ERDC/CERL TR-01-60

Construction Engineering Research Laboratory

US Army Corps of Engineers®
Engineer Research and Development Center

Site Evaluation for Application of Fuel Cell Technology

Edwards Air Force Base, CA

Michael J. Binder, Franklin H. Holcomb, and William R. Taylor

August 2001

Approved for public release; distribution is unlimited.

ERDC/CERL TR-01-60

Construction Engineering Research Laboratory

US Army Corps of Engineers®
Engineer Research and Development Center

Site Evaluation for Application of Fuel Cell Technology

Edwards Air Force Base, CA

Michael J. Binder, Franklin H. Holcomb, and William R. Taylor

August 2001

Foreword

In fiscal years 93 and 94, Congress provided funds for natural gas utilization equipment, part of which was specifically designated for procurement of natural gas fuel cells for power generation at military installations. The purchase, installation, and ongoing monitoring of 30 fuel cells provided by these appropriations has come to be known as the "DoD Fuel Cell Demonstration Program." Additional funding was provided by: the Office of the Deputy Under Secretary of Defense for Industrial Affairs & Installations, ODUSD (IA&I)/HE&E; the Strategic Environmental Research & Development Program (SERPD); the Assistant Chief of Staff for Installation management (ACSIM); the U.S. Army Center for Public Works (CPW); the Naval Facilities Engineering Service Center (NFESC); and Headquarters (HQ), Air Force Civil Engineering Support Agency (AFCESA).

This report documents work done at Edwards Air Force Base (AFB), CA. Special thanks is owed to the Edwards AFB point of contact (POC) Captain Tony Faaborg for providing investigators with access to needed information for this work. The work was performed by the Energy Branch (CF-E), of the Facilities Division (CF), Construction Engineering Research Laboratory (CERL). The CERL Principal Investigator was Michael J. Binder. Part of this work was performed by Science Applications International Corp. (SAIC), under Contract DACA88-94-D-0020, task orders 0002, 0006, 0007, 0010, and 0012. The technical editor was William J. Wolfe, Information Technology Laboratory. Larry M. Windingland is Chief, CEERD-CF-E, and L. Michael Golish is Chief, CEERD-CF. The Acting Director of CERL is Dr. Alan W. Moore.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL John Morris III, EN and the Director of ERDC is Dr. James R. Houston.

Contents

List of Tables and Figures

Tables

Figures

1 Introduction

Background

Fuel cells generate electricity through an electrochemical process that combines hydrogen and oxygen to generate direct current (DC) electricity. Fuel cells are an environmentally clean, quiet, and a highly efficient method for generating electricity and heat from natural gas and other fuels. Air emissions from fuel cells are so low that several Air Quality Management Districts in the United States have exempted fuel cells from requiring operating permits. Today's natural gas-fueled fuel cell power plants operate at electrical conversion efficiencies of 40 to 50 percent; these efficiencies are predicted to climb to 50 to 60 percent in the near future. In fact, if the heat from the fuel cell process is used in a cogeneration system, efficiencies can exceed 85 percent. By comparison, current conventional coal-based technologies operate at efficiencies of 33 to 35 percent.

Phosphoric Acid Fuel Cells (PAFCs) are in the initial stages of commercialization. While PAFCs are not now economically competitive with other more conventional energy production technologies, current cost projections predict that PAFC systems will become economically competitive within the next few years as market demand increases.

Fuel cell technology has been found suitable for a growing number of applications. The National Aeronautics and Space Administration (NASA) has used fuel cells for many years as the primary power source for space missions and currently uses fuel cells in the Space Shuttle program. Private corporations have recently been working on various approaches for developing fuel cells for stationary applications in the utility, industrial, and commercial markets. Researchers at the U.S. Army Engineer Research and Development Center (ERDC) Construction Engineering Research Laboratory (CERL) have actively participated in the development and application of advanced fuel cell technology since fiscal year 1993 (FY93), and have successfully executed several research and demonstration work units with a total funding of approximately $55M.

As of November 1997, 30 commercially available fuel cell power plants and their thermal interfaces have been installed at DoD locations, CERL managed 29 of these installations. As a consequence, the Department of Defense (DoD) is the owner of the largest fleet of fuel cells worldwide. CERL researchers have developed a methodology for selecting and evaluating application sites, have supervised the design and installation of fuel cells, and have actively monitored the operation and maintenance of fuel cells, and compiled "lessons learned" for feedback to manufacturers. This accumulated expertise and experience has enabled CERL to lead in the advancement of fuel cell technology through major efforts such as the DoD Fuel Cell Demonstration Program, the Climate Change Fuel Cell Program, research and development efforts aimed at fuel cell product improvement and cost reduction, and conferences and symposiums dedicated to the advancement of fuel cell technology and commercialization.

This report presents an overview of the information collected at Edwards Air Force Base (AFB), CA along with a conceptual fuel cell installation layout and description of potential benefits the technology can provide at that location. Similar summaries of the site evaluation surveys for the remaining 28 sites where CERL has managed and continues to monitor fuel cell installation and operation are available in the companion volumes to this report (see Table 1).

Objective

The objective of this work was to evaluate Edwards AFB as a potential location for a fuel cell application.

Approach

On 14 and 15 August 1996, CERL and Science Applications International Corp. (SAIC) representatives visited Edwards Air Force Base (the site) to investigate it as a potential location for a 200 kW fuel cell. This report presents an overview of information collected at the site along with a conceptual fuel cell installation layout and description of potential benefits. The Appendix to this report contains a copy of the site evaluation form filled out at the site.

Table 1. Companion ERDC/CERL site evaluation reports.

