Thirty-five Years of Renewable Energy Project Experience at Fort Huachuca, AZ

William J. Stein, CEM, CEP, CSDP, CMVP, CEA, REP, CDSM
Bruce R. Johnson

ABSTRACT

Fort Huachuca, Arizona, located 60 miles (96 km) southeast of Tucson, has had 35 years of experience with various renewable energy systems. This article discusses lessons learned from the successes and failures over the past 35 years, including: an indoor pool solar water heating system installed in 1980; a solar domestic hot water system installed in 1981; a grid connected photovoltaic (PV) system installed in 1982; transpired air solar collectors (Solarwalls™) installed in 2001; daylighting installed in 2001; a 10-kW wind turbine installed in 2002; a 1 MW wind turbine installed in September 2011; PV powered outdoor lighting installed in 1994; a prototype Dish/Stirling solar thermal electric generator installed in 1996; two 30-kW building integrated photovoltaic systems installed on new membrane roofs in January 2009; a 42.84 kW photovoltaic system that was moved from the Pentagon in June 2009 and was operational in early November 2009 on a truck shed roof at Fort Huachuca; and a utility owned 13.6 MW (AC) photovoltaic system installed in 2014. Also discussed is an experimental solar attic system that collects the hot air in an attic and uses a heat exchanger and tank to produce solar domestic hot water. This article discusses the design, installation, metering, operations, and maintenance of these systems, and also work in progress on the installation of commercial, off-the-shelf 3-kW Dish/Stirling solar thermal electric generators and solar thermal/natural gas-to-electric systems at a central plant. Discussions also include biogas (methane from a wastewater digester) and biomass (a wood chip boiler) recently installed at a central heating/cooling plant.

INTRODUCTION

Fort Huachuca, AZ, is a U.S. Army installation originally established in 1877 as a camp to conduct the Indian Wars in the Southwest and also the base camp for the founder of Tombstone, AZ, 20 (33 km) miles to the east of Fort Huachuca. It became a stationing and training ground for the "Buffalo Soldiers" of that era, and for training in WWI and WWII. Since 1954, it has been the location of the Army Electronic Proving Ground, and more recently, the home of the Network Enterprise Technology Command and the Army Intelligence Center and School. It also houses the Department of Defense Joint Operability Test Command and is 60 miles (97 km) southeast of Tucson and 6 miles (10 km) from the border with Mexico. Available renewable energy resources include solar at 80 percent availability, wind with some areas at class three, biomass from forestry debris for fire control and grassland restoration, biogas from a wastewater treatment plant, and evidence of geothermal energy in the East Range area and in the mountains. The fort is part of the city of Sierra Vista and has a topography that rises from an elevation of 3,400 feet (1,037 m) just west of the San Pedro River to an elevation of 8,400 feet (2,561 m) in the Huachuca Mountains. The main building area is at an elevation of 4,700-5,100 feet (1,433-1,555 m).

Experience with renewable energy systems started in the late 1970s with two solar systems. The first was a parabolic trough solar system at the South Central Plant that was used for heating and cooling a single building. This system used a single-stage absorption chiller for cooling.

The system was eventually removed. The second system was a solar domestic hot water system with two panels and a solar tank. Located on a fire station, it was abandoned when the station was moved to another building. In 1996 the system was moved to another building on Fort Huachuca and is still operational. This article discusses each system type from start to the present and includes ongoing and future plans for various renewable energy systems.

SOLAR HEATING FOR AN INDOOR POOL

Indoor pool solar heating project parameters are:

- Year Installed: 1980
- Collector Area: 2,000 sq ft (185.8 m^2) unglazed with copper waterways

- Cost: $53,000
- Cost/sq ft: $26.50 ($285/m^2)
- First Year Energy Savings: 8,348 therms (880,761 Mjoule [834.8 million Btu] measured
- First Year Savings: $2,337 measured
- First Year Solar Fraction: 49 percent
- Simple Payback: 23 years
- Present Status: End of life with a repair project underway in 2015

Background

In the late 1970s the Army published a plan that called for one percent of its facilities' energy to come from solar energy. Bruce Johnson was a mechanical engineer in the design branch of the Facilities Engineering Directorate (now the Directorate of Public Works, or DPW) at Fort Huachuca. After the second round of oil price increases in the United States in 1979, Bruce became interested in installing solar systems at Fort Huachuca. He developed a design and economic analysis that convinced the director to approve the installation of a solar heating system for the Indoor Pool at Barnes Field House on Fort Huachuca (Figure 1).

Design Features

The 3,500 sq ft (325 m^2) pool heating energy was measured as part of the design process. It was noted that the pool heating energy closely tracked the outdoor air temperature during the winter. This was interesting, since the pool enclosure was heated to a constant temperature. Leaky sliding doors were causing cold air to layer across the pool surface greatly increasing the pool heat loss during winter storms. The doors were replaced to correct the air leakage. Innovative aspects of the design included: a failsafe collector drain back to the pool when solar energy is not being collected (to prevent freezing of the solar collectors); unglazed collectors (mild winter daytime temperatures are common

Figure 1. Solar Pool at Barnes Field House (1980).

at Fort Huachuca) with high flow to minimize collector heat loss (3-4°F [2-3°C] delta T across the collectors); and a stagnation sensor tuned to the characteristics of the solar collectors to sense when solar and outdoor air conditions were adequate to collect solar energy. The stagnation sensor consists of an enclosed box with a small black plate at the same angle as the collector field with field installed insulation behind the plate/sensor to tune it to the same characteristics as the unglazed collectors. Stagnation sensors sense the "no flow" condition of the collector field. Advantages of a stagnation sensor include stable operation of the field and optimization of the energy gathered. If a sensor were placed on the collector plate it would result in short cycling of the valve that directs pool water to the collector field when the cold pool water entered the collectors and cooled them. The system is activated if the stagnation sensor reaches set point and if the pool thermostat is calling for heating (no differential controller is used).

The system was installed in 1980. The system was ground mounted in two rows, facing true south with a 45 degree tilt. The latitude of Fort Huachuca is 31.6 degrees N, so the panels are 13.4 degrees plus latitude. The ten unglazed 3 x 10-ft (0.9 –3 m) panels were screwed to plywood which was connected to steel racks.

Field Verification of Energy Savings

Sophisticated monitoring of the solar contribution was not included in the project. Energy consumption of the pool was monitored with a natural gas meter connected to the pool heater. The solar system was deactivated for about a week per month and the results extrapolated to determine solar contribution and overall pool energy usage. The design assumed a pool blanket would be installed to minimize pool heat loss during unoccupied periods. The annual pool heat loss was estimated to be 8,500 therms (896,798 Mjoule) with a pool blanket. The solar system was designed to save 75 percent of this value, or 6,407 therms. The pool blanket was not installed and the solar system actually saved 8,348 therms (880,761 Mjoule) measured, or 30 percent more than was forecasted.

