XI.9 Global Hydrogen Resource Analysis

Thomas Drennen
Earth Systems Analysis, Department 6926
Sandia National Laboratories
Albuquerque, NM 87185
Phone: (315) 781-3419
Email: Drennen@hws.edu

Todd West
Systems Research and Analysis II
Sandia National Laboratories
P.O. Box 969 M/S 9406
Livermore, CA 94551-0969
Phone: (925) 294-3145
Email: thwest@sandia.gov

DOE Manager
Fred Joseck
Phone: (202) 586-7932
Email: Fred.Joseck@ee.doe.gov

Project Start Date: June 2010
Project End Date: December 31, 2013

Overall Objectives

This project is a subtask of the International Energy Agency (IEA) Hydrogen Implementing Agreement (HIA) Task 30 (Global Hydrogen Systems Analysis). The overall objectives of Subtask 30A (Global Hydrogen Resource Analysis) are to:

- Analyze potential hydrogen production and distribution pathways for participating countries.
- Develop a user-friendly pathways analysis tool that allows users the ability to:
  - Understand the resource options and constraints to meeting future hydrogen demand for various fuel cell vehicle market shares.
  - Estimate potential petroleum savings and greenhouse gas emission reductions associated with various scenarios.
- Collaborate with IEA analysts as appropriate to support global hydrogen resource analysis.

The objective for U.S. participation in this international effort is to inform ongoing analysis in regards to international efforts to identify pathways and assumptions for the widespread implementation of hydrogen in the transportation sector.

Fiscal Year (FY) 2013 Objectives

- Completion of pathways analysis tool and final report.
- Demonstrate value of pathways tool for understanding country and regional-level resource availability to support large-scale rollout of hydrogen vehicles and the associated greenhouse gas (GHG) emission reductions over a business-as-usual scenario.
- Gather feedback on analysis results from relevant stakeholders through final report and webinar.

Technical Barriers

This project addresses the following technical barriers from the Systems Analysis section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan:

(A) Future Market Behavior

(C) Inconsistent Data, Assumptions, and Guidelines

(D) Insufficient Suite of Models and Tools

Contribution to Achievement of DOE Systems Analysis Milestones

This project will contribute to achievement of the following DOE milestones from the Systems Analysis section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan:

- Milestone 1.9: Complete analysis and studies of resource/feedstock, production/delivery, and existing infrastructure for technology readiness. (4Q, 2014)
- Milestone 1.13: Complete environmental analysis of the technology environmental impacts for hydrogen and fuel cell scenarios and technology readiness. (4Q, 2015)

FY 2013 Accomplishments

- Completed development of version 1.0 of the Global Pathways Resource Analysis Tool (GPAT). GPAT is a user-friendly tool to help participants in HIA Task 30 and other interested stakeholders understand resource options and constraints to meeting future hydrogen demand for various market share scenarios for hydrogen fuel cell vehicles.
- Presented initial results from GPAT to the HIA Task 30 experts, the HIA Executive Committee, and to IEA analysts.
- Results demonstrate a large range of potential pathways for providing hydrogen to fuel a significant hydrogen fuel

cell fleet and that resource availability is not the limiting factor in a hydrogen economy. For example, for a scenario where the fuel cell vehicle market share reaches 40% by 2050, if natural gas was the sole feedstock used for hydrogen production in the U.S. and Germany, the additional natural gas demand would be limited to about 25% of current demand for natural gas in those countries. In the more likely case where hydrogen would be produced from a variety of feedstocks, the added demand for natural gas would be considerable less. See results for additional scenarios.

✧ ✧ ✧ ✧ ✧

INTRODUCTION

The IEA established the HIA to pursue collaborative hydrogen research and development and information exchange among its member countries. The goal of Task 30 (Global Hydrogen Systems Analysis) is to "perform comprehensive technical and market analysis of hydrogen technologies and resources and supply and demand related to the projected use of hydrogen." Task 30 includes four main subtasks. Subtask A, the focus of this effort, focuses on the potential hydrogen production and distribution pathways for participating countries. Subtask B is developing a harmonized hydrogen technology database. Subtask C is focused on collaboration with IEA analysts regarding the potential future role for hydrogen in a clean energy future.

APPROACH

The GPAT calculates least-cost pathways for H2 supply for eight participating countries: France, Germany, Italy, Norway, Spain, Sweden, the United Kingdom, and the United States. The pathways include consideration of feedstock, conversion, distribution (regional and long-distance), and carbon costs. For each country, hydrogen demand is calculated based on assumptions about future hydrogen vehicle market shares. Hydrogen production costs are calculated based on country-supplied data on feedstock availability for hydrogen production by type, cost, and quantity from 2010 to 2050, and assumptions about hydrogen production technology assumptions (efficiencies, costs, etc.). Where country-level data was not available, U.S.-based analysis estimates derived from H2A [1], the Hydrogen Delivery Scenario Analysis Model [2], and the Macro-System Model [3] were used. Integration of results from Subtask 30B (Technology Database) and HIA Task 28 (Distribution) is expected by in first quarter 2014.