Location	Report No.
Pine Bluff Arsenal, AR	TR 00-15
Naval Oceanographic Office, John C. Stennis Space Center, MS	TR 01-3
Fort Bliss, TX	TR 01-13
Fort Huachuca, AZ	TR 01-14
Naval Air Station Fallon, NV	TR 01-15
Construction Battalion Center (CBC), Port Hueneme, CA	TR 01-16
Fort Eustis, VA	TR 01-17
Watervliet Arsenal, Albany, NY	TR 01-18
911th Airlift Wing, Pittsburgh, PA	TR 01-19
Westover Air Reserve Base (ARB), MA	TR 01-20
Naval Education Training Center, Newport, RI	TR 01-21
U.S. Naval Academy, Annapolis, MD	TR 01-22
Davis-Monthan AFB, AZ	TR 01-23
Picatinny Arsenal, NJ	TR 01-24
U.S. Military Academy, West Point, NY	TR 01-28
Barksdale Air Force Base (AFB), LA	TR 01-29
Naval Hospital, Naval Air Station Jacksonville, FL	TR 01-30
Nellis AFB, NV	TR 01-31
Naval Hospital, Marine Corps Air Ground Combat Center (MCAGCC), Twentynine Palms, CA	TR 01-32
National Defense Center for Environmental Excellence (NDCEE), Johnstown, PA	TR 01-33
934th Airlift Wing, Minneapolis, MN	TR 01-38
Laughlin AFB, TX	TR 01-41
Fort Richardson, AK	TR 01-42
Kirtland AFB, NM	TR 01-43
Subase New London, Groton, CT	TR 01-44
Little Rock AFB, AR	TR 01-47
U.S. Army Soldier Systems Center, Natick, MA	TR 01-49
Naval Hospital, Marine Corps Base Camp Pendleton, CA	TR 01-51
Edwards AFB, CA	TR 01-60

Units of Weight and Measure

U.S. standard units of measure are used throughout this report. A table of conversion factors for Standard International (SI) units is provided below.

1 ft	=	0.305 m
1 mile	=	1.61 km
1 acre	=	0.405 ha
1 gal	=	3.78 L
°F	=	°C (X 1.8) + 32

2 Site Description

Edwards AFB is located approximately 60 mi north of Los Angeles, CA. Edwards AFB is the site of the original space shuttle landings, and home to the Air Force Flight Test Center (AFFTC), whose mission is to provide premier air vehicle development, testing, and evaluation. Approximately 4500 personnel are assigned to AFFTC, and as many as 10,000 contractor who support the mission.

The ASHRAE design temperatures for the site are 101 and 22 °F. Extreme temperatures range from 20 to 120 °F.

Four potential applications were investigated for a 200 kW phosphoric acid fuel cell. These included a dining hall facility, a dormitory complex, an indoor swimming pool, and a hospital. Only the hospital emerged as a viable fuel cell application site. The other three potential applications were eliminated for reasons discussed in the "Fuel Cell Interfaces" section of this report (p 12).

The hospital is a 65,000 sq ft facility built in 1955. Additions were made to it in 1966. The hospital currently has 30 beds, an emergency room, and a number of clinic facilities. The average occupancy is about 10 beds per night. The hospital has a 500 kW backup generator and a 300 kW emergency generator. There are two steam boilers in the mechanical room that provide space heating, domestic hot water (DHW), and steam for sterilization. The building is cooled by two, 200-ton chillers.

Site Layout

Figure 1 shows the overall site map for Edwards AFB. The hospital is located in the lower left hand corner of the map (Building 5500). Figure 2 shows the site layout of the hospital. An adjacent building houses the pumps for the fire protection system. Behind this building is a fenced area that contains the two chillers and an electrical transformer. An asphalt driveway near this area provides access to the building mechanical room. Figure 3 gives a more detailed site layout of the mechanical room area.

