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The U.S. Department of Energy's Fuel Cell Technologies Program

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Abstract

This paper describes U.S. efforts to address energy security, economic, and environmental challenges. Within the U.S. Department of Energy, the Fuel Cell Technologies Program supports the broad national goals of reducing petroleum use, greenhouse gas emissions, and air pollution; developing a more diverse and efficient energy infrastructure; and creating high-skilled jobs in emerging technical fields. The FCT Program supports research, development and demonstration of fuel cell power system technologies for transportation, stationary, and portable applications. Key challenges to commercialization Fuel Cell Technologies Program Achievements will be described.

1 Introduction

President Obama has proposed a number of actions to help the United States address its energy security, economic, and environmental challenges. For example, final rules for increasing fuel economy standards for vehicles were recently unveiled by the Department of Transportation and the Environmental Protection Agency [1]. In October 2009, the President signed Executive Order 13514, Federal Leadership in Environmental, Energy, and Economic Performance. This executive order is focused on reducing the Federal Government's greenhouse gas emissions. Targets include reducing vehicle fuel petroleum use by 30% by 2020, requiring 15% of buildings to meet a set of guiding principles by 2015, and designing new Federal buildings to be zero-net by 2030.

Within the U.S. Department of Energy (DOE), the Fuel Cell Technologies (FCT) Program supports the broad national goals of reducing petroleum use, greenhouse gas emissions, and air pollution; developing a more diverse and efficient energy infrastructure; and creating high-skilled jobs in emerging technical fields. The goal of the Program is to enable widespread commercialization of fuel cells in diverse sectors of the economy, with emphasis on applications that will most effectively strengthen our nation's energy security and improve our stewardship of the environment. To achieve its goal, the FCT Program supports research, development and demonstration (RD&D) of fuel cell power system technologies for transportation, stationary, and portable applications. The key objective is to make fuel cells competitive with incumbent technologies and other advanced technologies in terms of lifecycle cost, performance, and market acceptance. The Program works with partners in industry, academia, non-profit institutions, and the national labs, and coordinates closely with other programs in other DOE offices, namely Science, Nuclear Energy and Fossil Energy.

The cost of fuel cells must be reduced and durability and performance must be improved to be competitive with existing technologies. As the cost of fuel cells comes down, through technological improvements and economies of scale, fuel cells will become competitive in a

growing number of markets. Much of the program's work focused on automotive applications and PEMFC component research. Recent program changes led to an increased emphasis on near-term and mid-term applications.

2 Current status

Fuel cells have moved from the laboratory and into the marketplace. Currently, fuel cells are being sold in forklifts for material handling applications and for backup power particularly for telecommunications towers. For stationary and auxiliary power, more than 75,000 fuel cell systems have been sold worldwide and approximately 24,000 fuel cell systems were shipped in 2009, which represents a more than 40% increase over the number of units sold in 2008 [2]. For transportation fuel cell applications, there are currently 230 vehicles worldwide, with around 130 buses and around 200 refueling stations. Several manufacturers, including Toyota, Honda, Hyundai, Daimler, GM, and Proterra (buses), announced plans to commercialize vehicles by 2015 [3]. In 2009, Germany announced that it planned to develop a roadmap leading to a comprehensive nationwide infrastructure for hydrogen refueling, to be place in Germany by 2015 [4]. Partners in the "H2 Mobility" initiative plan for three phases: concepts for the expansion of new hydrogen refueling stations should be developed by 2011, next the infrastructure will be put in place, and finally fuel cell-powered electric vehicles will be on the roads by ~2015.

3 Benefits of Hydrogen and Fuel Cells

Electric vehicles provide many benefits with respect to reductions in greenhouse gas emissions and petroleum energy use. The benefits have been quantified using well-to-wheels analyses [5] that are based upon a projected state of technologies in 2020. The analyses show that conventional vehicles fueled by gasoline or natural gas generate the most grams of carbon dioxide equivalent per mile driven of all the technologies that were examined. For hybrid electric vehicles and for plug-in hybrids, those powered by renewable energy fuels generate the least greenhouse gas emissions. However, of all the technologies evaluated, the most benefits are obtained with fuel cell vehicles, in which vehicles powered by hydrogen fuel from electrolysis from central wind or nuclear high-temperature processes generate the least carbon dioxide emissions.

For petroleum energy use, conventional vehicles operating on gasoline consume the most petroleum energy per mile driven of all the technologies examined whereas conventional vehicles operating on natural gas consume much less. Hybrid electric vehicles and plug-in hybrids consume about one-third to one-half the petroleum energy per mile of a conventional vehicle. Note that those vehicles operating on a renewable fuel do require some petroleum to produce the renewable fuel. The most petroleum use savings per mile driven are obtained with fuel cell vehicles operating on hydrogen from fossil fuels (with sequestration) or from renewable resources.

