XI.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 interaction of individual technologies and components and their contributions to the performance of larger systems—e.g., the entire hydrogen fuel system, from production to utilization. The sub-program also analyzes cross-cutting issues, such as the integration of hydrogen and fuel cell systems with the electrical sector and the use of renewable fuels. Particular emphasis is given to assessing stationary fuel cell applications, the impacts of fuel quality on fuel cell performance, and the implications of various approaches to establishing hydrogen infrastructure.

The Systems Analysis sub-program made several significant contributions to the Hydrogen and Fuel Cells Program (the Program) during Fiscal Year (FY) 2012. Hydrogen infrastructure costs were compared with similar costs for other advanced fuels, and opportunities for reducing these infrastructure costs were examined by utilizing stakeholder input and exploring synergies with other fuels such as natural gas. The JOBS FC model was developed by Argonne National Laboratory (ANL) and RCF Economic and Financial Consulting, and it was issued to the public domain to enable employment and revenue generation to be estimated from fuel cell and hydrogen deployment. Infrastructure and early market analyses were conducted to better understand supply and demand issues, and the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model was modified to enable greenhouse gas emissions to be evaluated on a well-to-wheels basis for hydrogen generation from natural gas extracted by hydraulic fracturing.

GOAL

Provide system-level analysis to support the development of hydrogen and fuel cell technologies, including: evaluating individual technologies and technology pathways to assess issues such as resource needs and infrastructure challenges; providing insight and guidance for balancing the Program's research, development and demonstration (RD&D) portfolio; and estimating the potential value of various RD&D approaches.

OBJECTIVES

- By 2012, complete an evaluation of the use of hydrogen for energy storage and as an energy carrier to supplement energy and electrical infrastructure.
- By 2012, complete an evaluation of fueling station costs for early vehicle penetration to determine the cost of fueling pathways for low and moderate fueling demand rates.
- By 2014, complete environmental studies that should be done in advance of widespread commercialization.
- By 2017, complete analysis of Program performance, cost status, and the potential benefits of using fuel cells for a portfolio of commercial applications.
- By 2019, complete analysis of the market potential for hydrogen, stationary fuel cells, fuel cell electric vehicles and other fuel cell applications such as material handling equipment; the analysis will address the various needs for commercialization of these applications, including: hydrogen production, transportation infrastructure, and required performance of stationary fuel cells and vehicles. It will also assess the impact of the growth of fuel cell market shares on various sectors of the economy.
- Provide milestone-based analysis, including risk analysis, independent reviews, financial evaluations, and environmental analysis, to identify other needs the Program should address as fuel cells achieve technology readiness for various applications.

- Periodically update analyses of the life-cycle energy, petroleum use, greenhouse gas emissions, and criteria pollutant emissions from various fuel cell technologies and hydrogen fuel pathways—including updates based on technological advances or other changes.

FY 2012 STATUS

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. Activities in FY 2012 included: assessing socio-economic impacts, such as increased employment from fuel cell deployment; coordinating with the DOE Vehicle Technologies Program to assess the life-cycle cost of various vehicle platforms, including fuel cell electric vehicles; identifying early markets for fuel cells and opportunities to reduce cost; and exploring various approaches to reducing the cost of hydrogen infrastructure. The Systems Analysis sub-program has transitioned from activities focused on developing key models, to the application of those models in order to complete critical program analyses. As evidenced by the completed and ongoing analysis activities in the "FY 2012 Key Accomplishments" section, the initial strategy of the Systems Analysis sub-program has been effective in enabling the completion of a diverse portfolio of analytical projects.