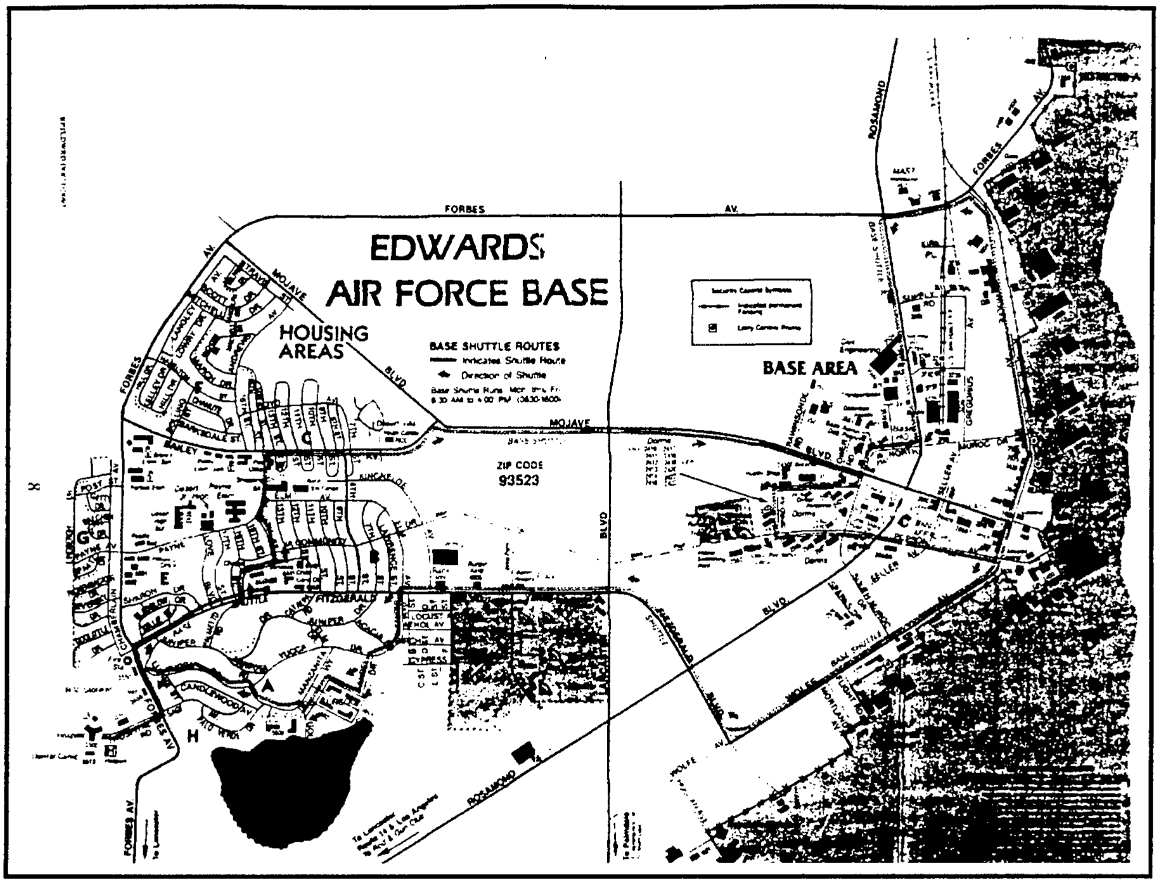

Figure 1. Edwards AFB site map.

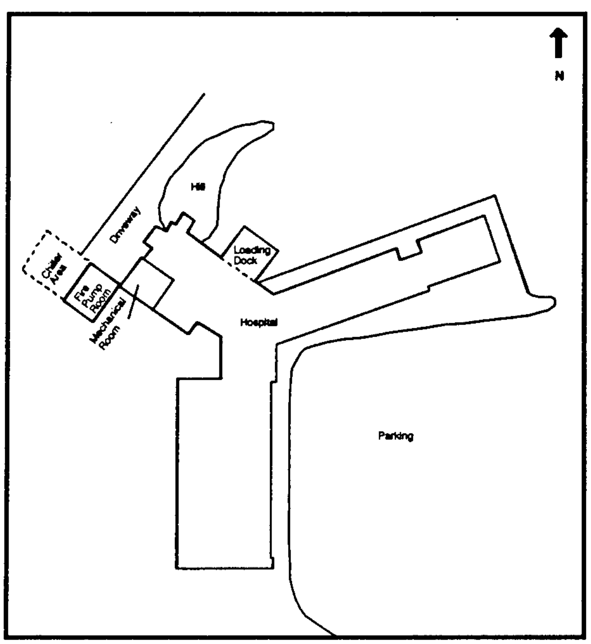

Figure 2. Hospital site layout, Edwards AFB.

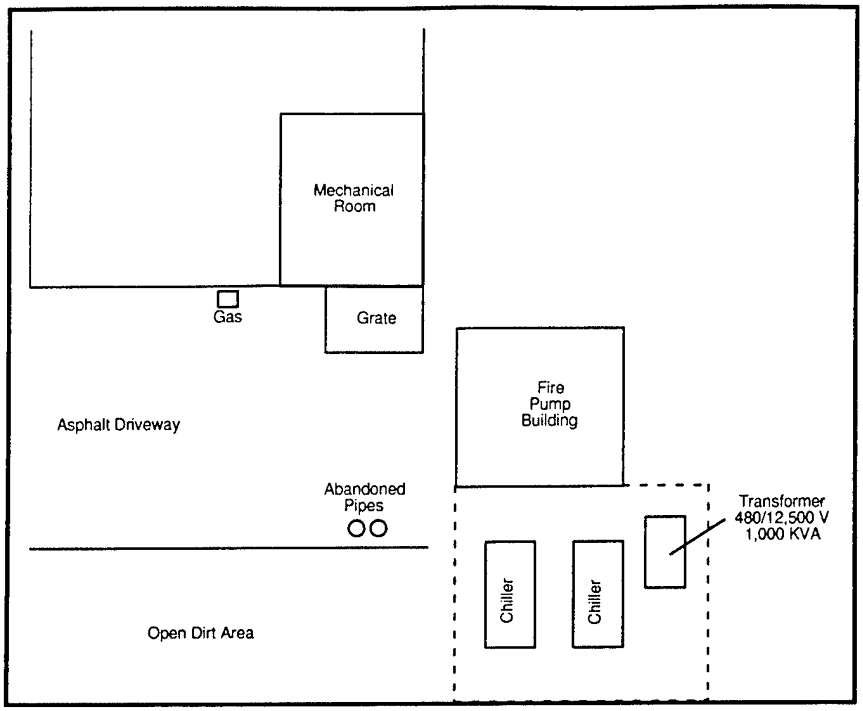

Figure 3. Hospital site layout detail of mechanical room area.

Electrical System

The Base distributes electric power at 12,500 V. The hospital has 208/12,500 V transformers. A 1000 kVA, 480/12,500 V transformer is also located inside the chiller fenced area.

Steam/Hot Water System

The hospital mechanical room has two, 4.184 MBtu (million BTU) per hour Cleaver Brooks natural gas driven boilers. The boilers supply two 950-gal storage tanks located inside the mechanical room, which are used for DHW. Figure 4 shows the mechanical room layout.

Space Heating System

The hospital boilers provide steam to two space heating heat exchanger loops. One heat exchanger is located in the fire protection system pump room and serves approximately three-quarters of the building. The other heat exchanger is located at the far wing of the building. Hot water is provided to the air handlers throughout the year to control temperature and humidity in the hospital.

