National Renewable Energy Laboratory
Innovation for Our Energy Future

System Design, Analysis, Modeling, and Media Engineering Properties for Hydrogen Energy Storage

2009 U. S. DOE Hydrogen Program and Vehicle Technologies Annual Merit Review and Peer Evaluation Meeting

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Project ID: stp_11_thornton

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Overview

Timeline

HSECoE start date: FY09
HSECoE end date: FY13
Percent complete: 0%

Budget

FY 2009: $425K
FY 2010: $745K

Barriers

A. System Weight and Volume
B. System Cost
C. Efficiency
D. Durability/Operability
E. Charging/Discharging Rates
F. Codes and Standards
G. Materials of Construction
H. Balance of Plant Components
I. Dispensing Technology
J. Thermal Management
K. System Life-Cycle Assessments

Compressed Gas Systems

L. High-pressure Conformability
M. Lack of Tank Performance Data and Understanding of Failure Mechanisms

Cryogenic Liquid Systems

N. Liquefaction Energy Penalty
O. Hydrogen Boil-Off

Reversible Materials-Based Storage Systems (Reversible On Board)

P. Lack of Understanding of Hydrogen Physisorption and Chemisorption
Q. Reproducibility of Performance

Chemical Hydrogen Storage Systems (Regenerated Off Board)

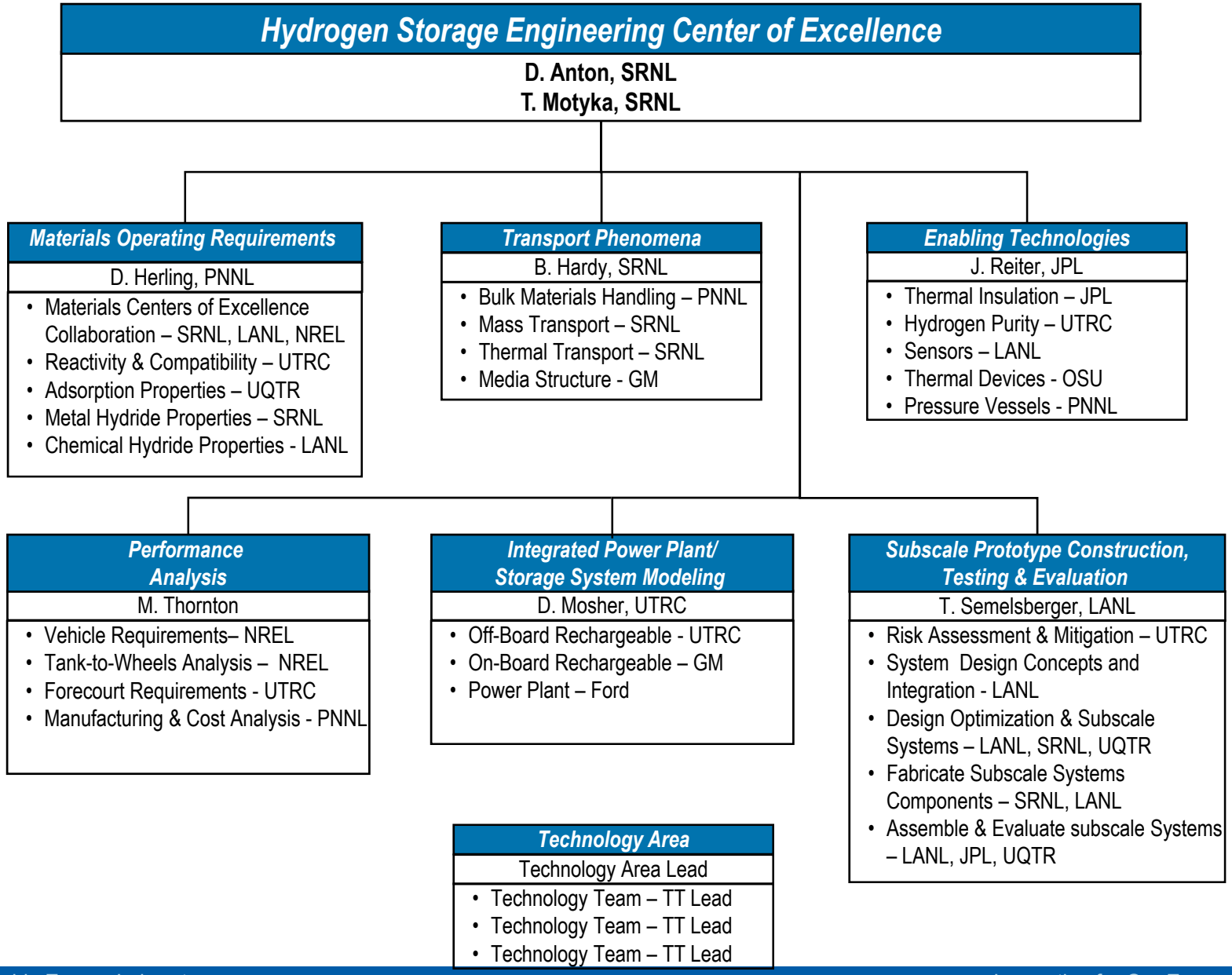
R. Regeneration Processes
S. By-Product/Spent Material Removal