SOLAR DOMESTIC HOT WATER

Parameters for the solar domestic hot water project are:

- Location: Barnes Field House
- Year Installed: 1981

- Collector Area: 900 sq ft (83.6 m^2) glazed collectors
- Cost: $82,000
- Cost/sq ft: $91/sq ft ($979/m^2)
- First Year Energy Savings: 5641 therms (595,157 Mjoule [564 million Btu]) based on design
- First Year Monetary Savings: $1,570 based on design
- Solar Fraction: 40 percent
- Simple Payback: 52 years
- Present Status: End of life with a repair project underway in 2015

Background

Following on the success of the solar pool system, the next project pursued by Bruce Johnson was a solar domestic hot water system at the same building, Barnes Field House.

Design Features

The load was measured for the domestic hot water system and it was adjusted to account for energy saving flow restricting shower heads to be installed as part of the project. A drain back type system was selected with captive water in the solar loop. A solar preheat tank with an in-tank heat exchanger were used. The heat exchanger was liberally sized to avoid operating the collectors warmer than necessary; domestic hot water is on the outside of the heat exchanger with the captive solar water loop on the inside. The heat exchanger material is copper to encourage a high rate of thermal expansion. The constant expansion and contraction of the heat exchanger tubes results in scale cracking off and falling to the bottom of the solar preheat tank where it does not impede heat transfer. The solar collectors are protected against freezing by several important features. The captive water is held in the solar collectors by the normal pump head. When the pump (controlled by a differential controller) is deactivated, the water drains to a drain back tank inside

Figure 2. Solar Domestic Hot Water System at Barnes Field House (1981).

the mechanical room. The use of isolation valves is minimized to avoid accidental isolation of the collector field to minimize freeze potential. Note that, during normal operation, the captive solar loop forms a siphon after the air is vented from the collectors to minimize pump head during normal operation.

Also, should the heat exchanger leak, the drain back tank has an overflow line to a floor sink that will shunt any pressurized water entering the captive solar system to drain (to protect the collectors especially during a freezing condition). Air vents on the solar field are piped to the drain back tank via a sight glass so leaking air vents can be detected. The collector field is cantilevered off a wall to keep the collectors off of the roof to minimize roof penetrations. A pump without seals minimizes introduction of raw water into the captive solar loop.

Field Verification of Energy Savings and Maintenance History

In October 2001, Bill Stein worked with the Solar Thermal Design Assistance Center of Sandia National Laboratories to obtain a permanent British thermal unit (Btu) meter for the solar domestic hot water system at Barnes Field House. In the first year after the Btu meter was installed, the recorded solar output was 117 MBtu (123,441 Mjoule). The meter recorded a steady flow of 19.6 gallons per minute (74.2 l/m) to the collectors when in operation. Repairs were made to some leaks in the system, and a reading of 337,681Mjoule (320 MBtu) was taken on 28 August 2003, for an 11-month output of 214,176 Mjoule (203 MBtu). Data was collected manually, as there was no system in place to export the data from the meter in that building. A meter reading of 682,621 Mjoule (647 MBtu) was taken on 30 September 2005. That gives an output of 345,109.4 Mjoule (3,271 MBtu) for the two-year, one-month period. This indicates reduced output that was caused by a failed pump and the period of time to get it ordered and replaced, plus a few small leaks. A read of 741,704 Mjoule (703 MBtu) was taken on 6 April 06, giving a six-month output of 59,033 Mjoule (56 MBtu).

Before Bill Stein left as the Fort Huachuca Energy Coordinator in April 2008, he detected a problem with the system that appeared to be a bad temperature sensor in the collectors. Sam Montanez, the energy engineer, reported that the system had been non-operational since about June 2008, even though he had initiated a work order to repair the system. It was also observed in the mechanical room that houses the solar tank that there were new absorber plates for the glazed solar collectors. This information was passed on to the current Director of Public Works, John Ruble. Mr. Ruble committed to repairing this system. When Bill Stein took a reading of the Btu meter on 21 December 2009, it was reading 1,081,432 Mjoule (1,025 MBtu). It can be assumed that 339,728 Mjoule (322 MBtu) was produced from April 2006 to April 2008. While this system has been in operation, the pump was replaced three times and the differential controller once. A project was completed in the early 2000s to replace the air vents. It is now the end of economic life for the panels and the absorber plates need to be replaced. It is also time to repair the insulation on the solar tank and piping to and from the collectors.

The Barnes Field House solar domestic hot water system is at the end of its useful life (1981-2015) with extensive repairs required. The Directorate of Public Works (DPW) presently has a project underway to renovate the solar domestic hot water system. Many components are being replaced including: glazed solar panels; controls; drain back and solar preheat tanks; conventional domestic hot water tank; solar pump; Btu meter; thermal insulation; and miscellaneous piping components. The basic design will remain unchanged. The designer (Kelly, Wright & Associates, P.C., Tucson, Arizona) anticipates the upgraded solar system will provide about 2,832 therms or 49% of the annual domestic hot water (5,000 gallons of hot water are used per day). The project has been delayed due to the required removal and remediation of asbestos insulation on the existing piping and tanks.

In 1996, Bill Stein worked with Larry Lister from the U.S. Army Construction Engineering Research Laboratory (USACERL) to get a solar domestic hot water system installed on a barracks to test the use of a solar design specification that USACERL had developed for the Department of Defense. A design/build contract was signed with AAA Solar from Albuquerque, New Mexico. Due to space limitations in the mechanical room, a unique system was developed, designed and installed by AAA Solar. This system was installed in April 1996 and consisted of a ground mounted system with 12, 4 x 8-ft (1.2–2.4 m) glazed panels for a 384 sq ft (35.7 m^2) system at a cost of $35,000. That results in an average cost of $91sq ft ($980/m^2) of panel. The system also consisted of nine 80-gal solar water storage tanks and nine quad rod heat exchangers. The total storage capacity was 720 gal, for a ratio of 1.9 gal of storage per sq ft (20.2 gal/m^2) of collector area. This was higher than the typical 1.5 gal of storage per sq ft (16.1 gal/m^2) of collector area due to the high solar resource at Fort Huachuca. The storage tanks and heat exchangers were installed behind the panels in an insulated sheet metal siding enclosure. The 80-gal (303 L) tanks were installed horizontally. The system had a Data Industrial Btu meter installed on original construction. This system was read manually, and at the time the meter was replaced the system had produced 1,296,664 Mjoule (1,229 MBtu). The water lines to the building's mechanical room were installed underground, and there was a problem discovered with the original construction. The system had three subsystems, one in the front row with four panels and two in the back row with eight panels. It was discovered by the Fort Huachuca maintenance personnel that the front row was connected backwards with reverse flow to the panels. The system has a water and propylene glycol mix in the panels and all the tanks and heat exchangers are in the back row. This was not detected originally because of the underground connection (One lesson learned is to do a thorough check of the piping before burying the pipe).

