X.0 Systems Analysis Sub-Program Overview

INTRODUCTION

The Systems Analysis sub-program supports decision-making by providing a greater understanding of technology gaps, options and risks, and the contribution of individual technology components to the overall system. Examples include fuel production to utilization and the interaction of components and their effects on the system. Analysis is also conducted to assess cross-cutting issues, such as integration of hydrogen and fuel cells with the electrical sector for energy storage.

The Systems Analysis sub-program made several significant contributions to the Fuel Cell Technologies Office (FCTO) during Fiscal Year (FY) 2014. The cost reduction of hydrogen refueling infrastructure was examined, the impact of improving the fuel cell efficiency and the impact on fuel cell electric vehicle (FCEV) performance was studied, and opportunities to apply hydrogen for energy storage and electrical grid applications were evaluated. The JOBS and economic impacts of Fuel Cells (JOBS FC) model continues to be enhanced by Argonne National Laboratory (ANL) and RCF Economic and Financial Consulting (RCF), by adding the capability to assess employment impacts of infrastructure development for the early market penetration of FCEVs. Infrastructure analyses were conducted to better understand early market hurdles such as cash flow, station utilization, and low-volume cost-reduction strategies. The Greenhouse gases, Regulated Emissions and Energy use in Transportation model is being enhanced to evaluate greenhouse gas (GHG) emissions and petroleum use on a well-to-wheels life-cycle basis for hydrogen pathways, and to include water consumption analysis capability in the model to conduct life-cycle analysis of various hydrogen production pathways.

GOAL

The goal of the Systems Analysis sub-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, guiding the selection of research, development, and demonstration projects, and estimating the potential value of research, development, and demonstration efforts.

OBJECTIVES

- Complete analysis of milestones and technology targets, including risk analysis, independent reviews, financial evaluations, and environmental analysis to identify technology gaps and risk mitigation strategies by 2015.
- Complete analysis of FCTO performance, cost status, and potential for use of fuel cells in a portfolio of commercial applications by 2017.
- Complete analysis of the potential for hydrogen, stationary fuel cells, fuel cell vehicles, and other fuel cell applications such as material handling equipment to become cost competitive by 2019. 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 FCTO's needs prior to technology readiness.
- Periodically update the life-cycle energy, petroleum use, GHG and criteria emissions analysis for technologies and pathways for FCTO to include technological advances or changes.

FY 2014 TECHNOLOGY STATUS AND ACCOMPLISHMENTS

The Systems Analysis sub-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 2014 included socio-economic impacts such as increased employment from early market infrastructure development, life-cycle analysis of various vehicle platforms including FCEVs with the Bio-Energy Technologies and Vehicle Technologies Offices, hydrogen use for energy storage, fuel cell system cost impact to improve fuel cell efficiency, life cycle impacts of water use of hydrogen production pathways, identification of early markets for fuel cells and opportunities to reduce cost through various mechanisms, and options to reduce infrastructure cost through the application of tri-generation fuel cell systems.

Develop and Maintain Models and Systems Integration

ANL, with assistance from RCF, continues to estimate job creation as a result of DOE FCTO projects and created the JOBS H2 model to estimate employment and revenue impacts of infrastructure development to support the early market penetration of FCEVs. The JOBS H2 model uses the same model structure and input-output methodology as developed for the JOBS FC model to estimate changes in industry expenditures as a result of hydrogen fueling infrastructure deployment and calculates the effects of those changes throughout the economy. Version 1.0 of the model was released for public use in June 2014 and includes the economic impacts along the supply chain for infrastructure deployment and user-specified analyses at the state, regional, or national level and is available for download at http://jobsmodels.es.anl.gov. (ANL and RCF)

The model is being used to assess the employment impacts of infrastructure development for the early market introduction of FCEVs. Figure 1 illustrates that the infrastructure development of 25 hydrogen fueling stations for five years will create or retain approximately 2,400 jobs. Note that jobs will start to decline once the station construction is completed but operation-related jobs will be retained.

