Regional Supply of Hydrogen

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Project Start Date: October 1, 2016
Project End Date: September 30, 2018

Overall Objectives

- Evaluate hydrogen supply chain scenarios for fuel cell electric vehicles (FCEVs) using the Scenario Evaluation and Regionalization Analysis (SERA) model.
- Leverage existing hydrogen production supply and determine lowest-cost supply chain growth options conforming to hydrogen demand growth through 2040.
- Evaluate novel high-pressure intra-city hydrogen supply (HyLine) economic competitiveness and practicality.

Fiscal Year (FY) 2018 Objectives

- Update the SERA model with the latest production, distribution, and dispensing capital and maintenance and operating specifications from the H2A (Hydrogen Analysis) and HDSAM (Hydrogen Delivery Scenario Analysis Model) model suites.
- Perform high-level technology cost estimation of high-pressure hydrogen pipelines.
- Produce an algorithm for estimating high-pressure pipeline build-out in urban areas.
- Update SERA with regional energy cost projections.
- Disaggregate U.S. hydrogen growth regionally using H2USA scenarios.
- Use SERA model to generate least-cost hydrogen supply chains.
- Prepare a final report.

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[1]:

Technical Approach: Infrastructure Analysis

A. Future Market Behavior: Scenarios to understand vehicle-fuel interactions

E. Unplanned Studies and Analysis: Response to H2USA public-private partnership and infrastructure deployment goals.

Contribution to Achievement of DOE Systems Analysis Milestones

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

- Milestone 1.16: Complete analysis of program performance, cost status, and potential use of fuel cells for a portfolio of commercial applications. (4Q, 2018)
- Milestone 1.17: Complete analysis of program technology performance and cost status, and potential to enable use of fuel cells for a portfolio of commercial applications. (4Q, 2018)

FY 2018 Accomplishments

- Produced optimization framework for supply chain deployment for more than 3,000 cities in the United States in 5-year investment increments through the year 2040 with the use of the SERA model. The optimization included a new algorithm for intra-urban pipeline distribution to hydrogen stations from semi-central hydrogen production units.

[1] https://energy.gov/eere/fuelcells/downloads/fuel-cell-technologies-office-multi-year-research-development-and-22

- Exercised the model over disaggregated hydrogen demand growth scenarios from H2USA: National Expansion (high demand growth), State Success (medium growth), and Urban Markets (low growth).
- Produced regionalized cost of hydrogen based on regionally optimal supply chains.
- Showed substantial potential for retail adoption and economic and functional advantage of employment of high pressure pipeline intra-city hydrogen distribution (HyLine).

INTRODUCTION

This project evaluates a least-cost hydrogen supply chain to meet the growing hydrogen demand from light-duty FCEVs using the SERA model. Existing and new production technologies as well as various conventional transmission, delivery, and dispensing technologies are competed economically to determine the lowest-cost supply chain. A high-pressure (~1,000 bar) hydrogen transmission and delivery pipeline network (HyLine) is proposed to reduce distribution costs and improve network reliability. Three demand scenarios were evaluated as well as constraining different production technologies and varying existing hydrogen plant capacity utilization and selling price.

APPROACH

This work examines the existing U.S. hydrogen production capacity as well as potential nearby Canadian hydrogen production import availability. This work then combines three scenarios of estimated market demand for hydrogen from light-duty FCEVs [1] with the existing hydrogen supply to determine the highest probability locations for the development of new hydrogen generation capacity and quantify the investment costs required. Lastly, a least-cost, temporally and spatially resolved hydrogen production and distribution network is modeled using the SERA model to meet the growing hydrogen demand through 2050 under each FCEV demand scenario.

To reduce hydrogen distribution costs, this work introduces a scalable, semi-distributed high-pressure intraurban pipeline production and distribution network system (HyLine). Various semi-central production sites connecting stations via intraurban pipelines can reduce costs while delivering reliability and scalability improvements to the hydrogen distribution system. Pipeline distribution is the most cost-effective, industrial-scale distribution pathway for hydrogen today and has been implemented within as well as between major refinery and other hydrogen user and production facilities. Thus, a network of hydrogen refueling stations is also expected to ultimately make use of this lowest-cost delivery pathway. Prior work for examining pipelines has looked at the long-term cost potential [2], and this work adds transition analysis for market penetration and timing of the technology.

RESULTS

Results show that average U.S. dispensed hydrogen cost is \$16/kg (2016 real dollars) in 2018 and decreases to \$4.60/kg by 2040 (see Figure 1).

