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Energy Optimization Assessment at U.S. Army Installations

Fort Bliss, TX

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David M. Underwood, Alexander Zhivov, and James P. Miller
Construction Engineering Research Laboratory (CERL)
U.S. Army Engineer Research and Development Center
2902 Newmark Dr.
Champaign, IL 61824

Alfred Woody
Ventilation/Energy Applications, PLLC
Rochester Hills, MI 48309

Robert Colbert
Ameresco Federal Solutions
Knoxville, TN 37921

Leon Shapiro
VRTX Technologies
Schertz, TX 78154

Curt Bjork
Curt Bjork Fastighet & Konsult AB, Sweden

William D. Chvala, Jr. and Douglas Dixon
Pacific Northwest Laboratory
Richland, WA 99352

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Abstract: An Energy Optimization Assessment was conducted at Fort Bliss as a part of the "Annex 46 Holistic Assessment Toolkit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo)" initiative to identify energy inefficiencies and wastes and propose energy related projects with applicable funding and execution methods that could enable the installation to better meet the energy reduction requirements mandated by Executive Order 13123 and Energy Policy Act (EPAct) 2005. The assessment included a Level I study of energy conservation opportunities in a number of representative buildings including an analysis of their building envelopes, ventilation air systems, controls, interior and exterior lighting as well as opportunities to use renewable energy resources. The Annex 46 initiative at Fort Bliss did not include the evaluation of industrial or manufacturing processes. The study identified 210 different energy conservation measures (ECMs) that if implemented would reduce Fort Bliss's annual energy use by up to 65 MWH/yr electric and 170,023 MMBtu/yr thermal savings (mostly natural gas). Savings of $552K/yr in maintenance costs were also identified. The total energy and maintenance savings would be $7.9 million/yr. An investment of $23.4 million to implement the ECMs results in a simple payback of 3 yrs. These ECMs are presented in nine groups according to the system type that the ECM affects.

Executive Summary

General

This project conducted an Energy Optimization Assessment at Fort Bliss as a part of the Annex 46 showcase studies to identify energy inefficiencies and wastes and to propose energy-related projects with applicable funding and methods of execution that could enable the installation to better meet the energy reduction requirements mandated by Executive Order 13423 and EPACT 2005.

The study was conducted by a team of researchers from the Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL), the Pacific Northwest National Laboratory (PNNL) and Subject Matter Experts (SMEs), and was limited to a "Level I" assessment. The scope of this study included an analysis of building envelopes, ventilation air systems, controls, interior and exterior lighting, and an evaluation of opportunities to use renewable energy resources.

The study identified a total of 214 different potential energy conservation measures (ECMs), 210 of which were economically quantified (summarized in Appendix A to this report). These ECMs (summarized in Table ES1) are organized into six categories:

1. Building Envelope
2. Controls
3. Evaporative Cooling
4. Heating, Ventilating, and Air-Conditioning (HVAC)
5. Lighting
6. Renewables.

If all these ECMs were implemented, they would yield savings of approximately $7.9 million/yr (65 MWh/yr in electrical energy savings, 170 MMBtu/yr in thermal savings (mostly natural gas), and $552K/yr in maintenance savings. Implementation of these projects would require investment of $24 million, and would achieve an average simple payback in 3.0 yrs.

Table ES1. Summary of ECMs.

ECM Group	Report Chapter	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec. Demand, Thermal, and Maint. $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
Building Envelope	3	5,883,905	1,966	$603,758	134,108	1193809	0	$1,797,567	$7,561,243	4.2
Controls	5	2,730,000	0	$177,450	0	0	0	$177,450	$100,000	0.6
Evaporative Cooling	6	36,811,000	0	$3,533,856	0	0	98,571	$3,533,856	$5,207,500	1.5
HVAC*	8	2,846,097	-474	$227,841	42,286	396459	43571	$722,871	$1,490,490	2.1
Lighting	9	16,354,861	3,146	$1,315,194	-6,739	-111028	508124	$1,712,290	$9,043,584	5.3
Renewables	10	0	0	$0	368	3343	0	$3,343	$18,000	5.4
Totals		*64,625,864*	*4,638*	*$5,858,099*	*170,023*	*1482583*	*551695*	*$7,947,377*	*$23,420,817*	*2.9*

* Note that HVAC includes a credit of $605K for avoided costs.

Thirty-four of these ECMs resulted from an SME analysis, which included a survey of the specific buildings to which each ECM applies. The other 180 ECMs resulted from modeling the installation's energy use using the Facility Energy Decision System (FEDS) tool. Because the FEDS analysis does not involve a visit to each building an ECM is proposed for, the FEDS analyses (and the resultant ECMs) were less thorough than the SME analyses and ECMs. The FEDS ECMs were further divided into subsets of ECMs (fully described in Chapters 3 [p 13] to 10 [p 102]). Note that, in Tables ES2–ES5, ECM summaries resulting from FEDS analysis are indicated by an asterisk.

The **Building Envelope** category consists of 61 ECMs (summarized in Table ES2). BE #4 through BE #7 are summarize ECMs for groups of buildings; these resulted from a FEDS analysis and can be broken into smaller projects. (Chapters 3.4 [p 24] through 3.7 [p 30] give a detailed description.) If all Building Envelope ECMs were implemented, they would save 5,888 MWh/yr and 134,108 MBtu/yr in thermal savings (mostly natural gas), resulting in savings of $1.8 million/yr. The investment cost of $7.6 million would achieve simple payback in 4.2 yrs.

The **Controls** category consists of two ECMs. Establishing and maintaining a uniform setpoint for all space temperatures would save 2,730 MWh/yr, resulting in savings of $177K/yr. The investment cost of $100K would achieve a quick simple payback in 0.6 yrs. The second Controls ECM, of expanding the base wide control system, was not economically analyzed in this effort, but is being pursued separately.

The **Evaporative Cooling** ECM group consists of three types of ECMs, which include a total of 19 ECMs (Table ES3). Eleven buildings were identified in which EC #1 could be applied; implementation would save 2,417 MWh/yr resulting in savings of $232K/yr. The investment cost of $188K would achieve simple payback in 0.8 yrs. Five buildings were identified in which EC #2 could be applied; implementation would save 31,166 MWh/yr, resulting in savings of $3 million/yr. The investment cost of $4.6 million would achieve simple payback in 1.5 yrs. Three buildings were identified in which EC #3 could be applied; implementation would save 3,228 MWh/yr resulting in savings of $310K/yr. The investment cost of $400K would achieve simple payback in 1.3 yrs.

The **HVAC** ECM group consists of 48 ECMs (summarized in Table ES4). HVAC #5 through HVAC #10 summarize ECMs for groups of buildings that resulted from a FEDS analysis, and that can be broken into smaller projects. (Chapters 8.5 [p 77] through 8.9 [p 83] give a detailed description.) Implementation of all HVAC ECMs would save 2846 MWh/yr and 42,286 MBtu/yr in thermal costs (mostly natural gas), and $44K in maintenance costs, resulting in a total savings of $723K/yr. The investment cost of $1.5 million would achieve simple payback in 2.1 yrs. In these totals is an avoided cost credit of $605K for HVAC #4.

The **Lighting** ECM group consists of 80 ECMs (summarized in Table ES5). LI #3 through LI #10 summarize ECMs for groups of buildings that resulted from a FEDS analysis, and that can be broken into smaller projects (for details, see Chapters 9.3 [p 91] through 9.10 [p 100]). Implementation of all Lighting ECMs would save 17 MWh/yr, have a 6,739 MBtu/yr thermal penalty, and reduce maintenance costs by $508K, resulting in total savings of $1.7 million/yr. The investment cost of $9 million would achieve simple payback in 5.3 yrs.

One **Renewable** type of ECM was identified. Shower water heat recovery would save 368 MBTU/yr for a savings of $3,343/yr. The investment cost of $18K would achieve simple payback in 5.4 yrs.

Several **Miscellaneous** ECMs, involving commissioning and electrical motors, were also identified. These were not analyzed economically.

The Level I analyses of multiple complex systems conducted during the Energy Optimization Assessment are not intended to be (nor should they be) precise. The quantity and quality of the systems improvements identified suggests that significant potential exists.

Table ES2. Summary of building envelope ECMs.

ECM	ECM Description	Electrical Savings			Thermal		Plant Energy Savings		Maintenance $/yr	Total Savings: Electrical Use, Elec. Demand, Thermal, and Maint. $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr	MBtu/yr	$/yr				
BE #1	Establish a strategic approach for re-roofing projects, incorporating the use of cool roof materials	1,014,000	0	$65,910	–480	–$4,360	0	0	0	$61,550		0.0
BE #2	Place transparent panels behind windows in vehicle maintenance buildings and barracks	0	0	$–	609	$5,532	0	0	0	$5,532	$124,560	22.5
BE #3A	Install exterior shading for windows in barracks and administrative areas	72,800	0	$4,732	379	$3,443	0	0	0	$8,175	$132,000	16.1
BE #3B	Install exterior shading for windows in barracks and administrative areas with avoided cooling capacity	72,800	0	$4,732	379	$3,443	0	0	0	$8,175	$66,000	8.1
BE #4 *	Install foundation insulation	116,642	106	$15,074	5,672	$51,506	4513	41244	0	$66,580	$607,256	9.1
BE #5*	Insulate roofs, ceilings, and attics	2,747,248	1,357	$355,246	82,353	$723,687	81082	705238	0	$1,078,933	$3,809,632	3.5
BE #6*	Install wall insulation	1,269,584	161	83,880	41,007	372,504	40,449	367,437	0	456,384	1,894,324	4.2
BE #7*	Replace inefficient metal frame windows	590,831	342	74,184	4,189	38,055	4,189	38,055	0	112,239	927,471	8.3
Totals		*5,883,905*	*1,966*	*$603,758*	*134,108*	*$1,193,809*	*130233*	*1151974*	*0*	*$1,797,567*	*$7,561,243*	*4.2*

* Indicates that the ECM is a result of FEDS analysis. These are broken down into groups of buildings in Chapter 3.

Table ES3. Evaporative cooling summary.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec. Demand, Thermal, and Maint. $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
EC #1	Replace small existing direct evaporative cooling units with one larger unit	2,417,000	0	$232,032	0	0	0	$232,032	$187,500	0.8
EC #2	Provide indirect and direct evaporative cooling (IDEC) - DX units instead of DX only units	2,417,000	0	$2,991,936	0	0	0	$2,991,936	$4,620,000	1.5
EC #3	Replace direct evapora-tive cooling units	3,228,000	0	$309,888	0	0	0	$309,888	$400,000	1.3
Totals		*36,811,000*	*0*	*$3,533,856*	*0*	*0*	*0*	*$3,533,856*	*$5,207,500*	*1*

Table ES4. Summary of HVAC ECMs.

ECM	ECM Description	Electrical Savings			Thermal		Maintenance	Total Savings: Electrical Use, Elec. Demand, Thermal, and Maint.	Investment	Simple Payback
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr	$/yr	$/yr	$	yrs
HVAC #1	Schedule air handling units to match building usage	1,065,000	0	$69,225	0	$55,000	$–	$124,225	$–	0.0
HVAC #2	Install solar heating for domestic hot water at selected buildings	0	0	$–	6040	$–	$–	$–	$–	0.0
HVAC #3	Replace warm air heating system in vehicle maintenance areas with radiant	0	0	$–	0	$9,084	$–	$9,084	$120,000	13.2
HVAC #4**	Install radiant cooling in barracks areas	1,100,000	0	$71,500	1000	$–	$55,000	$126,500	–$605,000	0.0
HVAC #5*	Replace existing chillers with high-efficiency chillers	712,456	–460	88,462	0	0	4,804	93,266	1,170,220	12.5
HVAC #6*	Replace existing boilers with high-efficiency boilers	0	0	0	4,591	41,708	4,250	45,958	267,781	5.8
HVAC #7*	Replace existing heating and cooling systems with air source heat pumps	–31,359	–14	–1,346	962	8,740	35,322	42,716	200,406	4.7
HVAC #8*	Condensing gas boiler - 91% combustion efficiency, wrap tank, aerators	0	0	0	9,165	83,254	–805	82,449	283,764	3.4
HVAC #9*	Replace existing water heaters with high efficiency heaters	0	0	$0	20528	$198,673	$0	$198,673	$53,319	0.3
Totals		*0*	*–474*	*$227,841*	*42286*	*$396,459*	*$98,571*	*$722,871*	*$1,490,490*	*2.1*

* Indicates that the ECM is a result of FEDS analysis. These are broken down into groups of buildings in Chapter 8.

**Note that the HVAC group includes HVAC #4 which takes a $605,000 avoided cost credit.

Table ES5. Summary of Lighting ECMs.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec. Demand, Thermal, and Maint. $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
LI #1	Provide daylighting In Medical Warehouse (Bldg. 11156) and in parts of Bldg. 2592	70,640	0	$4,592	0	$0	$4,350	$8,942	$173,000	19.3
LI #2	Install daylight sensors (photo-cells) to control artificial lighting in vehicle maintenance areas	187,000	0	$12,155	0	$0	$0	$12,155	$20,000	1.6
LI #3*	Replace incandescent lights with compact fluorescent lights	2,435,127	448	$161,692	–3,399	–$28,855	$113,251	$246,088	$271,221	1.1
LI #4*	Replace existing exit signs with electroluminescent exit signs	944,861	93	$61,767	–1,026	–$10,026	$88,760	$140,501	$400,292	2.8
LI #5*	Replace metal halide high-bay lighting with T5HO lighting	1,402,345	325	$126,671	–920	–$8,358	$85,726	$204,039	$1,245,658	6.1
LI #6*	Replace T8 lighting with Super T8 lighting	4,542,602	971	$360,052	141	–$28,078	$83,431	$415,405	$3,416,130	8.2
LI #7*	Replace T12 with Super T8 light-ing	6,211,934	1,449	$537,387	–1,045	–$31,261	$113,742	$619,868	$2,961,179	4.8
LI #8*	Replace metal halide high-bay lighting with biaxial Super T8	489,722	–123	$44,916	–474	–$4,305	$14,265	$54,876	$463,983	8.5
LI #9*	Replace T12 U-tube fixtures with T8 U-tube fixtures	70,630	–17	$5,962	–16	–$145	$4,599	$10,416	$92,121	8.8
Totals		*16,354,861*	*3,146*	*$1,315,194*	*–6,739*	*–111028*	*$508,124*	*$1,712,290*	*$9,043,584*	*5.3*

* Indicates that the ECM is a result of FEDS analysis. These are broken down into groups of buildings in Chapter 9.

Recommendations

Policy Related Measures

The following measures require virtually no additional capitol investment. These low cost/low-risk (so-called "slam dunk" measures) can be implemented quickly and should be funded internally as soon as possible. While the estimated cost of establishing installation wide setpoints is $100K, this could be implemented as part of the planned expansion of the installation wide building control system at virtually no additional cost:

- cool roof strategy
- establishment of an installation wide building temperature setpoint.

Low to Moderate Cost Projects

The 56 ECMs summarized in Table ES6 were found to have an investment of $20K or less and to result in a simple payback of less than 6 yrs. All 56 ECMs could be implemented as a group for a total of $357K; if implemented, they would save $620K/yr and result in a simple payback of just over 6 months. Fort Bliss should seek internal funding for these projects.

Re-Commissioning

Although re-commissioning of HVAC systems was not economically analyzed, an aggressive re-commissioning of HVAC systems is recommended because numerous opportunities that typically have a very short payback period were noted throughout the installation. It is recommended that Fort Bliss pursue this through third party financing such as an Energy Savings Performance Contract (ESPC).

Demonstration Projects

Two ECMs were identified at Fort Bliss as potential demonstration projects and submitted as candidate Installation Technology Transition Project (ITTP) projects at either Fort Bliss or other army installations. The first is entitled "Grey Water Heat Recovery From Showers" as described in ECM "REN #1." The second is an evaporative cooling demonstration entitled "Hybrid Air Cooling for the Army Facilities."

Table ES6. ECMs with investment less than $20K and simple payback less than 6 yrs.