FY 2012 KEY ACCOMPLISHMENTS

Develop and Maintain Models and Systems Integration

ANL, with assistance from RCF Economic and Financial Consulting, developed the JOBS FC model to estimate the employment and revenue impacts of fuel cell manufacturing and deployment. The model was used to estimate the impact of American Recovery and Reinvestment Act (ARRA) deployments of fuel cells (this analysis was supplemented with calculations that capture economic impacts from expenditures unique to the ARRA program that are not modeled in JOBS FC)—preliminary results indicate that nearly 700 net jobs were created in 2011 as a result of ARRA funding for fuel cell deployments (Figure 1). The JOBS FC model uses input-output methodology to estimate changes in industry expenditures as a result of fuel cell

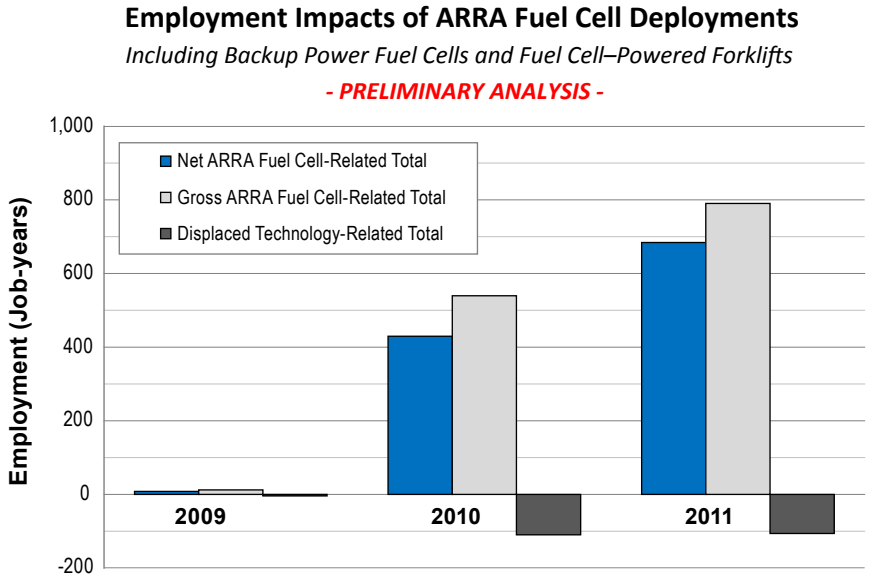


FIGURE 1. Preliminary analysis of employment impacts from ARRA fuel cell deployments, using the JOBS FC model (supplemented with calculations that capture economic impacts from expenditures unique to the ARRA program that are not modeled in JOBS FC) (source: ANL).

deployments and calculates the effects of those changes throughout the economy. Version 1.0 of the model was released for public use in May 2012 and includes forklift and backup power applications of polymer electrolyte membrane fuel cells and stationary power applications of phosphoric acid and molten carbonate fuel cells for user-specified analyses at the state, regional or national level. The model, a user's guide, and other background material are available for download at http://jobsfc.es.anl.gov.

Studies and Analysis

Market Analysis

- Pike Research completed a global and domestic market analysis of the fuel cell markets for portable, stationary power, and transportation applications—identifying increased growth in the fuel cell market and showing that the market remains strong, with over 20,000 systems shipped in 2011, an increase of more than 35% over 2010 (Figure 2).

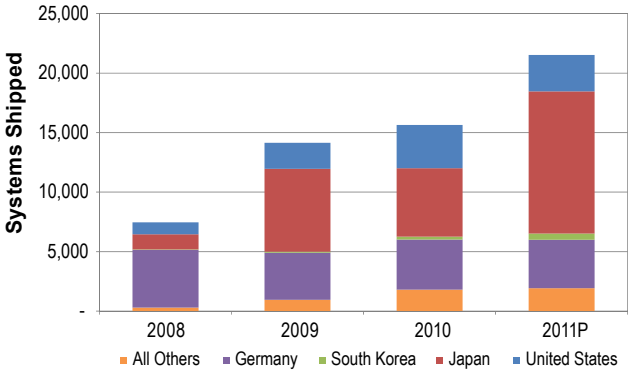
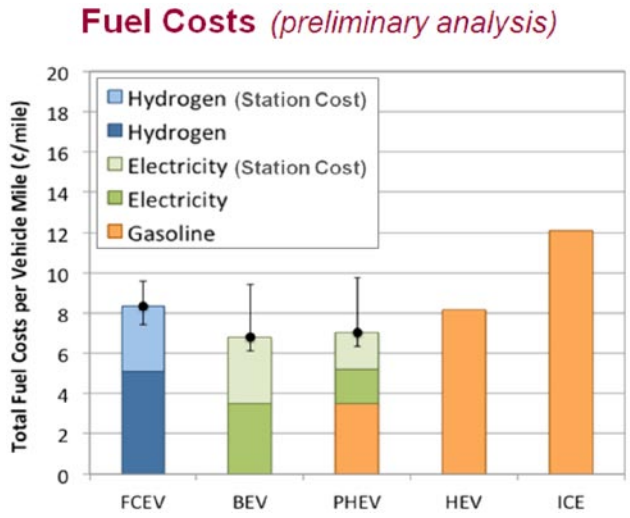