SOLAR ATTIC (EXPERIMENTAL)

(Experimental) solar attic project parameters are:

- Year Installed: 2002
- Collector Area: 1,000 sq ft (92.9 m^2) unglazed roof
- Cost: $82,000
- Energy Savings to Date: 136 million Btu (143,487 million Joules)

Background

The solar attic was an experimental solar domestic hot water project that was first conceived by Dr. Dave Menicucci of Sandia National Laboratories and Bill Stein in the late 1990s when discussing the standard dark roof color for the barracks at Fort Huachuca and many other military installations. It was discovered that there was an air space of about 4-in. (10 cm) between the roof insulation and the structural B deck holding the standing seam metal roof. The concept was proposed that if the temperatures were high enough, air could be circulated under the hot metal deck and directed through a heat exchanger to make domestic hot water. Data were taken in the late 1990s with instrumentation from Sandia National Laboratories to verify stagnation temperatures of 185°F (85°C) in the summer and 140°F (60°C) in the winter. Eventually Army Headquarters (Army Chief of Staff for Installation Management) was convinced this concept would work, and in 2001 funding in the amount of $82,000 was provided by Army Headquarters to design and build this system.

Design Features

The system was designed by Bruce Johnson and installed in late 2002. At that time, no definitive design guidance was available for an unglazed air cooled solar collector. Extensive measurements of the roof temperature and entering and leaving air temperature across the "collector" with varying air flow rates were made. Analysis of the results led to the conclusion that the optimum airflow for this scenario was roughly two ft^3/minute (cfm, or 0.057 m^3/minute) per square foot (0.093 m^2) of roof collector. Since the "collector" parameters were unknown it was impossible to model the performance of the system. As more data are gathered it is hoped that ways to model this type of system will be developed and its viability for future installations determined. This system has 1,000 sq ft (92.9 m^2) of "collector," an air-to-water heat exchanger and fan, and an 1,100-gal (4,164 L) solar preheat tank. Ten gal/minute (37.8L) was selected as the water flow rate for the coil. The peak heat production was estimated as 79,129 joule/hr (75,000 Btu/hr). Peak collector efficiency was estimated at 25 to 30 percent based on data obtained from the original monitoring. The building domestic hot water load varied from 29,542 Mjoule/month (28 MBtu/month) to almost twice as much based on varying occupancy. An average of 10 gal/person (37.8L/person) was measured as the actual domestic hot water use. A complete weather station including solar insolation data gathering was provided in the design to facilitate modeling of this unusual solar application.

Energy Monitoring and Savings

The solar attic system was installed with a Btu meter and was to be monitored for performance. Due to the difficulty of connecting the data gathering system to the Fort Huachuca information systems network, no real time data was gathered. Bill Stein manually read of the system on 21 December 2009, and since the startup, the solar attic system produced 57.5 million Btu (60,679 million Joules). Another read on 27 July 2015 had a reading of 136 million Btu (143,746 million Joules).

A small, two-panel active solar domestic hot water system was installed on a fire station in the old post area in the late 1970s. That system used a glycol/water system and a heat exchanger. The system was not being used by the early 1990s because the fire station was converted to a military police desk and headquarters, so at the recommendation of a study done by the Solar Thermal Design Assistance Center of Sandia National Laboratories in 1994, the system was moved to the roof of the Joint Interoperability Test Command in 1996. The system was metered, but there is no available record of the output.

Passive solar hot water systems were installed in family housing units on Fort Huachuca. In 1997 Russell Hewitt of the National Renewable Energy Laboratory (NREL) funded a project to install six passive solar domestic hot water units on housing at Fort Huachuca and collect data for comparison. The units installed were different manufacturers' products for insulated collection tanks (40 gal) and progressive tube-type systems. Freeze protection was inherent in the mass of the water. While these systems worked well, the data was never collected and analyzed.

Another passive solar hot water system was developed in 2000 with funding from Sandia National Laboratories and the Salt River Project. This system was called Roof Integrated Thermosiphon Heat (RITH). The system was a passive solar hot water system designed with the collector on the roof surface and the tank slung under the collector as one unit. The system eventually gained Underwriters Laboratories (UL) and Florida Solar Energy Center (FSEC) certification, but was never made operable. The test system placed on a family housing unit at Fort Huachuca was installed improperly and failed. The contractors did not correctly install the integrated flashing on the panel and the plumber used water, then opened the bypass valve shutting off water flow to the system. The system froze in early winter.

In the past few years newer Solar Domestic Hot water systems have been installed on newly constructed buildings by both the Army and the Fort Huachuca Accommodation Schools (not Army owned). The new fire station on Fort Huachuca was built with a three panel system and was operational in May 2012. When Bill Stein read the meter on 24 July 2015 it showed the total production as 799 million Btu (942,909 million Joules). There were also new buildings built with solar domestic hot water systems at a new complex near the Black Tower on the West Range. These two buildings were maintenance and training buildings. The systems were improperly designed and had too many panels for the tank size. The overheating ruined the glycol/water mix and panels had to be removed from each system. The Fort Huachuca Accommodation Schools built a new Middle School and installed three solar domestic hot water systems on the school.

TRANSPIRED AIR SOLAR SYSTEMS

Bill Stein encouraged the Energy Savings Performance Contractor (ESPC) at Fort Huachuca to install renewable energy systems as part of each task order along with standard energy conservation measures. In 2001, as part of the third task order of the ESPC contract, Southwest HEC (now AMERESCO) installed two transpired air solar systems above the South facing hangar doors of Hangars #1 and #3 on Fort Huachuca. Each system (trade name Solarwall) was 2,300 sq ft (214 m^2) and used a 15,000 CFM (425 m^3/min) fan and sock duct to distribute the solar heated air. One unique feature was that the controller was also set to pull in outside cool air in the summer to pre-cool the hangars. The system used an Allerton Microview standalone microcomputer to control the fan operation. There are currently operational problems with the controller setpoints. The total cost for these two Solarwalls was $191,381, for an average of $41.60/sq ft ($447/m^2) of collector area. This system was constructed by Weatherguard of Sierra Vista. The estimated annual energy savings is 1,797,816 Mjoule (1,704 MBtu) of natural gas for both Solarwalls (combined) and the annual dollar savings is $9,006, for a simple payback period of 21.5 years. Current status is non-operational.

SOLAR AIR PANEL SYSTEMS

In Fiscal Year 2008 (FY08) the Army started a program called the Installation Technology Transition Program (ITTP). The goal of the program is to demonstrate newer off-the-shelf technologies, prove them at Army installations, and transfer them for use in the entire Army through standard specifications. One of the first ITTP projects was to install a solar air panel system at Fort Huachuca to preheat a generator oil sump for the emergency generator at Riley Barracks. This system was installed in July 2009 by American Solar and no data have been gathered on this system. Preliminary estimates show that this particular application may not be cost effective at Fort Huachuca because of the mild climate there. There is also a strong probability that it would be much more cost effective to use these air panel systems for heating and solar domestic hot water production at Fort Huachuca.

DAYLIGHTING

Daylighting was first installed on family housing projects at Fort Huachuca in 1997. The units used were 10 in. diameter units produced by Solatube. After remodeling or constructing over 1,000 new replacement housing units, there are about 3,500 of these daylighting units on Fort Huachuca. Each unit costs about $300 to install.

