SESSION IX
P^2 THROUGH ENERGY EFFICIENCY

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Fuel Cells: Meeting the DOD's Critical Energy Requirements

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INTRODUCTION

The use of fuel cells in Department of Defense (DOD) applications was investigated with an emphasis on stationary power applications, as opposed to transportation and portable power applications. In addition to investigating the current uses of fuel cells, several DOD-unique applications for the "premium power" offered by fuel cells were identified. Fuel cell operating and economic data were collected for analysis and air pollution emission reductions were quantified. Collectively, this information is useful for DOD decision makers in evaluating potential sites for future fuel cell installations.

BACKGROUND

A fuel cell is an electrochemical device that converts chemical energy into usable electricity and heat without combustion as an intermediate step. A fuel cell power plant is composed of four major subsystems: the fuel processor or reformer, the power section, the power conditioner, and the thermal energy recovery system. The fuel processor or reformer converts a hydrocarbon fuel, typically natural gas, into a clean, hydrogen-rich gas. The power section is where the hydrogen-rich gas combines with oxygen to produce direct current (DC) power, heat, and water. The power conditioner converts the DC power into clean, alternating current (AC) power. A thermal energy recovery system removes the fuel cell by-product heat and diverts it to a heat exchanger for use in thermal applications.

Fuel cell technology offers several environmental and operational advantages over conventional fossil fuel power generation methods. Fuel cell exhaust emissions of sulfur oxides (SO_x), nitrogen oxides (NO_x), carbon monoxide (CO), carbon dioxide (CO_2), and other pollutants are well below even the most stringent regulatory levels. In addition to low pollutant emissions, fuel cells also operate at low noise levels (below 60 decibels). This allows installation in and adjacent to buildings and makes fuel cells an attractive option for energy generation in urban areas. Finally, fuel cells can operate on a wide variety of fuels, including natural gas, petroleum products, ethanol, methanol, coal-derived gas, landfill gases, and biogas.

Four types of fuel cells are currently under development: phosphoric acid fuel cells (PAFCs), polymer electrolyte membrane fuel cells (PEMFCs) (also known as proton exchange membrane fuel cells), molten carbonate fuel cells (MCFCs), and solid oxide fuel cells (SOFCs). Low-temperature fuel cell technologies (PAFC and PEMFC) are well suited for transportation and

light-duty cogeneration applications. High-temperature technologies (MCFC and SOFC) are suited for larger multi-megawatt applications having high-duty cycles.

Although several fuel cell technologies are being researched, developed, and demonstrated around the world, ONSI (a subsidiary of International Fuel Cells) currently offers the only commercially available fuel cell in the U.S. It is a 200-kW PAFC system with the current version marketed as the model PC25™C. ONSI has sold more than 100 stationary fuel cells worldwide and has proven the effectiveness and efficiency of this technology in a variety of applications.

The PC25™C is designed for automatic, unattended operation. The power plant can power electrical loads either in parallel with the local utility grid or isolated from the grid. With an electrical output of 200 kW, the PC25™C has an electrical efficiency exceeding 40 percent (lower heating value) and an overall efficiency approaching 85 percent if the waste heat is recovered. The PC25™C provides over 700,000 Btu/hr of useful heat at temperatures in the range of 140°F. A high-grade heat recovery option is available to provide more than 300,000 Btu/hr at 250°F.

DOD FUEL CELL APPLICATIONS

The DOD is the single largest user of energy in the world. Due to their high efficiency, the use of fuel cells has the potential to reduce the DOD's fossil fuel consumption by 20 percent by the year 2005. In addition, fuel cells will also aid the DOD in achieving environmental compliance and meeting pollution prevention goals by significantly reducing air emissions.

The National Defense Center for Environmental Excellence (NDCEE), operated by Concurrent Technologies Corporation (*CTC*), has been tasked to support the Environmental Security Technology Certification Program (ESTCP) in investigating the use of fuel cells in DOD applications. To date, 30 fuel cells have been installed at DOD facilities. Most of these installations are for non-critical electric and heating applications. However, depending on their configuration, fuel cells can also provide "premium power" to critical or semicritical loads that require higher quality and/or reliability than that normally provided by the electric utility grid. For example, fuel cells can be used to provide continuous power while serving as a backup or uninterrupted power supply. Fuel cells can also provide power to remote sites that are not connected to a utility power grid. For future fuel cell installations, the DOD should take greater advantage of the premium power offered by fuel cells.