ECM #	ECM Description	Electricity Savings				Thermal		Maint $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		MBtu/yr	KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
BE #1	Establish a strategic approach for re-roofing projects, incorporating the use of cool roof materials	3,460	1,014,000		65910	−480	−$4,360	$0	$61,550	$0	0.0
HVAC #1	Schedule air handling units to match building usage	3,634	1,065,000		$69,225	6,040	$55,000		$124,225	–	0.0
HV_9G	Wrap tank with insulation	0	—	0	$0	403	$3,663	–	$3,663	310	0.1
HV_9L	Wrap tank with insulation, aerators	0	—	0	$0	7,012	$63,693	—	$63,693	6,652	0.1
HV_9W	Wrap tank with insulation, LFSHs	0	–	0	$0	909	$8,256	–	$8,256	933	0.1
HV_9C	Wrap tank with insulation	0	–	0	$0	5,202	$47,257	–	$47,257	5,949	0.1
HV_9V	Wrap tank with Insulation, LFSHs	0	–	0	$0	4,392	$52,084	–	$52,084	6,655	0.1
HV_9K	Wrap tank with Insulation, Aerators	0	–	0	$0	925	$8,399	–	$8,399	1,218	0.1
LI_3E	CF7: CFL 23 integral unit ELC	116	33,996	7	$3,199	104	$2,879	$6,111	$12,189	$1,978	0.2
LI_3D	CF5: CFL 18 integral unit ELC	703	206,029	47	$17,118	−45	−$405	$58,693	$75,406	$15,831	0.2
HV_9X	Wrap tank with insulation, LFSHs, aerators	0	–	0	$0	534	$4,853	–	$4,853	1,048	0.2
LI_3F	CF9: CFL 26 integral unit ELC	830	243,249	65	$23,704	−132	−$1,109	$3,729	$26,324	$16,937	0.6
LI_4U	EX11: Exit - electroluminescent panel	275	80,595	9	$5,510	138	$—	$4,287	$9,797	$9,152	0.9
LI_4D	EX11: Exit - electroluminescent panel	36	10,551	0	$746	−14	−$126	$476	$1,096	$1,148	1.0
LI_4AA	EX11: Exit - electroluminescent panel	163	47,771	5	$3,169	−31	−$282	$2,620	$5,507	$5,620	1.0
LI_4AF	EX11: Exit - electroluminescent panel	290	84,991	9	$5,332	−82	−$744	$4,287	$8,875	$9,152	1.0
LI_4X	EX11: Exit - electroluminescent panel	526	154,155	17	$9,964	−118	−$1,069	$8,494	$17,389	$18,066	1.0
LI_4AE	EX11: Exit - electroluminescent panel	77	22,566	2	$1,382	−29	−$263	$1,072	$2,191	$2,340	1.1
LI_4AD	EX11: Exit - electroluminescent panel	40	11,723	1	$743	−8	−$65	$635	$1,313	$1,079	0.8
LI_4S	EX11: Exit - electroluminescent panel	232	67,992	8	$4,413	−118	−$1,070	$3,811	$7,154	$8,143	1.1
LI_4AK	EX11: Exit - electroluminescent panel	40	11,723	1	$755	−24	−$220	$635	$1,170	$1,415	1.2
HV_9O	Wrap Tank with Insulation, Aerators, Lower Tank Temperature	0	–	0	$0	24	$217	–	$217	314	1.4
BE_5G	Attic ceiling: Increase insulation by R-30 (blow-in cellulose)	141	41,323	32	6308	172	$1,563	$0	$7,871	$11,824	1.5

ECM #	ECM Description	Electricity Savings				Thermal		Maint	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint	Investment	Simple Payback
		MBtu/yr	KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr	$/yr	$/yr	$	yrs
LI_4F	EX11: Exit – electroluminescent panel	490	143,605	6	$9,464	–300	–$2,047	$7,538	$14,955	$16,180	1.1
LI #2	Install Daylight Sensors (Photocells) To Control Artificial Lighting In Vehicle Maintenance Areas	638	187,000	0	$12,155		$–		$12,155	$20,000	1.6
HV_9T	Wrap Tank with Insulation, Aerators, Lower Tank Temperature	0	–	0	$0	12	$111	–	$111	197	1.8
HV_9N	Wrap Tank with Insulation, Aerators, Lower Tank Temperature	0	–	0	$0	57	$517	–	$517	959	1.9
LI_4AG	EX11: Exit – electroluminescent panel	17	4,982	1	$333	–2	–$15	$476	$794	$1,583	2.0
HV_8B	Conventional Gas Boiler - 84% Combustion Efficiency, Wrap Tank, Aerators	0	–	0	$0	185	$1,679	–$2	$1,677	3,433	2.0
HV_9U	Wrap Tank with Insulation, Aerators, Lower Tank Temperature	0	–	0	$0	148	$1,348	–	$1,348	2,876	2.1
HV_9Q	Wrap Tank with Insulation, Aerators, Lower Tank Temperature	0	–	0	$0	22	$201	–	$201	460	2.3
HV_9R	Wrap Tank with Insulation, Aerators, Lower Tank Temperature	0	–	0	$0	78	$705	–	$705	1,662	2.4
HV_8A	Condensing Gas Boiler - 91% Combustion Efficiency, Wrap Tank, Aerators	0	–	0	$0	482	$4,380	–$179	$4,201	10,732	2.6
HV_9M	Wrap Tank with Insulation, Aerators, Lower Tank Temperature	0	–	0	$0	116	$1,049	–	$1,049	2,725	2.6
HV_9P	Wrap Tank with Insulation, Aerators, Lower Tank Temperature	0	–	0	$0	15	$139	–	$139	364	2.6
HV_9S	Wrap Tank with Insulation, Aerators, Lower Tank Temperature	0	–	0	$0	36	$333	–	$333	890	2.7
HV_9Y	Wrap Tank with Insulation, LFSHs, Aerators	0	–	0	$0	97	$884	–	$884	2,426	2.7
HV_9Z	Wrap Tank with Insulation, LFSHs, Lower Tank Temperature	0	–	0	$0	138	$1,252	–	$1,252	3,525	2.8
HV_9D	Wrap Tank with Insulation	0	–	0	$0	14	$124	–	$124	426	3.4
HV_9J	Wrap Tank with Insulation	0	–	0	$0	18	$165	–	$165	568	3.4
HV_9F	Wrap Tank with Insulation	0	–	0	$0	2	$18	–	$18	62	3.4
HV_9A	Wrap Tank with Insulation	0	–	0	$0	33	$299	–	$299	1,030	3.4
HV_9H	Wrap Tank with Insulation	0	–	0	$0	61	$556	–	$556	1,918	3.4
HV_9B	Wrap Tank with Insulation	0	–	0	$0	120	$1,091	–	$1,091	3,766	3.5
HV_9E	Wrap Tank with Insulation	0	–	0	$0	70	$638	–	$638	2,203	3.5
REN #1	Shower Gray Water Heat Recovery	0			0	368	$3,343		$3,343	18,000	5.4

ECM #	ECM Description	Electricity Savings				Thermal		Maint $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		MBtu/yr	KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
LI_4A	EX11: Exit – electroluminescent panel	24	7,034	1	$467	0	$–	$2,146	$2,613	$14,702	5.6
LI_4L	EX11: Exit – electroluminescent panel	6	1,758	0	$128	0	$–	$551	$679	$3,830	5.6
LI_4P	EX11: Exit – electroluminescent panel	29	8,499	1	$601	–12	–$108	$2,664	$3,157	$18,234	5.8
LI_4H	EX11: Exit – electroluminescent panel	15	4,396	1	$308	–6	–$51	$1,406	$1,663	$9,657	5.8
LI_4Y	EX11: Exit – electroluminescent panel	14	4,103	0	$276	0	–$1	$1,579	$1,854	$10,834	5.8
LI_4M	EX11: Exit – electroluminescent panel	24	7,034	1	$455	17	$–	$2,664	$3,119	$18,234	5.8
LI_4AI	EX11: Exit – electroluminescent panel	21	6,154	1	$433	–9	–$84	$2,072	$2,421	$14,198	5.9
LI_4Z	EX11: Exit – electroluminescent panel	12	3,517	0	$230	–3	–$23	$1,270	$1,477	$8,728	5.9
LI_4I	EX11: Exit – electroluminescent panel	24	7,034	1	$445	–7	–$62	$2,516	$2,899	$17,225	5.9
LI_4V	EX11: Exit – electroluminescent panel	25	7,327	1	$470	–5	–$44	$2,812	$3,238	$19,244	5.9
Total			*3,488,107*	*217*	*$243,243*	*26,519*	*$254,548*	*122,363*	*$620,154*	*$356,635*	*0.6*

Evaporative Cooling

Fort Bliss has an ideal climate for cooling by evaporation. There are numerous evaporative coolers currently installed. However, many of these units are in poor condition and are operating at less than ideal condition. This results in overly humidified air and resulting problems such as mold and uncomfortable working environments. This has resulted in a general trend at Fort Bliss of replacing evaporative cooling with direct expansion (DX) cooling, which is much more costly to operate. If this trend is allowed to continue the additional electrical demand will be considerable. Three types of evaporative cooling were identified and the energy consequences of each analyzed. It is recommended that Fort Bliss pursue a Level II analysis to determine the type of evaporative cooling that will meet each building's cooling requirements and produce a 20 percent design.

Good Payback and Moderate Investment Projects

Table ES7 lists ECMs that would yield a simple payback of less than 10 yrs, but that would require moderate investments of between $20K and $200K. These 53 ECMs together would yield annual savings of $1.4 million at a cost of $3.7 million for a simple payback of 2.7 yrs. Due to their size and complexity (for example EC #1), some may need to be developed further by an Energy Optimization Assessment Level II effort.

Good Payback and Significant Investment Projects

Table ES8 lists ECMs that would yield a simple payback of less than 6 yrs, but that would also require significant investments of over $200K each. At a cost of $11 million, these 16 ECMs would together yield annual savings of $5 million, resulting in a simple payback of 2.2 yrs. Due to their size and complexity, most need to be developed further by an Energy Optimization Assessment Level II effort, which is geared toward funds appropriation.

Level II Analysis Candidates

Some of the ripest opportunities for savings come from the moderate and high cost ECMs identified. These often require a combination of in-house and outside support.

Table ES7. ECMs with investments between $20K and $200K and simple payback of less than 10 yrs.

ECM #	ECM Description	Electricity Savings				Thermal		Maint $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		MBtu/yr	KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
BE_5A	Add insulation to interior surface of metal roof: 4-in. fiberglass	1,828	535,734	306	65092	2,919	$26,517	$0	$91,609	$31,685	0.3
CON #1	Establish and maintain a uniform and general set point for space temperature in all buildings	9,315	2,730,000		177,450		$–		177,450	100,000	0.6
EC #1	Replace small existing direct evaporative cooling units with one larger unit	8,247	2,417,000		232032		$–		$232,032	$187,500	0.8
LI_4T	EX11: Exit - electroluminescent panel	609	178,480	20	$11,595	–316	–$2,869	$10,003	$18,729	$21,262	1.1
BE_5C	Add insulation to interior surface of metal roof: 4-in. fiberglass	1,649	483,274	0	41896	16,361	$146,362	$0	$188,258	$385,859	2.0
LI_3A	CF5: CFL 18 integral unit ELC	1,518	444,882	77	$26,646	–773	–$7,023	$10,086	$29,709	$43,498	1.5
LI_3B	CF5: CFL 18 integral unit ELC	4,630	1,356,919	235	$81,343	–2,439	–$22,160	$30,849	$90,032	$133,037	1.5
BE_5H	Attic ceiling: Increase insulation by R-38 (blow-in cellulose)	405	118,694	78	16225	620	$5,630	$0	$21,855	$35,422	1.6
LI #2	Install daylight sensors (photocells) to control artificial lighting in vehicle maintenance areas	638	187,000	0	$12,155		$–		$12,155	$20,000	1.6
HV_8D	Conventional gas boiler - 84% combustion efficiency, wrap tank, LFSHs	0	–	0	$0	1,341	$12,182	–$14	$12,168	21,104	1.7
BE_6J	Add interior metal wall surface insulation: 4-in. fiberglass	677	198,409	23	20184	7,913	$71,885	$0	$92,069	$172,148	1.9
HV_8I	Conventional gas boiler - 84% combustion efficiency, wrap tank, LFSHs, aerators	0	–	0	$0	2,567	$23,322	–$101	$23,221	46,295	2.0
HV_8C	Conventional gas boiler - 84% combustion efficiency, wrap tank, aerators	0	–	0	$0	1,112	$10,099	–$10	$10,089	20,714	2.1
BE_5F	Attic ceiling: Increase insulation by R-19 (blow-in cellulose)	9	2,638	0	119	1,050	$9,534	$0	$9,653	$33,242	3.4
LI_7E	FL280: FL 2X4 3F32ST8 ELC3 REF (FIX REPL)	623	182,583	47	$16,843	–148	–$1,349	$3,296	$18,790	$80,133	4.3
HV_6D	Conventional gas boiler - 84% combustion efficiency	0	–	0	$0	2,264	$20,569	69	$20,638	96,607	4.7
LI_7D	FL280: FL 2X4 3F32ST8 ELC3 REF (FIX REPL)	182	53,339	17	$5,638	–36	–$324	$1,122	$6,436	$30,306	4.7
LI_7K	FL303: FL 2X4 2F25ST8 ELC2 REF (FIX REPL)	431	126,314	23	$9,375	–31	–$282	$1,527	$10,620	$50,694	4.8
LI_3C	CF5: CFL 18 integral unit ELC	512	150,052	17	$9,682	–114	–$1,037	$3,783	$12,428	$59,940	4.8
BE_5E	Attic ceiling: increase insulation by R-19 (blow-in cellulose)	209	61,252	64	10730	0	$–	$0	$10,730	$59,504	5.5

ECM #	ECM Description	Electricity Savings				Thermal		Maint $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		MBtu/yr	KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
BE_4M	Insulate perimeter of slab on grade: Increase insulation by R-15	122	35,755	30	4401	509	$4,621	$0	$9,022	$52,024	5.8
HV_8E	Conventional gas boiler - 84% combustion efficiency, wrap tank, LFSHs, aerators	0	–	0	$0	948	$8,610	–$138	$8,472	48,922	5.8
LI_4Q	EX11: Exit - electroluminescent panel	54	15,826	2	$1,126	–25	–$226	$5,032	$5,932	$34,381	5.8
HV_8F	Conventional gas boiler - 84% combustion efficiency, wrap tank, LFSHs, aerators	0	–	0	$0	624	$5,665	–$91	$5,574	32,312	5.8
HV_8H	Conventional gas boiler - 84% combustion efficiency, wrap tank, LFSHs, aerators	0	–	0	$0	1,263	$11,475	–$179	$11,296	66,176	5.9
LI_4B	EX11: Exit — electroluminescent panel	32	9,378	1	$620	–3	–$28	$3,552	$4,144	$24,359	5.9
HV_6C	Conventional gas boiler — 84% combustion efficiency	0	–	0	$0	2,288	$20,783	–$45	$20,738	122,501	5.9
HV_8G	Conventional gas boiler — 84% combustion efficiency, wrap tank, LFSHs, aerators	0	–	0	$0	643	$5,842	–$91	$5,751	34,076	5.9
LI_4N	EX11: Exit — electroluminescent panel	33	9,671	1	$617	–17	–$157	$3,552	$4,012	$24,289	6.1
LI_6C	FL279: FL 2X4 2F32ST8 ELC2 REF	208	60,959	18	$6,067	–59	–$540	$584	$6,111	$37,473	6.1
BE_4L	Insulate perimeter of slab on grade: Increase insulation by R-15	62	18,170	15	2225	229	$2,078	$0	$4,303	$26,673	6.2
BE_5L	Insulate built-up roof surface (R-20) and re-roof	142	41,616	25	5433	168	$1,526	$0	$6,959	$44,133	6.3
LI_6O	FL279: FL 2X4 2F32ST8 ELC2 REF	633	185,514	61	$18,427	–187	–$1,699	$1,892	$18,620	$121,470	6.5
LI_5A	FL269: FL 2X4 4F28T5 ELC4 REF	517	151,518	30	$12,305	–93	–$847	$10,236	$21,694	$145,945	6.7
BE_4N	Insulate perimeter of slab on grade: Increase insulation by R-15	–5	–1,465	0	–63	529	$4,803	$0	$4,740	$32,241	6.8
BE_4F	Insulate perimeter of slab on grade: Increase insulation by R-15	41	12,016	13	1637	228	$2,073	$0	$3,710	$26,048	7.0
LI_6P	FL279: FL 2X4 2F32ST8 ELC2 REF	556	162,948	50	$16,010	–201	–$1,823	$1,773	$15,960	$113,834	7.1
BE_4D	Insulate perimeter of slab on grade: Increase insulation by R-15	21	6,154	14	1477	267	$2,422	$0	$3,899	$28,634	7.3
BE_5K	Insulate built-up roof surface (R-10) and re-roof	108	31,652	0	1359	2,138	$19,424	$0	$20,783	$157,904	7.6
LI_6M	FL279: FL 2X4 2F32ST8 ELC2 REF	144	42,202	10	$3,768	–51	–$466	$457	$3,759	$29,310	7.8
BE_5P	Suspended ceiling: Increase insulation by R-19	139	40,737	26	5293	211	$1,913	$0	$7,206	$57,110	7.9
BE_4I	Insulate perimeter of slab on grade: Increase insulation by R-15	161	47,184	17	3841	0	$–	$0	$3,841	$30,476	7.9

ECM #	ECM Description	Electricity Savings				Thermal		Maint $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		MBtu/yr	KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
BE #3B	Install exterior shading for windows in barracks and administrative areas with avoided cooling capacity	248	72,800		4732	379	$3,443	$0	$8,175	$66,000	8.1
LI_7H	FL283: FL 2X4 2F30ST8 ELC2 (FIX REPL)	177	51,874	10	$4,212	–32	–$286	$883	$4,809	$39,129	8.1
LI_6L	FL279: FL 2X4 2F32ST8 ELC2 REF	183	53,632	18	$5,735	–36	–$326	$811	$6,220	$51,536	8.3
LI_7F	FL280: FL 2X4 3F32ST8 ELC3 REF (FIX REPL)	276	80,888	20	$3,482	–100	–$912	$1,403	$3,973	$34,106	8.6
LI_6B	FL279: FL 2X4 2F32ST8 ELC2 REF	474	138,916	33	$12,487	–192	–$1,737	$2,010	$12,760	$112,770	8.8
BE_7B	Install thermal break aluminum frame double pane argon/super low-E window	161	47,184	32	6604	307	$2,788	$0	$9,392	$81,841	8.7
LI_9A	FL54: FL 2X2 2F32T8U ELC2	241	70,630	–17	$5,962	–16	–145	$4,599	$10,416	$92,121	8.8
LI_6N	FL279: FL 2X4 2F32ST8 ELC2 REF	290	84,991	21	$7,807	–136	–$1,234	$1,045	$7,618	$70,276	9.2
BE_5R	Suspended ceiling: increase insulation by R-19	429	125,727	49	11721	0	$–	$0	$11,721	$108,863	9.3
BE_7C	Install thermal break aluminum frame double pane argon/super low-E window	147	43,081	9	4229	222	$2,019	$0	$6,248	$59,271	9.5
HV_6B	Conventional gas boiler — 80% combustion efficiency	0	–	0	$0	–	$4	3,761	$3,765	36,456	9.7
Total			*10,866,128*	*1,395*	*$888,519*	*42,095*	*$380,119*	*101,656*	*$1,370,294*	*$3,671,610*	*2.7*

Table ES8. ECMs requiring investment greater than $200K and simple payback less than 6 yrs.

