IX.0 Systems Analysis Program Overview

INTRODUCTION

The Systems Analysis program supports the decision-making of the Fuel Cell Technologies Office (FCTO) by providing a greater understanding of technology gaps, options, and risks. The Systems Analysis team analyzes the contribution of individual technology components and systems to overall pathways. For example, the team will provide technoeconomic analysis of fuel production to utilization on a lifecycle basis. Analysis is also conducted to assess cross-cutting issues, such as integration of hydrogen and fuel cells with the electric grid for energy storage and hydrogen infrastructure development.

The Systems Analysis program made several significant contributions to the Hydrogen and Fuel Cells Program in Fiscal Year (FY) 2016. The hydrogen financial analysis scenario tool (H2FAST) was expanded to provide in-depth financial and stochastic analysis of hydrogen refueling stations. The impact of improving the fuel cell efficiency on the costs of the fuel cell and storage systems and fuel cell electric vehicle (FCEV) performance was studied. The Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) model continues to be enhanced for the analysis of greenhouse gas (GHG) emissions, petroleum use, and water consumption for emerging renewable hydrogen pathways on a lifecycle basis.

GOAL

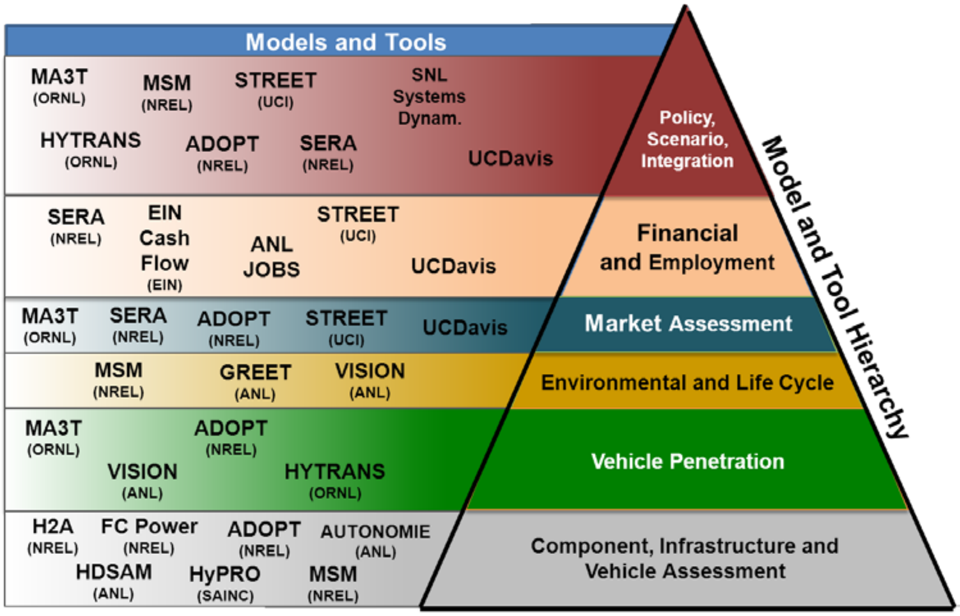
The goal of the Systems Analysis program is to provide system-level analysis to support hydrogen and fuel cell technology development and technology readiness by evaluating technologies and pathways, including resource and infrastructure issues, to guide the selection of research, development, and demonstration projects, and to estimate the potential value of specific research, development, and demonstration efforts.

OBJECTIVES

- By 2017, complete assessment of potential employment impacts and establish linkages with U.S. veteran community for growing hydrogen and fuel cell industries.
- By 2017, complete sustainability analysis and develop framework for incorporating metrics (such as greenhouse gas emissions, ecological footprint, economic/societal impact, etc.) into hydrogen production and infrastructure assessments.
- By 2017, complete analysis of program performance, cost status, and potential for use of fuel cells for a portfolio of commercial applications.
- By 2017, complete a preliminary resource analysis supporting the H2@Scale initiative and identify excess hydrogen generation capacity available for hydrogen fueling or other applications.
- By 2019, complete analysis of the potential for hydrogen, stationary fuel cells, fuel cell vehicles, and other fuel cell applications such as grid services. The analysis will address necessary resources, hydrogen production, transportation infrastructure, performance of stationary fuel cells and vehicles, and the system effects resulting from the growth of fuel cell market shares in the various sectors of the economy.
- Provide milestone-based analysis, including risk analysis, independent reviews, financial evaluations, and environmental analysis, to support the fuel cell technologies' needs prior to technology readiness.
- Periodically update the lifecycle energy, petroleum use, and greenhouse gas and criteria emissions analysis for technologies and pathways for fuel cell technologies to include technological advances or changes.

