single-cell testing of baseline and advanced materials
  - Initiate stack testing, measure operational parameters, performance of materials
- **HTE Final Design**
  - Develop testing objectives and designs for integrated lab-scale (50 kW) and pilot-plant (500 kW) experiments
- **HTE Flowsheet Analysis**
  - Analyze requirements and components for integrated lab-scale (50 kW) and pilot-plant (500 kW) experiments
- **HTE Engineering Analysis**
  - Identify options for demo (5 MW) and commercial scale (~300 MW) plants

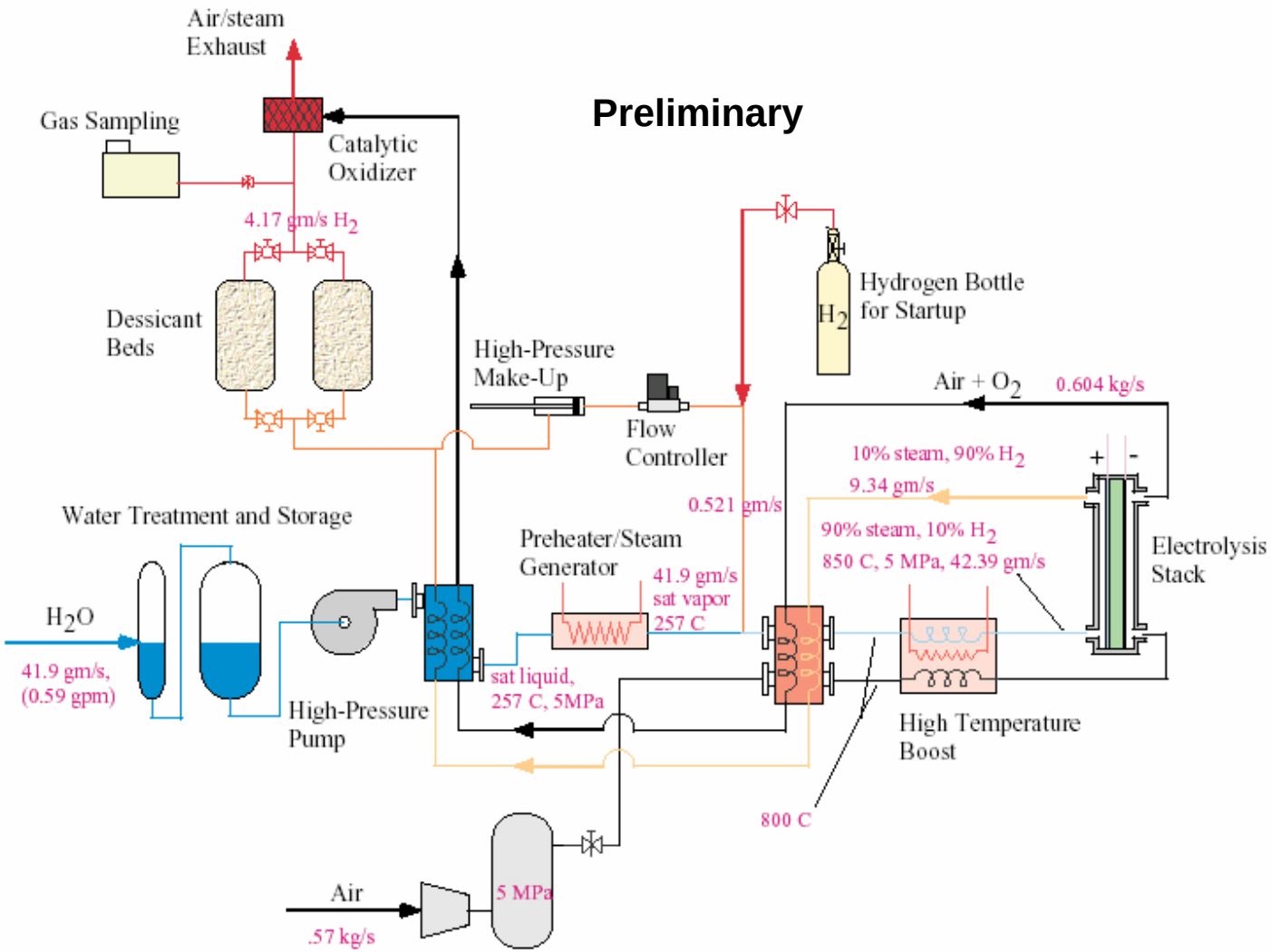
Work in Progress for FY-04: Interconnect Plate and Electrolyte for Stack Testing