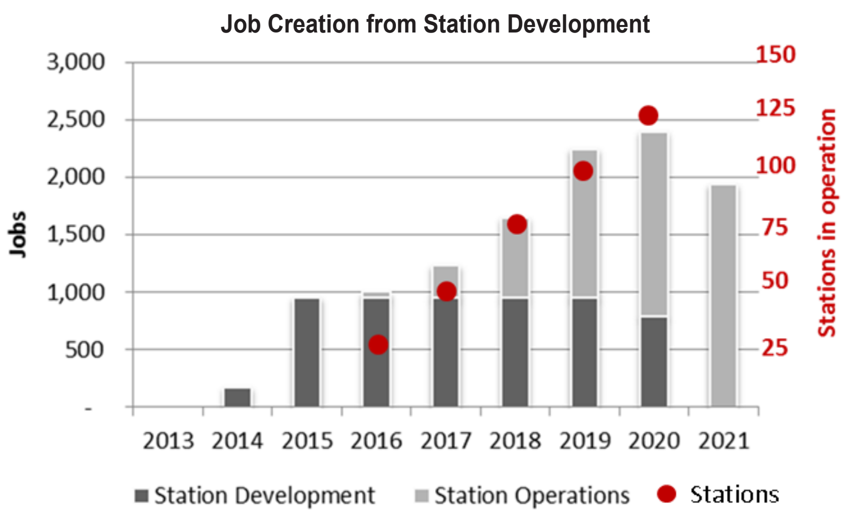
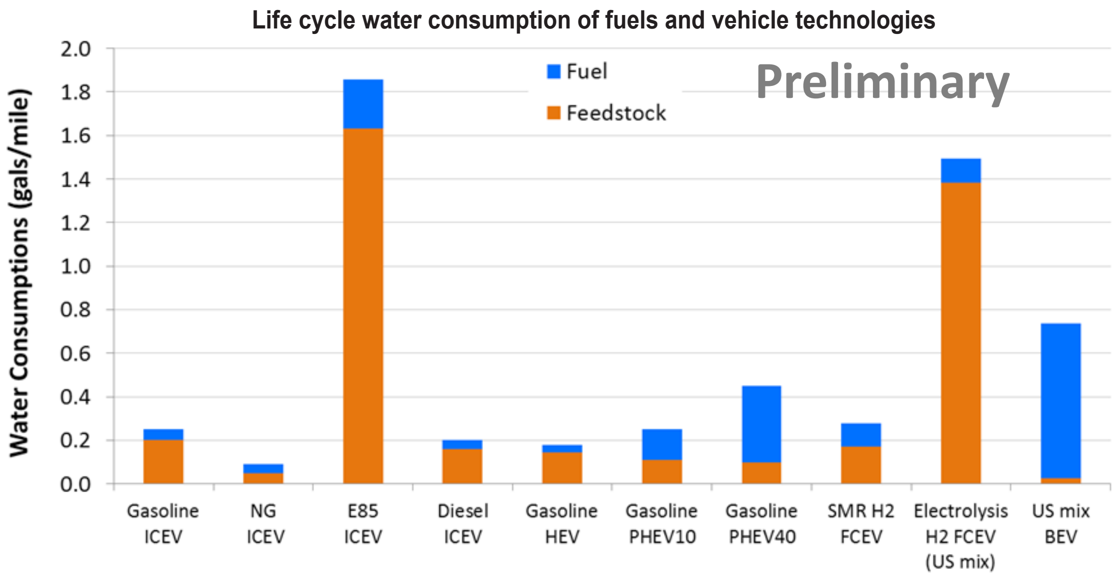


FIGURE 1. (Source: ANL)

Water Life-Cycle Analysis

Enhancements to the Greenhouse gases, Regulated Emissions and Energy use in Transportation Model's life-cycle analysis capabilities were continued in FY 2014 to examine water consumption for hydrogen production and delivery pathways from natural gas, water electrolysis, and other fuels such as gasoline and ethanol. The analysis includes the water use assessment of pathway components including feedstocks such as natural gas and crude oil, and energy use such as electricity. Also, the water use for growing biofeedstocks such as corn and cellulosic sources are included in the model. Converting these conventional and new feedstocks to fuels require additional water consumption. Similarly, water is needed for heat rejection in thermo-electric power generation cycles. Producing hydrogen from electricity (via electrolysis), natural gas (via steam methane reforming), or biomass (via gasification) requires additional use of water as a feed for the conversion process as well as for cooling. The results of the analysis shown in Figure 2 exhibit that water for irrigation, cooling water for electricity generation, and evaporation associated with hydropower generation has the greatest impact on life cycle water consumption of 85% ethanol/15% gasoline (E85) fuel, and hydrogen fuel cell and electric vehicles. (ANL)



ICEV – internal combustion engine vehicle; NG – natural gas; HEV – hybrid electric vehicle; PHEV10 – plug-in hybrid electric vehicle with 10-mile all-electric range; PHEV40 – plug-in hybrid electric vehicle with 40-mile all-electric range; SMR – steam methane reformer; H2 – hydrogen; BEV – battery electric vehicle

FIGURE 2. (Source ANL)

Studies and Analysis

Global and domestic market analysis of the fuel cell markets for portable, stationary power, and transportation applications continue to be assessed. The analysis identified increased growth in the fuel cell market in the domestic and international markets. As exhibited in Figure 3, the fuel cell market remains strong with over 35,000 systems shipped in 2013, an increase of greater than 25% over 2012. (Navigant Research)

