Systems Analysis Subprogram Overview

INTRODUCTION

The Systems Analysis subprogram supports the decision making of the Fuel Cell Technologies Office (FCTO) by providing a greater understanding of technology gaps, options, and risks for early-stage research and development (R&D). The analytical effort provides techno-economic analysis of fuel production to utilization on a life-cycle basis for light-, medium- and heavy-duty fuel cell electric vehicles (FCEVs) and supports the H2@Scale concept. Analysis is also conducted to assess cross-cutting issues, such as integration of hydrogen and fuel cells with the electric grid for energy storage development and hydrogen technologies that support infrastructure development through innovative R&D. The goal is to provide system-level analysis to support hydrogen and fuel cell technologies development and technology readiness by evaluating technologies and pathways including resource requirements to guide the selection of research, development, and demonstration (RD&D) projects and estimate the potential value of specific early-stage R&D efforts. The subprogram also collaborates with industry and other federal offices and agencies (such as Fossil Energy and Nuclear Energy) to leverage outside activities, coordinate efforts, and build opportunities for new technology applications and input.

The Systems Analysis subprogram made several significant contributions to the Hydrogen and Fuel Cells Program in fiscal year (FY) 2018. The hydrogen cost target—to represent the hydrogen fuel cost at which hydrogen FCEVs are projected to become competitive on a cost-per-mile basis with the competing fuel/vehicle combination, gasoline in hybrid-electric vehicles—was updated and determined to be $7/gasoline gallon equivalent (gge) (untaxed) in 2025 and ultimately less than $4/gge (untaxed). The impact of improving the fuel cell efficiency on the costs of the fuel cell and storage systems for medium- and heavy-duty FCEV performance was studied. The Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) model continues to be enhanced for the analysis of water consumption for multiple hydrogen pathways on a life-cycle basis. The integration of hydrogen delivery with onboard storage was examined to understand impacts of novel storage systems on the levelized cost of hydrogen and program targets.

GOAL

The goal of the Systems Analysis subprogram is to provide system-level analysis to support hydrogen and fuel cell technologies development and technology readiness by evaluating technologies and pathways including resource requirements to guide the selection of early-stage RD&D projects and estimate the potential value of specific RD&D efforts.

OBJECTIVES

- By 2018, complete an assessment of fuel cell cost and power requirements for multiple medium- and heavy-duty truck applications.
- By 2018, update the risk analysis process for FCTO technologies, prepare a risk analysis plan for FCTO, and apply the process to at least one FCTO program.
- By 2018, 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 a sustainability analysis of FCTO metrics and develop a method of incorporating metrics in program targets.
- By 2019, complete an 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, and performance of stationary fuel cells and vehicles.

- Provide milestone-based analysis, including risk analysis and independent reviews, to support the fuel cell technologies' needs prior to technology readiness.
- Periodically update the life-cycle energy and petroleum use analysis for technologies and pathways for fuel cell technologies to include technological advances or changes.

FY 2018 STATUS

The Systems Analysis subprogram 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 2018 included updating the hydrogen cost target, examining the life-cycle cost of various vehicle platforms including fuel cell vehicles with the Vehicle Technologies Office, analyzing the impact of novel onboard storage systems interaction with hydrogen delivery systems on hydrogen pathway levelized cost of driving, studying the improvement of fuel cell and storage system costs as a result of improved fuel cell efficiency, and analyzing life-cycle water use for multiple hydrogen and conventional light-duty fuel/vehicle pathways. The Systems Analysis subprogram leverages the key models shown in Figure 1. These models have been developed in prior years for critical program analyses.