Partners

SRNL, PNNL, UTRC, UQTR, JPL, Ford, GM, LANL, OSU,BASF, DOE HSCoE, DOE MHCoE, ANL, and the DOE Vehicle Technologies Program.

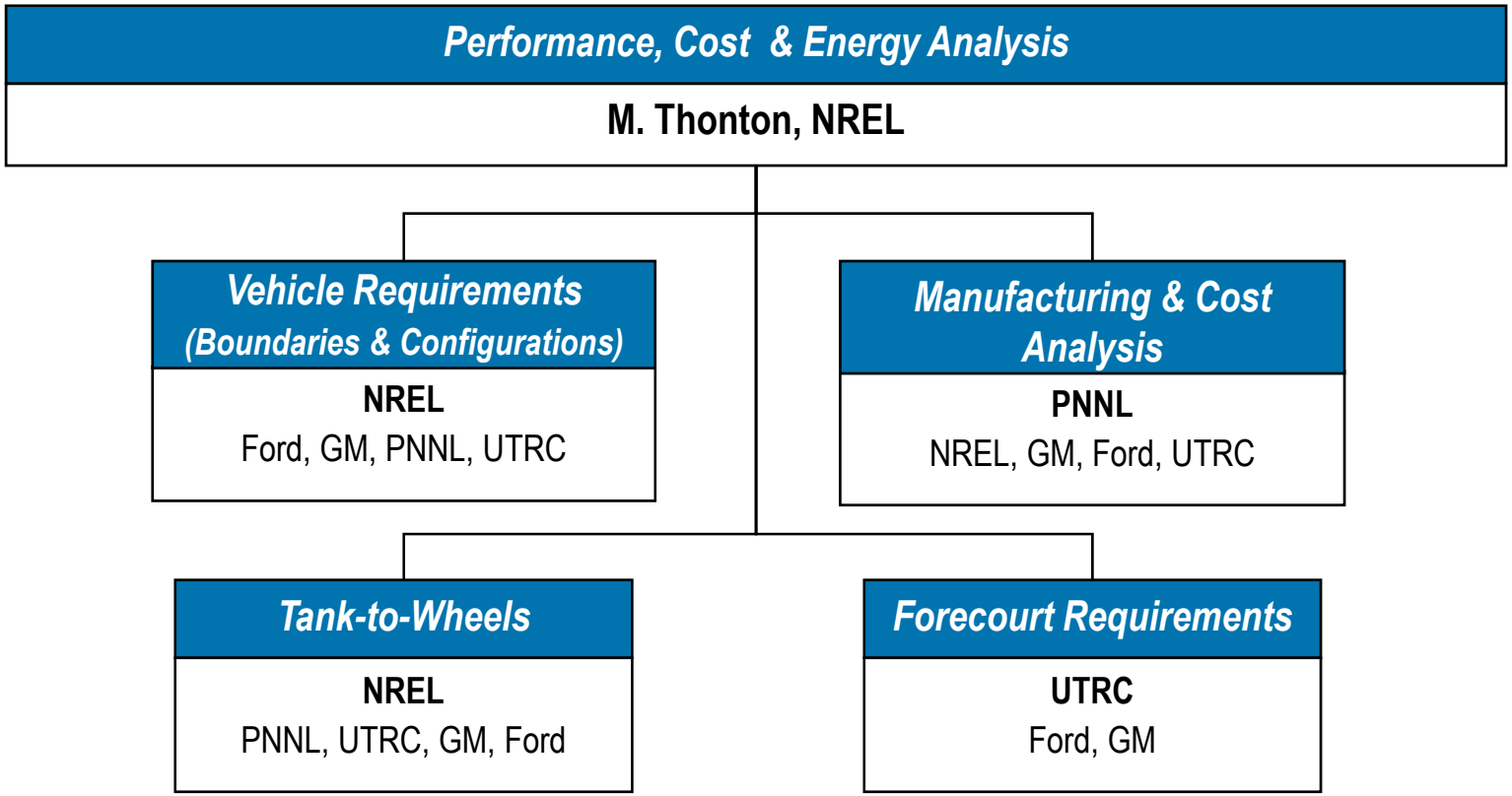
Hydrogen Storage Engineering
CENTER OF EXCELLENCE

