Hydrogen Demand Analysis for H2@Scale

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Project Start Date: October 2018
Project End Date: Project continuation and direction determined annually by DOE

Overall Objectives

- Evaluate the potential demand for hydrogen across energy sectors and industrial applications.

Fiscal Year (FY) 2019 Objectives

- Evaluate the potential hydrogen demand for hydrogen fuel cell vehicles, synthetic fuels (synfuels), upgrading of oil, fertilizer production, metal refining, along with injection into natural gas infrastructure.
- Provide results that are supported by an in-depth analysis of market potential and economics.
- Identify regional opportunities and challenges.

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 (MYRDD) Plan[1]:

- (A) Future Market Behavior—Potential market for low-value energy and potential hydrogen markets beyond transportation
- (D) Insufficient Suite of Models and Tools—Tools integrating hydrogen as an energy carrier into the overall energy system and quantifying the value hydrogen provides
- (E) Unplanned Studies and Analysis—H2@Scale is a new concept and requires analysis of its potential impacts for input in prioritizing research and development.

Contribution to Achievement of DOE Milestones

This project contributes to the achievement of the following DOE milestone from the Systems Analysis section of the Fuel Cell Technologies Office MYRDD 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).

FY 2019 Accomplishments

- Evaluated potential annual hydrogen demand for various applications, including petroleum refining, ammonia production, synfuels, metal refining, biofuels production, fuel cell electric vehicles, and injection into natural gas pipelines.

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

INTRODUCTION

H2@Scale is a U.S. Department of Energy (DOE) initiative bringing together stakeholders to advance affordable, wide-scale hydrogen production, transport, storage, and utilization to unlock revenue potential and value across sectors. The advantages of hydrogen-based technologies for energy storage and use include scalability and fast fueling rates. Developing an improved method to assess the potential long-term demand for hydrogen in existing and new markets is the focus of this project.

Current and emerging hydrogen production technologies utilize diverse energy sources, including natural gas (NG) reformation, as well as solar and nuclear power for low-temperature and high-temperature water splitting (Figure 1). The produced hydrogen also enables emerging domestic industries that value conventional and renewable hydrogen as an energy carrier for intermediate and end use. The success of H2@Scale depends not only on hydrogen demand from growing existing markets such as petroleum refining and ammonia (NH_3) production, but also on the development of new markets such as light-duty (LD) and heavy-duty (HD) hydrogen fuel cell electric vehicles (FCEVs), synfuel and chemical production, biofuels, metal refining, and injection into NG pipelines, all of which can significantly increase hydrogen demand relative to current levels (~10 million metric tons [MMT] annually).

This study focused primarily on five of the demand sectors shown on the right-hand side of Figure 1. For each sector, the "market potential" of hydrogen demand was quantified, which reflects the amount of hydrogen that could be used in that sector, barring economic considerations. The potential demand for hydrogen was assessed for each sector by documenting current and possible growth in existing hydrogen end uses and examining the potential for future growth from existing and emerging hydrogen end uses. While methodologies differed by sector, they shared a common objective of utilizing existing DOE- and industry-supported tools, data and projections, and capturing regional differences to the extent possible.

