VII.0 Systems Analysis Sub-Program Overview

Introduction

Systems Analysis supports decision-making by providing a greater understanding of technology gaps, options, and risks; the contribution of individual technology components to the overall system (i.e., from fuel production to utilization); and the interaction of the components and their effects on the system. Analysis is also conducted to assess cross-cutting issues, such as integration with the electrical sector and the use of renewable fuels. Particular emphasis is given to assessing stationary fuel cell applications, fuel quality impacts on fuel cell performance, resource needs, and potential infrastructure options.

The Systems Analysis activity made several significant contributions to the Program during Fiscal Year (FY) 2010. Several analytical tools, including the Stationary Fuel Cell Power Model, the Hydrogen Demand and Resource Analysis (HyDRA) tool, and the Macro-System Model (MSM) were updated and peer reviewed to support the analytical process. Resource, infrastructure, and early market analyses were conducted to better understand supply and demand issues. In particular, biogas from waste treatment facilities and landfill systems was identified as a large resource with the HyDRA model and was determined to be predominately located near urban centers that can provide feedstock for fuel to be used in stationary fuel cells for power generation. A cost model was developed to evaluate the cost of removing impurities from these resource streams. In addition, a study was initiated to evaluate the impact of the biogas impurities on fuel cell performance and durability. The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model was modified to enable criteria pollutants to be evaluated on a life-cycle basis for stationary fuel cells for combined heat and power production in comparison with other competing technologies such as natural gas microturbines, internal combustion engines, and electrical generation from natural gas and coal fired systems. Risk analyses were also conducted to help identify key research and development (R&D) gaps for fuel cell systems and areas of high risk in terms of meeting targets and timelines.

Goals

Provide system-level analysis products to support the overall Program by evaluating technologies and pathways, guiding the selection of research, development, and deployment projects, and determining technology gaps, risks, and benefits.

Objectives

- By 2011, enhance the MSM to include the stationary electrical generation and infrastructure.
- By 2014, complete environmental studies that are necessary for technology readiness goals.
- By 2015, analyze the potential benefits of fuel cells for multiple applications such as portable, stationary, and backup power; and assess resource needs, infrastructure requirements, and potential interactions with the electric power sector.
- Provide analysis of Program milestones, including risk analysis, independent reviews, financial evaluations, and environmental analysis, to support the Program's needs prior to the technology readiness milestone.
- On an annual basis, update the well-to-wheels and life-cycle analyses for technologies and pathways for the overall Program by incorporating technological advances and changes.

FY 2010 Status

Systems Analysis focuses on examining the economics, benefits, risks, opportunities, and impacts of fuel cells and renewable fuels within a consistent, comprehensive analytical framework. Analysis conducted in FY 2010 included identifying early markets for fuel cells and opportunities to reduce cost through various mechanisms, such as tax credits and other legislation. The Systems Analysis sub-program has transitioned from activities focused on key model development to the application of the models for completing critical program analyses. As evidenced by the completed and ongoing analysis activities shown in the "Accomplishments" section, the initial strategy of the Systems Analysis sub-program has been effective in providing critical analysis results that help guide the Program's overall hydrogen and fuel cell activities.

FY 2010 Accomplishments

Models

- The MSM, a dynamic engineering transition model, was updated to include infrastructure and resource analysis for diverse resources, various regions, and a variety of hydrogen production pathways. The model is used for the simulation of the performance and evolution of hydrogen infrastructure, using a distributed architecture to link existing and emerging models for system components. Infrastructure and resource analysis capabilities were made feasible by the addition of the resources model, HyDRA, and the infrastructure model, HyPRO, to the MSM.
- The Fuel Cell Power Model, developed by National Renewable Energy Laboratory (NREL) to evaluate costs from combined heat and power generation for polymer electrolyte membrane fuel cells, phosphoric acid fuel cells (PAFCs), and molten carbonate fuel cells (MCFCs), was upgraded to include business and financial analysis useful to multiple entities such as building owners, fuel cell vendors, station owners, utilities, and fleet operators. The model features analysis of power, heat, and hydrogen fuel costs based on capital equipment costs, feedstock prices, operating climate conditions, and the heat and power loads for the system.

