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Working Towards Net Zero Energy at Fort Irwin, CA

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Final Report

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Abstract. This work conducted an Energy Assessment at Fort Irwin, CA, as a part of a Net-Zero initiative. The scope included an assessment of a "Cluster" of buildings with a focus on retrofits to minimize net energy use within the Cluster. The work additionally identified energy savings measures and wastes and inefficiencies on a limited basis for other areas of the installation. This report explores two strategies for evaluating energy-efficient technologies: (1) to install and evaluate several different energy efficient heating, ventilating, and air-conditioning (HVAC) system designs and renewable energy projects that may lead to the lowest lifecycle cost for a facility, and (2) to "cherry-pick" the least-first-cost options and install them at a complex, and then to evaluate their performance against each other. This work concluded that, depending on the type of HVAC system chosen for the Cluster, the savings potential (simple payback) of upgrading to a Net-Zero energy ready building (beyond the savings of a normal Army upgrade) varies from 2.8 to 13.8 yrs. This work also explored renewable energy opportunities as part of the Net-Zero concept. Results showed that energy use could be significantly reduced towards Net-Zero energy use with a payback of less than 15 yrs with the implementation and use of renewable energy technologies.

Executive Summary

This work conducted an energy assessment at Fort Irwin, CA as a part of a Net-Zero initiative. The scope of the assessment included an assessment of a "Cluster" of buildings with a focus on retrofits to minimize net energy use within the Cluster. During the assessment, this work also identified (on a limited basis) energy savings measures, and wastes and inefficiencies in other areas of the installation.

Barracks 261, 262, 264, 265 and 267 (i.e., "The Cluster") were selected for study to develop concepts for Net-Zero. These barracks are all of the same vintage and are nearly identical in structure; they differ only in minor details, such as the flow (cubic feet per minute [cfm]) of the respective makeup air units (MAUs). The Cluster includes Central Energy Plant 263 and Dining Facility 271. The Net-Zero energy study focuses on barracks Bldg 264, Central Plant 263, and the dining facility. The study results for Barracks Bldg 264 were multiplied five times to represent the five barracks buildings. Those amounts were then added to the results for the dining facility to represent the Cluster results. This work used the building energy use simulation computer program "*eQuest*" to predict the Cluster building energy use. Table ES1 lists the results for the current estimated energy.

Major (and relatively expensive) building changes are needed to prepare a building to be Net-Zero candidate. The Army has a large stock of existing buildings and is required to achieve the goals of U.S. Energy Independence and Security Act of 2007 (EISA) 2007 Section 433, which states that buildings must use no fossil fuel energy (Net-Zero) by 2030. This will require buildings to have an extremely low energy demand, and to be serviced by renewable energy sources. The only way to accomplish this goal is to initiate Net-Zero building improvements during major renovations or upgrades such as those that occur in the Barracks Upgrade Program (BUP).

Table ES1. Estimated energy use of current building in the Cluster.

Annual Energy Use	Barracks No. 264	Five Barracks	DFAC 271	Six Bldg Cluster
Total electrical, Kwh/yr	486,507	2,432,535	669,580	3,102,115
Total heat, million Btu/yr	1,293	6,467	2,726	9,193

Since these upgrades are ongoing, this study focuses on the costs and savings of initiating the Net-Zero building improvements that exceed those of a typical building upgrade. These improvements to a building will be collectively termed to provide a “Net-Zero energy ready” building. A building that has gone through the typical upgrade will be called an “upgraded building.” To establish the energy use performance of upgraded buildings a representative barracks building (Bldg 264) and the dining facility were modeled using *eQuest*. Table ES2 lists the results of this analysis. The costs to make these building changes were estimated. The upgrade of the five barracks and the dining facility was estimated at $29.4 million. The resulting energy savings range from $27,000 (for the typical upgrade) to $242,000 for the most energy efficient alternative investigated (from 1265 million KWh to 1424 million KWh electrical, and from 27,155 to 54,255 gal of liquid petroleum gas [LPG]).

The building improvements for the Net-Zero energy ready building included greater insulation in the walls and roof of the buildings, triple pane Low-E windows, greater building air tightness, high efficient lighting and domestic water systems, advanced control systems and energy star appliances and devices for use by the occupants. For all options, these building modifications were analyzed for application to a Net-Zero energy-ready building. The following four different heating, ventilating, and air-conditioning (HVAC) methods were developed for the barracks:

1. Dedicated outdoor air system (DOAS)-variable air volume (VAV), with direct evaporative cooling
2. DOAS with radiant heating and cooling, direct and indirect evaporative cooling
3. DOAS with fan coils, direct and indirect evaporative cooling
4. DOAS-VAV with direct and indirect evaporative cooling.
5. One HVAC solution was developed for the dining facility and one for the improvements made to the central heating/cooling plant that is part of the Cluster. The results of these improvements are combined into Cluster solutions as discussed below.

Table ES2. Estimated energy use of typical upgraded buildings in the Cluster.

Annual Energy Use	Barracks No. 264	Five Barracks	DFAC 271	Six Bldg Cluster	Typical Upgrade vs. Current Conditions Savings
Total electrical, Kwh/yr	446,965	2,234,825	669,580	2,904,405	6%
Total heat, million Btu/yr	1,207	6,033	2,726	8,759	5%

It was found that it is possible to reduce the energy consumed to heat, cool, and ventilate the barracks facilities by 44 to 49 percent of electrical use and 30 to 59 percent of heating use with paybacks of 2 to 10 yrs depending on the alternative chosen. In climates where mold is an issue, the avoided costs of mold mitigation can decrease the payback to 1.2 yrs. This can be done by using more efficient heating, cooling, and lighting systems. This is in line with real world projects that have exhibited savings in excess of 70 percent for similar HVAC retrofits, even without envelope modifications. In total, renewable energy generation of 4832 MMBtu/yr of thermal energy use and 41,630KWh of electrical use were identified within the Cluster. Because there are five barracks and the modeled savings vary significantly, five alternatives using various combinations of the four HVAC options along with envelope, Dining facility (DFAC), and chiller plant upgrades were analyzed. Table ES3 summarizes those five alternatives, which are more fully described in section 3.10 (p 52).

Significant renewable opportunities were also identified to supply much of the remaining energy requirements. A total of 11,000 tons/yr of biomass are generated at Fort Irwin. Since this biomass has energy value and must be disposed of in some way, it may potentially be used for heating (yielding LPG gas savings), and even for electrical generation.

Note that the levels of savings listed in Table ES3 may be achieved while simultaneously improving occupant comfort and substantially reducing the potential for biological (mold) growth in these facilities. In many climates, the costs to mitigate biological growth in barracks facilities can exceed the total annual energy costs of the facilities. This benefit alone could be the driving factor to use the proposed designs, even if there were no energy savings.

Table ES3. Modeled savings of five alternatives.

Alternative	Total Cost $ Millions	Incremental Cost $ Millions	% Electrical Savings	% LPG Savings	$K Savings /yr	Simple Payback (yrs)
Typical renovation	29.4	29.4	6%	5%	$27	1,089
1	31.7	2.4	48%	59%	$242	10.0
2	30.9	1.6	48%	58%	$240	6.7
3	30.7	1.3	49%	58%	$242	5.4
4	29.9	0.48	45%	30%	$171	2.8
5	30.7	1.4	44%	30%	$168	8.3

Since the proposed energy efficiency work includes the implementation of DOAS and high efficiency dehumidification systems that would dramatically reduce the potential for biological growth, the lifecycle cost of these systems is far lower than typical designs currently being designed and built. The cost savings associated with reducing biological growth problems is difficult to quantify, but in many climates, the costs and associated savings are not trivial; costs associated with biological growth remediation and manpower displacement and relocation can far exceed the energy costs for the life of the facility.

It is recommended that each facility be equipped with substantial metering and sub-metering capabilities to record energy use and to correlate energy use (or savings) with occupant comfort. The facilities should be modified to monitor the systems in detail, to perform monthly evaluations, to determine trends in energy use and savings, and to correlate this data with occupant-related issues (if any). Monthly reports and a year-end wrap-up could summarize objective, real world findings for the installation.

Outside the Cluster, considerable opportunities were also found. The following uses of waste were investigated:

- fermentation of green refuse
- waste pyrolysis in a rotating tube under pressure or fixed-bed reactor
- combustion of solid waste using a waste incinerator.

Fermentation was not found to be feasible due to the small amount of the waste stream that is fermentable. Waste pyrolysis and combustion of solid waste, however, did appear to be feasible. A Pyrolysis system designed to use the available waste stream could produce 300KW on a nearly continuous basis (8000 hrs/yr) for a total of 2.4 million KWh/yr.

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Preface

This energy assessment initiative at Fort Irwin, CA was funded by the Installation Management Command (IMCOM) and conducted for Fort Irwin under the Annex 51 program. The technical monitors were Lance Toyofuku, Chief Directorate of Public Works (DPW) Fort Irwin, and Paul Volkman, Headquarters, Installation Management Command (HQIMCOM).

The work was managed and executed by ERDC-CERL. The Energy Team, as funded by IMCOM, is composed of individuals from Construction Engineering Research Laboratory (CERL), Facilities Division (CF), Energy Branch (CF-E). Appreciation is owed to Hossam Kassab, Resource Efficiency Manager and the Public Works staff at Fort Irwin who contributed significantly to the information gathering and feasibility analysis. The CERL principal investigators were David Underwood and Alexander Zhivov. Franklin H. Holcomb is Chief, CEERD-CF-E, and L. Michael Golish is Chief, CEERD-CF. The associated Technical Director was Martin J. Savoie, CEERD-CV-T. The Director of ERDC-CERL is Dr. Ilker R. Adiguzel.

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 Gary E. Johnston, and the Director of ERDC is Dr. Jeffery P. Holland.

Unit Conversion Factors

Multiply	By	To Obtain
Acres	4,046.873	square meters
British thermal units (Btu, International Table)	1,055.056	joules
MMBtu	0.293	MWh
cubic feet	0.02831685	cubic meters
cubic inches	1.6387064 E-05	cubic meters
cubic yards	0.7645549	cubic meters
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
Feet	0.3048	meters
gallons (U.S. liquid)	3.785412 E-03	cubic meters
Inches	0.0254	meters
miles (U.S. statute)	1,609.347	meters
miles per hour	0.44704	meters per second
square feet	0.09290304	square meters
square inches	6.4516 E-04	square meters
square miles	2.589998 E+06	square meters
square yards	0.8361274	square meters
tons (2000 pounds, mass)	907.1847	kilograms
tons (2000 pounds, mass) per square foot	9,764.856	kilograms per square meter
Yards	0.9144	meters

1 Introduction

1.1 Background

Fort Irwin, the home of the National Training Center — considered to be the premier training site of the U.S. Army — is a U.S. Army installation located 37 miles northeast of Barstow, CA, in the High Mojave Desert midway between Las Vegas, NV and Los Angeles, CA. The energy required to serve the needs of more than 1600 buildings located on the installation is not generated on site; it must be conveyed over long distances. Electric power is transmitted from distant generators through the power grid; LPG for heating and Domestic Hot Water (DHW) is trucked to Fort Irwin in bulk. The costs associated with fuel transport raise already high energy costs.

Army installations must meet the energy reduction requirements mandated by such recent directives as Executive Order 13123, Energy Policy Act of 2005 (EPACT) 2005, EISA 2007, Executive Order (EO) 13423, EO 13514. These and other current policies and directives require energy use reduction with the goal by 2030 (EISA 2007) to eventually eliminate fossil fuel use by new buildings and buildings undergoing major renovations. The Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) was tasked with investigating energy-related projects, along with applicable funding and execution methods, that could help Fort Irwin meet these requirements.

1.2 Objectives

The objectives of this study were to identify energy inefficiencies and wastes at Fort Irwin and to propose energy-related projects with applicable funding and execution methods that could enable the installations to better meet the energy reduction requirements of by recent directives.

1.3 Project team and summary of activities

1.3.1 ERDC-CERL

ERDC/CERL developed the team of contractors and consultants with the expertise necessary for the assessment.

1.3.2 Private contractors

Private contractors with skills in various areas of technical expertise were a vital part of the Energy Team. Experts in HVAC, building envelope, central plants, and lighting, rounded out the contractor portion of the team.

1.4 Approach

A group of buildings physically located close to each other was found for the major focus of this effort. In focusing on this Cluster of buildings to develop holistic energy systems concepts, a plan for applying them through advanced community-wide energy master planning as well as executing renovation projects by building clusters can be developed.

1.5 Scope

This Energy Assessment included a Level I study of the central energy plant and associated distribution system providing heat to the subject building Cluster. The Cluster included five barracks, a dining facility, and a central heating and cooling plant.

1.6 Mode of technology transfer

The results of this work will be presented to IMCOM, the Assistant Chief of Staff for Installation Management (ACSIM) and Fort Irwin for their consideration for implementation and funding, and for use as the basis for other currently conducted studies related to planning for a new central energy plant and utilization of renewable energy sources. It is anticipated that the results of this work will contribute to an enhanced awareness within the Installation Management Command (IMCOM), the U.S. Army Corps of Engineers and its districts, and other Army organizations of opportunities to the opportunities to improve the overall energy efficiency of Army installations. This information will be disseminated through workshops, presentations, and professional industrial energy technology conferences. This report will also be made accessible through the World Wide Web (WWW) at: http://www.cecer.Army.mil

2 Energy Data

2.1 Installation energy use rates

Table 1 lists Fort Irwin's utility rates.

Table 1. Fort Irwin utility rates.

Energy Type	Unit Price
Electricity	$0.083/KWh
LPG	$2.47/Therm

2.2 Net-Zero energy for 263 Cluster introduction

During the week of 3–7 August 2009, the Energy Team performed an energy assessment at Fort Irwin to initiate an effort to make Fort Irwin independent from external energy supply, i.e., to make selected buildings self-supported in terms of energy. The ultimate goal of this project is to make the entire installation independent from external energy supply. Thus, the team studied a group of buildings and proposed various solutions that could make these buildings "Net-Zero" energy consumers. This report generally describes a process to achieve "Net-Zero" status and the technical measures to achieve that goal, and specifically addresses how that goal may be achieved for a Cluster of buildings within Fort Irwin.

The group of buildings (the "Cluster") consists of barracks 261, 262, 264, 265, and 267, Central Energy Plant 263, and Dining Facility 271. The barracks are all of the same vintage and are nearly identical in design and structure. They differ only in minor details such as the flow (cfm) of the respective makeup air units (MAUs). Of the buildings in the Cluster, this study focuses specifically on barracks Bldg 264, Central Plant 263, and the dining facility.

In the future, it may be possible to connect Bldg 272 (the club) and three administrative buildings (276, 278, and 280) to the central plant. During the assessment week, however, there was not sufficient time to study those buildings in detail. To be candidates for Net-Zero energy buildings and to be part of the 263 Cluster, these four buildings must also be analyzed and modeled in a follow-up study, using the methodology outlined here. There would apparently be no hindrance to including those four additional buildings in the Cluster as long as the efficiency of the buildings is improved in the same way as proposed for the present seven buildings in the Cluster.

2.3 Methodology

This project used the following methodology:

1. Analyze the present systems and buildings.
2. Model the actual buildings using the *eQuest* building simulation model to establish the base-line.
3. Model the buildings with building improvements that should be consistent with a major upgrade (BUP project type). The upgrades would improve the building envelope for more efficient energy use, and install energy efficient lighting, HVAC, domestic water, and other building system components.
4. Propose Energy Conservation Measures (ECMs) to improve the building performance with respect to energy use, and to reduce costs associated with maintenance, sustainability, mold prevention, etc.
5. Model the buildings again (with the proposed ECMs applied) to establish the annual energy use when the buildings (barracks and dining facility) have been improved to an economically viable standard.
6. Develop renewable energy projects to supply the Cluster with sufficient electric energy and heat to cover the annual needs.
7. Apply this methodology and results to all other buildings to make Fort Irwin a Net-Zero energy U.S. Army installation.

2.4 Analysis of present systems and buildings

The Energy Team made a site visit to Barracks 264, Dining Facility 271, and Central Energy Plant 263, established the present status of the buildings and their associated systems, and made the observations summarized in the following sections.

2.4.1 Analysis of Barracks Bldg 264

The total area of Bldg 264 (Figure 1) is 28,959 sq ft. It is three stories and can lodge 136 people. Two people share a room. Two rooms share a bathroom. The walls are 8-in. concrete masonry unit (CMU) with 1-in. insulating board plus stucco. The floor is 6-in. concrete. The windows are double-pane, aluminum frames without thermal break. There is external horizontal sun shading above the windows, approximately 1 ft shade depth. The roof has a pitched metal surface with 4 in. of insulation underneath.

Figure 1. Bldg 265 (identical to Bldg 264).

Heating and cooling is provided by 300 cfm two-pipe fan coil units that serve the living areas. Two Makeup Air Units (MAUs) are located above the third floor ceiling. Supply air ducts that run from these MAUs provide ventilation air that enters the fan coil's return air plenum located above the false ceiling in the hallway of each living quarter.

Since the fan coils are located inside the soldiers' living areas, which are kept locked, gaining access for maintenance is quite difficult (Figure 2). Thus, fan coil maintenance is time consuming and not always done at specified intervals. Filters get dirty quickly and need to be replaced regularly to maintain nominal air flow through the fan coil units (Figure 3). Dirty air filters are also a potential breeding ground for biological growth, and this typically goes undetected, as it is out of sight. The ability to maintain the units without entering an occupied space must be incorporated into any design solution.

There are three MAUs in the building, two of which are for the living quarters (1320 cfm and 1120 cfm), and one for the main areas and the corridors (2700 cfm). The field survey found that none of the MAUs for the living quarters in any of the barracks in the Cluster studied were running. This means that there is no fresh air coming into the soldiers' rooms. The MAUs for the living quarters total a supply capacity of 2440 cfm, which is equivalent to 18 cfm/person.

Figure 2. Fan coil return air plenum at Bldg 265.

Figure 3. Dirty filter from fan coil unit at Bldg 264.

The exhaust from the bathrooms in Bldg 264 (Figure 4) is provided by an individual exhaust fan in every bathroom, ducted to exhaust ducts that end at vents on the roof. The exhaust fans only run when the lights are on in the bathroom, not continuously. These exhaust fans are difficult to maintain and very dirty.

Figure 4. Bathroom exhaust fan at Bldg 264.

In some of the other barracks in the Cluster, the bathroom exhaust had been changed to use roof-mounted central exhaust fans such that the bathroom exhaust runs continuously. This is the case with Bldg 265. Figure 1 (p 5) shows the exhaust fans on the roof of Bldg 265.

Heating and cooling is supplied from the central plant, Bldg 263. For the fan coils, there are manual switch-over valves in the mechanical room. Every spring and autumn, as the seasons change, flow is switched from the cooling source to that for heating and vice versa. This manual switchover creates comfort problems during the change of seasons when the weather variation between night, morning, and afternoon is dramatic, when heating is required overnight and cooling by the afternoon. Since this manual switchover only occurs twice a year, comfort conditions may be compromised through several months of the year.

DHW is generated within the building with heat from the central plant that passes through a heat exchanger that is controlled to keep a certain DHW temperature in the DHW storage tank.

2.4.2 Analysis of Dining Facility 271

Dining Facility 271 has a total area of 12,040 sq ft. It is one story high and serves an average of 1000 meals per day. The dining area (Figure 5) occupies approximately 40 percent of the building area, and serving, kitchen, and utility rooms occupy the remainder of the building. The original building construction was supplemented with an addition to the dining room.

Figure 5. Dining Facility 271.

The walls are 8-in. CMU block with 1 in. insulating board plus drywall. The floor is 6 in. concrete. The windows in the original building are single pane, and the windows in the addition are double-pane. Both window types have aluminum frames with no thermal break. The roof is a flat metal deck with 4 in. of rigid insulation under a black single ply roof.

Heating and cooling is provided by an air handling unit, three make-up air units, and two evaporative cooling units. All units have hot water heating coils and chilled water cooling coils. The cooling coils are downstream of the evaporative coolers in the evaporative cooling units. The air handling unit has a capacity of 12,000 cfm and services the dining and serving areas of the building. A 3600 cfm make-up air unit also provides air for the exhaust hoods in the serving area. One evaporative cooling unit in the kitchen and one makeup air unit (MAU) provide 5500 cfm to the general area. The MAU has a capacity of 4400 cfm; both supply air units together support the exhaust of two large hoods and several smaller exhaust systems. In the dishwashing area, the other evaporative cooling unit (2000 cfm) and MAU (4000 cfm) are located. These units provide air for the exhaust from the dishwasher machine and general dining room exhaust. All these units are located on the roof except for the air handling unit (AHU), which is located in the first floor mechanical room.

The ventilation rate for the dining room is over 2 cfm/sq ft. The amount of outside air is adjustable. The evaporative cooling units and MAUs use 100 percent outdoor air. The mode of the current operation is that "all supply and exhaust air systems run all the time."

Heating and cooling is supplied from the central plant, Bldg 263. The supply air units have both heating and cooling coils, and thus can easily handle changing weather conditions that require heating and shortly thereafter cooling, which is often experienced in the spring and autumn.

DHW is generated within the building with heat from the central plant that passes through a heat exchanger, controlled to keep a certain DHW temperature in the DHW storage tank at all times.

2.4.3 Analysis of Central Energy Plant 263

The central energy plant in Bldg 263 is operated to supply heating and cooling to five barracks buildings within the Cluster plus the dining facility, Bldg 271. The dining facility also has its own mechanical systems such as a steam boiler, direct expansion (DX) and evaporative cooling units in addition to the heating and cooling supply from 263.

Figure 6. Steam boiler at Dining Facility 271.

The central plant has one area for heating with three fairly new Patterson Kelley boilers (e.g., Figures 6 and 7) that burn a combustible gas (LPG from the central LPG farm, expanded and distributed as gas around Fort Irwin). The heating capacity is 2000 MBH/boiler. The Hot Water (HW) supply temperature is set at 180 °F (Figure 8). The HW circulation pump is driven by a 30 hp motor connected to a variable frequency drive (VFD) that is set at 33 percent constant load.

In the central plant, all boilers were on. Boiler B was the lead, and all boilers were on standby. HW supply temperature was 180 °F and the HW return temperature was also 180 °F. Substantial savings could obviously be generated by modifying the system's mode of operation. Note that, since the energy waste of the existing system operating strategy was not captured in the computer models, the savings potential is greater than shown.

The central plant also houses a centrifugal chiller (a Trane CVHE 036G, with a nominal capacity is 360 tons, installed in 1987). An external open cooling tower removes excess heat. The chilled water (CHW) pump is 25 hp, constant speed unit. The condenser pump is also a 25 hp, constant speed unit. The CHW supply temperature setpoint is fixed at 45 °F, and the condenser water supply temperature setpoint is fixed at 85 °F. In the chiller plant, the CHW supply and return temperatures were 47 °F and 53 °F, respectively.

This chiller runs at partial load for most of the summer and mid-seasons. Partial load efficiency of chillers of this era is notoriously poor and can exceed 3 kW/ton during very light loads. The chillers do not typically unload much below 30 to 40 percent of their design capacity, so loads below this level are served in an extremely inefficient manner.

In addition, the constant speed pumps are designed to deliver 360 tons of capacity at all times. At full load, the pumping energy penalty is approximately 0.10 kW/ton. At a 10 percent load, the pumps contribute approximately 1.0 kW/ton to the energy consumption equation. A properly controlled variable speed pumping scheme will use less than 0.1 kW/ton at nearly all loads and will operate at less than 0.05 kW/ton across most of the load range.

Figure 7. Patterson Kelley Boilers in Central Energy Plant 263.

Figure 8. Central Energy Plant 263 — heat-timer for temperature control.

Cooling plant efficiency could be improved by more than 50 percent by replacing old constant speed technology for the compressor, chilled water, and condenser water pumps with new technology and automatic reset control systems.

The designs anticipated in this document can improve the energy efficiency of the new cooling plant by more than 50 percent by using variable speed drives on all of the equipment, higher chilled water supply temperatures, lower condenser water supply temperatures, and Load Based Optimization System based reset strategies that reset the chilled water supply temperature and differential pressure, the condenser water temperature, and the supply air temperature and static pressure setpoint based on the needs of the end use cooling loads. Additionally, the insulation levels anticipated in this report will substantially reduce cooling loads, and reduce chiller plant energy consumption by nearly 70 percent overall in comparison with the base case.

After the initial assessment of the sample buildings, including detailed studies of drawings, data was available for input into the *eQuest* Energy simulation model. These data formed the base case (present situation) with the goal to establish the annual energy use per buildings, and ultimately for the entire Cluster, at present.

2.4.4 Modeling of buildings and systems

The modeling of the buildings, the systems within the buildings, and the systems supporting the buildings was done by using the *eQuest* building energy analysis tool.

eQuest® is a freeware building energy analysis tool that provides professional-level results with an affordable level of effort. *eQuest* was designed to provide a detailed comparative analysis of building designs and technologies by applying sophisticated building energy use simulation techniques without requiring extensive experience in the "art" of building performance modeling. This is done by combining schematic and design development building creation wizards, an energy efficiency measure (EEM) wizard, and a graphical results display module with a completely up-to-date *DOE-2* (Version 2.2) building energy use simulation program.

DOE-2 is a widely used and accepted freeware building energy analysis program that can predict the energy use and cost for all types of buildings. *DOE-2* uses a description of the building layout, construction, operating schedule, conditioning systems (lighting, HVAC, etc.), utility rates, and weather data to perform an hourly simulation of the building and to estimate utility bills. The "plain" *DOE-2* program is a "DOS box" or "batch" program, which requires substantial experience to use effectively while offering researchers and experts significant flexibility. *eQuest* is a complete interactive Windows implementation of the *DOE-2* program with added wizards and graphic displays to aid in the use of *DOE-2*.

2.4.4.1 Input data, base case — Barracks Bldg 264

In addition to the observations listed above, the following input data was used in the base case simulation of the barracks buildings:

- The infiltration is estimated to be equivalent to 1 Air Change per Hour (ACH).
- The total window area is 20 percent of the gross wall area on the north and south walls. No windows are on the east or west walls.
- There is a laundry on the ground floor; it is estimated that each soldier washes three loads of laundry per week.
- Lighting is estimated to be at a level of 1.10 W/sq ft in the living quarters and 0.8 W/sq ft in the corridors and storage areas. For the laundry, common areas, and the administrative spaces, the lighting levels modeled are 1.6 W/sq ft.
- Miscellaneous electric loads (plug loads) are estimated to be 1 W/sq ft.
- DHW use is estimated to be 12 gal/day/person, supplied at 140 °F. Inlet water temperature is assumed to equal the ground temperature.

2.4.4.2 Input data, base case — Dining Facility 271

Other input data for the computer model for the dining facility is:

- The infiltration is estimated to be equivalent to 0.3 ACH.
- All the windows are fixed with an area of 23 percent of the gross wall area on the southwest side, 14 percent on the southeast side, and 4 percent on the northwest side of the building.
- Lighting is estimated to be at a level of 1.85 W/sq ft in the dining area, 0.92 W/sq ft in the serving area, 1.19 W/sq ft in the kitchen, and 0.81 W/sq ft in the mechanical room.
- The cooking energy use is estimated to be 11.6 W/sq ft in the kitchen and 5.0 W/sq ft in the serving area. There is also a natural gas cooking energy use of 198 Btu/sq ft in the kitchen and 50 Btu/sq ft in the serving area.
- The refrigeration load used for the kitchen is the default value of 3.6 W/sq ft.
- The miscellaneous load inputs are 1.0 W/sq ft in the dining area, 0.2 W/sq ft in the kitchen and 0.1 W/sq ft in both the serving and mechanical room areas.
- The office equipment energy use estimate is 0.2 W/sq ft for all spaces except the mechanical room.
- The DHW use is the default value in the program for a full service restaurant.

2.4.4.3 Input data, Central Energy Plant 263

Other input data for the computer model for the Central Energy Plant is as follows:

- Heating:
  - There are three boilers, gas-fired, 80 percent efficient.
  - There is constant flow in the hot water loop.
  - The hot water temperature is set at a fixed value of 180 °F.
  - The boilers are on all year, 24 hrs/day, as a standby measure for whenever heat is requested.*

* Note that the negative effects of the current design and operational strategy, which are associated with substantial energy waste are not included. With the current operational strategy, it is likely that the boilers are less than 40 percent efficient overall, as they are running when there is no need for them to be operated.

- Cooling:
  - There is one chiller (360 tons) for the entire Cluster. Efficiency is estimated to be 0.8 kW/ton.
  - The chiller is electric centrifugal hermetic type, constant speed, and water-cooled by a cooling tower. The cooling tower is an open tower, and the temperature setpoint is fixed at 85 °F.
  - The CHW loop flow is constant.
  - The CHW temperature is a constant 45 °F.
  - The chiller is in standby mode all year, 24 hrs/day.

2.4.4.4 Results of simulation, annual energy use

Table 2 lists the present use of electric energy and fuels in one barracks building according to the *eQuest* simulations.

Table 2. Present use (base case) of electric energy and fuels in one barracks building.

Usage	Consumption
Electric Consumption (kWh)	
Space cool	124,401
Space heat	0
Vent. Fans	58,120
Pumps and aux.	69,223
Laundry	69,300
Plug loads	85,190
Area lights	74,885
Total	***486,507***
Gas Consumption (kBtu)	
Space heat	665,131
Hot water	628,307
Total	***1,293,438***

Tables 3 and 4 list the results of the base case simulation for Dining Facility 271.

Table 3. Base case electrical energy use for Dining Facility 271.

Electrical	kWh/yr	MMBtu/yr
Cooling	82,500	281.6
Heat rejection	7,260	24.8
Ventilation fans	270,130	922.0
Pumps	40,800	139.3
Cooking equipment	201,950	689.3
Lights	66,940	228.5
Subtotal	*669,580*	*2,285.3*

Table 4. Base case natural gas energy use for Dining Facility 271.