FIGURE 2. Global shipments of fuel cell systems, by key countries, including stationary, portable, and transportation fuel cell systems (source: Pike Research).

Infrastructure Analysis

- Analysis of infrastructure costs for hydrogen fueling and electric vehicle charging, conducted by the National Renewable Energy Laboratory (NREL), show that the capital intensities of the two infrastructure systems are roughly comparable, as illustrated in Figure 3. The analysis also indicates that the cost of fuel for fuel cell electric vehicles, battery electric vehicles, and plug-in hybrid-electric vehicles would be comparable to the cost of gasoline for hybrid electric vehicles, on a cents-per mile basis. Advanced light-duty vehicles fueled by hydrogen and electricity offer significant benefits by reducing greenhouse gas emissions, improving energy security, and improving air quality. A complete report based on this analysis will be issued by the end of 2012.
- NREL, along with a diverse group of stakeholders, examined opportunities for reducing the cost of hydrogen infrastructure. Using their infrastructure cost calculator, NREL evaluated potential cost reductions for early market fueling stations. Using stakeholder input, NREL analysis indicated that station cost could be reduced by >70% through standardization and modular station design in the early commercial phases; analysis also indicated that additional station cost reductions of >40% could be realized through economies of scale (Figure 4). Results from the stakeholder input to the cost calculator are shown below and will be published at the end of 2012.



FCEV – fuel cell electric vehicle; BEV – battery electric vehicle; PHEV – plug-in hybrid electric vehicle; HEV – hybrid electric vehicle; ICE – internal combustion engine (vehicle)

FIGURE 3. Preliminary analysis of the total fuel costs (on a cents-per-mile basis) for various vehicles, including the costs of refueling stations or charging stations (Error bars shown represent variations in retail infrastructure capital costs, source: NREL)

