2004 DOE Hydrogen, Fuel Cells & Infrastructure Technologies Program Review

Chemical Hydride Slurry for Hydrogen Production and Storage

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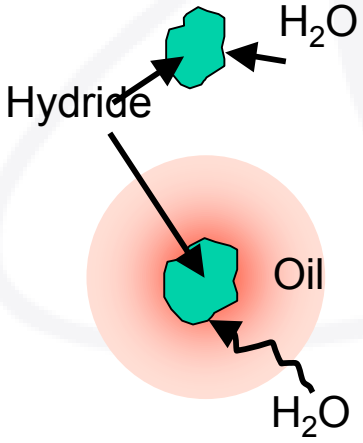
Objectives

- Project Objective
  - Demonstrate Magnesium Hydride Slurry is a cost effective, safe, and high-density hydrogen storage, transportation, and production medium
    - Pumpable and High density slurry offers infrastructure advantages
    - High system energy density with high vehicle range
- Objective of Work Over Past Year
  - This is a new project



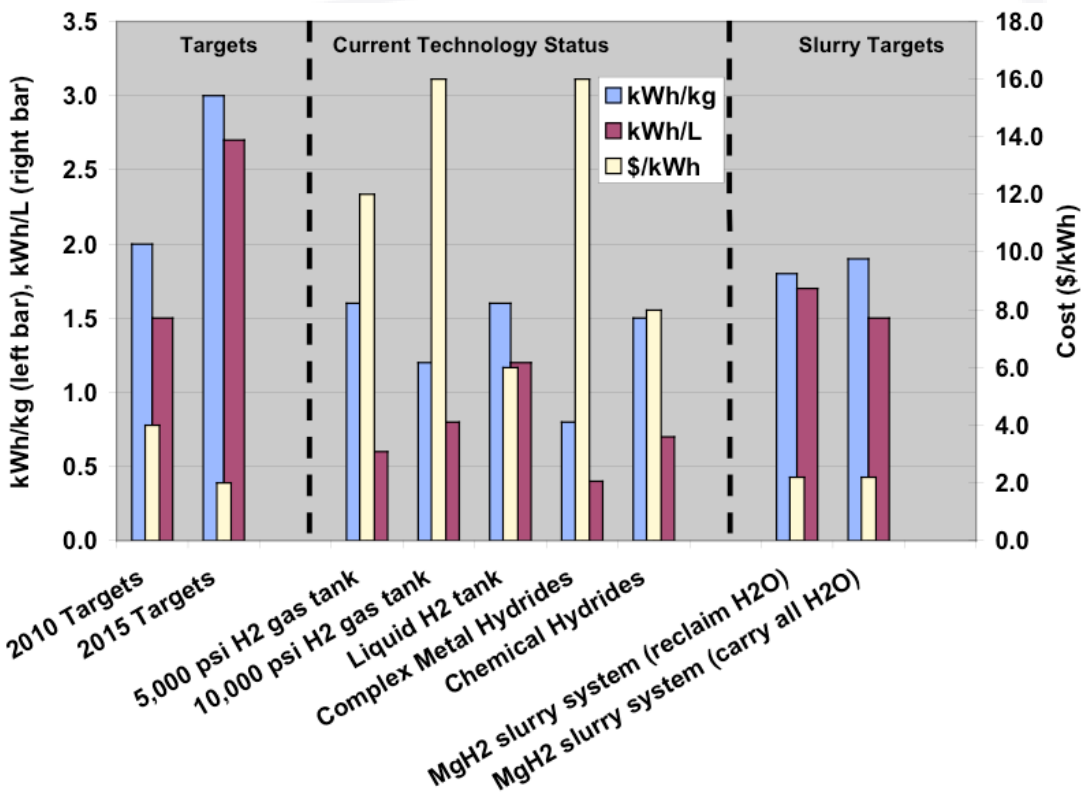
Budget

- Total funding for project
  - $2,272,244
- Cost Share
  - $1,800,000 DOE
  - $472,244 Safe Hydrogen
- Funding for FY04
  - $756,974

Technical Barriers and Targets

- DOE Technical Barriers for Chemical Hydride Storage
  - A. Cost
  - B. Weight and Volume
  - C. Efficiency
  - G. Life Cycle and Efficiency Analyses
  - Q. Regeneration Processes
  - R. Byproduct Removal