Natural Gas Use	MMBtu/yr
Space Heating	678.6
DHW	131.9
Cooking Equipment	1,915.7
Subtotal	2,726.2
Total	*5,011.5*
Btu/yr/sq ft	*416,236*
Btu/yr/sq ft – Cooking Equip.	*199,877*

Note: the energy use by building area is 5012 million Btu/12,040 sq ft, or 416,236 Btu/yr sq ft. The cooking equipment use is 216,360 Btu/yr sq ft, leaving 199,877 Btu/yr/sq ft for HVAC, DHW and lighting. Much of the HVAC and DHW energy use is related to cooking operations.

2.5 Typical building upgrade improvements

Barracks buildings in the Army inventory typically get a major renovation at an age of approximately 25 yrs old under the BUP. The funding amount per barracks is approximately $5 to $7 million. This work attempts to reduce the building's energy use to the energy usage level of a newly constructed building. The building envelope should be improved by adding insulation to the walls and roof, by installing tight fitting and well insulated doors, and by replacing windows with ones that have a low heat transfer and a minimum solar heat gain. The lighting, HVAC, and domestic water energy systems need to use high efficient equipment and effective controls. Appliances and equipment used in the barracks should be energy star rated to minimize their energy use.

Also, lower level funding programs for barracks are generally used to replace damaged system elements and to clean-up and repair buildings. One of these is the Barracks Improvement Program (BIP), which has funding levels in the range of $1 to $3 million dollars per barracks building. Another is the Flagship Program, which funds building clean-up and refurbishment when troops that occupy the barracks are deployed overseas.

This analysis for cost effectiveness of achieving Net-Zero energy use of the building Cluster assumes that the major building upgrade has already been accomplished under the BUP. The subject barracks buildings in this Cluster would therefore already have had a major improvement in their efficiency of energy use and a significant investment would have been made in the buildings. The recommendations in this report would build on these improvements to achieve buildings that would be ready to apply renewable energy systems for the achievement of Net-Zero energy use. To minimize the cost of these additional improvements, it is expected that they would be accomplished during the BUP building upgrade.

To define the cost effectiveness of these Net-Zero energy use improvements, a prediction of the building energy use with the BUP improvements must be made. (Note that, since most of the dining facility energy use depends on the type and operation of the cooking equipment, the Net-Zero energy use is assumed to be the same as the base case.) This will be done by using the *eQuest* model to simulate the building energy use with the following building characteristics:

- Roof insulation = R-30, light colored reflectance = 0.27
- Wall insulation = R-18
- Infiltration same as base case (approximately 0.4 cfm/sq ft @75 Pa
- Windows = double pane, U=0.45, Low E
- Lighting = 0.9 Watt/sq ft in living quarters and 1 Watt/sq ft in the laundry area
- HVAC = fan coil units with central heating and cooling system. Add DOAS unit (DX coil and HW heating) if model can handle this type system
- DHW heater = Gas heater 90 percent efficient with storage tank.

Table 5 lists the building energy use results of the *eQuest* computer run for a building typical of the barracks buildings.

Table 5. Energy use after typical barracks building upgrade.

Element	Consumption
Electric Consumption (kWh)	
Space cool	112134
Space heat	0
Ventilation Fans	52560
Pumps and aux.	63907
Laundry	69300
Plug loads	85190
Area lights	63874
Total	***446965***
Gas Consumption (kBtu)	
Space Heat	626166
Hot Water	580470
Total	***1206636***

The data listed in Table 5 indicate that a typical upgrade of a barracks building only saves 8 percent of the electricity use compared to the barracks "as we found them" and 7 percent of the heating energy. In other words, a typical barracks upgrade is not very energy efficient.

3 Proposed Energy Conservation Measures

3.1 ECMs — Barracks Buildings

The following possible improvements were identified for the Barracks:

- Upgrade the external insulation of the walls to R-42.
- Install a new roof using a cool roof surface and R-39 insulation.
- Install triple-pane, Low-E, operable windows.
- Install window and door monitoring switches that turn heating or cooling off when the switch is activated (i.e., then the door or window is open). This measure was initially deleted to reduce the first cost of the project, but it is a desirable option that should be considered.
- Install more efficient lighting to reduce the load to 0.5 W/sq ft.
- Assume Army influence on plug loads to get down to 0.6 W/sq ft.
- Install efficient laundry equipment (EnergyStar) to reduce the electric load by 50 percent.
- Duct all bathroom exhausts to common roof-mounted exhaust fans with continuous operation, mainly to prevent mold growth in the bathrooms. Install a heat recovery unit to recover heat from exhaust air to outside air entering the DOAS AHU. This is considered for all systems mentioned below except the DOAS-VAV system (see Section 3.1.1.1 , p 19).
- Replace the existing two-pipe fan coil units with these system types:
  - DOAS-VAV System with Direct Evaporative Cooling
  - DOAS System with Radiant Heating and Cooling (direct and indirect evaporative cooling)
  - DOAS System with Fan Coils (direct and indirect evaporative cooling)
  - DOAS-VAV System with Direct and Indirect Evaporative Cooling (same as Option 3.9.9.1, but with an indirect cooling section added).

For both the VAV system and the new fan coil system, it is suggested that VAV boxes and fan coil units are made accessible from the corridor to ease maintenance without disturbing the occupants. The control valves for the radiant heating and cooling systems should also be accessible from the corridor, without having to enter the living quarters to work on them. Detailed descriptions of the proposed DOAS related alternatives follow.

3.1.1.1 DOAS-VAV system with direct evaporative cooling

- A VAV version of a DOAS would be used for delivery of heated and cooled air. It would be capable of providing 100 percent outside air, when conditions warrant, through the use of economizer dampers, ducting, and controls.
- The AHU would be equipped with a return fan system to provide proper system pressurization control and direct evaporative cooling to reduce the load on the chiller plant, and would be sized to meet the loads of the facility.
- The unit would be designed to include the High-Efficiency Dehumidification System (HEDS) design strategy, so that this technology could be tested to determine suitability for more humid climates such as Fort Huachuca during the monsoon season or Fort Shafter year-round.
- MERV 15 – 16 air filtration would be used to reduce the impact of very fine desert dust on the heat transfer coil systems. Dirt intrusion has been a major problem with the existing systems.
- Each occupied space would be heated and cooled using a VAV air distribution system design. Each VAV box would be equipped with direct digital controls (DDCs) that report to a central workstation.
- The system would be a two-pipe switchover design, with automatic control valves to allow the building-level system to provide heating in the mornings as required and cooling in the afternoon.
- There will be a need to create chases for the VAV boxes and duct risers. The duct chases will need to be 2-hr rated.
- There will be a need to install access doors for VAV box controls. The VAV box controls must be accessible from the hallway so that maintenance may be done without entering the soldiers' living spaces. This will require a section of the block wall to be saw-cut, and a locking access door to be installed.
- The new DDC system needs to be equipped with controls and monitoring equipment for the DOAS AHU and HEDS systems to help determine their performance relative to the other options that are proposed to be installed on other barracks facilities.
- A new on-grade pad and equipment enclosure for equipment will need to be installed at the mid-point of the building.
- Piping to the DOAS AHU will be set up as a dynamic two-pipe switchover system.

- Three Fan Coil Units will be needed for other spaces (game room, laundry, misc.) that are not cost effective to run ductwork to.
- Dynamic, load based heating/cooling switchover controls will be added to the systems at the building level.
- Exhaust system modifications in rooms should include adding manual balancing dampers to the installed exhaust duct drops.
- Exhaust system modifications at roof should include one common exhaust fan and associated controls.
- Window and door monitoring switches will be installed to curtail heating and cooling when the windows and doors have been open for a predetermined time period. This measure was initially deleted to reduce the first cost of the project, but it is a desirable option that should be considered.
- Automatic heating/cooling switchover valves and controls will be added in the mechanical room to eliminate manual operation of this equipment and to ensure that the building level system can provide heating or cooling as dictated by the loads.
- New room supply air diffusers will be installed.
- The ceiling fans will remain in place under local, manual control.

3.1.1.2 DOAS system with radiant heating and cooling (direct and indirect evaporative cooling)

- Each occupied space would be heated and cooled using radiant heating and cooling panels, augmented as needed from a variable temperature DOAS unit. Each room would be equipped with smart thermostat DDC controls reporting to a central workstation.
- The DOAS AHU would be equipped with direct and indirect evaporative cooling. It would be a variable – constant volume system. The volume of the heated or cooled air would be varied as required to provide minimum make up air needs and then to augment the Radiant Heating and Cooling (RHC) system as the need arises.
- The project would include insulating the existing make-up air duct that currently runs from the attic space to each room. This duct would be used for DOAS distribution to each space.
- The new single fan bathroom exhaust system would be equipped with a bathroom exhaust system heat recovery unit and the associated controls and monitoring equipment to determine its effectiveness/efficiency.

- RHC water temperature mixing controls would be installed in the existing mechanical spaces, along with the RHC circulating pump system and VFD/controls.
- New ceiling mounted RHC panels would be installed in each occupied room and serve as the primary source of heating and cooling.
- The RHC installation will include ceiling modifications, controls and piping to each unit.
- MERV 15 – 16 air filtration would be used to reduce the impact of very fine desert dust on the heat transfer coil systems. Dirt intrusion has been a major problem with the existing systems.
- The system would be a two-pipe design, with automatic control valves to allow the system to provide heating in the mornings as required and cooling in the afternoon.
- The new DDC system needs to be equipped with controls and monitoring equipment for the DOAS AHU, the bathroom exhaust heat recovery system, and the RHC systems to help determine their performance relative to the other options that are proposed to be installed on other barracks facilities.
- A new on-grade pad and equipment enclosure for equipment will need to be installed at the mid-point of the building.
- Piping to the DOAS AHU will be set up as a dynamic two-pipe switchover system. This will allow the DOAS system to augment the cooling and heating capacity of the RHC system on a limited basis.
- Three Fan Coil Units will be needed for other spaces (game room, laundry, misc.) that the RHC system cannot effectively serve due to humidity and highly variable loads. These fan coils will be slightly larger than the fan coils used to serve these loads in the other options, as the chilled water temperature in the building piping system will most likely be 60 °F or higher, as required for the RHC system.
- Dynamic, load based heating/cooling switchover controls will be added to the systems at the building level.
- Exhaust system modifications in rooms should include adding manual balancing dampers to the installed exhaust duct drops.
- Exhaust system modifications at roof should include one common exhaust fan and associated controls.
- Window and door monitoring switches will be installed to curtail heating and cooling when the windows and doors have been open for a predetermined time period. This measure was initially deleted to reduce

the first cost of the project, but it is a desirable option that should be considered.

- Automatic heating/cooling switchover valves and controls will be added in the mechanical room to eliminate manual operation of this equipment and to ensure that the building level system can provide heating or cooling as dictated by the loads.
- New room supply air diffusers will be installed.
- The ceiling fans will remain in place under local, manual control.

3.1.1.3 DOAS system with fan coils (direct and indirect evaporative cooling)

- Each occupied space would be heated and cooled using a multi-speed fan coil unit located in a closet adjacent to each room. Each fan coil would be equipped with DDC controls reporting to a central workstation.
- A DOAS AHU with direct and indirect evaporative cooling would be used to provide make-up air to each room.
- The project would include insulating the existing make-up air duct that currently runs from the attic space to each room. This duct would be used for DOAS distribution to each space.
- There will be a need to create rooms (closets) from each occupied space for the Fan Coil Units. Each closet should have access doors for the Fan Coil Units. The Fan Coil Units must be accessible from the hallway so that maintenance can be done without entering the living spaces of the soldiers. This will require a substantial section of the block wall to be saw-cut and a locking access door to be installed.
- The new single fan bathroom exhaust system would be equipped with a bathroom exhaust system heat recovery unit and the associated controls and monitoring equipment to determine its effectiveness/efficiency.
- The new two-pipe fan coil units (FCUs) would be sized at approximately ½ ton each. Once the envelope changes have been made, the load in the space will be less than ½ ton, but selecting the units for this load will allow the chilled water supply temperature to be increased to approximately 50 °F while still meeting the loads.
- The desire is to supply 50 °F chilled water to the units and to deliver 68 to 72 °F chilled water return from the FCUs to the chiller plant.

- The FCUs should be selected with eight rows and 12 fins/in., with a blow-thru coil design (not the more typical draw-thru design). The air velocity thru the coils should not exceed 350 ft/minute, at the highest fan speed setting.
- The FCU installation will include new piping to the FCUs, DDC controls for FCUs and a dedicated electrical service for FCUs for sub-metering of their energy use.
- MERV 15 – 16 air filtration would be used to reduce the impact of very fine desert dust on the heat transfer coil systems. Dirt intrusion has been a major problem with the existing systems.
- The system would be a two-pipe design, with automatic control valves to allow the system to provide heating in the mornings as required and cooling in the afternoon.
- The new DDC system needs to be equipped with controls and monitoring equipment for the DOAS AHU, the bathroom exhaust heat recovery system, and the FCU systems to help determine their performance relative to other options proposed to be installed on other barracks facilities.
- A new on-grade pad and equipment enclosure for equipment will need to be installed at the mid-point of the building.
- Piping to the DOAS AHU and FCUs will be set up as a dynamic two-pipe switchover system.
- Three additional Fan Coil Units will be needed for other spaces (game room, laundry, misc).
- Dynamic, load based heating/cooling switchover controls will be added to the systems at the building level.
- Exhaust system modifications in rooms should include adding manual balancing dampers to the installed exhaust duct drops.
- Exhaust system modifications at roof should include one common exhaust fan and associated controls.
- Window and door monitoring switches will be installed to curtail heating and cooling when the windows and doors have been open for a predetermined time period. This measure was initially deleted to reduce the first cost of the project, but it is a desirable option that should be considered.
- Automatic heating/cooling switchover valves and controls will be added in the mechanical room to eliminate manual operation of this equipment and to ensure that the building level system can provide heating or cooling as dictated by the loads.

- New room supply air diffusers will be installed.
- The ceiling fans will remain in place under local, manual control.

3.1.1.4 DOAS-VAV system with direct and indirect evaporative cooling (same as Option 7.1 with the addition of indirect evaporative coolers and bathroom exhaust system heat recovery)

- A VAV version of a DOAS would be used for delivery of heated and cooled air. It would be capable of providing 100 percent outside air when conditions warrant through the use of economizer dampers, ducting, and controls.
- The AHU would be equipped with a return fan system to provide proper system pressurization control and direct and indirect evaporative cooling to reduce the load on the chiller plant, and it would be sized to meet the loads of the facility.
- The unit would be designed to include the HEDS design strategy so that this technology could be tested to determine suitability for more humid climates, such as at Fort Huachuca during the monsoon season, or Fort Shafter year-round.
- MERV 15 – 16 air filtration would be used to reduce the impact of very fine desert dust on the heat transfer coil systems. Dirt intrusion has been a major problem with the existing systems.
- The new single-fan bathroom exhaust system would be equipped with a bathroom exhaust system heat recovery unit and the associated controls and monitoring equipment to determine its effectiveness/efficiency.
- Each occupied space would be heated and cooled using a VAV air distribution system design. Each VAV box would be equipped with DDC controls reporting to a central workstation.
- The system would be a two-pipe design, with automatic control valves at the building level to allow the system to provide heating in the mornings as required and cooling in the afternoon.
- There will be a need to create chases for the VAV boxes and duct risers. The duct chases will need to be 2 hour rated.
- There will be a need to install access doors for VAV box controls. The VAV box controls must be accessible from the hallway so that maintenance can be done without entering the living spaces of the soldiers. This will require a section of the block wall to be saw-cut and a locking access door to be installed.

- The new DDC system needs to be equipped with controls and monitoring equipment for the DOAS AHU and HEDS systems to help determine their performance relative to the other options that are proposed to be installed on other barracks facilities.
- A new on-grade pad and equipment enclosure for equipment will need to be installed at the mid-point of the building.
- Piping to the DOAS AHU will be set up as a dynamic two-pipe switchover system.
- Three Fan Coil Units will be needed for other spaces (game room, laundry, misc.) that are not cost effective to run ductwork to.
- Dynamic, load based heating/cooling switchover controls will be added to the systems at the building level.
- Exhaust system modifications in rooms should include adding manual balancing dampers to the installed exhaust duct drops.
- Exhaust system modifications at roof should include one common exhaust fan and associated controls.
- Window and door monitoring switches will be installed to curtail heating and cooling when the windows and doors have been open for a predetermined time period. This measure was initially deleted to reduce the first cost of the project, but it is a desirable option that should be considered.
- Automatic heating/cooling switchover valves and controls will be added in the mechanical room so manual operation is not required.
- New room supply air diffusers will be installed.
- The ceiling fans will remain in place under local, manual control.

3.2 ECMs – Dining Facility 271

The modifications to the Dining Facility to reduce energy use are:

- Add external insulation to walls (R-12) for a total of R-20.
- Install a new roof with a cool roof surface and R-42 insulation.
- Install triple-pane, Low-E, fixed windows with aluminum frames having thermal breaks.
- Install new doors with double pane glass.
- Reduce infiltration to 0.1 ACH by sealing unwanted openings in the building.
- Install more efficient lighting to reduce the load to 1.0 W/sq ft in the dining area, and install controls to reduce lighting by 50 percent when unoccupied.

- Install skylights in dining and serving areas and controls so lights may be switched off when natural light is adequate.
- Change cooking equipment to electric, which is three times more efficient than gas or steam-heated appliances.
- Improve kitchen hood performance by adding wings to the hoods and air flow control.
- Install a heat recovery unit in the kitchen exhaust system.
- Reduce DHW energy use by 50 percent by improving the dish washing machine and drain water heat recovery as well as refrigeration equipment heat recovery.
- Readjust the dining and serving area space temperatures to 75 °F when occupied and cooling and to 70 °F when occupied and heating. When unoccupied, the temperature set-point would be 78 °F cooling and 68 °F heating.
- Replace existing MAUs and AHU with units having evaporative coolers followed by cooling coils that reduce the cooling energy use.
- Reduce the dining area miscellaneous load by turning off the TV when the space is unoccupied.

The total estimated cost for these improvements is $2,441,000.

3.3 ECMs – Central Energy Plant 263

The modifications to the Central Energy Plant to reduce energy use are:

- Replace the boilers with (92 percent) more efficient boilers.
- Control hot water supply temperature vs. outdoor temperature with a maximum of 160 °F and a minimum of 100 °F.
- Install VFDs for variable hot water loop flow.

3.4 Chiller plant upgrade project

- Install a downsized, high efficiency VSD centrifugal chiller designed to operate properly at high lift conditions (for Thermal Energy Storage system charge cycles).
- There is currently a project being considered separately that may add a chilled water Thermal Energy Storage system to cool the complex.
- The chiller shall be designed for variable flow evaporator and condenser systems.
- Convert the chilled water piping/pumping system to be a primary-only, variable flow design.

- Install a new variable speed condenser water pump.
- Install a new high surface area, low fan horsepower (hp), variable speed, high wet bulb rated, cooling tower system. The cooling tower (CT) should be rated at 78 °F wet bulb temperature, with a maximum of 0.05 brake horsepower (BHP) per rated ton of heat rejection.
- The CT should be designed to operate with flow down to 30 percent of the design flow.
- Install a cooling tower condenser water filtration system. A sub-1 micron sand filter system is recommended to reduce the volume of fine solids while minimizing the impact to labor.
- Install a chilled water filtration system. A sub-1 micron sand filter system is recommended to reduce the volume of fine solids while minimizing the impact to labor.
- Install a heating hot water filtration system. A sub-1 micron sand filter system is recommended to reduce the volume of fine solids while minimizing the impact to labor.
- Install a refrigerant monitor and refrigerant exhaust system for the new chiller for code compliance.
- Modify the chilled water piping for the new design/chiller.
- Modify the condenser water piping for the new design/chiller.
- Install a 20-ton heat recovery chiller (set up for 135 °F water) and a storage tank for domestic hot water needs. This measure was initially deleted from the project, as it is expected that there will be a solar thermal heating system, or a waste heat recovery system that would be implemented along with the system upgrades. If no form of “free” heating is available for the project, this would be a viable option.
- Integrate the heat recovery system into the existing heating system.
- This measure was initially deleted from the project, as it is expected that there will be a solar thermal heating system, or a waste heat recovery system that would be implemented along with the system upgrades. If no form of “free” heating is available for the project, this would be a viable option.
- Interface the proposed new chilled water Thermal Energy Storage Tank with the appropriate TES piping/pumping systems.
- Install Load Based Optimization System (LOBOS) controls for the heating and cooling central plant systems.
- Upgrade the DDC Controls in the plant.
- Install an Energy Monitoring/evaluation System.

3.5 Simulation results with proposed ECMs applied

The data in Tables 6 to 9 show anticipated use of electric energy and fuels in the barracks when the ECMs are implemented, per *eQuest* simulations.

3.5.1 Efficient DOAS — fan coil system with indirect evaporative cooling

Table 6. Estimated energy use of single Net-Zero ready barracks with efficient DOAS — fan coil system with indirect evaporative cooling.

Parameter	Measure
Electric Consumption (kWh)	
Space cool	7625
Space heat	148
Ventilation fans	26404
Pumps and aux.	33033
Laundry	34600
Plug loads	52037
Area lights	35290
Total	189136
Gas Consumption (kBtu)	
Space heat	99332
Hot water	545827
Total	*645159*

3.5.2 Efficient DOAS — VAV system

Table 7. Estimated energy use of single Net-Zero ready barracks with efficient DOAS — VAV system.

Parameter	Measure
Electric Consumption (kWh)	
Space cool	20520
Space heat	192
Ventilation fans	10507
Pumps and aux.	29415
Laundry	34600
Plug loads	52037
Area lights	35290
Total	182560
Gas Consumption (kBtu)	
Space heat	217073
Hot water	545827
Total	*762900*

3.5.3 Efficient DOAS — VAV system with indirect evaporative cooling

Table 8. Estimated energy use of single Net-Zero ready barracks with efficient DOAS — VAV system with indirect evaporative cooling.

Parameter	Measure
Electric Consumption (kWh)	
Space cool	9531
Space heat	82
Ventilation fans	56398
Pumps and aux.	30455
Laundry	34600
Plug loads	52037
Area lights	35290
Total	218392
Gas Consumption (kBtu)	
Space heat	92340
Hot water	545827
Total	***638167***

3.5.4 Efficient DOAS — radiant heating/cooling system

Table 9. Estimated energy use of single Net-Zero ready barracks with efficient DOAS — radiant heating/cooling system.

Parameter	Measure
Electric Consumption (kWh)	
Space cool	19348
Space heat	82
Ventilation fans	16919
Pumps and aux.	30455
Laundry	34600
Plug loads	52037
Area lights	35290
Total	188731
Gas Consumption (kBtu)	
Space heat	92340
Hot water	545827
Total	***638167***

3.6 Dining Facility 271

Table 10 lists the anticipated use of electric energy and fuels in the Dining Facility when the ECMs are implemented, according to the *eQuest* simulations. The estimated building energy use after the modifications is 177,093 Btu/yr/sq ft for a 57 percent reduction. The plug loads were reduced from 216,358 Btu/yr/sq ft to 103,577 Btu/yr per sq ft for a reduction of 52 percent. The building energy use minus the cooking equipment loads with the improvements totals 73,515 Btu/yr per sq ft, for a reduction of 63 percent. These savings result in an annual cost reduction of $71,000.

3.7 Cost estimates

The following costs are estimated retrofit costs. If the scopes described in this document were installed as a part of a new construction project, the incremental costs for the work would likely yield simple payback periods of less than 10 yrs in most utility rate environments. Additionally, the proposed work includes the implementation of DOAS and high efficiency dehumidification systems that would dramatically reduce the potential for biological growth, so the lifecycle cost of these systems is lower than typical systems currently being designed and built. Moreover, the occupants of the facilities will be more comfortable than in typical barracks.

Table 10. Estimated energy use of NET ZERO ready Dining Facility 271.

Electrical	kWh/yr	MMBtu/yr
Cooling	15,752	53.8
Heat rejection	1,529	5.2
Ventilation fans	113,218	386.4
Pumps	18,620	63.6
Miscellaneous equipment	365,390	1,247.1
Lights	35,035	119.6
Subtotal	549,544	1,875.6
Natural Gas Use	**kWh/yr**	**MMBtu/yr**
Space heating		190
DHW		66.6
Miscellaneous equipment		0
Subtotal		256.6
Total		2,132.2
Btu/yr/sq ft		177,093
Btu/yr/sq ft — misc Equip.		73,515

3.7.1 Estimated costs for HVAC/envelope related projects for barracks and DFAC

Table 11 lists a summary of the additional cost above those contained in normal building upgrades to make the building Net-Zero energy ready for the application of renewable energy systems. These buildings have been made extremely energy efficient so that they are appropriate to fuel their remaining energy needs by renewable energy sources.

Table 11. Cost summary of barracks/DFAC building Cluster for NET-ZERO ready buildings.

Project	Cost	Comment
Chiller plant upgrades — Typical upgrade project rehabilitation project	$2,522,790	Detail shown in Table 13
Chiller plant upgrades — Efficient case project — smaller chiller etc.	$2,168,693	Detail shown in Table 13
Incremental costs for energy efficiency chiller plant (savings, smaller plant due to more efficient HVAC/Envelope)	$(354,097)	
Typical barracks upgrade project (per Barracks)	$4,403,137	Detail shown in Table 14
Barracks HVAC Option 1 — DOAS-VAV	$4,365,709	Detail shown in Table 14
Incremental cost over typical barracks upgrade for HVAC Option 1 — DOAS-VAV (slight cost savings for this option)	$(37,427)	
Barracks HVAC Option 2 — DOAS-radiant heating and cooling (two of these are proposed for inclusion, in the pricing below)	$4,284,090	Detail shown in Table 14
Incremental cost over typical barracks upgrade for HVAC Option 2 — DOAS-radiant heating and cooling	$(119,047)	
Barracks HVAC Option 3 — $DOAS-two pipe fan coils	$5,169,140	Detail shown in Table 14
Incremental cost over typical barracks upgrade for HVAC Option 3 — DOAS-two pipe fan coils	$766,004	
Barracks HVAC Option 4 — DOAS-VAV, alternate	$4,525,802	Detail shown in Table 14
Incremental cost over typical barracks upgrade for HVAC Option 4 — DOAS-VAV, alternate	$122,666	
Net-zero energy Ready envelope modifications (Per barracks/DFAC)	$898,878	Detail shown in Table 15
Typical barracks upgrade envelope modifications (Per barracks/DFAC)	$645,050	Detail shown in Table 15
Incremental net-zero energy ready envelope modifications cost over typical barracks upgrade for five barracks	$1,269,142	

Project	Cost	Comment
1 yr of monitoring/evaluation/training/reporting, on and off-site		
Net-zero ready Dining facility HVAC/envelope and equipment modifications	$2,440,562	Detail shown in Table 16
Add three administrative buildings and club to chiller plant, not included in the project estimate.		
Approximate cost for net-zero energy ready of five barracks, one of each option, two of the radiant heating/cooling options plus the DFAC HVAC, envelope and chiller equipment upgrade	$31,732,478	Sum of Chiller, five barracks HVAC and Envelope and Dining Facility Net-Zero Energy Improvements

3.7.2 Typical upgrade project financial summary, envelope and HVAC rehabilitation costs for 265 Building Cluster

The data in Table 12 summarize the cost of a typical Army building upgrade of the subject building complex at Fort Irwin. This would include barracks upgrades of five buildings, an upgrade of the nearby dining facility and an upgrade of the chilled water system that services these buildings. The total estimated cost is 29.4 million dollars to accomplish this work.

Table 12. Cost summary for typical upgrade of barracks and DFAC in the Cluster.

Upgrade	Cost
Typical barracks upgrade project envelope rehabilitation costs for five barracks	$3,225,250
Typical barracks upgrade project HVAC rehabilitation costs for five barracks	$22,015,684
Typical upgrade project envelope and HVAC rehabilitation costs for DFAC	$1,614,932
Typical upgrade project chiller plant rehabilitation costs for 265 complex	$2,522,790
Typical upgrade project HVAC, envelope and chiller plant rehabilitation costs for 265 barracks and DFAC complex	$29,378,656

The data listed in Tables 11 and 111112 show that the estimated typical building upgrade of the five Barracks and Dining Facility is 29.4 million dollars. To obtain a Net-Zero energy ready status for this six building Cluster would cost an estimated $31.7 million dollars, which is an increase of 2.3 million over the upgrade cost.

Tables 13 to 16 list the cost of the recommended Net-Zero energy ready building/system improvements compared to the cost of energy use related improvements typically found in Army building upgrade projects. This most common of these projects is the BUP. A BUP project typically replaces the windows and doors of the building, the wall and roof insulation may be increased especially if those components are being a new outer surface. The HVAC and DHW systems would normally receive new equipment that would be a high efficient type. Piping systems may be replaced. System insulation would be replaced and controls upgraded. Table 12 lists the result of these analyses.

3.7.3 Barracks scope for HVAC and envelope improvements

Table 14 lists cost details of Net-Zero ready HVAC options for barracks buildings.

Table 13. Cost comparison between Net-Zero ready and typical building upgrade of Cluster chiller plant.