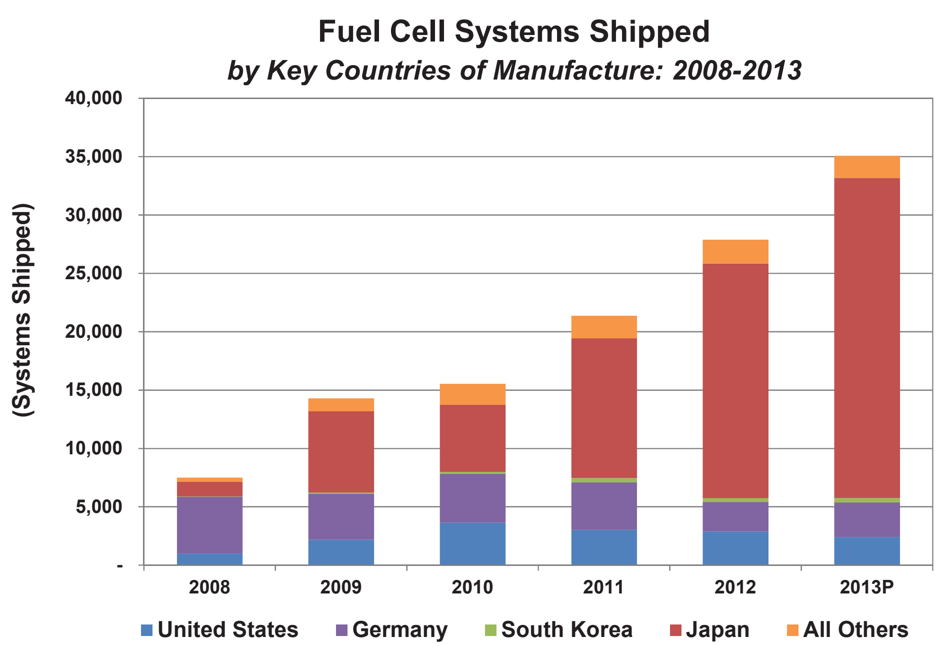


FIGURE 3. (Source Navigant Research)

Research also shows a continued growth in revenues from the fuel cells of greater