FY 2016 STATUS

The Systems Analysis program focuses on examining the economics, benefits, opportunities, and impacts of fuel cells and renewable fuels with a consistent, comprehensive analytical framework. Analysis conducted in FY 2016 included assessment of socio-economic impacts such as employment impacts from the penetration of hydrogen and FCEVs, enhancement of the financial analysis tool (H2FAST), quantification of the reduction in fuel cell and storage system costs resulting from improved fuel cell efficiency, development of an interim hydrogen cost target for early markets, and analysis of lifecycle water use for multiple hydrogen and conventional fuel/vehicle pathways. The Systems Analysis program leverages the key models shown in Figure 1. These models have been developed in prior years for critical program analyses, as evidenced by the completed and ongoing analysis activities in the Accomplishments section that follows.



Source: Argonne National Laboratory

FIGURE 1. Systems Analysis models and tools (see Section XII: Acronyms, Abbreviations, and Definitions, for full model and organization names)

FY 2016 ACCOMPLISHMENTS

Models and Systems Integration

Lifecycle Analysis of Emerging Hydrogen Production Technologies

The GREET model has been used by DOE to evaluate the environmental footprint of fuel production, vehicle production, and vehicle operation. In this preliminary study, three emerging hydrogen production technologies, including dark fermentation of lignocellulosic biomass (DF), high temperature electrolysis with a solid oxide electrolyzer cell (SOEC), and reforming of biomass-derived liquid (BDL), have been incorporated into the GREET model. Figure 2 shows the lifecycle GHG emissions from the three hydrogen production pathways evaluated; the major GHG emission sources are identified and compared to conventional hydrogen production technologies such as steam methane reforming (SMR) and electrolysis. The analysis showed that hydrogen produced from DF, SOEC, and BDL can reduce well-to-wheels GHG emissions by 26%, 82%, and 43%, respectively, when compared to hydrogen produced from SMR. The corresponding GHG emission reductions are 58%, 90%, and 68%, respectively, when compared to a gasoline internal combustion engine vehicle on a per-mile-driven basis. The GREET model will continue to be expanded to include other emerging hydrogen production technologies such as solar thermochemical, photobiological, and photoelectrochemical. (Argonne National Laboratory [ANL])

The Hydrogen Financial Analysis Scenario Tool (H2FAST)

The H2FAST tool has been enhanced to provide quick and convenient in-depth financial analysis for hydrogen fueling stations. H2FAST is available in two formats: an interactive online tool and a downloadable Excel spreadsheet. The spreadsheet version of H2FAST offers basic and advanced user interface modes for modeling individual stations or groups of up to 300 stations. It provides users with detailed annual finance projections in the form of income