Infrastructure Analysis

- Infrastructure analysis conducted by Oak Ridge National Laboratory with the HyTrans model, NREL with the Scenario Evaluation and Regionalization Analysis model, and Sandia National Laboratories revealed that synergies between fuel cells for stationary power generation and transportation could be realized in the early phases of market adoption of hydrogen for light-duty fuel cell vehicles. Widespread deployment of combined heat, hydrogen, and power (CHHP) could reduce the problem of hydrogen availability in the early stages of transition to fuel cell vehicles. Results of this analysis indicate that hydrogen produced from CHHP could result in smaller stations with higher capital utilization and lower hydrogen cost, supplementing hydrogen supplied from distributed natural gas–based steam methane reforming (SMR).
- Analysis conducted by NREL with the Fuel Cell Power Model indicates that hydrogen produced from a stationary fuel cell would have a lower cost than hydrogen produced from an SMR system at low volumes, as exhibited in Figure 1 (stationary fuel cells have the unique ability to produce hydrogen in addition to heat and power and to use diverse renewable fuels such as waste gas or biogas). This factor will be important during the early stages of transportation fuel cell adoption because hydrogen demand and resultant hydrogen production will be at low volumes.
- DOE participated in an infrastructure workshop sponsored by the International Partnership for Hydrogen and Fuel Cells in the Economy to examine the key drivers and gaps to early market infrastructure development for light-duty vehicles. Providing adequate fueling infrastructure for consumers is one of the key barriers to hydrogen fuel cell vehicle commercialization. The outcomes of the workshop included the following ideas:
  - Develop low-cost 100 kg/day starter stations
  - Define a "line of sight" path to business profitability
  - Create co-ops or public-private partnerships
  - Enact policies and incentives to make hydrogen more attractive to investors
  - Explore innovative ways to boost hydrogen demand by serving multiple applications
  - Promote novel business models that utilize new methods of financing
  - Leverage existing natural gas and hydrogen infrastructure to reduce costs

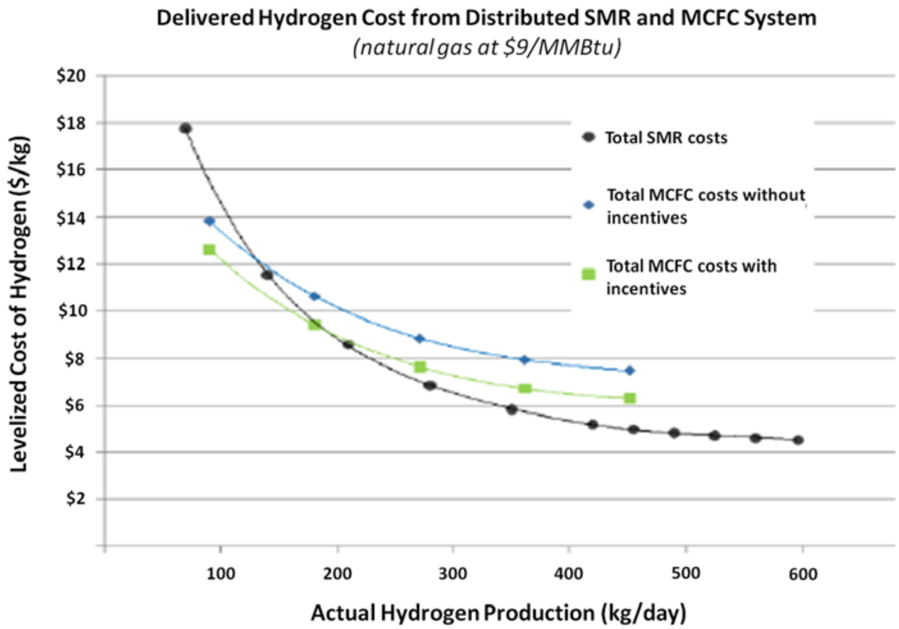
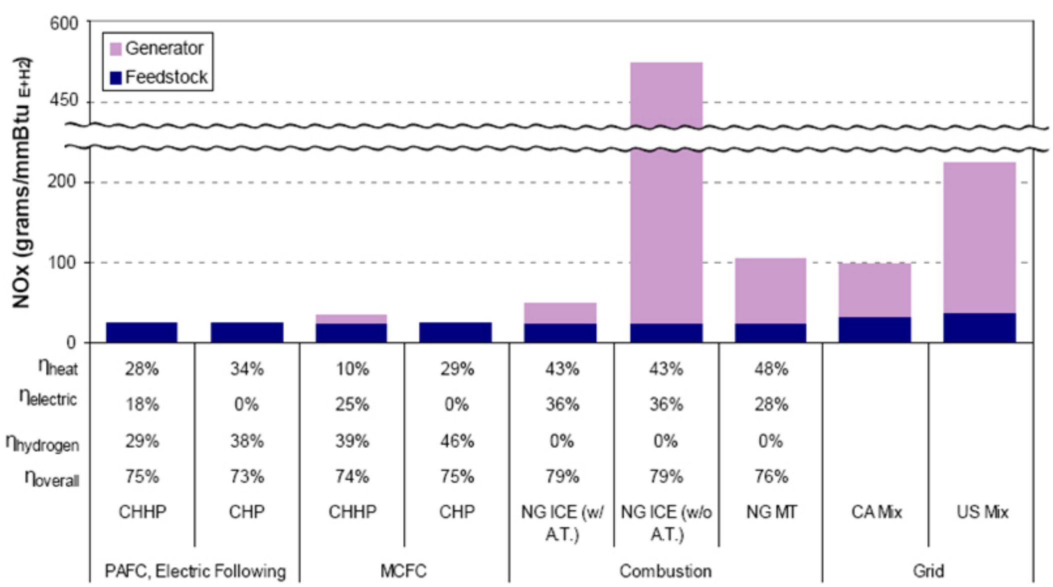