than 44% from 2012 to 2013 to over $1.3 billion as exhibited in Figure 4.

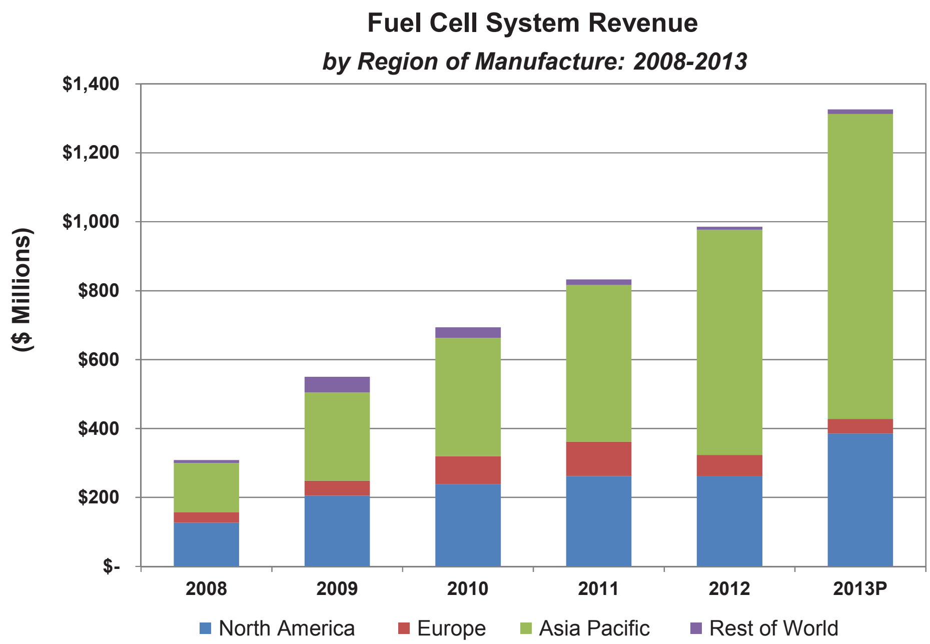
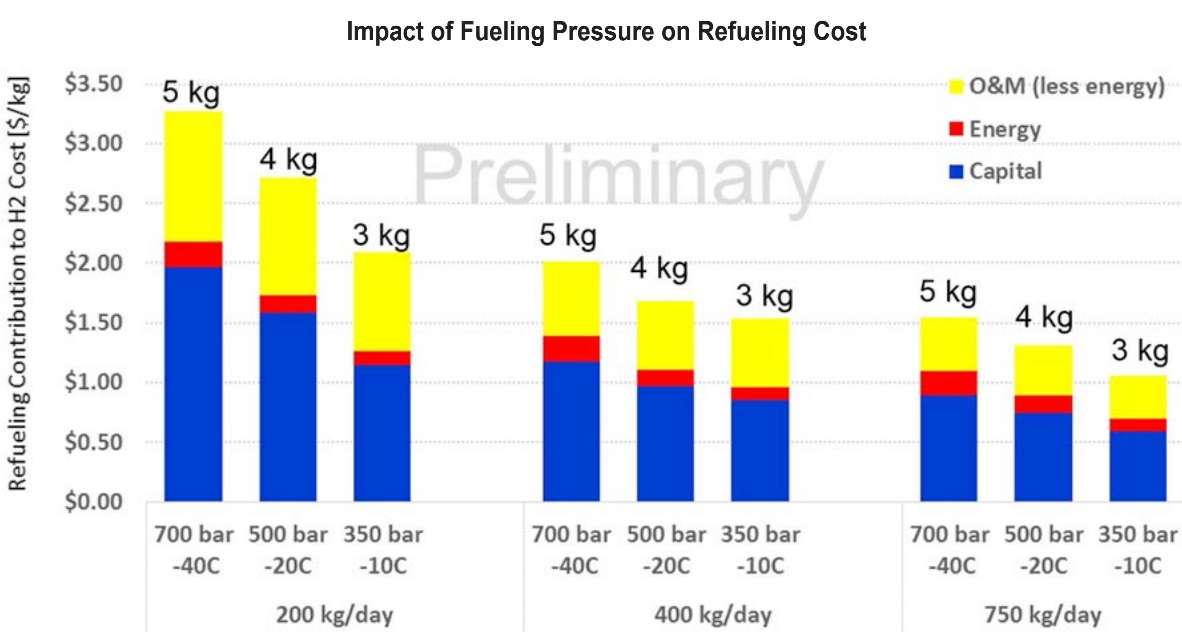