Typical Upgrade Chiller Plant Rehabilitation Cost Estimate	Chiller Plant Net-Zero Energy Case	Description
$157,500	$108,000	Variable speed drive centrifugal chiller set up for high lift duty. Smaller chiller and supporting equipment required for Efficient Case system, since a more efficient HVAC/Envelope is included.
$25,000	$20,000	Primary-only chilled water pump
$25,000	$20,000	Condenser water pump
$70,000	$36,000	Cooling tower
$24,000	$16,000	Cooling tower filtration system (1 micron sand filtration)
$25,000	$25,000	Refrigerant monitor for new chiller
$25,000	$20,000	CHW piping
$25,000	$20,000	CDW piping
$—	$—	20 ton heat recovery chiller (135F) Eliminated from Scope — Solar or trash to heat recovery will be used for heating.
$—	$—	Heat recovery chiller piping, pumps, electrical
$—	$—	Hot water thermal energy storage tank — DHW
$35,000	$35,000	Rigging/demo/crane
$10,000	$5,000	Minimum flow bypass line and valve
$58,000	$50,000	Chilled water and hot water filtration systems
$50,000	$35,000	VFDs
$50,000	$45,000	Electrical
$—	$—	TES piping/pumping systems for hot water storage
$200,000	$200,000	Optimization System for heating and cooling
$175,000	$175,000	Controls – plant
$75,000	$75,000	Energy monitoring/evaluation system
$1,029,500	$885,000	Subtotal

Typical Upgrade Chiller Plant Rehabilitation Cost Estimate	Chiller Plant Net-Zero Energy Case	Description	
$102,950	$88,500	10%	Mechanical contractor overhead
$102,950	$88,500	10%	Mechanical contractor profit
$102,950	$88,500	10%	General contractor fee – Army
$1,338,350	$1,150,500	Subtotal, hard costs	
$214,136	$184,080	16%	Chief of Engineers (COE) administration
$133,835	$115,050	10%	Mechanical engineering
$26,767	$23,010	2%	Electrical engineering
$53,534	$46,020	4%	Controls engineering
$13,384	$11,505	1%	Structural engineering
$26,767	$23,010	2%	Construction management
$26,767	$23,010	2%	Project management
$40,151	$34,515	3%	Travel related expenses, all disciplines
$66,918	$57,525	5%	Commissioning (all onsite, no remote)
$—	$—	0.0%	Operator training – quarterly
$—	$—	0.0%	1 yr offsite monitoring and summary report monthly
$—	$—	0.0%	1 yr onsite (monthly) monitoring
$602,258	$517,725	Subtotal, soft costs	
$1,940,608	$1,668,225	Project subtotal	
$291,091	$250,234	Project escalation due to future installation date @ 15%	
$291,091	$250,234	Remote site multiplier @ 15%	
$2,522,790	$2,168,693	Chiller plant total	

Table 14. Cost details of Net-Zero ready HVAC options for barracks buildings.

Typical Barracks Upgrade Project Cost Estimate	DOAS-VAV w/Direct Evap Cooling	DOAS w/ Radiant Heat/Cool	DOAS w/ Fan Coils	DOAS-VAV w/ Direct and Indirect Evap Cooling	Description
$—	$40,000	$10,000	$90,000	$40,000	DOAS-VAV AHU with direct evaporative cooling
$—	$7,500	$—	$—	$7,500	1 return fan
$—	$—	$20,000	$20,000	$20,000	Indirect evaporative coolers
$—	$25,000	$—	$—	$25,000	Economizer dampers/ducting/controls
$—	$45,000	$35,000	$35,000	$45,000	Pad/equipment enclosure for external equipment
$—	$10,000	$10,000	$10,000	$10,000	Duct riser from equipment enclosure into building
$—	$15,000	$15,000	$12,000	$15,000	Electrical power to equipment pad
$—	$20,000	$—	$—	$320,000	Ductwork, Supply and return
$—	$83,000	$—	$—	$283,000	144 VAV Boxes, installed
$35,000	$45,000	$35,000	$35,000	$45,000	CHW Piping to AHU dynamic 2 pipe switchover
$18,000	$18,000	$18,000	$18,000	$18,000	Ductwork for bathroom exhaust system
$5,000	$5,000	$5,000	$5,000	$5,000	Electrical for exhaust fan system
$30,000	$30,000	$45,000	$30,000	$30,000	Three fan coil units for other spaces (game room, laundry, misc) (Larger for RHC system due to 60 °F CHWS temps)

Typical Barracks Upgrade Project Cost Estimate	DOAS-VAV w/Direct Evap Cooling	DOAS w/ Radiant Heat/Cool	DOAS w/ Fan Coils	DOAS-VAV w/ Direct and Indirect Evap Cooling	Description
$—	$—	$12,000	$12,000	$12,000	Indirect evaporative cooler related controls/monitoring
$18,000	$18,000	$18,000	$18,000	$18,000	Dynamic, load based heating/cooling switchover controls
$—	$309,600		$—	$309,600	144 VAV box DDC controls
$30,000	$30,000	$30,000	$30,000	$30,000	Exhaust system modifications in rooms — add manual dampers
$6,000	$6,000	$6,000	$6,000	$6,000	Exhaust system modifications at roof — 1 EF/controls
	$68,040	$—	$—	$68,040	Create rooms for VAV boxes/duct risers — 2 hour rated
	$69,120	$—	$—	$69,120	Install access doors for VAV box controls
	$—	$64,800	$64,800	$—	Insulate existing make-up air duct — re-use for DOAS distribution
$30,000	$—	$30,000	$30,000	$—	Ducting in rooms for DOAS — Radiant to diffuser
$50,400	$—	$—	$50,400	$—	Create rooms for fan coil units
$86,400	$—	$—	$86,400	$—	Install access doors for Fan Coil Units
$—	$48,800	$—	$—	$48,800	Core floors — 48 risers, 2 per riser 3'x3', fire stopping for ductwork
$—	$40,000	$40,000	$40,000	$40,000	DOAS AHU controls/monitoring equipment

Typical Barracks Upgrade Project Cost Estimate	DOAS-VAV w/Direct Evap Cooling	DOAS w/ Radiant Heat/Cool	DOAS w/ Fan Coils	DOAS-VAV w/ Direct and Indirect Evap Cooling	Description
$17,000	$17,000	$17,000	$17,000	$17,000	Automatic heating/cooling switchover valves and controls
$4,320	$4,320	$4,320	$4,320	$4,320	New room supply air diffusers
	$—	$25,000	$25,000	$25,000	Toilet exhaust system heat recovery
$—	$—	$24,000	$—	$—	RHC room controls/DDC thermostat heating and cooling — switchover
$—	$—	$8,000	$—	$—	RHC water temperature mixing con-trols
$—	$—	$20,000	$—	$—	RHC circulating pump system and VFD/controls
$—	$—	$94,400	$—	$—	RHC panels system
$—	$—	$—	$—	$—	RHC installation (ceiling spraying)
$—	$—	$38,800	$—	$—	RHC attachment to ceiling (need a ceiling for third floor)
$—	$—	$400,000	$—	$—	RHC piping to each unit (larger than existing piping, low TD)
$458,200	$—	$—	$415,000	$—	144 two pipe FCUs (nominal ½ ton each, derated to use 50 °F/68 °F CHWS/CHWR temperatures)
$400,000	$—	$—	$400,000	$—	Piping to FCUs
$338,400	$—	$—	$338,400	$—	DDC controls for FCUs

Typical Barracks Upgrade Project Cost Estimate	DOAS-VAV w/Direct Evap Cooling	DOAS w/ Radiant Heat/Cool	DOAS w/ Fan Coils	DOAS-VAV w/ Direct and Indirect Evap Cooling	Description
$—	$—	$—	$—	$—	Dedicated electrical service for FCUs for sub-metering (deleted, was$72,000.00, use DDC system for run status, estimating kWh consumption)
$1,526,720	$1,554,380	$1,525,320	$1,792,320	$1,611,380	Subtotal
$152,672	$155,438	$152,532	$179,232	$161,138	Mechanical contractor overhead @10%
$152,672	$155,438	$152,532	$179,232	$161,138	Mechanical contractor profit @10%
$152,672	$155,438	$152,532	$179,232	$161,138	General contractor fee — Army @10%
$1,984,736	$2,020,694	$1,982,916	$2,330,016	$2,094,794	Subtotal, hard costs
$317,558	$323,311	$317,267	$372,803	$335,167	COE administration @ 16%
$198,474	$202,069	$198,292	$233,002	$209,479	Mechanical engineering @10%
$59,542	$20,207	$19,829	$69,900	$20,948	Electrical engineering @ 1% to 3%
$59,542	$60,621	$59,487	$69,900	$62,844	Controls engineering @ 3%
$19,847	$20,207	$19,829	$23,300	$20,948	Structural engineering @ 1%
$99,237	$101,035	$99,146	$116,501	$104,740	Construction management @ 5%
$99,237	$101,035	$99,146	$116,501	$104,740	Project management @ 5%
$59,542	$60,621	$59,487	$69,900	$62,844	Travel related expenses, all disciplines @ 3%
$138,932	$101,035	$99,146	$163,101	$104,740	Commissioning (all onsite, no remote) @ 5% to 7%
$1,051,910	$990,140	$71,629	$1,234,908	$1,026,449	Subtotal, soft costs

Typical Barracks Upgrade Project Cost Estimate	DOAS-VAV w/Direct Evap Cooling	DOAS w/ Radiant Heat/Cool	DOAS w/ Fan Coils	DOAS-VAV w/ Direct and Indirect Evap Cooling	Description
$3,036,646	$3,010,834	$2,954,545	$3,564,924	$3,121,243	Project subtotal
$455,497	$451,625	$43,182	$534,739	$468,186	Unseen conditions multiplier @ 15%
$455,497	$451,625	$443,182	$534,739	$468,186	Project escalation due to future installation date @ 15%
$455,497	$451,625	$443,182	$534,739	$468,186	Remote site multiplier @ 15%
$4,403,137	$4,365,709	$4,284,090	$5,169,140	$4,525,802	System total

Table 15. Cost detail of typical upgrade and Net-Zero ready building envelope improvements for barracks buildings.

Typical Barracks Upgrade Project Cost Estimate	Option 1. DOAS-VAV, with direct evaporative cooling.	Option 2. DOAS-VAV with radiant heating and cooling, direct and indirect evaporative cooling.	Option 3 DOAS-VAV with fan coils, direct and indirect evaporative cooling.	Option 4. DOAS-VAV with direct and indirect evaporative cooling (variation of Option 1.).	Other Work Common to All Systems
					Window and door monitoring switches
					Card access system
$91,000	$200,000	$200,000	$200,000	$200,000	R-40 roof insulation
$79,000	$79,000	$79,000	$79,000	$79,000	R-18 Wall insulation
$107,000	$107,000	$107,000	$107,000	$107,000	Double pane, Low E, operable windows
$277,000	$386,000	$386,000	$386,000	$386,000	Subtotal
					Electrical contractor overhead @ 10%
					Electrical contractor profit @ 10%
$27,700	$38,600	$38,600	$38,600	$38,600	General contractor fee — Army @ 10%
$304,700	$424,600	$424,600	$424,600	$424,600	Subtotal, hard costs
$48,752	$67,936	$67,936	$67,936	$67,936	COE administration @ 16%
$3,047	$4,246	$4,246	$4,246	$4,246	Mechanical engineering @ 1%
$15,235	$21,230	$21,230	$21,230	$21,230	Electrical engineering @ 5%
$9,141	$12,738	$12,738	$12,738	$12,738	Controls engineering @ 3%
$9,141	$12,738	$12,738	$12,738	$12,738	Structural engineering @ 3%
$15,235	$21,230	$21,230	$21,230	$21,230	Construction management @ 5%
$15,235	$21,230	$21,230	$21,230	$21,230	Project management @ 5%
$9,141	$12,738	$12,738	$12,738	$12,738	Travel related expenses, all disciplines @ 3%
$15,235	$21,230	$21,230	$21,230	$21,230	Commissioning (all onsite, no remote) @ 5%
$140,162	$195,316	$195,316	$195,316	$195,316	Subtotal, soft costs
$444,862	$619,916	$619,916	$619,916	$619,916	Project subtotal
$66,729	$92,987	$92,987	$92,987	$92,987	Unseen conditions multiplier @ 15%
$66,729	$92,987	$92,987	$92,987	$92,987	Project escalation due to future installation date @ 15%

Typical Barracks Upgrade Project Cost Estimate	Option 1. DOAS-VAV, with direct evaporative cooling.	Option 2. DOAS-VAV with radiant heating and cooling, direct and indirect evaporative cooling.	Option 3 DOAS-VAV with fan coils, direct and indirect evaporative cooling.	Option 4. DOAS-VAV with direct and indirect evaporative cooling (variation of Option 1.).	Other Work Common to All Systems
$66,729	$92,987	$92,987	$92,987	$92,987	Remote site multiplier @ 15%
$645,050	$898,878	$898,878	$898,878	$898,878	System total
Base Case	$253,828	$253,828	$253,828	$253,828	Incremental cost difference for net-zero energy facility modifications, per barracks building

3.7.4 Estimated costs for DFAC related projects — Base case and efficient case

Table 16. Cost comparison of typical upgrade and Net-Zero ready improvements for dining facility.

Base Case DFAC Cost Estimate	DFAC — Net Zero Energy Ready Case		
$21,700	$21,700	HVAC System Controls Rehab	
$50,000	$50,000	Air to air heat recovery from exhaust hoods	
$30,000	$30,000	Water heat recovery	
$22,000	$22,000	Exhaust hood adjustments	
$74,000	$74,000	Replacement of evaporative coolers	
	$300,000	Cooking equipment conversion to electric	
$240,000	$240,000	Replacement roof and insulation upgrade, addition of skylights	
$24,400	$24,400	Lighting system rehab	
$10,600	$10,600	Sealing of the building envelope	
$77,300	$77,300	Skin-walls insulation upgrade	
$36,800	$36,800	Windows — double pane, low-E replacements	
$586,800	$886,800	Subtotal	
$58,680	$88,680	10%	Mechanical Contractor Overhead
$58,680	$88,680	10%	Mechanical Contractor Profit
$58,680	$88,680	10%	General contractor fee — Army
$762,840	$1,152,840	Subtotal, hard costs	

Base Case DFAC Cost Estimate	DFAC — Net Zero Energy Ready Case		
$122,054	$184,454	16%	COE administration
$7,628	$11,528	1%	Mechanical engineering
$38,142	$57,642	5%	Electrical engineering
$22,885	$34,585	3%	Controls engineering
$22,885	$34,585	3%	Structural engineering
$38,142	$57,642	5%	Construction management
$38,142	$57,642	5%	Project management
$22,885	$34,585	3%	Travel related expenses, all disciplines
$38,142	$57,642	5%	Commissioning (all onsite, no remote)
$350,906	$530,306	Subtotal, soft costs	
$1,113,746	$1,683,146	Project Subtotal	
$167,062	$252,472	Unseen conditions multiplier @ 15%	
$167,062	$252,472	Project escalation due to future installation date @ 15%	
$167,062	$252,472	Remote site multiplier @ 15%	
$1,614,932	$2,440,562	DFAC Total	
	$825,630	Incremental Cost for Net Zero Energy Ready DFAC	

3.7.5 Energy savings estimates

The estimated energy use of the five barracks and dining facility as operating during the site visit was 3.1 million kWh/yr and 9193 million Btu of LPG gas. Some of these building are scheduled for a major upgrade, which is understood to include increased insulation in the walls and roof, new windows, and improvements to the lighting and HVAC system. The energy savings if all five barracks and the dining facility were upgraded is approximately 6 percent of the estimated current energy use.

As part of the evaluations to determine the most appropriate Net-zero ready barracks building, four HVAC options were explored. These improvements were modeled using *eQuest* computer model and the resulting estimated annual energy use savings as the result of the various upgrades range from 51 to 59 percent for electrical use and 37 to 47 percent for LPG gas. Table 17 lists this energy use for the energy use of two of the four HVAC options applied to a Barracks building.

It is possible to further reduce the net energy consumed by more improvements to the building envelope, the HVAC, domestic hot water, lighting, and other energy using systems. These improvements are contained in several Net-Zero ready options that have been presented in previous sections of this report. The data in Tables 17 to 22 summarize the savings they can provide for a barracks building. Using the current energy costs this represents a annual energy cost savings for the five barracks of $170,000. For the dining facility, a Net-Zero energy ready set of improvements were also modeled. These improvements reduced the buildings electrical use from 670,000 kWh/yr to 550,000 kWh/yr. The LPG gas use was reduced from 2726 million Btu/yr to 257 million Btu/yr. This represents a 18 percent electrical savings and a 91 percent reduction of the heating energy use. The electrical energy use reduction would have been greater if all the cooking equipment had not been switched to an electrical type. The resulting operating cost reduction is an savings of $71,000/yr.

These levels of savings were achieved while improving occupant comfort and substantially reducing the potential for biological growth in the facilities and achieving a payback period of less than 15 yrs based on the incremental costs for the more energy efficient upgrade. In many climates, the cost to mitigate biological growth in barracks facilities far exceeds the total annual energy cost of the facilities. This benefit alone could be the driving factor to use the proposed designs, even if there were no energy savings.

Improvements in the dining facility will add to these savings. Thus the total annual energy cost savings for the Cluster is estimated to be $170,950 plus $71,000, or $241,950.

Table 17. Net-Zero option energy use.

Energy Use Comparison	Upgrade Case	DOAS-VAV	DOAS-FCU
Space cooling, kWh/yr	112,100	20,700	7,700
Ventilation fans, kWh/yr	52,600	10,500	26,400
Pumps and auxiliary equipment, kWh/yr	63,900	29,400	33,000
Plug loads (soldiers) + laundry, kWh/yr	154,500	86,600	86,600
Lighting, kWh/yr	63,900	35,300	35,300
Total electric, kWh/yr	447,000	182,500	189,000
Space heating million Btu/yr	626	217	99
Domestic hot water million Btu/yr	580	546	546
Total LPG gas, million Btu/yr	1,206	763	645
Energy Use Comparison	**Upgrade Case**	**DOAS-VAV & Evap. Cooling**	**DOAS-Radiant Cooling**
Space cooling, kWh/yr	112,100	9,500 500500	19,400
Ventilation fans, kWh/yr	52,600	56,400	16,900
Pumps and auxiliary equipment, kWh/yr	63,900	30,500	30,500
Plug loads (soldiers) + laundry, kWh/yr	154,500	86,600	86,600
Lighting, kWh/yr	63,900	35,300	35,300
Total electric, kWh/yr	447,000	218,300	188,700
Space heating million Btu/yr	626	92	92
Domestic hot water million Btu/yr Btu	580	546	546
Total LPG gas, million Btu/yr	1,206	638	638

Table 18. Net-Zero options energy use savings.

Energy Savings Calculations Barracks 264	Upgrade Case vs. DOAS-VAV	Upgrade Case vs. DOAS-FCU	Upgrade Case vs. DOAS-VAV & Evap. Cooling	Upgrade Case vs. DOAS-Radiant Cooling
kWh/yr	264,500	258,000	228,600	258,200
Million Btu/yr	443	561	568	568
Energy savings calculations Barracks Cluster 263 (five Barracks)	Upgrade case vs. DOAS-VAV	Upgrade case vs. DOAS-FCU	Upgrade case vs. DOAS-VAV & Evap. cooling	Upgrade case vs. DOAS- Radiant Cooling
kWh/yr	1,322,500	1,290,000	1,143,000	1,291,000
Million Btu/yr	2,215	2,805	2,840	2,840

Table 19. Fort Irwin energy costs.

Utility Rates Used for Savings Calculations	Rate
Cost per kWh (Electrical)	$0.083
Cost per Million Btu (LPG)	$24.73

Table 20. Net-Zero options energy use cost savings in barracks.

Utility Cost Savings Calculations Barracks Cluster 263 (five Barracks)	Upgrade Case vs. DOAS-VAV	Upgrade Case vs. DOAS-FCU	Upgrade Case vs. DOAS-VAV & Evap. Cooling	Upgrade Case vs. DOAS-Radiant Cooling
Electrical cost savings/yr	$109,800	$107,100	$94,900	$107,200
LPG cost savings/yr	$54,800	$69,400	$70,300	$70,300
Estimated utility cost savings per yr	$164,600	$176,500	$165,200	$177,500
Average utility savings/yr		$170,950		
Potential biological issue avoided costs/yr (humid areas of the country)		$150,000		
Utility + avoided biological costs/yr		$320,550		

Table 21. Net-Zero option average payback.

Option	Cost
Potential first cost	$31,732,000
Project typical upgrade cost	$29,379,000
Projected incremental first cost after cost of typical upgrade	$2,353,000
Estimated incremental Net-Zero energy ready cost savings	$242,000
Simple payback period based on incremental cost, and energy savings	9.7 yrs

Table 22. Net-Zero options biological problem avoidance (humid climate biological issue reduction estimate).

Number of Avoided Biological Issues (25,000 sf over 5 yrs)	Avoided Cost per Biological Issue	Avoided Costs of Biological Issues (25,000 sf over 5 yrs)	Avoided Costs of Biological Issues (per yr per 25,000 sf)
2.5	$50,000	$125,000	$25,000
Barracks Size (sq ft)	**Barracks Quantity**	**Barracks Total (sq ft)**	**Barracks Avoided Biological Issues Savings**
29,000	5	150,000	$150,000
Note this is an estimate of the avoided biological-related costs that may occur due to the design of the proposed HVAC systems in humid climates. These savings will not occur without the monsoon season that occurs in seemingly similar desert environments such as Fort Huachuca in AZ. In some areas of the country, these estimates will be on the low side.			

The data in Table 23 summarize the cost of a typical Army building upgrade of the subject building complex at Fort Irwin. This would include barracks upgrades on five buildings, an upgrade of the nearby dining facility and an upgrade of the chilled water system that services these buildings. Total estimated cost is 29.4 million dollars to accomplish this work.

Table 23. Typical upgrade project financial summary, envelope and HVAC rehabilitation costs for 265 Building Cluster.

Project	Cost
Typical Barracks Upgrade Project Envelope rehabilitation costs for five barracks	$3,225,250
Typical Barracks Upgrade Project HVAC rehabilitation costs for five barracks	$22,015,684
Typical Upgrade Project Envelope and HVAC rehabilitation costs for DFAC	$1,614,932
Typical Upgrade Project Chiller Plant rehabilitation costs for 265 complex	$2,522,790
Typical Upgrade Project HVAC, Envelope and Chiller Plant rehabilitation costs for 265 barracks and DFAC complex	$29,378,656

3.8 Net-Zero alternative analysis

Tables 24 to 29 list the savings potential of going beyond the energy savings typically achieved in a normal Army Upgrade project with building features that would be found in a Net-Zero energy ready building. Depending on the type of HVAC system chosen for the barracks, the payback of the extra costs based on energy savings would vary from 2.8 to 13.8 yrs.

Alternate 1 is comprised of near Net-Zero energy ready efficient case HVAC and envelope rehabilitation costs for five barracks and a DFAC, 265 barracks Cluster, excluding grey water reclamation system. While generally only a concern a few months out of the year in the climate of Fort Irwin, in other locations this approach also offers the benefit of mold prevention, which can have substantial monetary benefits; the cost avoidance of mold remediation can save $150K/yr, reducing the simple payback to 7.5 yrs.

Table 24. Economics Net-Zero energy improvements for five barracks and DFAC Cluster with all HVAC options and an second radiant cooling HVAC options in 1 barracks — Alternative 1

Improvement	Cost
Envelope rehabilitation and upgrade costs for five barracks	$4,494,391
HVAC system upgrade costs (one of Option 1, 3 and 4, two of Option 2) for five barracks	$22,628,832
Envelope, HVAC and cooking equipment rehabilitation and upgrade costs for DFAC	$2,440,562
Chiller Plant rehabilitation and upgrade costs for 265 complex	$2,168,693
Efficiency upgrade case HVAC, Envelope and Chiller Plant rehabilitation costs for 265 barracks and DFAC complex	$31,732,478
Incremental costs between typical upgrade project case and Net-zero energy ready efficient case	$2,353,823
Annual operating savings for five barracks and DFAC/yr (electricity and gas)	$170,550
Year simple payback period	13.8

Table 25. Alternative 1 energy use results.

	Total Electric kWh/yr	Total LPG Million Btu/yr
Typical cluster upgrade	2,904,405	8,759
Barracks	967,550	3,323
Dining Facility	549,544	257
Total Cluster	1,517,094	3,579
Savings	1,387,311	5,180
Percent savings	48%	59%
Cost savings	$115,147	$126,769
Total cost savings	$241,916	

Alternate 2 (near Net-Zero energy ready efficient case HVAC and envelope rehabilitation costs for five barracks and a DFAC, 265 barracks complex, excluding grey water reclamation system) replaces installation of Option 3 (fan coil system) with another option to reduce incremental costs. Use two of option 1, two of Option 2, and one of Option 4.

Table 26. Costs of Alternative 2.

Improvement*	Cost
Envelope rehabilitation and upgrade costs for five barracks	$4,494,391
HVAC system upgrade costs (two of Option 1 and 2, none of Option 3, one of Option 4) for five barracks	$21,825,401
Envelope, HVAC and cooking equipment rehabilitation and upgrade costs for DFAC	$2,440,562
Chiller Plant rehabilitation and upgrade costs for 265 complex	$2,168,693
Efficiency upgrade case HVAC, Envelope and Chiller Plant rehabilitation costs for 265 barracks and DFAC complex	$30,929,047
Incremental costs between Typical Upgrade Project and Net Zero-Energy Ready Efficient Case	$1,550,391
Annual operating savings for five barracks and DFAC/yr (electricity and gas)	$170,550
Year simple payback period	9.1
* Alternative 2: Economics Net-Zero energy improvements for five barracks and DFAC Cluster with two DOAS/VAV, two DOAS/Radiant Cooling and one DOAS/VAV evaporative cooling HVAC option in Barracks —.	

Note that, while generally only a concern a few months out of the year in the climate of Fort Irwin, in other locations this approach also offers the benefit of mold prevention, which can have substantial monetary benefits; the cost avoidance of mold remediation can save $150K/yr, reducing the simple payback to 4.9 yrs.

Table 27. Costs of Alternative 3.

Rehabilitation*	Cost
Envelope rehabilitation and upgrade costs for five barracks	$4,494,391
HVAC system upgrade costs (two of Option 1 three of Option 2, none of Option 3, none of Option 4) for five barracks	$21,583,689
Envelope, HVAC and cooking equipment rehabilitation and upgrade costs for DFAC	$2,440,562
Chiller Plant rehabilitation and upgrade costs for 265 complex	$2,168,693
Efficiency upgrade case HVAC, envelope and chiller plant rehabilitation costs for 265 barracks and DFAC complex	$30,687,335
Incremental costs between typical upgrade project and Net-Zero energy ready efficient case	$1,308,679
Annual operating savings for five barracks and DFAC/yr (electricity and gas)	$170,550
Year simple payback period	7.7

* Alternative 3: Near Net-Zero energy ready efficient case HVAC and envelope rehabilitation costs for five barracks and a DFAC, 265 barracks Complex, excluding grey water reclamation system excludes installation of Options 3 and 4 to reduce incremental costs (use two of Option 1, use three of option 2).

Note that, while generally only a concern a few months out of the year in the climate of Fort Irwin, in other locations this approach also offers the benefit of mold prevention, which can have substantial monetary benefits; the cost avoidance of mold remediation can save $150K/yr, reducing the simple payback to 4.2 yrs.

Table 28. Costs of Alternate 4.

Rehabilitation*	Cost
Envelope rehabilitation and upgrade costs for five barracks	$4,494,391
HVAC System Upgrade Costs (two of Option 1 three of Option 2, none of Option 3, none of Option 4) for five barracks	$21,583,689
Envelope, HVAC and cooking equipment rehabilitation and upgrade costs for DFAC (Same as base case, no upgrade)	$1,614,932
Chiller Plant rehabilitation and upgrade costs for 265 complex	$2,168,693
Efficiency upgrade case HVAC, envelope and Chiller Plant rehabilitation costs for 265 barracks and DFAC complex	$29,861,705
Incremental costs between typical upgrade project and Net-Zero energy ready efficient case	$483,049
Annual operating savings for five barracks/yr (electricity) and gas	$170,550
Year simple payback period	2.8

* Alternate 4 Near Net-Zero Energy Ready Efficient Case HVAC and Envelope Rehabilitation Costs for five barracks and a DFAC, 265 barracks Complex, Excluding grey water reclamation system Excludes installation of Options 3 and 4 to reduce Incremental costs — Use two of Option 1, three of option 2, excludes DFAC incremental costs

Note that, while generally only a concern a few months out of the year in the climate of Fort Irwin, in other locations this approach also offers the benefit of mold prevention, which can have substantial monetary benefits; the cost avoidance of mold remediation can save $150K/yr, reducing the simple payback to 1.5 yrs.

Table 29. Costs of Alternate 5.

Rehabilitation*	Cost
Envelope rehabilitation and upgrade costs for five barracks	$4,494,391
HVAC System Upgrade Costs (two of Option 1 two of Option 2, one of Option 3, none of Option 4) for five barracks	$22,468,739
Envelope and HVAC rehabilitation and upgrade costs for DFAC (Same as base case, no cooking equipment upgrade)	$1,614,932
Chiller Plant rehabilitation and upgrade costs for 265 complex	$2,168,693
Efficiency Upgrade Case HVAC, Envelope and Chiller Plant rehabilitation costs for 265 barracks and DFAC complex	$30,746,755
Incremental costs between typical upgrade project and Net-Zero energy ready efficient case	$1,368,099
Annual operating savings for five barracks/yr (electricity) and gas	170,550
Year simple payback period	8.0
* Alternate 5: Near Net-Zero Energy Ready Efficient Case HVAC and Envelope Rehabilitation Costs for five barracks and a DFAC, 265 barracks Complex, Excluding grey water reclamation system Excludes installation of Option 4 to reduce Incremental costs — Use two of Option 1, three of option 2, excludes DFAC incremental costs	

Note that, while generally only a concern a few months out of the year in the climate of Fort Irwin, in other locations this approach also offers the benefit of mold prevention, which can have substantial monetary benefits; the cost avoidance of mold remediation can save $150K/yr, reducing the simple payback to 4.3 yrs.