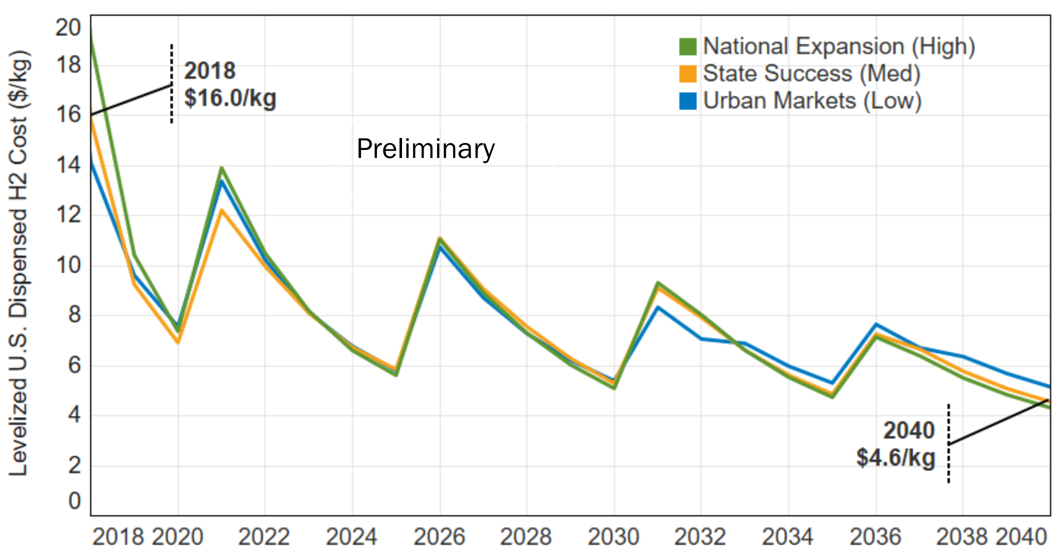

Figure 1. Average U.S. dispensed hydrogen cost for each light-duty vehicle demand scenario considered

SERA results, shown in Figure 2, indicate that existing hydrogen capacity in the Gulf Coast is used to meet demand in California while Northeast plants meet the large urban area demand around them. However, by 2030, new production plants are built both in the Northeast and in California to support the nearly 50 tonne/day hydrogen demand.

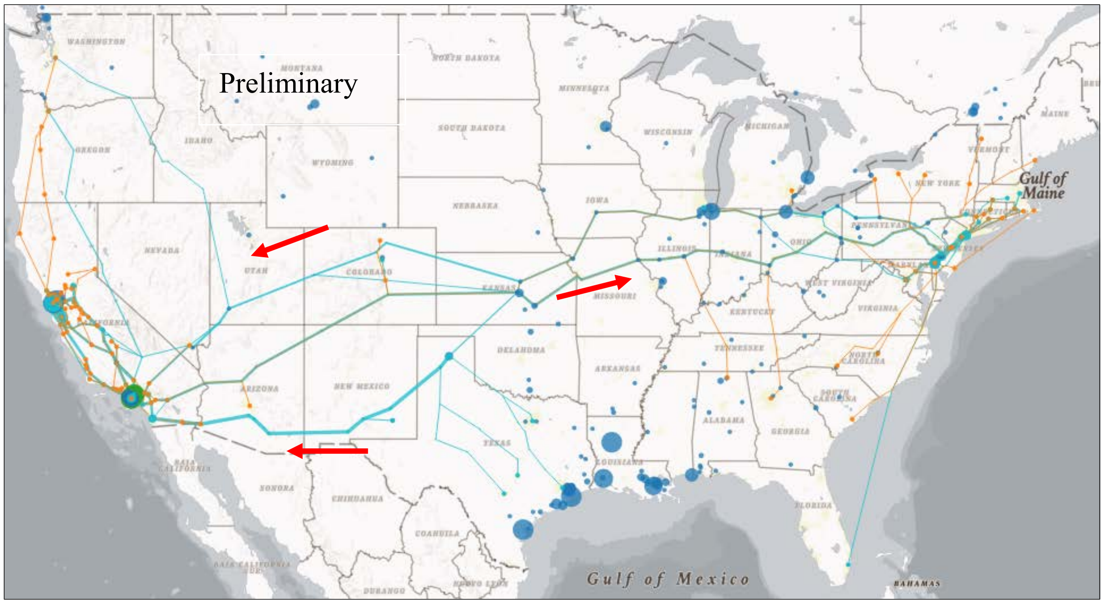

Figure 2. Hydrogen supply chain development over time for the State Success (Med) scenario. Infrastructure snapshot is of 2030.