FIGURE 4. (Source Navigant Research)

Infrastructure Analysis

Fueling Pressure Analysis

Although the sub-program recognizes that market entry will focus on infrastructure to accommodate 700-bar hydrogen storage tanks, the impact of pressure on cost is valuable for assessing potential future scenarios. The dispensing options which would refuel a 700-bar-rated FCEV tank at various pressures (350, 500 and 700 bar) were examined, to evaluate the cost impact on the delivery system. The project assessed the performance of the refueling system and the impact of fueling pressure and pre-cooling requirements on the tank fill time and refueling cost. The refueling costs for station capacities of 200 kg/day, 400 kg/day and 750 kg/day are shown in Figure 5. The refueling cost savings with the lower fueling pressures is much greater for smaller station capacities compared to the larger stations. Greater cost savings would be realized in early FCEV markets where the deployed stations are of small capacities and the utilization of the station is expected to be low with a slow initial vehicle deployment rate. (ANL)



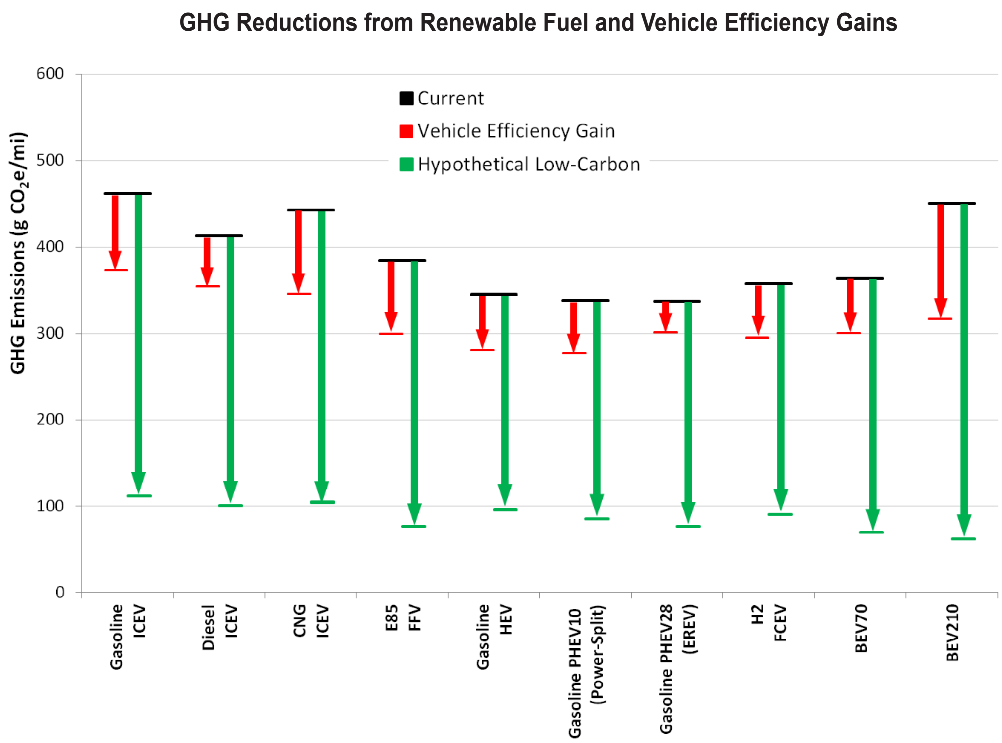
O&M – operations and maintenance

FIGURE 5. (Source ANL)

Environmental Analysis

Vehicle Portfolio Life Cycle Analysis

Analysis was conducted in collaboration with the Office of Energy Efficiency and Renewable Energy's (EERE) Bioenergy Technologies Office, Vehicles Technologies Office, national laboratories, and industry stakeholders to examine the life-cycle GHG emissions and energy use of multiple hypothetical low-carbon pathways for various fuels and vehicle configurations. Major inputs to the calculation of GHG emissions included the fuel economy of each vehicle and fuel production pathway efficiency. The data and major assumptions and results are documented in the following Hydrogen and Fuel Cells Program Record #14006: http://hydrogen.energy.gov/pdfs/14006_cradle_to_grave_analysis.pdf. The results of the analysis show that GHG emissions could be reduced by improving the efficiency of the vehicles but the major contribution of the GHG emissions will result from reducing the carbon content of the fuel. Also, a portfolio of fuels and advanced vehicle technologies will be needed to achieve significant GHG emission reductions from the transportation sector (Figure 6).



CNG – compressed natural gas; PHEV28 – plug-in hybrid electric vehicle with 28-mile all-electric range; EREV – extended-range electric vehicle; BEV70 – battery electric vehicle with 70-mile range; BEV120 – battery electric vehicle with 120-mile range

FIGURE 6. (Source FCTO)

Energy Storage Analysis

Hydrogen and Fuel Cell Application for Electrical Grid Energy Storage

The use of hydrogen generated from an electrolyzer via renewable energy, such as wind, for energy storage and dispatched to the electrical grid was examined. The analysis found that the operating flexibility of electrolyzers acting as demand response devices is fast enough (sub-second) and can be maintained long enough for them to participate in energy, capacity, and ancillary service electricity markets. Hydrogen and fuel cell technologies have the ability to generate fuel for FCEVs and supply electricity to the grid through arbitrage and ancillary services. The system economics showed the optimum regime occurs when hydrogen production equipment is designed to provide grid services and fuel for FCEVs. Also, the optimum hydrogen energy storage system was found to have a rated storage capacity for supplying ~3-16 hours of fuel and electricity for grid services; additional storage capacity is not more valuable in ancillary grid services markets (Figure 7). (National Renewable Energy Laboratory, NREL)

