U.S. DEPARTMENT OF ENERGY

Nuclear-Based Hydrogen R&D

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2006 DOE Hydrogen Program
Merit Review and Peer Evaluation Meeting

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NHI
NUCLEAR HYDROGEN INITIATIVE

Origin of the Nuclear Hydrogen Initiative (NHI)

- **FY 2003**
  - ➔ $2M appropriated under Generation IV Nuclear Energy Systems Initiative to investigate hydrogen production using an advanced nuclear reactor
  - ➔ Program planning for NHI began
- **FY 2004**
  - ➔ First NHI appropriation: $6.5M
  - ➔ Nuclear Hydrogen R&D Plan issued March 2004
  - ➔ Program focus: process development for sulfur-iodine cycle and high-temperature electrolysis and modeling of high-temperature heat exchangers
- **FY 2005**
  - ➔ NHI receives $9M appropriation
  - ➔ Program focus: process development for sulfur-iodine cycle and high-temperature electrolysis and materials for high-temperature heat exchangers
- **FY 2006**
  - ➔ NHI receives $25M appropriation
  - ➔ Program focus: construct integrated laboratory-scale experiments for sulfur-iodine cycle and high-temperature electrolysis, process development for hybrid sulfur and calcium-bromine cycles, identification of most promising alternative cycles, and supporting technologies (membranes, catalysts, materials, and heat exchangers)

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Program Goal

- **The goal of NHI is:**

  To demonstrate the commercial-scale, economically-feasible production of hydrogen using nuclear energy by the year 2020

- **In support of this goal, NHI has these major project targets:**
  - ➔ **2008: Operate laboratory-scale thermochemical and electrolytic processes to determine feasibility of coupling them with a nuclear reactor**
  - ➔ **2011: Select process for coupling with advanced nuclear reactor as part of the Next Generation Nuclear Plant**
  - ➔ **2014: Pilot-scale demonstration of thermochemical hydrogen production system for use with nuclear reactors that projects to a cost of $2.50/gge (ultimate target: $3.50/gge delivered)**
  - ➔ **2020: Engineering-scale demonstration of thermochemical hydrogen production system for use with nuclear reactors that projects to a cost less than $2.00/gge ($3.00/gge delivered)**

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Program Scope

- **Thermochemical Cycles**
  - ➔ Offer potential for high efficiency hydrogen production at large-scale production rates, but technology is relatively immature.
- **High-Temperature Electrolysis**
  - ➔ Based on much of the technology developed for solid oxide fuel cells, high-temperature electrolysis promises higher efficiencies than conventional electrolysis.
- **Systems Interface**
  - ➔ Deals with issues associated with interface between the nuclear reactor and the hydrogen production process, balance of plant, and infrastructure and support facilities for the processes' experimental demonstrations.
- **Technical Integration**
  - ➔ System studies to help focus program research and provide the extensive coordination necessary for such a complex program.

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Progress on Thermochemical Cycles

- **Sulfur-Iodine (S-I) Cycle**
  - ➔ Collaboration between DOE and French *Commissariat à l'Energie Atomique* (CEA) under an International Nuclear Energy Research Initiative (I-NERI)
    - Sulfuric Acid Decomposition – SNL; Bunsen Reaction – *CEA;* Hydriodic Acid Decomposition – General Atomics
    - Integrated Laboratory-Scale Experiment will begin operation in early FY 2008.
- **Hybrid Sulfur (HyS) Cycle [SRNL]**
  - ➔ Primary research focus on development of a SO2 - H2O electrolyzer
  - ➔ Electrolyzer to be used in conjunction with sulfuric acid decomposition section being developed for the S-I cycle in an Integrated Laboratory-Scale Experiment
- **Calcium-Bromine (Ca-Br) Cycle [ANL]**
  - ➔ Go/No-Go decision on the viability of Ca-Br cycle in June 2006
- **Alternative Thermochemical Cycles [ANL]**
  - ➔ Several cycles have potential for high efficiencies or operation at lower temperatures
  - ➔ Coordination with the UNLV Solar Hydrogen Generation Research (SGHR) project
  - ➔ Subcontract to Universities to analyze and evaluate the most promising cycles, including flowsheet analysis on selected cycles

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Progress on High-Temperature Electrolysis (HTE)

- **Process Development [INL, Ceramatec, ANL, UNLV, ORNL]**
  - ➔ Activities coordinated with DOE solid oxide fuel cell research activities
  - ➔ Cell electrode materials with improved durability for variable cell environment being developed
  - ➔ High-temperature inorganic membrane for the separation of hydrogen from steam being developed to improve the overall production efficiency
  - ➔ Components for laboratory-scale experiments fabricated; button cell and stack experiments conducted to evaluate candidate electrolyzer characteristics and performance
  - ➔ 1000-hour continuous production run at >100 liters/hour completed February 2006

- **Computational Fluid Dynamics (CFD) [ANL]**
  - ➔ Modeled integrated performance of an HTE plant and the thermal optimization of the reactor plant through various component arrangements
  - ➔ Current focus on analyses of individual flow channels in a solid oxide electrolyzer cell model the temperature, current density, and local hydrogen production

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Progress on Systems Interface

- Identification of issues related to coupling an advanced nuclear reactor to a high-temperature hydrogen production process [INL]
  - ➔ High-temperature heat exchangers
  - ➔ Heat transfer fluids
  - ➔ Materials of construction
  - ➔ Safety
  - ➔ Environmental requirements
  - ➔ Licensing
  - ➔ Oxygen and hydrogen handling
- Current focus on S-I and HTE heat exchanger requirements and analysis of the heat transfer medium
- Establishment of a partnership between universities, private industry and national laboratories [UNLVRF]
  - ➔ Identify candidate materials
  - ➔ Perform screening corrosion (coupon) tests
  - ➔ Perform physical property tests