ECM	ECM Description	Electricity Savings				Thermal		Maint	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint	Investment	Simple Payback
		MBtu/yr	KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr	$/yr	$/yr	$	yrs
HVAC #4*	Install radiant cooling in barracks areas	3,753	1,100,000		$71,500		$–		$71,500	–605,000	0.0
BE_5B	Add insulation to interior surface of metal roof:4-in. fiberglass	–159	–46,598	0	–2007	35,992	$326,947	$0	$324,940	$413,002	1.3
EC #3	Replace direct evaporative cooling units	11,014	3,228,000		309888		$–		$309,888	$400,000	1.3
EC #2	Provide indirect and direct evaporative cooling (IDEC)-DX units instead of DX only units	106,338	31,166,000		2991936		$–		$2,991,936	$4,620,000	1.5
BE_5S	Suspended ceiling: increase insulation by R-19	1,100	322,378	170	43942	4,391	$39,891	$0	$83,833	$210,900	2.5
BE_6I	Add interior metal wall surface insulation: 4 in. fiberglass	2,493	730,626	0	31502	16,863	$153,185	$0	$184,687	$549,482	3.0
BE_6H	Add interior metal wall surface insulation: 4 in. fiberglass	0	0	0	0	9,032	$82,043	$0	$82,043	$281,878	3.4
LI_7A	FL280: FL 2X4 3F32ST8 ELC3 REF (FIXREPL)	4,722	1,383,882	369	$130,960	–357	–$3,242	$25,239	$152,957	$613,566	4.0
LI_7C	FL280: FL 2X4 3F32ST8 ELC3 REF (FIXREPL)	4,486	1,314,717	348	$123,992	–1,070	–$9,713	$23,474	$137,753	$570,655	4.1
LI_6F	FL279: FL2X42 F32ST8 ELC2 REF	4,507	1,320,871	163	$88,571	2,965	$–	$11,305	$99,876	$429,196	4.3
LI_7B	FL280: FL2X43 F32ST8 ELC3 REF (FIXREPL)	5,428	1,590,790	413	$149,034	–1,618	–$14,698	$29,537	$163,873	$718,057	4.4
HV_7A	High efficiency electric air source heat pump (commercial)	–107	–$31,359	–14	–$1,346	962	$8,740	35,322	$42,716	200,406	4.7
BE_6G	Add interior metal wall surface insulation: 4 in. fiberglass	0	0	0	0	5,720	$51,961	$0	$51,961	$269,463	5.2
BE_5N	Insulate built-up roof surface (R-20) and re-roof	2,207	646,808	365	82600	2,598	$23,604	$0	$106,204	$605,727	5.7
LI_5C	FL269: FL 2X4 4F28T5 ELC4 REF	3,530	1,034,541	224	$91,275	–688	–$6,249	$59,322	$144,348	$829,400	5.7
LI_6A	FL279: FL 2X4 2F32ST8 ELC2 REF	2,323	680,804	199	$65,353	0	$–	$6,603	$71,956	$423,889	5.9
Total			*44,441,460*	*2,237*	*$4,177,200*	*74,790*	*$652,469*	*190,802*	*$5,020,471*	*$10,529,621*	*2.1*

*Note that HVAC #4 is listed here with a negative investment cost but since this is an avoided cost it still requires a significant investment.

It is recommended that Fort Bliss pursue Level II of this Energy Optimization Assessment for:

- evaporative cooling
- grey water heat recovery.

Recommendations for the scope of the Level II study can be based on the Level I and demonstration project results. A specific Level II scope will be jointly developed by the CERL and Fort Bliss teams through review and discussion of results documented in this Level I report. The Level II report will include an analysis that "guesses at nothing – measures everything." The results will be a set of demonstrated process and systems improvements based on hard numbers. CERL and expert consultants will provide guidance and further assistance in identifying a specific Level II scope of work, respective roles, and the most expeditious implementation path. This will begin with a formal review of this (Level I) report, combined with a planning session to organize the Level II program.

Significant Maintenance Savings Projects

Table ES9 lists the ECMs that offer the greatest maintenance savings. It is recommended that Fort Bliss review these projects along with its maintenance program to determine the suitability of these ECMs as projects, or as modifications to maintenance contracts (or both).

Table ES9. ECMs with greatest maintenance savings.

ECM	ECM Description	Electricity Savings				Thermal		Maint. $/yr	Total Savings: Electrical Use, Elec. Demand, Thermal, and Maint. $/yr	Investment $	Simple Payback yrs
		MBtu/yr	KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
LI_4T	EX11: Exit - electroluminescent panel	609	178,480	20	$11,595	–316	–$2,869	$10,003	$18,729	$21,262	1.1
LI_6G	FL279: FL 2X4 2F32ST8 ELC2 REF	757	221,855	38	$13,295	–375	–$3,409	$10,072	$19,958	$315,906	15.8
LI_3A	CF5: CFL 18 integral unit ELC	1,518	444,882	77	$26,646	–773	–$7,023	$10,086	$29,709	$43,498	1.5
LI_5A	FL269: FL 2X4 4F28T5 ELC4 REF	517	151,518	30	$12,305	–93	–$847	$10,236	$21,694	$145,945	6.7
LI_6F	FL279: FL 2X4 2F32ST8 ELC2 REF	4,507	1,320,871	163	$88,571	2,965	$–	$11,305	$99,876	$429,196	4.3
LI_6J	FL279: FL 2X4 2F32ST8 ELC2 REF	1,176	344,652	74	$22,212	–527	–$4,783	$12,931	$30,360	$405,577	13.4
LI_5B	FL269: FL 2X4 4F28T5 ELC4 REF	738	216,286	71	$23,091	–139	–$1,262	$16,168	$37,997	$270,313	7.1
LI_7C	FL280: FL 2X4 3F32ST8 ELC3 REF (FIX REPL)	4,486	1,314,717	348	$123,992	–1,070	–$9,713	$23,474	$137,753	$570,655	4.1
LI_7L	FL304: FL 2X4 3F25ST8 ELC3 REF	4,269	1,251,120	156	$84,278	2,397	$–	$23,631	$107,909	$675,395	6.3
LI_7A	FL280: FL 2X4 3F32ST8 ELC3 REF (FIX REPL)	4,722	1,383,882	369	$130,960	–357	–$3,242	$25,239	$152,957	$613,566	4.0
LI_7B	FL280: FL 2X4 3F32ST8 ELC3 REF (FIX REPL)	5,428	1,590,790	413	$149,034	–1,618	–$14,698	$29,537	$163,873	$718,057	4.4
LI_3B	CF5: CFL 18 integral unit ELC	4,630	1,356,919	235	$81,343	–2,439	–$22,160	$30,849	$90,032	$133,037	1.5
HV_7A	High efficiency electric air source heat pump (commercial)	–107	–$31,359	–14	–$1,346	962	$8,740	35,322	$42,716	200,406	4.7
LI_3D	CF5: CFL 18 integral unit ELC	703	206,029	47	$17,118	–45	–$405	$58,693	$75,406	$15,831	0.2
LI_5C	FL269: FL 2X4 4F28T5 ELC4 REF	3,530	1,034,541	224	$91,275	–688	–$6,249	$59,322	$144,348	$829,400	5.7
Total			*10,985,183*	*2,251*	*$874,369*	*–2,116*	*–$67,920*	*$366,868*	*$1,173,317*	*$5,388,044*	*4.6*

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Preface

This study was conducted for Fort Bliss under the Annex 46 program. The technical monitors were Ken Valovcin (Resource Energy Manager, Fort Bliss), Michael C. Lockamy (Deputy Director of Public Works), and Paul Volkman, Headquarters, Installation Management Command (HQ-IMCOM).

The work was managed and executed by the Energy Branch (CF-E) of the Facilities Division (CF), Construction Engineering Research Laboratory (CERL). The CERL principal investigators were Dr. Alexander Zhivov and David M. Underwood. The Survey Team, as funded by IMCOM, was composed of individuals from the U.S. Army Engineer Research and Development Center, and the Pacific Northwest National Laboratory (PNNL). Each organization provided individuals to the team that have expertise in various engineering and energy related fields. Appreciation is owed to Ken Valovcin (Fort Bliss) for his coordination of the Survey Team and to others of the Fort Bliss Directorate of Public Works (DPW) who contributed significantly to the information gathering and feasibility analysis. Dr. Thomas Hartranft is Chief, CEERD-CF-E, and Mr. L. Michael Golish is Chief, CEERD-CF. The associated Technical Director is Martin J. Savoie, CEERD-CV-T. The Director of 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 Richard B. Jenkins, and the Director of ERDC is Dr. James R. Houston.

Unit Conversion Factors

Multiply	By	To Obtain
acres	4,046.873	square meters
British thermal units (International Table)	1,055.056	joules
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 (nautical)	1,852	meters
miles (U.S. statute)	1,609.347	meters
ounces (mass)	0.02834952	kilograms
ounces (U.S. fluid)	2.957353 E-05	cubic meters
pints (U.S. liquid)	4.73176 E-04	cubic meters
pints (U.S. liquid)	0.473176	liters
quarts (U.S. liquid)	9.463529 E-04	cubic meters
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
yards	0.9144	meters

1 Introduction

1.1 Background

Fort Bliss, TX, is a Training and Doctrine Command (TRADOC) installation located in the Northern Chihuahuan Desert of Western Texas and South Central New Mexico. The mission of Fort Bliss is to train, sustain, mobilize, and deploy members of the joint team to conduct global, full spectrum operations in support of the national military strategy, while providing for the well-being of the regional military community.

Fort Bliss is primarily an artillery testing and training installation, and with 1,119,700 acres, is one of the largest Army posts in the country. While the main post and cantonment area is located north of El Paso, most of the land crosses the state line into New Mexico, and is adjacent to White Sands Missile Range. Tank maneuvers, Patriot missile launches, and ground forces training associated with Air Defense Artillery take place throughout the range. Approximately 23,000 military and civilian personnel are located at Fort Bliss. Fort Bliss's facilities include 217 major buildings and 10 million sq ft total buildings including 2.9 million sq ft of barracks and housing and 2.5 million sq ft of administration space.

1.2 Objectives

The objectives of this study were to identify energy inefficiencies and wastes at Fort Bliss and propose energy related projects with applicable funding and execution methods that could enable the installation to better meet the energy reduction requirements mandated by Executive Order 13123 and EPACT 2005.

1.3 ANNEX 46 Project Team

1.3.1 ERDC-CERL

ERDC-CERL implemented an Energy Assessment methodology, which was previously developed as part of the "Industrial Process Modeling and Optimization" program under the auspices of the International Energy Agency (IEA) Energy Conservation in Buildings and Community Systems (ECBCS) Programme Annex 46 "Holistic Assessment Toolkit on Energy

Efficient Retrofit Measures for Government Buildings (EnERGo).” The protocol is designed to assist installation energy managers and Regional Energy Managers to develop energy conservation projects (self-help for energy managers).

1.3.2 PNNL

PNNL developed an installation-wide energy model of Fort Bliss using the Facility Energy Decision System (FEDS) software. PNNL used FEDS to develop a list of life cycle cost-effective energy- and cost-reducing retrofit measures. These ECMs were extrapolated to all the appropriate buildings at the installation to determine the total installation energy reduction impact.

1.3.3 Private Contractors

Private contractors with various types of technical expertise were a vital part of the Survey Team. Experts in heating, ventilating, and air-conditioning (HVAC), building envelope, and lighting, rounded out the contractor portion of the team.

1.4 Approach

1.4.1 General

This study was conducted using an Energy Assessment Protocol developed by CERL in combination with a FEDS (Facility Energy Decision System) analysis conducted by PNNL. This process is unique in that it combines a “ground level” survey of existing systems with a “higher level” model-based assessment of the installation based on data gathered from a small number of buildings deemed to represent groups of buildings having similar occupancy, construction type, age, etc. While either an Energy Assessment Protocol or a FEDS analysis could be conducted and provide stand-alone output, the combining of these processes should produce a superior end result in that the output of the ground level Energy Assessment Protocol is used as input to help calibrate and refine the FEDS model of the installation’s energy systems. The resulting enhanced FEDS model is then executed to extrapolate the energy and financial impacts of implementing packages of ECMs on an installation-wide basis. At Fort Bliss, FEDS was used to examine the impact from using the specific ECMs proposed by the

ANNEX 46 team in addition to a list of other energy cost-reducing retrofit measures identified by FEDS. The impact of implementing these ECMs was extrapolated to all appropriate buildings at Fort Bliss to predict the total installation energy reduction impact. The general process was:

1. Make an initial site visit to, among other items, determine the Site's major energy issues and familiarize the Survey Team with installation and operations
2. Assemble a team of SMEs with expertise in technical areas relating to those identified in the initial site visit
3. Make a Technical Assessment visit with the SMEs and FEDS team to:
   a. make building specific ECM evaluations, and
   b. gather data for installation wide FEDS model development and calibration
4. Calibrate FEDS model for entire installation
5. Perform FEDS optimization of ECMs for cost effectiveness
6. Analyze findings and developed implementation strategies.

1.4.2 FEDS Analysis

The number of conceivable energy conservation measures, fuel-switching opportunities, and renewable-energy projects at Federal sites is potentially enormous. The FEDS model is used to cost-effectively identify energy saving opportunities for a given site. FEDS is a Windows-based software tool developed by PNNL that provides a comprehensive method to quickly and objectively identify energy improvements that offer maximum life-cycle cost savings by determining an optimum set of cost-effective retrofits from a current database of hundreds of proven technologies. These retrofit candidates include heating, cooling, lighting, motors, building envelopes, and hot water systems. Interactive effects are also evaluated as part of the optimization process so that energy savings are not double counted or undercounted. The results are based on life-cycle cost economics consistent with 10 CFR 436.

The general approach taken by FEDS is to develop a model of the buildings and energy-related infrastructure at an installation, calibrate that model to actual historic energy use, and then use the model to predict energy consumption and identify cost-effective retrofits under typical meteorological year (TMY) weather conditions. The model was calibrated using 2006 utility consumption data from Fort Bliss utility bills. For determining cost-effective retrofits, the model uses Typical Meteorological Year weather data, so the results are not specific to 2006.

Building inventory data for a given installation are obtained from existing databases, if available. From this data, building groups that reasonably describe the installation's building stock are developed and each building on the installation is assigned to one of these building groups based on building type (use), size (square footage), and age. Within each building group, at least one facility is designated to represent the group and to be audited during the site visit.

Beyond the information available from databases, building characteristics for each facility category are further developed from a combination of walk-through audits of the representative buildings within each building group, discussions with knowledgeable site personnel, and inferential relationships within the FEDS model (driven by building type, size, climate, and age).

Developing an installation energy model included characterization of non-building energy-related infrastructure such as central energy plants, central chiller plants, electrical distribution systems, etc. To the extent available, historic information such as boiler logs, meter readings, billing data and easily observable characteristics such as steam distribution system loop length, pipe diameter, insulation level, pipe location (in/above ground), steam temperature, and leakage rate of flow were entered as inputs to the FEDS model.

FEDS simulates building and central plant energy use combined with other loads' consumption to predict the total site energy consumption for the most recent year with complete data at the time of the analysis. Uncertain elements of the modeling assumptions are adjusted until the model's energy consumption prediction matches "reasonably well" with actual historic energy consumption. Model calibration is achieved for site "total" energy use by fuel type and also at specific buildings where submeter data were available.

Once FEDS is satisfactorily calibrated, it identifies packages of retrofits that individually and collectively minimize the life-cycle cost of building energy services, resulting in projects where the net present value (NPV) of the investment is greater than or equal to zero and the savings-to-investment ratio (SIR) is greater than or equal to one. These results assume the government will appropriate funding; they will change slightly if financing is obtained through alternative methods (e.g., Energy Savings Performance Contract [ESPC], Utility Energy Services Contract [UESC]).

1.4.3 Energy Assessment Protocol

This study was conducted using an Energy Assessment Protocol developed by CERL in collaboration with a team of government, institutional, and private sector parties as a part of the International Energy Agency's Energy Conservation in Buildings and Community Systems (IEA ECBCS) Program Annex 46. This protocol is based on the analysis of information available from the literature, training materials, the documented and non-documented practical experiences of contributors, and previous successful showcase energy assessments conducted by a diverse team of experts at the U.S. Army facilities. Details regarding IEA ECBCS Program Annex 46 are available through URL: https://kd.erdc.usace.army.mil/projects/ecbcs/

The Energy Assessment Protocol addresses technical and nontechnical organizational capabilities required to make a successful assessment geared to identifying energy and other operating costs reduction measures without adversely impacting Indoor Air Quality, product quality, or (in the case of repair facilities) safety and morale.

A critical element for energy assessment is a capability to apply a "holistic" approach to the energy sources and sinks in the audited target (installation, building, system, and their elements). The holistic approach suggested by the protocol includes the analysis of opportunities related to the energy generation process and distribution systems, building envelope, lighting, internal loads, HVAC, and other mechanical and energy systems. A useful way of visualizing the energy flows within a facility or process is the Sankey diagram shown in Figures 1 and 2.

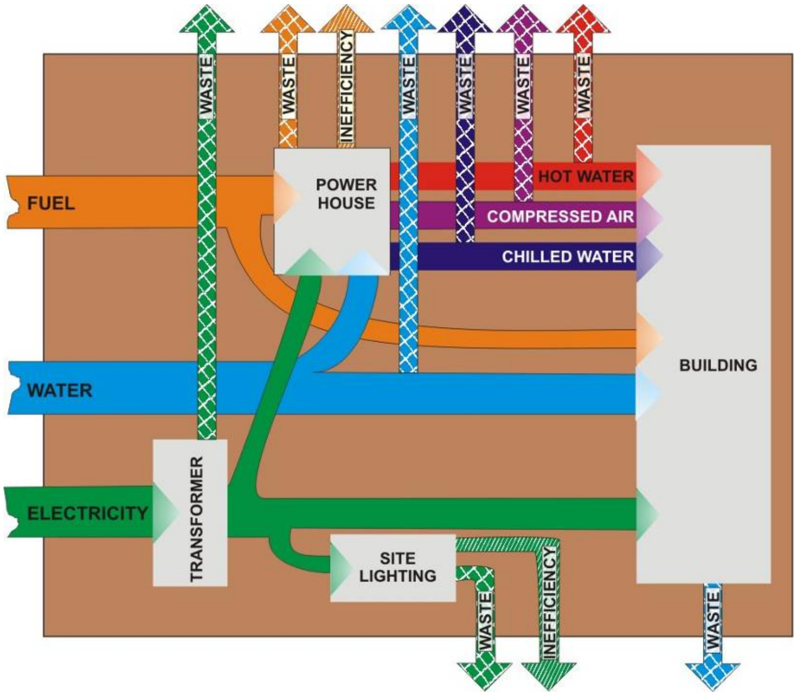

Figure 1. Example Sankey diagram of energy usage, waste, and inefficiencies for an Army installation.