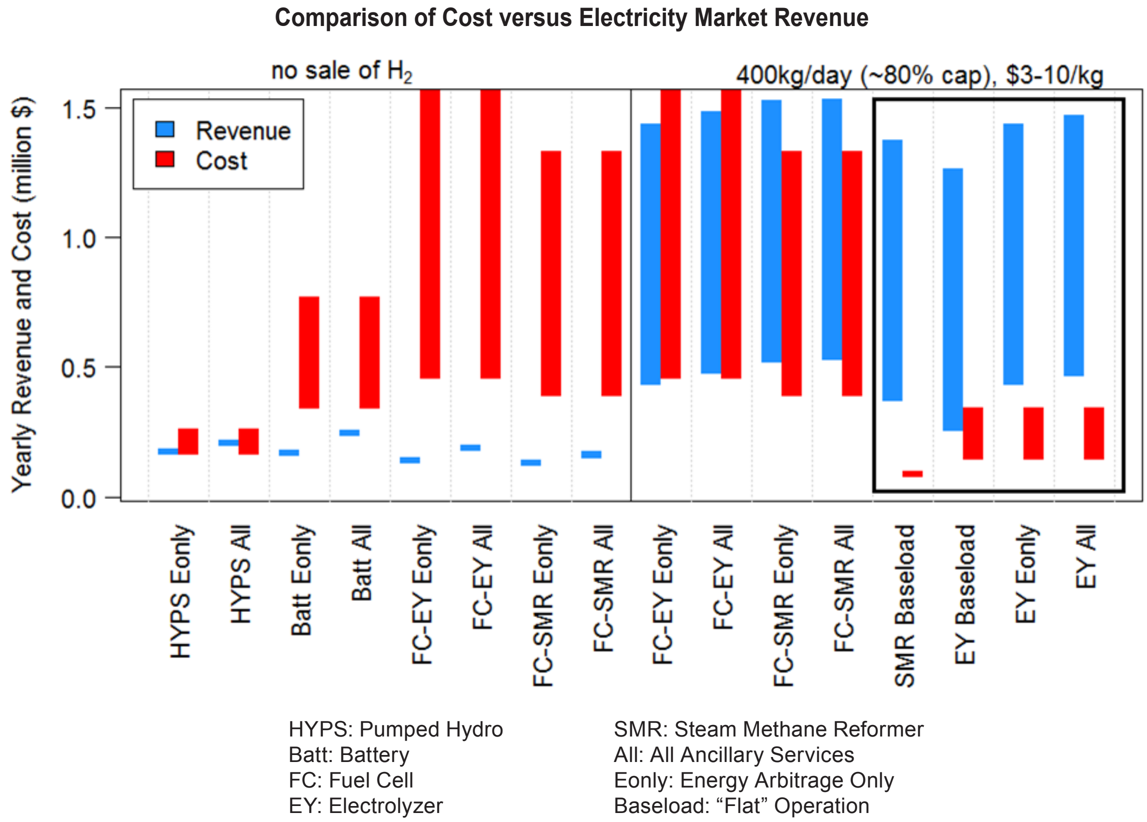


FIGURE 7. (Source NREL)

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

The impact of different fuel cell targets on the vehicle energy consumption and cost were studied using the Autonomie model and compared to conventional gasoline internal combustion powertrains. In addition, the impact of fuel cell system improvements on the potential onboard storage requirements and cost were analyzed. The findings of the study indicate the fuel economy of the FCEV could be improved by 10-14% by increasing the fuel cell peak efficiency from 60 to 68%. When the FCEV improvements are compared to a conventional vehicle, the FCEV fuel economy was found to be five times higher than the conventional vehicle in the 2030 timeframe (Figure 8). (ANL)

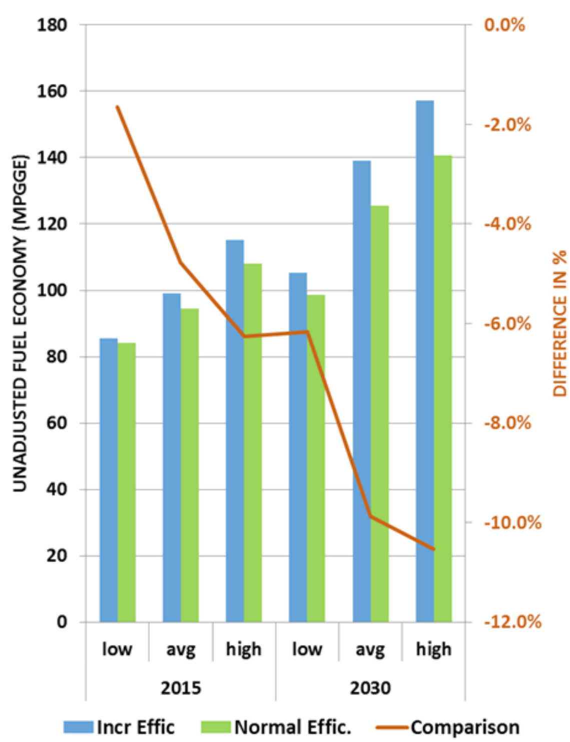


FIGURE 8. (Source ANL)

Analysis of the Levelized Costs of Electricity (LCOE) from Combined Heat & Power (CHP) and Solar Photovoltaic (PV) Technologies

The LCOE associated with for stationary fuel cells were compared to other conventional technologies in CHP applications, and renewable technologies such as solar PV technologies. In this analysis, the systems in CHP service had a capacity of 200-500 kW and the PV and micro fuel cells had a capacity of 7 kW. Fuel cells in the CHP service had a LCOE of $0.065-$0.085/kWh which is comparable to the LCOE of conventional technologies. In the case of the micro systems, the micro fuel cell had a LCOE range of $0.08-$0.13/kWh which is comparable to an average solar PV LCOE of ~$0.105/kWh (Figure 9). The details of the analysis, which was peer reviewed by EERE's Solar Technologies Office and the NREL, are provided in the following Hydrogen and Fuel Cells Program Record #14003: http://hydrogen.energy.gov/pdfs/14003_lcoe_from_chp_and_pv.pdf