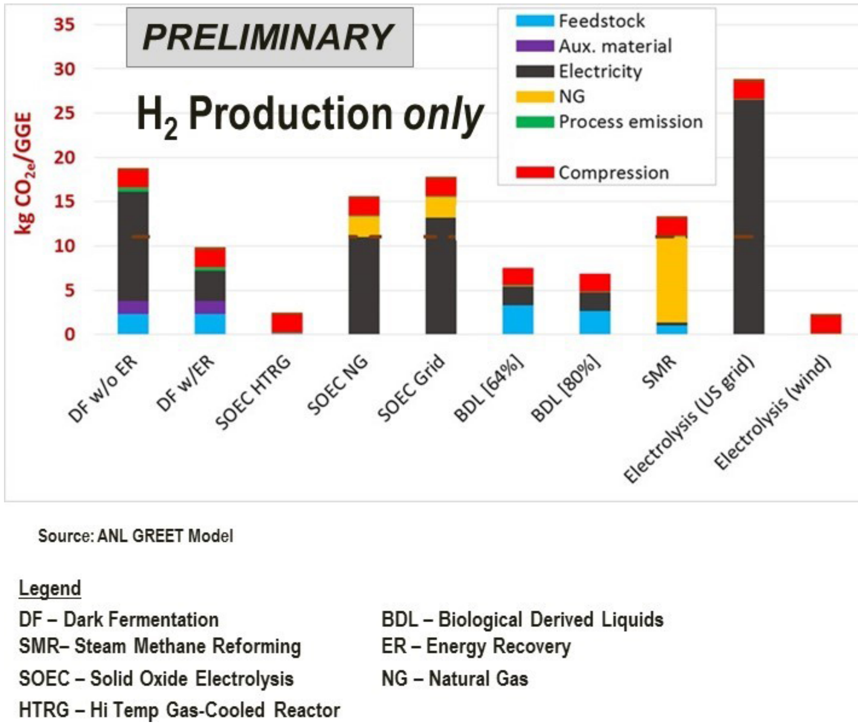


FIGURE 2. Lifecycle GHG emissions of hydrogen production pathways

statements, cash flow statements, and balance sheets. It also provides graphical presentation of financial performance parameters for 65 common metrics; lifecycle cost breakdown for each analysis scenario; and common ratio analysis results such as debt/equity position, return on equity, and debt service coverage ratio. The expanded version includes risk analysis for input parameters, assessment of incentives and policies, take or pay contract implications, and additional feedstocks for hydrogen production. It also increases the numbers of stations. (National Renewable Energy Laboratory)

Future developments will include capability to assess investments for multiple stations or components across different timeframes, linkages between supply chain components, and incorporation of externality costs such as water impacts or the social cost of carbon. The tool was thoroughly peer reviewed and issued to the public through the following URL: http://www.nrel.gov/hydrogen/h2fast/.

Environmental Analysis

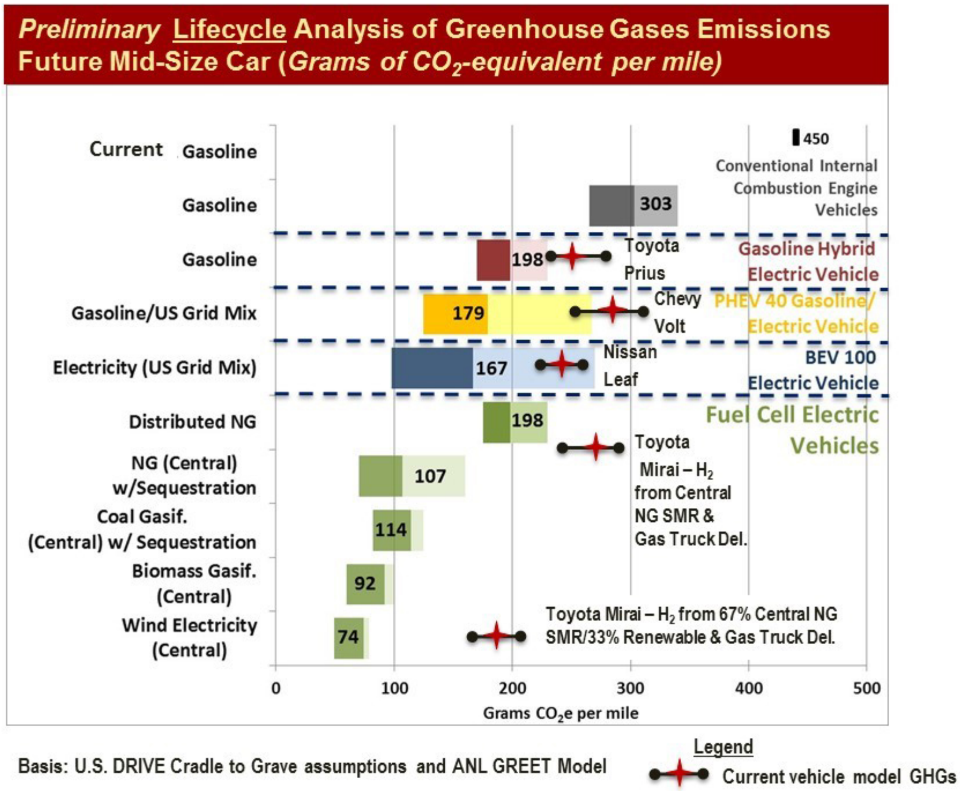
Lifecycle Analysis

The GREET model was used to compare the GHG emissions associated with current gasoline, hybrid electric, battery electric, and fuel cell vehicles versus future versions of gasoline and alternative fuel vehicles based on expected technology advancements. As shown in Figure 3, the lifecycle GHG emissions of the current alternative vehicles are 20–50% less than the current gasoline internal combustion engine vehicle. The GHG emissions of the future versions of these vehicles are 20–50% lower than the current versions.

