IV.B.6 System Design, Analysis, Modeling, and Media Engineering Properties for Hydrogen Energy Storage

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Project Start Date: February 2, 2009
Project End Date: September 30, 2015

Overall Objectives

- Perform vehicle-level modeling and simulations of various storage systems configurations
- Lead the storage system energy analysis and provide results
- Compile and obtain media engineering properties for adsorbent materials
- Coordinate the public access of select Hydrogen Storage Engineering Center of Excellence (HSECoE) models, including web posting documentation and tracking downloads and web activity

FY 2015 Objectives

- Coordinate the public access of select HSECoE models, including web posting documentation and tracking downloads and web activity
- Complete final report

Technical Barriers

This project addresses the following technical barriers from the Hydrogen Storage section of the Fuel Cell Technologies Program's Multi-Year Research, Development and Demonstration Plan:

(A) System Weight and Volume

(B) System Cost

(C) Efficiency

(E) Charging/Discharging Rates

(I) Dispensing Technology

(K) Systems Life-Cycle Assessments

Technical Targets

This project is conducting simulation and modeling studies of advanced onboard materials-based hydrogen storage technologies. Insights gleaned from these studies are being applied toward the design and synthesis of hydrogen storage vessels that meet the following DOE 2015 hydrogen storage for light-duty vehicle targets:

- Cost: to be determined
- Specific energy: 0.055 kg H_2/kg system
- Energy density: 0.040 kg H_2/L system
- Charging/discharging rates: 3.3 min
- Well to power plant efficiency: 60%

FY 2015 Accomplishments

- Updated and integrated several center storage system models with the molding framework and posted them on the web site portal
  - Included a 700 bar physical storage model, a metal hydride model two chemical hydride models and adsorbent system models
- Completed documentation updates for the posted models (including website text and downloadable user manual)
- Competed submodel validation, graphical user interface (GUI) improvement, model parametrization and simulation run time improvements
- Performed vehicle-level tradeoff analyses to better understand the impact of key engineering designs, for example, the tradeoff between mass, onboard hydrogen storage capacity, and vehicle range
- Completed final report

INTRODUCTION

Overcoming challenges associated with onboard hydrogen storage is critical to the widespread adoption of hydrogen-fueled vehicles. The overarching challenge is

identifying a means to store enough hydrogen onboard to enable a driving range greater than 300 miles within vehicle-related packaging, cost, safety, and performance constraints. By means of systems analysis and modeling, hydrogen storage system requirements for light-duty vehicles can be assessed. With these findings and through collaboration with our HSECoE partners, optimal pathways for successful hydrogen storage system technology can be identified to enable future commercialization of hydrogen-fueled vehicles. At this stage of the project the focus of activities has moved from the model application and analysis to model validation and making select models developed under the HSECoE publicly available and accessible to other researcher.

APPROACH

An array of tools and experience at NREL are being used to meet the objectives of the HSECoE. Specifically, extensive knowledge of multiple vehicle simulations, well-to-wheels analysis, and optimization are being employed and integrated with fuel cell and material-based hydrogen storage system models developed by other HSECoE partners. This integrated model framework allows for the evaluation of various hydrogen storage options on a common basis. Engineering requirements are defined from these studies thus enabling the design of hydrogen storage vessels that could meet DOE performance and cost targets in a vehicle system context. The approach for FY 2015 is to complete updates, validation, troubleshooting, debugging, and documenting these framework and other models to that can be made accessible and use by other research organizations.

RESULTS

The following will provide results from work completed this year to support the HSECoE with a focus on the coordination of the public access of select HSECoE models, including web posting documentation and tracking downloads and web activity. In collaboration with several HSECoE partners, NREL worked on the validation, refinement, GUI improvements, troubleshooting, improving simulation run time, documentation of models selected for web posting and web activity monitoring/tracking and model download tracking. To date there have been 50 downloads of the tank volume/cost model, 31 downloads of the framework model, 17 downloads of the metal hydride (MH) finite element model and 13 down loads of the MH acceptability envelop.