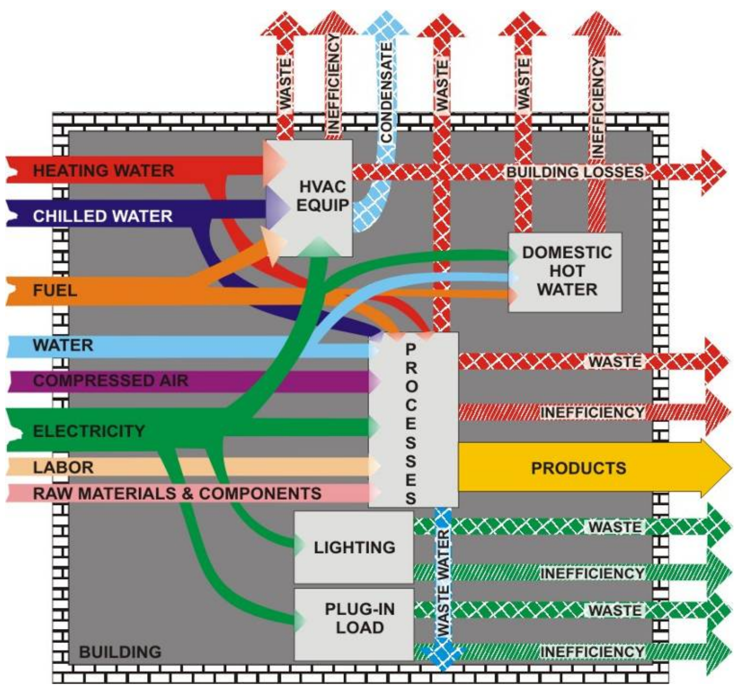

Figure 2. Example Sankey diagram of energy usage, waste, and inefficiencies for a building with production process.

The Protocol addresses several different scopes (building stock, individual building, system, and component) and levels of assessment. It distinguishes between the pre-assessment phase (Level 0: selection of objects for Energy Assessments and required composition of the audit team) and three levels of energy audits with differing degrees of rigor. Each of these three levels may be implemented in different ways: simplified or more detailed assessments, depending on the availability of energy consumption information and other data.

During the selection phase, one can choose from a building stock those facilities that have the most promising energy saving potential. Similarly, one can select the systems to be audited from a specific building or, from a system, the components to be considered for more detailed analysis. The scope and depth of the assessments differ in their objectives, methodologies, procedures, required instrumentation, and approximate duration (Figure 1).

1.4.4 Level I Audit

A *Level I* audit (qualitative analysis) is a preliminary energy and process optimization opportunity analysis consisting primarily of a walk-through review to analyze and benchmark existing documents and consumption figures. The Level I audit takes from 2 to 5 days, and identifies the bottom-line dollar potential of energy conservation and process improvements. No engineering measurements using test instrumentation are made. If the consumption figures are not available (e.g., due to the absence of metering), which is typical for many industrial facilities and manufacturing processes, the Level I audit can be based on analyses and estimates by experienced auditors.

A Level I audit would normally recommend that the installation perform some metering, which could be followed by a Level II audit to verify the Level I assumptions, and to more fully develop the ideas from the Level I screening analysis.

1.4.5 Level II Audit

A *Level II* audit (quantitative analysis) includes an analysis geared towards funds appropriation; this analysis uses calculated savings and partial instrumentation measurements with a cursory level of analysis. The Level II study typically takes 5 to 10 times the effort of a Level I, and could be accomplished over a 2- to 6-month period, depending on the scope of the effort. The Level II effort includes an in-depth analysis in which the most crucial assumptions are verified. The end product will be a group of "appropriation grade" energy and process improvement projects for funding and implementation.

1.4.6 Level III Audit

Finally, the *Level III* audit (continuous commissioning) is a detailed engineering analysis with implementation, performance measurement and verification (M&V) assessment, and fully instrumented diagnostic measurements (long term measurements). This level takes 3 to 18 months to accomplish. For ESPC projects, the *Level III* audit is prolonged until the end of the contract to guarantee that all installed systems and their components operate correctly over their useful lifetimes.

1.4.7 Keys to a Successful Audit

The key elements that guarantee success of the Energy Assessment are:

- Involvement of key facility personnel and their on-site contractors who know what the major problems are, where they are, and have already thought of many potential solutions;
- The facility personnel's sense of "ownership" of the ideas, which encourages a commitment to successful implementation; and
- A focus on site-specific, critical cost issues. If solved, the greatest possible economic contribution to a facility's bottom line will be realized. Major potential cost issues can include: facility utilization (bottlenecks), mission, labor (productivity, planning and scheduling), energy (steam, electricity, compressed air), waste (air, water, solid, hazardous), equipment (outdated or state-of-the-art).

From a strictly cost perspective, process capacity and labor utilization/productivity and soldiers' well-being can be far more significant than energy and environmental concerns. All of these issues, however, must be considered together to accomplish the facility's mission in the most efficient and cost-effective way.

1.4.8 General Overall Process

The process used at Fort Bliss was unique in that it combined a “ground level” survey of existing systems with a “higher level” model-based assessment of the installation based on data gathered from a small number of buildings deemed to be representative of groups of buildings having similar occupancy, construction type, age, etc. While either an Energy Assessment Protocol or a FEDS analysis could be conducted to provide standalone output, combining these processes should produce a superior end result in that the output of the ground level Energy Assessment Protocol is then used as input to help calibrate and refine the FEDS model of the installation’s energy systems., which is then used to extrapolate the energy and financial impacts of implementing applicable ECMs on an installation-wide basis.

1.5 Scope

This Annex 46 Energy Optimization Assessment included a Level I study of energy conservation opportunities in a number of representative buildings including an analysis of their building envelopes, ventilation air systems, controls, interior and exterior lighting as well as opportunities to use renewable energy resources. The ANNEX 46 initiative did not include the evaluation of industrial or manufacturing processes.

1.6 Benefits of an Energy Assessment

The desired benefits of any energy assessment is to identify projects with the potential to reduce an installation’s energy usage and operational costs. A very real, but often difficult to quantify, benefit of an energy audit is increased process capacity, better labor utilization/productivity and enhanced quality of life for soldiers. These results can sometimes be far more significant than the direct energy and environmental benefits. All of these issues, however, must be considered together to accomplish the facility’s mission in the most efficient and cost-effective way.

1.7 Mode of Technology Transfer

The results of this work will be presented to IMCOM, ACSIM and Fort Bliss for their consideration for implementation and funding. 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 improve the overall energy efficiency of Army installations. It is anticipated that 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 Installation Energy Use Rates and Historic Use

Fort Bliss reported that the installation consumed 1,253,195 MMBtu in fiscal year 2006 (FY06) and 1,433,919 MMBtu in FY05. Natural gas consumption was 599,478 MMBtu; propane consumption was 10,182 MMBtu; and electricity consumption was 643,535 MMBtu in FY06, at a total cost of $37,026,089.

Table 1 lists Fort Bliss energy costs for FY06. (Not that the electricity cost is the blended rate.)

Table 1. Fort Bliss energy costs for FY2006.

Energy Type	Consumption	Units	Unit Price
Electricity (blended)	188,554	MWh	$0.065/KWh
Natural gas	599,478	MMBtu	$9.0839/MMBtu
Propane	10,182	MMBtu	Unknown
Fuel oil	107,181	gal	$1.95/gal

Fort Bliss electrical charges consist of a flat energy charge (kWh), a demand charge (kW), and a fuel surcharge for a block of firm power and a block of interruptible power.

Fort Bliss has negotiated a more attractive rate for a block of “interruptible power” up to 16 MW – power that can be curtailed at the utilities discretion. All other consumption is considered “firm” energy and billed at a higher rate.

There is no seasonal variation of the rate. However, the utility provider does add a fuel surcharge to account for fluctuations in fuel costs. The fuel surcharge is adjusted periodically (but not monthly). The fuel surcharge was changed starting in February 2006 (Table 2).

Table 2. Change in fuel surcharge starting in February 2006.

Charges	Prior to February 2006	Post February 2006
Energy charge (cents/KWh)		
Interruptible energy	0.545	0.545
Firm energy	0.853	0.853
Fuel surcharge (cents/KWh)		
Interruptible fuel surcharge	2.875	3.401
Firm fuel surcharge	2.875	3.401
Total energy charge (cents/KWh)		
Interruptible fuel	3.420	3.946
Firm fuel surcharge	3.728	4.254
Demand charge ($/KW)		
Interruptible	$1.52	$0.52
Firm	$0.25	$0.25

During FY06, Fort Bliss's peak electric demand (as recorded in July 2006) was 35,423 MW.

The following chapters summarize and describe the ECMs studied and economically quantified in this work.

3 Building Envelope ECMs

3.1 BE #1—Establish a Strategic Approach for Re-Roofing Projects, Incorporating the Use of Cool Roof Materials

3.1.1 Existing Conditions and Problems

A number of the buildings at Fort Bliss are scheduled for new roofs. Currently many roofs at the installation are white or nearly white in color. Some roofs are also dark or have a tar layer covered with stones. The dark color absorbs the sun's energy making the roof hotter than the outdoor air temperature. This is also the case with white or nearly white roofs that do not have cool roof surfaces.

3.1.2 Cool Roofs

People who live in tropical climates usually wear light-colored or white clothing to help keep themselves cool. They know that light colors reflect heat and sunlight; and that dark colors absorb heat and light. Buildings operate similarly. Buildings with dark-colored roofs will be hotter those with light-colored roofs.

Cool Roofs consist of materials that very effectively reflect the sun's energy from the roof surface. Cool materials for low-slope roofs are mainly bright white in color, although nonwhite colors are starting to become available for sloped roof applications. Cool Roofs must also have high emissivity, allowing them to emit infrared energy. Bare metals and metallic coatings tend to have low emissivity and are not considered "cool" materials. Unfortunately, the new roof being installed on Bldg. 2629 at Fort Bliss (Figure 3) during the energy assessment week was not a cool roof.

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, cut maintenance costs and to increase the life cycle of the roof.

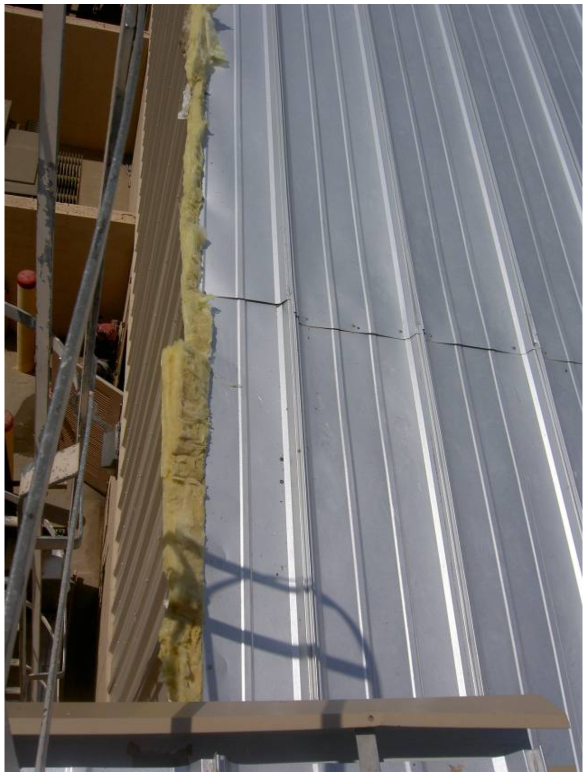

Figure 3. "Un-cool" roof installed on Bldg. 2629.

Some benefits of cool roofs are that they:

- save on annual electricity bills by reducing summer air-conditioning costs
- save peak electricity demand costs (assumes 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.

Figure 4 shows the roof of Bldg. 11156, the Medical Warehouse at Fort Bliss, which illustrates the difference between dark and white roofs. Note that neither of the two sections of roof shown use cool roof materials. Nevertheless, the surface temperature of the dark roof was 160 °F while the surface temperature of the white roof was 115 °F (a temperature difference of 45 °F). With a cool roof surface on the white roof the temperature difference would have been even higher. Figures 5 and 6 show temperature measurements on a building at another installation on a hot summer day, before and after installation of a cool roof.

Figure 4. White and black sections of roof of Medical Warehouse, Bldg. 11156.

Figure 5. Before installation of a cool roof, a thermometer at the original roof surface reads 178 °F on a hot summer afternoon.

Figure 6. After installation of a cool roof, there was a dramatic decrease in roof surface temperature.

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.

Products for sloped roofs, usually found on residences, are currently available in clay, or concrete tiles. These products stay cooler by the use of special pigments that reflect the sun's infrared heat. Lower priced shingles or coated metal roofing products are not yet available in "cool" versions. The ENERGY STAR® website lists cool roof products and manufacturers at URL: http://www.energystar.gov

If a cool roof were used, much of the sun's energy will be reflected keeping the roof cooler. 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 Bliss the cooling savings out-weighs the extra heating energy costs.

3.1.3 Solution

Whenever replacing a building's roof, provide an outer surface that is categorized as a Cool Roof. This will reflect the solar energy resulting in a cooler roof temperature and thus less energy will be used in air-conditioned spaces. (Even without air-conditioning, the comfort in the building will be much improved.) Incorporate Cool Roof requirements into the Installation Design Guide.

3.1.4 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 cooling system, and most importantly, the climate of the building's location.

Using the Energy Star Roofing Calculator for El Paso conditions showed the following for a 10,000 sq ft roof:

- office building, air-conditioned, used 7 days/wk.
- existing dark roof: bitumen, white granular, reflectance 0.25
- Energy Star labeled roof: membrane, white, reflectance 0.75
- electricity savings: 10,141 kWh/yr, worth $660
- natural gas increase: 48 therms, worth $43
- net savings: $615/yr/10,000 sq ft
- assume 1 million sq ft where this ECM is applicable, making available total annual savings of $61.5K.

3.1.5 Investments

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 makes cool roofing a better bargain over the long term.

3.1.6 Payback

Payback will be Immediate.

3.2 BE #2—Place Transparent Panels behind Windows in Vehicle Maintenance Buildings and Barracks

3.2.1 Existing Conditions

At Fort Bliss, TX, single pane windows were found in the older vehicle maintenance facilities such as Bldg. 2588 (Figure 7) and in some of the single story barracks buildings near the airfield such as Bldgs. 11144 and 11147 (Figure 8). This section will analyze the placement of insulated panels in the windows of Bldg. 2588 to establish the economics of this type of project.

This vehicle maintenance facility has windows that run the length of both sides of the building's two wings (for a total length of 432 ft). The wings are approximately 36 ft high and in the upper section of the building contain large areas of windows. In each building bay, the window area is 20 ft wide by 17 ft high on both sides of the building. The building is heated during the winter. The subject windows have a very poor insulating value and lose much heat in the winter.

3.2.2 Solution

Place insulated panels behind the windows to reduce heat loss; these can be placed in the window opening behind the existing single pane windows. Without this system, excessive energy will be lost through these windows.

Figure 7. Windows in Maintenance Shop, Bldg. 2588.

Figure 8. Single story barracks.

3.2.3 Savings

The placement of the insulating panels behind the existing windows will reduce the heat loss through the windows by 60 percent. There are 346 sq ft of window area in each bay on both sides of the building. The resulting window area is 12,456 sq ft:

Q = (1.17 – 0.35) Btu/sq ft/ °F * 12,456 sq ft * (2432 degree days * 24 hrs/day)/ 0.8 heating system efficiency = 609 million Btu/yr

The insulating panels are placed in frames and sealed in place. Thus there is no infiltration of cold air that can pass through the window area where these panels are installed.

The total energy savings is 609 million Btu/yr.

Cost Savings = 609 million Btu/yr * $9.0839/ million Btu/yr = $3,191/yr

3.2.4 Investments

The cost of the insulating panels is approximately $10/sq ft or $124,560 for the window area identified.

3.2.5 Payback

The resulting payback is 23 yrs.

3.3 BE #3—Install Exterior Shading for Windows in Barracks and Administrative Areas

3.3.1 Existing Conditions

The older barracks buildings are being renovated to provide 1 + 1 soldier housing. When this construction occurs the single pane windows are being reduced in size and double pane windows are being installed. Shading extensions from the building are installed around the new windows to keep the sunlight out. The buildings are also receiving new air-conditioning systems. Of the 48 older buildings, 11 have not been upgraded with new windows. These remaining buildings would be ideal candidates for window shading.

The barracks shown in Figure 9 are three stories high and have windows that run the length of both sides of the building. The existing window areas are quite large. On the outside of the barracks are 66 groups of six windows (40 in. wide by 48 in. high), placed side by side. Each group fills a space 20 ft long by 4 ft high for a total area of 80 sq ft. These window areas provide natural ventilation to two rooms that will house two soldiers each.

The older barracks buildings have window areas with no means for shading sunlight, which enters the occupied spaces of the building and increases the space temperatures. Fort Bliss is located in the most southern part of the United States; solar heating impact on the building's cooling load can be significant. The spaces on the east, west, and south sides of buildings with no shading are harder to cool due to the impact of the solar heat gain through the windows.

These buildings have single-pane windows with operable sash sections. The single pane construction offers little insulating value. Consequently, outside conditions heat building spaces in the summer and cool those spaces in the winter. The operable sashes often do not close tightly, which also allows outside air to infiltrate into the building. The infiltration air must then be brought to room temperature, which affects the buildings' heating and cooling energy use.