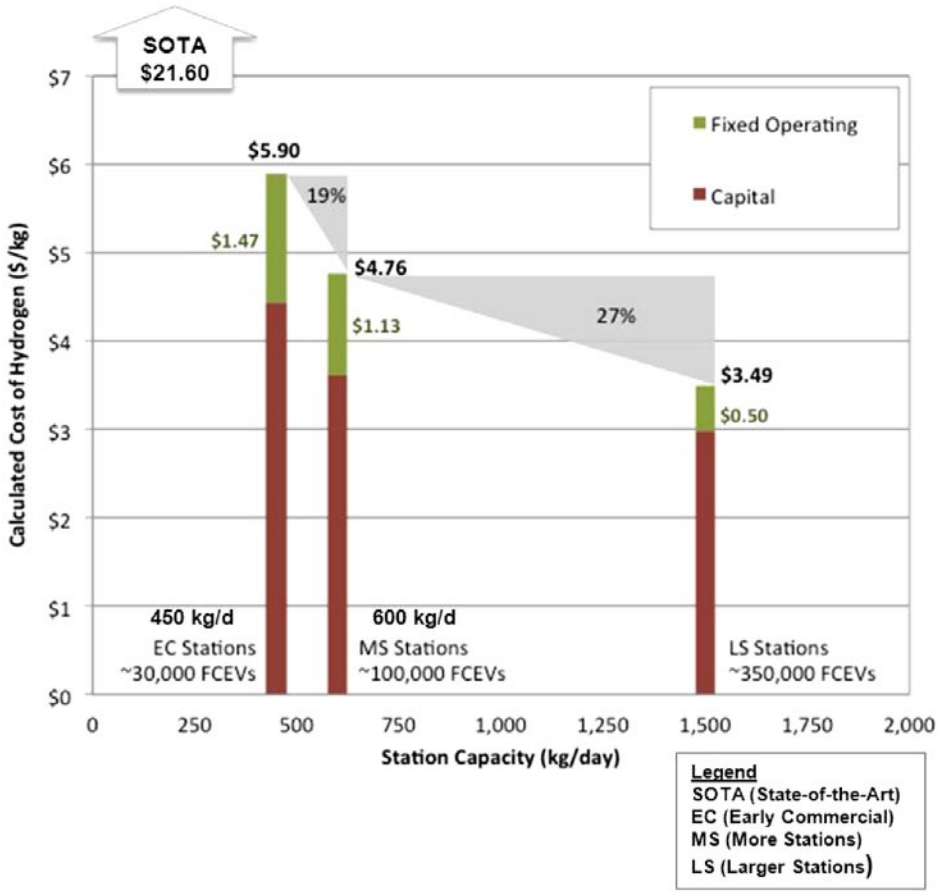


FIGURE 4. Results of stakeholder input to NREL's cost calculator show the potential for substantial reductions in the impact of station cost on the overall cost of hydrogen (source: NREL).

- DOE and ANL held a natural gas workshop with multiple stakeholders to gain valuable insight for potential synergies between hydrogen and natural gas. The objectives were to identify the current status of natural gas and hydrogen infrastructure, identify key challenges preventing or delaying widespread deployment of natural gas and hydrogen infrastructure, and identify opportunities for addressing challenges and for government and industry stakeholders. The results of the workshop highlighted that natural gas and hydrogen have similar storage and regulatory concerns; clusters of refueling centers are required to support a critical mass of both types of vehicles; by types of infrastructure should be developed along major commercial corridors; and consistent, long-term energy policies are required for natural gas and hydrogen fuel applications. A summary report was published by ANL and is available at: www.transportation.anl.gov/pdfs/AF/812.PDF

Environmental Analysis

- ANL revised the GREET model to include hydraulic fracturing for natural gas to assess the impact of various pathways utilizing natural gas as a feedstock or an energy source. As shown in Figure 5, the greenhouse gas emissions would be ~10% lower for a natural-gas-to-hydrogen pathway that used natural gas from hydraulic fracturing. Hydraulic fracturing and horizontal drilling require fewer wells to be drilled to produce the same amount of natural gas as the conventional production method, resulting in less methane leakage.