Model validation work on the HSECoE MH stand lone acceptability envelope, MH finite element, the tank volume/cost models and the compressed gas, MH and chemical hydride (CH) framework models have been compete. Documentation and users guides for all of these HSECoE models have also been complete this year and all are currently or will soon be available via the HSECoE

FIGURE 1. HSECoE web home page

website (hsecoe.org). Figure 1, shows a screen caption of the current HSECoE home page which has direct links to the documentation, user guides and download area for all available models (Figure 2).

The following Table 1, shows all of the select HSECoE models that are available on the website.

TABLE 1. HSECoE Models Available on Web Portal and Model Posting Status

Model Name	HSECoE Lead	Status
MH Acceptability Envelop	SRNL	Complete
MH Finite Element Model	SRNL	Complete
Tank Volume/Cost Model	PNNL	Complete
MH Framework Model	UTRC/NREL	Complete
CH Framework Model	PNNL/UTRC/NREL	Complete
AD Framework Model	SRNL/UTRC/NREL	Complete

SRNL – Savannah River National Laboratory; PNNL – Pacific Northwest National Laboratory; UTRC – United Technologies Research Center; AD - adsorbent

In addition to the validation, documentation, user guide and posting activities this year efforts were also focused on the continued refinement of a GUI for the framework model in order to make the models more user friendly. In FY 2015 UTRC, NREL and other HSECoE partners teamed

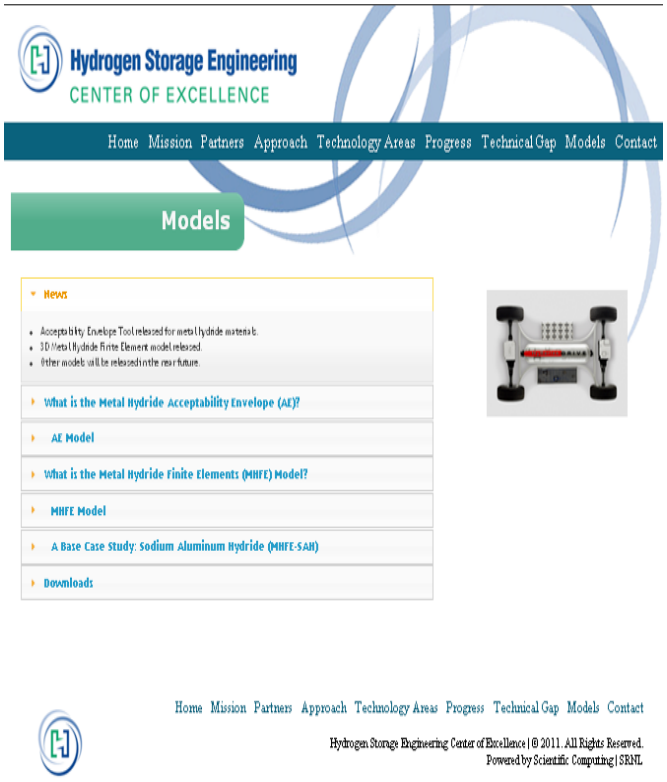

FIGURE 2. HSECoE web models documentation and download page

on the GUI improvement effort. Figure 3 shows the current framework model GUI developed by UTRC. In this figure the model selection pull down menu, the parameter settings location and the model output and plot area. This specific storage system diagrams were also added to the GUI this year when available.

Now that several HSECoE models are available to a wider research audience via the HSECoE web page, the final task for this year has been to continue tracking and documenting website activity and model downloads. Figure 4 shows the latest web site activity over the last three months. As can be seen the site has received over 200 visitors since during this time and of those 66% were new visitors. The bounce rate, which indicates sessions under 10 seconds, is 19% which meant that 81% of the visitors stay longer than 10 seconds and stay over five minutes on average. The bounce rate last year was 53% and the session time was four minutes indicating that more users are staying at the site and saying for a longer time. Figure 5 shows the user flows for the site.