Figure 9. Barracks building with old windows.

3.3.2 Solution

To reduce the solar heat entering the building spaces, a shading device can be placed outside the windows, or the window area can be reduced, or both alternatives can be implemented. Since the importance of natural ventilation has been reduced having large window areas is not critical. Thus, some of the windows can be eliminated, or the window area can be reduced. Windows can be shaded by adding building ledges over the windows or providing fins to the building on both sides of the window. Both of these exterior building shades will block the sunlight from entering the building space. Another approach would be to install roll down shutters that would cover the window area (Figures 10 and 11). This type of shade would also improve the insulation quality of the window area and reduce the window leakage that allows outside air to enter the soldier rooms. This project will evaluate the economics of using the roll down shutter type shades in the old barracks buildings.

The shades would be installed outside the window area and would roll down covering the window area. They would slide up and down in aluminum rails attached to the sides of the window area. Two 10-ft long shade sections would be used to cover the 20-ft long window area. The shade would be made using interconnecting slats that are filled with polyurethane foam approximately $^{3}/_{8}$-in. thick. When the shade is pulled down, a dead air space is created that increases the "R" value of the shade assembly to 1.5.

If this system is not provided, excessive energy will be lost from the windows placed in the barracks and the heating and cooling loads will be higher than necessary.

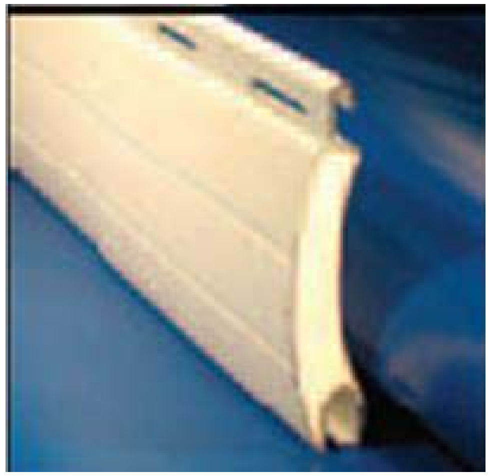

Figure 10. Foam filled slat.

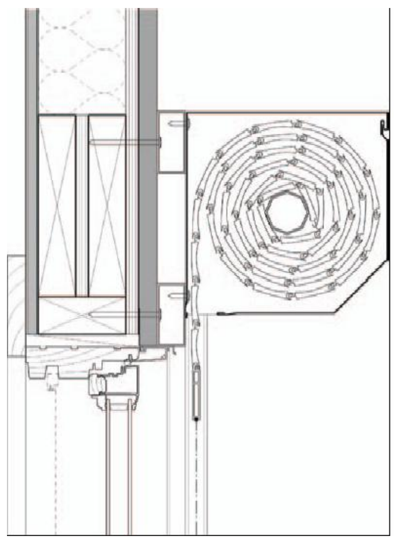

Figure 11. Installation of shade outside window.

3.3.3 Savings

The roller shades save energy by reducing the solar heat load an other heat gain from the hot outdoor conditions in the cooling season, and by reducing heat loss to the outside in the heating season. The calculated solar load in July at 3:00 pm on a westward facing window is 125 Btuh/sq ft. This added to the insulating and air tightness values of the shutter will reduce the cooling load by approximately 1 ton of cooling for each 20 sq ft window area. The total cooling savings is approximately 72,800 ton-hrs. Using one kW/ton-hour this equals an electrical energy saving of 72,800 kWh/yr.

The heating energy saved results from better insulation in the window area and a reduction in infiltration of cold air. The existing windows are single pane windows having an "R" value of 0.85. Adding the insulating value of the shades, the "R" value at the window area increases to 2.35. This reduces the window "U" value by 0.73 Btu/sq ft/°F.

Q =(1.17 – 0.44) Btu/sq ft/°F * 5280 sq ft * (2432 degree days * 24 hrs/day)/ 0.8 heating system efficiency = 281 million Btu/yr

Q =1.08 * 100 fpm * 0.375 sq ft/window area * 33 areas * (2432 degree days * 24 hrs/day)/ 0.8 heating system efficiency = 98 million Btu/yr

Electrical cost savings = 72,800 kWh/yr * $0.065 = $4730

Heating cost savings = (281 + 98) million Btu/yr * $9.08/million Btu = $3,443

Total cost savings = $8,175/yr

3.3.4 Investments

3.3.4.1 BE #3A

The installed cost of the roller shades is $25/sq ft of window area. Since there are 5,280 sq ft of window area in the barracks building the cost to install the roller shades is estimated to be $132,000.

3.3.4.2 BE #3B

If the roller shades are part of a bigger renovation project for a barracks building, then the cooling load can be reduced thereby lowering the size of the cooling system by approximately 33 tons. Using a cost of $2,000/ton this represents a cooling system cost saving of $66,000, which can be used to offset part of the shade cost. If this is done, the roller shades system would cost $66,000.

3.3.5 Payback

The resulting payback of the roller shades is 8.1 yrs when the cooling equipment cost savings is factored into the shade cost. If there are no offsetting system cost savings and the cost of the shades is not reduced, the payback period grows to 16.1 yrs.

3.4 BE #4—Install Foundation Insulation

3.4.1 Existing Conditions and Problems

When most of Fort Bliss's Buildings were built, it was not standard practice to insulate the building foundation. It is standard practice now, even in southern climates and makes economic sense given the energy cost at Fort Bliss. Buildings with foundation insulation have smaller heating and cooling loads than buildings without foundation insulation. This should be done to the extent possible where buildings do not abut concrete sidewalks and/or driveways.

3.4.2 Solution

Add insulation to the perimeter of buildings with slab on grade foundations as listed in Table 3. The insulation should cover the building perimeter from grade level to the depth of the foundation.

Table 3. BE #4 Install foundation insulation in slab on grade buildings.

ECM	Current Technology	Retrofit Technology	Current R-Value	Retrofit R-Value	Investment $	Savings $/yr	Simple Payback (yrs)
BE_4A	Slab on grade with no perimeter insulation	Insulate perimeter of slab on grade: Increase insulation by R-10	0	10	$3,520	$263	13.4
BE_4B	Slab on grade with no perimeter insulation	Insulate perimeter of slab on grade: Increase insulation by R-15	0	15	$26,299	$2,293	11.5
BE_4C	Slab on grade with no perimeter insulation	Insulate perimeter of slab on grade: Increase insulation by R-15	0	15	$125,425	$11,350	11.1
BE_4D	Slab on grade with no perimeter insulation	Insulate perimeter of slab on grade: Increase insulation by R-15	0	15	$28,634	$3,899	7.3
BE_4E	Slab on grade with no perimeter insulation	Insulate perimeter of slab on grade: Increase insulation by R-15	0	15	$2,565	$315	8.1
BE_4F	Slab on grade with no perimeter insulation	Insulate perimeter of slab on grade: Increase insulation by R-15	0	15	$26,048	$3,710	7.0
BE_4G	Slab on grade with no perimeter insulation	Insulate perimeter of slab on grade: Increase insulation by R-15	0	15	$18,613	$2,035	9.1
BE_4H	Slab on grade with no perimeter insulation	Insulate perimeter of slab on grade: Increase insulation by R-15	0	15	$1,428	$197	7.2
BE_4I	Slab on grade with no perimeter insulation	Insulate perimeter of slab on grade: Increase insulation by R-15	0	15	$30,476	$3,841	7.9
BE_4J	Slab on grade with no perimeter insulation	Insulate perimeter of slab on grade: Increase insulation by R-15	0	15	$38,575	$3,208	12.0
BE_4K	Slab on grade with no perimeter insulation	Insulate perimeter of slab on grade: Increase insulation by R-15	0	15	$25,449	$2,148	11.8

ECM	Current Technology	Retrofit Technology	Current R-Value	Retrofit R-Value	Investment $	Savings $/yr	Simple Payback (yrs)
BE_4L	Slab on grade with no perimeter insulation	Insulate perimeter of slab on grade: Increase insulation by R-15	0	15	$26,673	$4,303	6.2
BE_4M	Slab on grade with no perimeter insulation	Insulate perimeter of slab on grade: Increase insulation by R-15	0	15	$52,024	$9,022	5.8
BE_4N	Slab on grade with no perimeter insulation	Insulate perimeter of slab on grade: Increase insulation by R-15	0	15	$32,241	$4,740	6.8
BE_4O	Slab on grade with no perimeter insulation	Insulate perimeter of slab on grade: Increase insulation by R-15	0	15	$18,774	$1,455	12.9
BE_4P	Slab on grade with no perimeter insulation	Insulate perimeter of slab on grade: Increase insulation by R-15	0	15	$35,464	$2,822	12.6
BE_4Q	Slab on grade with no perimeter insulation	Insulate perimeter of slab on grade: Increase insulation by R-15	0	15	$2,036	$164	12.4
BE_4R	Slab on grade with no perimeter insulation	Insulate perimeter of slab on grade: Increase insulation by R-15	0	15	$13,181	$1,585	8.3
BE_4S	Slab on grade with no perimeter insulation	Insulate perimeter of slab on grade: Increase insulation by R-15	0	15	$71,060	$6,711	10.6
BE_4T	Slab on grade with no perimeter insulation	Insulate perimeter of slab on grade: Increase insulation by R-15	0	15	$12,105	$1,154	10.5
BE_4U	Slab on grade with no perimeter insulation	Insulate perimeter of slab on grade: Increase insulation by R-7.5	0	7.5	$16,666	$1,365	12.2

Appendix A to this report lists the buildings corresponding to “Building Designation.”

3.4.3 Energy Savings

According to FEDS calculations, adding insulation to the buildings listed above would save 5,672 MMBtu/yr (a combination of gas, electric, and propane), for a total savings of $66.6K/yr.

3.4.4 Additional Benefits

There are no O&M savings associated with this ECM, but comfort levels will be improved for the occupants of these buildings.

3.4.5 Investment

A total of $607K will be required to install foundation insulation across the site where cost-effective.

3.4.6 Payback

The simple payback is 9.1 yrs.

3.5 BE #5—Insulate Roofs, Ceilings, and Attics

3.5.1 Existing Conditions and Problems

In most buildings on site, roof insulation is inadequate. Roof insulation is critical to reduce heat loss during the winter and solar gain from the sun during the summer.

3.5.2 Solution

The amount of insulation that is appropriate to add depends on the amount of insulation that currently exists, how much the facility is heated and cooled, and what type of roof the building has. Some buildings will need insulation placed above the suspended ceiling. Others will need insulation added to the attic. Metal roofs tend to need insulation installed under the surface of the roof. Adding insulation to built-up roofs often requires replacement of the roofing system. Table 4 summarizes conditions believed to currently exist and recommended retrofit conditions based on building groupings resulting from a FEDS model of Fort Bliss.

Appendix A to this report lists the buildings corresponding to "Building Designation."

3.5.3 Energy Savings

According to FEDS calculations, adding insulation to the buildings listed above would save 93,366 MMBtu/yr, for a total savings of $1,045K/yr.

3.5.4 Additional Benefits

There are no O&M savings associated with this ECM, but comfort levels will be improved for the occupants of these buildings.

3.5.5 Investment

A total of $3,984K will be required to install roof, attic, and ceiling insulation across the site where cost-effective.

3.5.6 Payback

The simple payback is 3.8 yrs.

Table 4. BE #5 Insulate roofs, ceilings, and attics.

ECM	Current Technology	Retrofit Technology	Current R-Value	Retrofit R-Value	Investment $	Savings $/yr	Simple Payback yrs
BE_5A	Roof insulation R-value 0.00	Add insulation to interior surface of metal roof: 4 in. fiberglass	0	9.75	$31,685	$91,609	0.3
BE_5B	Roof insulation R-value 0.00	Add insulation to interior surface of metal roof: 4 in. fiberglass	0	9.75	$413,002	$324,940	1.3
BE_5C (Hangars)	Roof insulation R-value 0.00	Add insulation to interior surface of metal roof: 4 in. fiberglass	0	9.75	$357,797	$167,677	2.1
BE_5C (Offices)	Roof insulation R-value 0.00	Add insulation to interior surface of metal roof: 4 in. fiberglass	0	9.75	$28,062	$20,581	1.4
BE_5D	Roof insulation R-value 0.00	Attic ceiling: Increase insulation by R-13 (blow-in cellulose)	0	13	$47,024	$3,827	12.3
BE_5E	Roof insulation R-value 11.00	Attic ceiling: Increase insulation by R-19 (blow-in cellulose)	11	30	$59,504	$10,730	5.5
BE_5F	Roof insulation R-value 0.00	Attic ceiling: Increase insulation by R-19 (blow-in cellulose)	0	19	$33,242	$9,653	3.4
BE_5G	Roof insulation R-value 0.00	Attic ceiling: Increase insulation by R-30 (blow-in cellulose)	0	30	$11,824	$7,871	1.5
BE_5H	Roof insulation R-value 0.00	Attic ceiling: Increase insulation by R-38 (blow-in cellulose)	0	38	$35,422	$21,855	1.6
BE_5I	Roof insulation R-value 0.00	Insulate Built-up Roof Surface (R-10) and Re-Roof	0	10	$535,848	$54,846	9.8
BE_5J	Roof insulation R-value 0.00	Insulate Built-up Roof Surface (R-10) and Re-Roof	0	10	$362,760	$46,126	7.9
BE_5K	Roof insulation R-value 0.00	Insulate Built-up Roof Surface (R-10) and Re-Roof	0	10	$157,904	$20,783	7.6
BE_5L	Roof insulation R-value 0.00	Insulate Built-up Roof Surface (R-20) and Re-Roof	0	20	$44,133	$6,959	6.3
BE_5M	Roof insulation R-value 0.00	Insulate Built-up Roof Surface (R-20) and Re-Roof	0	20	$300,756	$49,639	6.1
BE_5N	Roof insulation R-value 0.00	Insulate Built-up Roof Surface (R-20) and Re-Roof	0	20	$605,727	$106,204	5.7
BE_5O	Roof insulation R-value 8.90	Suspended Ceiling: Increase Insulation by R-11	8.9	19.9	$185,626	$15,085	12.3
BE_5P	Roof insulation R-value 8.90	Suspended Ceiling: Increase Insulation by R-19	8.9	27.9	$57,110	$7,206	7.9
BE_5Q	Roof insulation R-value 13.35	Suspended Ceiling: Increase Insulation by R-19	13.35	32.35	$131,966	$11,050	11.9
BE_5R	Roof insulation R-value 8.90	Suspended Ceiling: Increase Insulation by R-19	8.9	27.9	$108,863	$11,721	9.3
BE_5S	Roof insulation R-value 0.00	Suspended Ceiling: Increase Insulation by R-19	0	19	$210,900	$83,833	2.5
BE_5T	Roof insulation R-value 13.35	Suspended Ceiling: Increase Insulation by R-19	13.35	32.35	$84,714	$6,090	13.9
BE_5U	Roof insulation R-value 8.90	Suspended Ceiling: Increase Insulation by R-38	8.9	46.9	$5,763	$648	8.9

BE #6—Install Wall Insulation

3.5.7 Existing Conditions and Problems

Many buildings were built with concrete block or masonry walls, and were never insulated. This allows heat to conduct through the walls easily, forcing heating and cooling systems to work harder and/or leaving the occupants uncomfortable.

3.5.8 Solution

Install insulation on the interior surface of the masonry walls. Add insulation to the interior surface of metal walls. Table 5 lists a summary of the conditions believed to currently exist and recommended retrofit conditions. These are based on building groupings resulting from a FEDS model of Fort Bliss.

Appendix A to this report lists the buildings corresponding to “Building Designation.”

3.5.9 Energy Savings

According to FEDS calculations, adding insulation to the buildings listed above would save 45,339 MMBtu/yr, for a total savings of $456K/yr.

3.5.10 Additional Benefits

There are no O&M savings associated with this ECM, but comfort levels will be improved for the occupants of these buildings.

3.5.11 Investment

A total of $1,894K will be required to install wall insulation across the site where cost-effective.

3.5.12 Payback

The simple payback is 4.2 yrs.

Table 5. BE #6 Install wall insulation.

ECM	Current Technology	Retrofit Technology	Current R-Value	Retrofit R-Value	Investment $	Savings $/yr	Simple Payback (yrs)
BE_6A	Wall insulation R-value 0.00	Add interior masonry surface insulation: R-12.4	0	12.4	$44,503	$3,533	12.6
BE_6B	Wall insulation R-value 0.00	Add interior masonry surface insulation: R-12.4	0	12.4	$152,625	$11,498	13.3
BE_6C	Wall insulation R-value 0.00	Add interior masonry surface insulation: R-12.4	0	12.4	$41,317	$3,149	13.1
BE_6D	Wall insulation R-value 0.00	Add interior masonry surface insulation: R-12.4	0	12.4	$175,869	$13,332	13.2
BE_6E	Wall insulation R-value 0.00	Add interior masonry surface insulation: R-12.4	0	12.4	$18,422	$1,454	12.7
BE_6F	Wall insulation R-value 0.00	Add Interior Metal Wall Surface Insulation: 4 in. Fiberglass	0	9.75	$188,617	$12,658	14.9
BE_6G	Wall insulation R-value 0.00	Add Interior Metal Wall Surface Insulation: 4 in. Fiberglass	0	9.75	$269,463	$51,961	5.2
BE_6H	Wall insulation R-value 0.00	Add Interior Metal Wall Surface Insulation: 4 in. Fiberglass	0	9.75	$281,878	$82,043	3.4
BE_6I	Wall insulation R-value 0.00	Add Interior Metal Wall Surface Insulation: 4 in. Fiberglass	0	9.75	$549,482	$184,687	3.0

BE #7—Replace Inefficient Single Pane Metal Windows

3.5.13 Existing Conditions and Problems

Some buildings on site, such as Bldg. 2 (Figure 12), are older and still have their original windows in place (single pane with metal frames), with no improvements made. This means that any damage that has occurred to the windows or other deterioration due to age has not been repaired. In addition, significant progress has been made over the years in energy efficient windows, so the energy efficiency of these older windows is greatly lacking. These buildings are heated and cooled, which means heat escapes easily in the cold months and enters easily in the hot months, both through cracks and conduction through the panes and window frames.