In 1998 the first commercial daylighting units were installed on Hangar #1 at Fort Huachuca as part of ESPC task order #1. Thirty, 5 x 6-ft (1.5 x 1.8 m) units were installed at a cost of about $50,000. A daylighting controller was installed and data was recorded before installation and for the first two years of operation to verify how long the lights stayed off. After two years the lights were kept off an average of 7.6 hours per day in the hangar due to the daylighting system. In 2001, as part of task order #3 of the ESPC contract, 450 daylighting units were installed in 22 buildings. That project cost $671,071 and saved $86,685 in annual electric costs (at an average rate of $0.07/kWh). That project was constructed by Natural Lighting Company, now called Daylight America.

PARABOLIC TROUGH SOLAR HEATING AND COOLING

As mentioned in the Introduction, this system was an early attempt (late 1970s) to use solar energy for heating and cooling for a single classroom building. It was located at the South Central Plant and was designed by a reputable engineering firm in Tucson. The system cost about $1.1M and was supposed to save $2,397 in electricity and $645 in natural gas during the first year. The simple payback for this system was more than 360 years, however, it was considered a demonstration project so economic payback was secondary to its experimental findings. It should be noted that the design firm forgot to consider the coefficient of performance of the absorption chiller when calculating the energy savings. Calculations for energy savings were performed manually. It is not surprising that analysis errors occurred. The primary reason for failure of the system were problems with an overly complex design (18 operating modes) and material failures of the absorber (differential expansion and contraction caused warping of the absorber tubes and breakage of the glass tube over the absorber). Bruce Johnson briefed the Vice Chief of Staff of the Army when he visited the central plant solar system and its shortcomings were presented and simpler solar energy systems were emphasized.

GRID CONNECTED PHOTOVOLTAIC SYSTEMS

The first grid connected photovoltaic system installed on Fort Huachuca was funded by the Federal Photovoltaic Utilization Program (FPUP) and was operational in September 1982. This system was also the first grid connected system in the Army. The system was designed by a professor from Arizona State University and was installed under contract to USACERL by Monegan, Ltd, of Gaithersburg, Maryland. The system consisted of 196 Solarex Corporation Model 5300EG photovoltaic (PV) panels at a fixed tilt of 30 degrees from horizontal for a total system peak of 6.2 kW. The array was installed on the roof of the Holman Guest House with the grid tied inverter in an enclosure on the west side of the building. A meter was installed to measure the output of the system. The inverter was a Windworks Gemini three phase inverter.

The system worked well for two years, and it was during this time that Roch Ducey began working for USACERL. One of his first jobs in 1983 was to monitor the system and record performance data. After the first two years the system began to trip off line. The repair of the system was not prioritized, and during this time, the facilities maintenance was subcontracted with no specific instructions for the contractor to maintain this system. The system had been non-operational for nine years when the Photovoltaic Design Assistance Center (PVDAC) from Sandia National Laboratories was funded to do a study of the system and present options. Jerry Ginn from the PVDAC identified a defective bridge circuit in the inverter, confirmed that the array was in good condition, and found that a contactor in the ground fault circuitry was not capable of interrupting the array's short circuit current. Options were to repair the inverter, replace the inverter with a new single phase inverter or decommission the system and use the panels in standalone systems elsewhere on Fort Huachuca. Current voltage (I-V) curves were recorded for the 14 strings of panels, and there was evidence of a few bad panels. One panel was removed and taken to Sandia National Laboratories Photovoltaic Evaluation Laboratory for testing. The panel was tested at standard test conditions (25°C) and Typical Operating Conditions

(50°C) and was found to produce 24.9W at 50°C. The original manufactures rating was 31.5W at 25°C which equates to 29W at 50°C. All ratings are at one sun, or 1,000W/m^2.

In December 1994, it was decided to repair the system and a work order was initiated by Bill Stein to repair failed components. Replacement parts for the inverter were available from Omnion, so after isolating the bad panels into an unused string and repairing the inverter and the contactor, the system was again operational on 5 July 1995. By 19 July 1995 the PV meter was reading 757 kWh. On 21 December 2009 the meter was reading 57,049 kWh. The meter failed and was replaced on 27 October 2010. Since then the production to 30 June 2015 was 29,709 kWh.

In 2001 funding was received to replace the inverter with an off-the-shelf 10 kW three-phase inverter from Omnion. In September 2010, the PV meter was connected to the automated meter reading system. Craig Hansen, the former Energy Technician at Fort Huachuca, had been working toward automating all of the metering since he started in November 1995. He has since retired, but the meters are now automatically read. The first grid connected PV system in the Army (now 33 years old) remains in operation.

The next grid connected PV system on Fort Huachuca was funded by the Environmental Protection Agency (EPA) Strategic Environmental Research and Development Program (SERDP) and the local utility. The original system cost was a total of $200K, with the EPA funding $140K and Tucson Electric Power (TEP) Company funding $60K. The system as designed was an 18 kW single phase system. The system was installed and operational in late January 1996. The system consisted of three arrays of 30 each 285W ASE Americas model GP-50-DG panels and three Omnion Power Engineering Series 2400 6 kW inverters. The site chosen was the Thrift Shop roof at the main gate of Fort Huachuca with the inverters installed on the north wall exterior and the meter on the east wall next to the building service. The panels were mounted directly to a shingled roof, with an orientation of 20 degrees east of south and a tilt of 16 degrees. The system was designed and installation supervised by Miles Russell of Ascension Technology. Bill Stein and Craig Hansen from Fort Huachuca coordinated the support agreement with Andy Myer of TEP. Since there is typically more than one sun of insolation at Fort Huachuca and there was almost 9 kW of panels for each 6 kW inverter, the average time between failures for an inverter was four months. In the first year the system output was about 33,000 kWh. Bill Stein reached an agreement with Andy Myer of TEP that if Fort Huachuca would get 10 more panels, TEP would buy and install two more 6 kW inverters and restring the array with 20 panels per inverter. Bill Stein was able to get 10 more identical panels for just shipping ($300) from Jack Nixon at Yuma Proving Ground, Arizona due to a stalled project. He also obtained another 29 from that same stalled project in the same shipment that was used for two other projects.

In July 1997, TEP installed the new balanced system, which now had 100 panels and five inverters for a 30 kW rating. Since the system was at a full summer tilt (latitude minus 15) and was only 4 in. above a shingle roof (where it got very hot), the system only averaged 50,000 kWh per year. The panels were not installed according to the manufacturer's recommendation on wooden sleepers, and over time, numerous leaks developed in the roof. In October 2008, the system was removed from the Thrift Shop. At that time, two of the five inverters had failed and it was discovered that the PV panel electrical connectors were defective. Funding was secured from the Army ITTP program to replace the defective connectors and relocate the system. At the time of this writing, the contract had been awarded to replace the defective electrical connectors on the PV panels. All the panels were tested in 2009 and only the good ones will get new connectors. Figure 3 shows 20 of the 100 panels on the thrift shop 30 kW PV system. This system was removed and the roof was repaired. The panels currently (as of August 2015) sit in storage.