Overview: HSECoE Organization



Overview: HSECoE Organization

Performance, Cost and Energy Analysis Organization



Relevance

NREL Project Objective - Support HSECoE led by SRNL:

- Identify optimal pathways for successful hydrogen storage system technologies through modeling, analysis, and testing support
  - Perform vehicle simulations of various system configurations to support the overall systems engineering technology area
- Support SRNL and UTRC in defining the fuel interface and forecourt energy requirements and in developing thermal management strategies on board the vehicle
- Lead Tank-to-wheels analyses and provide the HSECoE with results that will help guide engineering design
- Compile and obtain media engineering properties for the HSECoE through collaboration with the Hydrogen Storage Materials CoE's (HSMCoE)

Relevance

Impact:

NREL's work is an integral component of DOE's new HSECoE. As part of the National Hydrogen Storage Project it will help meet the overall goals of the Hydrogen, Fuel Cells & Infrastructure Technologies Program. DOE's Program supports the Advanced Energy Initiative. NREL's work will support DOE's objectives and expected outcomes of the HSECoE.

Relevance

Specific objectives of the HSECoE:

(a) Develop and utilize an understanding of storage system requirements for light-duty vehicles to design innovative components and systems with the potential to meet DOE performance and cost targets;

(b) Develop innovative on-board system concepts for materials-based storage technologies;

(c) Develop and test innovative concepts for storage subsystems and component designs;

(d) Develop engineering, design and system models which address both on-board subsystems and the fuel cycle, including refueling, transfer and separation of fresh and spent fuel for chemical approaches, hydrogen discharge profiles, thermal management and the storage-delivery interface; and

(e) Design, fabricate and test subscale prototype components and systems for each material-based technology (adsorbents, metal hydrides and chemical hydrogen storage materials).

Relevance: Expected HSECoE Outcomes

(a) Improve database of the engineering properties of promising hydrogen storage materials;

(b) Experimentally validate key component models (e.g. hydrogen discharge reactor, waste heat rejection and on-board thermal integration) that predict the steady-state and transient response for a select number of performance scenarios;

(c) Improve system-level models incorporating component-level fidelity for a number of power plant, refueling and vehicle type scenarios;

(d) Optimize system design(s) including specific trade-offs required to meet DOE targets; system analysis of the interplay of DOE system requirements;

(e) Develop three (3) subscale prototype systems based upon adsorbents, metal hydrides and chemical hydrides (nominally one prototype for each material type);

(f) Update system projections of weight, volume and transient performance for each material type for a number of vehicle types based upon entire effort conducted; and

(g) Comprehensive documentation of experimental and theoretical results.

Approach

NREL activities are organized into four distinct tasks:

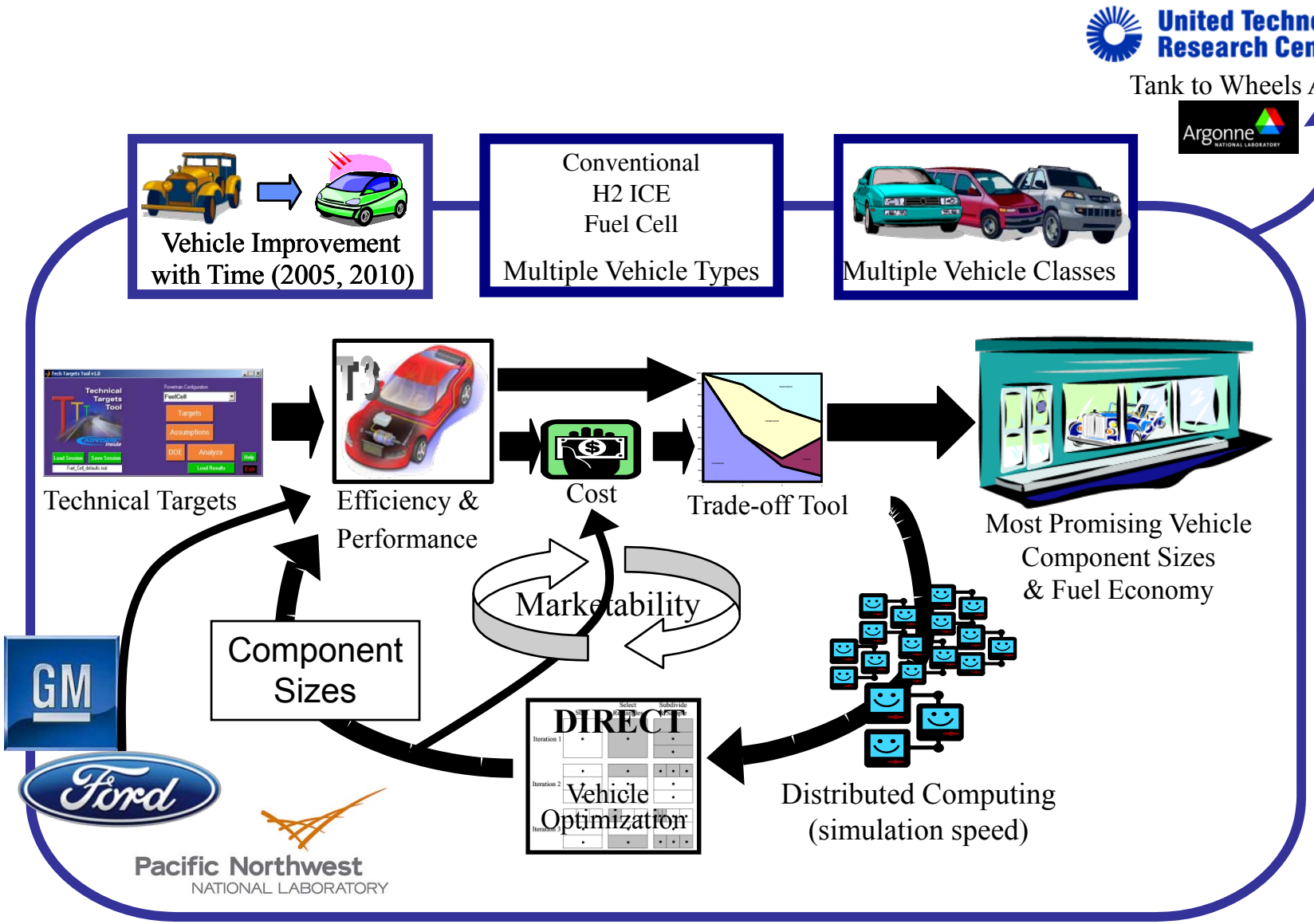
1. System Configuration
   a) NREL's vehicle systems analysis team will leverage an array of tools and experience to meet objectives by modeling vehicle system configurations
      I. Develop and use an understanding of storage system requirements for a light-duty vehicle to design innovative components and systems
2. Define Fuel Interface Requirements
   a) NREL's Hydrogen, Fuel Cells, and Infrastructure Technologies Program will assist the fuel interface technology lead, SNRL, by helping to define fuel interface requirements.
      I. Provide high-level characterization modeling and, as needed, review the Society of Automotive Engineers (SAE) J2600 Compressed Hydrogen Surface Vehicle Refueling Connection Devices, October 2002. The SAE J2600 applies to the design, safety, and operation verification of the compressed hydrogen surface vehicle (CHSV).