3.9 Savings estimates

The estimated energy use of the five barracks and dining facility as operating during the site visit was 3.1 million kWh/yr and 7278 million Btu of LPG gas. Some of these building are scheduled for a major upgrade, which is understood to include increased insulation in the walls and roof, new windows and improvements to the lighting and HVAC system. Four HVAC options were explored. These improvements were modeled using *eQuest* computer model; the resulting estimated annual energy use savings as the result of the various upgrades range from 47 to 53 percent and 51 to 59 percent of LPG gas. Table 30 lists this energy use for a Barracks.

It is possible to further reduce the net energy consumed by further improvements to the building envelope, the HVAC, domestic hot water, lighting and other energy using systems. These improvements are contained in several Net-Zero energy ready options that have been presented in previous sections of this report. Table 31 lists the savings they can provide for a barracks building. Using current energy costs, this represents an annual energy cost savings for the five barracks of $170,000. For the dining facility, a Net-Zero energy ready set of improvements were also modeled. These improvements reduced the buildings electrical use from 670,000 kWh/yr to 550,000 kWh/yr. The LPG gas use was reduced from 811 million Btu/yr to 257 million Btu/yr. This represents a 18 percent electrical savings and a 68 percent reduction of the heating energy use. The electrical energy use reduction would have been greater if all the cooking equipment had not been switched to an electrical type. The resulting operating cost reduction is an savings of $71,000/yr.

These levels of savings were achieved while improving occupant comfort and substantially reducing the potential for biological growth in the facilities and achieving a payback period of less than 15 yrs based on the incremental costs for the more energy efficient upgrade. In many climates, the cost to mitigate biological growth in barracks facilities far exceeds the total annual energy cost of the facilities. This benefit alone could be the driving factor to use the proposed designs, even if there were no energy savings.

Table 30. Energy use of Upgrade Case, DOAS-VAV, and DOAS-FCU.

Energy Use	Upgrade Case	DOAS-VAV	DOAS-FCU
Space cooling, kWh/yr	112,100	20,700	7,700
Ventilation fans, kWh/yr	52,600	10,500	26,400
Pumps and auxiliary equipment, kWh/yr	63,900	29,400	33,000
Plug loads (soldiers) + laundry, kWh/yr	154,500	86,600	86,600
Lighting, kWh/yr	63,900	35,300	35,300
Total electric, kWh/yr	447,000	182,500	189,000
Space heating million Btu/yr	626	217	99
Domestic hot water million Btu/yr Btu	580	546	546
Total LPG gas, million Btu/yr	1,206	763	645

Table 31. Calculated energy savings for Barracks 264.

Savings	Upgrade Case vs. DOAS-VAV	Upgrade Case vs. DOAS-FCU
kWh/yr	264,500	258,000
Million Btu/yr	443	561
Energy savings calculations Barracks Cluster 263 (five Barracks)	Upgrade case vs. DOAS-VAV	Upgrade case vs. DOAS-FCU
kWh/yr	1,322,500	1,290,000
Million Btu/yr	2,215	2,805

Table 32. Utility rates used for savings calculations.

Unit	Rate
Cost per kWh	$0.083
Cost per million Btu	$24.73

Table 33. Calculated utility cost savings for Barracks Cluster 263 (five barracks).

Calculated savings	Upgrade Case vs. DOAS-VAV	Upgrade Case vs. DOAS-FCU
Electrical cost savings/yr	$109,800	$107,100
LPG cost savings/yr	$54,800	$69,400
Estimated utility cost savings per year	$164,600	$176,500
Average utility savings/yr		$170,550
Potential biological issue avoided costs/yr (humid areas of the country)		$145,000
Utility + avoided biological costs/yr		$315,550

Improvements in the dining facility will add to these savings Thus the total annual energy cost savings for the Cluster is estimated to be $170,550 plus $70,000 or $240,550.

Table 34. Costs of dining facility improvements.

Element	Cost
Potential first cost	$31,732,000
Project typical upgrade cost	$29,379,000
Projected incremental first cost after cost of typical upgrade	$2,353,000
Estimated incremental Net-Zero energy ready cost savings	$231,000
Simple payback period based on incremental cost, and energy savings	10.2 yrs

Table 35. Humid climate biological issue reduction estimate.

Number of Avoided Biological Issues (25,000 sf over 5 yrs)	Avoided Cost per Biological Issue	Avoided Costs of Biological Issues (25,000 sf over 5 yrs)	Avoided Costs of Biological Issues (per yr per 25,000 sf)
2.5	$50,000	$125,000	$25,000
Barracks size (sq ft)	Barracks quantity	Barracks total (sq ft)	Barracks avoided biological issues savings
29,000	5	145,000	$145,000
Note this is an estimate of the avoided biological-related costs that may occur due to the design of the proposed HVAC systems in humid climates. These savings will not occur without the monsoon season that occurs in seemingly similar desert environments such as Fort Huachuca in AZ. In some areas of the country, these estimates will be on the low side.			

3.10 Summary of building Cluster energy use

Considering the five barracks using the DOAS VAV HVAC system and one dining facility together as a group, the total use after a typical Army upgrade (Table 36) is an estimated 2900 MWh and 8800 million Btu of liquid propane per year. After the identified energy conservation measures are implemented in such an upgrade the annual energy use will be reduced to 1460 MWh and 4100 million Btu. The resulting energy savings is 1440 MWh of electricity and 4700 million Btu of LPG gas for an annual energy cost savings of $234,000. This cost saving value is reduced to $231,000/yr assuming the average savings between the DOAS VAV and DOAS FCU HVAC system is applied.

Table 36. Summary of building Cluster energy use after typical building upgrade.

	Upgrade Case		Base Case	
Energy use comparison	One Barracks	Five Barracks	Dining Facility	Total Use
Space cooling, kWh	112,100	560,500	82,500	643,000
Heat rejection, kWh			7,260	7,260
Ventilation fans, kWh	52,600	263,000	270,130	533,130
Pumps and auxiliary equipment, kWh	63,900	319,500	40,800	360,300
Plug loads (soldiers) + laundry, kWh	154,500	772,500	201,950	974,450
Lighting, kWh	63,900	319,500	66,940	386,440
Sum, kWh/yr	447,000	2,235,000	669,580	2,904,5800
Space heating million Btu	626	3,130	679	3,809

Energy use comparison	Upgrade Case		Base Case	
	One Barracks	Five Barracks	Dining Facility	Total Use
Domestic hot water million Btu	580	2,900	132	3,032
Misc. equipment, million Btu			1,915	1,915
Sum, million Btu/yr	1,206	6,030	2,726	8,756

Table 37. Summary of building Cluster energy use after Energy Conservation Measure (ECM) implementation

Energy Use Comparison	1 Barracks — DOAS — VAV After ECMs	five barracks — DOAS — VAV After ECMs	Dining Facility After ECMs	Total Energy Use Before	Total Use After ECMs	Savings	%
Space Cooling, kWh	20,700	103,500	15,752	643,000	119,252	523,748	
Heat rejection, kWh		-	1,529	7,260	1,529	5,731	
Ventilation fans, kWh	10,500	52,500	113,218	533,130	165,718	367,412	
Pumps and auxiliary equipment, kWh	29,400	147,000	18,620	360,300	165,620	194,680	
Plug loads (soldiers) + laundry, kWh	86,600	433,500	365,390	974,450	798,890	175,560	
Lighting, kWh	35,300	176,500	35,035	386,440	211,535	174,905	
Sum, kWh/yr	182,500	912,500	549,544	2,904,500	1,462,044	1,442,456	33%
Space heating MMBtu	217	1,085	190	3,809	1,275	2,534	
Domestic hot water MMBtu	546	2,730	67	3,032	2,797	235	
Misc. equipment, MMBtu		-	0	1,915	-0	1,915	
Sum, MMBtu/yr	763	3,815	257	8,756	4,072	4,684	84%

3.11 Net-Zero

For a "Net- Zero" energy using building group the resulting energy use would need to be satisfied by renewable energy sources. These sources could include energy generated by solar, wind, hydro power, biomass, waste products and geothermal energy sources. For the location of Fort Irwin, the energy sources of solar and waste products seem to be the most attractive for satisfying the energy demands of this building group. As discussed in the following chapter, Installing Solar Thermal, Biomass (Wood Chip), and photovoltaic (PV) electrical generation can save 4832 million Btu/yr (48,320 therms/yr) in heating energy (both space and DHW) and generate 41,630 KWh/yr. This combined with the measures discussed here would result in a zero net energy heating use and 1,420,414 KWh/yr electrical use. The electrical use can be offset further with waste to energy cogeneration, or the use of a trigeneration plant.

4 Additional Cluster Savings Measures

4.1 DHW-1: Turn off DHW circulation pump during off-hours, Dining Facility 271

4.1.1 Existing conditions/problems

During the site survey, the pump that circulates hot water through the dining facility building (Figure 9) was observed to be operating with no controls to shut it down when the building is unoccupied.

4.1.2 Solution

Provide time clock type controls to turn the domestic hot water pump off from 1930 to 0530 in the morning.

4.1.3 Savings

The total energy savings from shutting down this pump are:

Pump energy = 1/12 hp x 0.746 kW/hp x 10 hr/day x 365 days/yr = 227 kWh/yr

Electrical cost savings = 227 kWh/yr x $0.083/kWh = $19/yr

Figure 9. Hot water circulating pump.

4.1.4 Investment

The cost for a time clock to shut off this pump is $570. (The value used was obtained from the RS Means estimating guide.)

4.1.5 Payback

The resulting payback is 30 yrs.

4.2 CEP-1: Turn off boilers when no demand, Bldg 263

4.2.1 Existing conditions/problems

During the site visit, all three boilers were in the operating mode with one cycling on and off to heat domestic water for five barracks and a dining facility. The outdoor temperatures were very warm and all building heating systems were off. A gas meter that measures the energy use of these boilers was read over a day period and it was noted that 3600 cu ft were consumed. The major domestic hot water use in the barracks is in the morning from 0730 to about 0830, in the afternoon from 1600 to about 1800, and at night from 2200 to about midnight. In the dining facility, the hot water use is somewhat continuous from 0700 to 1900.

The boilers could be shut down from midnight to 0700 without affecting the domestic hot water availability since there is little or no use during this time period. In all buildings, there are hot water storage tanks, so any unexpected requirement for hot water could come from these storage tanks. The current operation of the boilers wastes heating energy.

4.2.2 Solution

Install controls to shut down one boiler during the summer and all the boilers from midnight to 0700 in the morning. The hot water circulating pump should also be shut down during the 7-hr time period.

4.2.3 Savings

It is estimated that the use of controls to regulate the cycling of the boiler to generate heat, combined with the avoidance of heat losses from the piping system for 7 hrs per day, will yield a 5 percent energy savings. Also, a 30 hp pump that circulates the hot water to all be buildings could be shut off when the boilers are off to further save electrical energy. These savings total:

Heating energy saved = 3600 cu ft propane gas/day x 5% x 120 days/yr x 2500 Btu/cu- ft = 54 MMBtu/yr
Heating cost savings = 54 MMBtu/yr x $24.73/MMBtu = $1,335
Pump energy = 30 hp x 0.746 kW/hp x 7 hr/day x 120 days/yr = 18,800 kWh/yr
Electrical cost savings = 18,800 kWh/yr x $0.083/kWh = $1,560/yr
Total cost savings = $2,900/yr

4.2.4 Investment

The total estimated cost of installing the boiler controls $9600. (This estimate was determined using RS Means estimating guides.)

4.2.5 Payback

The resulting payback is 3.3 yrs.

4.3 L–1: Improved lighting controls, Barracks 261

4.3.1 Existing conditions/problems

It was noted that the laundry and day room (lounge) areas in Barracks 261 (Figure 10) had their lights on even when unoccupied. Occupancy in these spaces varies; lights could be shut off many hours of the day to save electricity.

Figure 10. Fort Irwin Barracks Building.

4.3.2 Solution

In these areas, use varies depending on the building's occupancy. In such cases, the operation of the lighting system can be best controlled by occupancy sensors. Occupancy sensors can be installed that automatically switch lights on when movement is sensed. The lighting level will be maintained until a set period of time has elapsed with no movement observed. A period of 5 to 10 minutes would be adequate to ensure the space is truly unoccupied.

Such lighting controls should be placed in the laundry and day room areas of all barracks. One sensor would be at the light switch when you enter the laundry room, and two sensors would be required for the lounge area. Both of these spaces have fluorescent lighting, which will relight quickly after being off.

4.3.3 Savings

Using barracks number 261 as an example, the total estimated energy cost savings is $174/yr. It is estimated that the lights are on 34 percent of the time in the laundry room when they are not needed and 30 percent of the time in the day rooms. This Energy Conservation Measure (ECM) applies to all barracks at Fort Irwin. Total savings may be calculated as:

Electrical savings = 1 laundry x 4 fixtures x 0.064 kW/fixture x 168 hr/wk x 34% x 52 wk/yr + 1 day room x 8 fixtures x 0.064 kW/fixture x 168 hr/wk x 30% x 52 wk/yr = 2100 kWh/yr

Electrical cost savings = 2100 kWh/yr x $0.083/kWh = $174/yr

4.3.4 Investment

The cost to install an infrared, wall-mounted occupancy sensor where the lighting switch is $200 each for a simple replacement of the light switch. The total investment cost for installing occupancy sensors in the laundry room and day room of one barracks is $600.

4.3.5 Payback

The resulting payback for lighting controls in the laundry room and day room of Barracks 261 is 3.4 yrs. This application applies to all barracks at Fort Irwin.

5 Renewable Energy Sources for the Cluster

5.1 Heating Option A: Solar thermal systems for domestic hot water, Bldgs 261, 262, 264, 265, 267, 271

5.1.1 Existing conditions/problems

The Energy Assessment 2009 at Fort Irwin focused on a Cluster of buildings including Barracks 261, 262, 264, 265, 267, Dining Facility 271, and Central Heating Bldg 263 (Figure 11). The target of the Energy Assessment activities was to minimize the net energy use of this Cluster.

The Barracks and the Dining Facility are connected to the Central Heating Plant (Bldg 263) by a district heating grid. Three boilers, 2060 MBtu/hr each, are generating heat for DHW and Space Heating (SPH). No water storage tanks are installed in the Central Heating Plant. DHW storage tanks with a capacity of approx. 1500 gal are installed in each building.

Table 38 lists the basic data used for calculations. The LPG and electricity prices are the actual values given during the energy assessmant. The assumption of the price increases per year for LPG, electricity, and other issues (labor, etc.) are certainly at a lower level compared to energy price increases of the past, but the calculations are based on a conservative approach.

Figure 11. Building Cluster (Bldgs 261–267, 271).

Table 38. Basic data used for calculations.

Basic Data – Energy Concepts	Units	Value
LPG	$/kWh	0.084
Electricity	$/kWh	0.083
Price increase LPG/yr		5%
Price increase power/yr		3%
Price increase others/yr		2%
Total electricity consumption (1 building)	kWh	292,500
Electricity — building load (1 building)	kWh	139,000
Electricity — plug-in load (1 building)	kWh	153,500
Total electricity consumption (271-DFAC)	kWh	549,544
Total electricity consumption (all buildings)	kWh	2,012,044
DHW (1 building) — heat requirement — net	MMBtu	533.6
DHW (1 building) — heat requirement — net	kWh	156,344
Boiler efficiency		92%
DHW (1 building) — heat requirement — gross	MMBtu	580.0
DHW (1 building) — heat requirement — gross	kWh	169,940
DHW (271-DFAC) — heat requirement — net	MBtu	61.27
DHW (271-DFAC) — heat requirement — net	kWh	17,952
Boiler efficiency		92%
DHW (271-DFAC) — heat requirement — gross	MMBtu	66.6
DHW (271-DFAC) — heat requirement — gross	kWh	19,513
No. Barracks		5
DHW (all buildings) — heat requirement — net	MMBtu	2,729.3
DHW (all buildings) — heat requirement — net	kWh	799,676
DHW (all buildings) — heat requirement — gross	MMBtu	2,966.6
DHW (all buildings) — heat requirement — gross	kWh	869,213
Capacity LPG boiler	MBtu	2,060
Capacity LPG boiler	kW	603
No. LPG boiler (existing)		3
Total capacity LPG boiler	MBtu	6,180
Total capacity LPG boiler	kW	1,810
Estimated maintenance LPG labor/yr	hr	250
Labor cost	$/hr	65
Maintenance/cost LPG/yr	$	13,000
Estimated repair cost LPG/yr	$	15,000
Total maintenance LPG/yr	$	28,000

5.1.2 Solution

Install Solar Thermal Systems on top of the Barracks to cover most of the DHW demand of these buildings (reference Figure 12). Because of the minor DHW demand in the Dining Facility, the heat for DHW supply of the Dining Facility would be produced by the central heating system.

The DHW demand is met with 35 solar thermal collectors placed on top of each barracks (Figure 13). The Solar Thermal System is connected to the water storage tank located in the mechanical room of each barracks.

Due to the performance of the Solar Thermal System, one LPG boiler can be removed from the Central Heating Plant.

The Solar Thermal System of Paradigma (Figure 14) is selected as the most appropriate system. The CPC Star Azzurro is suitable for installation on pitched roofs, flat roofs, facades or as a free-standing installation. High-quality, corrosion-resistant and tested materials ensure reliable operation over the entire service life.

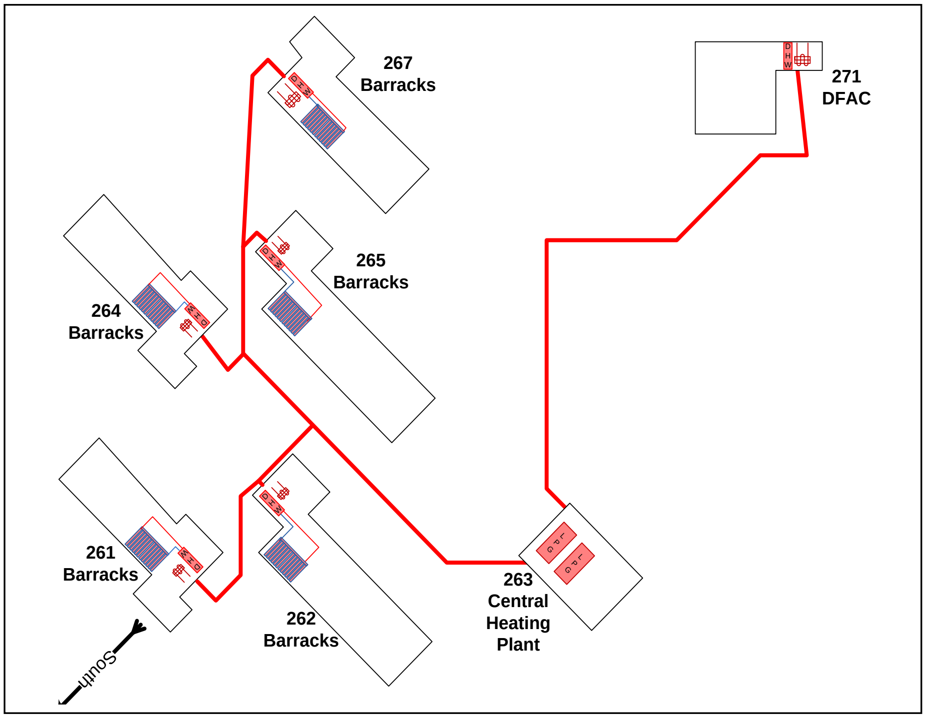


Figure 12. Schematic of DHW and SPH Supply (building Cluster).

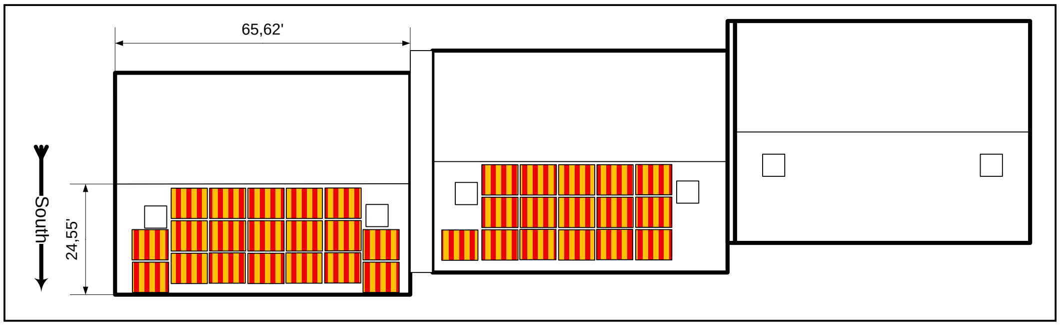


Figure 13. Position of solar thermal panels.

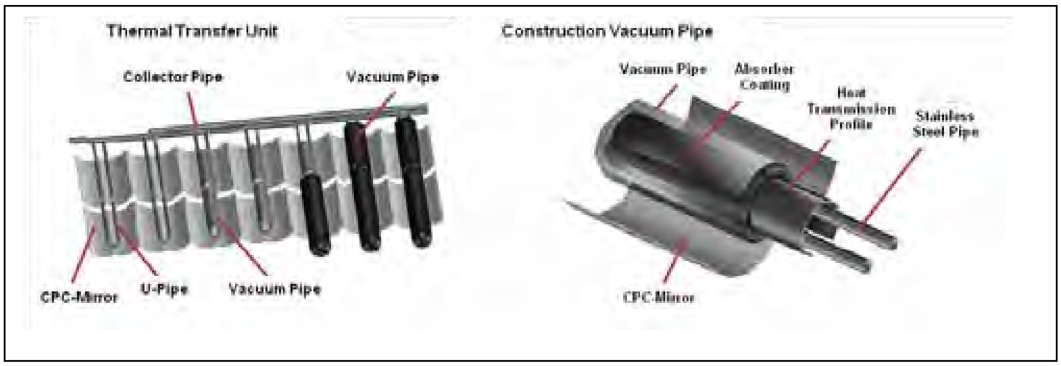


Figure 14. CPC Star Azzuro — Paradigma.

The system achieves an extremely high energy yield even with a small gross collector area. The collector modules with different widths and lengths make it highly flexible. It consists of three main components, which are completely pre-assembled: the evacuated tubes, the mirror, and the manifold with a heat transfer unit and integrated return pipe.

The coverage of the DHW demand with the Solar Thermal System for one building is approximately 90 percent. In the summer period, the Solar Thermal System is designed to cover 100 percent of the DHW demand (Figure 15). Table 39 lists the required solar thermal system investment.

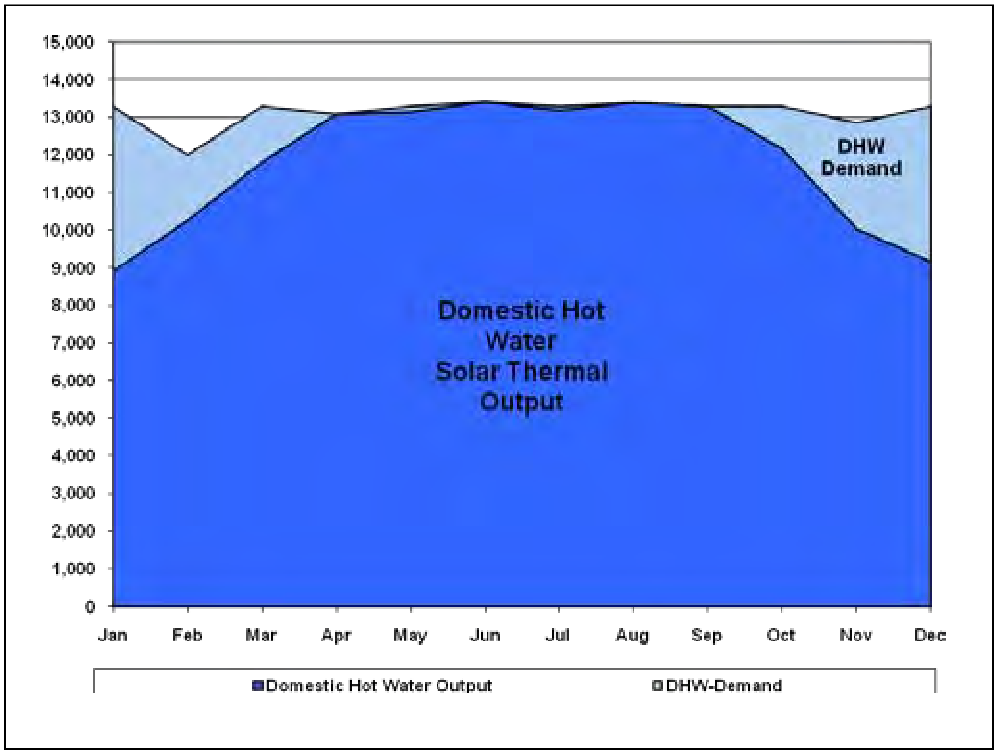


Figure 15. Solar thermal DHW coverage.

5.1.3 Investment

Table 39. Solar thermal system investment.

Investment	Unit	Value	Remarks
No Panels CPC 45 Star		35	
Panel area — Aperture	m²	4.50	
Panel area — gross	m²	4.95	
Total area — Aperture	m²	157.50	
Total area – Aperture	sq ft	1,695	
Investment PV-panels	$/m²	400	
Total panel investment	$	63,000	
Roof mounting systems (% of panel investment)	$	15%	
Investment roof mounting systems	$	9,450	
Investment materials/pipes	$	5,000	
Investment solar storage tank	$	7,500	Optional to use existing storage tanks.
Labor roof mounting	hr	100	
Labor piping	hr	150	
Labor system integration	hr	100	

Investment	Unit	Value	Remarks
Labor system check	hr	50	
Total labor	hr	400	
Investment labor cost	$	26,000	
Planning/consulting cost — % of investment		15%	
Planning/consulting cost	$	16,642	
Total investment	$	127,592	
Maintenance cost/yr (% of invest)		0.50%	
Maintenance cost/yr	$	424	
Investment solar system (1 building)	$	127,592	
Incentive CSI solar system (1 building)	$	-33,906	$20/sq ft
Total investment (1 building)	$	93,685	
Total incentive CSI cluster	$	75,000	Maximum CSI incentive if Cluster Solar Thermal Systems are defined as one system. If defined as five different Systems incentives ➔$220,350 achievable.
Total investment solar all buildings	$	637,962	Total investment with higher incentives ➔$468,425.

The investment prices for the Solar Thermal System are verified by the subsidy of Paradigma in the United States. The total investment for the Solar Thermal Systems includes costs of planning, consulting, and installation.

The Army could be eligible for the California Solar Initiative (CSI) offered through their Pilot Solar Water Heating Program. This incentive is $20/sq ft up to a maximum of $75,000 for larger commercial buildings. Note that collectors must be Solar Rating and Certification Corporation (SRCC) OG100 rated and must have a minimum of a 10-yr manufacturer's warranty on the individual balance of system components, and 1-yr warranty on installation labor and workmanship.

In the total investment, the lower incentives of $75,000 for the Cluster are considered because the five Solar Thermal Systems are assumed to be treated as one Solar Thermal System. In case the five Solar Thermal Systems are treated as separate systems the total investment can be reduced by $220,350. Such a reduction of investment cost will improve the return of investment by approximately 2 to 3 yrs (Table 40).

The total savings of heat production cost is approximately 56 percent (in 1 yr) and approximately 57 percent (in 20 yrs). In the first year, the LPG consumption can be reduced by 28,501 gal. In 20 yrs the LPG consumption will be reduced by 661,163 gal.

5.1.4 Savings

Table 40. Savings attributed to solar thermal systems.

Savings	Unit	First Year	20 Years
Total cost heat production ECM-case	$	153,844	4,841,483
Total cost heat production	$	86,183	2,781,222
Total energy production cost	$	253,183	7,268,565
Savings heating cost — without financing	$	67,661	2,060,261
Savings heating cost — with financing	$	22,488	1,156,790
Total heat production LPG	kWh	789,395	16,441,429
Total heat production solar	kWh	708,750	13,521,464
Total heat production LPG	MBtu	2,694,180	56,114,092
Total heat production Solar	MBtu	2,418,942	46,148,343
Savings LPG	kWh	708,750	16,441,429
Savings LPG	l	107,877	2,502,501
Savings LPG	gal	28,501	661,163

5.1.5 Payback

Figure 16 shows the heating costs and return of investment.