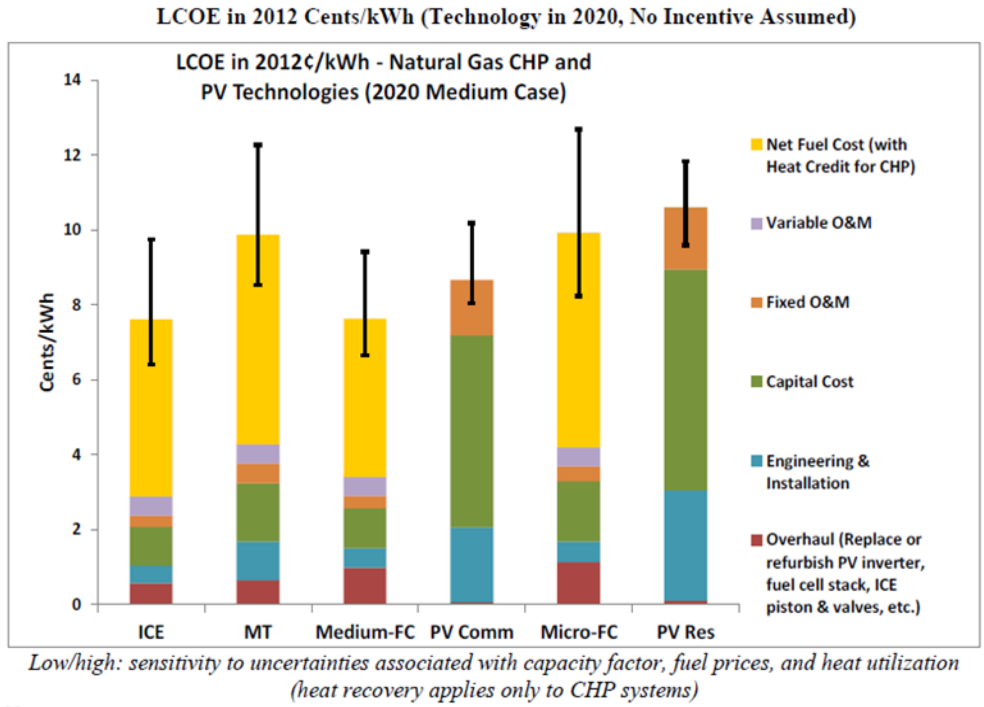


FIGURE 9. (Source FCTO)

Commercial Products and Patents Resulting from DOE Sponsored R&D

The commercial benefits of FCTO were analyzed by tracking the commercial products and technologies and patents developed from R&D funding. The benefits of DOE-funded projects continue to grow. Over 499 patents were awarded and 45 products were commercialized by 2014 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 2014 Pathways to Commercial Success Report. (Pacific Northwest National Laboratory, PNNL)