3.5.14 Solution

Replace existing single pane metal frame window systems with argon-filled double pane windows with aluminum frames and low-e coating. Some buildings should also have thermal breaks in the windows, and some need super low-e coatings (cf. Table 6).

Figure 12. Single pane windows in Bldg. 2.

3.5.15 Energy Savings

According to FEDS calculations, replacing inefficient single pane metal windows in all of the buildings listed above would yield energy savings of 4,189 MMBtu/yr, which equates to $112K/yr for the various heating and cooling fuels being saved.

3.5.16 Additional Benefits

There are no O&M savings associated with this ECM, but comfort levels will be improved for the occupants of these buildings due to reduced drafts.

3.5.17 Investment

A total of $927K will be required to replace these windows.

3.5.18 Payback

The simple payback for this ECM is 8.3 yrs (cf. Table 7).

Table 6. BE #7 Replace inefficient metal frame windows with argon-filled double-pane aluminum windows with low-e glass.

ECM	Current Technology	Retrofit Technology	Current R-Value	Retrofit R-Value	Investment $	Savings $/yr	Simple Payback (yrs)
BE_7A	Metal frame single pane window	Install thermal break aluminum frame double pane argon/ super low-E window	1.26	0.42	$18,676	$2,193	8.5
BE_7B	Metal frame single pane window	Install thermal break aluminum frame double pane argon/ super low-E window	1.26	0.42	$81,841	$9,392	8.7
BE_7C	Metal frame single pane window	Install thermal break aluminum frame double pane argon/ super low-E window	1.26	0.42	$59,271	$6,248	9.5
BE_7D	Metal frame single pane window	Install thermal break aluminum frame double pane argon/ super low-E window	1.26	0.42	$47,909	$4,623	10.4
BE_7E	Metal frame single pane window	Install thermal break aluminum frame double pane argon/ super low-E window	1.26	0.42	$243,954	$30,809	7.9
BE_7F	Metal frame single pane window	Install thermal break aluminum frame double pane argon/ super low-E window	1.26	0.42	$475,820	$58,974	8.1

Table 7. Simple payback calculations for Building Envelope ECMs.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
BE #1	Establish a strategic approach for re-roofing projects, incorporating the use of cool roof materials	1,014,000	0	$65,910	−480	−$4,360	0	$61,550	$—	0.0
BE #2	Place transparent panels behind windows in vehicle maintenance buildings and barracks	0	0	$—	609	$5,532	0	$5,532	$124,560	22.5
BE #3A	Install exterior shading for windows in barracks and administrative areas	72,800	0	$4,732	379	$3,443	0	$8,175	$132,000	16.1
BE #3B	Install exterior shading for windows in barracks and administrative areas with avoided cooling capacity	72,800	0	$4,732	379	$3,443	0	$8,175	$66,000	8.1
BE #4 *	Install foundation insulation	116,642	106	$15,074	5,672	$51,506	0	$66,580	$607,256	9.1
BE #5*	Insulate roofs, ceilings, and attics	2,747,248	1,357	$355,246	82,353	$723,687	0	$1,078,933	$3,809,632	3.5
BE #6*	Install wall insulation	1,269,584	161	$83,880	41,007	$372,504	0	$456,384	$1,894,324	4.2
BE #7*	Replace inefficient metal frame windows	590,831	342	$74,184	4,189	$38,055	0	$112,239	$927,471	8.3
Totals		*5,883,905*	*1,966*	*$603,758*	*134,108*	*$1,193,809*	*0*	*$1,797,567*	*$7,561,243*	*4.2*

4 Commissioning ECM

4.1 COM #1—Retrocommission Building Controls And EMS (Energy Management System) In Most Buildings

4.1.1 Existing Conditions and Problems

The condition of existing building controls has deteriorated so that they no longer effectively control AHUs, boilers, chillers, perimeter heat systems, etc. Sequences of operation are not accurate with respect to the way buildings and spaces are currently used. Setpoints for temperature and air flow need to be revised. Formerly active control functions no longer work properly (e.g., regarding economizing modes with outdoor and return air dampers in sequence and according to initial design and construction). Signals from temperature, static pressure, and other sensors are no longer calibrated. In some cases, variable frequency drives (VFDs) run at their maximum value (i.e., 60 Hz or 100 percent of nominal air flow) even though there are many opportunities to vary the flow depending on building usage. For example, in Bldg. 11293, air handling unit (AHU) 3 runs steadily at 60 Hz even though the system is pressure controlled (cf. Figure 13). This indicates that something is wrong or has been changed for unknown reasons.

Figure 13. AHU-3 inverter in Bldg. 11293 continually operates at 60 Hz.

A typical EMS (or UMCS as it is called at Fort Bliss) consists of a central computer and numerous measurement and control points that activate or modulate fans, dampers, pumps, coils, chillers, boilers and other HVAC equipment. Many schedules are programmed into that system. (At Fort Bliss, no night or weekend temperature setbacks are done from UMCS.) Sequences of operation and control schemes are designed to maintain comfort while trimming energy costs. For savings to occur, however, not only must the programming be correct (without conflicts, such as simultaneous heating and cooling), but all measuring devices (e.g., temperature sensors) and actuators must be working as designed. As with links in a chain, failure at one level makes the rest essentially irrelevant.

When an EMS is installed, it is usually tested to ensure it will deliver comfortable conditions, but its operation may not be verified with regard to optimal energy efficiency. To ensure an EMS will deliver promised savings, it needs to be commissioned on installation or retrocommissioned thereafter. An EMS and its control points need to be retrocommissioned if one finds:

- unusually high energy use
- chronic failures of building equipment, the control system, or both
- numerous and growing comfort problems.

4.1.2 Solution

Evaluate the building's original function and the original specifications and design of the heating and cooling systems. Compare that data with the building's current needs, occupancy level, and type of use. Check every signal and every function, validating that the functions are still available. If not, fix whatever needs to be fixed. Make sure simultaneous heating and cooling can never occur by programming new sequences and blocking use of units that can cause the simultaneous heating and cooling. Set alarm points for important signals such as high temperatures, low temperatures, damper failure, pressure too high or too low, etc. Troubleshoot all the AHUs and their respective functions. Log dampers, temperatures, actuator signals, and other parameters to identify problems. Adjust chiller and boiler setpoints and control curves. Replace malfunctioning hardware and adjust software. Implement night and weekend temperature setback. Optimize economizer modes/cycles. Check VAV-boxes, VFDs, pressure sensors, and controls.

Figure 14. Bldg. 2457, Dining Hall, OA and RA dampers not operating correctly.

More specific things to fix should also include:

1. Insulate pipes and ductwork. Temperature increases in summer and temperature drops in winter are not negligible.
2. Repair or replace all failing equipment, e.g., non-operating dampers, controls out of control, 100 percent outdoor air (OA) instead of 100 percent return air (RA). Figure 14 shows failed dampers in Bldg. 2457 (Dining Hall).
3. Adjust building air and water flows to design values.

Also:

4. Upgrade controls to direct digital control (DDC) at most buildings, connect to UMCS/EMS.
5. Install DDC Controls including Operator Workstation (OWS) in Centennial Club's manager's office. Bldg. 11199 (the Centennial Club) is an "energy hog" with long operating hours (24/7 in some cases) due to nonfunctioning time clocks and also very low temperature setpoints. During our visit, the building manager indicated he would gladly use DDC to schedule equipment for actual hours of use if it were available. Figure 15 shows the existing control panel in the Centennial Club mechanical room. (Also see related energy conservation opportunity CON #1, below.)

Figure 15. Existing control panel in the Centennial Club mechanical room, Bldg. 11199.

4.1.3 Savings

Savings from proper commissioning or later retrocommissioning will vary widely, depending on how well systems were designed, installed and maintained prior to review. Independent studies have shown cuts in energy costs ranging from 3 to 50 percent with paybacks for commissioning ranging from 3 months to 5 yrs.* In the case at Fort Bliss, with more than just normal retrocommissioning (points 1, 3, 4, and 5 must be seen as additional work), the savings will be in the upper range.

*Lindsay Audin. January 2007. "What's AILING the EMS," *Building Operating Management*, accessible through URL: http://www.facilitiesnet.com/bom/article.asp?id=5917&keywords=retrocommissioning

4.1.4 Investment

Due to variations among buildings and systems, costs for commissioning or retrocommissioning services vary widely, from $0.03 to $0.43/sq ft, with $0.20/sq ft being a generally accepted average. That cost typically encompasses review of all EMS programming, testing of all measurement and control points, identification of all problems, minor repairs and a short-term verification of savings. Implementing points 1, 3, 4, and 5 above will yield investments and resulting savings in the upper range.

4.1.5 Payback

Payback will occur in less than 5 yrs.

5 Controls (Building and Centralized Utility Monitoring and Control System) ECMs

5.1 CON #1—Establish and Maintain a Uniform and General Setpoint for Space Temperature in All Buildings

5.1.1 Existing Conditions and Problems

A large variation of actual space temperatures and space temperature setpoints were found throughout the installation. The lowest setpoints were found in the Centennial Club, with 52 °F during unoccupied hours (morning). The chillers ran pretty much fully loaded, but the setpoints were not reached. Other buildings had setpoints ranging from 52 °F to 74 °F. A setpoint of 74 °F would provide a comfortable environment.

5.1.2 Solution

Make a general written statement, signed by the Fort Bliss Commander, that the lowest acceptable space temperature setpoint during the cooling season is 72 °F and the highest acceptable setpoint for the heating season is 74 °F. At the same time, make sure that these setpoints are included in the Installation Design Guide for all new projects and also for renovation/modernization projects. Lock all thermostats in locked cages, and allow only the respective building managers to have keys. (Take control away from the individuals working in the building.) In buildings connected to the UMCS/EMS, update all setpoints to match the new limits.

5.1.3 Savings

The savings by lowering the temperature setpoints will be calculated on a per-square-foot basis and at this stage only for the cooling season. Assume:

- 10,000 sq ft building with 10-ft ceiling (i.e., 100,000 cu ft volume), and air supply of 10,000 cfm and with 30 percent outdoor air, 3,000 cfm.
- Increase space temperature (and also Supply Air temperature) by 10 °F. Chiller coefficient of performance (COP) = 3.0
- Cooling savings air handling unit: 1.42 m^3/s * 1.2 * 5.5 °C * 26 wks * 168 hrs/3.0 = 13,650 kWh worth $900.

- Cooling savings from reduced transmission losses vary according to building design, construction and installation quality, but can (on average) be assumed to be at least as high as the savings from the AHU.

Total savings are then approximately $1,800/yr, or 18 cents/sq ft/yr. Assume 1 million sq ft of buildings where this is applicable, yielding annual savings of $180K. Heating savings are not calculated or estimated now, but add to the total savings when reducing maximum setpoints to 74 °F.

5.1.4 Investment

Not more than $1,000 for a 10,000 sq ft building, all of which is related to locking thermostats. For 1 million sq ft then, the total investment would be is $100K.

5.1.5 Payback

Payback will occur within 7 months.

5.2 CON #2—Connect All Major Buildings at Fort Bliss to a Central Monitoring and Control System, Utility Management and Control System

5.2.1 Existing Conditions and Problems

Various buildings at Fort Bliss are currently connected to three separate energy management systems. Approximately 10 buildings are connected to a Trane Tracer Summit system, 40 buildings are connected to a Williams Electronics Control system and five buildings are controlled by Web Controls marketed by PC Automated. Many buildings are not connected to any supervisory or control system. In most cases, the buildings connected to an EMS must be physically visited if something is to be changed or checked since the Information people at Fort Bliss have disconnected some of the network once used for the building controls systems. The Survey Team studied the systems and their features, and drew the following conclusions regarding their practical usefulness.

From an energy standpoint, the systems at Fort Bliss currently operate inefficiently. The UMCS operator is supposed to maintain a working knowledge of three separate systems that do not work as intended and require a lot of physical visits to buildings, which is very time consuming and inefficient. Most buildings are not connected to a centralized control system, do not have functioning time clocks, and have poorly functioning local controls. This results in operating hours that are longer than intended and energy use that is much higher than it would be if a proper EMS were in operation. Night and weekend temperature setbacks are not used. There is no information available to show that this works, or that the temperature setpoints would return to normal daytime settings during the hours that the buildings are occupied. When night and weekend temperature setbacks were tried, they resulted in complaints from occupants, reduced comfort levels, higher work load for manual reset, etc.

5.2.2 Solution

The results of a study currently being done by the Corps of Engineers at Huntsville, AL hopefully describe the situation and the costs related to connecting all major buildings (51 buildings) to a single central monitoring and control system. At this point, Fort Bliss is encouraged to make this investment and to choose a system supplier that can incorporate most (if not all) of the existing control systems, or at least make it possible to retain the existing sensors, actuators, control valves, VFDs, etc., to minimize the investment. Johnson Controls has said they can do this and integrate the existing equipment, but also a company named Citect and others should be contacted in this respect.

5.2.3 Savings

There are many unknown factors in the equation, but with the status of existing building controls (both those connected to the EMS and those not connected) it is safe to say that the potential savings in major buildings could be in the range of 25–40 percent regarding heating, and electricity for cooling and motors. Comfort improvements can be made easily with working building controls. Maintenance costs can be reduced (reducing Kings Aire work orders significantly as well as renegotiating their contract) substantially.

5.2.4 Investment

The required investment would total several million dollars depending on how many buildings would be included in the system. The study done by

Energy Management Control (EMC) Engineers indicates costs in the range of $3.5M.

5.2.5 Payback

Normally payback would occur within 5 yrs of operation, after everything is commissioned, tested, and verified. With a 1- to 2-yr installation and commissioning period, the investment should be paid back 7 yrs after awarding the contract.

5.3 Special Facilities: DIN #1—More Efficient Dining Facility Operations

5.3.1 Existing Conditions

Six dining facilities were identified at Fort Bliss (Bldgs. 250, 906, 2408, 5095, 11142, and 11199). Dining facilities are among the highest energy users on an Army installation. They consume a lot of heat and electricity in storing, preparing, cooking, and serving food. The washing and cleaning of cooking items and dishes (see Figure 16) also consumes much energy. In addition, the building systems are energy intensive.

There is a large outdoor air component in the ventilation rates due to large amounts of air that are exhausted above cooking equipment through the use of hoods (see Figure 17). Hot water is needed in many operations, requiring a large domestic hot water heater for an adequate supply.

Figure 16. Automated dishwasher.

Figure 17. Cooking equipment under exhaust hood.

It is often feasible to replace kitchen equipment and/or components with more efficient types. Doing so will improve the energy performance of the facility without sacrificing effectiveness. Examples of components that can be replaced in typical dining facilities are:

- Replace high flow nozzles at washing stations with low flow ones that can save approximately 3 gallons per minute (gpm) of water.
- Replace evaporator coil fan motors with more efficient ones in walk-in coolers and freezers to save 120 Watt per motor that runs continuously.
- Replace incandescent lamps with screw in fluorescent bulbs in freezers, hoods, etc.
- Switch from gas-heated cooking equipment to electric-powered types
- Ensure proper operation of cooking and cleaning equipment to avoid wasting energy. Keeping equipment commonly left "On" when not in use (resulting in waste). Exhaust hoods are left running when no cooking is in operation. Food warmers and coolers are operated empty. Steamers are kept "On" between cooking periods. Other modifications and things that can be done to keep kitchen equipment performing efficiently include:
  - Installing plastic curtains in freezer and cooler doorways
  - Using automatic door closers on freezer and cooler doors
  - Maintaining the door seals on freezer and cooler doors in good condition
  - Using manufacturer's recommended temperature and pressure settings in cooking, cleaning, and washing equipment
  - Placing cooking equipment under hoods and near the rear wall if one exists.

The kitchen and dining area can also be evaluated for improved ventilation by better controlling the exhaust hoods and air balance between the spaces. Cooking operations can be sensed and the exhaust air flow of a hood can be adjusted to suit the need.

5.3.2 Solution

A number of performance and operation items can be analyzed in a dining hall. There are kitchen specialists that have knowledge of the operation of cooking and cleaning equipment who can evaluate the performance of Fort Bliss's dining facilities. It is recommended that a visit by one of these specialists be made to Fort Bliss.

If this analysis is not provided, energy will be wasted since Fort Bliss does not have the most efficient available cooking and dining systems.

5.3.3 Savings

The estimated savings that could be easily achieved in a dining facility are approximately 10 percent of the dining facility energy use.

5.3.4 Investments

The cost of a visit by a kitchen energy use specialist would be approximately $10,000 for a 3-day visit plus a report.

5.3.5 Payback

Payback should occur in less than a year.

6 Evaporative Cooling Technologies and ECMs

Fort Bliss has an ideal climate for cooling by means of evaporative cooling. There are numerous evaporative coolers currently installed. However, many of these units are in poor condition and are operating at less than ideal condition. This results in overly humidified air and resulting problems such as mold and uncomfortable working environments. This has resulted in a general trend at Fort Bliss of replacing evaporative cooling with direct expansion (DX) cooling, which is much more costly to operate. The following discussion explains three types of evaporative cooling and the energy consequences of each.

6.1 Evaporative Cooling Technologies

Evaporative cooling is the cooling of air by the evaporation of water. Direct evaporative cooling (DEC) is the process of evaporating water into the air to be cooled while simultaneously humidifying it. When the air to be cooled is kept separate from the evaporation process through the use of a heat exchanger, it is not humidified as it is cooled; this process is called indirect evaporative cooling (IEC). When a direct or indirect evaporative cooling unit alone cannot provide sufficient cooling, a hybrid indirect/direct (IDEC) unit can be used to meet the desired cooling conditions. If the hybrid IDEC unit cannot meet the desired cooling conditions, then a third stage mechanical cooling section can be added to the IDEC to achieve the final design conditions. In addition, a heating section can be added to the configuration to satisfy the design conditions during the winter months. The efficiency of evaporative cooling systems is defined as effectiveness. Typically, the effectiveness of direct units ranges between 80 and 90 percent, and indirect units range from 70 to 80 percent.