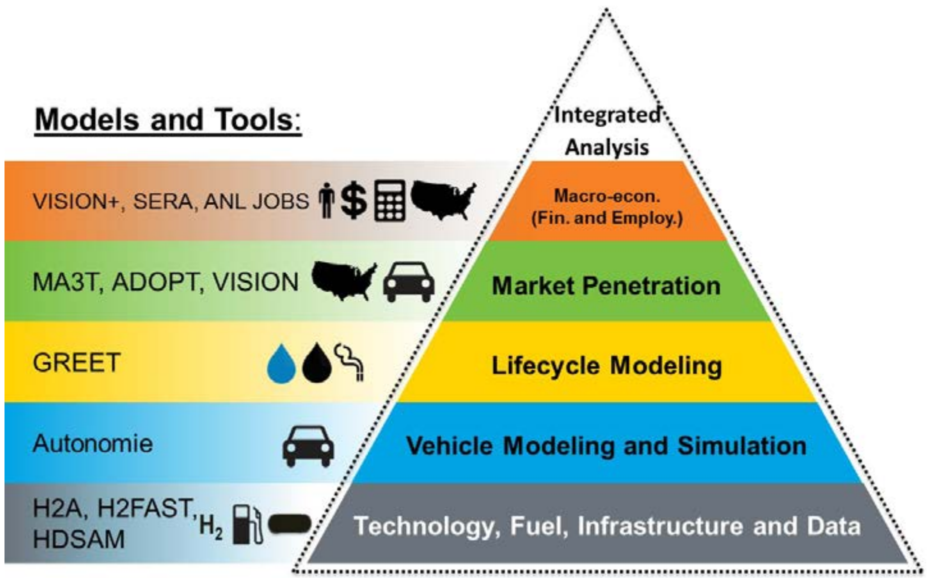

Figure 1. Systems analysis models and tools

Model description fact sheets: http://www.energy.gov/eere/fuelcells/systems-analysis

FY 2018 ACCOMPLISHMENTS

Studies and Analysis

H2@Scale Analysis

This analysis updated the estimate of the maximum hydrogen demand market size to be 151 million metric tonnes (MMT) annually, including demands from refineries and the chemical processing industry, metals refining, ammonia production, hydrogen use for biofuels refining, hydrogen use for synthetic fuels production, direct injection into the nation's natural gas system, light-duty FCEVs, other transportation including medium-duty and heavy-duty trucks, and seasonal energy storage for the electricity grid.

Also, the study developed four national supply and demand curves for hydrogen consisting of supplies from steam reforming natural gas, high-temperature electrolysis using nuclear energy, and low-temperature electrolysis of otherwise curtailed electricity. The scenarios vary based on varying assumptions of natural gas prices, low-temperature electrolyzer prices, and electricity market structures. The national demand curves for the hydrogen demands varied depending upon assumptions regarding the evolution of the U.S. electricity system and the U.S. metals industry. The results quantified the national economic potential for H2@Scale ranging from 22 MMT/yr to 45 MMT/yr over five scenarios with various technology and market assumption.

Sustainability Analysis: Hydrogen Regional Sustainability

This project developed and implemented an analytic framework that integrates Argonne National Laboratory's GREET model and the National Renewable Energy Laboratory's Scenario Evaluation and Regionalization Analysis (SERA), Automotive Deployment Options Projection Tool, and Future Automotive Systems Technology Simulator models, updating results to reflect current model capabilities.

The analysis compared petroleum fuel impacts from the four FCEV case study life cycles to the life-cycle impacts from conventional gasoline vehicles, hybrid-electric vehicles, and battery-electric vehicles, all with 400-mile range. Result indicate the FCEVs require the least amount of petroleum over the vehicle life cycle. The analysis included the monetized social benefits of air pollution reductions associated with FCEV adoption in the H2USA scenarios, which were found to range from $1.2 billion to $2.2 billion in the Urban Markets and the State Success scenarios, respectively.

Market Segmentation Analysis of Medium- and Heavy-Duty Trucks with a Fuel Cell Emphasis

This study developed a total cost of ownership systems analysis framework for several medium- and heavy-duty trucks that included both direct costs (purchase price, fuel, operating and maintenance) and indirect costs (dwell time costs due to refueling/recharging and payload opportunity costs from forgone revenue due to the truck being weight limited). By incorporating dwell time and payload opportunity costs, this analysis more accurately analyzes fuel cells for commercial applications than previous studies have done.