FIGURE 1. Hydrogen Production Cost from CHHP and SMR Systems (Source: NREL)

Environmental Analysis

- Argonne National Laboratory (ANL) enhanced the well-to-wheels analysis capabilities of the GREET model by including analysis of criteria pollutant emissions from stationary fuel cells for combined-heat-and-power (CHP) generation and CHHP generation. The analysis shows that fuel cell systems for CHP and CHHP produce significantly less carbon monoxide, particulate matter and oxides of nitrogen (NOx) emissions than conventional generation technologies. For example, Figure 2 shows that PAFCs and MCFCs emit at least 80% less NOx than other conventional generation technologies without after treatment.



E – electricity; η – efficiency; NG – natural gas; ICE – internal combustion engine; AT – aftertreatment; MT – microturbine: CA - California

FIGURE 2. NOx Emissions from CHHP, CHP, and Competing Technologies (Source: ANL, GREET Model)

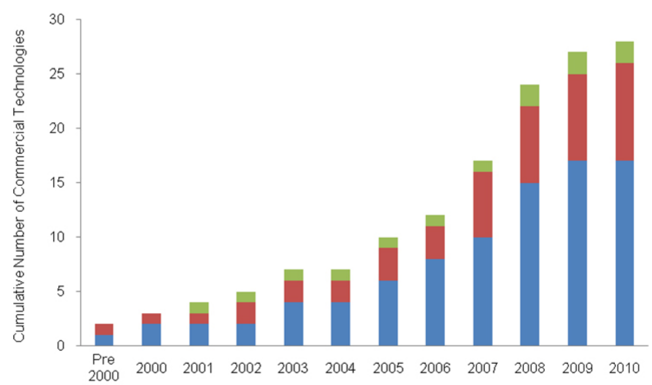
- ANL has started the impact analysis of feedstock quality on stationary fuel cell performance and the costs associated with meeting the required feedstock quality specifications. The feedstocks being assessed include natural gas, landfill and anerobic digestion biogases, and syngas from coal and biomass gasification. The key impurity analysis shows sulfur, siloxanes, heavy metals, and halides are detrimental to the fuel cell anode. Ammonia, carbon monoxide, and hydrocarbons are less damaging for higher-temperature fuel cells such as solid oxide fuel cells (SOFCs) and MCFCs. Further R&D will be needed to determine separation technologies and costs to remove these contaminants from the feedstock streams.

Resource Analysis

- Analysis by Lawrence Livermore National Laboratory of the impact of water on hydrogen production has found that it will have a minor effect–of less than $0.10/gasoline gallon equivalent. The assessment included an examination of water permitting and allocation on water cost, and found that these effects varied from region to region. Water was found to be abundant at a national level, but permitting and allocation at a regional level could be problematic in regions with high water stress such as California, Arizona, and Colorado. Expansion of industrial water demand for applications such as hydrogen production in these regions may encounter water availability limits before reaching a cost constraint.
- NREL developed a model to examine the cost of purifying biogas streams to enable them to be used in a fuel cell or in hydrogen production from steam methane reforming. Biogas–which can come from landfills, wastewater treatment plants, and farms–is an abundant energy source that is often strategically located near major urban centers; however, it contains contaminants such as ammonia, sulfur, hydrocarbons, siloxanes, and heavy metals. This model will supplement other models in the DOE portfolio for hydrogen production cost analysis, fuel cell electrical cost analysis, and greenhouse gas emission evaluation.