Figure 3. 20 panels of 100 on the Thrift Shop 30 KW Photovoltaic System (1996).

The next two grid connected systems were the result of having the 29 panels from the prior project and funding from Roch Ducey to install more PV systems and repair the existing solar thermal systems. Bill Stein designed the new PV systems and chose west facing systems for reasons of economics. While a system using this orientation produces less kWh, the energy that is produced in the late afternoon is worth much more than the average due to peak demand charges. The two systems were installed by Chuck Marken from AAA Solar in December 1998. The larger system used 16 panels of the same model as the Thrift Shop (4.8 kW nominal) and used to a 5 kW Omnion inverter. The system was installed on the west side of Barnes Field House with the panels elevated on racks 10 ft (3 m) above the ground and at a 45 degree tilt. This maximizes the output at 4 p.m. on the 21st of June, typically the hottest time of the year at Fort Huachuca (thus the highest peak load). That system was operational in December 1998 and by February 2008 the system had produced 50,661 kWh. The inverter had a small problem that was repaired in 2005 and one of the panels had the glass break from compression. There was no space between panels on the racks, and the differential expansion of the steel racks and the aluminum framed panels caused the failure. That broken panel was replaced. The meter was replaced in December 2009. Since June 2015 the system has produced 34,740 kWh.

The other small system was half the size at eight panels (2.4 kW nominal) and was also connected to a 5 kW Omnion inverter. The system was installed on the west side of the main supply warehouse on racks 10 ft (3 m) above the loading dock. The panels faced 20 degrees south of west and were also at a 45 degree tilt. This maximizes the output in mid-afternoon. The system was operational in December 1998. By December 2009, the system had produced 30,856 kWh. The only maintenance problem was that the meter base was pulling out of the wall. That system was repaired with new panels, a new inverter and a new meter in 2015. The new system has produced 245 kWh (as of July 2015) since it was installed.

Figure 4. Grid connected photovoltaic system (4.8 kW at Barnes Field House) 1998.

The next two systems were conceived by Roch Ducey of USACERL and funded by the Army ITTP program. These were two building integrated photovoltaic (BIPV) systems. These systems were funded by the first year of the ITTP program in FY08 and included new membrane roofs and thermal welded flexible PV systems. These two identical 30 kW systems were designed and installed by Solar Integrated. The two buildings chosen were the furniture warehouse and the Military Intelligence Library. The total cost of the two systems was $650K and the preliminary calculations showed that the systems would produce from 91,830 kWh/year (BP website) to a maximum of 168,580 kWh/year. The high value appeared to be a calculation error resulting from using the wrong angle for the panels, and not accounting for dirt accumulation. The initial calculated payback period was about 25 years, with annual savings being $4.7K for energy, $11.4K for demand, and $10K for roof operations and maintenance savings. The systems were installed and operational in January 2009. On 21 December 2009, Bill Stein took a reading from each system, and the inverters (PV Powered Model PVP 30 kW) gave the following readings. The furniture warehouse had a reading of 37,138 kWh and the Military Intelligence (MI) Library had a reading of 39,951 kWh. It was also noted that a separate meter installed on the furniture warehouse showed only 21, 078 kWh. A check with the automated metering technician verified that the meter was installed on 21 May, 2009. Also, the inverter was tripped due to a ground fault on the Military Intelligence Library. The inverters were still under the one-year warranty, so it is anticipated that they will be repaired. The total for the two systems for a 49 week period was 77,089 kWh as compared with the projected 91,830 kWh. This is reasonable, considering the time periods the one system was inoperable due to inverter ground faults. The meter on the MI library was installed in March 2012. By 30 June 2015 it was reading 61,434 kWh. The monthly meter reads showed there were multiple times the system was offline for two to four months. The meter on the furnishings warehouse read 176, 874 kWh on 30 June 2015. The monthly readings showed this system was only offline for a total of about three months.

The next grid connected PV system is one that was originally at the Pentagon in Washington, D.C. The land space was needed, and two systems had to be relocated from the Pentagon. One was a 70 kW system and the other was a 26 kW system. After the Air Force decided not to take the systems, the Army was afforded the opportunity. Fort Huachuca volunteered to take the systems and using some of the ITTP funding and funding from the Pentagon, retrieved both systems in June 2009. The smaller system was first moved to Fort Huachuca, then to Fort Sill, Oklahoma in October 2009 for use in a micro-grid. The larger system was used for a 43 kW DC system installed on a truck shed roof. That system was installed by Systems Integration of Benson and Net Zero Solar of Tucson. The system was operational in November 2009. It used a new SATCON PVS 50 kW inverter. That inverter has the capability of exporting data directly to the internet. Dale Benth of Fort Huachuca showed Bill Stein the web site that monitored the system on 21 December 2009. The website showed a reading of 6,884 kWh at 1:20 p.m. Bill Stein went to the actual site and, at 1:46 p.m., the inverter showed 6,895 kWh. There is also a meter on this system, and it showed 7,050 kWh and a peak output of 35.5 kW. On 30 June 2015 the meter showed the system had produced 265,055 kWh. The panels are facing due south and are currently at a 15 degree tilt on adjustable racks. The original plan was to change the tilt angle on a seasonal or annual basis to verify the optimal configuration. Due to safety concerns and the cost of changing the rack angles, the system is in the original configuration. The reinstallation of the system cost $30K for the new inverter and $70K for the balance of the system (panels, racks, conduit, and wiring). There was no follow on funding from the ITTP program to publish the energy output and lessons learned from this system.

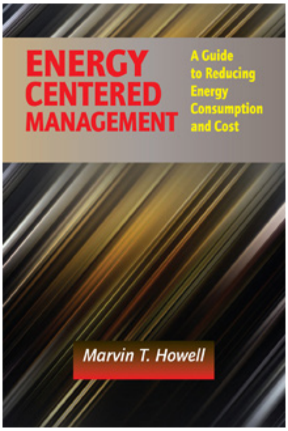
Starting in March 2013 there were 97 remote training area buildings that were outfitted with small grid connected photovoltaic systems that included a battery back-up which would island as a secure microgrid when the electric grid failed. By 30 June 2015 each system had produced an average of 2,800 kWh, with the larger systems producing over 6,000 kWh.