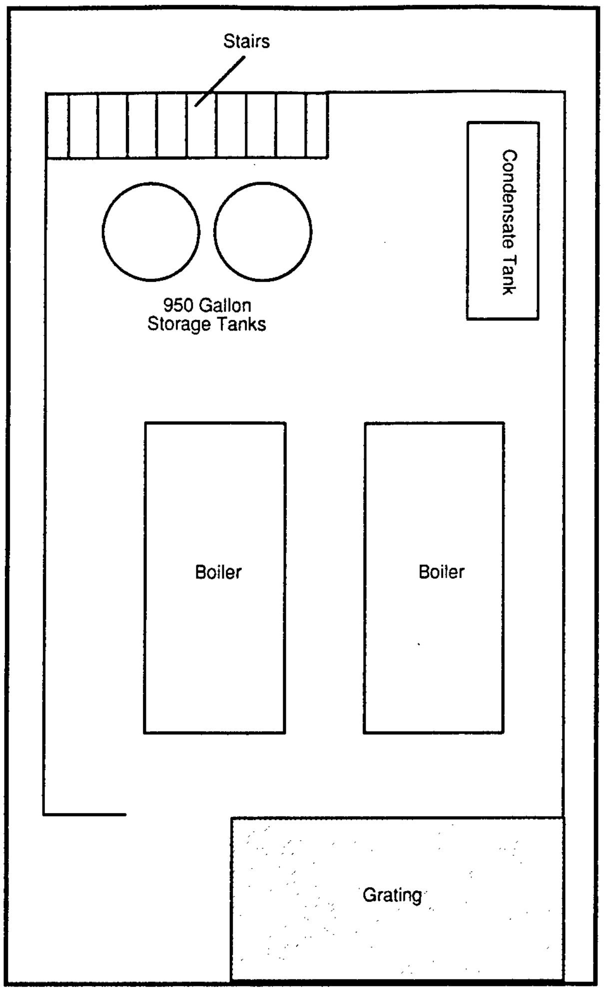

Figure 4. Hospital mechanical room layout.

Space Cooling System

Two 200-ton Carrier chillers are located at the hospital behind the fire protection system pump room. The chillers operate year round to provide space cooling and to control humidity inside the hospital building.

Fuel Cell Location

The fuel cell should be sited just outside the mechanical room across the driveway (Figure 5). The cooling module should be located in the existing dirt area next to the driveway. The nitrogen tanks should be located inside the fenced chiller area, as shown. The two abandoned pipes in the driveway area will need to be removed before siting the fuel cell.

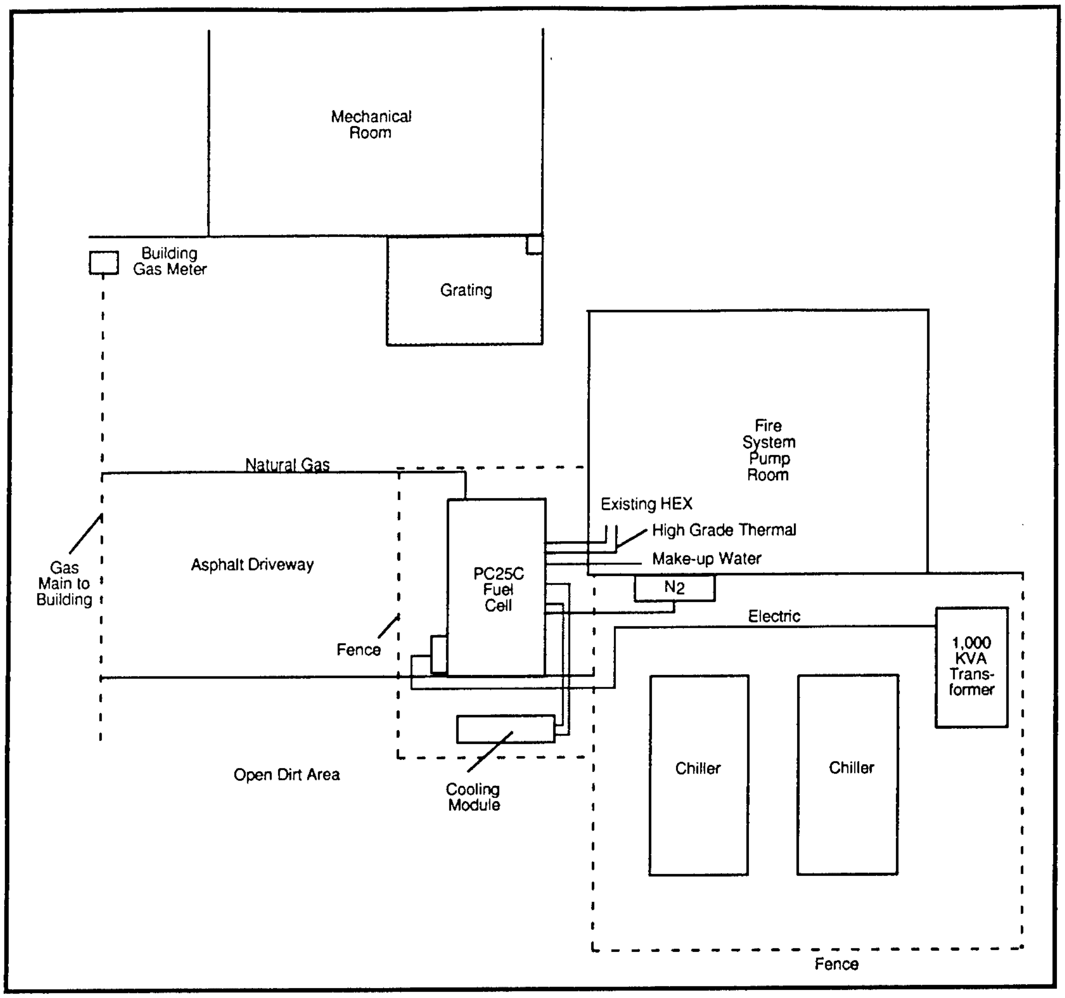

Figure 5. Fuel cell location and interfaces layout.