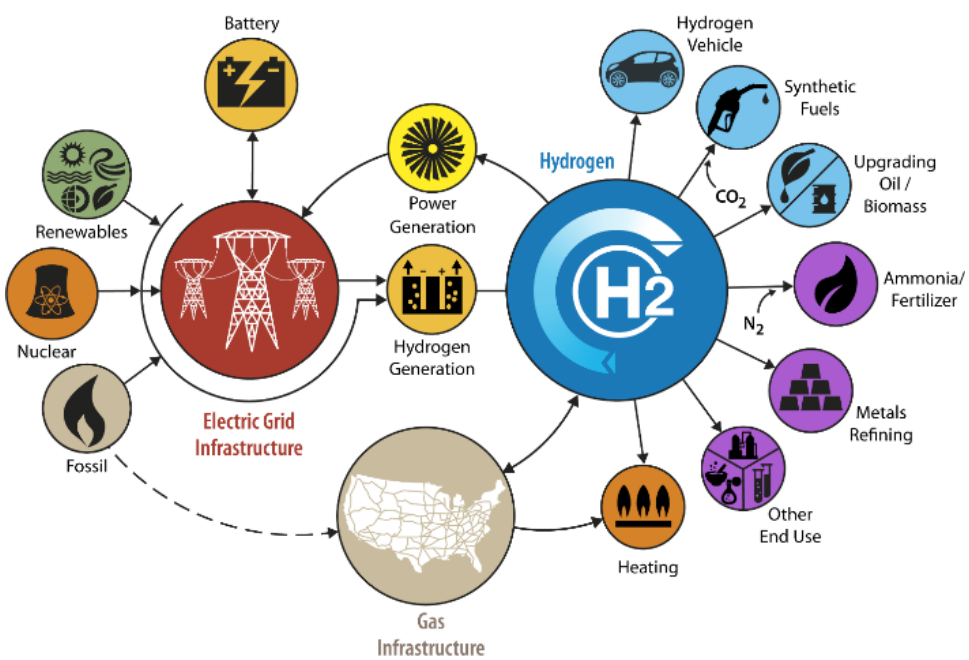

Figure 1. H2@Scale production sources and demand applications

APPROACH

- Evaluate the current hydrogen market, the underlying drivers for hydrogen demand, and potential growth using projections of these market, policy, and economic drivers.
- Evaluate the technical and economic potential of emerging and new applications and markets for hydrogen use, such as FCEVs, synfuel production, and metal refining.

- Evaluate the technical and economic constraints and challenges associated with market acceptance of large-scale deployment of zero- and low-carbon hydrogen production.
- Evaluate economic and market factors that determine the current prices of competing technologies.

RESULTS

Potential hydrogen demand for FCEVs was evaluated using the MA3T vehicle choice model, developed by Oak Ridge National Laboratory, for light-duty vehicles (LDVs). A corresponding demand by fuel cell medium- and heavy-duty vehicles (M/HDVs) is estimated assuming penetrations similar to LDVs. The retail price of hydrogen was assumed to drop from an estimated $8.7/kg near term to $5.0/kg in 2050. The potential hydrogen demand for FCEVs can exceed 10 MMT and 5 MMT by fuel cell LDVs and M/HDVs, respectively.

Today, petroleum refineries are the major consumer of hydrogen in the U.S. Hydrogen demand by petroleum refineries depends largely on the volume of crude processed, the ratio of gasoline-to-diesel production, and the heaviness and sulfur content of crude input. Figure 2 shows hydrogen demand by Petroleum Administration for Defense District (PADD) regions. The figure shows that potential hydrogen demand for petroleum refining grows from 5.9 MMT in 2017 to an estimated 7.5 MMT in 2030. This study also assessed the potential hydrogen demand for biofuel production, using projections of biofuel development from the Renewable Fuel Standard (RFS)-mandated volume of cellulosic biofuel production of 16 billion gallons per year by 2022, and assuming that up to 50% of that volume is cellulosic ethanol and the remainder is cellulosic biofuels. The potential hydrogen demand for biofuel production is estimated at 4 MMT annually to produce 8 billion gallons of cellulosic (drop-in) biofuels.

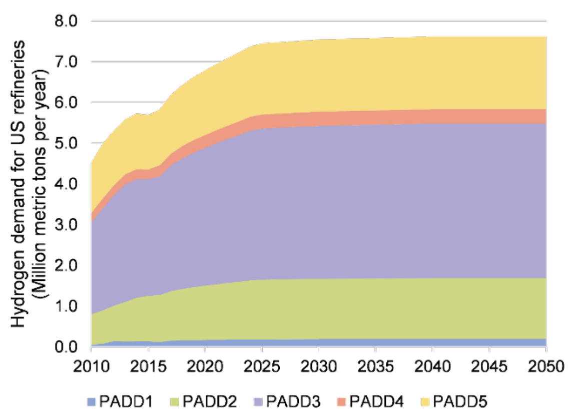

Figure 2. Potential hydrogen demand for U.S. refineries by PADD through 2050

Nitrogen fertilizers are an integral part of food- and energy-crop production and rely on the production of ammonia. The NH_3 synthesis process requires approximately 0.18 kg of hydrogen per kg of NH_3. Of the 13.6 MMT of NH_3 consumed in the U.S. in 2016, the U.S. Geological Survey estimates that 9.8 MMT were produced domestically, while 3.8 MMT were imported. We assumed that domestic NH3 production beyond 2018 grows at a moderate pace (~1%/year), compared to the recent 4.5% annual growth rate in 2017–2018. This results in potential growth in hydrogen demand for ammonia production from 2.5 MMT in 2017 to 3.6 MMT in 2050.