Programmatic Analysis

- Pacific Northwest National Laboratory analyzed the commercial benefits of the Fuel Cell Technologies (FCT) Program by tracking the commercial products and technologies developed with the support of the Program (Figure 3). The results show 198 patents were issued and 28 products were commercialized by 2010 as a result of research funded by FCT in the areas of storage, production, delivery, and fuel cells, which will be highlighted in the FY 2010 *Pathways to Commercial Success Report*.
- A workshop was held in FY 2010 to identify gaps to reduce costs for fuel cells for distributed CHP generation in the 200-kW to megawatt range. The gaps identified included:
  - High cost of feedstock contaminant removal
  - Need for higher power density
  - High cost of balance-of-plant components



	Pre 2000	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Storage	0	0	1	1	1	1	1	1	1	2	2	2
Production/Delivery	1	1	1	2	2	2	3	3	6	7	8	9
Fuel Cell	1	2	2	2	4	4	6	8	10	15	17	17
Total	2	3	4	5	7	7	10	12	17	24	27	28

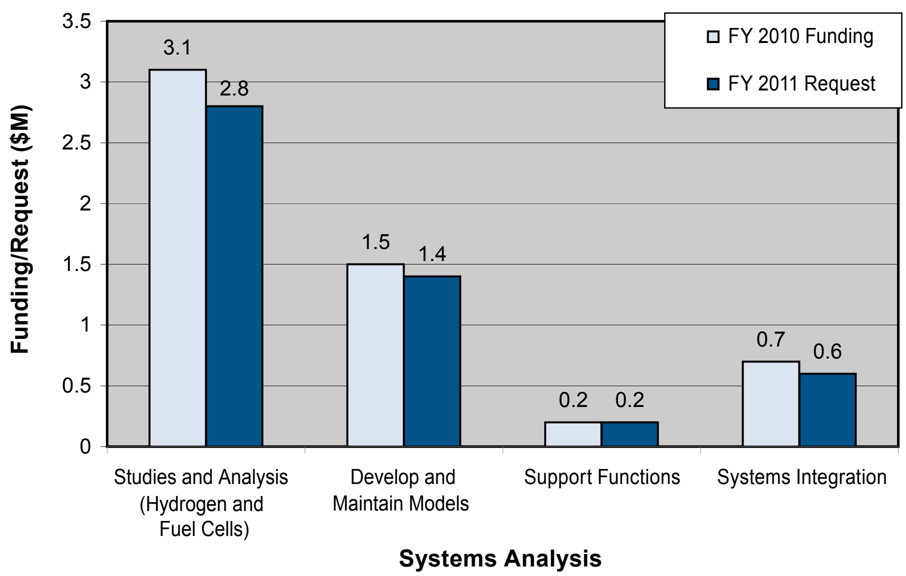
FIGURE 3. Cumulative Number of Commercial Technologies as a result of Energy Efficiency and Renewable Energy Funding for Hydrogen and Fuel Cells[1]

[1] Pathways to Commercial Success: Technologies and Products Supported by the Fuel Cell Technologies Program, Prepared by Pacific Northwest National Laboratory for the DOE Fuel Cell Technologies Program, August 2010, www.eere.energy.gov/hydrogenandfuelcells/pdfs/pathways.pdf.

– Need for increased stack and cell durability
– Need to reduce platinum content of phosphoric acid fuel cells

Budget

The budget for the Systems Analysis activity is consistent with the goals and objectives of the sub-program and enables assessment of fuel cell applications for energy storage, stationary power generation, specialty applications, and light duty transportation. The FY 2011 budget request includes funding for resource and infrastructure analysis, as well as fuel quality evaluation, environmental analysis, overall program analysis, modeling, and systems integration. New fuel cell opportunities for energy storage and transmission will also be explored.



FY 2011 Plans

In FY 2011, the Systems Analysis sub-program will focus on conducting analyses to determine technology gaps for fuel cell systems and infrastructure for different applications, and utilizing fuel cells and hydrogen for energy storage and transmission. Analyses will be focused on understanding the tradeoffs and regional impacts of fuel cells with other alternative fuels and the electrical sector on a well-to-wheels basis, and the synergies of linking stationary fuel cell power generation with the electrical sector. The FY 2010 appropriation included $5.5 million for Systems Analysis; the FY 2011 request is $5 million. The budget request for FY 2011 reflects the focus on early market analysis, fuel cell technology evaluations, renewable fuel benefits, as well as resource and infrastructure analysis.

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