IX.7 Regional Supply of Hydrogen

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Project Start Date: October 2016
Project End Date: Project continuation and direction determined annually by DOE

Overall Objectives

- Evaluate existing hydrogen production capacity and hypothetical excess capacity.
- Forecast production capacity expansion requirements for growing fuel cell electric vehicle (FCEV) market demand.
- Simulate regional supply chain network dynamics.
- Incorporate market competition considerations.

Fiscal Year (FY) 2017 Objectives

- Assess current hydrogen production assets by capacity and type as well as current hydrogen and natural gas pipelines.
- Identify potentially constrained production regions.
- Develop modeling framework for semi-central production with spoke-hub distribution pipelines, with eventual transition to large-scale central renewable production.
- Complete preliminary cost estimates for spoke-hub pipeline distribution networks.

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

(E) Unplanned Studies and Analysis

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 1.19: Complete analysis of the potential for hydrogen, stationary fuel cells, fuel cell vehicles, and other fuel cell applications such as material handling equipment including resources, infrastructure and system effects resulting from the growth in hydrogen market shares in various economic sectors. (4Q, 2020)
- Milestone 2.2: Annual model update and validation. (4Q, 2011 through 4Q, 2020)

FY 2017 Accomplishments

- Assessed current hydrogen production assets by capacity and type as well as current hydrogen and natural gas pipelines.
- Identified the Northeast as a potentially constrained production region.
- Developed modeling framework for semi-central production with spoke-hub distribution pipelines, with eventual transition to large-scale central renewable production.
- Completed preliminary cost estimates for spoke-hub pipeline distribution networks.
- Completed initial simulation of regional supply chain network dynamics.

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INTRODUCTION

Numerous supply chain components will contribute to the regional availability and cost of hydrogen for fueling FCEVs. For this reason, comprehensively forecasting the near- and long-term development of hydrogen supply chains is critical for forecasting the regional and national growth of FCEV markets and supporting refueling infrastructure. For such analyses, the National Renewable Energy Laboratory uses its Scenario Evaluation, Regionalization, and Analysis (SERA) model. Work on this project accomplished in FY 2017 expands SERA's capabilities by accounting for current hydrogen production and distribution assets as well as producing a design for semi-central hydrogen production with spoke-hub distribution pipelines.

APPROACH

Additional hydrogen supply pathways and market-competition parameters are developed to extend the SERA modeling framework and forecast competitive retail price and hydrogen availability on a regional basis. SERA is used to develop optimized hydrogen supply networks in response to FCEV hydrogen demands. It accounts for the geography of energy resource availability, extraction and conversion costs, transmission and distribution costs, and retail station network costs. The modeling approach also accounts for a broad range of influences on the decision to invest in new hydrogen production capacity. These include internal rate of return, 5-year demand growth horizon, capacity function of demand growth rate, potential installations, market growth (internal and external FCEV market forecasts), investment risk reduction due to an emerging track record, and total cost of FCEV ownership including policy support. It bases market competition and resulting prices on the production/delivery cost of the second-nearest competitive source.

In FY 2017, this project used data from IHS Markit [1] and ABB [2] to assess current hydrogen production and distribution assets. This information is used to forecast when various regions would experience stress on their hydrogen supply infrastructure based on projected demand from FCEVs. A modeling framework for semi-central hydrogen production with spoke-hub distribution pipelines—with eventual transition to large-scale central renewable hydrogen production—is also developed, and cost information derived from the *Oil & Gas Journal* is applied to estimate hydrogen supply costs [3]. Parameters from Argonne National Laboratory's Hydrogen Delivery Scenario Analysis Model [4] and H2A Delivery Components Model [5] also inform the analysis.