GPAT also estimates petroleum savings and GHG reductions and compares the feedstock use for H2 production through 2050 with 2010 primary energy consumption. The tool includes consideration of inter-regional transfers of hydrogen based on total cost of producing and delivering hydrogen.

A key feature of GPAT is the ability for users to vary key assumptions, including resource availability and price, vehicle shares and efficiencies, carbon taxes, and renewable portfolio standards, and view real-time results, making the tool ideal for policy-level discussions.

RESULTS

Our analysis shows that there are a large number of potential pathways for providing hydrogen to fuel a significant vehicle fleet and that resource availability is not the limiting factor in a hydrogen economy. Using GPAT, each participating country has identified multiple options for producing hydrogen domestically.

GPAT results are presented at both the regional (i.e., Europe) and then country-level (France, Denmark, Sweden, Spain, Norway, and Germany). Illustrative, preliminary results for Europe are shown in Figures 1-3. Comparable graphs exist at the country level, or, in the U.S., at the regional level. Figure 1 shows the least-cost pathways for supplying the required hydrogen for a 40% hydrogen fuel vehicle (HFV) 2050 market share scenario in the absence of either carbon taxes or country-level renewable portfolio standards. In the absence of the carbon taxes, natural gas, coal, and wind are the dominant feedstocks used for the production of hydrogen, with small contributions from biomass and hydro. Distributed steam methane reforming is the lowest cost option in the early years; in later years, electrolysis using onshore wind resources and centralized coal gasification play a more dominant role. Because of the increasing reliance on coal in this scenario, annual CO_2 emissions from the light-duty vehicle sector are just 12.5% lower than for the non-H2 case in 2050.

Figure 2 shows the least-cost pathways with $100 per ton CO_2 price phased in over time, beginning in 2015. For this case, natural gas is the dominant feedstock initially, but as the CO_2 tax increases, H2 production begins to shift to onshore wind and centralized coal gasification with Carbon capture and storage. For this case, CO_2 emissions in 2050 from light-duty vehicles are reduced 24% over the base case.

Figure 3 shows the projected delivered hydrogen costs ($/kg) in 2050 for one European country (country not identified here due to preliminary nature of results) for the $100/ton CO_2 tax case. Costs are broken down by feedstock, conversion, distribution, and carbon tax component. The lowest cost option in this year is biomass gasification. In the absence of the CO_2 tax, centralized coal would be the low-cost option.

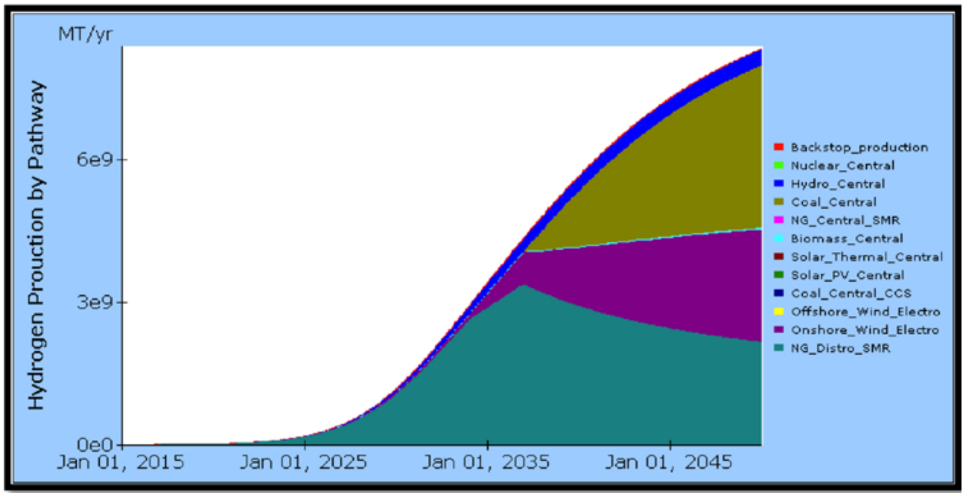

FIGURE 1. Least-cost H2 pathways in Europe for HFV market share of 40% by 2050.