The thermal piping run to the space heating heat exchanger (from fuel cell high grade heat exchanger) will be approximately 15 ft into the pump room. Natural gas should be tee'd off the main gas line that goes to the building gas meter (about 40 ft). The make-up water can be taken from inside the pump room building (15 ft). The electrical run will be approximately 60 ft over to the chiller electrical transformer. The cooling module piping run will be about 20 ft. The nitrogen piping run will be approximately 15 ft. A security fence is required.

Fuel Cell Interfaces

Four fuel cell applications were considered at this site: the dining hall, a dormitory complex, an indoor swimming pool, and a hospital. The hospital was selected as the recommended application. The others were rejected for the reasons discussed below.

The dining hall serves about 1000 meals/day. This equates to an average domestic hot water (DHW) thermal load of 92 kBtu/hr:

92 kBtu/hr = 1000 meals/day x 2.4 gal/meal x 8.35 lb/gal x (180° - 70°) x
(0.001 kBtu/lb-F°) / 24 hrs/day

The thermal utilization at the dining hall would only be about 13 percent (92 kBtu / 700 kBtu). Space was limited and a new transformer as well as a high grade heat exchanger would be required.

The dormitory complex was made up of five separate buildings, each with its own DHW heater. The largest of these buildings had 60 rooms. These buildings have an average DHW load of 19 kBtu/hr:

19 kBtu/hr = 60 people x 13.1 gal/person x 8.35 lb/gal x (140°-70°) x 0.001 kBtu/lb-F°
/ 24 hrs/day

This equates to a thermal utilization of only 3 percent (19 kBtu / 700 kBtu) for the dormitories. The physical layout of the buildings also made it impractical to interface with multiple buildings.

The swimming pool had a somewhat higher thermal load. It was assumed that the pool heating load was for evaporative loss only, since the air temperature was above the water temperature for most of the year. Assuming an average of 70 percent relative humidity at 80 °F air temperature, the heat required to make up for the evaporative loss was about 152 kBtu/hr. The evaporative loss was calculated using the ASHRAE method shown below.

Water Evaporation = 0.1 x pool surface area x
(vap. pressure H_2O - vap. pressure air) **Eq 1**

152 lb/hr = 0.1 x 4921 sq ft x (1.032 in. Hg - 0.7224 in. Hg)

Heat Loss = water loss, lb/hr x 1 kBtu/lb **Eq 2**

152 kBtu/hr = 152 lb/hr x 1 kBtu/lb

The DHW load for the showers in the pool building was 28 kBtu/hr:

28 kBtu/hr = 100 showers/day x 20 gal/shower x 8.35 lb/gal x (110°-70°) x
0.001 kBtu/lb-°F / 24 hrs/day

The thermal utilization for both the showers and pool losses would be about 26 percent (180 kBtu / 700 kBtu). The electrical interface at the pool was on the opposite side of the building and would require a new transformer.

After evaluating all of the sites, the hospital was the recommended fuel cell application. The location, aesthetics, and interfaces were better than the other sites with the fuel cell thermal utilization approximately the same as at the pool.

The hospital uses 480V power for the chillers. The chillers are fed by a 480/12,500V, 1000 kVA transformer. The fuel cell electric output should be connected to the 480V side of the transformer. If the hospital chiller electric load drops below 200 kW, the excess fuel cell power would feed back through the transformer into the base grid. Base personnel expressed an interest in using the fuel cell's grid independent output to power one chiller during grid outages. Based on the chiller manufacturer's specification, one chiller draws 264 kW when operating at 115 °F ambient temperature and 225 kW when operating at 85 °F ambient temperature. This load is clearly above the 200 kW fuel cell electrical output capability and precludes using the fuel cell grid-independent output for the chillers.

The hospital has two steam boilers that provide heat for generating DHW, space heat, and steam for sterilization. The hospital is billed for gas use at the estimated (by the base) rate of 250,000 cu ft/month. Base personnel estimated that about 5 percent of the steam was used for sterilization, about 10 percent for DHW, and about 85 percent for space conditioning (space heating and air-conditioning [A/C] reheat). Hot water for space conditioning is provided by two heat exchangers.

The recommended thermal interface for the fuel cell is to use the high grade heat exchanger to heat water for space conditioning. Space heating is used year-round and is by far the largest thermal load at the hospital. Figure 6 shows this interface. It is recommended that the fuel cell's high grade heat be used to heat hot water for one of the spacing conditioning loops (located in the fire protection system pump room), which supplies about 75 percent of the hospital.

The fuel cell thermal use was estimated from the hospital gas consumption. The total hospital thermal load is 250 kBtu/hr:

250 kBtu/hr = (250,000 cu ft/mo x 1.03 kBtu/cu ft x 0.70 boiler eff.) / 720 hr/month.

The fuel cell load would be 159 kBtu/hr:

159 kBtu/hr = 250 kBtu/hr x 85% heating x 75% load.