Programmatic Analysis

Impact of Fuel Cell System Peak Efficiency on Fuel Consumption and Cost

The impact of different fuel cell targets on vehicle energy consumption and cost was studied using the Autonomie model and compared to conventional gasoline internal combustion powertrains. This study shows that if the 2030 technology targets for fuel cell technologies are achieved, then FCEVs could be economically feasible with present-day vehicle technologies. The current technology targets for 2030 are sufficient to overcome any uncertainties associated with other vehicle technologies. Fuel cell system improvement has the greatest impact on FCEV fuel consumption.



PHEV – plug-in hybrid electric vehicle; BEV – battery electric vehicle

FIGURE 3. Well-to-wheels GHG emissions of H_2 FCEV pathways compared to gasoline internal combustion engine vehicle pathways

Manufacturing costs will decrease mostly due to the decrease in both fuel cell system and hydrogen tank costs. Future work will be focused on examining the marginal benefits of improved fuel cell efficiency and onboard storage versus the marginal cost. (ANL)

Analysis of Current Hydrogen Cost and Targets

The current hydrogen delivered cost was assessed relative to the early market cost target, which was developed to guide and prioritize research and development (R&D) for the Hydrogen and Fuel Cells Program. Figure 4 shows that the current delivered cost of hydrogen is \$13/gge–\$16/gge compared to the 2020 early market hydrogen cost estimate of \$7/gge, untaxed and dispensed at the pump, and the ultimate target of <\$4/gge. This current hydrogen cost was documented in DOE Record #15012, which was peer reviewed by a panel that included industrial gas suppliers. URL: https://www.hydrogen.energy.gov/pdfs/15012_hydrogen_early_market_cost_target_2015_update.pdf

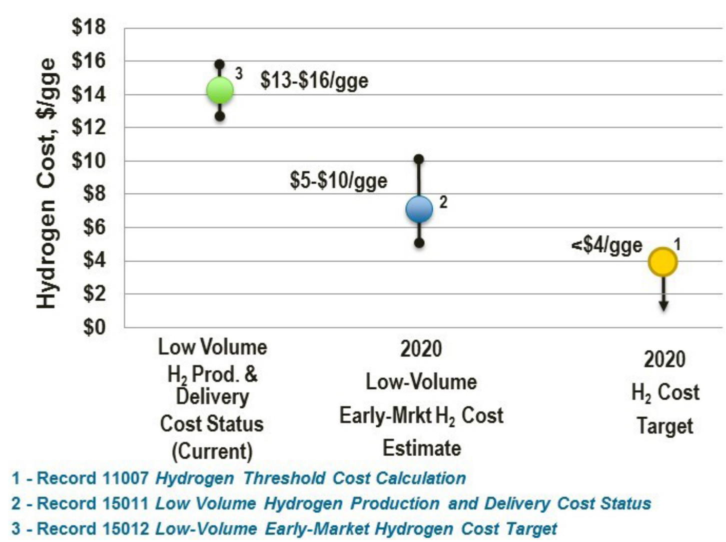


FIGURE 4. Hydrogen cost status and targets

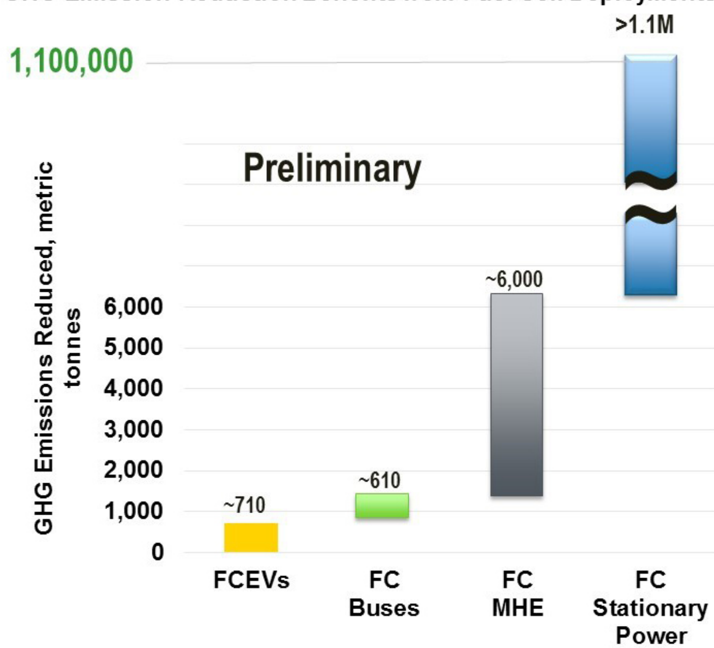
Program Benefits

The implementation of fuel cell technologies R&D has resulted in a cumulative GHG emissions reduction of over 1 million metric tons of CO_2.