The Fort Huachuca Accommodation Schools (not Army owned) installed various photovoltaic systems under different programs starting in 2009. Under a program run by Sulphur Springs Valley Electric Cooperative (SSVEC) there were three identical 24.1 kW (DC) RV shed photovoltaic systems installed at the three schools in August 2009. Each system had an elevated structure with 104 each 60 cell SOLON photovoltaic panels. Each system used a 30 kW SATCON inverter. The total cost of each system was $240,607. The project was funded using Clean Renewable Energy Bonds (CREBS). It was paid for by the REST program funded by surcharges on SSVEC member's bills. There was a 15-year warranty on the SATCON inverters which is now worthless due to the bankruptcy of SATCON in October 2012. No SSVEC operating funds were involved. The output of each system feeds to the schools at no charge for the energy (kWh). By 30 June 2015 one of the

10% Online Discount
Use Code JR10

ENERGY CENTERED MANAGEMENT: A GUIDE TO REDUCING ENERGY CONSUMPTION AND COST

Marvin T. Howell



This practical, hands-on reference is designed to serve as a guide for any organization in planning, developing, and implementing an optimally effective energy cost reduction and management program. The information presented is intended, first, to facilitate the achievement of energy reduction deployment (ERD) which includes top management, all employees and onsite contractors. Although ERD, implemented by itself, can indeed render significant energy reductions, the book shows how to accomplish even greater savings by putting in place an energy centered management system (ECMS) which can identify and address additional critical sources of preventable energy waste. It also clarifies specific measures necessary to conform to the ISO 50001 energy management standard. The author has included a useful checklist, information on how to perform an internal audit or self-inspection, and tips on the best ways to create an overall energy awareness organizational culture.

ISBN: 0-88173-746-1

6 x 9, 262 pp., Illus., Hardcover

$115
Order Code 0707

CONTENTS

BOOK ORDER FORM

① Complete quantity and amount due for each book you wish to order:

Quantity	Book Title	Order Code	Price	Amount Due
	Energy Centered Mgmt: Guide to Reducing Energy Consumption and Cost	**0707**	**$115.00**	
			Applicable Discount	
			Georgia Residents add 6% Sales Tax	
			Shipping $10 first book $4 each additional book	**10.00**
			TOTAL	

② Indicate shipping address: CODE: Journal 2014

NAME (Please print) BUSINESS PHONE

SIGNATURE (Required to process order) EMAIL ADDRESS

COMPANY

STREET ADDRESS ONLY (No P.O. Box)

CITY, STATE, ZIP

MEMBER DISCOUNTS—A 15% discount is allowed to AEE members (discounts cannot be combined).

☐ **AEE Member (Member No.____________________)**

③ Select method of payment:

☐ **CHECK ENCLOSED**
☐ **CHARGE TO MY CREDIT CARD**
☐ *VISA* ☐ *MASTERCARD* ☐ *AMERICAN EXPRESS*

Make check payable in U.S. funds to:
AEE ENERGY BOOKS

CARD NO.

Expiration date *Signature*

④ Send your order to:
AEE BOOKS
P.O. Box 1026
Lilburn, GA 30048

INTERNET ORDERING
www.aeecenter.org/books
(use discount code)

TO ORDER BY PHONE
Use your credit card and call:
(770) 925-9558

TO ORDER BY FAX
Complete and Fax to:
(770) 381-9865

INTERNATIONAL ORDERS
Must be prepaid in U.S. dollars and must include an additional charge of $10.00 per book plus 15% for shipping and handling by surface mail.

10% Online Discount
Use Code JR10

ENERGY AND ANALYTICS: BIG DATA AND BUILDING TECHNOLOGY INTEGRATION

John J. "Jack" McGowan

The goal of this book is to provide an energy manager's master reference for learning how to leverage "big data" style analytics to manage and coordinate the key issues in both energy supply and demand for a facility—and thereby to offer a more holistic approach for optimizing energy-related facility performance. The author provides a detailed explanation of the underlying systems technologies which enable big data in buildings, and how these technologies can be utilized to provide added cost benefit from energy efficiency, onsite solar and electricity markets. The book was written to serve as a primer on building automation systems (BAS) standards, web services, and electricity markets and programs, providing a complete tutorial on energy analytics hardware, software and internet-enabled offerings which successful energy managers must understand today.

ISBN: 0-88173-744-5

6 x 9, 355 pp., Illus., Hardcover

$125
Order Code: 0709

BOOK ORDER FORM

① Complete quantity and amount due for each book you wish to order:

Quantity	Book Title	Order Code	Price	Amount Due
	Energy and Analytics: Big Data and Building Technology Integration	**0709**	**$125.00**	
			Applicable Discount	
			Georgia Residents add 6% Sales Tax	
			Shipping $10 first book $4 each additional book	**10.00**
			TOTAL	

② Indicate shipping address: CODE: Journal 2014

NAME (Please print) BUSINESS PHONE

SIGNATURE (Required to process order) EMAIL ADDRESS

COMPANY

STREET ADDRESS ONLY (No P.O. Box)

CITY, STATE, ZIP

MEMBER DISCOUNTS—A 15% discount is allowed to AEE members (discounts cannot be combined).

☐ **AEE Member (Member No.__________________)**

③ Select method of payment:

☐ **CHECK ENCLOSED**

☐ **CHARGE TO MY CREDIT CARD**

☐ *VISA* ☐ *MASTERCARD* ☐ *AMERICAN EXPRESS*

Make check payable in U.S. funds to:
AEE ENERGY BOOKS

CARD NO.

Expiration date *Signature*

④ Send your order to:
AEE BOOKS
P.O. Box 1026
Lilburn, GA 30048

INTERNET ORDERING
www.aeecenter.org/books
(use discount code)

TO ORDER BY PHONE
Use your credit card and call:
(770) 925-9558

TO ORDER BY FAX
Complete and Fax to:
(770) 381-9865

INTERNATIONAL ORDERS
Must be prepaid in U.S. dollars and must include an additional charge of $10.00 per book plus 15% for shipping and handling by surface mail.

systems had produced 209,644 kWh of energy at the Johnston elementary school.

Much larger photovoltaic systems were installed on carport structures at the new Colonel Smith Middle School (CSMS) along with a roof mounted system. There were also three roof mounted systems installed at the Colonel Johnston Elementary School. One of the larger carport mounted photovoltaic systems at CSMS has produced 939,180 kWh of electricity from November 2013 to June 2015. The two larger systems are at a 9 degree tilt with one facing 15 degree south of east and one facing 15 degrees west of south.

And last but not least is a first of its kind utility owned large scale photovoltaic system on an Army installation. This project was facilitated by the then Army Energy Initiatives Task Force (EITF), now the Army Office of Energy Initiatives (OEI) and a General Services Administration (GSA) area wide utility contract resulting in a nominal 20 Mega-Watt (MW) ground mounted photovoltaic system. The system is owned by Tucson Electric Power (TEP) Company. The construction contractor was EON. It was built in phases, with Phase I consisting of 17.3 MW of DC and 13.6 MW of AC inverters. The total site is 90 acres (36.4 ha). The first phase was started on 14 April 2014. Construction on Phase I was completed on 17 December 2014. As of 30 June 2015 the system had produced 15,451 MWh. There were 57,600 each 305 watt BYD panels and 16 each SMA 850 kW inverters.