RESULTS

The assessment of current hydrogen production and distribution assets is illustrated in Figure 1. Based on that information, Figure 2 projects the development of

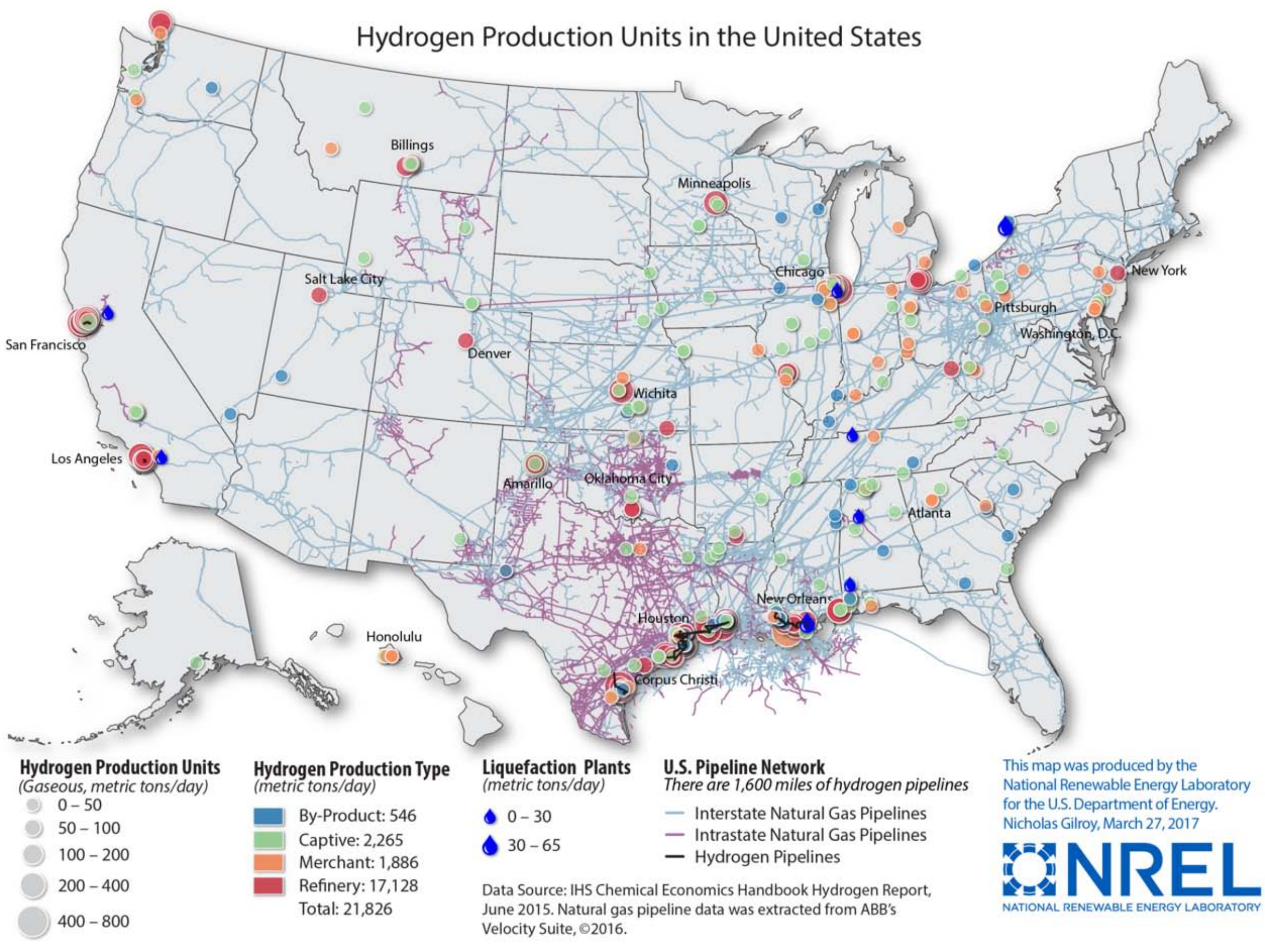

FIGURE 1. Existing U.S. hydrogen production units and hydrogen and natural gas pipelines