Figure 5 shows that the largest GHG reduction has resulted from the stationary fuel cell penetration in the power market. Other fuel cell applications in the transportation sector have resulted in lower GHG reductions due to the lower market penetration in these applications. The ANL GREET model was used to perform this analysis.

Commercial Products and Patents Resulting from DOE-Sponsored R&D

The commercial impact of FCTO funding continues to be analyzed by tracking the commercial products entering the market and patents resulting from FCTO R&D projects. The benefits of FCTO-funded projects continue to grow, as illustrated in Figures 6 and 7. Over 589 patents were awarded and 46 products were commercialized by 2015 as a result of research funded by FCTO in the areas of storage, production, delivery, and fuel cells, which will be highlighted in the FY 2015 Pathways to Commercial Success Report. (Pacific Northwest National Laboratory)



FC – fuel cell; MHE – material handling equipment

FIGURE 5. Cumulative GHG emissions reductions from fuel cell deployments

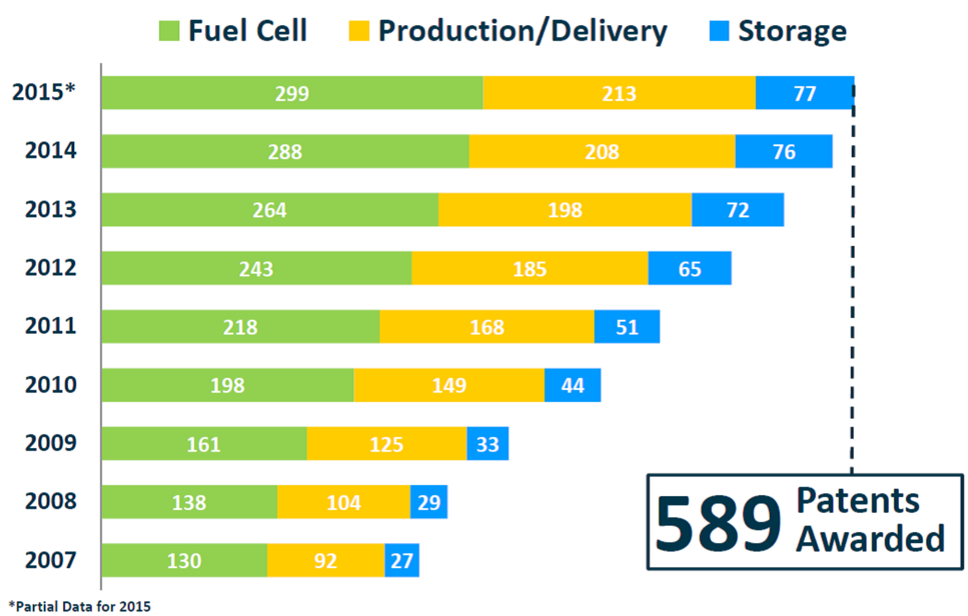


FIGURE 6. Cumulative number of patents awarded

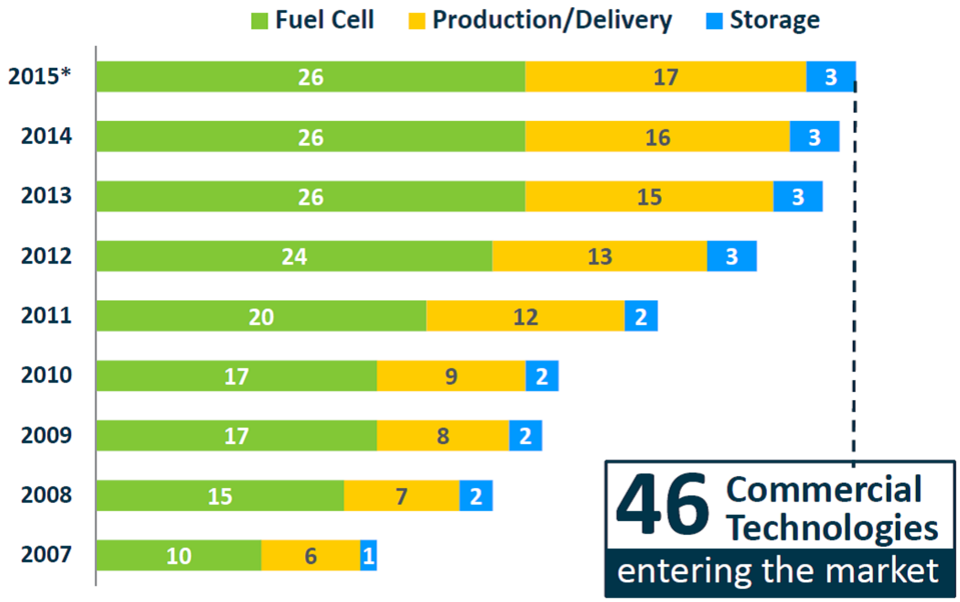


FIGURE 7. Cumulative number of commercial products entering the market

BUDGET

The FY 2016 appropriation for the Systems Analysis program was $3 million (Figure 8). Funding continues to focus on conducting analysis using the models developed by the program. In particular, analysis projects are concentrated on the following:

- Early market adoption of fuel cells
- Lifecycle analysis of water use for advanced hydrogen production technology pathways
- Determining the levelized cost of hydrogen from emerging hydrogen production pathways

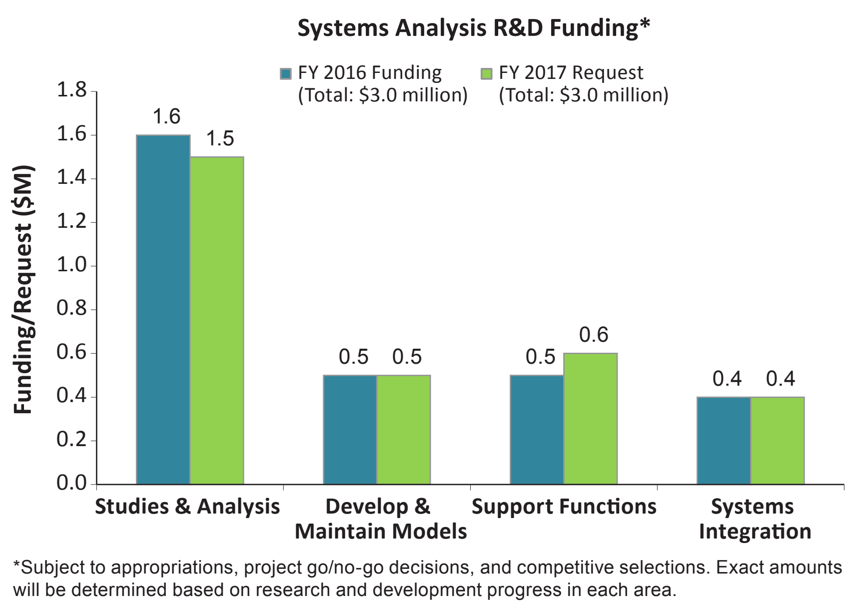