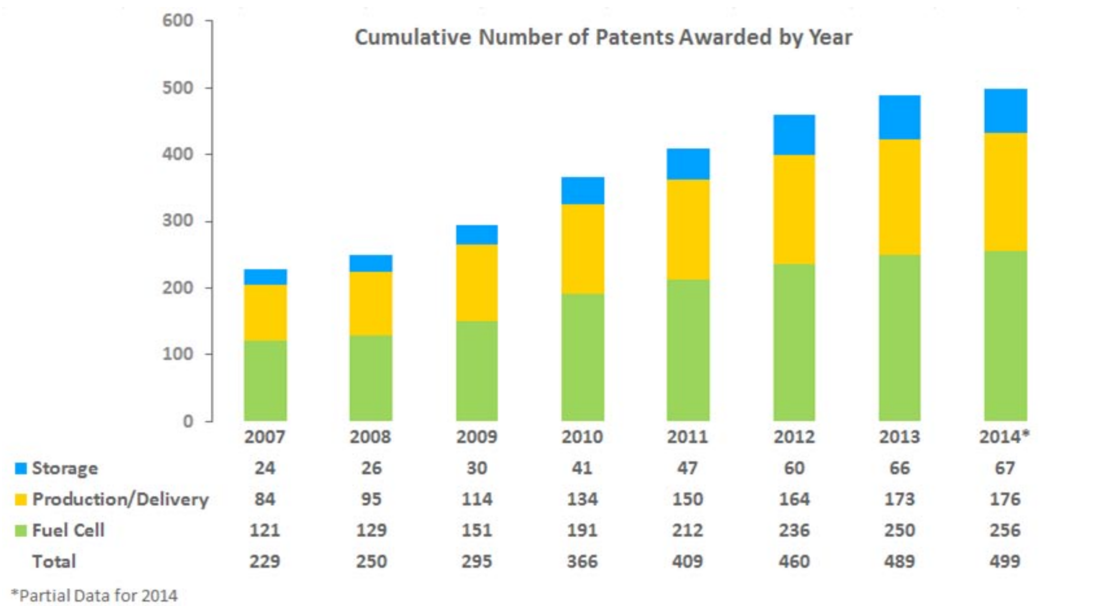
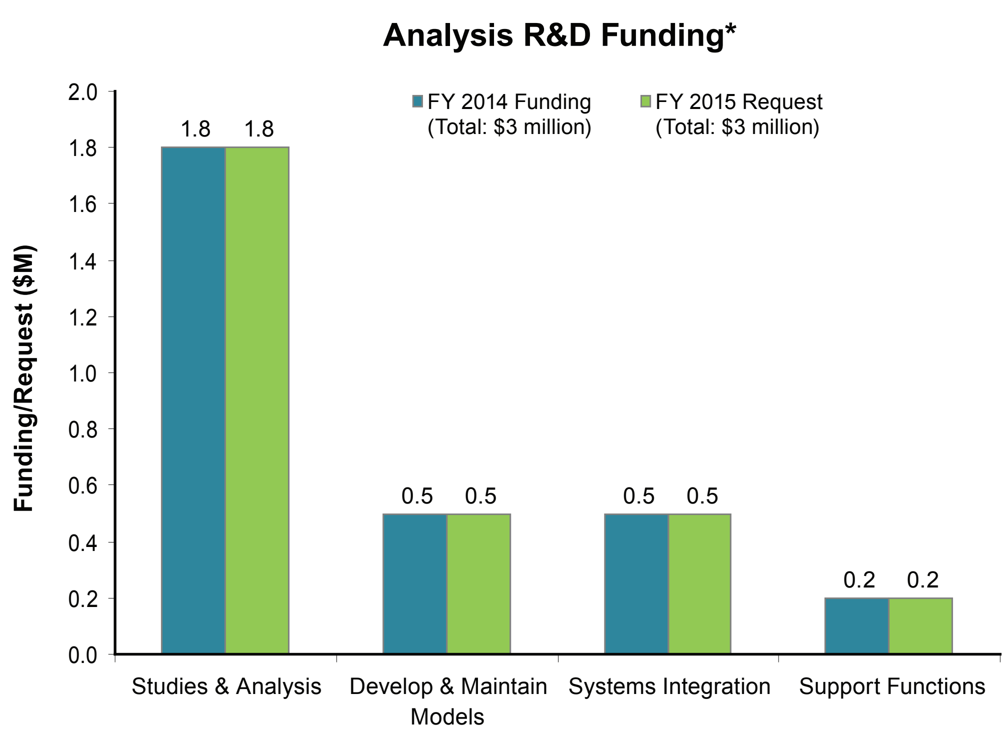


FIGURE 10. (Source PNNL)

BUDGET

The budget for the Systems Analysis sub-program is consistent with the goals and objectives of FCTO and is responsive to assessing hydrogen and fuel cell applications for light-duty transportation applications, as well as energy storage, stationary power generation, and specialty applications. The FY 2015 budget request includes funding for early fuel cell and hydrogen market and infrastructure analysis, as well as environmental life-cycle analysis, overall sub-program analysis of targets and technology gap assessment, market impact analysis, socio-economic analysis of fuel



* Subject to appropriations, project go/no-go decisions, and competitive selections. Exact amounts will be determined based on research and development progress in each area.

cells and hydrogen infrastructure, market segmentation of fuel cell vehicles in the light-duty vehicle fleet, and business analysis of opportunities to reduce the cost of infrastructure for early market penetration of FCEVs. New opportunities for energy storage and integration with existing energy supply networks such as natural gas transmission will continue to be evaluated.

FY 2015 PLANS

The Systems Analysis activity for FY 2015 will focus on conducting analyses to determine technology gaps for fuel cell systems and infrastructure for fuel cell vehicles, benefits and opportunities for new onboard storage options and utilizing fuel cells for energy storage and transport. Analysis will be focused on business case studies of hydrogen supply infrastructure for the early market penetration of fuel cell vehicles, understanding the tradeoffs and regional impacts of fuel cells with other alternative fuels, light-duty vehicle life cycle costs for multiple platforms, socio-economic impacts of job creation based on hydrogen supply infrastructure development, and the market segmentation of light-duty fuel cell vehicles. The FY 2014 appropriation included $3 million for Systems Analysis; the FY 2015 request is $3 million. The budget request for FY 2015 reflects the focus on early market analysis, fuel cell technology evaluations, renewable fuel benefits, as well as water resource and infrastructure analysis.

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