Ten high-impact, premium power applications have been identified for the DOD, including:

- Medical Treatment Facilities
- High-Security Facilities
- Communications and Data Centers
- Advanced Manufacturing Processes
- Electronics Manufacturing Processes
- Air Traffic Control Facilities
- Radar Sites
- Shipboard Service
- Research and Testing Facilities
- Remote Sites and Field Operations

In addition to these premium power applications for AC power, several potential DOD applications have been identified for the DC power generated by fuel cells. These applications include many electrotechnologies, such as electroplating, electrocoating, and other industrial processes found in many Army, Navy, Air Force, and Marine Corps maintenance and repair facilities.

Finally, potential alternative fuel sources that can be used to power a fuel cell have been identified. DOD facilities with sewage treatment plants and landfills can use the hydrogen-rich biogas recovered from these sources to generate electricity using fuel cell technology. Other means of generating a hydrogen-rich gas, such as industrial heat treatment processes could also be utilized.

While the focus of this study is on applications for fuel cell power, several thermal applications for the recovered heat are also available. In many applications, the thermal energy is used to heat water for space heating, domestic use, or even recreational use (e.g., swimming pools). Using the high-grade heat recovery option, it is also feasible to use the waste heat from a fuel cell to run an adsorption chiller or provide desiccant regeneration for humidity reduction systems. In applications in which the waste heat is not used, it is removed from the fuel cell via a separate cooling module.

DOD CLIMATE CHANGE FUEL CELL PROGRAM

The fuel cell program within the DOD has different features and criteria depending on the funding for a particular fiscal year. In the past, some sites received total funding for equipment and installation, while others received a portion of the total cost. Also, the agency that is responsible for administering the program varies from year to year. Specific details for the different fiscal years, past and present, are provided in Table 1.

Table 1. Past and Present Fuel Cell Program Characteristics

Fiscal Year	Program Management	Available Funding	No. of Fuel Cell Installations
1993/1994	USACERL[1]	$18,000,000 (FY93) $18,750,000 (FY94)	12 (FY93) 18 (FY94)
1995	DOE[2]	$8,200,000 (up to $1000/kW)	3 DOD 21 non-DOD 9 non-DOD foreign
1996/1997	DUSD-ES[3] (TACOM-ARDEC[4])	$10,400,000 (up to $1000/kW)	53 grants awarded
1998	DOE[2]	~ $5,000,000	TBD

1) U.S. Army Construction Engineering Research Laboratories
2) U.S. Department of Energy
3) Office of the Deputy Under Secretary of Defense for Environmental Security
4) Tank-Automotive and Armaments Command, Armament Research, Development, and Engineering Center

The current DOD Climate Change Fuel Cell Program objectives are to reduce greenhouse gas emissions through efficient use of fossil fuels, accelerate fuel cell commercialization for U.S.

manufacturers, and satisfy DOD goals for the environment, mission-readiness, and economy through activities that would stimulate end user applications. The current maximum amount of each grant is $1000/kW or one-third of the project cost, whichever is lower. DOD applicants are given preference over non-DOD sites. However, DOD installations must partner with a private entity, such as an energy services company, who will bear the remainder of the system costs. This last requirement supports the Defense Reform Initiative (DRI), which involves the privatization of utility systems infrastructure.

ECONOMIC ANALYSIS

The decision to purchase a fuel cell is based, in part, upon an economic analysis of a DOD facility's existing energy costs and the anticipated savings from operating a fuel cell. When evaluating fuel cell economics, one must consider the capital costs, operating and maintenance costs, and potential avoided costs from installing a reliable, on-site power plant. Compared to conventional on-site power generation and backup systems, such as diesel generators and battery systems, fuel cells typically have higher capital costs, but can have significantly lower operating and maintenance costs. In many applications, fuel cells are easier to install because of fewer permitting restrictions due to their low levels of noise, vibration, and emissions. In addition, generators and uninterruptible power supply systems only operate during a grid outage. A fuel cell power plant, however, is continuously available, producing power and thermal energy with significant cost savings.

A 20-year life-cycle cost (LCC) analysis of fuel cell technology was conducted to provide DOD decision makers with a reasonable estimate of the costs (and savings) involved with a fuel cell power plant installation. This analysis was calculated for various fuel cell power plant configurations (on-site, backup, uninterrupted, and remote power) using different combinations of natural gas and electric rates (or diesel rates for the remote power configuration) The results of the LCC analysis indicate that for all configurations, the use of a fuel cell results in a net savings in areas with high electric rates (>5.6 ¢/kWh). Even with a low electric rate (<5.6 ¢/kWh) and a low gas rate (<3.29 $/1000 ft^3) the uninterruptible fuel cell configuration results in a net savings.