Phase II construction started in September 2015. It will consist of 5 MW of DC BYD (46,729 each 107W First Solar modules) and 3.4 MW of AC (four each SMA 850 kW inverters). Phase II is scheduled for completion by April 2016. When Bill Stein asked at a meeting in early 2014 with Fort Huachuca and TEP the cost of the system, he was told that the Phase I system was $40 million with an additional $6 million for the two mile connection and substation upgrades.

Figure 5. Phase I of the 20 MW PV system on Fort Huachuca owned by Tucson Electric Power (TEP) looking West (2014).

NON-GRID CONNECTED PHOTOVOLTAIC SYSTEMS

The first non-grid connected PV systems were range weather-monitoring stations used in the late 1970s to present by the Meteorological team of the U.S. Army Electronic Proving Ground. The next documented use was for marquee signs used for information and advertisements in 1992. There were a total of six signs, one at the main gate and one at the east gate of Fort Huachuca. One of these signs was upgraded and moved in 2003, and the others were removed or grid connected. The next independent PV system was an entrance to a parking lot at the Non-Commissioned Officers Academy. It was a scientific engineering system with a panel, square box pole, battery box, controller, and a light at the top of the pole. It was installed in 1994. The next project used the same manufacturer and eight units were installed by Electrical Power and Control of Phoenix at a parking lot at Alchesay barracks. These units were installed in July 1995. The project cost was $32K, but this was less than excavating the existing paved parking lot and installing grid-connected parking lot lights. These units were replaced with four single unit and four double units from Solar Outdoor Lighting (SOL) in August 2009. There were two more units from that manufacturer installed in March 1996. The next round of grid independent PV systems were installed in 2004 at the Electronic Proving Ground main building parking lot. A substantial grid independent PV system was installed in 2005 at the golf course entrance. This system had four lights (two on each side of the road) that were connected underground with the panels and battery enclosure on the south side of the road. This system was installed by 1MD of Sierra Vista. Another non grid connected PV system was installed in the main Directorate of Public Works building in 2007. There were three PV powered attic fans. There is no battery storage with this system, but there is a thermostat to prevent the fans from operating with attic temperatures below 70°F (21°C) (to help trap winter heat gain).

DISH/STIRLING SOLAR THERMAL ELECTRIC GENERATOR

In 1995 Fort Huachuca was chosen as the one Department of Defense (DoD) site to receive a SERDP funded 7.5 kW Dish/Stirling Solar Thermal Electric Generator. Dave Menicucci, Rich Diver, Tim Moss, and Chuck Andraka from Sandia National Laboratories (SNL) managed this program for the DOD.

The original project cost was $900K. In January 1996, the system was operational and the Southwest Technical Development Institute (SWTDI) of New Mexico State University (Las Cruces) collected a year's worth of data. The unit was built and installed by Cummins Power Group (CPG). The unit was located in the compound of the Joint Interoperability Test Command (JITC) with the enthusiastic support of their operations officer, Bill DePew. As part of the project, an operator from JITC (Andrea Beaudet) was trained to operate and maintain the system. The original system had a free piston Stirling engine coupled to a linear generator with a sodium heat receiver. When CPG sold the technology to the Turkish government, U.S. Support for the system was lost. There was still funding left from the original amount, so SNL bought a new 10 kW two cylinder kinematic Stirling engine with a direct illumination receiver from SB&P in Germany. The unit at Fort Huachuca was adapted to receive this engine and the unit was operational by June 1999. The data and development of the system in the early 2000s was instrumental in the development of Dish/Stirling technology both at SNL and by a U.S. firm, Stirling Energy Systems. There was no funding in the DOD SERDP program for ongoing maintenance, so from June 2003 until October 2009 the unit was not operational. JITC finally decided it needed the land, so it paid Systems Integration $1 to remove the unit in November 2009.

WIND TURBINE

Wind power development started with data gathering in 1996. Roch Ducey funded a study to identify wind resources for three specific areas on Fort Huachuca. Due to limited funding, only one, 40m (131 ft) tower was used and two existing towers were used for the data gathering. The three sites were not favorable wind sites and one lesson learned was that the mesoscale model was very inaccurate in sky island topography. Later wind data was taken with a 40-m tower at a South Range, then moved to a West Range site funded by Tom Hansen of TEP. The data showed that both sites had a low class three wind, with the West Range being slightly better than the South Range site. Data showed a wind pattern that only varied 9 percent month to month (even year to year). In September 2001 Army Headquarters funded $72K to Fort Huachuca for the installation of a 10 kW Bergey Windpower Corporation (BWC) horizontal axis wind turbine. The turbine was installed by 1MD with a subcontract to BWC. It was installed on a 120 ft (36.4 m) tower. It was operational in February 2002. The site finally chosen turned out to be a poor wind site. The unit was installed at an elevation of 5,000 ft (1,524 m) so the power is de-rated by 20 percent due to air density. The highest power recorded at the electric meter was 8.88 kW. From the time the unit was installed until 21 December 2009 it produced 31,925 kWh. On 19 February 2003, the meter read 5,256 kWh. On 8 February 2005, the reading was 12,323 kWh, averaging 3,534 kWh in years two and three. In October 2003, the fiberglass spinner (nosecone) cracked and was replaced with an aluminum one. In June 2006, the Xantrex inverter failed and was returned for repair under the five-year warranty period. On 11 January 2007, the meter read 18,075 kWh. On 29 January 2008, the reading was 23,695 kWh, for a production of 5,620 kWh in year six. On 21 December 2009, the meter read 31,925 kWh for a production of 8,230 kWh for a 23-month period. The meter was replaced on the wind turbine in January 2012 with no read on the old meter. On 30 September 2014 it had produced 6,195 kWh. After that date the reading stayed the same due to an inverter failure.

Bill Stein pushed for a newer type wind system for inclusion in the fourth task order of the ESPC contract in January 2008. That task order with AMERESCO included a multiple vertical axis wind machine from Massmegawatts. The unit was designed at 90 kW and had canvas augmenters. The unit was constructed on the West Range, but there were safety issues with the actual construction, and the unit was removed in November 2009. While that unit was never functional, other vertical axis wind machines are commercially available.

In FY07, the Army funded an 850 kW commercial scale wind turbine under the Energy Conservation Investment Program (ECIP), managed by Ron Diehl of the Office of the Army Chief of Staff for Installation Management (OACSIM). That project was originally estimated at $1.15M, which would no longer purchase that size turbine. In FY08, the Army increased the funding to $3.1M and increased the turbine size to one megawatt (MW). A contract was awarded by the U.S. Army Corps of Engineers to install a one MW Nordic Windpower turbine on a 70 meter (231 ft) tower. Final contract cost was $3.3 M and the West range location was changed. The new location on the South Range was not an optimum location for the turbine. The turbine was installed and first operated in September 2011. Operation was intermittent due to issues with the remote monitoring of the system by Nordic and part failures. Nordic went bankrupt in October 2012. The final month of operation for the 1 MW wind turbine was February 2013. The last meter read was 4,663 with an 80 multiplier for a total production of 373,040 kWh. The wind turbine was used in a $1.05 million funded Army electronics and wind interaction study. Bill Stein called ETHOS Services, the company doing the operations and maintenance of all the other Nordic wind turbines in the USA, to obtain an estimate to repair the turbine. The cost was a low of $20K to a maximum of $160K. Due to the bankruptcy of Nordic, the Supervisory Control and Data Acquisition (SCADA) system lost permission to operate over the Army network.