Work in Progress for FY-04: Ten-Cell Stack Experiment



Work in Progress for FY-04: Pilot Plant Design



Plans for FY-05 - FY-07

- **Modeling**
  - Transport in cells
  - Plant modeling
    - Steady state – then dynamic response to transients
    - Reduction of thermal cycling
  - Integration of HTE units into a electric power grid
    - Implications of other sources, e.g. wind, hydro,..
- **Heat Exchangers**
  - Oxygen cooling – possible use of diluent
  - Steam reheat
- **Separations**
  - Steam – hydrogen separation
    - Advantages of isothermal process
  - Water preparations

Plans for FY-05-07 (continued)

- **Materials**
  - Electrolyte
  - Electrodes - cathode and anode
  - Interconnect plate – metal or ceramic
  - Cell sealing – either a materials or configuration issue
  - Oxygen cooling heat exchanger – may be most severe problem
    - **Use of diluent – pumping power considerations**
    - **Should the oxygen be sold or discharged?**
  - Hydrogen cooling HX
- **Plant integration**
  - Power electronics
  - Modes of operation
  - Overall material demands – avoidance of scarce materials

PLANS FOR FY05-07

- Complete HTE cell testing (05)
- Complete HTE stack / module tests (06)
- Complete design of integrated laboratory test (50 kW) (06)
- Complete assembly of integrated laboratory test for 2008 operation (07)
- Start pilot plant-scale experiment design for 2011 operation (07)
- High temperature heat exchanger and separations demo tests (06)

BUDGETS (FY03-04)

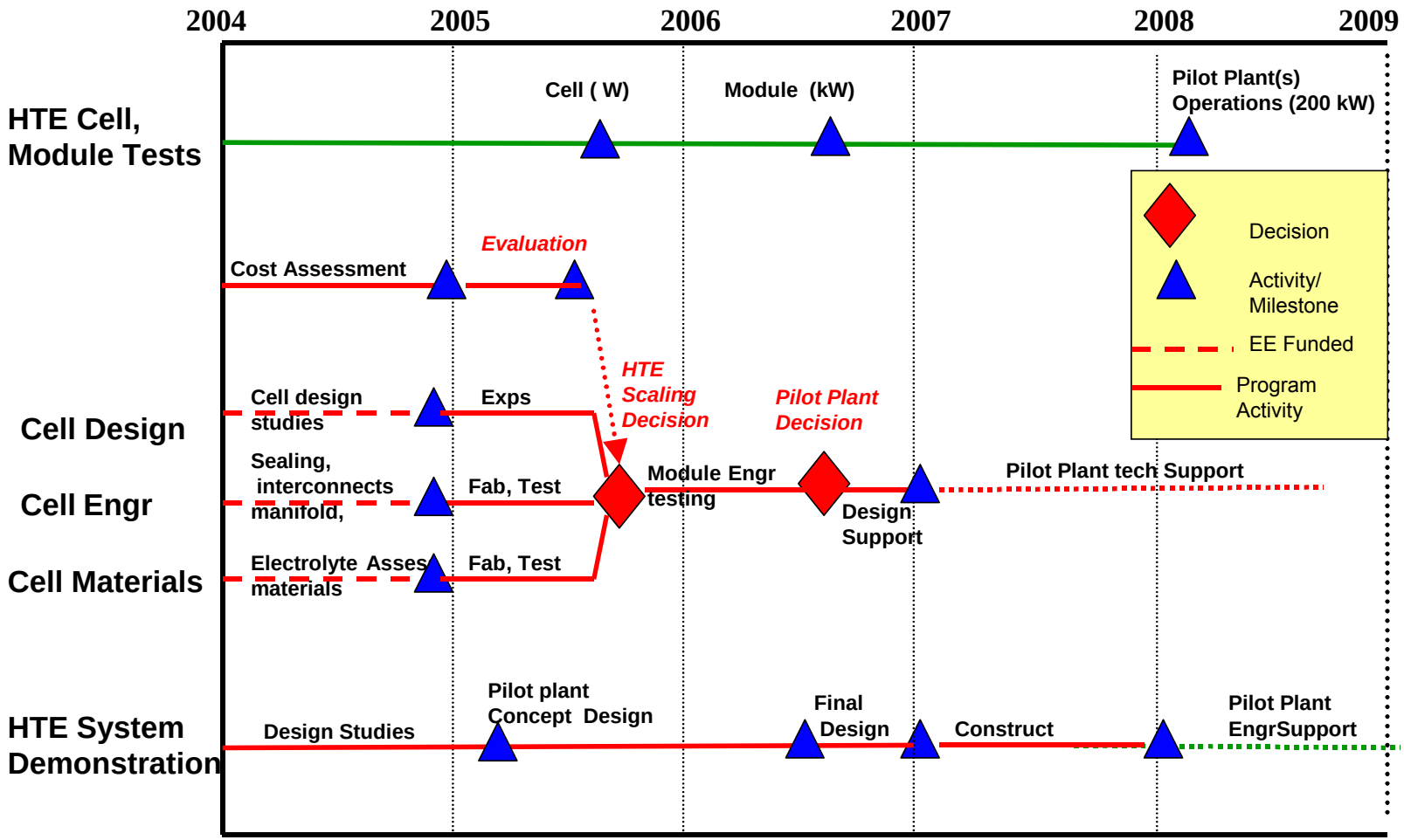
Functional Area	Tasks	Performers	FY-03	FY-04
			(DOE-EE)	(DOE-NE)
Experimental Proof of Concept	Button Cell Tests	INEEL	$ 247	$ 100
	Button Cell and Stack Development	Ceramatec	$ 103	
	HTE Experiment Construction	Ceramatec		$ 110
		INEEL		$ 50
	HTE Cell/Stack Operation	INEEL		$ 90
Conceptual Design	HTE Final Experimental Design	INEEL		$ 50
	HTE Flowsheet analysis	INEEL		$ 250
	HTE Engineering analysis	INEEL		$ 200
			$ 350	$ 850