Approach

NREL activities are organized into four distinct tasks:

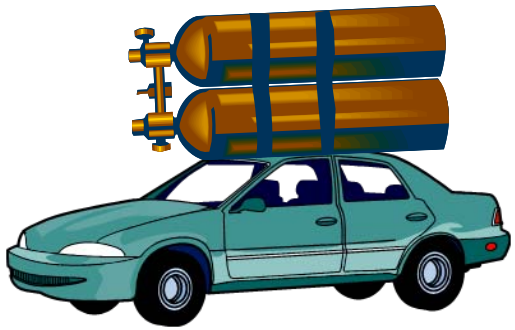
3. Tank to Wheels Energy Analyses
   a) Lead the storage system efficiency portion of the tank to wheel analysis and coordinate with ANL and the Tank to Wheels Technology Team that comprises Pacific Northwest National Laboratory (PNNL), SRNL, and UTRC.
4. Media Engineering Properties
   a) Apply an array of techniques to analyze sorption materials identified by the HSECoE for application in commercial on-board hydrogen storage systems
   b) Provide detailed materials data analyses for tank fabricated
   c) Liaison between materials synthesis and tank engineering to achieve the best automotive designs

Approach: Model Framework



Approach: Vehicle Modeling Summary

- Use a systems approach
  - Explores trade-offs for most promising solution
  - Maintains feasibility
- Combine validated models
  - Vehicle
  - Cost
  - Consumer choice
- Estimate
  - H2 storage size requirements for given set of tech targets, performance constraints and time horizons
  - Determine Best associated component size combinations (e.g., FC, battery, motor, etc.)
  - Most promising FC vehicle design for each storage material



Approach: Defining Fuel Interface Requirements

Fuel interface standards requirements are primarily set in SAE J2600 “Compressed Hydrogen Surface Vehicle Refuelling Connection Devices”

There are also potential requirements for communication between the storage system and the vehicle described in SAE J2799 “Surface Vehicle Information Report”

SAE J2600 divides requirements into:

1. Nozzle (storage and fueling system side of the process)
2. And receptacle (vehicle side of the process) requirements

Approach: Tank to Wheels Analysis

Lead tank to wheels analysis of energy utilization for various hydride types and system configurations :

- Analyze storage system efficiency
- Provide vehicle level efficiency output for each storage technology (from vehicle modeling) and incorporate forecourt requirements
- Coordinate with ANL (through SSAWG) over-all WTW analysis
  - e.g. GREET input/output