6.1.1 Direct Evaporative Cooling (DEC)

6.1.1.1 Operation

Figure 18 shows a schematic diagram of a Direct Evaporative Cooler. During direct evaporative cooling, outside air is pulled through a saturated paper media by a draw-through fan. As the air passes through the media, the water particles evaporate, cooling the outside air.

For example, if the outside air dry bulb (db) temperature is 95 °F and the wet bulb (wb) temperature is 75 °F, and the DEC unit is 90 percent effective, the dry bulb supply air temperature can be calculated by subtracting the wet bulb temperature from the dry bulb temperature and multiplying the result by the DEC effectiveness (95 – 75 = 20; 20 * 90% = 18 °F). Therefore, the dry bulb supply air temperature would be 95 – 18 = 77 °F. The wet bulb temperature would stay relatively constant at 75 °F. The limiting factor in DEC is the wet bulb temperature of the outside air. In relatively dry climates such as El Paso where the design wet bulb temperature is 70 °F, there is a greater difference between the dry bulb and wet bulb temperatures (known as “wet bulb depression”). The greater the wet bulb depression, the more cooling that can be achieved using DEC.

6.1.1.2 Psychrometrics

Psychrometrics is the measurement of the heat and water vapor properties of air. For convenience, these properties have been plotted on Psychrometric Charts by the HVAC industry and societies. Given any two psychrometric properties, all of the other properties can be found on the psychrometric chart. The chart in Figure 19 shows the psychrometrics of a 90 percent effective direct evaporative cooler at the 99 percent summer design condition of 100 °F db and 65 °F wb for El Paso.

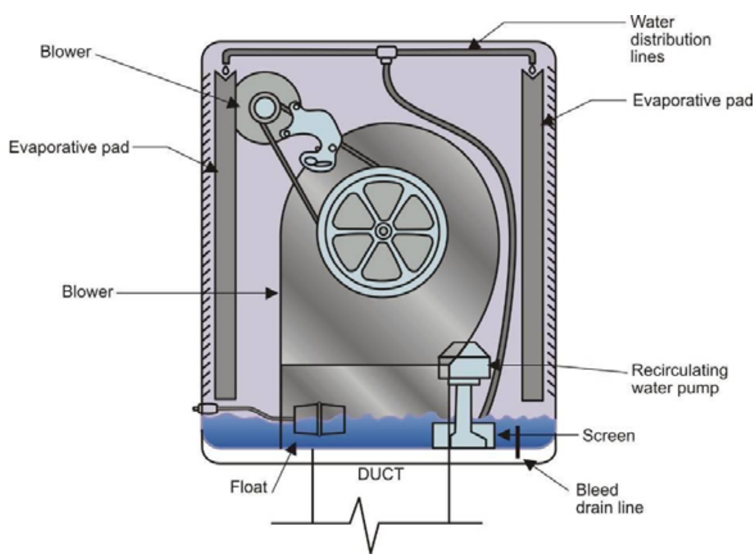

Figure 18. Diagram of a direct evaporative cooler.

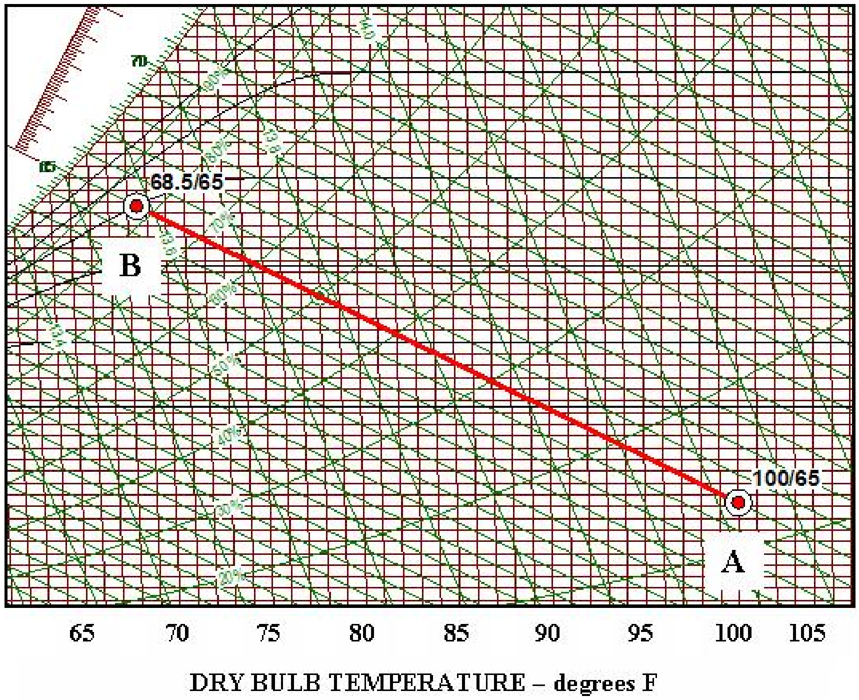

Figure 19. Psychrometrics of 90 percent effective direct evaporative cooling.

Since moisture is added going from state A to B, the final wet bulb temperature remains constant and the relative humidity of the supply air increases.

6.1.1.3 Maintenance

Direct evaporative coolers are relatively easy to maintain. The evaporative media in smaller direct evaporative units (Figure 18), often referred to as "Swamp Coolers," should be replaced every 1 to 2 yrs. These are inexpensive and easy to install. Care should be given to keep the air intakes free from debris. If the intakes become plugged, the effectiveness of the DEC will be reduced dramatically. The sump should be dumped monthly. This is the most cost effective method of maintaining necessary water quality. Periodic pump, fan, and motor replacements will also be required.

6.1.1.4 Controls

DEC units typically require no controls. The units are operated in either the on or off position. A float switch is used to control the make-up water valve. Controls could be added to automate the required monthly sump dump.

6.1.1.5 Energy Use

Direct evaporative cooling units consume a small fraction of energy compared to traditional mechanical cooling. The energy consumption comes from the fan and pump. Typically, these are both fractional horsepower motors. The energy saved by using DEC versus traditional mechanical cooling is calculated by:

$$Q_{BTU\,/\,Hr\ Saved} = 1.08 * \Delta T * Direct\ Evaporative\ Cooler\ Effectiveness * Volumetric\ Air\ Flowrate$$

For example, if the building were served by a 10,000 cfm unit and the design dry and wet bulb temperatures were 100 °F and 65 °F, respectively, the energy saved with a 90 percent effective unit is calculated to be:

$$Q_{Tons\ of\ Cooling\ Saved} = \frac{1.08 * \left(T_{Outside\ Air,\ Dry\ Bulb} - T_{Outside\ Air,\ Wet\ Bulb}\right) * 90\% * 10{,}000\ cfm}{12{,}000\ BTU\,/\,HR\,/\,Ton} = Tons\ of\ Cooling\ Saved$$

$$Q_{Tons\ of\ Coolin\ Saved} = \frac{1.08 * \left(100^{\circ}\ F_{dry\ bulb} - 65^{\circ}\ F_{wet\ bulb}\right) * 90\% * 10{,}000\ cfm}{12{,}000\ BTU\,/\,HR\,/\,Ton} = 28.4\ Tons\ of\ Cooling\ Saved$$

6.1.1.6 Water Consumption

The water evaporated by the direct evaporative cooler is the difference between the humidity ratio of the outside air and the supply air leaving the unit. The humidity ratio can be determined graphically from a psychrometric chart and is given in grains of moisture per pound of air. The rate of water evaporated in the DEC is calculated by:

$$Q_{GPM\ Evaporated} = \frac{\left(\omega_{Supply\ Air} - \omega_{Outside\ Air}\right) * Density\ of\ Air * Volumetric\ Air\ Flowrate}{7{,}000\ \frac{grains}{lb} * 8.33\ \frac{lb}{gallon}}$$

where:

$\omega =$ humidity ratio, measured in grains of moisture per pound of dry air

By multiplying the rate of water evaporated for a given temperature bin by its corresponding number of occurrence hours per year, the total water evaporated for each bin can be calculated. The required bleed-off rate (draining of evaporative cooler water to dilute mineral content) should be equal to 2/3 of the maximum evaporation rate. This bleed-off rate is then multiplied by the total number of run hours per year to obtain the total amount of water used for bleed-off.

6.1.1.7 Parasitic Losses

The pumping energy used in a DEC unit is inconsequential compared to the energy used in traditional mechanical cooling. Both types of systems have fans of approximately the same size. Therefore, parasitic losses are typically ignored for direct evaporative coolers.

6.1.2 Indirect Evaporative Cooling (IEC)

6.1.2.1 Operation

Figure 20 shows an indirect evaporative cooling system. Indirect systems cool air without adding moisture. This is accomplished because there is no direct contact between the water and the air stream to be cooled. A plate and frame air-to-air heat exchanger is used to separate the building supply air from the water used for evaporation. Outside air, known as secondary air, is drawn through the wet side of a plate and frame heat exchanger. Water is then sprayed into the wet side of the heat exchanger causing the secondary air to cool as the fine water particles evaporate. Next, primary air passes through the dry side of the plate and frame heat exchanger. The heat exchanger then transfers sensible heat from the warm dry primary air stream (building supply) to the cooler secondary air stream. Typical effectiveness ratings for IEC units are 70 to 80 percent. Unlike the direct evaporative cooling units, there is no moisture added to the building supply air. Both the dry bulb and wet bulb supply air temperatures are reduced. Since IEC units are less effective than most DEC units, the supply air temperatures achievable with IEC are not as favorable as DEC units.

For example, if one uses the outside air dry bulb and wet bulb temperatures in the example for DEC of 95 °F and 75 °F, respectively, and the IEC unit is 75 percent effective, the dry bulb supply air temperature can be calculated by subtracting the wet bulb temperature from the dry bulb temperature and multiplying the result by the IEC effectiveness (95 – 75 = 20; 20 * 75% = 15 °F).

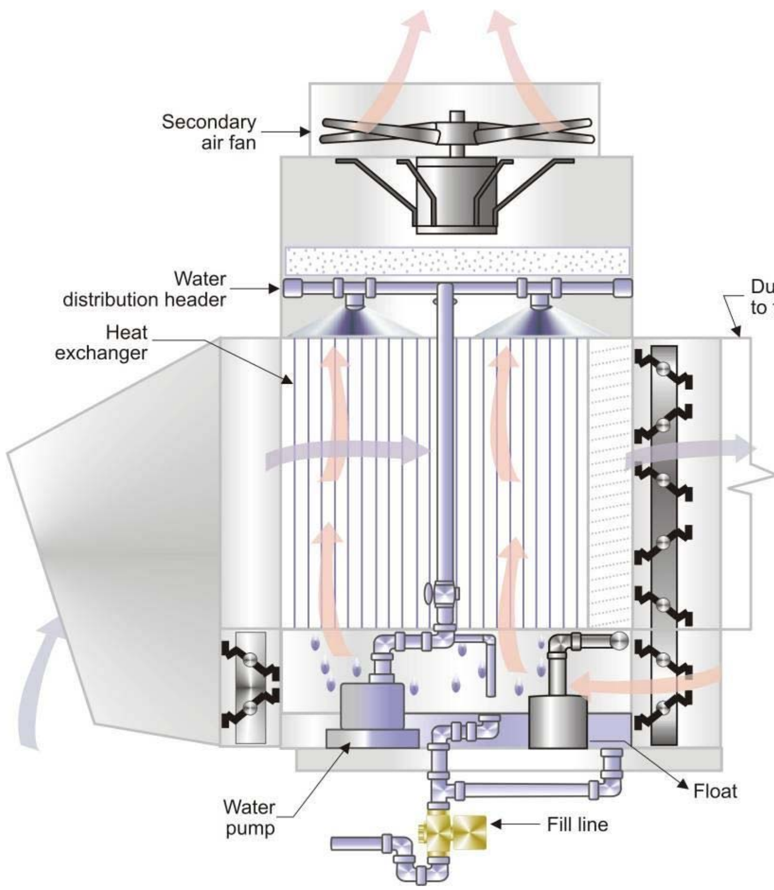

Figure 20. Diagram of an indirect evaporative cooler.

Therefore the dry bulb supply air temperature would be 95 – 15 = 80 °F. Unlike DEC, the wet bulb temperature during IEC would also be reduced. IEC is very effective at pre-cooling the supply air to traditional mechanical cooling units, or when supply air has low humidity requirements.

6.1.2.2 Psychrometrics

As discussed earlier, Psychrometrics is the measurement of the heat and water vapor properties of air. Since there is no moisture added to the supply air during the IEC process, the cooling performed is sensible only. The humidity ratio, measured in grains of moisture per pound of dry air, remains constant during the IEC process. Figure 21 plots the psychrometrics of a 75 percent effective indirect evaporative cooler at the 99 percent summer design condition of 100 °F db and 65 °F wb, for El Paso, TX.

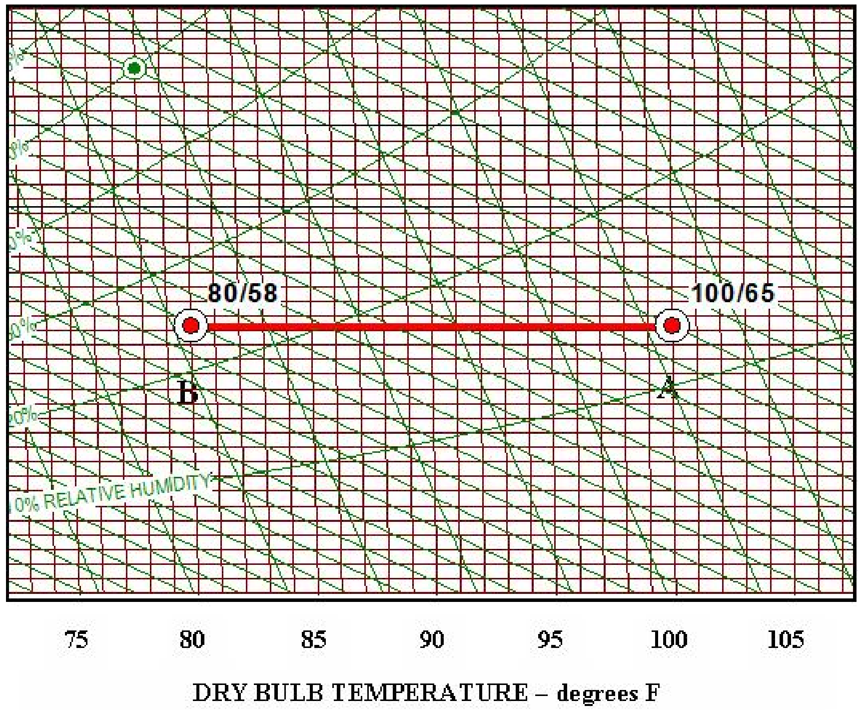

Figure 21. Psychrometrics of 75 percent effective indirect evaporative cooling.

IEC units require little maintenance. The heat exchanger should be backwashed monthly and the sump should be dumped daily. These functions should be performed with simple, inexpensive time clocks and control valves. Care should be given to keep the air intakes free from debris. If the intakes become plugged, the effectiveness of the IEC will be reduced dramatically. Periodic pump, fan, and motor replacements will also be required. A base wide EMCS could help to predict required maintenance and give the ability to predict when preventative maintenance items should be performed. However, with the site-wide EMCS at Fort Bliss still in its infancy, this is not currently recommended.

6.1.2.3 *Energy Use*

Like direct evaporative cooling, IEC units consume a small fraction of energy compared to traditional mechanical cooling. Energy is used by the primary fan, the secondary fan, and the sump pump. In larger units, there may be multiple secondary fans, but typically these are fractional horsepower. The sump pumps in the larger units may be as large as 2 horsepower (hp). Most medium-sized units will have fractional horsepower sump pumps and secondary fans. The energy saved by using IEC versus traditional mechanical cooling can be calculated by using the same equations as those for DEC:

$$Q_{BTU/Hr\ Saved} = 1.08 * \Delta T * Indirect\ Evaporative\ Cooler\ Effectiveness * Volumetric\ Air\ Flowrate$$

Using the same example, of a 10,000 cfm unit serving a building and design dry and wet bulb temperatures of 100 °F and 65 °F, respectively, the energy saved with a 75 percent effective unit is calculated to be:

$$Q_{Tons\ of\ Cooling\ Saved} = \frac{1.08 * \left(T_{Outside\ Air,\ Dry\ Bulb} - T_{Outside\ Air,\ Wet\ Bulb}\right) * 75\% * 10{,}000\ cfm}{12{,}000\ BTU/HR/Ton} = Tons\ of\ Cooling\ Saved$$

$$Q_{Tons\ of\ Coolin\ Saved} = \frac{1.08 * \left(100^{\circ}\ F_{dry\ bulb} - 65^{\circ}\ F_{wet\ bulb}\right) * 75\% * 10{,}000\ cfm}{12{,}000\ BTU/HR/Ton} = 23.6\ Tons\ of\ Cooling\ Saved$$

6.1.2.4 Water Consumption

The water evaporated by the indirect evaporative cooler is calculated using the same formula found in the Direct Evaporative Cooling section. Since IEC units are less effective than DEC units, the water consumed by the IEC units is greater than that of DECs.

6.1.2.5 Parasitic Losses

The parasitic losses found in large IEC units must be accounted for. Typical units may have as many as eight secondary fans. These units have large sump pumps that operate continuously during the cooling season. The energy used by these larger motors would reduce the total energy saved by using IEC versus traditional mechanical cooling.

6.1.3 Hybrid Indirect/Direct (IDEC)

6.1.3.1 Operation

When design space temperatures cannot be met with direct evaporative cooling or indirect evaporative cooling alone, hybrid indirect/direct units (Figure 22) can be used to meet these conditions throughout most of the year. Hybrid units can be configured many different ways. There are direct/direct units, indirect/indirect units, and indirect/direct. The most favorable arrangement that provides the most cooling is the indirect/direct unit (IDEC). An IDEC unit has all of the components of an IEC and DEC unit. First, the outside air passes through an IEC module. Here the air is cooled without adding moisture. This air is then drawn through a DEC module. During this process the air is cooled and humidified. This process allows a much lower discharge air temperature over IEC or DEC alone.