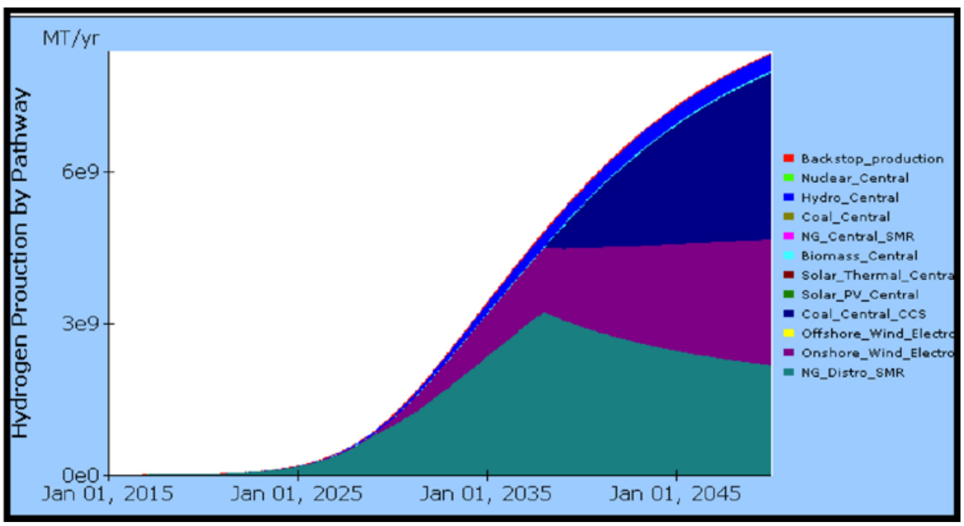

FIGURE 2. Least-cost H2 pathways in Europe for HFV market share of 40% by 2050 with $100 per ton CO_2 tax.

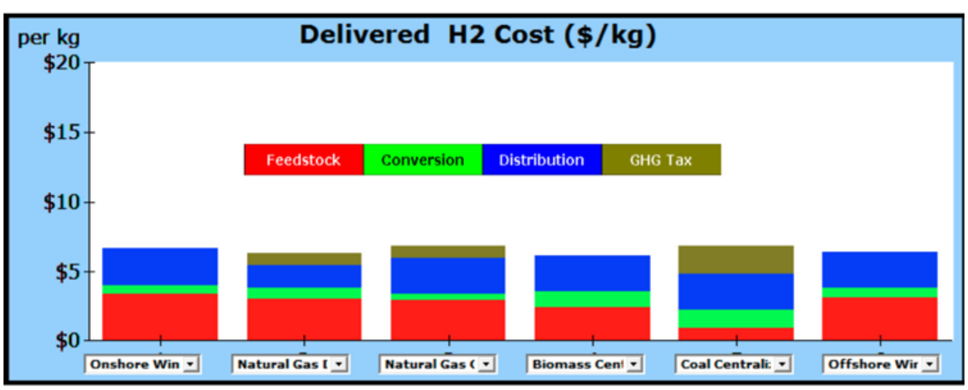

FIGURE 3. Illustrative H2 production costs in 2050 ($/kg).

CONCLUSIONS AND FUTURE DIRECTIONS

This global resource analysis work is a subtask of the IEA HIA Task 30 (Global Hydrogen Systems Analysis). The main objective is to analyze potential hydrogen production and distribution pathways for participating countries. To accomplish this objective, we developed a user-friendly pathways tool to help participants understand the resource options and constraints to meeting future hydrogen demand for various scenarios. The results show there are a large number of potential pathways for providing hydrogen to fuel significant fuel cell fleets and that resource availability is not the limiting factor for a hydrogen economy. While one of the stated goals for pursuing fuel cell vehicles are reduced GHG emissions, access to cheap supplies of fossil fuels could limit the GHG emission reductions. For this reason, many countries expect their countries to require some percentage of their hydrogen production to come from low-carbon intensity fuels such as wind or biomass. The final results will be presented to the HIA participating countries in October 2013 for approval and will be presented in a final report.

FY 2013 PUBLICATIONS/PRESENTATIONS

1. T. Drennen, "Global Hydrogen Resource Analysis", DOE/EERE Annual Merit Review, Project ID: AN038, Washington, D.C., May 14, 2013.

2. T. Drennen and S. Schoenung, "Hydrogen Resource Analysis Update", HIA Task 30, Spring meeting, Paris, March 10, 2013.

3. T. Drennen and S. Schoenung, "Task 30, Subtask A Update for HIA ExCo", Paris, March 11, 2013.

4. T. Drennen, D. Reichmuth, T. West, "Hydrogen Analysis Update", HIA Task 30, Fall meeting, Oslo, September 27, 2013.

REFERENCES

1. The Department of Energy Hydrogen Analysis (H2A) Cost models are available online at: www.hydrogen.energy.gov/h2a_analysis.html.

2. The Department of Energy Hydrogen Analysis Delivery Scenario Analysis Model (HDSAM) is available at: http://www.hydrogen.energy.gov/analysis_repository/project.cfm/PID=218.

3. The Department of Energy Macro System Model (MSM) is available at: http://www.hydrogen.energy.gov/macro_system_model.html.