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Progress on Technical Integration

- Provides coordination between program activities and conducts all necessary systems analysis [SNL]
- The NHI systems analysis activity coordinates with:
  - ➔ Generation IV Evaluation Methodology Working Group (EMWG)
  - ➔ Office of Energy Efficiency and Renewable Energy's Hydrogen Analysis Working Group (H2A)
- Current systems analysis focus:
  - ➔ Identify nuclear-based hydrogen system requirements
  - ➔ Evaluate system configuration options
  - ➔ Develop criteria and framework for comparison of hydrogen production process options
  - ➔ Identify required nuclear hydrogen infrastructure and potential markets to estimate infrastructure costs for hydrogen delivery.
  - ➔ Investigate technology implications of potential applications and implementation strategies

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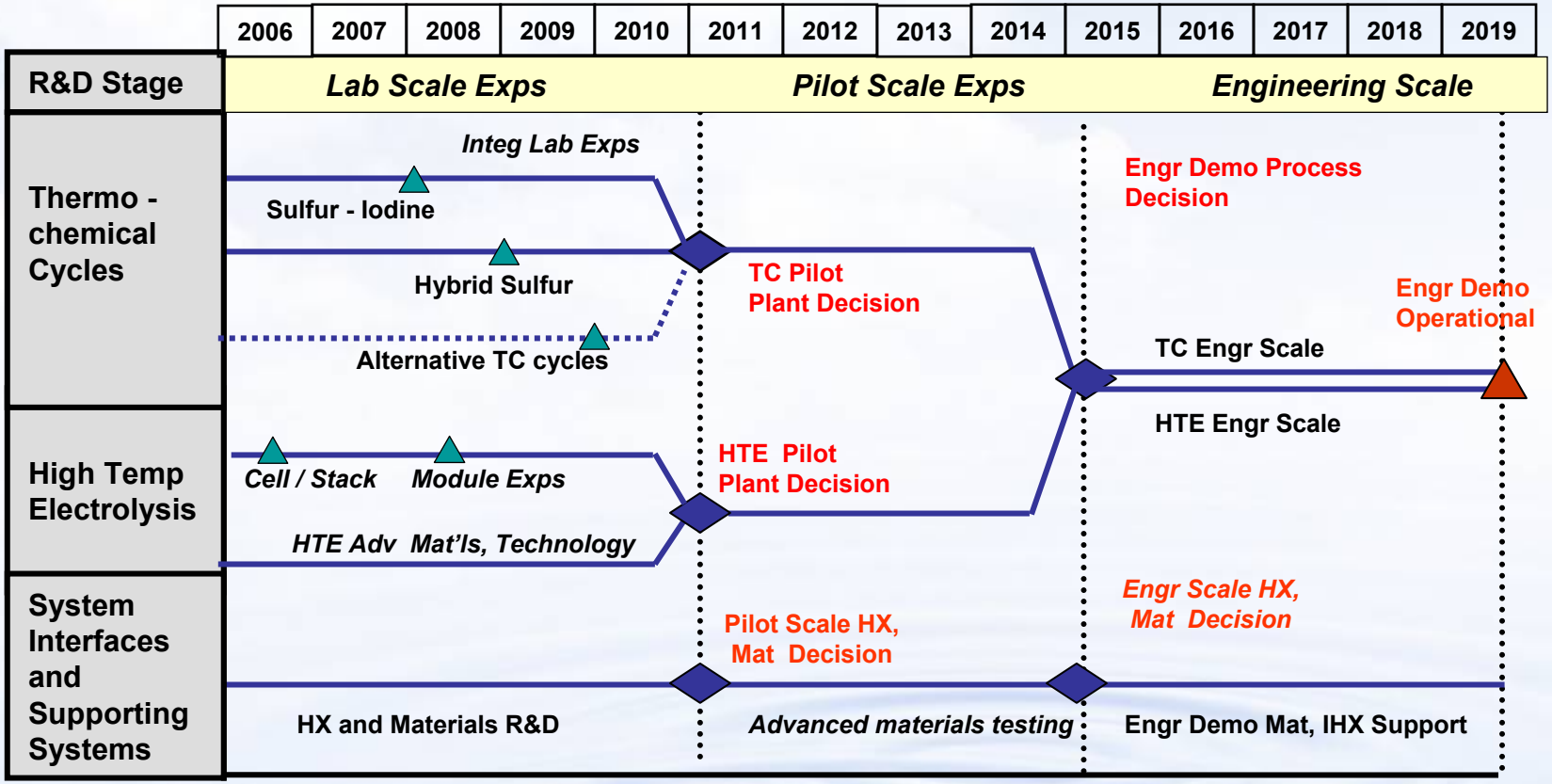
Program Schedule



Hydrogen Production Feasibility Study

- EPAct Section 634 calls for two projects to demonstrate the commercial production of hydrogen at existing nuclear power plants, preceded by an economic analysis of such production
- NHI has solicited proposals for industry to perform a feasibility study involving small-scale hydrogen production equipment utilizing nuclear energy, to inform the required economic analysis
- Purpose is to obtain analysis on the economics, regulatory requirements, and environmental impacts of hydrogen production at existing nuclear power plants
- Solicitation was announced on April 13, 2006; proposals due by June 5, 2006.

See *www.nuclear.gov* for announcement and links

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Conclusion

- NHI is progressing on schedule to meet our milestones and program goals
- Budget support for the program remains strong
- See *www.hydrogen.energy.gov* for more details

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