This equates to a fuel cell thermal utilization of about 23 percent (159 kBtu/hr / 700 kBtu/hr). Annually the fuel cell would provide 1393 MBtu:

1393 MBtu = 159 kBtu/hr x 8760 hr/yr / 1000 kBtu/MBtu

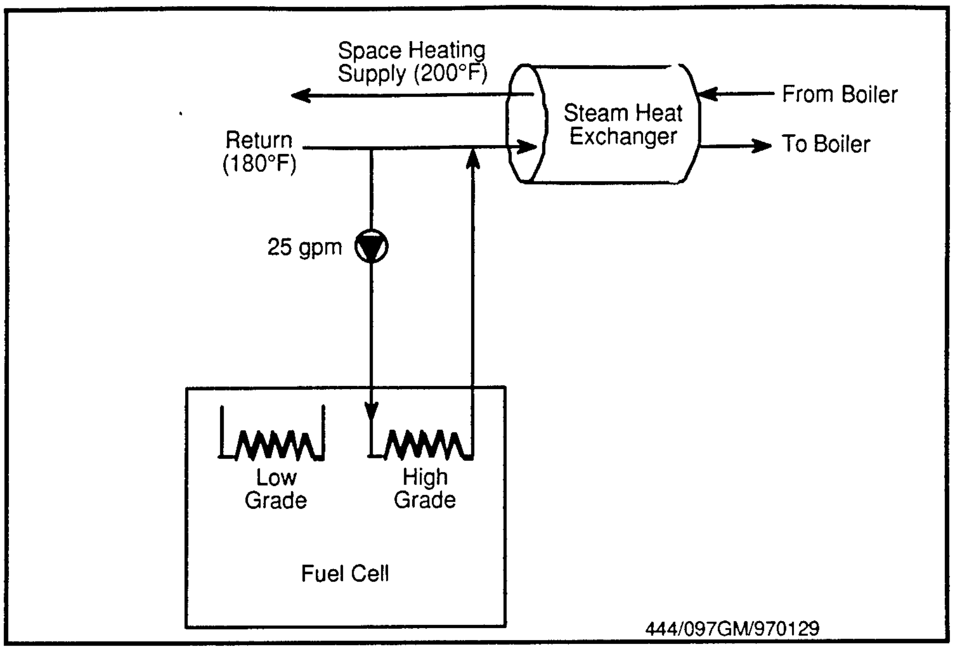

Figure 6. Fuel cell thermal interface, Edwards AFB.

Table 2. TOU-8, time-of use rate schedule.

	June-Sept.	Oct.-May
Demand ($/kW)		
Non-time related	$ 3.40	$ 3.40
On-Peak Period	$17.10	—
Mid-Peak Period	$ 2.55	—
Energy ($/kWh)		
On-Peak Period	$0.14558	—
Mid-Peak Period	$0.06909	$0.08147
Off-Peak Period	$0.04329	$0.04603

Economic Analysis

Edwards AFB purchases electricity from Southern California Edison under rate schedule TOU-8. Table 2 shows TOU-8, the time-of-use rate schedule.

The on-peak period is weekdays between 1200 and 1800 hours, June–September (summer). The mid-peak period occurs on weekdays between 0800 and 1200, and 1800-2300 hours in the summer, and weekdays between 0800 and 2100 hours during the winter period. The off-peak period is all remaining hours in the year, including holidays. Table 3 lists total electricity consumption and costs for Edwards AFB from October 1994 to September 1995.

Table 3. Edwards AFB electricity consumption and costs.

Date	WAPA KWH	SCE KWH	Total KWH	Total Cost	$/KWH
Oct-94	5,115,000	14,168,042	19,283,042	$1,041,373	$0.0540
Nov-94	5,115,000	11,036,900	16,151,900	$882,190	$0.0546
Dec-94	5,115,000	15,030,600	20,145,600	$885,810	$0.0440
Jan-95	5,115,000	13,176,606	18,291,606	$844,972	$0.0462
Feb-95	4,618,890	12,572,910	17,191,800	$807,130	$0.0469
Mar-95	9,123,000	8,173,800	17,296,800	$598,189	$0.0346
Apr-95	8,809,000	9,017,705	17,826,705	$500,241	$0.0281
May-95	9,123,000	8,310,600	17,433,600	$604,802	$0.0347
Jun-95	8,809,000	9,325,400	18,134,400	$973,438	$0.0537
Jul-95	9,123,000	12,397,200	21,520,200	$1,162,562	$0.0540
Aug-95	9,123,000	11,404,459	20,527,459	$1,089,119	$0.0531
Sep-95	8,808,685	11,219,300	20,027,985	$1,273,120	$0.0636
Tot/Avg	**87,997,575**	**135,833,522**	**223,831,097**	**$10,662,946**	**$0.0476**

Edwards also receives electricity from the Western Area Power Administration (WAPA) for a certain percentage of its total electricity. The site currently pays $0.01625/kWh for WAPA electricity. Because WAPA electricity does not represent the entire electricity bill and installation of the fuel cell would not impact the allocation of WAPA electricity, the fuel cell would be displacing electricity from the TOU-8 rate schedule.

Natural gas is purchased from the Defense Fuel Supply Center (DFSC) and transported by Pacific Gas & Electric (PG&E). Table 4 lists DFSC natural gas consumption and costs for Edwards AFB for the Oct-94 to Sep-95 time period. The average rate paid by the site was $1.46/MBtu for this period. Table 5 lists the PG&E transportation costs for this period. The average transportation rate paid was 5.13 cents/therm, or $0.513/MBtu. Total gas costs (fuel plus transportation) for this period averaged $1.97/MBtu.

Electric savings from the fuel cell were calculated based on the fuel cell operating 90 percent of the year (1,576,800 kWh). Demand savings were calculated assuming that the energy bill for the site would be reduced for the full 200 kW each month. Table 6 lists the full estimated demand savings and 90 percent capacity factor savings.

The fuel cell was previously estimated to displace 1393 MBtu/yr. Assuming a displaced boiler efficiency of 70 percent and the fuel cell capacity factor of 90 percent, the fuel cell would displace 1791 MBtu of natural gas per year:

1791 MBtu = (1393 MBtu x 90%) / 70% boiler efficiency

At $1.97/MBtu, the fuel cell will displace $3528 in natural gas in a year.