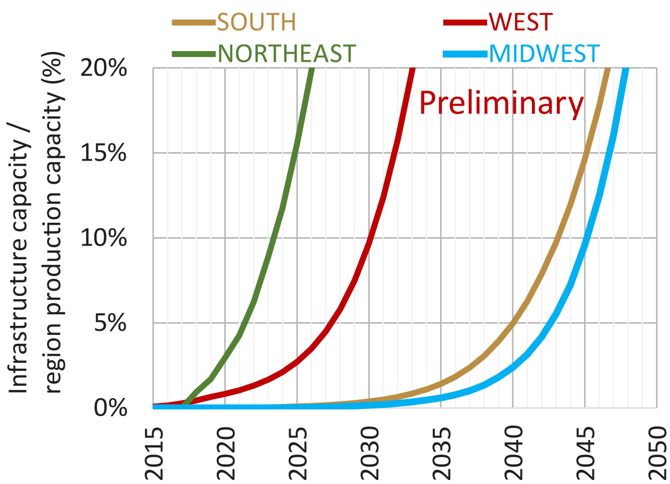

FIGURE 2. Projected regional development of infrastructure capacity as a percentage of total regional production capacity through 2050

infrastructure capacity as a percentage of total existing regional production capacity through 2050. Projected development for growing FCEV markets is based upon national scenarios developed in conjunction with H2USA. Because the Northeast's FCEV market and refueling station network is projected to develop relatively rapidly and its hydrogen production capacity is relatively low, it likely would be the first region to experience stresses in supply. The West, South, and Midwest—in that order—likely would experience stress on regional supply capacities next as their FCEV markets developed.

Figure 3 compares the modeling framework for semi-central hydrogen production with spoke-hub distribution pipelines with a traditional central production framework with long-distance pipeline distribution. In the traditional framework, each retail refueling station in a network would draw hydrogen directly from a pipeline connected to a large hydrogen production facility (Figure 3a). Compared with some other supply approaches, this approach simplifies retail station delivery, eliminates delivery truck emissions, reduces station storage requirements, and enables siting on small urban sites. However, it also requires a large upfront investment, presents high investor risk, and has a long demand ramp-up period (resulting in a poor return on investment). In addition, subsequent investments for network off-shoots may still be needed. Semi-central hydrogen production with spoke-hub distribution pipelines addresses these drawbacks by connecting stations in series to a smaller, scalable production plant (Figure 3b). This approach enables organic growth of the station network, which requires smaller incremental investments, reduces investment risk, provides quicker capital utilization ramp-up, allows for diverse