FIGURE 8. FY 2016 appropriations and FY 2017 budget request for the Systems Analysis program

- Quantifying employment impacts of hydrogen and fuel cell technologies
- Calculating the cost of onboard hydrogen storage options
- Estimating the reduction in GHG emissions and petroleum use based on various hydrogen pathways
- Performing hydrogen fueling station business assessments
- Analysis of the use of hydrogen as an energy carrier with applications across sectors (e.g., industrial, grid services, in addition to vehicles) supporting the H2@Scale initiative

The FY 2017 request level of $3 million, subject to congressional appropriation, provides greater emphasis in several areas. Analysis in FY 2017 will focus on the large-scale deployment and utilization of hydrogen through the H2@Scale concept as well as the employment impacts of hydrogen and fuel cell technologies. Analysis of pathway sustainability will be expanded to include regional variability. Additional hydrogen fueling station business assessments such as a mobile refueling scenario will be analyzed, and GREET will be expanded to include lifecycle analysis of GHG emissions and petroleum use for future hydrogen production technology pathways including solar thermochemical, photobiological, and photoelectrochemical. A study is also planned to look at hydrogen production capacity at the national and regional levels. Finally, activities included in the Vehicle Technologies Office's Smart Mobility Decision Science pillar will be leveraged to look at the impacts of consumer behavior.

Fred Joseck
Systems Analyst
Fuel Cell Technologies Office
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy
1000 Independence Ave., SW
Washington, DC 20585-0121
Office: (202) 586-7932
Email: Fred.Joseck@ee.doe.gov