4 Key challenges to commercialization

The Fuel Cell Technologies Program addresses both technology barriers as well as economic and institutional barriers to the commercialization of hydrogen and fuel cell technologies. The principal technical barriers include reducing the cost and increasing the durability of fuel cell systems as well as decreasing the cost of producing, delivering, and storing hydrogen. For consumer acceptance, the performance of hydrogen and fuel cell systems needs to be demonstrated under real-world conditions. Market transformation activities, especially procurement of fuel cell systems for federal facilities, are need to assist the growth of emerging markets, including achieving significant cost reductions through economies-of-scale. Codes and standards must be harmonized for global marketing and a robust, domestic manufacturing and supplier base must be established. Public awareness of hydrogen and fuel cell technologies must be increased. Last, a hydrogen infrastructure must be developed.

Innovative concepts have been proposed to establish an initial fueling infrastructure. DOE has partnered with the Southern California Air Quality Management District and the California Air Resources Board to develop a high temperature fuel cell system that generates combined heat, hydrogen, and power (CHHP) at the Orange County Sanitation District in Fountain Valley. CHHP systems can produce clean power and fuel for multiple applications. High temperature, molten carbonate fuel cells can operate on a variety of hydrocarbon fuels and the unit in Fountain Valley will operate on digester gas from a wastewater treatment plant. Key advantages of CHHP include the ability to readily locate the fuel cell system at industrial and commercial sites and the fact that additional reformation concurrently aids in cooling the fuel cell and uses waste heat from the fuel cell [6]. Improvements in design have led to higher H_2-recovery (from 75% to >85%).

5 Fuel Cell Technologies Program Achievements

The fuel cell sub-program is focused on reducing the cost and increasing the performance and durability of fuel cell components. The sub-program monitors the projected high volume cost of fuel cells as a gauge of the progress of the technology. The high-volume cost of 80-kW fuel cell systems for transportation applications is projected to be $61/kW, a more than 35% reduction in the last two years [7]. High volume production is defined to be 500,000 units/year. Since the initial volume of fuel cell vehicle sales will be likely be less than 500,000 units/year, one of DOE principle investigators, DTI, examined the cost of 80-kW fuel cell systems at different production rates. DTI reported that the cost drops from $229/kW at 1,000 units/year to $103/kW at 30,000 units/year.

The FCT Program is examining both near-term and long-term pathways for hydrogen production. The high-volume cost target to produce hydrogen (delivered and untaxed) is $2-3/gallon gasoline equivalent (gge). [The energy content of a gallon of gasoline is about the same as a kilogram of hydrogen.] For near-term pathways, the cost target was met with distributed natural gas reformation. Other near-term pathways such as hydrogen from bio-derived renewable liquids and electrolysis are projected to cost ~$4-6/gge. For the longer term pathways, the cost of hydrogen from biomass or coal gasification is also $4-6/gge

whereas hydrogen from central wind electrolysis is $6-10/gge. Even longer-term pathways include hydrogen from solar high-temperature thermochemical cycles.

The Program is pursuing three pathways for hydrogen delivery including tube trailers, tanker trucks, and pipelines; the cost target for hydrogen delivery is $1/gge. Recent progress in new materials for tube trailers, advanced liquefaction processes, and replacing steel with fiber reinforced polymer for pipelines has led to 15-30% reduction in the cost of delivering hydrogen.

To increase the volumetric and gravimetric capacity of hydrogen storage vessels, DOE has focused on materials R&D and compressed/liquid hydrogen tanks. Compressed gas storage is a near-term opportunity for vehicle commercialization but reducing the cost of composite tanks is challenging; more than 75% of the cost of a tank is projected to be due to the carbon fiber layer. Carbon fiber is expensive. Materials discovery research is still needed for long-term, advanced storage technologies such as metal hydrides, surface adsorption, and chemical hydrides.

As mentioned previously, DOE is facilitating the development and adoption of codes and standards for hydrogen and fuel cells. Recent important key activities include the establishment of harmonized domestic and international fuel quality specifications. Educational activities to increase public awareness and understanding of fuel cells are an important part of the Program. DOE has conducted seminars and developed fact-sheets and case studies for end-users and conducted workshops to help state officials identify deployment opportunities.

Under its Technology Validation effort, DOE is validating the performance of hydrogen stations and fuel cell vehicles, under real-world conditions. More than 115,000 kg of hydrogen have been produced or dispensed and the fuel cell vehicles have travelled more than 2.3 million miles. Note that not all the hydrogen produced was consumed by the vehicles. Analysis of the performance data from the fuel cell vehicles by DOE's National Renewable Energy Laboratory shows vehicle efficiency of 53 – 58% (>2x higher than gasoline internal combustion engines), vehicle range of ~196 – 254 miles, and fuel cell system durability of ~ 2,500 hrs (~75,000 miles travelled). Through the Technology Validation effort, DOE is also evaluating stationary fuel cells and real-world forklift and bus fleet data (in collaboration with the U.S. Department of Defense (DOD) and the U.S. Department of Transportation).