$3528 = 1791 MBtu/yr x $1.97/MBtu

Table 4. Edwards AFB DFSC natural gas consumption and costs.

Date	MBTU	$/MBTU	Total
Oct-94	21,110	$1.35517	$28,608
Nov-94	67,514	$1.67068	$112,795
Dec-94	76,831	$1.78629	$137,242
Jan-95	74,236	$1.59175	$118,165
Feb-95	47,704	$1.22303	$58,344
Mar-95	51,215	$1.19165	$61,031
Apr-95	36,989	$1.17592	$43,496
May-95	23,271	$1.25906	$29,300
Jun-95	11,607	$1.28989	$14,971
Jul-95	6,472	$1.12651	$7,291
Aug-95	5,467	$1.26505	$6,916
Sep-95	5,292	$1.29910	$6,875
Tot/Avg	**427,708**	**$1.46**	**$625,033**

Table 5. Edwards AFB PG&E natural gas transportation costs.

Date	Therms	$/Therm	Trans. Cost	Cust. Charge	Total Bill
Oct-94	204,554	$0.04109	$8,405	$797	$9,202
Nov-94	654,209	$0.04725	$30,911	$1,141	$32,053
Dec-94	744,483	$0.04725	$35,177	$1,141	$36,318
Jan-95	719,345	$0.05654	$40,672	$1,202	$41,873
Feb-95	462,251	$0.05654	$26,136	$1,202	$27,337
Mar-95	496,273	$0.05654	$28,059	$1,202	$29,261
Apr-95	358,418	$0.05007	$17,946	$1,202	$19,148
May-95	225,495	$0.05007	$11,291	$1,202	$12,492
Jun-95	112,467	$0.05007	$5,631	$1,202	$6,833
Jul-95	62,715	$0.05007	$3,140	$1,202	$4,342
Aug-95	52,972	$0.05007	$2,652	$1,202	$3,854
Sep-95	51,279	$0.05007	$2,568	$1,202	$3,769
Tot/Avg	**4,144,461**	**$0.0513**	**$212,588**	**$13,895**	**$226,483**

Table 6. Estimated demand savings and 90-percent capacity factor savings.

Demand	KW	KW/Yr	Rate	Total
Non-Time (12 mos.)	200	2,400	$3.40	$8,160
On-Peak (4 mos.)	200	800	$17.10	$13,680
Mid-Peak (4 mos.)	200	800	$2.55	$2,040
Demand Savings:				*$23,880*
Energy	**Hrs/Yr**	**KWH/Yr***	**Rate**	**Total**
On-Peak (summer)	510	91,800	$0.14558	$13,364
Mid-Peak (summer)	765	137,700	$0.06909	$9,514
Off-Peak (summer)	1,629	293,220	$0.04329	$12,693
Mid-Peak (winter)	2,249	404,820	$0.08147	$32,981
Off-Peak (winter)	3,607	649,260	$0.04603	$29,885
Energy Savings				*$98,438*
Total Displaced Electricity Savings:				*$122,318*
* hr/yr x 200 kW x 90% capacity factor				

The fuel cell will consume 14,949 MBtu per year based on an electrical efficiency of 36 percent HHV (higher heating value). Input natural gas cost for the fuel cell would be $29,450 at $1.97/MBtu.

Total net savings for the fuel cell are summarized below and in Table 7. The net savings for the space conditioning thermal case (23 percent thermal utilization) would be $96,396. If all of the available fuel cell thermal could be utilized by the site then net savings would total $108,399. Should the fuel cell be down during the peak demand period in a month, no demand savings would be realized for that month. If only 50 percent fuel cell demand savings were realized, net savings would be $84,456. For zero demand savings, net energy savings would be $72,516.

The analysis is a general overview of the potential savings from the fuel cell. For the first 56 months, ONSI will be responsible for the fuel cell maintenance. Maintenance costs are not reflected in this analysis, but could represent a significant impact on net energy savings. Since detailed load energy profiles were not available, net energy savings could vary depending on actual thermal and electrical utilization.

Table 7. Economic savings of fuel cell installation.

Case	ECF	TU	Displaced kWh	Displaced Gas (MBtu)	Electrical Savings	Thermal Savings	Nat. Gas Cost	Net Savings
Full* Demand *Savings								
Max. Thermal Case	90%	100%	1,576,800	7,884	$122,318	$15,531	$29,450	$108,399
Base Case	90%	23%	1,576,800	1,791	$122,318	$3,528	$29,450	$96,396
50%* Demand *Savings								
Max. Thermal Case	90%	100%	1,576,800	7,884	$110,378	$15,531	$29,450	$96,459
Base Case	90%	23%	1,576,800	1,791	$110,378	$3,528	$29,450	$84,456
Zero *Demand Saving*								
Max. Thermal Case	90%	100%	1,576,800	7,884	$98,438	$15,531	$29,450	$84,519
Base Case	90%	23%	1,576,800	1,791	$98,438	$3,528	$29,450	$72,516

Assumptions*:*

Natural Gas Rate: $1.97/MBtu

Electricity Rate: TOU-8 See Text

Fuel Cell Thermal Output: 700,000 Btu/hr

Fuel Cell Electrical Efficiency (HHV): 36%

Seasonal Boiler Efficiency: 70%

ECF = Fuel cell electric capacity factor

TU = Thermal utilization

3 Conclusions and Recommendations

This study concludes that the hospital at Edwards AFB represents a good application for a 200 kW phosphoric acid fuel cell. It is recommended that the fuel cell be located in the driveway outside of the mechanical room. The fuel cell will need the high grade heat exchanger option for tying into the space heating loop, which is located in the fire protection system pump room. The low grade heat exchanger will not be used. The electrical output should be interfaced with the 1000 kVA transformer serving the chillers.