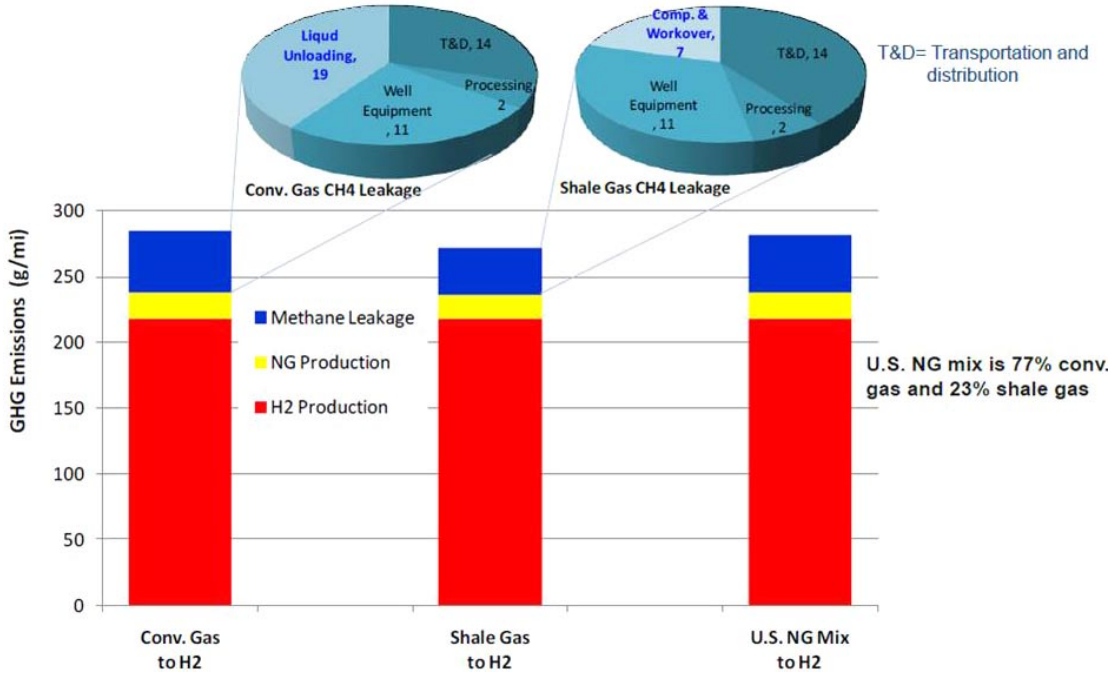
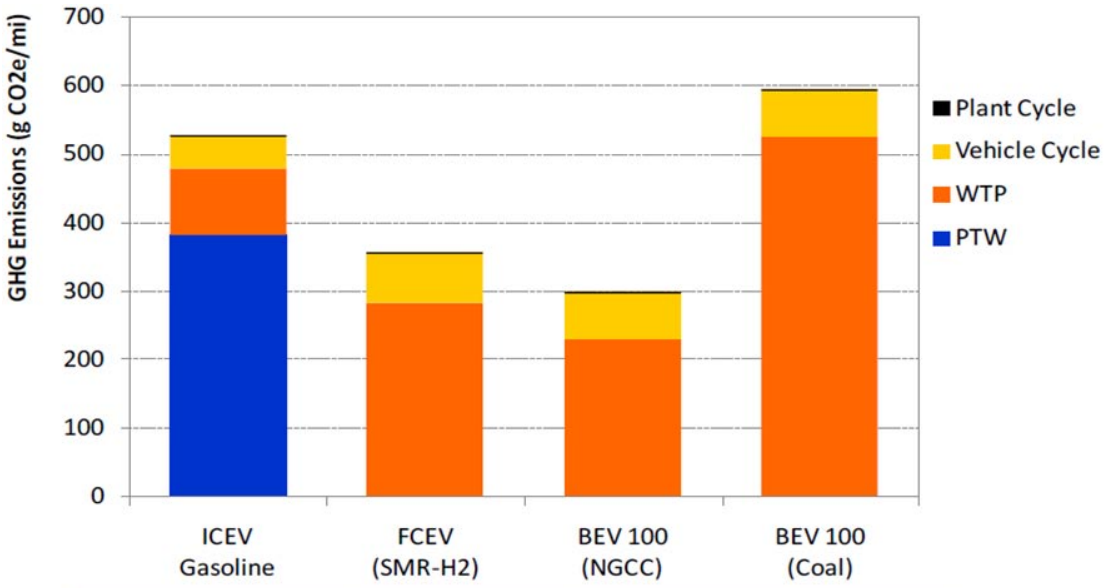


FIGURE 5. Results of analysis, using the GREET model, of life-cycle emissions from fuel cell electric vehicles using hydrogen produced from natural gas (source: ANL).

- ANL enhanced the life-cycle analysis capabilities of the GREET model by adding the greenhouse gas emissions associated with the plant cycle. Plant cycle emissions include those associated with the building, operation, and decommissioning of the power plants and steam methane reforming plants. The stages included in this life-cycle analysis include raw material acquisition, transportation and processing, product manufacturing and distribution, and disposal and recycling. With the addition of the plant cycle, the model indicates that the plant cycle would generally be a minor contributor to the total life cycle greenhouse gas emissions of various pathways (Figure 6). The key reason for this is that the emissions associated with a plant will be amortized over its lifetime.

Programmatic Analysis

- Pacific Northwest National Laboratory (PNNL) updated the commercial benefits of the Fuel Cell Technologies Program. Every year, PNNL's analysis tracks the commercial products and technologies and patents developed from Fuel Cell Technologies Program funding. This year, their analysis showed that the benefits of DOE funding continue to grow (as illustrated in Figures 7 and 8), with a total of 363 patents awarded and 36 products commercialized by 2012. Full results of PNNL's analysis are documented in *2012 Pathways to Commercial Success* (www.hydrogenandfuelcells.energy.gov/pdfs/pathways_2012.pdf).



