IV.B.5 System Design, Analysis, Modeling, and Media Engineering Properties for Hydrogen Energy Storage

Matthew Thornton (Primary Contact), Jeff Gonder, Aaron Brooker, and Jonathon Cosgrove

National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, CO 80401
Phone: (303) 275-4273
Email: Matthew.Thornton@nrel.gov

DOE Managers

Ned Stetson
Phone: (202) 586-9995
Email: Ned.Stetson@ee.doe.gov

Jesse Adams
Phone: (720) 356-1421
Email: Jesse.Adams@ee.doe.gov

Subcontractors

- Strategic Analysis Inc., VA
- Mark Pastor, MD

Project Start Date: February 2, 2009
Project End Date: June 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 2014 Objectives

Coordinate the public access of select HSECoE models, including Web posting documentation and tracking downloads and Web activity.

Technical Barriers

This project addresses the following technical barriers from the Hydrogen Storage section of the Fuel Cell Technologies Office 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-powerplant efficiency: 60%

FY 2014 Accomplishments

- Updated and integrated several center storage system models with the modeling framework and posted them on the website portal. These included a 700-bar physical storage model, a metal hydride model and two chemical hydride models.
- Completed documentation updates for the posted models (including website text and downloadable user manual).
- Developed disclaimer language to post alongside the models.
- Completed migration and link updates from the old SRNL.gov site to the current hsecoe.org site for all model postings.
- 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.

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 2014 is to now update, validate, troubleshoot, de-bug, and document these framework and other models to that they can be made accessible and used 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 (1) worked on the validation, refinement, Graphical User Interface (GUI) development, troubleshooting, and documentation of models selected for Web posting and (2) executed website migration, logistics, model posting and monitoring/tracking.

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

Table 1 shows all of the select HSECoE models that are either available or that will be 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	In progress
AD Framework Model	SRNL/UTRC/NREL	9/2014
AD Finite Element Model	SRNL	3/2015

In addition to the validation, documentation, user guide, and posting activities this year, efforts were also focused on the development of a graphical user interface for the framework model in order to make the models more user friendly. In FY 2014 UTRC, NREL, and other HSECoE

FIGURE 1. HSECoE Web Home Page

partners teamed up on the GUI development effort. Figure 2 shows the current framework model GUI developed by UTRC. In this figure are the model selection pull down menu, the parameter settings location, and the model output and plot area.

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 track and document website activity and model downloads. Figure 3 shows the website activity from when the site was migrated to the new location in March through August. As can be seen the site has received over 700 visitors since the migration and of those 75% are new visitors. The bounce rate, which indicates sessions under 10 seconds, is 53% which meant that 47% of the visitors stay longer than 10 seconds and stay over four minutes on average.

Figure 4 shows the geographic locations of the visitors to the website. As expected most of the activity originated in the U.S., but there was also significant activity from Europe, Japan, Brazil, and Australia.

FUTURE DIRECTION

- Work with center partners to continue to make select center developed models available and accessible to the broader research and academic community through a controlled Web-based access portal and track downloads and website activity.
- Continue to run vehicle simulations to support Phase III engineering designs for adsorbent systems as needed:
  - Run vehicle simulations to support high-level storage system design and engineering tradeoffs.
  - Run vehicle simulations to support storage systems sizing analyses.