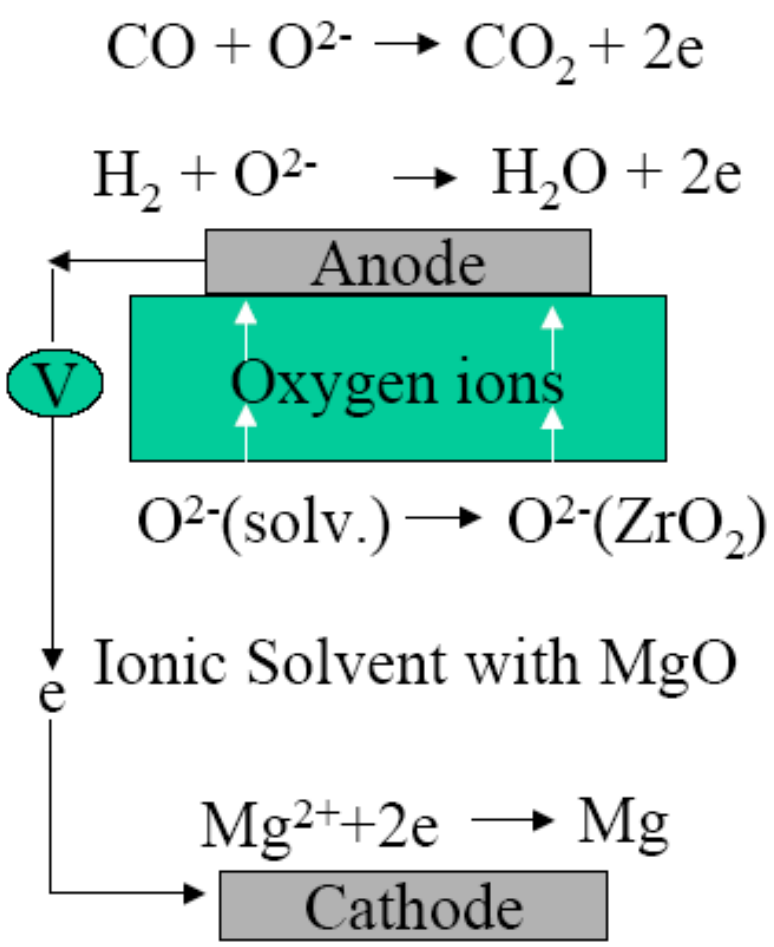
- DOE Technical Targets



Approach

- **Slurry** - Develop a stable and very fluid MgH_2 slurry with slurry energy density of 3.9kWh/kg and 4.8kWh/L
- **Mixer** - Develop mixing system to use MgH_2 slurry and to meet 2kWh/kg and 1.5kWh/L system targets
- **Cost** - Evaluate and develop Mg reduction and slurry production technologies to show potential cost of hydrogen, slurry, and system
  - Comparative evaluation of alternate Mg reduction technologies
  - Experimental Solid-oxide Oxygen-ion-conducting Membrane (SOM) process
  - Experimental carbothermic reduction process
  - Slurry production and component recycling