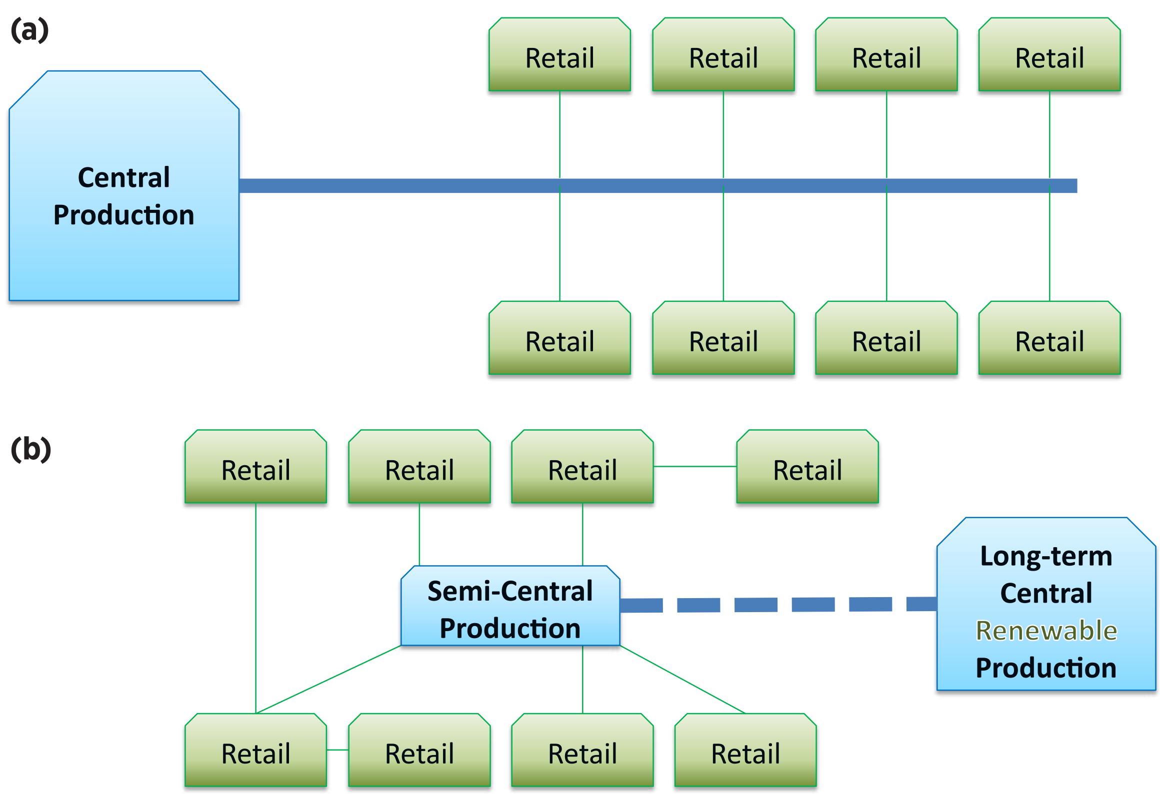

FIGURE 3. Schematics of central production with long-distance pipeline distribution (a) and semi-central production with spoke-hub distribution pipelines (b)

production strategies, and results in higher resilience and redundancy of supply. It also provides the opportunity to connect large centralized renewable production plants to the semi-central production nodes in the future.

Preliminary costs for the semi-central approach are benchmarked and compared with the costs of other hydrogen supply options. Figure 4 shows the resulting profited cost of hydrogen (in dollars per kilogram) for central steam methane reforming (SMR) with truck delivery, forecourt SMR (with hydrogen produced onsite at stations), low-pressure semi-central SMR with spoke-hub distribution pipelines, and dispensing-pressure semi-central SMR with spoke-hub distribution pipelines. Both semi-central approaches cost significantly less than the central approach. The low-pressure semi-central approach is slightly more expensive than the forecourt approach, although this gap narrows as more retail stations are added to the network. Dispensing-pressure semi-central SMR with spoke-hub distribution pipelines is the lowest-cost option in this analysis, and it becomes increasingly favorable as more retail stations are added to the network, demonstrating the effect of economies of scale. Centralizing compression can provide significant performance, siting, and economic benefits. A central compressor is much cheaper than many smaller compressors and enables improved compressor oversight and reliability. It greatly improves back-to-back fill capability. It also minimizes the retail footprint—because stations have no onsite storage, storage set-back distances, compressor, or maintenance access setbacks—so stations can be established on relatively small urban retail locations.

CONCLUSIONS AND UPCOMING ACTIVITIES

Extension of the SERA modeling framework has revealed potential regional hydrogen supply bottlenecks as well as the potential advantages of semi-central hydrogen production with spoke-hub distribution pipelines. Subject to funding received, upcoming activities may include continuing SERA updates based on evolving hydrogen production and delivery components, updating investment decision parameters and valuation metrics in response to stakeholder feedback, and integrating investment decision financial metrics with hydrogen sustainability indicators (the HyReS framework). In addition, activities could include accounting for the influence of additional market drivers and growth, such as power-to-gas with natural gas pipeline blending opportunities, promising near-term non-FCEV markets identified through H2@Scale, and Low Carbon Fuel Standard price signals in California.