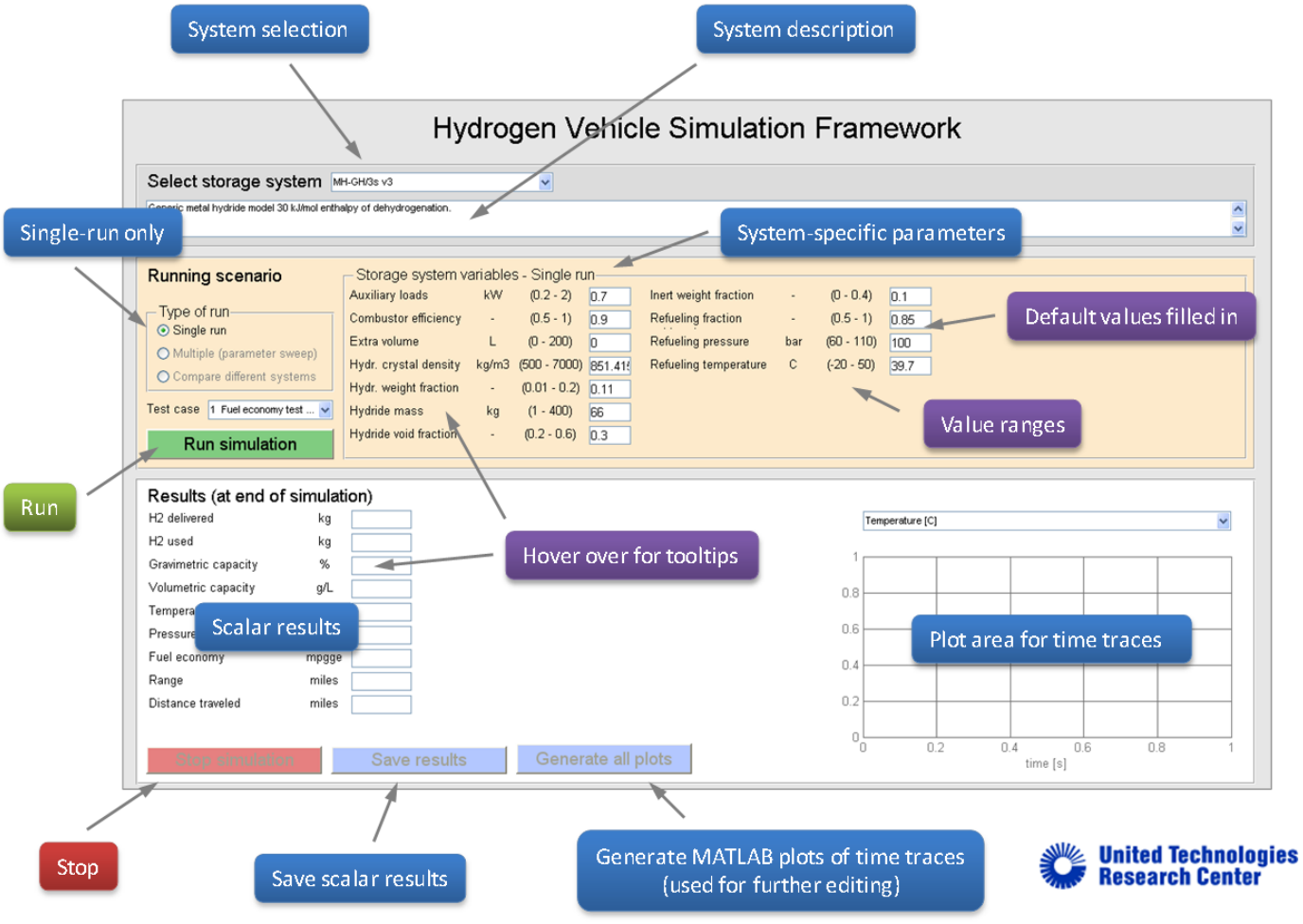


FIGURE 2. HSECoE Web Models Documentation and Download Page

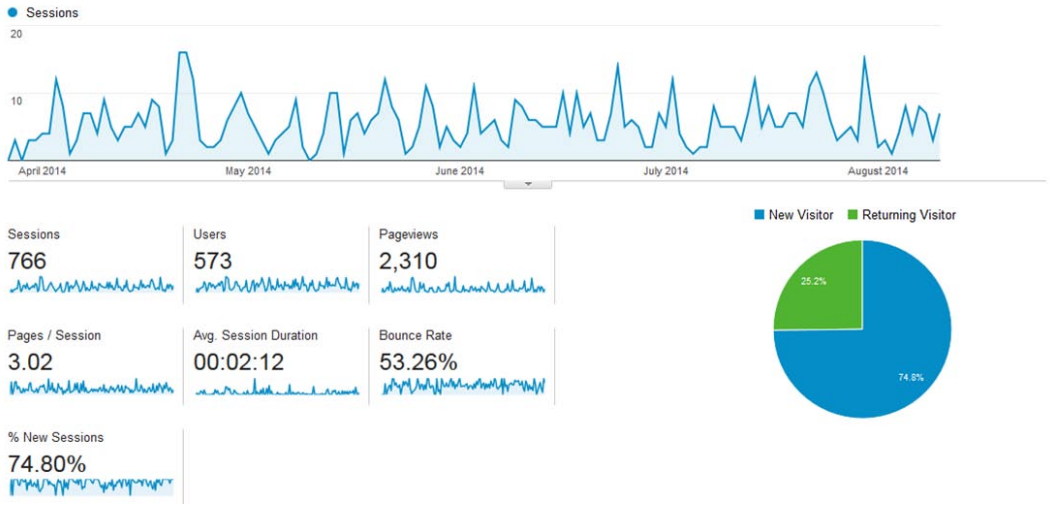
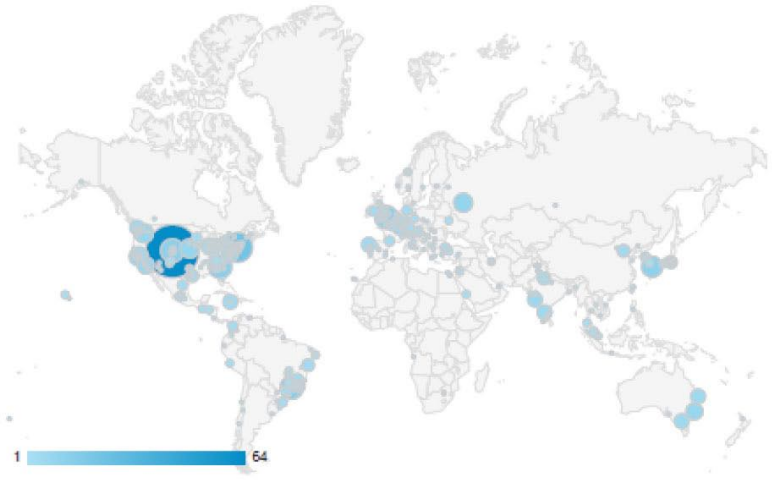