FUTURE DIRECTION

- Work with center partners to continue to update and improve center developed models available and accessible to the broader research and academic

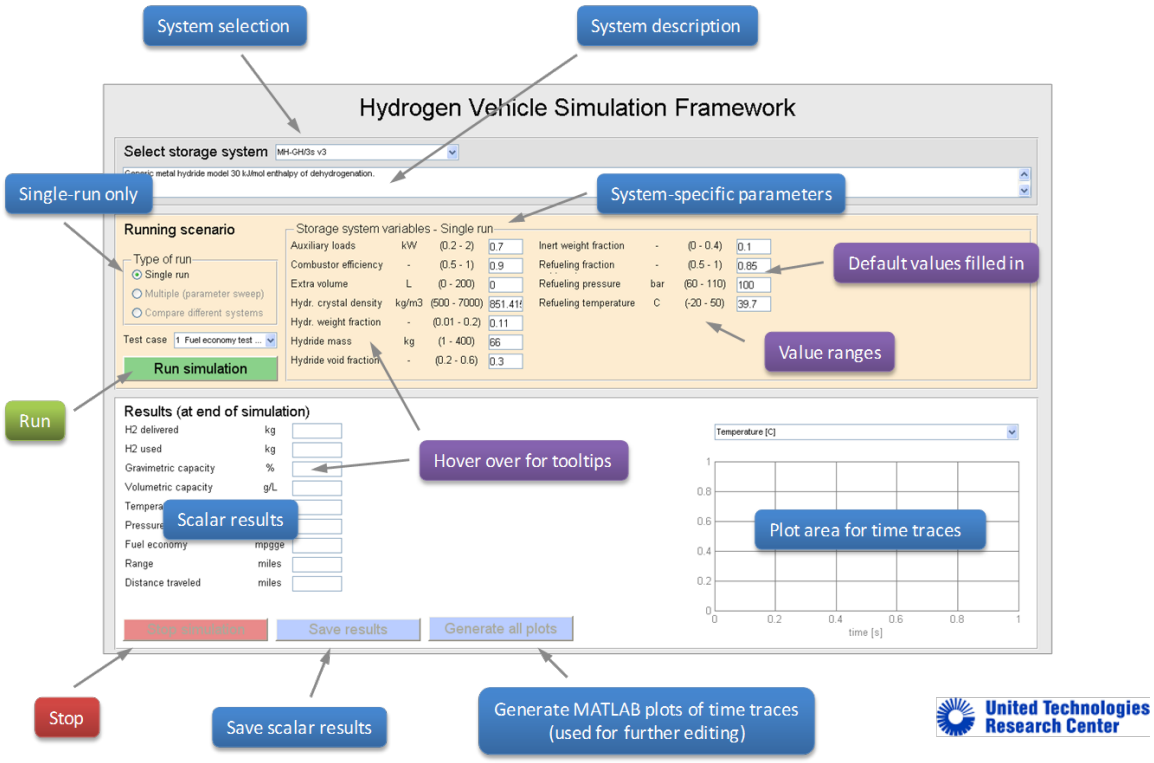

FIGURE 3. HSECoE framework model GUI

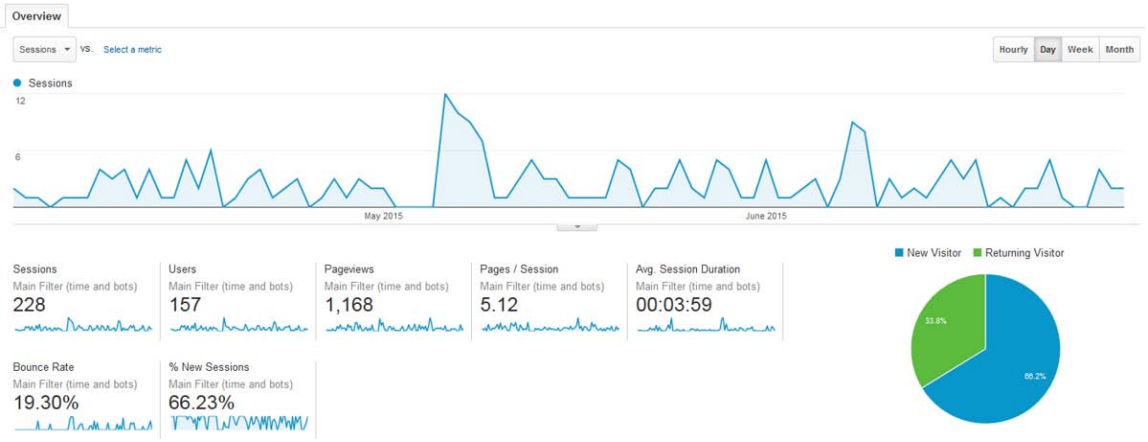

FIGURE 4. HSECoE web analytics: three-month site activity metrics

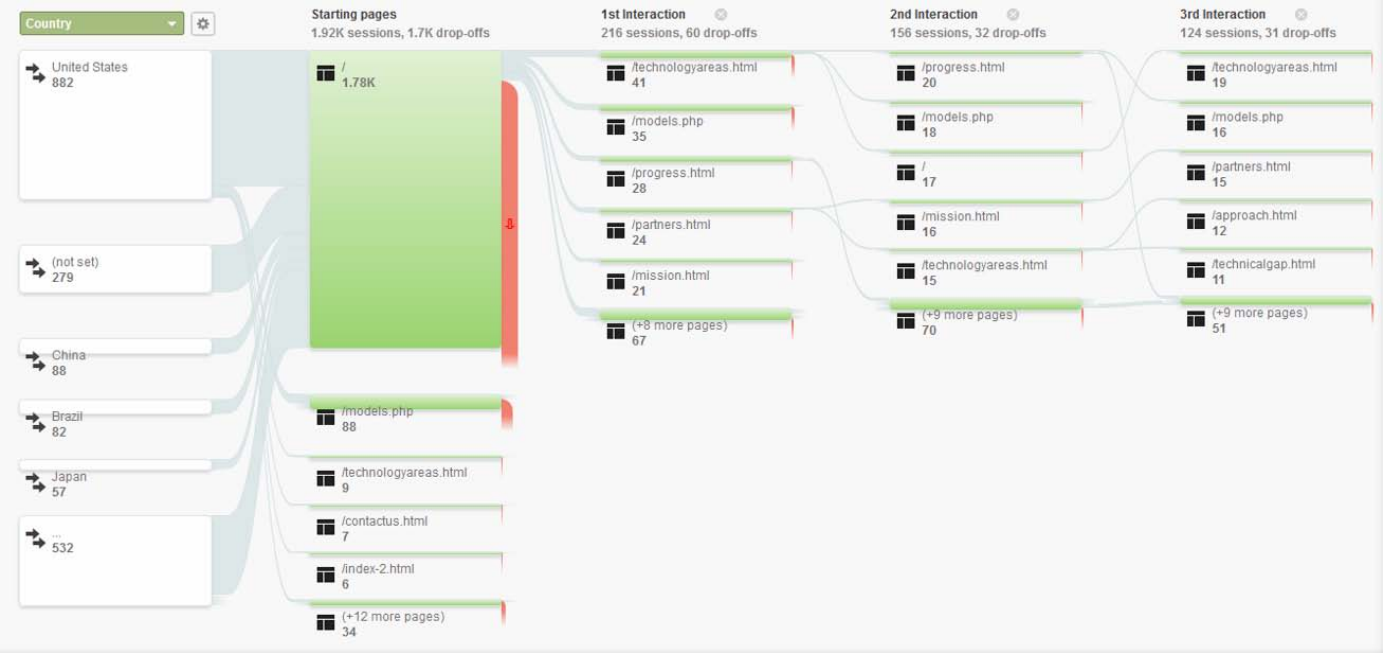

FIGURE 5. HSECoE web analytics: user flows

community through a controlled web based access portal and track downloads and website activity.

FY 2015 PUBLICATIONS/PRESENTATIONS

1. System Design, Analysis, Modeling, and Media Engineering Properties for Hydrogen Energy Storage, Matthew Thornton, DOE Annual Merit Review Meeting, June 9, 2015, Washington, D.C.