SOM Process Concept for MgO Reduction

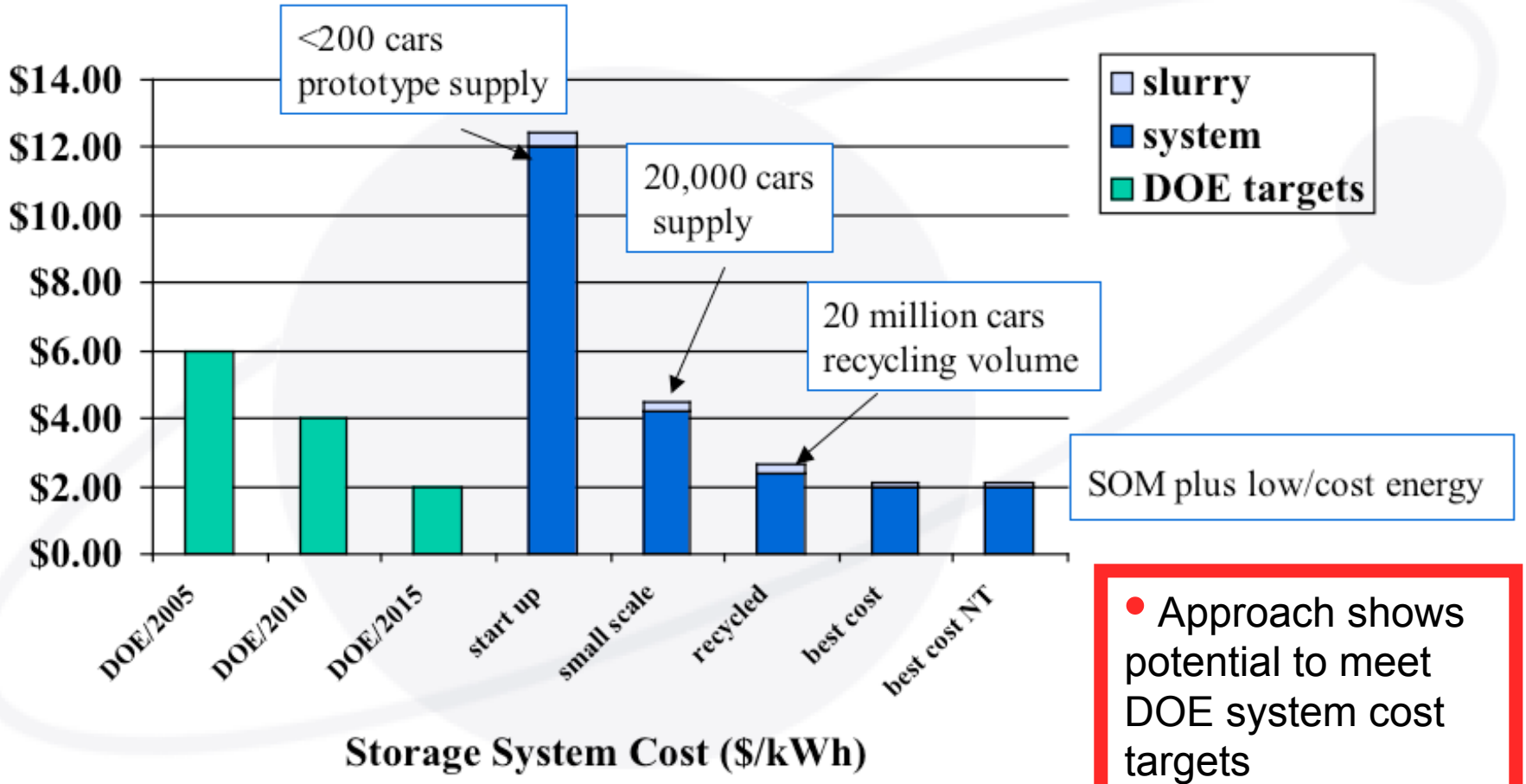


Advantages

- Reduced Energy-10 kWh/kg Mg
  (compare to 16 kWh/kg Mg for $MgCl_2$ process and 6.9 kWh/kg Mg theoretical min energy consumption)
- Reduced Plant Cost
  - Oxide source can be directly electrolyzed - 1/3 of plant footprint of $MgCl_2$ plant
  - High current densities (high production rates) are possible