Cumulative capital investment opportunity by 2040 is ~$28 billion. Additionally, the growth of light-duty fuel cell electric vehicles results in the displacement of 4.0 billion gallons of gasoline each year. Lastly, the HyLine distribution pathway is shown to be economically competitive by 2030 with more than 50% of stations joining the pipeline network in eight urban areas by 2040 (see Figure 3).

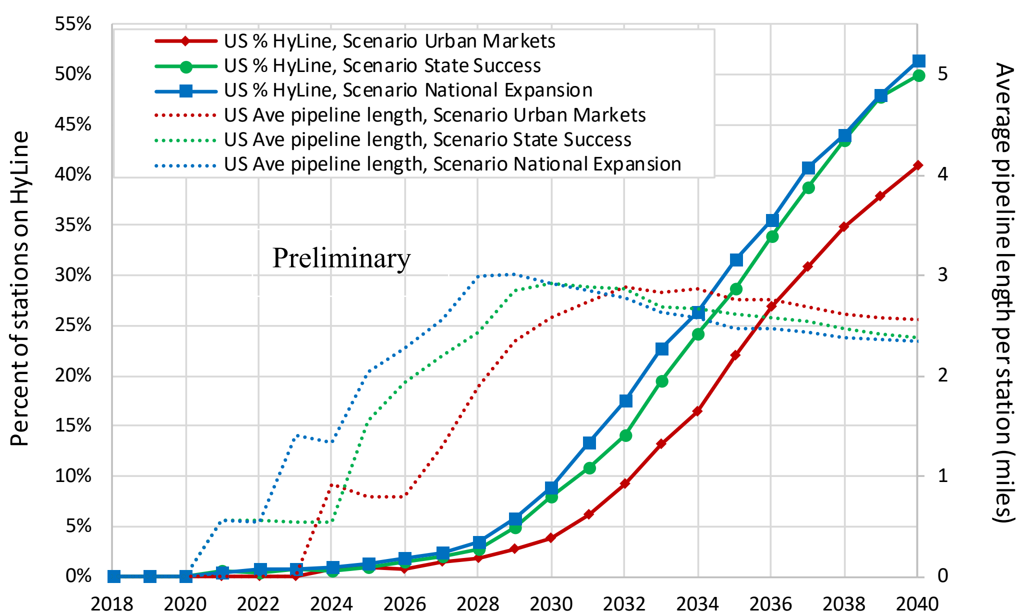

Figure 3. Estimated HyLine technology adoption over time for each demand scenario evaluated

CONCLUSIONS AND UPCOMING ACTIVITIES

The SERA model estimates that the average U.S. dispensed hydrogen cost is $16/kg (2016 real dollars) in 2018 but drops to $4.6/kg by 2040 driven by economies of scale. SERA results indicate that existing hydrogen capacity in the Gulf Coast is used to meet demand in California. However, by 2030, new production plants are built across the United States and concentrated in California and the Northeast to support the nearly 50 tonne/day hydrogen demand. Cumulative capital investment opportunity by 2040 is ~$28 billion indicating a large market for new firms to enter the industry. Additionally, the growth of FCEVs results in the displacement of 4.0 billion gallons of gasoline each year. Finally, the HyLine distribution pathway is shown to be economically competitive by 2030 with more than 50% of stations joining the pipeline network in eight urban areas by 2040.

Future work seeks to further enhance modeling accuracy and realism and explicitly add renewable hydrogen production pathways. Items to consider would be identifying regionally specific land costs, incorporating existing pipeline infrastructure, adding non-vehicular hydrogen demand through the H2@Scale effort, which this modeling framework can readily implement, and evaluating the impact of renewable energy credits in regions that offer them.

FY 2018 PUBLICATIONS/PRESENTATIONS

1. M. Penev and C. Hunter, "Regional Supply of Hydrogen," Project ID #SA063, U.S. Department of Energy Hydrogen and Fuel Cells Program 2018 Annual Merit Review and Peer Evaluation Meeting, Washington, DC, June 13–15, 2018.

REFERENCES

1. M. Melaina, B. Bush, M. Muratori, J. Zuboy and S. Ellis, *National Hydrogen Scenarios: How Many Stations, Where, and When?* Prepared by the National Renewable Energy Laboratory for the H2USA Locations Roadmap Working Group (2017), https://www.nrel.gov/docs/fy18osti/71083.pdf.

2. National Renewable Energy Laboratory, "SERA: Scenario Evaluation and Regionalization Analysis," (2018), http://nrel.github.io/sera/.