Annual net savings of $96,396 were estimated for the fuel cell. The site has requested a fence around the fuel cell, with the option open to build a wall at its own expense.

Appendix: Fuel Cell Site Evaluation Form

Site Name: **Edwards Air Force Base** Contacts: **Tony Faaborg**
Location: **Edwards Air Force Base, CA**

1. Electric Utility: **Southern California Edison** Rate Schedule: **TOU-8 w/WAPA Credit**

2. Gas Utility: **Pacific Gas & Electric** Rate Schedule: **Transportation (Gas purchased through DFSC) GIPBS**

3. Available Fuels: **Natural Gas, Fuel Oil, Propane**

4. Hours of Use and Percent Occupied: **Hospital operates 24 hrs/day**

Weekdays	5	Hrs	24
Saturday	1	Hrs	24
Sunday	1	Hrs	24

5. Outdoor Temperature Range:
   Design dry bulb temperatures: **22 to 101 °F**
   Extremes: **20 to 120 °F**

6. Environmental Issues: **No major issues. Base falls under Kern County Air Management District.**

7. Backup Power Need/Requirement: **Hospital has 500 kW and 300 kW generators**

8. Utility Interconnect/Power Quality Issues: **Aging distribution system contributes to periodic outages.**

9. On-site Personnel Capabilities: **Mechanical plant personnel.**

10. Access for Fuel Cell Installation: **Easy access from parking lot area.**

11. Daily Load Profile Availability: **No data available.**

12. Security: **Put in fence. The base may build a wall.**

Site Layout

Facility Type: **Hospital** Age: **41 years**

Construction: **Concrete & Steel**

Square Feet: **65,000 sq ft**

See Figures 2 & 3

Show:

- electrical/thermal/gas/water interfaces and length of runs
- drainage
- building/fuel cell site dimensions
- ground obstructions

Electrical System

Service Rating:

12.5 kV distribution system on base.
Hospital has mostly 208 V power.
A 480 V transformer (1000 kVA) sited in the existing chiller area.

Electrically Sensitive Equipment: **N/A.**

Largest Motors (hp, usage): **Chiller**

Grid Independent Operation?: **No**

Steam/Hot Water System

Description: **Two Cleaver Brooks steam boilers**

System Specifications: **4.184 MBtu/hr**

Fuel Type: **Natural Gas with fuel oil backup**

Max Fuel Rate: **4.184 MBtu/hr**

Storage Capacity/Type: **Two tanks at 950 gal each**

Interface Pipe Size/Description: **1.5 in.**

End Use Description/Profile: **Boilers provide space heat, DHW and Sterilization.**

Space Cooling System

Description: **Two, 200-ton Carrier chillers**

Air Conditioning Configuration:

Type: **Carrier**

Rating: **200 tons each**

Make/Model: **30GT-210–600 KA**

Seasonality Profile: **Chillers operate continuously throughout the year**

Space Heating System

Description: **Steam generated by Cleaver Brooks boilers. A steam to hot water heat exchanger used for space heating loop.**

Fuel: **Natural gas**

Rating:

Water supply Temp:

Water Return Temp:

Make/Model:

Thermal Storage (space?): **N/A**

Seasonality Profile: **Used continuously throughout the year to control humidity in hospital.**

CERL Distribution

Commander, Edwards AFB
    ATTN: CES/CEOEE (2)

Chief of Engineers
    ATTN: CEHEC-IM-LH (2)

Engineer Research and Development Center (Libraries)
    ATTN: ERDC, Vicksburg, MS
    ATTN: Cold Regions Research, Hanover, NH
    ATTN: Topographic Engineering Center, Alexandria, VA

Defense Tech Info Center 22304
    ATTN: DTIC-O

8
6/00

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE (DD-MM-YYYY) 08-2001

2. REPORT TYPE Final

3. DATES COVERED (From - To)

4. TITLE AND SUBTITLE
Site Evaluation for Application of Fuel Cell Technology:
Edwards Air Force Base, CA

5a. CONTRACT NUMBER
DACA 80-94-D-0020

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Michael J. Binder, Franklin H. Holcomb, and William R. Taylor

5d. PROJECT NUMBER
Reimbursable Order No.

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Research and Development Center (ERDC)
Construction Engineering Research Laboratory (CERL)
P.O. Box 9005
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
ERDC/CERL TR-01-60

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Edwards AFB
P.O. Box 9005
Edwards AFB, CA 93524-8500

10. SPONSOR/MONITOR'S ACRONYM(S)
95th CES/CEOEE

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

14. ABSTRACT

Fuel cells are an environmentally clean, quiet, and a highly efficient method for generating electricity and heat from natural gas and other fuels. Researchers at the U.S. Army Engineer Research and Development Center (ERDC), Construction Engineering Research Laboratory (CERL) have actively participated in the development and application of advanced fuel cell technology since fiscal year 1993 (FY93), and have selected and evaluated application sites, supervised the design and installation of fuel cells, actively monitored the operation and maintenance of fuel cells, and compiled "lessons learned" for feedback to manufacturers for 29 of 30 commercially available fuel cell power plants and their thermal interfaces installed at Department of Defense (DoD) locations.

This report presents an overview of the information collected at Edwards Air Force Base, CA, along with a conceptual fuel cell installation layout and description of potential benefits the technology can provide at that location. Similar summaries of the site evaluation surveys for the remaining sites where CERL has managed and continues to monitor fuel cell installation and operation are available in the companion volumes to this report.

15. SUBJECT TERMS
fuel cells
energy technology alternatives
energy conservation
Edwards AFB, CA

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
Unclassified	Unclassified	Unclassified	SAR	28	Michael J. Binder **19b. TELEPHONE NUMBER (include area code)** (217) 352-6511