Most critical fundamental question

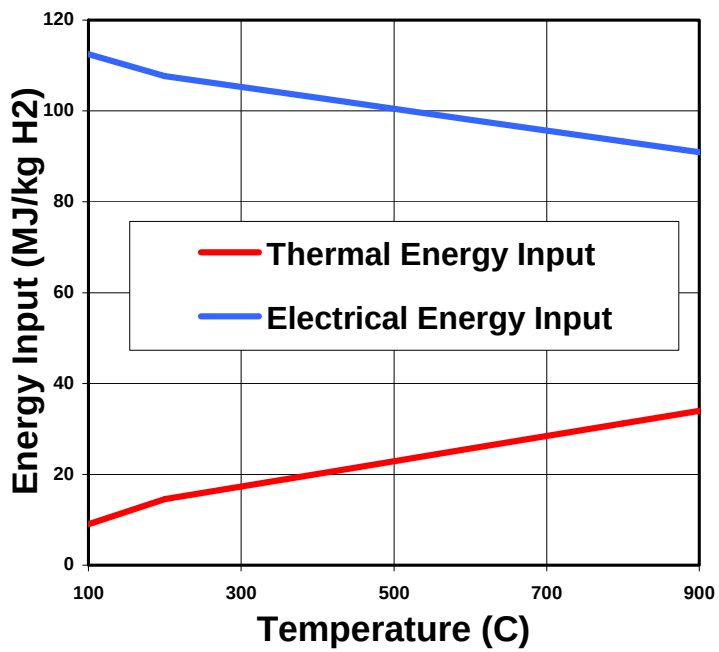
How do we reduce the cost of manufacturing electrolytic cells and components, increase the lifetime of units and thus produce hydrogen for the lowest cost?

Supplemental Slides

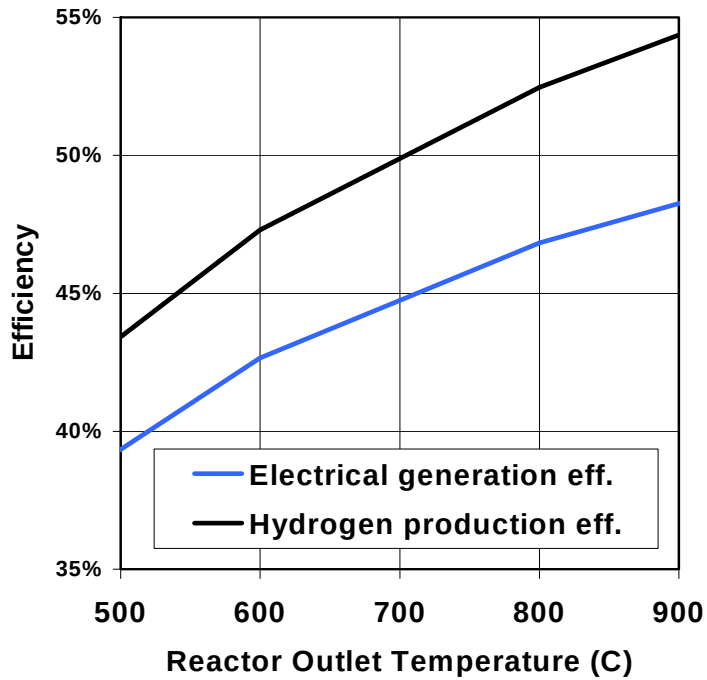
HTE Research Plans in the Nuclear Hydrogen Initiative



Energy Inputs to High Temperature Electrolysis



Overall energy requirements for high temperature electrolysis.



Efficiencies of electrical and hydrogen production