DOE's Market Transformation activities address the Energy Policy Act (EPAct) of 2005. EPAct's Section 783 directed the U.S. Federal Government to pay the incremental cost of fuel cells for stationary, portable, and micro fuel cells [8]. Government purchases of fuel cell systems could reduce the cost of fuel cells through economies-of-scale and help to support a growing supplier base. A recent study by Oak Ridge National Laboratory showed that a modest Federal acquisition program of fuel cells for material handling equipment and backup power (~2000 units per year) could enable cost reductions from ~$3500/kW to ~$1000/kW for fuel cell stacks in around 10 years [9].

Under the Market Transformation effort, DOE worked with the U.S. Department of Defense's Defense Logistics Agency to deploy 40 forklifts at the Defense Distribution Depot in Susquehanna, Pennsylvania (DDSP). DDSP is the largest DOD distribution center under

DLA. DOE is working with the Federal Aviation Administration and the U.S. Army installing fuel cells for telecommunications applications and with the Joint Forces Training Center and the Marines to deploy fuel cells in fire stations. In 2009, DOE partnered with the Army's Construction Engineering Research Laboratory to install ~90 fuel cell systems for backup power at 13 locations across the country including Army Forts, NASA Ames Research Center, a Marine Corps Command Center, and Fort Sumter, a National Park Service facility. Finally, DOE is working with the Hawai'i Natural Energy Institute to use hydrogen for energy storage in a grid-integrated hydrogen system to mitigate variable electricity generation from renewable sources.

The America Recovery and Reinvestment Act (ARRA) was passed by the U.S. Congress in 2009 to create jobs and promote investment and consumer spending during the economic downturn. The FCT Program awarded more than $40M in ARRA funds for 12 projects to deploy up to 1000 fuel cell systems. The fuel cell systems will be used primarily for backup power and specialty vehicles such as lift trucks in warehouses, and also for portable power, combined heat and power, and auxiliary power units. The fuel cell systems will be used in as battery replacements for fleets of electric lift trucks at five existing distribution centers (Coca Cola, Kimberly-Clark, Sysco Foods, Wegmans, Whole Foods), deployed into the telecommunications and utility networks at AT&T and PG&E for backup power, and used as battery replacements for a complete fleet of electric lift trucks at an existing FedEx service center. DOE provided funding for R&D by all of the fuel cell suppliers involved in the ARRA projects showing continued support from the laboratory to deployment.

DOE works with many organizations to carry out its activities. Industry, universities, and National Laboratories carry out the applied RD&D needed to advance the technology. The U.S. Government's federal agencies cooperate through the Interagency Working Group to coordinate fuel cell R&D and through the higher-level Interagency Task Force for policy matters. International collaboration is harmonized through the International Energy Agency and the International Partnership for Hydrogen and Fuel Cells in the Economy. Activities at the local level are coordinated by state organizations such as the California Fuel Cell Partnership and the Connecticut Center for Advanced Technology. The FCT Program is reviewed periodically by the National Research Council and by the Hydrogen and Fuel Cell Technical Advisory Committee. The U.S. Council for Automotive Research (whose members are three U.S. automakers: GM, Ford, and Chrysler) and DOE partner through the FreedomCAR and Fuel Partnership; one of the objectives of the partnership is to examine and advance R&D of technologies leading to affordable hydrogen fuel cell vehicles and the hydrogen infrastructure to support them. The FreedomCAR and Fuel Partnership provides feedback to DOE on the Department's R&D activities, from the viewpoint of an automotive manufacturer.

Besides providing funds for fuel cell system deployments as described earlier, the ARRA provides financial incentives to encourage the installation of fuel cells and hydrogen fueling infrastructure. Some examples include: the Hydrogen Fuel Facility Credit increases the hydrogen fueling credit from 30% or $30,000 to 30% or $200,000, the Manufacturing Credit creates a 30% credit for investment in property used for manufacturing fuel cells and other technologies, and the Fuel Cell Investment Tax Credit increases the investment tax credit to 30%, up to $3,000/kW for business installations, and extends the credit from 2008 to 2016.

References

[1] http://money.cnn.com/2010/04/01/autos/cafe_standards_final/index.htm

[2] http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/mefuelsconf_satyapal.pdf

[3] http://www.icars.sg/2009/8326/auto-manufacturers-sign-memorandum-of-understanding-on-fuel-cell-vehicles/].

[4] http://www.fuelcelltoday.com/online/news/articles/2009-09/Linde--Daimler--EnBW--NOW--OMV--].

[5] http://www.hydrogen.energy.gov/pdfs/9002_well-to-wheels_greenhouse_gas_emissions_petroleum_use.pdf

[6] www.californiahydrogen.org/getdoc.cfm?id=16

[7] http://www.fuelcellseminar.com/assets/2009/GHT41-3_0930AM_James.pdf

[8] http://www.epa.gov/oust/fedlaws/publ_109-058.pdf

[9] http://www-cta.ornl.gov/cta/Publications/Reports/ORNL_TM_2008_183.pdf