This option offers the chance to lower the energy cost by approximately 56 percent with an investment of approximately $640,000:

Return on Investment (ROI) period without cost of capital: 7 yrs

ROI period with cost of capital: 13 yrs

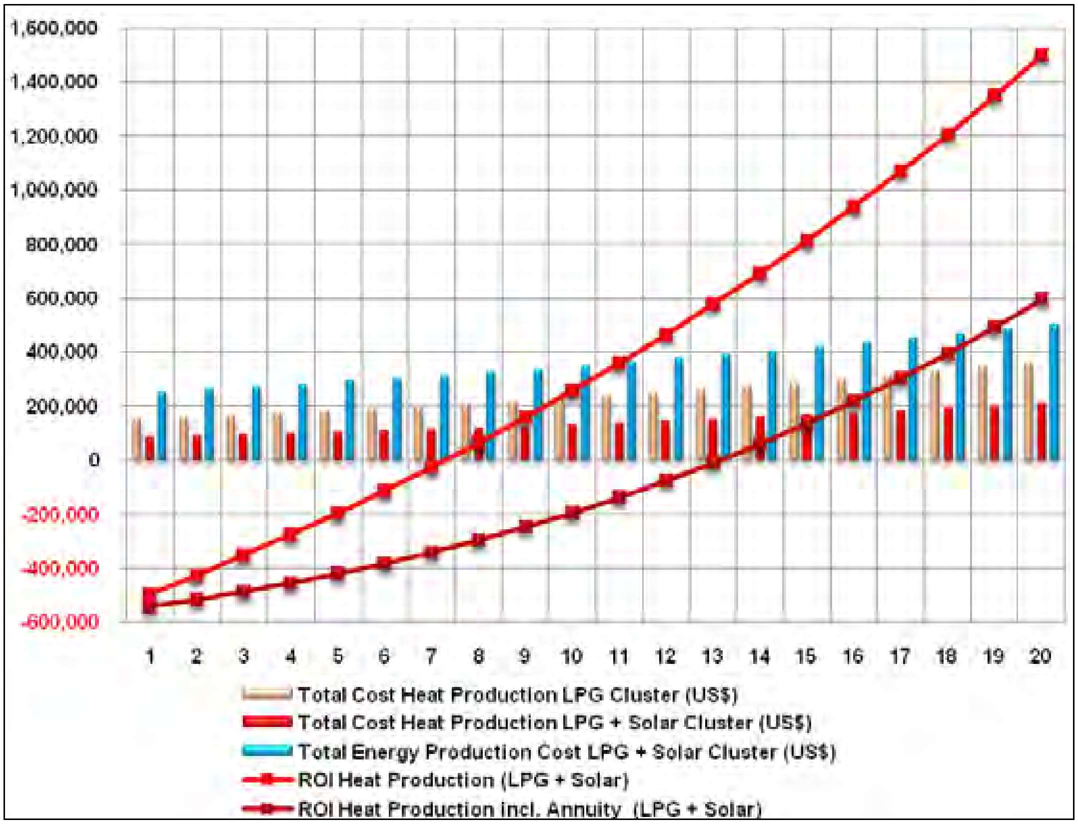


Figure 16. Heating cost and return of investment.

5.2 Heating Option B: Solar thermal systems for domestic hot water and biomass for space heating building heating, Bldgs 261, 262, 264, 265, 267, 271

5.2.1 Existing conditions/problems

The Energy Assessment 2009 at Fort Irwin focused on a Cluster of buildings including Barracks 261, 262, 264, 265, 267, Dining Facility 271, and Central Heating Bldg 263. The target of the Energy Assessment activities was to minimize the net energy use of this Cluster.

The Barracks and the Dining Facility are connected to the Central Heating Plant (Bldg 263) by a district heating grid. Three boilers, 2060 MBtu/hr each, are generating heat for DHW and SPH. No water storage tanks are installed in the Central Heating Plant. DHW storage tanks with a capacity of approximately 1500 gal are installed in each building.

Table 41 lists the basic data used for calculations. The LPG and electricity prices are the actual values given during the energy assessmant. The assumption of the price increases per year for LPG, electricity, and other issues (labor, etc.) are certainly at a lower level compared to energy price increases of the past, but the calculations are based on a conservative approach.

5.2.2 Solution

Install Solar Thermal Systems on top of the barracks to cover most of the DHW demand of these buildings (reference Figure 17). The heat production in the central heating plant would use wood waste as the fuel source for approximately 95 percent of the heat requirement. The LPG boilers would be used only as peak load boilers and for redundancy during Biomass System maintenance.

Table 41. Basic data used for calculations for 5.2 Heating Option B.

Basic Data – Energy Concepts	Units	Value
LPG	$/kWh	0.084
Electricity	$/kWh	0.083
Price increase LPG/yr		5%
Price increase power/yr		3%
Price increase others/yr		2%
Total electricity consumption (1 building)	kWh	292,500
Electricity — building load (1 building)	kWh	139,000
Electricity — plug-in load (1 building)	kWh	153,500
Total electricity consumption (271-DFAC)	kWh	549,544
Total electricity consumption (all buildings)	kWh	2,012,044
DHW (1 building) — heat requirement — net	MMBtu	533.6
DHW (1 building) — heat requirement — net	kWh	156,344
Boiler efficiency		92%
DHW (1 building) — heat requirement — gross	MMBtu	580.0
DHW (1 building) — heat requirement — gross	kWh	169,940
DHW (271-DFAC) — heat requirement — net	MBtu	61.27
DHW (271-DFAC) — heat requirement — net	kWh	17,952
Boiler efficiency		92%
DHW (271-DFAC) — heat requirement — gross	MMBtu	66.6
DHW (271-DFAC) — heat requirement — gross	kWh	19,513
SPH (1 building) — heat requirement — net	MMBtu	360.0
SPH (1 building) — heat requirement — net	kWh	105,480

Basic Data – Energy Concepts	Units	Value
Boiler efficiency		92%
SPH (1 building) — heat requirement — gross	MMBtu	391,3
SPH (1 building) — heat requirement — gross	kWh	114,652
SPH (271-DFAC) — heat requirement — net	MMBtu	174.8
SPH (271-DFAC) — heat requirement — net	kWh	52,216
Boiler efficiency		92%
SPH (271-DFAC) — heat requirement — gross	MMBtu	190.0
SPH (271- DFAC) — heat requirement — gross	kWh	55,670
No. barracks		5
DHW (all buildings) — heat requirement — net	MMBtu	2,729.3
DHW (all buildings) — heat requirement — net	kWh	799,676
DHW (all buildings) — heat requirement — gross	MMBtu	2,966.6
DHW (all buildings) — heat requirement — gross	kWh	869,213
SPH (all buildings) — heat requirement — net	MMBtu	1,974.8
SPH (all buildings) — heat requirement — net (kWh)	kWh	578,616
SPH (all buildings) — heat requirement — gross	MMBtu	2,146.5
SPH (all buildings) — heat requirement — gross	kWh	628,930
Capacity LPG boiler	MBtu	2,060
Capacity LPG boiler	kW	603
No. LPG boiler (existing)		3
Total capacity LPG boiler	MBtu	6,180
Total capacity LPG boiler	kW	1,810
Estimated maintenance LPG labor/yr	hr	250
Labor cost	$/hr	65
Maintenance/cost LPG/yr	$	13,000
Estimated repair cost LPG/yr	$	15,000
Total maintenance LPG/yr	$	28,000

The DHW demand is met with 35 solar thermal collectors placed on top of each barracks. The Solar Thermal System is connected to the water storage tank located in the mechanical room of each barracks. The heat production in the Central Heating Plant is done by a Biomass System. The two LPG boilers are only used for peak load and redundancy purposes. Due to the performance of the Solar Thermal System and the Biomass System, one LPG boiler can be removed from the Central Heating Plant.

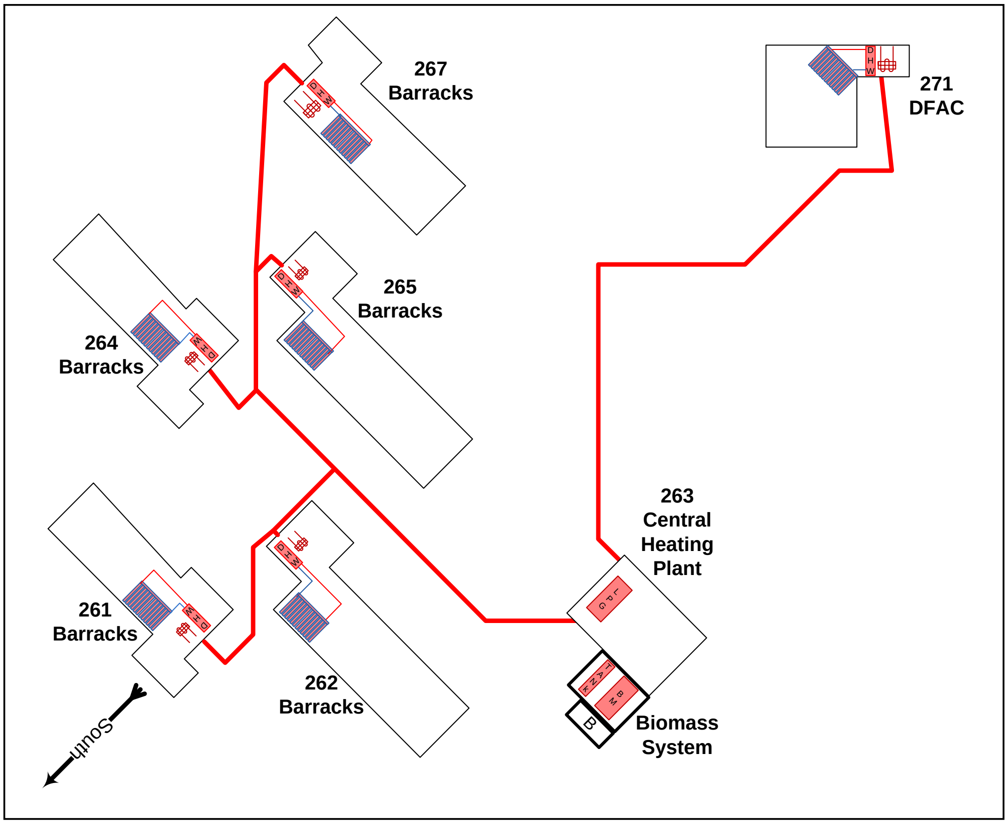


Figure 17. DHW and SPH supply (building Cluster).

5.3 Solar thermal system

The Solar Thermal System of Paradigma is selected as the most appropriate system. The CPC Star Azzurro is suitable for installation on pitched roofs, flat roofs, facades or as a free-standing installation. High-quality, corrosion-resistant and tested materials ensure reliable operation over the entire service life.

The system achieves an extremely high energy yield even with a small gross collector area. The collector modules with different widths and lengths make it highly flexible. It consists of three main components, which are completely pre-assembled: the evacuated tubes, the mirror, and the manifold with a heat transfer unit and integrated return pipe.

5.4 Biomass system

To install a Biomass System, an extension to Bldg 263 has to be designed and constructed (Figure 18).

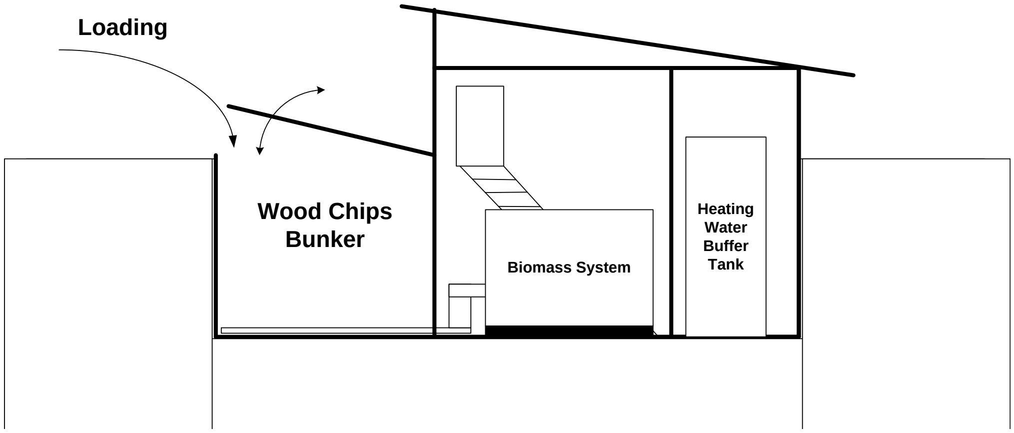


Figure 18. Proposed building expansion for biomass system at Bldg 263.

The floor of the bunker should be at the same level as the Biomass System. This type of construction increases the reliability of the operation.

The Biomass System requires an approximately 4000 gal heating water buffer tank, which optimizes the performance of a biomass system because biomass systems cannot be switched on and off like LPG systems. The bunker should be sized to run the Biomass System at least 1 week without refilling. In this case, the bunker size should be approximately 3530 cu ft. This storage volume offers a heating capacity of approximately 56,000 kWh. Since the heat requirement in January is approximately 150,000 kWh for DHW and SPH, the most frequent refilling schedule of the bunker (in winter time) would be three refillings per month.

The Bunker design (Figure 19) would be 16 ft wide x 16 ft long x 13 ft high. The Biomass System technology (Figure 20), in combination with the buffer tank, will modulate the different heat requirement levels and enable operation at lower heat requirement levels between spring and autumn.

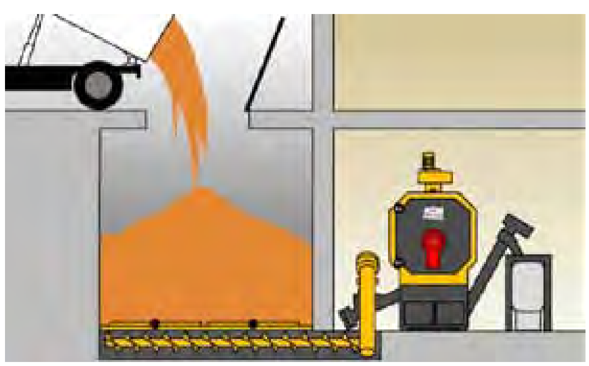


Figure 19. Proposed wood chip bunker.

Figure 20. Biomass System — Pyrot KÖB/Vissmann.

This system includes:

- feeder module with barrier control
- moving grate
- primary air control valve
- flue gas recirculation control valve
- ignition blower
- de-asher
- secondary air control valve with rotation blower
- rotation combustion chamber
- boiler heat exchanger
- safety heat exchanger
- pneumatic pipe cleaning system
- induced draft fan.

Continuous gasification is carried out on the moving grate with minimal primary air. The combustible gases rise into the rotary combustion chamber and are mixed with secondary air that has been diffused by the rotation blower and given spin impulse. This guarantees an optimal mixture of secondary air with the combustible gases. The optimal combustion lowers the emissions of CO and NO_x to below that of modern oil heating systems. Unlike oil and gas, wood is CO_2-neutral and renewable. Used with the modulating output controllers, burner efficiency of more than 90 percent is achievable. Figure 21 shows an example biomass system mechanical room.

Figure 21. Example biomass system mechanical room.

Fuel extraction from the bunker is by hydraulic pushrods and cross auger. With the sliding bar feeder located at the front, loading may also be done from the end. Large amounts of fuel can be efficiently loaded in this way.

The combustion is virtually dust free; however, for fuels with particles, a flue gas de-duster (flue cyclone, cf. Figure 22) is recommended. The dust emission limits are easily achieved even for the most difficult fuels.

Today the wood waste (pallets, packaging, trees, etc., cf. Figure 23) at Fort Irwin is shredded and dumped in the landfill. This is a waste of energy because approximately 50 percent of the wood waste is untreated wood, which can be used as fuel.

The reports of the fiscal year (FY) 2008 show availability of approximately 900 tons of wood waste (Figure 24). It is expected that the available volume of wood waste will remain at this level in the coming years.

Figure 22. Flue gas de-duster.

Figure 23. Wood waste at Fort Irwin.

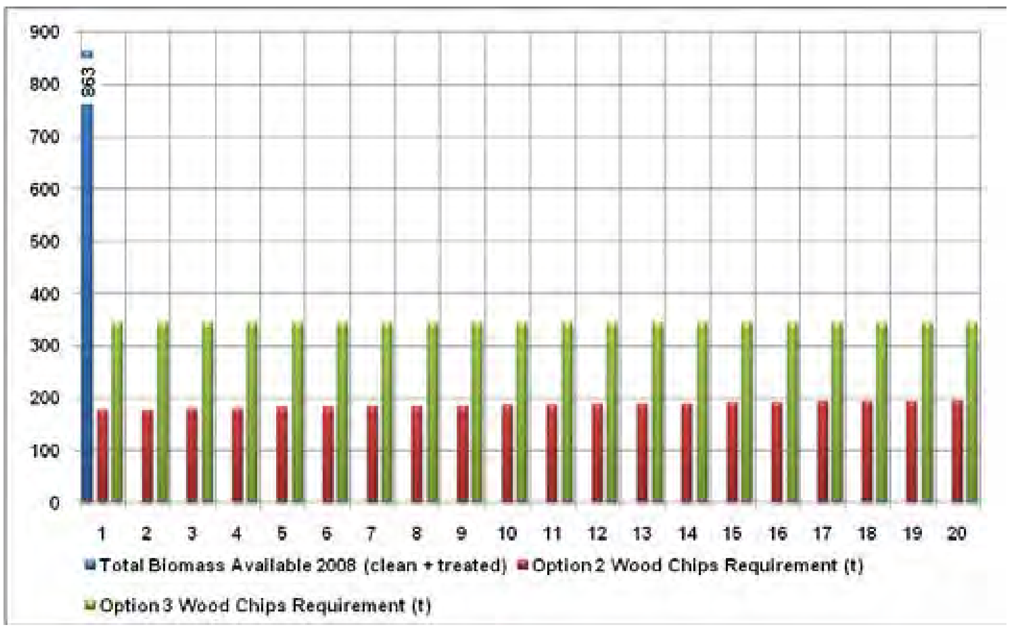


Figure 24. Availability of wood waste at Fort Irwin.

The required volume of wood waste is approximately 180 tons/yr. The expected volume of wood waste will cover the requirements if half of the wood waste is untreated wood. Treated wood should not be used as a fuel source because of emission problems (dioxin or other harmful substances).

To ensure a reasonable quality of wood chips, an investment in new wood chopping equipment (Figure 25) is included in the calculation.

Figure 25. Wood chopping system.

Figure 26. Wood chips and wood waste.

A wood chopping system comparable to the equipment shown here should be used for wood chip production (Figure 26). The chosen size of the wood chopping system is capable to cover the production needs.

Using the pre-drying system, the rotary boiler can also burn different qualities of chips efficiently. Waste wood (untreated wood waste from the wood processing industry) can be used.

The majority of the heat for the DHW demand is produced with the Solar Thermal System (Figure 27, Table 42). The heat requirement for the rest of the DHW demand and for the SPH is produced by the Biomass System. In periods where the full-load hours of the Biomass system are too low, the LPG boiler will produce the remaining heat requirement. During this period, the maintenance of the Biomass System can be done.

Investment prices for the Solar Thermal System are verified by the subsidy of Paradigma in the United States. The total investment for the Solar Thermal Systems includes costs of planning, consulting, and installation.

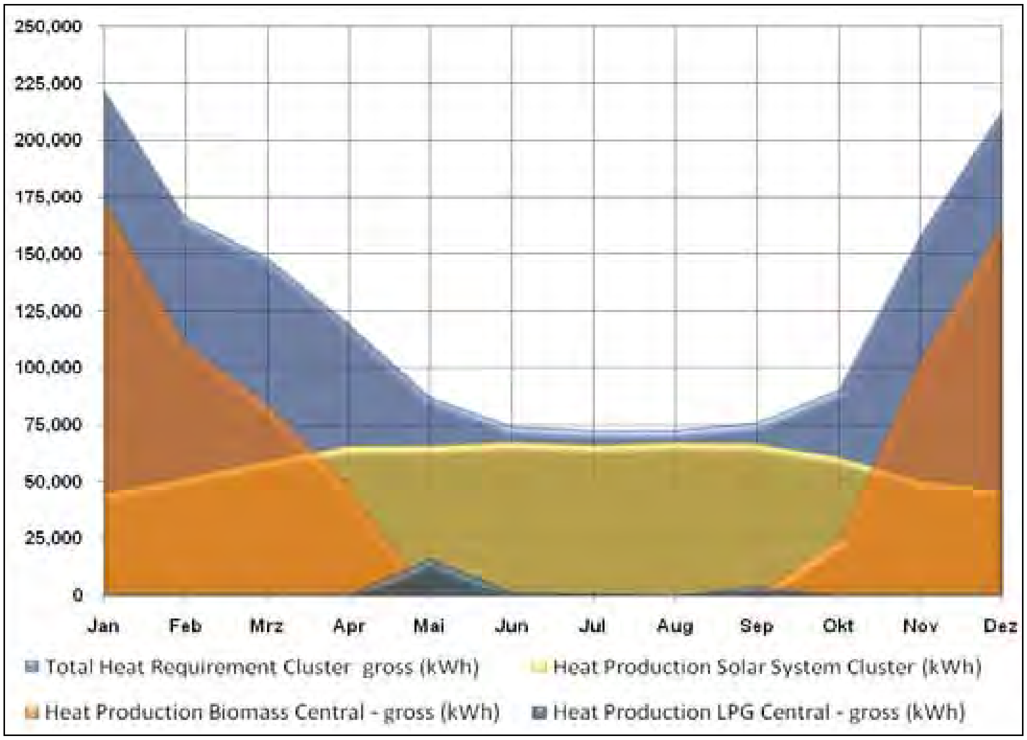


Figure 27. Portions of heat production.

5.4.1 Investment

Table 42. Solar thermal system

Solar Thermal System Investment	Unit	Value	Remarks
No panels CPC 45 Star		35	
Panel Area — Apertur	m²	4.50	
Panel area — gross	m²	4.95	
Total area — Apertur	m²	157.50	
Total area – Apertur	sq ft	1,695	
Investment PV-panels	$/m²	400	
Total panel investment	$	63,000	
Roof mounting systems (% of panel investment)	$	15%	
Investment roof mounting systems	$	9,450	
Investment materials/pipes	$	5,000	
Investment solar storage tank	$	7,500	Optional to use existing storage tanks.
Labor roof mounting	hr	100	
Labor piping	hr	150	
Labor system integration	hr	100	
Labor system check	hr	50	
Total labor	hr	400	

Solar Thermal System Investment	Unit	Value	Remarks
Investment labor cost	$	26,000	
Planning/consulting cost % of investment		15%	
Planning/consulting cost	$	16,642	
Total investment	$	127,592	
Maintenance cost/yr (% of invest)		0.50%	
Maintenance cost/yr	$	424	
Investment solar system (1 building)	$	127,592	
Incentive CSI solar system (1 building)	$	-33,906	$20/sq ft
Total investment (1 building)	$	93,685	
Total incentive CSI cluster	$	75,000	Maximum CSI incentive if cluster solar thermal systems are defined as one system. If defined as five different systems incentives ➔$220,350 achievable.
Total investment solar all buildings	$	637,962	Total investment with higher incentives ➔$468,425.

The Army could be eligible for the CSI offered through their Pilot Solar Water Heating Program. This incentive is $20/sq ft up to a maximum of $75,000 for larger commercial buildings. Note that collectors must be SRCC OG100 rated and must have a minimum of a 10-yr manufacturer's warranty on the individual balance of system components, and 1-yr warranty on installation labor and workmanship.

In the total investment, the lower incentives of $75,000 for the Cluster are considered because the five Solar Thermal Systems are assumed to be treated as one Solar Thermal System.

In case the five Solar Thermal Systems are treated as separate systems, the total investment can be reduced by $220,350. Such a reduction of investment cost will improve the return of investment by approximately 2 to 3 yrs.

Table 43 lists the calculation of the wood chips prices. The wood chips price decreases with higher production volume. Using wood chips instead of LPG lowers the fuel prices by approximately 78 percent. Investment cost and the cost of capital are included in the wood chips price (Table 44).

Table 43. Investment wood chopping system/wood chips price calculation.

Energy Price — Wood Chip Production	Units	Values
Wood chopping system	$	125,000
Dedicated transport container	$	25,000
Total investment wood chips supply	$	150,000
Total cost wood chips supply — 20 yrs	$	240,728
Total production wood chips — 20 yrs	tons	4,000
Investment allocation wood chips	$/ton	60.18
Labor cost wood chips production/transport	$/ton	2.00
Total cost wood chips supply	$/ton	62.18
Heat energy wood chips	kWh/kg	4.00
Total heat energy wood chips — 20 years	kWh	16,000,000
Energy price wood chips	$/kWh	0.0155

Table 44. Biomass system investment.

Investment	Cost ($)
Biomass boiler system	100,000
Control equipment	10,000
Scrabber floor	60,000
Flue gas de-duster	15,000
Stack system	40,000
Buffer storage tank	15,000
Hydraulic system integration	10,000
Piping system	25,000
Building extension – construction work	150,000
Bunker wood chips – construction work	100,000
Hydraulic bunker cover	40,000
miscellaneous	50,000
Planning/consulting cost — % of investment	15%
Planning/consulting cost	92,250
Total investment biomass system	707,250
Maintenance cost/yr (labor) biomass system	16,250
Contingencies cost biomass system/yr (% of investment)	2%
Contingencies (repair/replacement) biomass system/yr	14,145
Maintenance cost/yr LPG system	4,600
Total maintenance cost/yr	34,995

All construction work and all equipment needed to install the Biomass System is included in the investment calculation. Due to the fact that biomass technology is new to Fort Irwin, additional costs for training, technology transfer, planning, and consulting are included. The maintenance cost of the Biomass System is higher than the maintenance cost of the LPG System. Table 45 lists savings attributed to biomass system.

5.4.2 Savings

Table 45. Savings attributed to biomass system.

Savings	Units	First Year	20 Years
Total cost heat production ECM-case	$	153,844	4,841,483
Total cost heat production biomass	$	41,385	1,019,467
Total cost heat production lpg	$	6,347	172,833
Total cost heat production	$	47,732	1,192,300
Total cost heat production + annuity	$	138,080	2,999,243
Savings heating cost — without financing	$	106,112	3,649,183
Savings heating cost — with financing	$	15,765	1,842,240
Total heat production biomass	kWh	706,962	14,829,302
Total heat production LPG	kWh	20,802	436,348
Total heat production solar	kWh	708,750	13,521,464
Total heat production	kWh	1,436,514	28,787,114
Total heat production biomass	MBtu	2,412,840	50,611,951
total heat production LPG	MBtu	70,997	1,489,241
Total heat production solar	MBtu	2,418,942	46,148,343
Total heat production	MBtu	4,902,779	98,249,535
Savings LPG	kWh	1,477,343	29,526,546
Savings LPG	l	224,862	4,494,147
Savings LPG	gal	59,409	1,187,357

The total savings of heat production cost is approximately 70 percent (in 1 yr) and approximately 76 percent (in 20 yrs).

5.4.3 Payback

The resulting payback is:

- ROI period without cost of capital: 9 yrs
- ROI period with cost of capital: 16 yrs

5.5 Heating Option C: Biomass for domestic hot water and building heating, Bldgs 261, 262, 264, 265, 267, 271

5.5.1 Existing conditions/problems

The Energy Assessment 2009 at Fort Irwin focused on a Cluster of buildings including Barracks 261, 262, 264, 265, 267, Dining Facility 271, and Central Heating Bldg 263. The target of the Energy Assessment activities was to minimize the net energy use of this Cluster.

The Barracks and the Dining Facility are connected to the Central Heating Plant (Bldg 263) by a district heating grid. Three boilers, 2060 MBtu/hr each, are generating heat for DHW and SPH. No water storage tanks are installed in the Central Heating Plant. DHW storage tanks with a capacity of approximately 1500 gal are installed in each building.

Table 46 lists the basic data of all following calculations for Heating Option C. The LPG and electricity prices are the actual values given during the energy assessmant. The assumption of the price increases per year for LPG, electricity, and other issues (labor, etc.) are certainly at a lower level compared to energy price increases of the past, but the calculations are based on a conservative approach.

Table 46. Basic data used in calculations for Heating Option C.

Basic Data – Energy Concepts	Units	Value
LPG	$/kWh	0.084
Electricity	$/kWh	0.083
Price increase LPG/yr		5%
Price increase power/yr		3%
Price increase others/yr		2%
Total electricity consumption (1 building)	kWh	292,500
Electricity — building load (1 building)	kWh	139,000
Electricity — plug-in load (1 building)	kWh	153,500
Total electricity consumption (271-DFAC)	kWh	549,544
Total electricity consumption (all buildings)	kWh	2,012,044
DHW (1 building) — heat requirement — net	MMBtu	533.6
DHW (1 Building) — heat requirement — net	kWh	156,344
Boiler efficiency		92%
DHW (1 building) — heat requirement — gross	MMBtu	580.0

Basic Data – Energy Concepts	Units	Value
DHW (1 building) — heat requirement — gross	kWh	169,940
DHW (271-DFAC) — heat requirement — net	MBtu	61.27
DHW (271-DFAC) — Heat requirement — net	kWh	17,952
Boiler efficiency		92%
DHW (271-DFAC) — Heat requirement — gross	MMBtu	66.6
DHW (271-DFAC) — heat requirement — gross	kWh	19,513
SPH (1 building) — heat requirement — net	MMBtu	360.0
SPH (1 building) — heat requirement — net	kWh	105,480
Boiler efficiency		92%
SPH (1 building) — heat requirement — gross	MMBtu	391,3
SPH (1 building) — heat requirement — gross	kWh	114,652
SPH (271-DFAC) — heat requirement — net	MMBtu	174.8
SPH (271-DFAC) — heat requirement — net	kWh	52,216
Boiler efficiency		92%
SPH (271-DFAC) — heat requirement — gross	MMBtu	190.0
SPH (271- DFAC) — heat requirement — gross	kWh	55,670
No. barracks		5
DHW (all buildings) — heat requirement — net	MMBtu	2,729.3
DHW (all buildings) — heat requirement — net	kWh	799,676
DHW (all buildings) — heat requirement — gross	MMBtu	2,966.6
DHW (all buildings) — heat requirement — gross	kWh	869,213
SPH (all buildings) — heat requirement — net	MMBtu	1,974.8
SPH (all buildings) — heat requirement — net (kWh)	kWh	578,616
SPH (all buildings) — heat requirement — gross	MMBtu	2,146.5
SPH (all buildings) — heat requirement — gross	kWh	628,930
Capacity LPG boiler	MBtu	2,060
Capacity LPG boiler	kW	603
No. LPG boiler (existing)		3
Total capacity LPG boiler	MBtu	6,180
Total capacity LPG boiler	kW	1,810
Estimated maintenance LPG labor/yr	hr	250
Labor cost	$/hr	65
Maintenance/cost LPG/yr	$	13,000
Estimated repair cost LPG/yr	$	15,000
Total maintenance LPG/yr	$	28,000

5.5.2 Solution

The DHW and SPH demand of the Barracks and the Dining Facility could be met with a Biomass System using wood waste as the fuel source. The LPG boilers would be reduced to peak load boilers and for redundancy in case of maintenance of the Biomass System. No Solar Thermal Systems would be installed.