Argonne NATIONAL LABORATORY

United Technologies Research Center

Pacific Northwest NATIONAL LABORATORY

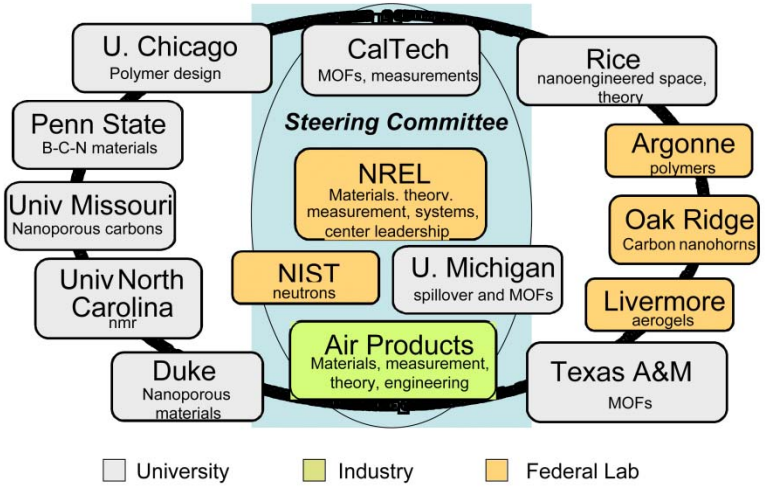
Approach: Media Engineering Properties

Hydrogen Sorption Center Collaboration

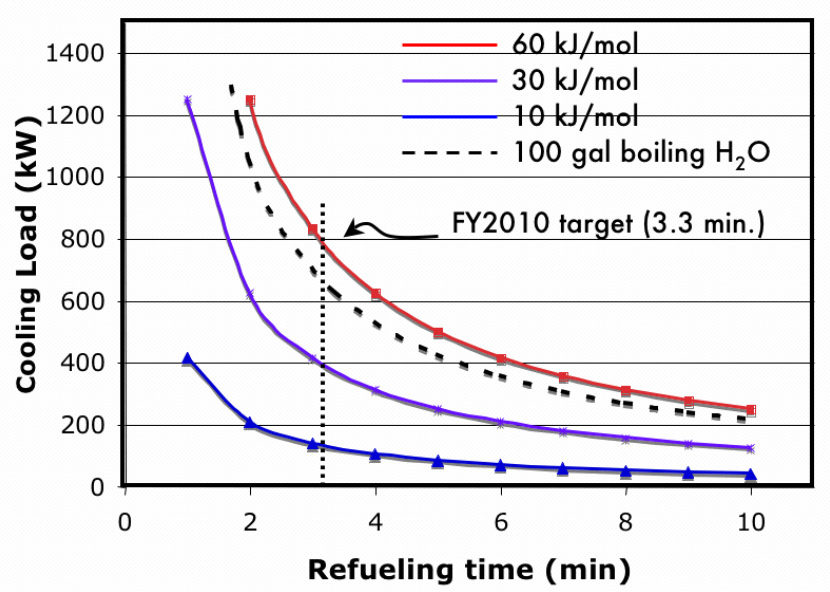
Liaison and assist with adsorption media engineering properties/kinetics modeling

Provide:

- Advanced Measurement Capabilities
- Enthalpy of Adsorption
- Required Heat Dissipation
- Determination of Binding Energy



9 universities, 5 government labs, 1 industrial partner



Technical Milestones and Deliverables

1. Report preliminary vehicle system configuration modeling/analysis results
2. Summarizes J2600 requirements and assist in developing strategies to meet relevant code requirements
3. Report preliminary storage system efficiency analyses (energy to fast fill and meet discharge target rates)
4. Report collaborations to compile/obtain media engineering properties
5. Define hydrogen storage system requirements for a light duty automotive application and bounds on materials' properties to achieve them in support of Center Go/No-Go decision for DOE 2015 Hydrogen Storage Targets

All FY 2009 Milestones are Due in September 2009

NREL Collaborations

Collaborations are already in place with our HSECoE partners:

- SRNL: HSECoE lead and metal hydride materials analysis
- PNNL and LANL: Chemical hydride materials analysis
- UTRC: Metal hydride materials analysis and properties
- UQTR: Sorption materials
- Jet Propulsion Laboratory: Enabling Technologies
- Ford and GM: OEM system down select and integration
- ANL: SSAWG team lead
- OSU: Micro-channels
- DOE HSCoE: NREL led center will provide materials and properties
- DOE MHCoE: provide metal hydride materials and media properties
- DOE Vehicle Technologies Program: technical guidance and expertise

Technical Accomplishments and Progress

- Held Center Kick-off meeting
- Hosted first Center face-to-face technical meeting
  - February 23-25, 2009 in Golden
- Developed vehicle modeling platform and modeling approach
- Held performance modeling technical area strategy meeting with OEMs in Detroit to refine modeling approach

FY 2010 Work

The HSECoE and NREL's contribution to the project is divided into three phases with Go/No-Go decisions at the end of each phase. Phase 1 and 2 will each be two years in duration. FY 2010 will continue Phase 1 work.

- Phase 1: System Requirements and Novel Concepts
  - Focus on system configuration modeling, vehicle simulations, cost analysis, fuel interface requirements, thermal management, and collaboration with HSMCoE
  - Identify the applications of highest value
    - Use experimental investigations and modeling to collect the data necessary to support the Go/No-Go decision to proceed to Phase 2
  - Work with UTRC, SRNL, Ford, and GM to model storage system requirements
  - Work with PNNL and SRNL to perform cost analyses
  - Collaborate with UTRC, SRNL, Ford, and GM to determine storage system requirements and down select system design concepts
  - Define preliminary fuel interface requirements and review forecourt requirements with UTRC and SRNL
  - With UTRC and SRNL, design, develop, test innovative thermal management and refueling concepts to determine preliminary heat rejection requirements
  - Perform Tank-to-Wheels analyses and initial energy requirements assessments with UTRC and PNNL
  - Compile/obtain media engineering properties with HSMCoE

Summary

NREL's work is an integral component of DOE's new HSECoE. As part of the National Hydrogen Storage Project it will help meet the overall goals of the Hydrogen, Fuel Cells & Infrastructure Technologies Program. DOE's Program supports the Advanced Energy Initiative. NREL's work will support DOE's objectives and expected outcomes of the HSECoE through vehicle performance modeling, energy analysis, and compiling and obtaining media engineering properties for the HSECoE through collaboration with the Hydrogen Storage Materials CoE's (HSMCoE)

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