Power quality problems lead to an increase in the overall cost of electric service, which is not always evident in the energy bills received from gas and electric utility. The impact of poor power quality varies depending on the application. Power outages, distortion, voltage spikes, and sags may result in a loss of data, product damage or loss, equipment damage, loss of productivity (downtime), and increased health and safety risks. These potentially avoided costs are typically difficult to quantify, but should be recognized when doing a complete economic analysis of a fuel cell installation.

In mission-critical applications, direct economic factors may have no bearing on the decision to pursue fuel cell technology. In these applications, the indirect benefits, such as higher quality, increased reliability, and reduced noise and emissions override all other considerations.

AIR EMISSION REDUCTIONS

As a non-combustion energy source, fuel cells reduce the amount of air pollutants attributed to electricity generation. Although the actual quantity and types of pollutants released depend largely on the type of fuel used – pure hydrogen fuel cells, for example, produce zero pollutants – fuel cells consistently emit pollutants at well below the levels emitted by conventional electricity generation technologies.

Emission savings for a natural gas supplied, 200-kW phosphoric acid fuel cell compared to average combustion source generation is provided in Table 2.

Table 2. Fuel Cell Emission Savings

Contaminant	Combustion Source[3] lb/yr	PC25™C Fuel Cell[4] lb/yr	Fuel Cell Emission Savings lb/yr
NO_x[1]	10,174.56	27.00	10,147.56
CO[1]	381.97	38.00	343.97
VOC[1]	57.13	7.00	50.13
SO_x[1]	19,609.67	0.00	19,609.67
PM10[1]	421.15	0.00	421.15
CO_2[2]	3,211,964.63	1,864,500.00	1,347,464.63

1) 1995 Statistical Abstracts of the United States
2) Energy Information Administration, Electric Power Annual Volume II, 1995
3) Source emissions at annual rate of 200kW, 1650 MWh/year, 94% availability
4) IFC documented test and evaluations

NO_x, SO_x, and CO_2 emission reductions equate to an emission savings of 5 tons, 10 tons, and 675 tons per year respectively.

The fuel cell thermal output may also have an effect on emission reductions. This will be the case if the thermal energy is used to offset the thermal energy produced by a combustion source or other electric source. One example of this is the replacement of an existing combustion boiler with the thermal output of a fuel cell. Maximum fuel cell emission savings are realized when electrical and heat outputs are both fully utilized to displace combustion power and heat sources. These savings can accumulate up to 10 tons of NO_x, 20 tons of SO_x, and over 1,000 tons of CO_2 emissions per year relative to combustion electric sources and coal fired thermal production.

These air emission reduction credits may be traded as a commodity on an open market in some states. Air emission trading is an innovative regulatory compliance concept. It is based on the notion that the most cost effective way to improve overall air quality is to create a mechanism that provides incentive for polluters to take advantage of the least expensive pollution reduction opportunities before embarking on more costly reduction options. Emission trading allows those who can cheaply reduce emissions to sell excess allowances to those that would find it difficult to achieve reductions. Thus, a certain level of pollution reductions can be achieved at less cost than if all sources had to make similar reductions.

NO_x and SO_x receive creditable, significant emission reductions if local emission reduction credit programs are available. These Discrete Emission Reductions (DER) or Emission Reduction Credits (ERC) and allowances will yield continuous environmental improvement and are being traded today in several areas. The typical value of common market NO_x credits is $1,000 to $2,000 per ton. SO_x allowances are presently traded at approximately $100 per ton.

Unfortunately, the economics of emission savings from a fuel cell is not as straight forward as is the energy savings. The emission programs throughout the U.S. have varying financial incentives on the saved emissions resulting from fuel cell use. Some state emission programs such as New Jersey, Michigan, and California are beginning to recognize the quantifiable, real emission savings achieved by using fuel cells. This emission savings is then projected to an emission trading program where financial credits may be obtained.

SUMMARY

Fuel cells offer premium power in high-impact applications and can successfully meet the high standards and critical power requirements of the DOD. In addition, fuel cells may play an important role in reducing air emissions from stationary power generation and thermal energy sources. Thus, the installation of fuel cells will assist DOD facilities in complying with Clean Air Act requirements while supporting DOD pollution prevention initiatives. Successful implementation of fuel cells in DOD applications will, in turn, further the development of this technology. This will result in reduced DOD energy costs and improved life-cycle cost savings.

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