The capacity of the Biomass System is 800 kW. The size of the water buffer storage tank is approximately 8000 gal. To install a Biomass System, an extension to Bldg 263 has to be designed and constructed. The floor of the bunker should be at the same level as the Biomass System. This type of construction increases the reliability of the operation. The Biomass System requires a heating water buffer tank. The volume of the tank is approximately 4000 gal. The buffer tank optimizes the performance of a biomass system because biomass systems cannot be switched on and off like LPG systems.

The bunker should be sized to run the Biomass System at least 1 week without refilling. The bunker size should be approximately 5085 cu ft. This storage volume offers a heating capacity of approximately 80,640 kWh. The heat requirement in January is approximately 220,000 kWh for DHW and SPH. The bunker design would be 19 ft wide x 19 ft long x 13 ft high

The Biomass System technology in combination with the Buffer Tank can modulate the different heat requirement levels and enable an operation at lower heat requirement levels between spring and autumn.

This system includes:

- feeder module with barrier control
- moving grate
- primary air control valve
- flue gas recirculation control valve
- ignition blower
- de-asher
- secondary air control valve with rotation blower
- rotation combustion chamber
- boiler heat exchanger
- safety heat exchanger

- pneumatic pipe cleaning system
- induced draft fan.

Continuous gasification is carried out on the moving grate with minimal primary air. The combustible gases rise into the rotary combustion chamber and are mixed with secondary air that had been diffused by the rotation blower and given spin impulse. This guarantees an optimal mixture of secondary air with the combustible gases.

The optimal combustion lowers the emissions of CO and NO_x to below that of modern oil heating systems. Unlike oil and gas, wood is CO_2-neutral and renewable. Used with the modulating output controllers, burner efficiency of more than 90 percent is achievable.

Fuel extraction from the bunker is done by hydraulic pushrods and cross auger. With the sliding bar feeder located at the front, loading may also be done from the end. Large amounts of fuel can be loaded efficiently in this way.

The combustion is virtually dust free; however, for fuels with particles, a flue gas de-duster (flue cyclone) is recommended. The dust emission limits are easily achieved even for the most difficult fuels.

Today the wood waste (pallets, packaging, trees, etc.) at Fort Irwin is shredded and dumped in the landfill. This is a waste of energy because approximately 50 percent of the wood waste is untreated wood, which can be used as fuel.

The reports of the FY 2008 show availability of approximately 900 tons of wood waste. It is expected that the available volume of wood waste will remain at this level in the coming years.

The required volume of wood waste is approximately 180 tons/yr. The expected volume of wood waste will cover the requirements if half of the wood waste is untreated wood. Treated wood should not be used as a fuel source because of emission problems (dioxin or other harmful substances). To ensure a reasonable quality of wood chips, an investment in new wood chopping equipment is included in the calculation. A wood chopping system comparable to the equipment shown here should be used for the wood chips production. The chosen size of the wood chopping system is capable to cover the production needs.

Using the pre-drying system, the rotary boiler can also burn different qualities of chips efficiently. Waste wood (untreated wood waste from the wood processing industry) can be used. Approximately 95 percent of the heat requirement is produced with the Biomass System. In summer time, when the full-load hours of the Biomass System are very low, the heat requirement will be met by the LPG boilers. During this period, the maintenance of the Biomass System can be done.

5.5.3 Investment

Table 47 lists the calculation of the wood chips prices. The wood chips price decreases with higher production volume.

Using wood chips instead of LPG lowers the fuel prices by approximately 78 percent. Investment cost and the cost of capital are included in the wood chips price (Table 48).

Table 47. Investment wood chopping system/wood chips price calculation.

Energy Price — Wood Chip Production	Units	Values
Wood chopping system	$	125,000
Dedicated transport container	$	25,000
Total investment wood chips supply	$	150,000
Total cost wood chips supply — 20 yrs	$	*240,728*
Total production wood chips — 20 yrs	tons	4,000
Investment allocation wood chips	$/ton	60.18
Labor cost wood chips production/transport	$/ton	2.00
Total cost wood chips supply	$/ton	62.18
Heat energy wood chips	kWh/kg	4.00
Total heat energy wood chips — 20 years	kWh	16,000,000
Energy price wood chips	$/kWh	0.0155

Table 48. Biomass system investment.

Investment	Cost ($)
Biomass boiler system	180,000
Control equipment	15,000
Scrabber floor	80,000
Flue gas de-duster	30,000

Investment	Cost ($)
Stack system	40,000
Buffer storage tank	25,000
Hydraulic system integration	15,000
Piping system	25,000
Building extension	200,000
Bunker for wood chips	120,000
Hydraulic bunker cover	50,000
Miscellaneous	80,000
Planning/consulting cost — % of investment	15%
Planning/consulting cost	129,000
Total investment biomass system	989,000
Maintenance cost/yr (labor) biomass system	16,250
Contingencies cost biomass system/yr (% of investment)	2%
Contingencies (repair/replacement) biomass system/yr	19,780
Maintenance cost/yr LPG system	4,600
Total maintenance cost/yr	40,630

All construction work and all equipment needed to install the Biomass System is included in the investment calculation. Due to the fact that biomass technology is new to Fort Irwin, additional cost for training, technology transfer, planning, and consulting are included.

The investment is approximately 30 percent higher than RE-2, and the maintenance costs are higher as well. Table 49 lists savings attributed to implementation of Heating Option C.

The total savings of heat production cost is approximately 59 percent (in 1 yr) and approximately 67 percent (in 20 yrs).

5.5.4 Payback

The resulting payback is:

- ROI period without cost of capital: 9 yrs
- ROI period with cost of capital: 17 yrs

5.6 Standalone photovoltaic systems, Barracks 261, 262, 264, 265, 267

5.6.1 Existing conditions/problems

The barracks (Figure 28) have a significant amount of roof space at a 30 degree tilt where PV panels could be installed to feed into the grid.

5.6.2 Savings

Table 49. Savings attributed to implementation of Heating Option C.

Savings	Units	First Year	20 Years
Total cost heat production LPG cluster	$	153,844	4,841,483
Total cost heat production biomass cluster	$	48,523	1,178,993
Total cost heat production LPG cluster	$	15,087	458,531
Total cost heat production biomass + LPG cluster	$	63,610	1,637,524
Total cost heat production biomass + LPG annuity cluster	$	142,970	3,224,722
Savings heating cost — without financing	$	90,234	3,203,959
Savings heating cost — with financing	$	10,874	1,616,761
Total heat production biomass cluster	kWh	1,373,299	27,465,986
Total heat production LPG cluster	kWh	124,845	2,496,908
Total heat production cluster	kWh	1,498,145	29,962,893
Total heat production biomass cluster	MBtu	4,687,028	93,740,565
Total heat production lpg cluster	MBtu	426,093	8,521,870
Total heat production cluster	MBtu	5,113,122	102,262,435
Savings LPG	kWh	-1,373,299	-27,465,986
Savings LPG	L	-209,026	-4,180,515
Savings LPG	gal	-55,225	-1,104,495

Figure 28. Typical Barracks (Bldg 264).

5.6.3 Solution

As part of the Net-Zero initiative, 35 solar water heating panels will be installed on the roof, which will leave approximately 2600 sq ft of roof area. This will provide enough room for 125 photovoltaic panels flush to the roof. This yields a total capacity of 21.9 kW_{DC}.

5.6.4 Savings

Electricity production:

$$e = 125 \text{ panels} \times 175\ W_{DC} \times (1\ kW/1000\ W) \times 18.99\%\ (kWh_{AC}/kWh_{DC}) \times 8760 \text{ hrs} = 36{,}390\ kWh_{AC}/yr$$

Annual electricity savings:

36,390 kWh x 8.3 cents/kWh = $3020/yr

The capacity factor for the solar photovoltaic analysis was based on simulations conducted by National Renewable Energy Laboratory (NREL) for Las Vegas, NV. This data is publicly available using the *PV Watts* performance calculator for grid-connected systems.

5.6.5 Investment

Capital costs are based on installer surveys and RS Means Mechanical Cost Data.* Table 50 lists the breakout of capital costs:

Table 50. Breakout of capital costs.

Element	Cost
Installation	$2.78/W
Modules	$2.50/W
BOS	$0.51/W
Monitoring	$0.10/W
Other Costs	$0.53/W
Inverter	$0.76/W

* NCI Analysis

Table 51. Breakdown for the capital cost of the PV system.

Element	Cost	Unit Cost
Installation	$60,813	($2.78/W)
Modules	54,688	($2.50/W)
BOS	$11,156	($0.51/W)
Monitoring	$2,188	($0.10/W)
Other Costs	$11,594	($0.53/W)
Inverter	$16,625	($0.76/W)

The estimated cost of the PV system is $157,063. Table 51 lists the breakdown for the capital cost of the PV system.

The Army could be eligible for the CSI. Expected performance-based buydowns for systems under 50 kW are $3.25/$W_{AC}$ for government entities. These projects could also be completed through a Power Purchase Agreement (PPA) with a third party. The advantage of having a private company as the owner is that they are able to use the Business Energy Investment Tax Credit (ITC) – a 30 percent tax credit.

5.6.6 CSI – Expected performance-based buy-downs for systems under 50 kW

Incentive: $13,501 ($3.25/W_{AC})

5.6.7 Payback

Payback is based on a cash flow model that includes degradation of 0.70 percent/yr. Rooftop PV has a long payback even with incentives. PV should be pursued for Net-Zero purposes and third party ownership should be explored.

5.7 Standalone photovoltaic system, Dining Facility 271

5.7.1 Existing conditions/problems

Dining Facility 271 has a significant DHW load for food processing, cleaning, and sanitation. Domestic water is heated using a 460-gal tank with a heat exchanger connected to an LPG fired central heating distribution system. A 400,000 lb/hr steam boiler is also used, which runs on LPG. However, the DHW load of the dining facility will be served by solar water heating collectors on the barracks, which are part of the same central heating loop. To take advantage of the roof space and become closer to a Net-Zero Cluster, photovoltaic panels should be installed on the dining facility roof.

5.7.2 Solution

The dining facility roof has approximately 122 m^2 of flat available roof area. For a 20 degree tilt, 2.25 m of spacing between each row of panels is recommended. This allows for 18 photovoltaic panels to be installed on roof and yields a total capacity of 3.2 kWDC. Figure 29 shows the placement of PV panels at Dining Facility 271.

5.7.3 Savings

Savings for electricity production are:

e = 18 panels x 175 WDC x (1 kW/1000 W) x 18.99% (kWhAC/kWhDC) x 8760 hrs
= 5240 kWhAC/yr

Savings for annual electricity savings are:

5240 kWh x 8.3 cents/kWh = $435/yr

The capacity factor for the solar photovoltaic analysis was based on simulations conducted by NREL for Las Vegas, NV. This data is publicly available using the PV Watts performance calculator for grid-connected systems.

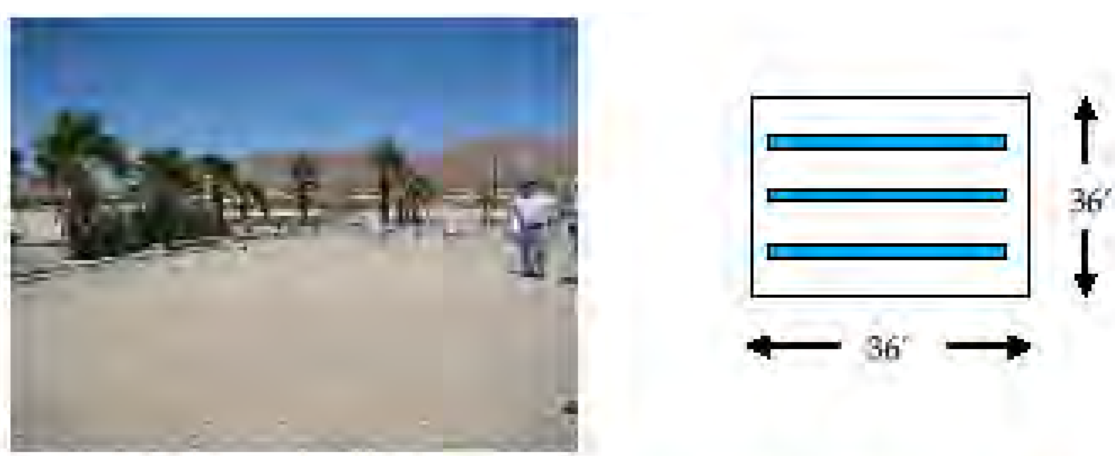


Figure 29. Placement of PV panels at Dining Facility 271.

5.7.4 Investment

The estimated cost of the PV system is $22,617. Table 52 lists the breakdown for the capital cost of the PV system.

Capital costs are based on installer surveys and RS Means Mechanical Cost Data.* Table 53 lists the breakout of capital costs.

The Army could be eligible for the CSI.† Expected performance-based buy-downs for systems under 50 kW are $3.25/$W_{AC}$ for government entities. These projects could also be completed through a PPA with a third party. The advantage of having a private company as the owner is that they are able to use the Business Energy ITC – a 30 percent tax credit.

5.7.5 Payback

Payback is based on a cash flow model that includes degradation of 0.70 percent/yr. Rooftop PV has a long payback even with incentives. PV should be pursued for Net-Zero purposes and third party ownership should be explored.

5.8 Summary of renewables within the Cluster

Installing Solar Thermal, Biomass (Wood Chip), and PV electrical generation can save 4832 million Btu/yr (48,320 Therms) and generate 41,630 KWh/yr. Table 54 lists renewable energy opportunities for the Cluster.

Table 52. Capital costs for standalone photovoltaic system at Dining Facility 271.

Element	Cost
Installation	$2.78/W
Modules	$2.50/W
BOS	$0.51/W
Monitoring	$0.10/W
Other costs	$0.53/W
Inverter	$0.76/W

Table 53. Breakdown for the capital cost of the PV system.

Element	Cost	Unit
Installation	$8,757	$2.78/W
Modules	$7,875	$2.50/W
BOS	$1,607	$0.51/W
Monitoring	$315	$0.10/W
Other costs	$1,670	$0.53/W
Inverter	$2,394	$0.76/W

* NCI Analysis

† CSI – Expected performance-based buy-downs for systems under 50 kW: Incentive: $1944 ($3.25/WAC)

Table 54. Renewable energy opportunities for the Cluster.

Element	Useable Heat Produced MMBtu/yr	$ Saved	Maintenance $/Yr	Investment	Simple Payback
Heating Option A — solar thermal	2,419	59,531	3,190	$637,962	11.3
Heating Option B — solar thermal & biomass	4,832	118,911	30,395	$1,345,212	15.2
Heating Option C – biomass	4,687	115,347	16,250	$989,000	10.0
PV Barracks	36,390	3,020	0	$143,562	47.5
PV DFAC	5,240	435	0	$20,673	47.5
Total PV	*41,630*				

6 Energy Conservation Measures Outside the Cluster

While the main focus of this work was to develop concepts for Net-Zero energy use within a Cluster of buildings, the team also investigated other energy conservation opportunities. This chapter describes the various opportunities found, including estimated costs and savings.

6.1 BE-1: Cool roofs strategy, various buildings

6.1.1 Existing conditions/problems

Currently, many of the buildings at Fort Irwin have roofs that are dark in color (Figure 30). The dark brown color will absorb more of the sun's energy than lighter colored roof, making the roof hotter than the outdoor air temperature. This is also the case with white or close-to-white roofs that do not have cool roof surfaces. As the roof becomes hotter, the building becomes warmer, increasing the cooling load on the air-conditioning equipment.

Figure 30. Building with brown roof.

Cool Roofs consist of materials that very effectively reflect the sun's energy from the roof surface, despite the color. Cool materials for low-slope roofs are mainly bright white in color (Figure 31), although non-white colors are available for sloped roof applications. Cool Roofs also have high emissivity, allowing them to emit infrared energy. Unfortunately, bare metals and metallic coatings tend to have low emissivity and are not considered cool materials.

Cool roofs reduce the roof surface temperature by up to 100 °F, thereby reducing the heat transferred into the building below. This helps to reduce energy costs (by keeping attics and ducts cooler), improve occupant comfort, lower maintenance costs, and increase the life cycle of the roof.

Some benefits of cool roofs are that they:

- save on annual electricity bills by reducing the summer cooling load and corresponding air-conditioning costs
- save peak electricity demand costs if there is time-of-use metering
- reduce roof maintenance and replacement expenses by extending roof life
- increase indoor comfort in summer by reflecting heat from the roof surface.

Figures 32 and 33 (from other installations on a hot summer day) show temperature differences between a cool roof and a roof that does not have that treatment.

Figure 31. Building with light roof.

Figure 32. Roof before treatment; thermometer reads 178 °F.

Figure 33. Decreased roof temperature with cool roof material.

Products for low-slope roofs, found on commercial and industrial buildings, fall into two categories — single-ply materials and coatings. Single-ply materials are large sheets of pre-made roofing that are mechanically fastened over the existing roof and sealed at the seams. Coatings are applied using rollers, sprays, or brushes, over an existing clean, leak-free roof surface. A list of cool roof products and manufacturers is available on the ENERGY STAR® website: http://www.energystar.gov

If a cool roof were used, much of the sun's energy will be reflected keeping the roof cooler (Figure 34). This will in turn reduce the cooling energy required to maintain building temperatures in the summer. A slightly larger amount of energy will be required for heating, but in the climate of Fort Irwin, the cooling savings outweighs the extra heating energy costs.

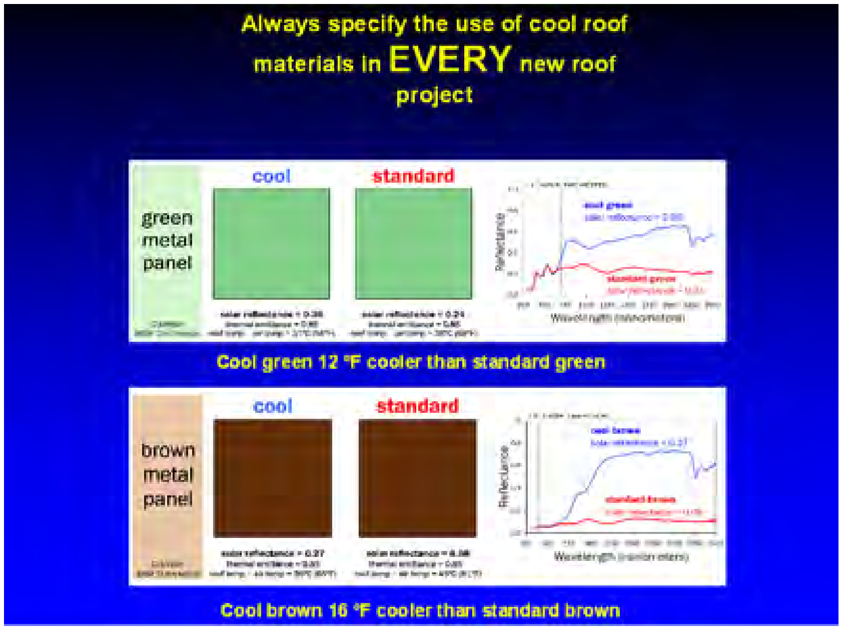


Figure 34. Temperature differences using cool roof technology.

6.1.2 Solution

Whenever replacing a building's roof, provide an outer surface that is categorized as a Cool Roof. Incorporate the Cool Roof requirements into the Installation Design Guide.

6.1.3 Savings

ENERGY STAR qualified roof products save money and energy by reducing the amount of air-conditioning needed to keep a building comfortable. ENERGY STAR qualified reflective roof products can reduce peak cooling demand by 10 to 15 percent and can reduce building energy use by up to 50 percent.

Exact energy and money savings will depend on a number of factors, such as the type and efficiency of insulation in the ceilings and exterior walls; the windows; the efficiency of the building's cooling system; and, most importantly, the climate of the building's location. The Energy Star Roofing Calculator for Fort Irwin conditions showed the following for a 10,000 sq ft roof:

- office building, air-conditioned, used 7 days per week
- existing dark brown roof, reflectance 0.1
- cool brown roof, reflectance 0.3

- electricity savings: 1640 kwh/yr worth $136
- propane gas increase: 30 therms worth $73
- net savings: $63/yr per 10,000 sq ft.

Since it is not currently known how many square feet of roofing at Fort Irwin could benefit from Cool Roofs, we assume application of this technology to 1 million sq ft of roofing. The savings would be $6300/yr.

If much cooler white membrane roofs were used having a reflectance of 0.75 there would be a savings of 5700 kWh of electricity with an additional 125 therms of natural gas used per 10,000 sq ft. The cost savings with the white roof would be $166 per 10,000 sq ft.

Total saving would be $16,600/yr.

There are no cost savings in buildings with no air-conditioning, but the cool roofs will keep them cooler and more comfortable in the summer.

6.1.4 Investment

Initial material costs are comparable with traditional roofing materials — some cool products cost less than traditional materials, some cost up to 20 percent more. Cool protective coatings can be reapplied repeatedly every 10 to 15 yrs and reduce, if not eliminate the need for expensive roof tear-offs. Combining these maintenance savings with an average 20 percent savings on air-conditioning costs make cool roofing a better bargain over the long term.

6.1.5 Payback

The resulting payback is within a few summer months.

6.2 HVAC-1: Modernize controls and reduce operational hours, various buildings

6.2.1 Existing conditions/problems

Many buildings at Fort Irwin have very poor controls for HVAC equipment. This leads to poor performance in terms of temperature control and low energy efficiency. As a consequence, there are no tools for scheduling to match HVAC operation with building occupancy. Furthermore, temperature control is poor, and examples of buildings with spaces that were significantly under-cooled were identified. Examples include certain spaces in the dining facility, Bldg 253. There are no tools available for night and weekend temperature set-backs. Many buildings have pneumatic controls, which also require energy and maintenance of air compressors and continuous calibration to make equipment work properly.

Some buildings were found to have electronic controls, but with pneumatic actuators and sensors. Some actuators do not work or operate correctly. Mixing outside air (OA) with return air (RA) depending on the OA temperature is crucial for saving energy. The timers shown in Figure 35 are installed to control hours of operation for this specific multi-zone AHU, but the timers are not programmed; the system runs 24/7.

Some buildings have HVAC equipment that is so old that it is not recommended to upgrade controls in these buildings unless all HVAC equipment is replaced or modernized. For some buildings, however, there are potential savings to be made by upgrading the controls, or by replacing existing controls with modern, DDC controls. A nucleus for an Energy Monitoring and Control System (EMCS) could later be expanded to become the base for future renovations and energy savings all over the installation.

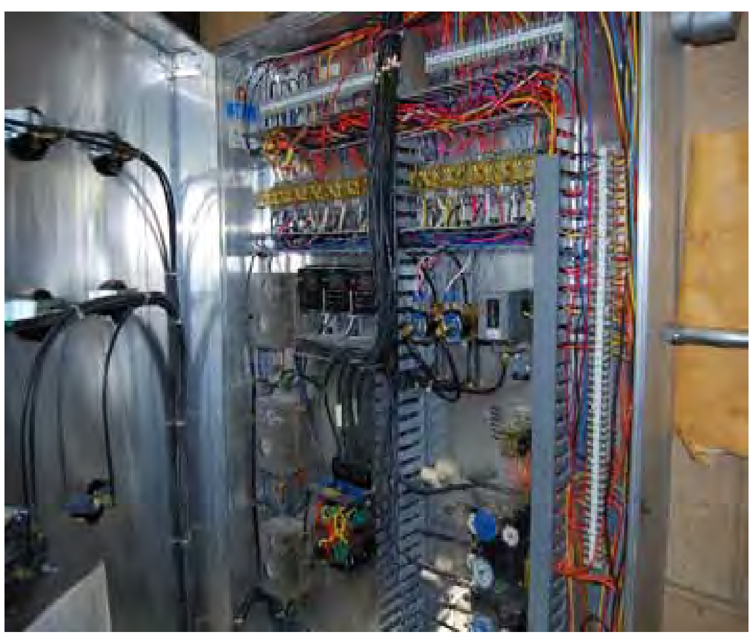


Figure 35. Controls for multi-zone AHU.

Many buildings are believed to have HVAC equipment running 24/7, even though the buildings are only occupied during fractions of the days. Running AHUs, MAUs, and FCUs and their fans continuously requires much more energy than if these units would go into an unoccupied mode during nights and weekends.

6.2.2 Solution

Re-commission the controls and the HVAC systems in these three buildings. Replace all old controls with DDC controls. Replace sensors, and valve and damper actuators. Install a central computer that links to all units in various buildings. Program operation of all HVAC equipment to match building occupancy and needs of the buildings. Use uniform setpoints for temperature installation-wide. This can easily be addressed and enforced by the Commander of Fort Irwin.

6.2.3 Savings

Table 55 lists the savings associated with reducing the hours of operation, assuming that electric chillers are used for cooling and using a coefficient of performance (COP) of 2.5 for the electric chillers. Note that the data used are only examples since specific buildings other than the ones in the 263 Cluster were not visited. Air flows and fan motor sizes are estimates based on experience. The basis for the calculations is the annual cooling and heating degree-days, 2744 °F and 2304 °F, respectively. Transmission savings, from not having the buildings cooled down or heated and thus not having the chillers or boilers running to cover for transmission losses, are estimated to be equal to the OA savings. Table 55 lists net savings regarding energy that enters the building and considerations regarding boiler efficiency.

Total savings are:

Electricity: 538,000 kWh. With an average cost of 8.3 cents/kWh, the value of the saved energy is $44,600/yr.

Net Heating Energy: 1870 MMBtu. With an assumed average efficiency of 70% for the boilers, energy equivalent to 2700 MMBtu is saved. The value of the savings, with an average of $25/MMBtu (LPG), is 2700 MMBtu x $25/MMBtu = $67,500 annually.

Total savings is $112,000/yr.

Table 55. Savings summary table.

Bldg	Total cfm	OA cfm	Motor hp	Per week Hrs now	Per week New hrs	Savings cooling OA Base 65 °F	Savings transmission (summer)	Savings motors, 80 % loaded	Savings heating OA, MMBtu/yr Base 65 °F	Savings transmission (winter)
A	20000	6000	20	116	90	7694	7694	16324	55	55
B	10000	3000	10	168	80	13020	13020	27624	93	93
C	25000	7500	25	168	60	39949	39949	84757	286	286
D	40000	12000	40	168	50	69837	69837	148167	500	500
Sum:	95000	28500			Sum:	130500	130500	276872	935	935
		30%				kWh	kWh	kWh		
					Total savings, kWh:		537872	Savings MMBtu:	1870	

Additional savings, from reduced maintenance costs for both AHUs and chillers and reduced costs for filters and belts (which need not be replaced so often when units run less) can be added. Also, better control of space temperatures with uniform setpoints, gives a substantial additional savings. Total savings will be well over $150,000/yr.

Assuming that the above examples are representative and that the equipment is installed in a total of 200,000 sq ft buildings, savings are 75 cents per sq ft/yr. By further assuming that the savings can be received from a total of 2 million sq ft, the total savings will be over $1.5 million/yr. (Maintenance savings were not calculated here.)

6.2.4 Investment

Because of the condition of the HVAC systems in the buildings at Fort Irwin, the estimated cost ($4/sq ft) for re-commissioning is quite high. The total investment is approximately $8 million.

6.2.5 Payback

The resulting payback is 5.3 yrs.

6.3 HVAC-2: Add insulation to boiler shell, Bldg 254

6.3.1 Existing conditions/problems

During the site survey, it was observed that the surfaces of the two boilers in Bldg 254 had surface temperatures above 125 °F. The surface temperature of these units is too high, resulting in excessive heating energy loss and safety issues of potential skin burns (Figure 36). The two boilers should be wrapped with additional insulation.

Figure 36. Boiler with 140 °F sides and top (Bldg 254).

6.3.2 Solution

Install 2 in. insulation to top and sides of the two boilers in Bldg 254. Refer to the following table for more information.

6.3.3 Savings

The total annual energy loss from the two boilers is 86.4 MMBtu/yr. Adding 2 in. of fiberglass insulation to the top, sides, and back will reduce the annual heat loss to 7.9 MMBtu/yr. Thus, adding the insulation saves 78.5 MMBtu/yr (Table 56). This analysis uses an annual time period of 12 months or 8760 hr/yr and a boiler efficiency of 80 percent.

6.3.4 Investment

The cost for adding the insulation to the two boilers is $1824. (The values used were obtained from the RS Means estimating guide.)

6.3.5 Payback

The resulting payback is 11 months.

Table 56. Savings from additional insulation on the boilers.

Bldg	Uninsulated Item	Area, sq ft	Surface Temp. °F	Current Insulation Heat loss/sq ft, Btuh	Insulation Heat loss/sq ft, Btuh	Differential Heat loss, Btuh	Differential Heat loss, MBtu /yr	Annual Cost Savings
254	Boiler surfaces	80	140	123	11	8.960	78,500	$1944

6.4 HVAC-3: Control space temperature in dining area, Bldg 254

6.4.1 Existing conditions/problems

In Bldg 254 (Figure 37), the new addition to the dining area is being maintained in the range of 66 to 68 °F. This is much cooler than what is needed, and results in a waste of electrical energy powering the cooling equipment. The adjacent, original dining area was a found to be at a more reasonable temperature of approximately 75 °F.

6.4.2 Solution

Reset the controls that monitor and establish the space temperatures in this space to maintain a 75 °F space temperature. Keeping better control of the supply temperature to this space would avoid the energy waste of over-cooling and perhaps over-heating.