The accommodation schools also installed three small wind turbines with the construction of the new Colonel Smith Middle School (CSMS) in 2012. These three turbines are mounted on 30-foot (27 m) American Resource & Energy (ARE) monopole towers. Two are Skystream 3.7s that had meter reads of 3,507 kWh and 3,136 kWh and an Urban Green Energy (UGE) Eddy that read 96 kWh on 3 August 2015. These systems were installed by Westwind Solar, who also installed some of the original photovoltaic systems. These systems are in the front (South) side of the school and are more for demonstration than for optimal production.

BIOMASS

In 2008, the Resource Efficiency Manager of Fort Huachuca, Wilson Prichett, started exploring biomass options as an alternative to the open burning of tree thinning debris for fire control. In preparation, a five acre site was used to stockpile the fuel. A project was funded in FY09 from funds received from the American Recovery and Reinvestment Act (ARRA) to install a wood chip boiler at the West Central Heating and Cooling Plant. One lesson learned from this process was that the boiler needed to be sized from the lesser of the required load and the available fuel. The system that will be installed will be a 50 Boiler Horsepower (BHP) ACT Bioenergy Model CP#1700 with fuel auger 1,794 Mjoule (1.7 MBtu) wood chip boiler. Installation was completed in February 2010. The system was tested and ran well, but there was an issue with the fuel chips size being too large coming from the wood chipper. The system also had issues with the storage hopper as it was not well designed to keep the rain off the fuel.

ORGANIC RANKIN CYCLE SOLAR THERMAL ELECTRIC

In late FY09 the Army decided to fund an ITTP project at Fort Huachuca to use an organic Rankin cycle generator designed to operate using hot water to generate electricity. The unit was to use a dual-fuel natural gas boiler and solar input. Fort Huachuca was chosen due to the excellent solar resources and available space in one of the central plants. Craig Hansen worked as project manager and the project budget was $745K. A contract was awarded to 1MD of Sierra Vista for $700K to install an ElectraTherm Green Machine with a 50 kW rating. The unit was installed at the South Central Plant in February 2010 and will use the space from the removed absorption chiller that was part of the failed solar heating and cooling system mentioned earlier. The system will use both an existing natural gas boiler along with new evacuated tubes solar thermal systems on the roof of the building for solar thermal input. The evacuated tube technology was chosen over the parabolic trough because of a lack of available land near the central plant and the desire to have no moving parts on the roof. Some of the existing piping and the original solar tank was to be used in this project. There were two issues that prevented operation of this system. The first was leaks in the piping or tank of the existing solar thermal storage system. The second was a hardware and safety issue in that the switch gear on the South Central Plant was not designed to safely flow power in both directions (to/from the plant). Bill Stein and Craig Hansen asked the ITTP board for funds to correct these issues but funds were unavailable. The system operated for four hours for commissioning but has not run since.

LONG-TERM FUTURE

Fort Huachuca is considering expanding the use of renewable energy through greater use of the aforementioned technologies. Alternative financing methods are being considered and the fort typically will volunteer to be a test site for new technology. The current focus is on a waste-to-energy (WTE) plant and additional photovoltaic parking shade structures.

CONCLUSION

Renewable energy systems that are low maintenance have the highest probability of staying operational after 20 years. Any organization must conduct due diligence before installing a renewable energy system. Funding is critical for both a good design and a successful installation. Operation and maintenance of the systems is critical to their success. Full organization support, including funding for maintenance and any data acquisition, is required for a successful renewable energy project. Training may be necessary and must be accomplished for the more complex renewable energy systems. If there are no on-site personnel qualified to maintain the more complex systems, you must get a warranty and long term maintenance contract.

Automated data gathering is extremely difficult to implement and maintain in the Army. Fort Huachuca is currently working on getting connectivity to the Army Meter Data Management System (MDMS) and permission to operate the existing Utility Monitoring and Control Systems (UMCS). With the high number of Army owned renewable systems that lack maintenance funding, the best course of action may be to privatize these systems then buy the energy back using the avoided utility costs.

RECOMMENDATIONS

When pursuing a renewable energy project, secure both organizational cooperation and funding sources to increase the opportunity for success. Find projects that are locally successful and imitate them. Adapt proven designs to your local climate and situation. As a general rule, focus on renewable energy systems that are simple and the most cost effective. Also consider using third-party financing for renewable energy systems and privatize the existing systems.

References

http://photovoltaics.sandia.gov/TecassforSolAmer Solarcities/Docs/new%20 docs/A%20Technical%20 and%20Economic%20Analysis%20of%20So lar%20Energy%20Projects%20At%20Fort%20Huachuca%20AZ.pdf

http://www.azsolarcenter.org/solar-in-arizona/virtual-tours-galleries/solar-and-wind-systems-in-sv-az.html

http://www.imcom.army.mil/hq/kd/cache/files/0D08EABE1E124899A38732834 7F05977.pdf pp. 24-25

http://www.p2pays.org/ref/19/18995.pdf, pg. 14
http://prod.sandia.gov/techlib/access-control.cgi/2000/001124.pdf slides 36-37
http://www.nrel.gov/data/pix/searchpix.php?getre c=05183&display_type=verbose
http://www.imcom.army.mil/hq/kd/cache/files/AD BAF0A0-423D-452D-48F5438F7876F5C0.pdf14

ABOUT THE AUTHORS

Bruce Johnson, PE, is a registered mechanical engineer with the State of Arizona. Bruce was employed by the Ft. Huachuca, Arizona Directorate of Public Works for 24 years where he developed several innovative solar thermal energy system designs. Bruce also provided facility engineering design expertise for a wide variety of HVAC, fire, fuel and energy systems. Bruce then transferred to U.S. Army Network Enterprise Technology Command (NETCOM) where he spent 22 years providing mechanical engineering expertise and troubleshooting for Theater Subcommands, various related military agencies, as well as communication sites across the world. Bruce is now retired and may be reached at bruce4795@gmail.com.

Bill Stein is a Research Mechanical Engineer for the U.S. Army Corps of Engineers Engineer Research and Development Center—Construction Engineering Research Laboratory. His focus is on application research of renewable energy systems in the Army. He has worked in the energy field since 1988 and has been a member of AEE since 1993. In 1993 he received an FY 1992 Individual Federal Energy Efficiency Award for his energy work at Dugway Proving Ground, Utah. In 2011 he did energy work at the Afghanistan National Security University near Kabul and in 2012 and 2013 for six months each time did energy work as the Operational Energy Manager at Bagram Airfield, Afghanistan. He developed the vulnerability and mitigation analysis for the recently awarded (10 September 2015) $200 million Power Delivery Power Purchase Agreement for the expansion of the electrical grid in Afghanistan.