Storage System Cost

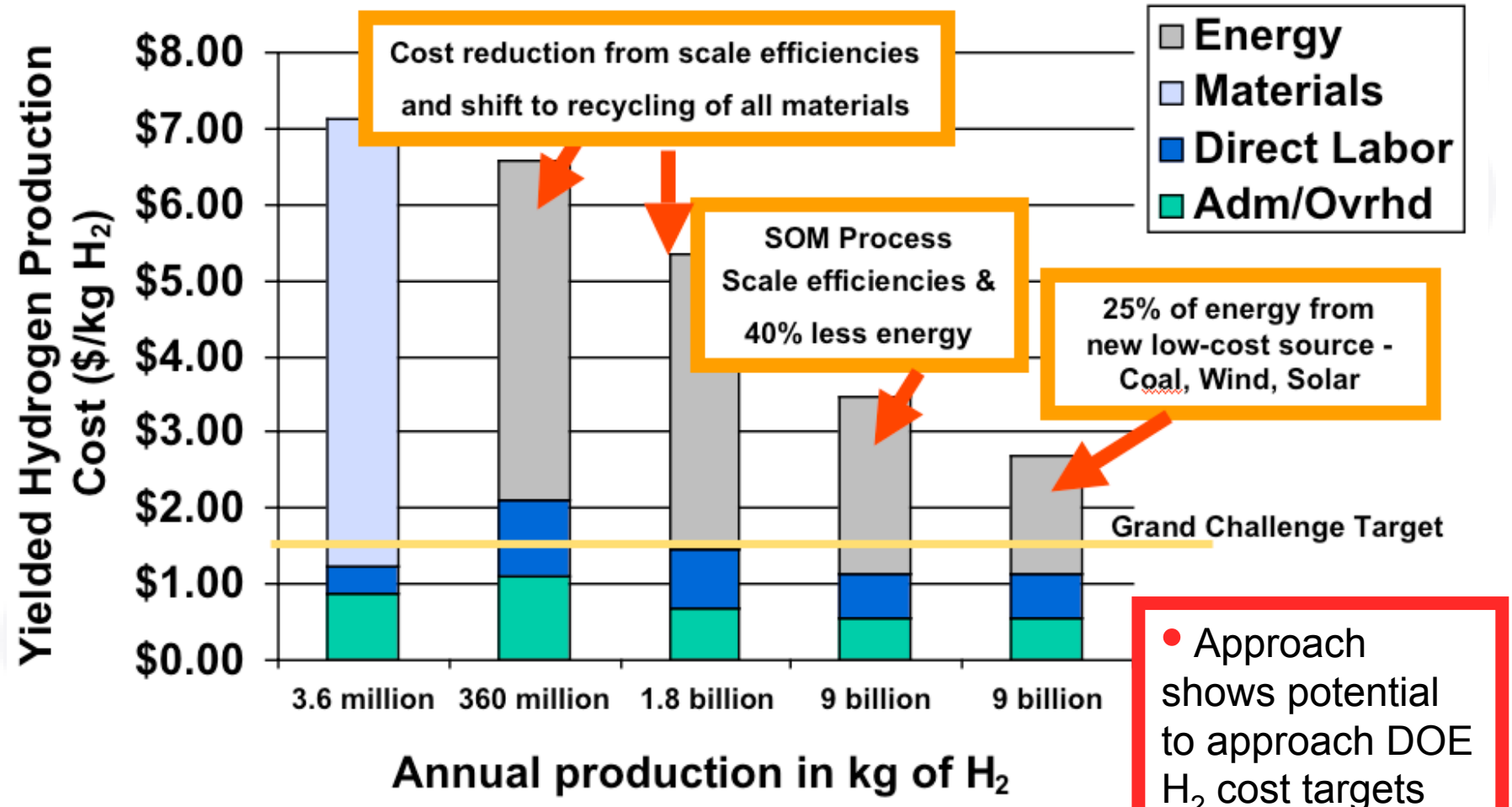
$/kW hour hour: based on 5kg system/tank with all system/tank charges allocated against first 5kg fill.