A comparative total cost of ownership evaluation was completed for five different truck powertrain technologies (diesel, diesel hybrid-electric, compressed natural gas, battery electric, and fuel cell electric) for three different truck applications (Class 8 long haul, Class 8 short haul, and Class 4 parcel delivery) and for different technology statuses (2018, 2020, 2040). Several scenarios for fuel cell powertrain trucks to have the lowest total cost of ownership of all powertrains by 2020 if FCTO program cost and performance targets are met were included in the evaluation. The analysis shows strong commercial application opportunities for fuel cell powertrains in Class 4 parcel delivery and Class 8 long haul trucking applications.

Regional Supply

This analytical project produced an 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 and three scenarios: National Expansion (high demand growth), State Success (medium growth), and Urban Markets (low growth).

The analysis produced regionalized cost of hydrogen based on regionally optimal supply chains and illustrated substantial potential for retail adoption and economic and functional advantages of employing high-pressure pipeline intra-city hydrogen distribution. 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. The 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, a novel hydrogen distribution pathway was shown to be economically competitive by 2030 with more than 50% of stations joining the pipeline network in eight urban areas by 2040.

Analysis of Cost Impacts of Integrating Advanced Onboard Storage Systems with Hydrogen Delivery

This study evaluated the potential of reducing fueling-station costs by reducing compressor, storage, and/or refrigeration costs, assuming hypothetical vehicle onboard storage options that require a combination of dispensing pressure and temperature that satisfies the same onboard hydrogen storage capacity and fill rate. In particular, this study evaluated a dispensing pressure much lower than the baseline 700 bar (e.g., 100 bar) and either cryogenic temperatures (e.g., liquid hydrogen or liquid nitrogen temperatures, such as these preferred by metal organic framework onboard storage systems) or near-ambient temperatures (300 K, e.g., temperatures preferred by metal hydride onboard storage systems). The hydrogen delivery and refueling cost is strongly impacted by the pressure and temperature requirements of the FCEV onboard storage system. Low-pressure and near-ambient-temperature dispensing can significantly reduce hydrogen dispensing cost to FCEV customers. These onboard storage options, including their respective boundary conditions, will be integrated with hydrogen delivery technologies to evaluate the cost impact on the hydrogen pathways.

Analysis of Program Benefits

Hydrogen Cost Target

The hydrogen cost target that was developed to assist DOE in focusing and prioritizing R&D options was updated in 2018. The cost target represents the cost at which hydrogen FCEVs are projected to become competitive on a cost-per-mile basis with the competing fuel/vehicle combination: gasoline in internal combustion engine vehicles and hybrid-electric vehicles. The ultimate hydrogen R&D cost target is set at $4/gge (approximately equal to 1 kg of hydrogen on a lower heating value basis), untaxed and dispensed at the pump; a 2025 cost target is set at $7/gge (targets expressed in 2016$). The methodology and assumptions used to calculate the hydrogen cost targets are documented in a peer-reviewed DOE program record.[1]

Water Life Cycle Analysis

This analysis focused on identifying water use impact of electricity generation and large-scale deployment of hydrogen FCEVs. The results illustrate that regional variation exists for water use impact of electricity generation and FCEV deployment. The spatial trend of electricity generation suggests that the power sector has already adapted to varying water availability by using non-freshwater resources (wind/solar/nuclear/reclaimed water) in water-stressed regions. The analysis found a majority of power plants (80%) are located in water-abundant regions. At the state level, Texas, Arizona, Colorado, and Kansas contributed 73% of the water scarcity footprint of thermal power generation in water-stressed regions. For hydropower electricity, Nevada, Arizona, Nebraska, and California contributed 88% of the water scarcity in water-stressed regions. For future energy systems deployment, such as FCEVs, any marginal increase in water demand in water-stressed regions will magnify the impact on water stress. This study provides a systematic approach to evaluate the sustainability of various energy systems in terms of water use and their impact on water stress in various regions in the United States.