	Gasoline ICEV	H_2 FCEV	BEV 100
Fuel Economy (mpgge)	23	54	80*

WTP - well to pump; PTW - pump to wheels

FIGURE 6. Life-cycle greenhouse gas emissions from various vehicle-fuel pathways, including plant-cycle emissions (source: ANL).

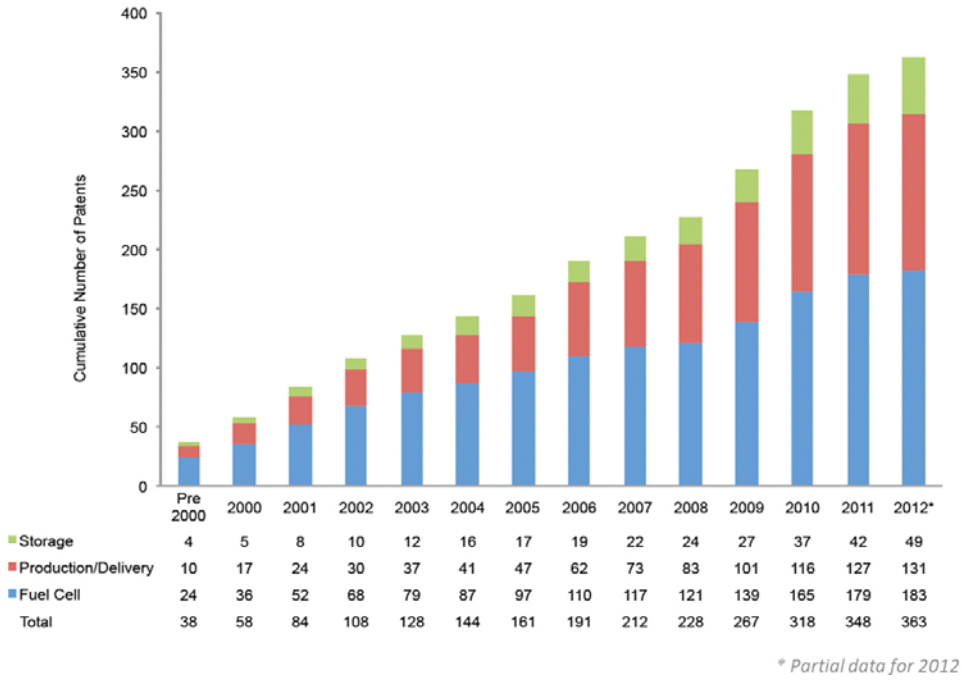


FIGURE 7. Cumulative number of patents awarded as a result of funding by the DOE Fuel Cell Technologies Program (source: Pacific Northwest National Laboratory).