In 2016, the U.S. emitted 5 billion metric tons of carbon dioxide (CO_2), of which approximately 100 MMT are produced in pure or concentrated form (e.g., in ethanol and steam methane reforming [SMR] plants, respectively). A large number of hydrocarbon synfuels and chemicals can be produced when hydrogen reacts with CO_2. A 3:1 hydrogen/CO_2 mole ratio was used to estimate hydrogen demand for the production of synfuels, such as Fischer-Tropsch fuels or Methanol. Converting all carbon in CO_2 from ethanol and SMR plants to synfuels would require 14 MMT of hydrogen input. The regional distribution of the 14 MMT potential hydrogen demand is presented in Figure 3.

Converting NG pipelines to carry a blend of NG and hydrogen may require substantial modifications, but the injected hydrogen could permit blending and resale of NG with a "renewable" component. The blended NG/hydrogen mix could be used as a combustion fuel. Injection of 20% (by volume) hydrogen into NG pipelines translates into a potential demand of 27,000 MT of hydrogen per day (or 10 MMT annually).

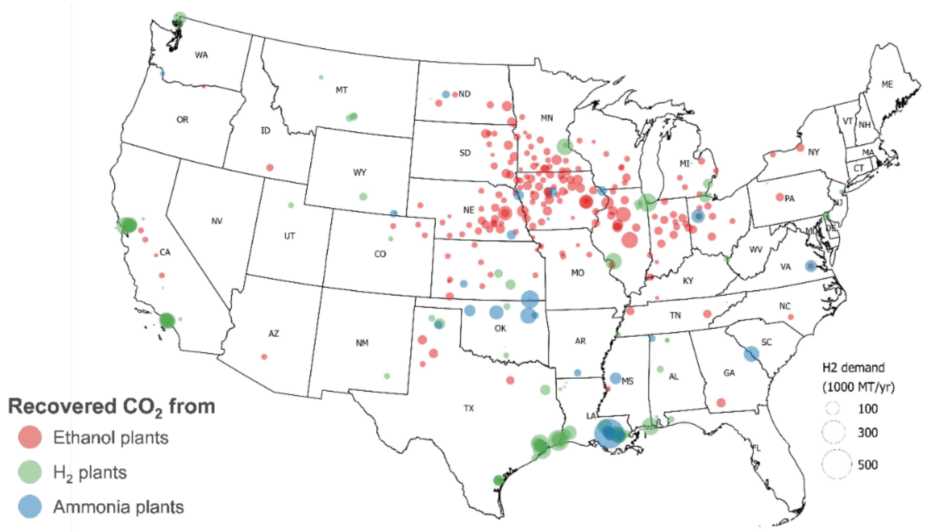

Figure 3. Potential hydrogen demand for Synfuel production

Iron production via blast furnace technology is projected to decline, while steel production via electric arc furnaces and facilities that employ direct reduction of iron (DRI) using syngas (a mixture of hydrogen and carbon monoxide produced from NG) are projected to grow. DRI manufacturers are interested in the use of renewable hydrogen blends, in lieu of natural gas to reduce CO_2 emissions associated with steel production. The range of hydrogen mass required to reduce 1 MT of iron ore fully is between 0.08 and 0.12 MT, depending on the technology employed. Mixing 30% hydrogen with NG is viable without changing the DRI reduction process. If the current imports of 35 MMT of steel annually were displaced with steel produced domestically via DRI using hydrogen as a reductant, the potential annual demand for hydrogen would be on the order of 3.5 MMT. If only 30% of the reductant gas mix is hydrogen, the hydrogen demand for all steel production via DRI in 2050 would be on the order of 4 MMT.

CONCLUSIONS AND UPCOMING ACTIVITIES

There is the potential for significant market growth for hydrogen use across the energy and industrial sectors. Potential growth of hydrogen use in existing applications is in the order of 3 MMT for petroleum refining and ammonia production through 2030. Emerging FCEV markets can demand more than 10 MMT of hydrogen if DOE cost and performance targets are met. New markets for biofuel and synfuel production, metal refining, and injection into natural gas pipelines can increase hydrogen demand by more than 20 MMT. We note that the assessed scenarios for potential hydrogen demand by various applications may be exclusive of one another (i.e., the hydrogen demand by different scenarios may not be additive). Thus, a more rigorous analysis of competition between sectors would improve this market analysis.

REFERENCES

1. A. Elgowainy et al. "Assessment of the potential demand for hydrogen in vehicle and industrial applications." Forthcoming ANL report, currently under review.