- Approach shows potential to meet DOE system cost targets

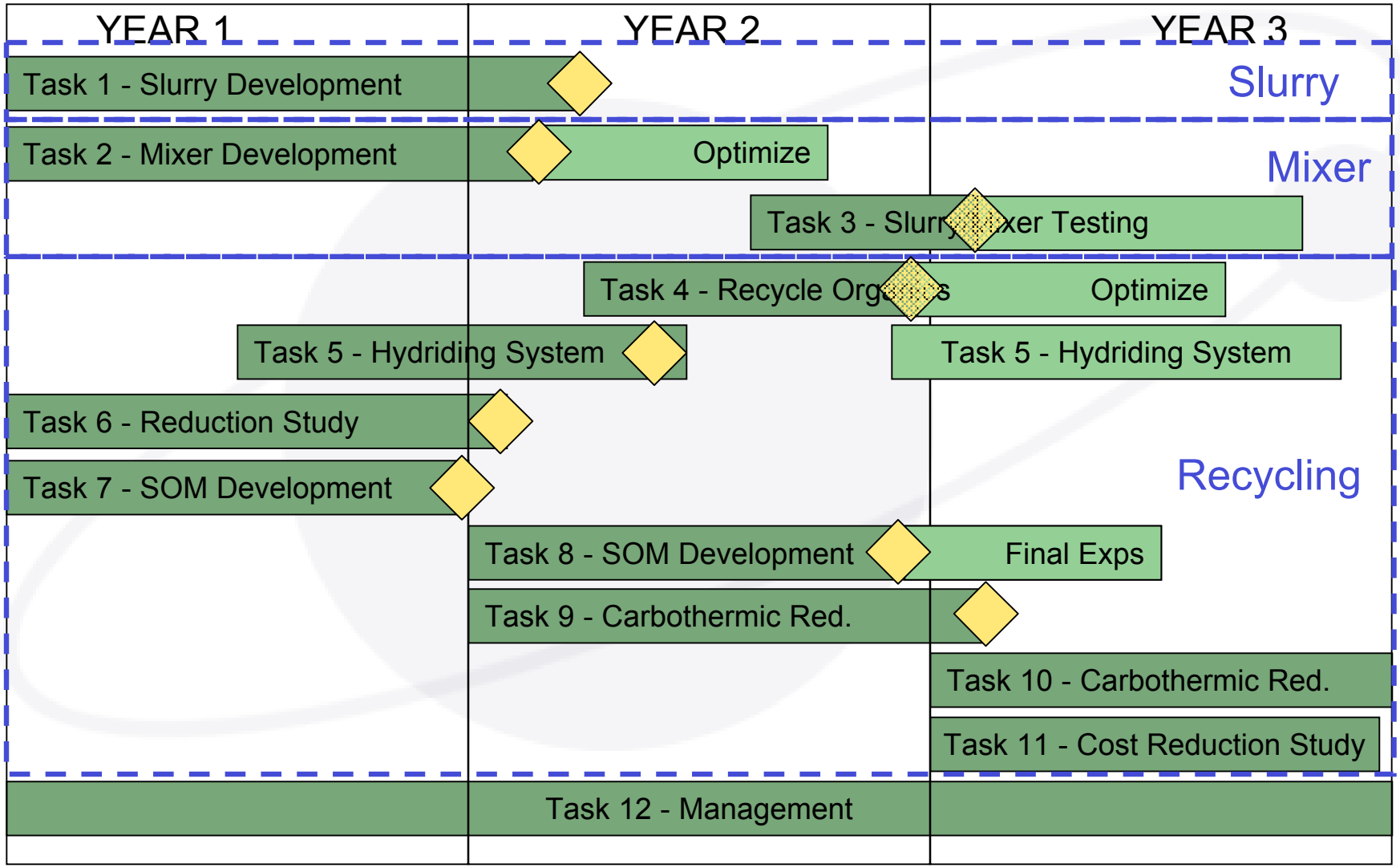
Fuel Cost & Production Cost Drivers

cost drivers shift from material to energy



- Approach shows potential to approach DOE H_2 cost targets

Project Timeline



Project Safety

- MgH_2 slurry
  - No gaseous hydrogen until it is mixed with water
  - Oils reduce slurry flammability
  - Oils in slurry protect hydride from inadvertent contact with moisture in air
  - Stable at normal temperatures and pressures
  - Does not react readily at normal environmental temperatures
- $Mg(OH)_2$ byproduct
  - $Mg(OH)_2$ also known as “Milk of Magnesia”
  - pH <10.5, mild caustic
  - Stable at normal temperatures and pressures
- Task safety
  - Safety analyses will be performed with each task
  - Written safety procedures will be set up for each task
  - All personnel will be trained in safety procedures

Technical Accomplishments/Progress

- New project. Work began in April 2004
- Presentation at the FreedomCAR Tech Team meeting in February 2004
- Contract signed, subcontracts in progress

Interactions and Collaborations

- Project team
  - Safe Hydrogen LLC: Lead, slurry developer
  - Boston University: SOM evaluation and development
  - Hatch Technology LLC: Reduction process comparisons, slurry mixer development, process designs for slurry oils reclamation, etc
  - Metallurgical Viability: Carbothermic Mg reduction evaluation
  - HERA Hydrogen Storage Systems, Inc: Mg hydriding process design

Responses to FreedomCAR Tech Team Comments

- Efficiency of processes
  - Task 6 Reduction study will compare efficiencies of the various potential processes
  - Over the duration of the project, we intend to determine production costs for large scale processing
- Cost of Mg
  - Task 6 Reduction Study will seek comparisons of the cost of Mg for four process alternatives
  - Reduction processes may not need to return high grade Mg so cost of process might be lower than those for metals grade systems
- Detailed breakout of system mass and volume
  - Task 1 Slurry Development and Task 2 Mixer Development will be concerned with minimizing the system mass and volume once the mixing system is proven
- Water balance
  - Task 2 Mixer development will deal with on-board water management

Future Work

- FY 2004/2005
  - Develop MgH_2 slurry
  - Develop MgH_2 mixer
  - Evaluate hydriding systems
  - Evaluate and compare Mg reduction systems
  - Begin experimental development of SOM process for slurry recycling