6.4.3 Savings

Bringing control to the air-conditioning system will reduce the excessive energy use resulting from cooling spaces below 70 °F in the summer. The dining area is an estimated 1200 sq ft in size. Using a rate of 325 sq ft per ton cooling capacity, the cooling load for this dining area is approximately 4 tons. Using an air flow of 400 cubic feet per minute (CFM) per ton cooling the area's air flow is 1600 CFM. If the outside air percentage is 10 percent, the outside airflow is 160 CFM. Electrical savings resulting from reducing cooling (i.e., increasing building temperature by 8 °F), is 417 kWh/yr:

Q = 1.08 x 160 CFM x 8 °F x 150 days/yr x 24 hr/day = 5 MMBtu/yr

Electrical energy saving = 5 MMBtu/yr / 12,000 Btu/ton x 1 kWh/ton = 417 kWh/yr

Electrical cost savings = 417 kWh/yr x $0.083/kWh = $35/yr

Figure 37. Dining Facility (Bldg 254).

6.4.4 Investment

Adjusting the thermostat that controls the space temperatures of this dining area adds no cost.

6.4.5 Payback

The resulting payback is immediate.

6.5 HVAC-4: Turn off HVAC equipment during unoccupied hours, Dining Facilities 254, 271

6.5.1 Existing conditions/problems

In these dining facilities, all air handling units, exhaust fans, and chillers run continuously. With new controls, there is no need to run more air handling units than necessary during nights when the building is unoccupied.

6.5.2 Solution

It is estimated the air-conditioning equipment will need to run approximately 25 percent of the time during the night to maintain suitable building temperatures. The exhaust fans and associated make-up air units can be turned off during these unoccupied hours. The occupied hours of the dining facilities are 0530 to 1930. Thus, it is reasonable to run the AHUs between 0500 and 2000, or 105 hrs/week. The remaining 63 hrs/week, AHUs can be controlled to minimize the volume of conditioned air (estimated to be 25 percent of the time).

6.5.3 Savings

During the occupied mode, approximately 21,000 cfm of outside air is cooled or heated to space temperature. Running the AHUs minimally to maintain a slight set back temperature of a few degrees will result in an estimated run time of 25 percent for these units. Energy savings will result not having to cool or heat an average of 15,750 cfm of outside air for 63 hrs/wk plus not having to run 75 percent of the installed AHU fan motors.

Fort Irwin has the 2304 heating degree-days and 2477 cooling degree-days annually:

Heating energy savings = 15,750 cfm x 1.08 x 2304 HDD °F x 63/168 x 24 hrs =
353 MMBtu/yr

With 80 percent boiler efficiency the propane gas use corresponds to 441 MMBtu/yr:

Heating cost savings = 441 MMBtu/yr X $24.73/MMBtu = $10,900/yr

6.5.4 Electrical savings

Total electrical savings are:

Cooling energy savings = 15,750 cfm x 1.08 x 2477 CDD °F x 63/168 x 24 hrs =
379 MMBtu/yr

Cooling electrical savings = 379 MMBtu/yr/12,000 Btu/ton-hr x 1 kWh/ton-hr =
31,600 kWh/yr

Fan hp savings: 32.5 hp x 75% x 0.746 kW/hp x 63 hr/wk x 52 wk/yr = 59,600 kWh/yr

Electrical cost savings = 91,200 kWh/yr x $0.083/kWh = $7,570/yr

Total savings: $18,470/yr

6.5.5 Investment

The installed cost for the controls to turn this equipment off is estimated to be $20,000. This includes relays to shut down motors, temperature sensors to define space temperatures, and the central controllers. This equipment could also be controlled from a central EMCS at approximately the same cost. (The values used were obtained from the RS Means estimating guide.)

6.5.6 Payback

The resulting payback is 1.1 yrs.

7 Utilization of Solid Waste

7.1 Existing conditions/problems

Table 57 summarizes the current waste load.

Table 57. Waste streams and origin.

	Metric tons/yr*	Comments
Solid waste	7,700	Regular trash – contains household trash, trash from administration buildings
Green waste	600	Organic waste from food etc.
Wood	900	60% untreated
Waste from construction	1,000	
Recycle materials (collected in recycle bins)	800	Cardboard, paper, aluminum cans, other metals/steel, plastic is collected by contractors and sold/recycled (2010 new tender for contractors)
Tires	Unknown	(collected separately)
Sewage	300,000 m^3/yr	(from ~ 12,000 persons)
*Data is based on site visit in August 2009 and is to be verified by installation personnel.		

7.2 Current processing of solid waste

"Regular trash" is compacted, fixed by wire, transported to a landfill, deposited, and covered by consecutive layers of earth. The landfill is sealed by plastic foil at the bottom.

7.2.1 Sewage

Sewage is pumped to a central sewage plant. Sludge is moved into flat concrete bays, dried by the sun, mixed with shredded wood chips and food remains, stocked (composted) in an unsheltered area, and later dispersed.

7.2.2 Solution

To prepare a combustible fraction from the collected solid waste, requires some pre-processing steps, as described in the following sections.

7.2.2.1 "Regular trash"

The combustible fraction in the raw waste material has to be separated (semi-automatically) from metals and glass before further use as an energy source. Refuse must then be shredded and sieved (0-60 mm / 60 – x mm).

7.2.2.2 "Green waste"

Pre-dry and mix with sewage sludge.

7.2.2.3 Wood

Wood can be stored in a free area and shredded to chips (<60 mm) one or two times a year. Chips can be bunkered at heating plant site.

7.2.2.4 Sewage sludge

For sewage sludge, the current method of processing can be continued. In the future, fermentation could be possible depending on "Total Organic Carbon Ratio." Chemical analysis is necessary. Table 58 lists estimated combustible content of waste streams and resulting calorific values. Consequently, considering a continuous operation (8000 hr/yr), a combustion power of ~3 MW (or about 1 metric ton of solid waste per hour) is available. With batch operation, e.g., 8 hrs every workday (1900 hr/yr), a design load of 12 MW is necessary to convert the available energy.

Technical options to convert waste into usable energy include:

1. Fermentation of green refuse
2. Waste pyrolysis in a rotating tube under pressure or fixed-bed reactor
3. Combustion of solid waste using a waste incinerator
4. Fluid bed gasification/incineration.

The proper choice will depend on available solid waste mass flow and its properties.

Table 58. Estimated combustible content of waste streams and resulting calorific values.

Waste	Metric tons/yr	Assumptions	Calorific Value (MWh/yr)
Regular trash	7,700 → 5,400	30% material that cannot be combusted and has to be extracted; remaining mass → 3 MWh/t calorific value	16,200
Green waste	600 → 300	Food remains etc.: after drying 50% remaining combustible mass → 3 MWh/t calorific value	900
Wood chips	→ 900	Calorific value: 4–5 MWh/ton	4,050
Recycle (in recycle bins)	800 → 80	Paper/cardboard, Metal, Plastic → 10% paper/cardboard → 4 MWh/t calorific value	320
Sewage water	300,000 m^3/yr → 600	Estimated for ca. 12,000 persons → 0.2% solids → dried sewage sludge → 2.5 MWh/t	1,500
→ Combustible tonnage	7300 t/yr	Combustion incinerator/pyrolysis tube	~ 23,000

7.3 Option 1: Fermentation of "green refuse" (organic/wet material)

This fraction can be fermented, resulting in biogas (methane with 50 percent CO_2) and sludge (the sludge can be used as fertilizer). Biogas can be used by a combustion engine to produce electricity and usable heat.

The available green refuse (300 t/yr) is somewhat below the lowest manageable mass flow, resulting in a continuous energy production of about 25 kW_{el}/50 kW_{th}. (Average size of agricultural biogas plants in Germany is about 300 kW_{el}.) Enlarging the available organic refuse by using sewage sludge and other organic material (like grass) would be necessary if available. Semi-automatic operation is possible, and experienced operators are necessary.

7.3.1 Investment (Option 1)

Biogas cogeneration plant (25 kW_{th} / 50 kW_{th}):	$70,000–$90,000
Fermentation plant (300 – 400 t/yr):	$150,000

7.3.2 Usable energy

200 MWh electricity (~ $20,000/yr), 400 MWh thermal (Usable all year if district heating network is available.)

Costs for maintenance, depreciation, personnel, approximately $40,000/yr.

Remaining costs of usable heat: > $60/MWhth.

7.3.3 Payback (Option 1)

The mass flow of fermentable materials available at Fort Irwin seems to be too low to calculate a meaningful payback. (In other regions with normal vegetation around, this could be improved using agricultural waste in addition to the regular green refuse.)

7.4 Solution (Option 2)

7.4.1 Option 2: Pyrolysis of a mix of combustible solid wastes

After pre-processing to separate glass and metals, the "regular trash" (~5400 t/yr) can be mixed with paper/cartonage (estimated to be 80 t/yr) from the "recycle fraction" (recycle bins) and with wood chips from waste wood (900 t/yr), resulting in ca. 6400 t/yr of combustible solid waste. After "homogenization" (chopping to achieve a defined grain size, sieving, and compaction), it can be loaded by continuous charges into a pyrolysis tube, where it is heated to 500 °C and turned partly into low-grade combustible gas and solid coke. The gas can be used, after purification, in a combustion engine to produce electricity and heating energy. The coke can be combusted using a conventional furnace. Green/organic refuse can, after pre-drying, be fed into the pyrolysis tube also.

Two technical concepts are in use:

1. Rotating pyrolysis tube, where synthesized gas and pyrolysis coke are extracted separately
2. Fixed-bed reactor, where the coke is finally also gasified within the same tube. All generated energy is extracted in the form of synthesized gas (calorific value is about one third that of natural gas).

In the first case, a wide range of solid waste can be used.

In the second case, there are more requirements to be fulfilled by the waste; however, the process seems to be easier to handle and also more reliable during operation. For the fixed-bed reactor (second case), no characteristic costs are currently available for the size necessary here. The order of magnitude should be similar to the rotating tube.

7.4.2 Energy balance (using total available waste stream)

As a rule of thumb, in a pyrolysis process, one third of the energy content of the waste material (calorific value 3–3.5 MWh/ton) is recovered as synthesized gas, one third as coke, and one third as waste heat. Using the estimate above, the following output is achieved from 23,000 MWh calorific value of solid waste:

> 7700 MWh low-grade gas (CO, H2, H2O, CO_2) → 2300 MWhel, 3800 MWhth usable heat (about 70–90 °C)
>
> 7700 MWh coke (can be stored) → 6300 MWhth usable heat.

It is advisable to plan a more or less continuous (about 8000 hr/yr) operation of the plant. In this case, the available (continuous) power would be ~ 300 kW_{el} electric power and 1.3 MWth thermal power.

This approach, to make use of the solid waste, can only be applied if there is a district heating system to transport the heat from the central plant to the users.

7.4.2.1 Savings (Option 2)

Using an LPG gas price of $0.05/kWh, the cost to generate 1 MWhth with LPG is about $60/MWhth. Therefore, the monetary value of the usable energy generated by the pyrolysis/cogeneration plant is given by:

electricity (price of utility: $0.10/kWh): 2300 MWhel/yr = $230,000/yr
heating energy: 3800 + 6300 MWhth/yr = $600,000/yr

7.4.2.2 Investment (Option 2)

The investment cost of a complete waste pyrolysis and gas utilization plant, with a turnover of about 8000 t/yr, is estimated to be about $1.0 million to $1.3 million. The cost of operating personnel may be $250,000/yr (for a four person staff). Maintenance costs (3 percent of investment) would be about $30,000/yr. Depreciation over 10 yrs, with an interest rate of 3 percent would be about $120,000/yr.

7.4.2.3 Payback (Option 2)

Consequently, a total cost of $400,000/yr is easily recuperated by the monetary value of the generated energy ($830,000/yr).

The resulting payback is:

$1300k / $430k/yr = 3.0 yrs.

7.4.2.4 Solution (Options 3 and 4)

The solid waste incinerator and fluid bed gasifier mentioned above are well introduced techniques, but are used for much higher mass turnover than achieved at Fort Irwin. Therefore, these are not considered here in detail.

7.4.2.5 Conclusions

1. The solid waste available at Fort Irwin can be transformed into usable energy best by using a pyrolysis/cogeneration waste utilization plant. About 10 percent of the energy demand of Fort Irwin may be served by this approach.
2. A first estimate shows that this measure may be feasible also in economic terms. Since the waste problem will be similar to many other installations, it should be worthwhile to develop a general concept that can be applied at Fort Irwin and to document the experiences as a pilot installation.

3. A complete new organization of waste management is necessary.
4. A detailed investigation of current waste management and recoverable fractions of waste is necessary as a next step to provide the basis of a detailed engineering design of the waste treatment (e.g., take samples and make chemical analysis and treatment tests).
5. A pre-requisite of this approach is the availability of a district heating network to be able to make proper use of the generated heat within the installation.

Steps for implementation:

- Investigate current waste management at Fort Irwin with personnel in charge of waste at the site.
- Perform a detailed waste analysis (take samples, analyze and treat it in laboratory scale, measure calorific values).
- Perform mass and energy balance of all waste collected.
- Develop a draft technical concept (or detailed investigation of different technical options) for energy conversion from waste. Show technical feasibility and general lay-out.
- Investigate investment costs, make economic calculations.
- Make decision for specific approach.
- Define precise task and prepare a tender for detailed engineering.

7.5 District heating with waste incineration

This section examines the cost effectiveness of a district heating system including a waste incineration plant.

7.5.1 1. Existing conditions/problems

Fort Irwin is located in the Mojave Desert in northern San Bernardino County, CA. It was built in 1940 and is now a major training area for the U.S. Military. The heat supply in Fort Irwin is currently based on a gas grid supplied by LPG, which is transported to a gas transfer station in Fort Irwin by truck. The gas price is $2.42/gal, which is a much higher price than usual in the United States. The annual demand of LPG gas in the installation is 10.5 mio. gal/a.

One option to dramatically alleviate Fort Irwin's dependence on fossil fuel based energies would be to use pyrolysis of a mix of combustible solid waste in a solid waste incinerator or a fluid bed gasifier. Large volumes of waste are collected every year at Fort Irwin, preliminarily estimated at

7300 t/a, which corresponds to a calorific value of approximately 23,000 MWh/a or 78,479 mio. Btu/a.

The following sections examine the feasibility and cost effectiveness of converting of this waste into usable energy using a waste incineration plant to supply heat to the surrounding buildings via district heating distribution network.

7.5.2 Solution

The large volumes of waste could be used as fuel for a waste incineration plant. The waste incinerator could produce combined heat and power and induct the heat into a district heating system. Since there is no extended district heating system in Fort Irwin, the primary task is to design a district heating network.

Besides the estimation of the resulting calorific value of combustible waste material (by Jank), an estimation of the heat demand in the installation had to be arranged. Therefore the footprint of every building was multiplied with a specific factor [MBtu/sq ft] for a certain building type.

It was estimated a total annual heat demand of about 52,120 mio. Btu, simulated in the annual load duration curve shown in Figure 38.

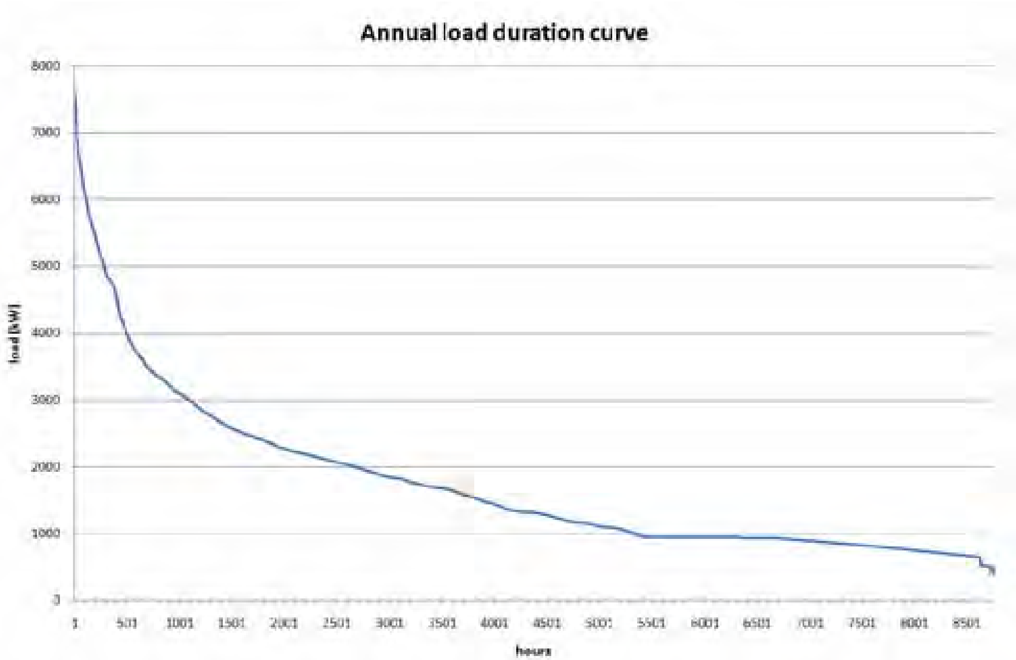


Figure 38. Annual load duration curve.

Next, the buildings with the largest heat demand were identified. They are mainly located at the right and the left of the Langford Lake Road and in the side roads. Family housing is located in a separate area; due to its low heat demand, family housing was excluded from the district heating system. This simplifies the determination of the pipeline route. Figure 39 shows a map of the proposed district heating network.

7.5.3 Savings

Due to their age, many local boilers will soon need to be renewed. This work assumed that all boilers older than 15 yrs would be replaced with new ones. Considering an n+1 backup doubles the investment costs and the costs for operation and maintenance. Assuming O&M costs are 1 percent of the investment costs, they will total $208,100/yr.

In comparison, the O&M costs for the centralized supply are composed of the O&M costs for waste incinerator ($29,900/yr), the costs for the gas boiler and gas backup boiler ($33,500/yr), and also the O&M costs for the piping system ($38,500/yr). The sum of the O&M components results in $101,900.

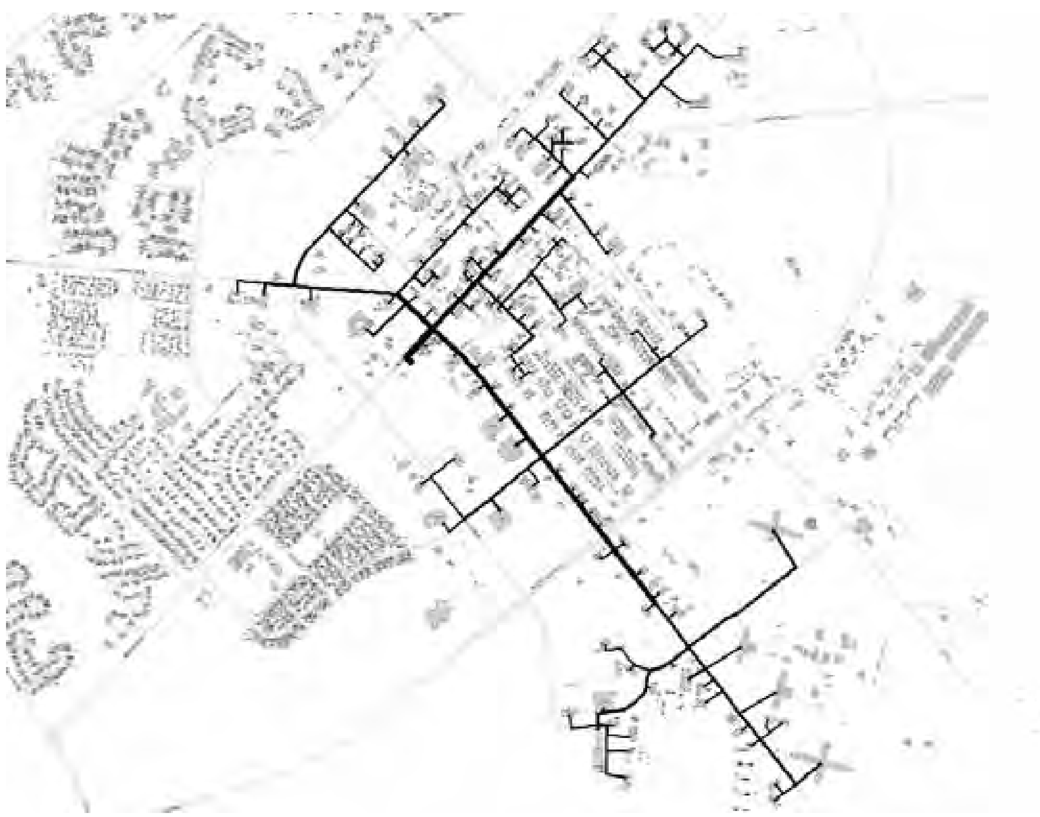


Figure 39. Design of the district heating network.

The O&M savings between local boilers and a district heating system with a centralized supply are $106,200/yr.

The use of combustible waste will decrease gas consumption. The costs for LPG gas (considering only the buildings connected to the potential district heating system) are currently about $1,069,300.

Assuming no costs for combustible waste, a great part of the existing fuel costs could be saved. There remain approximately half of the gas costs for the peak load boilers $520,500. Additionally there will be revenues due to the electricity payments of about $186,400.

Hence the savings concerning the fuel costs between local gas-fueled boilers and a central district heating system are $735,200.

7.5.4 Investment

The investment costs for a waste incineration plant as recommended in Janks report *Utilization of Solid Waste* (part of the Energy Master Plan of Fort Irwin) amount about $1,300,000. Additionally, gas boilers to support peak load demand and also to serve as backup are needed. The costs for the peak load and backup boilers are estimated at $3,353,500.

The costs for construction of the piping system are about $7,703,100, assuming the pipes are pre-insulated bonded pipes. Table 59 lists pipe costs, by required diameters and lengths. The costs for the customer interfaces, depending on their size, totals $1,336,500.

Table 59. Dimensioned pipe diameters, length and first costs.

Pipe Diameter	Length of Pipeline [ft]	Investment Cost [$]
1 in.	23,183	2,619,700
1.25 in.	5,922	669,200
1.5 in.	5,442	636,700
2 in.	7,015	904,900
2.5 in.	5,978	896,700
3 in.	2,063	379,600
4 in.	4,426	1,079,900
5 in.	1,278	341,200
8 in.	531	175,200
Total	*55,838*	*7,703,100*

The total investment cost for the installation of a district heating system is $13,693,100.

The investment costs for a decentralized solution include the costs for one tank per building and the costs for boilers and backup boilers; the costs for the tanks are $382,500 and for the boilers $9,640,000.

7.5.5 Summary/payback

The data in Table 60 list Fort Irwin life-cycle costs.

A central heating system is characterized by has somewhat smaller O&M costs, but more dramatic fuel cost savings. The investment costs for a new central district heating system are about $3,500,000 higher than the costs for a renewal of the existing local boilers altogether the resulting payback period is approximately 4.2 yrs.

7.6 Solar thermal system for domestic hot water, Barracks 98, 99

7.6.1 Existing conditions/problems

Bldgs 98 and 99 are barracks that are fully occupied most of the year. There are 48 single occupancy apartments in each barrack. The domestic water heating load is primarily from showers taken by the occupants. It is assumed that each occupant showers once a day in the morning and uses the laundry once a week. Domestic water is heated using a 365,000 Btu/hr boiler that runs on LPG and is stored in a 500-gal tank. A 211,290 Btu/hr boiler is used for space heating.

Table 60. Fort Irwin life-cycle cost summary.

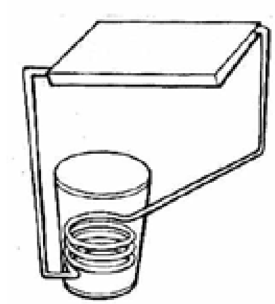
System	Type	Central	Decentral	Savings
Heat generation	Capital cost	$4,653,500	$9,640,000	
	O&M	$63,400/yr	$192,800/yr	$129,400/yr
	Fuel costs	334,100/yr	$1,069,300/yr	$735,200/yr
Network	Capital cost	$7,703,100	-	
	O&M	$38,500/yr	-	-$38,500/yr
Customer inter-face/tank	Capital cost	$1,336,500	$382,500	
	O&M	-	$7,700/yr	$7,700/yr
Total	Capital cost	$13,693,100	$10,022,500	
	O&M	$101,900/yr	$200,500/yr	$98,600/yr
	Fuel costs	$334,100/yr	$1,069,300/yr	$735,200/yr

7.6.2 Solution

Indirect active solar water heating systems use a non-potable fluid (usually glycol) that circulates through the collector and heat exchanger and does not freeze during the winter. The glycol must be inspected and/or replaced periodically. Glycol is more expensive than water, but provides excellent freeze protection and reduced scale. A circulating pump with a controller moves the liquid through the system.

Install an indirect, active solar heating system (Figure 40) to offset part of or the entire domestic hot water load. It is likely most occupants will take showers in the morning; therefore, the system should be configured to allow the temperature to reach 170 °F during the day and stay above 140 °F at night. Due to the shower demand in the morning, a storage-to-collector ratio of 2 gal/sq ft should be used.

Each barracks has 48 rooms with single occupancy. A total of 576 gal of hot water per day is required to meet the shower load, assuming 12 gal per shower. An additional 823 gal of hot water is required for the laundry, assuming each load requires 40 gal.



(Image obtained from North Carolina Solar Center)

Figure 40. Indirect solar water heating schematic.

There are two approaches for sizing the system. Option 1 would size the system to optimize the economics, which would result in 20 collectors. This option would require 1940 gal of storage that may be able to fit in the existing mechanical room. Option 2 would size the system for the entire domestic hot water load. Although this is not as cost effective, it would avoid part-loading the existing boiler, which would create an inefficient system or the need to buy a new smaller boiler. Option 2 would require 45 collectors and 4366 gal of storage. The storage tanks would likely have to be buried outside. Existing pumping equipment and hot water piping within the building could also be used. It was not possible to access the roof during the survey, but it is flat and appeared to have adequate roof area with solar access.

7.6.3 Savings

The solar water heating load analysis was conducted using RETScreen, a publicly available solar simulation model created by Natural Resources Canada. RETScreen uses weather information based on data provided by the National Aeronautics and Space Administration (NASA). In this particular study, the data was taken from the closest available weather station, which is located in Las Vegas, NV, approximately 150 miles north east of Fort Irwin. The RETScreen simulations were run using an evacuated tube collector system to determine:

- Domestic water heating load:

  h = 1399 gal/day x 365 days/yr x 8.33 pounds/gal x 80 °F / (100,000 Btu/therm x 0.80 gas water heater efficiency) = 4253 therms/yr

- Annual heating savings:

  Option 1: (245 MMBtu x $24.64/MMBtu) / 80% efficiency = $7,546/yr

  Option 2: (340 MMBtu x $24.64/MMBtu) / 80% efficiency = $10,472/yr

7.6.4 Investment

Capital costs are based on a panel cost of $400/solar module (SM) (pricing based on evacuated tube collectors manufactured by Paradigma), RS Means 2009 Mechanical Cost Data for storage tank and other material costs, and estimated costs for permitting, engineering reviews, installer profit, and installer labor and overhead.

Since Army is not an SDG&E customer, it is not eligible for the CSI offered through their Pilot Solar Water Heating Program because. This incentive is $20/sq ft up to a $75,000 maximum for larger commercial buildings. Note: collectors must be SRCC OG100 rated and must have a minimum of a 10-yr manufacturer's warranty on the individual balance of system components, and 1-yr warranty on installation labor and workmanship. This project could also be completed through a PPA with a third party. The advantage of having a private company as the owner is that they are able to use the Business Energy ITC – a tax credit worth 30 percent of the system cost.

The estimated cost of the solar heating system for Option 1 is $91,770 and for Option 2, $174,570. Table 61 lists the breakdown of the capital cost for solar heating system for Option 1.

Table 61. Breakdown of the capital cost for solar heating system for Option 1.

Element	Option 1	Option 2	Calculations
Solar collector panels	$36,000	$81,000	(20/45 x 4.5 m^2 x$400/$m^2$)
Solar storage tank	$14,300	$22,800	(2,000/4,500-gal tanks)
Roof mounting system	$5,400	$12,150	(15% of panel cost)
Piping + other materials	$4,600	$5,300	
Labor	$19,500	$30,550	($65/hr)
Planning/design	$11,970	$22,770	(15% of total cost)

7.6.5 Payback

The solar resource at Fort Irwin is excellent and results in a reasonable payback for domestic water heating applications. It is recommended to pursue solar water heating applications for facilities that have consistent domestic hot water use throughout the year, and have south facing or flat unobstructed roof space.

Payback is based on a cash flow model that includes O&M costs of 0.25 percent/yr and degradation of 0.80 percent/yr.

For Option 1, the resulting payback is 12.3 yrs without incentives and 8.4 yrs with the ITC.

For Option 2, the resulting payback is 15.7 yrs without incentives and 11 yrs with the ITC.

Option 1 is recommended.

7.7 RE-5: Solar thermal system for domestic hot water, Bldg 362

7.7.1 Existing conditions/problems

The physical fitness center in Bldg 362 has a large domestic hot water load due to the much used showers in the changing rooms. This load is year-round and peaks in the morning, lunch hour, and late afternoon/evening. Domestic hot water load is met using a 680,000 Btu/hr Raypack Boiler and space heating loads are met using two 414,000 Btu/hr Patterson Kelly Boilers. The system has a 1000-gal storage tank that could be used for solar. There is space in the mechanical room for additional storage.

7.7.2 Solution

Indirect active solar water heating systems use a non-potable fluid (usually glycol) that circulates through the collector and heat exchanger and does not freeze during the winter. The glycol must be inspected and/or replaced periodically. Glycol is more expensive than water, but provides excellent freeze protection and reduced scale. A circulating pump with a controller moves the liquid through the system.