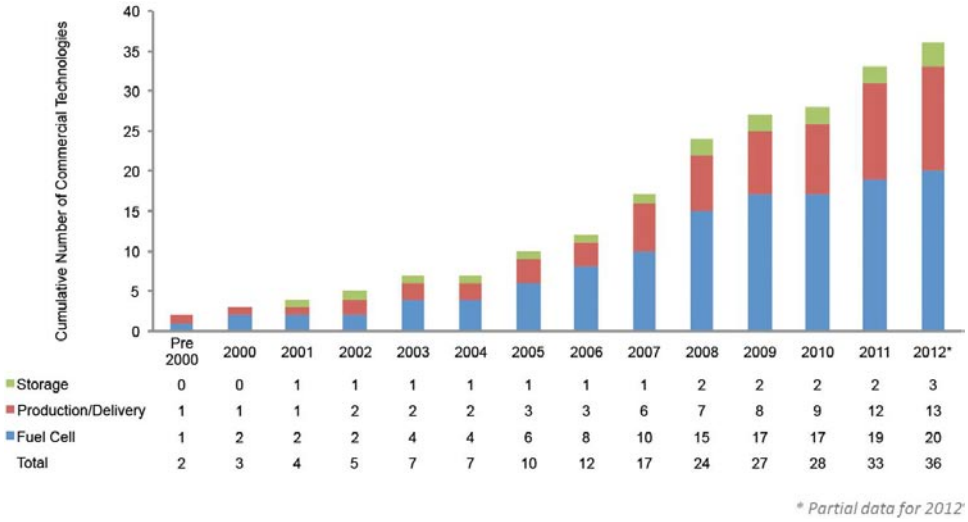
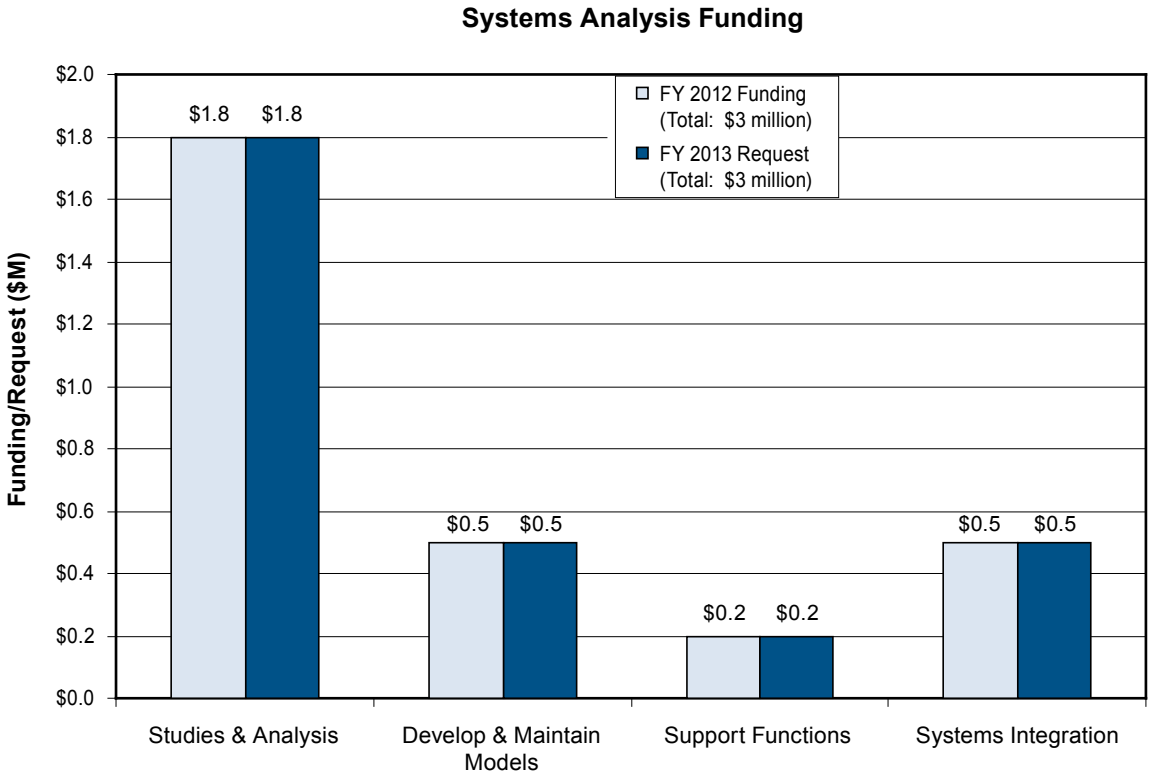


FIGURE 8. Cumulative number of commercial products on the market as a result of funding by the DOE Fuel Cell Technologies Program (source: Pacific Northwest National Laboratory).

BUDGET

The FY 2013 budget request for the Systems Analysis sub-program is consistent with the goals and objectives of the sub-program and is will enable the sub-program to continue to assess the viability and benefits of fuel cells for a wide range of applications, including stationary power generation, energy storage, specialty applications, and light-duty transportation.



FY 2013 PLANS

In FY 2013, the Systems Analysis sub-program will conduct analysis of: early fuel cell and hydrogen markets, hydrogen infrastructure, the impacts and tradeoffs of fuel quality requirements, and environmental and socio-economic impacts of fuel cell and hydrogen market growth. The sub-program will continue its systems integration efforts, analysis of Program impacts, and work on developing and improving models. The sub-program will also continue to assess new opportunities for using fuel cells and hydrogen in energy storage systems, explore potential synergies of linking stationary fuel cell power generation with other renewable technologies such biofuel production, and assess opportunities for integrating the distribution of hydrogen with existing natural gas pipeline networks.

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