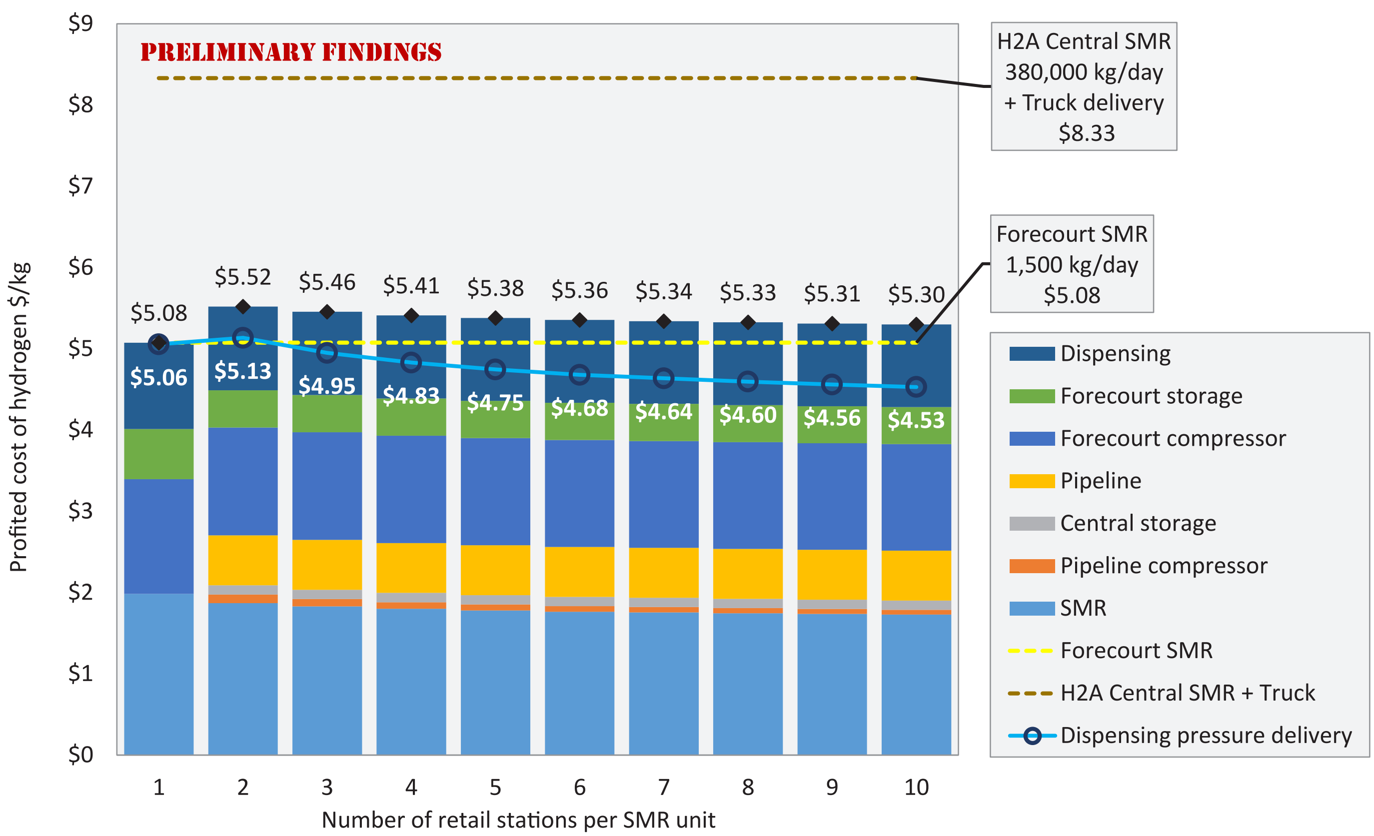

FIGURE 4. Profited cost of hydrogen estimates for various production/distribution approaches

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