Patents Resulting from DOE-Sponsored R&D

The commercial impact of FCTO funding continues to be analyzed by tracking the patents and patent applications resulting from FCTO-funded R&D projects. More than 738 patents were awarded by 2017 as a result of research funded by FCTO in the areas of storage, hydrogen production and delivery, and fuel cells. The patent application analysis identified 893 patent applications related to FCTO-funded R&D and found that approximately 80% of these applications received patent awards. These results were highlighted in the FY 2017 Pathways to Success: Innovations Enabled by the U.S. Department of Energy Fuel Cell Technologies Office report (prepared by Pacific Northwest National Laboratory).

[1] Hydrogen R&D Cost Target Calculation—2018 Update, Program Record (Hydrogen and Fuel Cells Program) 18004, 2018, https://www.hydrogen.energy.gov/pdfs/18004_h2_cost_target_calculation_2018.pdf.

BUDGET

The FY 2018 appropriation for the Systems Analysis subprogram was $3 million (Figure 2).

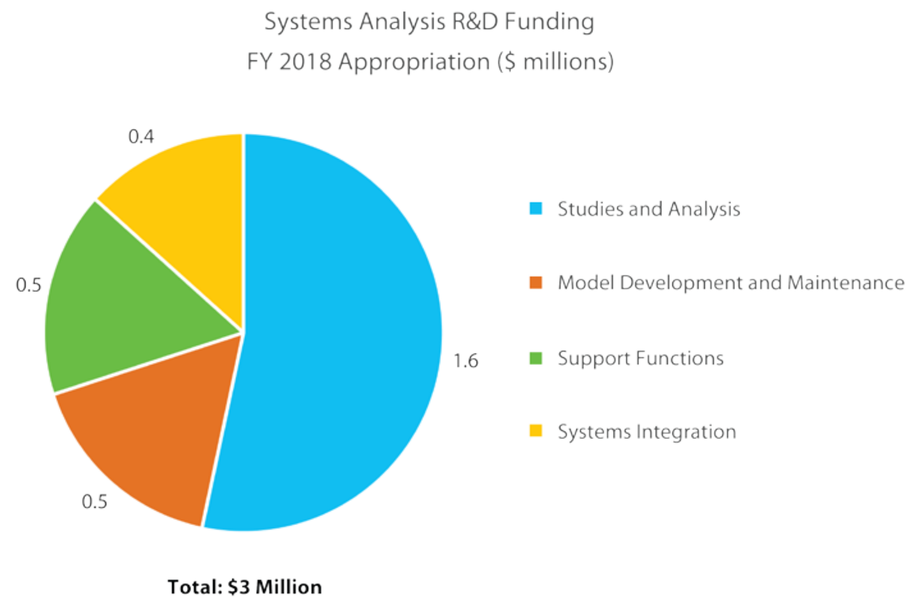

Figure 2. Systems Analysis subprogram FY 2018 appropriation

Funding continues to focus on conducting analysis using the models developed by the program. In particular, analysis projects are concentrated on:

- Analyzing market segmentation of fuel cell technology applications for light-, medium-, and heavy-duty vehicles
- Analyzing life-cycle water use for hydrogen production technology pathways for light-duty vehicles
- Calculating the cost of onboard hydrogen storage options
- Estimating the reduction in greenhouse gas emissions and petroleum use based on various hydrogen pathways for medium- and heavy-duty trucks
- Estimating the hydrogen production from diverse domestic energy resources (natural gas, coal, uranium, biomass, wind, solar) required for potential future FCEV demand
- Performing hydrogen fueling station business assessments
- Studying hydrogen's use as an energy carrier with applications across sectors (e.g., industrial, grid services, in addition to vehicles) and energy storage supporting the H2@Scale initiative
- Analyzing hydrogen supply and demand for multiple application to support H2@Scale
- Integrating with nuclear hybrid systems
- Integrating delivery and onboard storage systems.

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