Install an indirect, active solar heating system to offset a significant portion of the domestic hot water production. The system would be installed in series with the existing system, which could provide additional heating on cloudy days or during high peak times. The south roof of Bldg 362 (Figure 41) is tilted in an east-west direction. A rack-mounted system providing a flat surface to place the collector panels at a 20 degree angle facing south should be installed (Figure 42). On the north side of the roof, there is a 15-ft wall that will shade part of the roof. At the latitude of Fort Irwin, for every 1 ft of wall height, 1 ft of space is required to avoid shading from the wall. On the east and west ends of the roof there is a 6 ft wall, but the rack will be installed so that only 1 ft of spacing between the wall and the panel is required. On the south end of the wall, 1 ft of space is also required.

Figure 41. Roof of Bldg 362.

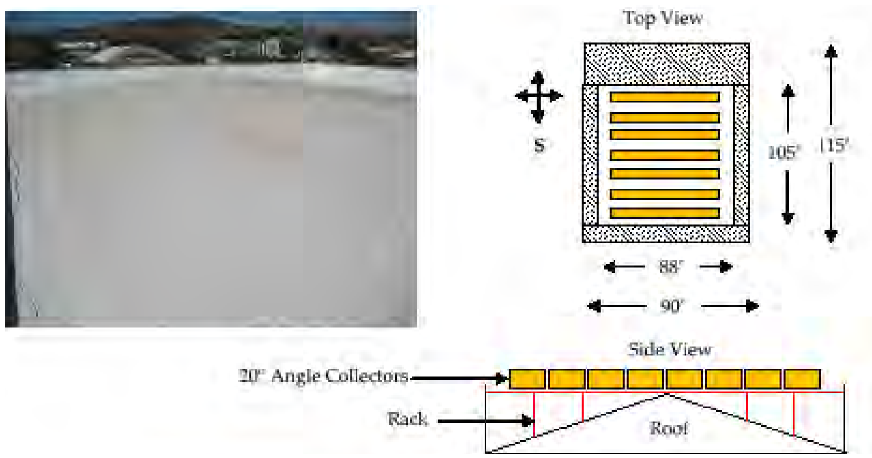


Figure 42. Solar water heater collector placement at Bldg 362.

The fitness facility is used by approximately 500 to 1000 people every day; about half take showers. Additionally, there are four washing machines that are used constantly throughout the day to wash towels. It is estimated that 4500 gal of hot water per day is required to meet the shower load, assuming 12 gal per shower and 1600 gal of hot water per day is required for the laundry, assuming each load requires 40 gal.

A rack-mounted 65 collector system is recommended. An additional 5300 gal of storage would be needed beyond the existing 1000 gal to support this system. There is some space inside the mechanical room, but it may be necessary to install or bury the tanks outside. Existing pumping equipment and hot water piping within the building could also be used.

On the northwest and northeast sections of the roof, a flat space is also available where photovoltaic panels could be installed that feed into the grid (Figure 43). On the northwest section of the roof, 80 panels could be installed, and on the northeast section of the roof, 42 panels could be installed. Each row should have 2.25 m spacing to avoid shading. This yields a total capacity of 21.4 kWDC.

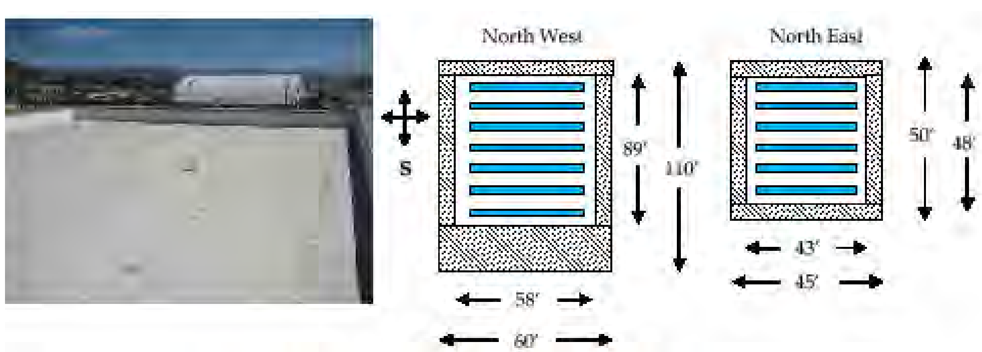


Figure 43. Placement of PV panels at Bldg 362.

7.7.3 Savings

The solar water heating load analysis was conducted using RETScreen, a publicly available solar simulation model created by Natural Resources Canada. RETScreen uses weather information based on data provided by NASA. In this particular study, the data was taken from the closest available weather station, which is located in Las Vegas, NV, approximately 150 miles north east of Fort Irwin. The RETScreen simulations were run using an evacuated tube collector system to determine the domestic water heating load:

h = 6100 gal/day x 365 days/yr x 8.33 pounds/gal x 80 °F / (100,000 Btu/therm x 0.80 gas water heater efficiency) = 18,547 therms/yr

Hot water cost savings are expected to reduce natural gas consumption by 56 percent.

7.7.4 Annual heating savings

(836 MMBtu x $24.64/MMBtu) / 80% efficiency = $25,755/yr

7.7.5 Electricity production

e = 122 panels x 175 WDC x 18.99% (kWhAC/kWhDC) x 8760 hrs = 35,516 kWh/yr

7.7.6 Annual electricity savings

35,516 kWh x 8.3 cents/kWh = $2,948/yr

7.7.7 Investment

Capital costs are based on a panel cost of $400/SM (pricing based on evacuated tube collectors manufactured by Paradigma), RS Means 2009 Mechanical Cost Data for storage tank and other material costs and estimated costs for permitting, engineering reviews, installer profit, and installer labor and overhead.

The Army is not eligible for the CSI offered through their Pilot Solar Water Heating Program because they are not an SDG&E customer. This incentive is $20/sq ft up to a maximum of $75,000 for larger commercial buildings. Collectors must be SRCC OG100 rated and must have a minimum of a 10-yr manufacturer's warranty on the individual balance of system components, and 1-yr warranty on installation labor and workmanship.

This project could also be completed through a PPA with a third party. The advantage of having a private company as the owner is that they are able to use the Business Energy ITC – a tax credit worth 30 percent of the system cost.

7.7.8 The estimated cost of the solar water heating system is $245,870.

Table 62 lists the breakdown for the capital cost of a solar water heating system.

7.7.9 The estimated cost of the PV system is $153,293.

Table 63 lists the breakdown for the capital costs of the PV system.

7.7.10 CSI – Expected performance-based buy-downs for systems under 50 kW:

Incentive: $13,176 ($3.25/W_{AC})

7.7.11 Payback

The solar resource at Fort Irwin is excellent and results in a reasonable payback for domestic water heating applications. It is recommended to pursue solar water heating applications for facilities that have consistent domestic hot water use throughout the year, and have south facing or flat unobstructed roof space.

Table 62. Breakdown for the capital cost of solar water heating system.

Element	Cost	Calculation
Solar collector panels	$117,000	(65 x 4.5 m^2 x$400/$m^2$)
Solar storage tank	$27,200	(6000 gallon tank)
Roof mounting system	$23,400	(20% of panel cost)
Piping + other materials	$5,900	
Labor	$40,300	(620 hrs x$65/hr)
Planning/design	$32,070	(15% of total cost)

Table 63. Breakdown for the capital cost of PV system.

Element	Cost	Unit cost
Installation	$59,353	($2.78/W)
Modules	$53,375	($2.50/W)
BOS	$10,889	($0.51/W)
Monitoring	$2,135	($0.10/W)
Other costs	$11,316	($0.53/W)
Inverter	$16,226	($0.76/W)

Payback is based on a cash flow model that includes O&M costs of 0.25 percent/yr and degradation of 0.80 percent/yr.

The resulting payback for the solar water heating system is 10.1 yrs without any incentives and 6.8 yrs with the ITC.

The resulting payback for the PV system is greater than 25 yrs with or without the CSI incentive. If a third party were to own the system and be able to take advantage of the ITC, the payback would be 21 yrs.

7.8 RE-6: Solar thermal system for domestic hot water, Fitness Bldg 127

7.8.1 Existing conditions/problems

The physical fitness center in Bldg 127 (Figure 44) has a small domestic hot water load from the showers and laundry. During the survey, it was not possible to access the mechanical room, but it is assumed there is some storage available.

7.8.2 Solution

Indirect active solar water heating systems use a non-potable fluid (usually glycol) that circulates through the collector and heat exchanger and does not freeze during the winter. The glycol must be inspected and/or replaced periodically. Glycol is more expensive than water, but provides excellent freeze protection and reduced scale. A circulating pump with a controller moves the liquid through the system.

Figure 44. Fitness Center (Bldg 127).

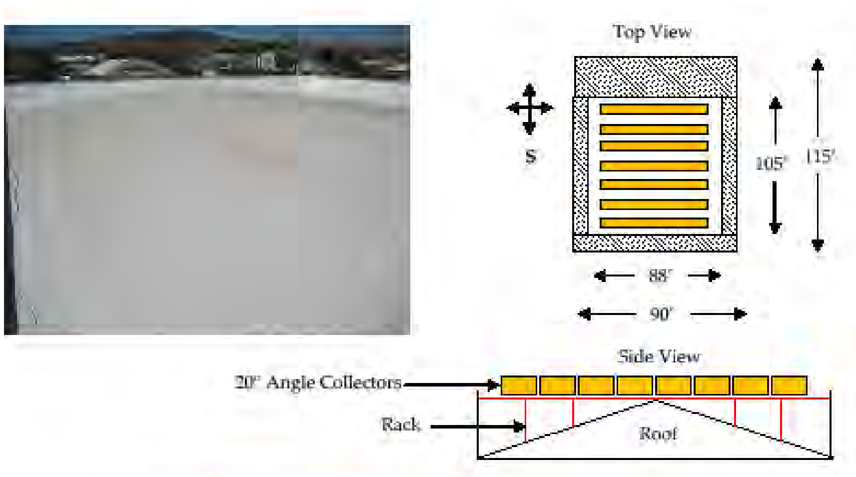


Figure 45. PV and solar hot water panel arrangement at Bldg 127.

Install an indirect, active solar heating system to offset a significant portion of the domestic hot water production. The system would be installed in series with the existing system, which could provide additional heating on cloudy days or during high peak times. Since there is a significant amount of available roof space, photovoltaic panels could be installed on the remainder of the roof (Figure 45). The south roof of Bldg 127 is tilted at 30 degrees.

The domestic hot water load at the fitness facility is due to the 15 daily showers and 15 loads of laundry at the facility. It is estimated that 780 gal of hot water per day is required to meet this load. A 10 collector system installed flush to the roof is recommended. This would require approximately 1000 gal of storage. It was not possible to access the mechanical room during the survey, but it is expected that there is storage available and that if more is required, there is space in the mechanical room. Existing pumping equipment and hot water piping within the building could also be used. On the remainder of the roof, 260 photovoltaic panels could be installed. This yields a total capacity of 45.5 kW_{DC}.

7.8.3 Savings

The solar water heating load analysis was conducted using RETScreen, a publicly available solar simulation model created by Natural Resources Canada. RETScreen uses weather information based on data provided by NASA. In this particular study, the data was taken from the closest available weather station, which is located in Las Vegas, NV, approximately 150 miles north east of Fort Irwin. The RETScreen simulations were run using an evacuated tube collector system to determine the domestic water heating load:

h = 780 gal/day x 365 days/yr x 8.33 pounds/gal x 80 °F / (100,000 Btu/therm x 0.80 gas water heater efficiency) = 2372 therms/yr

Hot water cost savings are expected to reduce natural gas consumption by 65 percent.

7.8.4 Annual heating savings

(123 MMBtu x $24.64/MMBtu)/ 80% efficiency = $3,800/yr

7.8.5 Electricity production

e = 260 panels x 175 WDC x (1 kW / 1000 W) x 18.99% (kWhAC/kWhDC) x 8760 hrs = 75,690 kWh/yr

7.8.6 Annual electricity savings

75,690 kWh x 8.3 cents/kWh = $6,282/yr

7.8.7 Investment

Capital costs are based on a panel cost of $400/SM (pricing based on evacuated tube collectors manufactured by Paradigma), RS Means 2009 Mechanical Cost Data for storage tank and other material costs and estimated costs for permitting, engineering reviews, installer profit, and installer labor and overhead.

The Army is not eligible for the CSI offered through their Pilot Solar Water Heating Program because they are not an SDG&E customer. This incentive is $20/sq ft up to a maximum of $75,000 for larger commercial buildings. Note that collectors must be SRCC OG100 rated and must have a minimum of a 10-yr manufacturer's warranty on the individual balance of system components, and 1-yr warranty on installation labor and workmanship.

This project could also be completed through a PPA with a third party. The advantage of having a private company as the owner is that they are able to use the Business Energy ITC – a tax credit worth 30 percent of the system cost.

The estimated cost of the solar water heating system is $228,390. Table 64 lists the breakdown for the capital cost.

The estimated cost of the PV system is $326,690. Table 65 lists the breakdown for the capital cost.

7.8.8 CSI – Expected performance-based buy-downs for systems under 50 kW:

Incentive: $28,081 ($3.25/W_{AC})

Table 64. The breakdown for the capital cost of a solar water heating system.

Element	Cost	Calculation
Solar collector panels	$18,000	(10 x 4.5 m^2 x$400/$m^2$)
Solar storage tank	$5,000	(1,000-al tank)
Roof mounting system	$2,700	(15% of panel cost)
Piping + other materials	$2,000	
Labor	$4,160	(64 hrs x$65/hr)
Planning/design	$4,779	(15% of total cost)

Table 65. The breakdown for the capital cost of the PV system.

Element	Cost	Calculation
Installation	$126,490	($2.78/W)
Modules	$113,750	($2.50/W)
BOS	$23,205	($0.51/W)
Monitoring	$4,550	($0.10/W)
Other costs	$24,115	($0.53/W)
Inverter	$34,580	($0.76/W)

7.8.9 Payback

The solar resource at Fort Irwin is excellent and results in a reasonable payback for domestic water heating applications. It is recommended to pursue solar water heating applications for facilities that have consistent domestic hot water use throughout the year, and have south facing or flat unobstructed roof space.

Payback is based on a cash flow model that includes O&M costs of 0.25 percent/yr and degradation of 0.80 percent/yr.

The resulting payback for the solar water heating system is 13.3 yrs without any incentives and 9.1 yrs with the ITC.

The resulting payback for the PV system is greater than 25 yrs without with the CSI incentive. If a third party were to own the system and be able to take advantage of the ITC, the payback would be 21 yrs.

7.9 RE-7: Solar thermal system for pool heating, Fitness Bldg 325

7.9.1 Existing conditions/problems

Bldg 325 consists of a 25 m x 25 m outdoor swimming pool, which is heated year-round (Figure 46). The pool temperature is kept at 85 °F by a 2,870,000 Btu/hr LPG-fired boiler. There are four 20,000 water treatment storage tanks.

7.9.2 Solution

One solution is to install an extruded polyethylene plastic direct solar heating system to heat the pool water during the warmer months of the year. Polymer solar thermal systems are excellent for low temperature applications, such as pools. Although this system cannot be used for the entire year, the capital costs are significantly less than those of regular systems. and they are easier to install.

The solar collectors could be installed on the flat roof of Bldg 325 (Figure 47). Generally, for pool heating, the solar array should be equal to 50 to 100 percent of the pool's surface area. However, the available roof area for the collectors is only 200 m^2, thus the maximum amount of collector panels should be installed on the roof. Note that there was no access to the roof during the survey.

Figure 46. Outdoor swimming pool (Bldg 325).

Figure 47. Bldg 325.

Additional storage tanks would need to be installed. If there is not enough room in the building, the tanks could be buried or located outside.

7.9.3 Savings

The pool heating load was calculated using the RETScreen Energy Model. Assumptions include 12 hrs of cover use during the night and 7 percent of makeup water per week due to water changes and pool activity levels.

7.9.4 Annual pool heating load

6579 therms / 0.80 gas water heater efficiency = 8224 therms/yr

Pool heating cost savings are anticipated to be 36 percent of the current annual cost, assuming that the solar collectors are drained during the 4 coldest months.

Pool Heating Savings = 233.7 MMBtu/yr / 80% efficiency x $24.64/MMBtu = $7199/yr

7.9.5 Investment

The estimated installed cost, including design, administration, installation, contingencies, overhead, and profit of the pool solar heating system, is $21,359. The cost assumes the panels are placed flat on the roof and thus does not include rack mounting. The cost estimate includes the collectors, storage tank and other equipment. This system is much less costly; however, it can only be used during the warmer months and must be drained during the colder months. Pool heating systems do not qualify for incentives.

7.9.6 Payback

The resulting payback is 3.6 yrs. The payback for pool systems using polymer collectors is generally very attractive due to the low capital cost. The drawback is that sometimes there are issues with aesthetics and it can only be used for half of the year. It is recommended that other outdoor pools on the installation also be considered for pool solar heating systems that use polymer collector systems.

Solar pool heating using plastic absorbers has an excellent payback and should be implemented.

7.10 RE-10: Standalone photovoltaic system, Bldg 602

7.10.1 Existing conditions/problems

Bldg 602 has a south facing roof tilted at approximately 30 degrees.

7.10.2 Solution

Install 150 photovoltaic panels flush on the south facing roof, which would not require significant row spacing (Figure 48). This yields a total capacity of 26.3 kWDC.

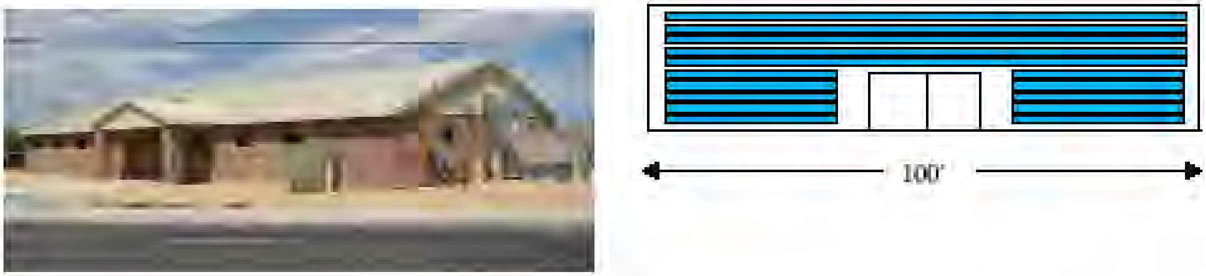


Figure 48. PV Placement at Bldg 602.

7.10.3 Savings

Savings related to electricity production are:

e = 150 panels x 175 WDC x (1 kW/1000 W) x 18.99% (kWhAC/kWhDC) x 8760 hrs = 43,668 kWh/yr

Annual electricity savings are:

43,668 kWh x 8.3 cents/kWh = $3624/yr

The capacity factor for the solar photovoltaic analysis was based on simulations conducted by NREL for Las Vegas, NV. This data is publicly available using the PV Watts performance calculator for grid-connected systems.

7.10.4 Investment

Capital costs are based on installer surveys and RS Means Mechanical Cost Data.*

Table 66 lists the breakout of capital costs.

The estimated cost of the PV system is $17,591. Table 67 lists the breakdown for the capital cost for a PV system in Bldg 602.

The Army could be eligible for the CSI. Expected performance-based buydowns for systems under 50 kW are $3.25/W$_{AC}$ for government entities. These projects could also be completed through a PPA with a third party. The advantage of having a private company as the owner is that they are able to use the Business Energy ITC – a 30 percent tax credit.

* NCI Analysis

Table 66. Breakout of capital costs for a stand-alone photovoltaic system, Bldg 602.

Element	Cost
Installation	$2.78/W
Modules	$2.50/W
BOS	$0.51/W
Monitoring	$0.10/W
Other costs	$0.53/W
Inverter	$0.76/W

Table 67. Breakout of capital costs for a PV system, Bldg 602.

Element	Cost	Unit Cost
Installation	$72,975	($2.78/W)
Modules	$65,625	($2.50/W)
BOS	$13,388	($0.51/W)
Monitoring	$2,625	($0.10/W)
Other costs	$13,913	($0.53/W)
Inverter	$19,950	($0.76/W)

7.10.5 CSI – Expected performance-based buy-downs for systems under 50 kW:

Incentive: $16,201 ($3.25/W_{AC})

7.10.6 Payback

Payback is based on a cash flow model that includes degradation of 0.70 percent/yr.

Rooftop PV has a long payback even with incentives. PV should be pursued for Net-Zero purposes and third party ownership should be explored.

7.11 RE-11: Standalone photovoltaic system, RUFMA

7.11.1 Existing conditions/problems

Another possibility for photovoltaic panels is the shading structures in RUFMA (Figure 49). There are a large number of them, and each has a relatively flat surface where a rack mounted PV array could be placed. However, the structural integrity must be investigated first.

7.11.2 Solution

Install a rack-mounted PV array on each RUFMA.

Figure 49. RUFMA shading structure.

7.11.3 Savings

Similar to other PV applications at Fort Irwin, the capacity factor for the solar photovoltaic analysis was based on simulations conducted by NREL for Las Vegas, NV. This data is publicly available using the PV Watts performance calculator for grid-connected systems.

7.11.4 Investment

The Army could be eligible for the CSI. Expected performance-based buydowns for systems under 50 kW are $3.25/W_{AC}$ for government entities. These projects could also be completed through a PPA with a third party. The advantage of having a private company as the owner is that they are able to use the Business Energy ITC – a 30 percent tax credit.

7.11.5 Payback

Rooftop PV has a long payback even with incentives. PV should be pursued for Net-Zero purposes and third party ownership should be explored.

8 Summary, Conclusions, and Recommendations

8.1 Summary

This work conducted an energy assessment at Fort Irwin, CA as a part of a Net-Zero initiative. The scope included an assessment of a Cluster of buildings with a focus on retrofits to minimize net energy use within the Cluster. Additionally energy savings measures and identification of wastes and inefficiencies were identified on a limited basis for other areas of the installation.

Barracks 261, 262, 264, 265, and 267 (referred to as "The Cluster") were selected to be studied to develop concepts for Net-Zero. These barracks are of the same vintage and nearly identical in structure. They differ only in minor details such as the flow (cfm) of the respective makeup air units (MAUs). The Cluster also includes Central Energy Plant 263 and Dining Facility 271. The Net-Zero energy study focuses on barracks Bldg 264, Central Plant 263 and the dining facility.

8.2 Conclusions

This work concludes that it is possible to reduce the energy consumed to heat, cool, and ventilate the facilities by 68 percent. This is in line with real world projects that have exhibited savings in excess of 70 percent for similar HVAC retrofits, even without envelope modifications. Significant renewable opportunities were also identified to supply much of the remaining energy requirements. This can be done by using more efficient heating, cooling, and lighting systems as well as using renewable energy opportunities, which would offset 4832 MMBtu/yr of thermal energy use and 41,630KWh of electrical use.

Space heating related energy would be reduced by up to 17 percent, domestic HW related energy by 13 percent, and lighting energy by 17 percent. The space heating and domestic hot water heating savings figures generated by the model are likely substantially lower than the actual project would provide, due to the current design and operation of the installed systems. It is likely that the actual domestic hot water and space heating savings would exceed 50 percent based on the projects discussed in this report.

These levels of savings would be achieved while improving occupant comfort and substantially reducing the potential for biological (mold) growth in these facilities. Note that, in many climates, the costs to mitigate biological growth in barracks facilities far exceed the total annual energy costs of the facilities, and this benefit alone could be the driving factor to use the proposed designs, even if there were no energy savings.

Four different methods to heat and cool the facilities were developed. A common envelope/skin solution was developed and applied to all the barracks facilities. A common central heating/cooling plant solution was developed and applied to all the barracks facilities.

The four different building HVAC options are:

1. DOAS-VAV, with direct evaporative cooling
2. DOAS with radiant heating and cooling, direct and indirect evaporative cooling
3. DOAS with fan coils, direct and indirect evaporative cooling
4. DOAS-VAV with direct and indirect evaporative cooling.

8.3 Recommendations

There are five barracks. From a research and lifecycle cost evaluation perspective, it is recommended to install one of each of the proposed HVAC systems in an individual barracks facility. It is proposed to install the radiant heating and cooling option in two of the barracks, as that technology may yield the best energy results, but there is less field experience with that technology as opposed to the other system types. This would be an opportunity to see this technology in direct comparison with other, more traditional HVAC system designs.

It is recommended that each facility be equipped with substantial metering and sub-metering capabilities so that occupant comfort and energy use could be recorded for comparison purposes. It is proposed to modify the facilities and monitor the systems in great detail, performing monthly evaluations to determine trends in energy use and savings as well as recording occupant related issues, if any, in comparison to one another. Monthly reports would be generated, and a year-end wrap-up report would be developed that would summarize the real world findings of the installation.

Note that the costs contained in this report are estimated retrofit costs. If the scopes described in this document were changed to reflect a new construction project, the incremental costs for the work would likely yield simple payback periods of less than 10 yrs in most utility rate environments.

Additionally, the proposed work includes the implementation of DOAS and high efficiency dehumidification systems that would dramatically reduce the potential for biological growth occurring, so the lifecycle cost of these systems is far lower than typical designs that are currently being designed and built.

The estimated first cost of the HVAC and Envelope related portions of the retrofit is $48,237,000. The estimated energy savings for the HVAC/Envelope modifications described for this site equate to $68,000/yr. So, as a cost effective retrofit project, this project would never qualify. Even if we include savings of $1.00/sq ft/yr for avoided biological mitigation costs in humid climates due to the proposed HVAC and envelope designs, the simple payback period is in excess of 200 yrs, as a retrofit project.

As stated earlier, during new construction projects, the incremental costs associated with getting the efficiency gains associated with the recommended projects is thought to deliver a simple payback period of 10 yrs or less in many climates and utility rate areas.

Where this project would shine is in a real world demonstration project where several different state of the art HVAC systems could be directly compared to one another. This site would point the direction for future barracks complexes where the cooling related energy can be reduced by over two-thirds compared to existing design and operational strategies.

The knowledge gained within a year after project completion would be invaluable, and would point the way future barracks complexes could be built to minimize the need for the consumption of energy resources.

Acronyms and Abbreviations

Term	Spellout
ACH	air changes per hour
ACSIM	Assistant Chief of Staff for Installation Management
AHU	air handling unit
ANSI	American National Standards Institute
BHP	brake horsepower
BIP	Barracks Improvement Program
BOS	Base Operating Systems
Btu	British Thermal Unit
BUP	Barracks Upgrade Program
CDD	total cooling degree days
CEERD	U.S. Army Corps of Engineers, Engineer Research and Development Center
CEP	Central Energy Plant
CERL	Construction Engineering Research Laboratory
CFM	cubic feet per minute
CHW	chilled water
CHWR	chilled water return
CHWS	chilled water supply
CMU	concrete masonry unit
CO	carbon monoxide
COE	Chief of Engineers
COP	coefficient of performance
CSI	California Solar Initiative
CT	Cooling tower
DDC	direct digital control
DFAC	Dining facility
DHW	domestic hot water
DOAS	dedicated outdoor air supply
DOE	U.S. Department of Energy
DOS	Disk Operating System
DPW	Directorate of Public Works
DX	direct expansion
ECM	Energy Conservation Measure
EEM	Energy Efficiency Measure
EISA	U.S. Energy Independence and Security Act of 2007
EMCS	Energy Management Control System
EO	Executive Order
EPACT	Energy Policy Act of 2005
ERDC	Engineer Research and Development Center

Term	Spellout
ERDC-CERL	Engineer Research and Development Center, Construction Engineering Research Laboratory
FCU	four-pipe fan coil unit
FY	fiscal year
HDD	heating degree days
HEDS	High-Efficiency Dehumidification System
hp	horsepower
HQIMCOM	Headquarters, Installation Management Command
HVAC	heating, ventilating, and air-conditioning
HW	Hot Water
IMCOM	Installation Management Command
ITC	Investment Tax Credit
LOBOS	Load Based Optimization System
LPG	liquid petroleum gas
MAU	makeup air unit
MBH	1000 Btu/hr
MBtu	1 million Btus
MMBtu	million Btu
MW	megawatt
NASA	National Aeronautics and Space Administration
NREL	National Renewable Energy Laboratory
NSN	National Supply Number
OA	outside air
OMB	Office of Management and Budget
PPA	Power Purchase Agreement
PV	photovoltaic
RA	return air
RHC	Radiant Heating and Cooling
ROI	Return on Investment
SF	standard form
SM	solar module
SPH	space heating
SRCC	Solar Rating and Certification Corporation
TD	Temperature Drop
TR	Technical Report
TV	television
VAV	variable air volume
VFD	variable frequency drive
WWW	World Wide Web

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14. ABSTRACT
This work conducted an Energy Assessment at Fort Irwin, CA, as a part of a Net-Zero initiative. The scope included an assessment of a “Cluster” of buildings with a focus on retrofits to minimize net energy use within the Cluster. The work additionally identified energy savings measures and wastes and inefficiencies on a limited basis for other areas of the installation. This report explores two strategies for evaluating energy-efficient technologies: (1) to install and evaluate several different energy efficient heating, ventilating, and air-conditioning (HVAC) system designs and renewable energy projects that may lead to the lowest lifecycle cost for a facility, and (2) to “cherry-pick” the least-first-cost options and install them at a complex, and then to evaluate their performance against each other. This work concluded that, depending on the type of HVAC system chosen for the Cluster, the savings potential (simple payback) of upgrading to a Net-Zero energy ready building (beyond the savings of a normal Army upgrade) varies from 2.8 to 13.8 yrs. This work also explored renewable energy opportunities as part of the Net-Zero concept. Results showed that energy use could be significantly reduced towards Net-Zero energy use with a payback of less than 15 yrs with the implementation and use of renewable energy technologies.

15. SUBJECT TERMS
energy assessment, Fort Irwin, CA, energy conservation, Annex 46, central energy plants

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