FIGURE 3. HSECoE Framework Model GUI



City	Acquisition			Behavior			Conversions		
	Sessions	% New Sessions	New Users	Bounce Rate	Pages / Session	Avg. Session Duration	Goal Conversion Rate	Goal Completions	Goal Value
	766 % of Total: 100.00% (766)	74.80% Site Avg: 74.80% (0.00%)	573 % of Total: 100.00% (573)	53.26% Site Avg: 53.26% (0.00%)	3.02 Site Avg: 3.02 (0.00%)	00:02:12 Site Avg: 00:02:12 (0.00%)	0.00% Site Avg: 0.00% (0.00%)	0 % of Total: 0.00% (0)	$0.00 % of Total: 0.00% ($0.00)
1. West Pleasant View	64 (8.38%)	18.75%	12 (2.09%)	28.12%	3.42	00:03:35	0.00%	0 (0.00%)	$0.00 (0.00%)
2. (not set)	43 (5.61%)	81.40%	35 (6.11%)	79.07%	2.21	00:01:00	0.00%	0 (0.00%)	$0.00 (0.00%)
3. Stratford	21 (2.74%)	23.81%	5 (0.87%)	9.52%	3.38	00:05:54	0.00%	0 (0.00%)	$0.00 (0.00%)
4. Aiken	13 (1.70%)	61.54%	8 (1.40%)	23.08%	2.69	00:00:24	0.00%	0 (0.00%)	$0.00 (0.00%)
5. Sao Paulo	12 (1.57%)	100.00%	12 (2.09%)	100.00%	1.00	00:00:00	0.00%	0 (0.00%)	$0.00 (0.00%)
6. London	12 (1.57%)	66.67%	8 (1.40%)	50.00%	3.33	00:05:58	0.00%	0 (0.00%)	$0.00 (0.00%)
7. Boulder	12 (1.57%)	8.33%	1 (0.17%)	83.33%	1.50	00:02:50	0.00%	0 (0.00%)	$0.00 (0.00%)
8. Fukuoka	11 (1.44%)	18.18%	2 (0.35%)	100.00%	1.00	00:00:00	0.00%	0 (0.00%)	$0.00 (0.00%)
9. Moscow	9 (1.17%)	100.00%	9 (1.57%)	44.44%	2.67	00:03:40	0.00%	0 (0.00%)	$0.00 (0.00%)
10. Livermore	9 (1.17%)	44.44%	4 (0.70%)	33.33%	4.78	00:02:49	0.00%	0 (0.00%)	$0.00 (0.00%)

FIGURE 4. HSECoE Web Analytics: Site Activity Metrics

FY 2014 PUBLICATIONS/PRESENTATIONS

1. System Design, Analysis, Modeling, and Media Engineering Properties for Hydrogen Energy Storage, Matthew Thornton, DOE Annual Merit Review Meeting, June 18, 2014, Washington, D.C.

2. Development of a Vehicle-Level Simulation Model for Evaluating the Trade-Off between Various Advanced On-Board Hydrogen Storage Technologies for Fuel Cell Vehicles, Matthew Thornton, Jon Cosgrove, Aaron Brooker and Jeff Gonder, 1st International Symposium on Energy Challenges and Mechanics, Aberdeen Scotland, July 10, 2014.