For example, if one uses the outside air dry bulb and wet bulb temperatures used in the previous examples for DEC and IEC of 95 and 75 °F, respectively, and the IEC unit is 75 percent effective and the DEC unit is 90 percent effective, the dry bulb supply air temperature can be calculated by subtracting the wet bulb temperature from the dry bulb temperature and multiplying the result by the IEC effectiveness (95 – 75 = 20; 20 * 75% = 15 °F). Thus the dry bulb supply air temperature would be 95 – 15 = 80 °F to the DEC module. The corresponding wet bulb temperature is still 58 °F. Next the air passes through the DEC where the final building supply temperatures are calculated by subtracting the wet bulb temperature of 58 from the dry bulb temperature of 80 for a difference of 22 °F. Multiply this result times the 90 percent effectiveness of the DEC and the wet bulb depression is 19.8 °F. Therefore, 80 – 19.8 = 60.2 °F dry bulb and 58 °F wet bulb supply air temperature to the space.

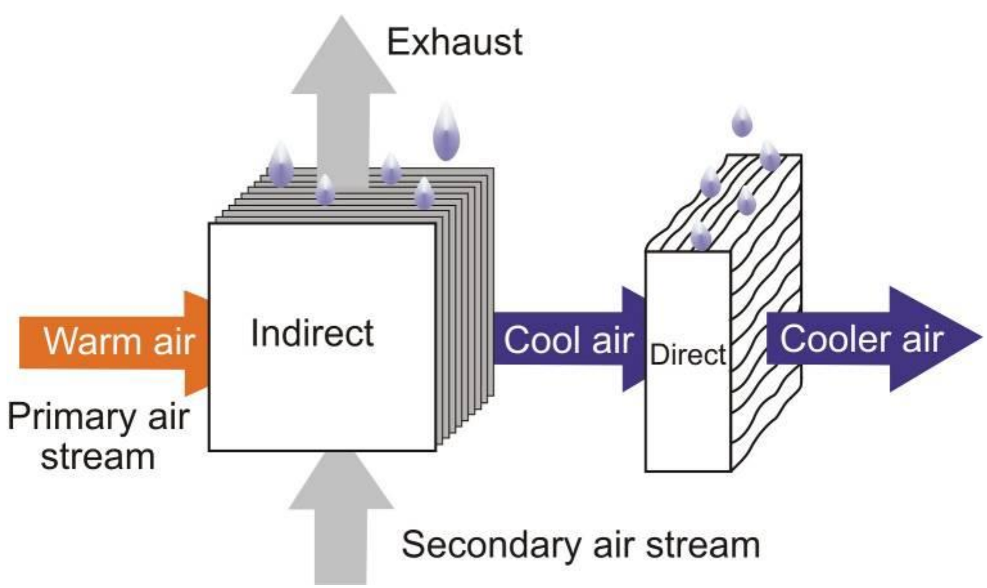

Figure 22. Diagram of a hybrid indirect/direct evaporative cooler.

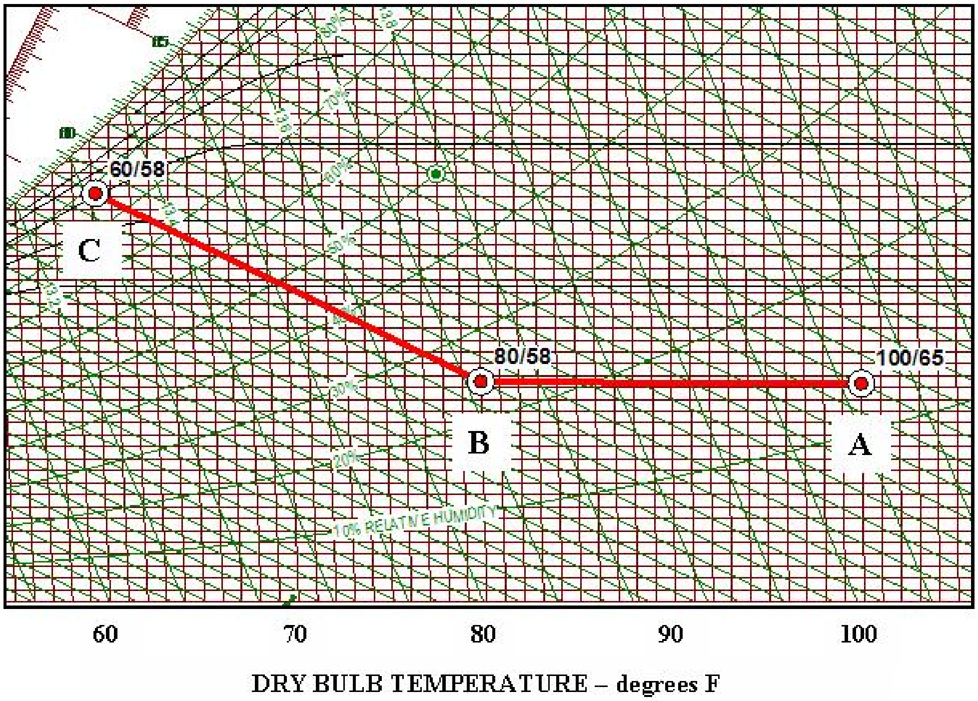

Figure 23. Psychrometrics of indirect/direct evaporative cooling.

6.1.3.2 Psychrometrics

Figure 23 plots the psychrometrics of hybrid IDEC unit with a 75 percent effective IEC module and a 90 percent effective DEC module.

6.1.3.3 Maintenance and Controls

The maintenance and controls of a hybrid IDEC unit is the same as the maintenance and controls for individual DEC and IEC units. The same procedures for each individual type of unit should be followed.

6.1.3.4 Energy Use

Since hybrid units have an indirect and direct section, they use more energy than a direct or indirect unit would alone. Energy is used by the primary fan, the secondary fan, and the sump pump. Like the IEC units, there may be multiple secondary fans. Most IDEC units are not economical to build unless they are at least 5,000 cfm. The energy saved by using IDEC versus traditional mechanical cooling can be calculated by using the same equations as those for IEC and DEC:

$$Q_{BTU/Hr\ Saved} = 1.08 * \Delta T * Evaporative\ Cooler\ Effectiveness * Volumetric\ Air\ Flowrate$$

Using the same example, of a 10,000 cfm unit serving a building and design dry and wet bulb temperatures of 100 and 65, respectively, the energy saved during the indirect stage, with a 75 percent effective unit, is calculated as:

$$Q_{Tons\ of\ Coolin\ Saved} = \frac{1.08 * \left(100^{\circ}\ F_{dry\ bulb} - 65^{\circ}\ F_{wet\ bulb}\right) * 75\% * 10{,}000\ cfm}{12{,}000\ BTU/HR/Ton} = 23.6\ Tons\ of\ Cooling\ Saved$$

During the direct stage with a 90 percent effective unit and dry/wet bulb discharge temperatures of 80/58 °F, the energy saved is calculated:

$$Q_{Tons\ of\ Coolin\ Saved} = \frac{1.08 * \left(80^{\circ}\ F_{dry\ bulb} - 58^{\circ}\ F_{wet\ bulb}\right) * 90\% * 10{,}000\ cfm}{12{,}000\ BTU/HR/Ton} = 17.8\ Tons\ of\ Cooling\ Saved$$

A total of 41.4 tons of cooling could be saved over using traditional mechanical cooling.

6.1.3.5 Water Consumption

The water evaporated by the indirect/direct evaporative cooler is calculated using the same formulas found in the DEC and IEC sections. The water evaporated by an IDEC unit can be roughly approximated by adding the evaporated water for each individual module. This will be a conservative number, since the amount of water evaporated during the direct stage of the IDEC would be less than the amount evaporated in a DEC unit alone.

6.1.3.6 Parasitic Losses

Since most IDEC units have fans that are at least 3 hp and larger sump pumps, the energy used by these devices must be accounted for in any savings calculations. The energy used can be closely approximated by assuming that the secondary fan and sump pump use 5 to 10 percent of the cooling energy saved. The exact quantity can be calculated by converting the fan and pumps' hp into kW, dividing by fan or pump efficiency, and then by multiplying by the number of run hours per year.

6.1.4 2-Stage Evaporative Cooling with Third Stage Integral DX Cooling (Indirect/Direct/DX)

6.1.4.1 Operation

If a hybrid indirect/direct unit cannot satisfactorily meet the design space temperature, a third stage DX cooling coil can be applied (Figure 24). These units allow the building cooling load to be met throughout the entire year, while still using less than 50 percent of the energy that a DX cooling unit alone would. During most of the year, the operation of a 3-stage IDEC-DX unit works exactly like an IDEC unit. Only during the hottest parts of the summer will the DX coil be needed to satisfy the loads. This will allow supply air temps as low as needed.

6.1.4.2 Psychrometrics

The psychrometrics of a 75 percent effective indirect evaporative cooler, a 90 percent effective direct evaporative cooler, and a DX section at the 99 percent summer design condition of 100 °F db and 65 °F wb, for El Paso, is plotted on the psychrometric chart shown in Figure 25.

6.1.4.3 Maintenance and Controls

The maintenance and control of an IDEC-DX system is the same as a DEC, IEC, and DX unit would be. The same procedures for each individual type of unit should be followed.

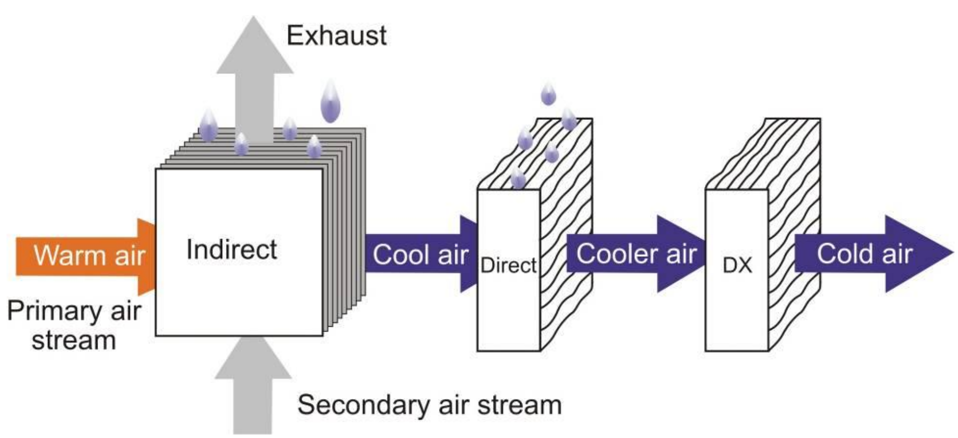

Figure 24. Diagram of a three-stage indirect/direct/DX cooler.

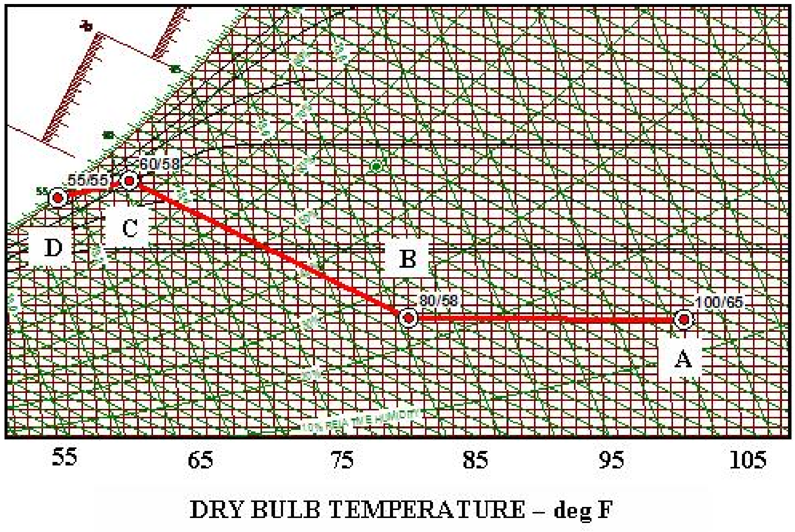

Figure 25. Psychrometrics of indirect/direct/DX cooling.

6.1.4.4 *Energy Use*

The energy used by the IDEC-DX unit would consume more than the IDEC unit alone. The DX section would consume the additional energy. This energy would be used by the compressor and the evaporator.

6.1.4.5 *Water Consumption*

The water evaporated by the IDEC-DX is the same as the IDEC unit alone.

6.1.4.6 *Parasitic Losses*

The parasitic losses for the IDEC-DX unit are the same as the IDEC unit alone.

6.1.5 Fort Bliss ANNEX 46 Survey Results

Evaporative cooling was analyzed at Fort Bliss during the week of 9 July 2007. Two SMEs with expertise in evaporative cooling, contracted by CERL, were dedicated to this task. The team surveyed 24 buildings for the application of evaporative cooling. Most buildings surveyed already use some form of evaporative cooling. Some more recent renovations show a trend of replacing older direct evaporative coolers with traditional DX cooling. Conversations with DPW confirmed this trend. The main reasoning given for this trend was quality of life (QoL). The determination has been made that the existing evaporative cooling systems do not satisfy the

QoL needs of the building occupants. One of the main benefits of a properly working evaporative cooling system is the effects that 100 percent outside air has on the occupants. Typical DX systems use 15 to 25 percent outside air. The rest of the air is re-circulated throughout the building when the air handling unit is operating. The effects of this practice have been termed “Sick Building Syndrome” by the U.S. Environmental Protection Agency (USEPA). The definition of Sick Building Syndrome, taken directly from the USEPA is:

> The term ‘sick building syndrome’ (SBS) is used to describe situations in which building occupants experience acute health and comfort effects that appear to be linked to time spent in a building, but no specific illness or cause can be identified. The complaints may be localized in a particular room or zone, or may be widespread throughout the building.*

In a building that is conditioned with evaporative cooling, 90 percent of the building air is exhausted outside. Therefore, most of the airborne contaminants are removed continually. These same contaminants would be re-circulated for the occupants to breathe and re-breathe in a traditional DX system.

Occupants of buildings that had evaporative cooling were surveyed. They complained about the systems not being able to provide enough comfort cooling. During the peak summer days, several occupants stated that they had to call in multiple service orders for the cooling systems. Some actually called in multiple orders throughout the same day for the same system. The HVAC maintenance contractor would come; fix a problem; leave, and then the system would stop working again. These QoL issues were not being met by the existing evaporative cooling systems, but it was not because of the type of system. It was because of the maintenance and condition of the existing systems. A vast majority of the evaporative cooling systems surveyed were in terrible condition. Most had rusted out housings, plugged evaporative media, in-operable sump pumps, improper intake filtering, disabled bleed-offs, bypassed bleed-offs, disabled controls, no controls, standing water in the housings, and no mist eliminators (to name a few). Some units were even modified mechanically from IDEC to DEC.

* USEPA. 09 August 2007 (last update). *Indoor Air Quality (IAQ)* (website), “Indoor Air Facts No. 4 (revised) Sick Building Syndrome,” accessible through URL: http://www.epa.gov/iaq/pubs/sbs.html

These units had the same problems listed above that the unconverted units had. By converting these units to DEC only, the original design conditions could never be met even if the systems were in proper working order.

The poor state of the existing evaporative cooling equipment, and its inability to provide comfort cooling, has led to systematic evaporative cooling replacement throughout the installation. The team recommends that some form of evaporative cooling be used to pre-cool the air on any future DX retrofits. The benefits of combining evaporative pre-cooling with DX cooling have been discussed in greater detail above. For some applications on the installation, it would be economical and energy conserving to correct the existing evaporative systems problems. These are discussed in detail below.

6.1.6 Buildings Surveyed

The CERL Evaporative Cooling Team surveyed the following buildings:

Bldg. 2	Bldg. 1026	Bldg. 2416	Bldg. 22912	Bldg. 2920
Bldg. 1001	Bldg. 1030	Bldg. 2418	Bldg. 2915	Bldg. 1034A\B
Bldg. 1003	Bldg. 1031	Bldg. 2497	Bldg. 2916	Bldg. 1033A\B
Bldg. 1007	Bldg. 2414	Bldg. 2910	Bldg. 2918	Bldg. 11108
Bldg. 1025	Bldg. 2415	Bldg. 2911	Bldg. 2919	

6.2 Evaporative Cooling ECMs

6.2.1 EC #1—Replace Small Existing Direct Evaporative Cooling Units with One Larger Unit

The buildings surveyed that had small direct evaporative coolers were:

Bldg. 11108	Bldg. 2415	Bldg. 2497	Bldg. 2915	Bldg. 2912
Bldg. 2910	Bldg. 2911	Bldg. 2916	Bldg. 2918	Bldg. 2919
Bldg. 2920				

6.2.1.1 Existing Conditions/Problems

The small DEC units found during the survey served a couple of shop areas and the rest served administration areas. Typically two DEC units served one building. All of these units were roof mounted and had no interior access to service the units. Most buildings had exhaust fans, some did not, and others had exhaust fans that were inoperable. Most of these exhaust fans were also roof mounted. The building occupants complained about the DEC units' inability to keep the buildings cool during the peak summer days. Most of the DEC units and the exhaust fans appeared to be undersized and poorly maintained.

6.2.1.2 Solutions

The survey team observed that similarly constructed buildings of approximately the same size and function are being renovated to include packaged DX rooftop-mounted cooling units—a very energy inefficient solution to the problem. Two options could be implemented that would save the installation energy while providing acceptable Quality of Life (QoL) and comfort cooling. One solution would be to replace the two smaller undersized DEC units with one larger DEC and replace the exhaust fan with a larger unit. This arrangement would allow for more air flow throughout the building, which would provide better comfort cooling. Another energy efficient solution would be to replace the two DEC units with one IDEC-DX. This would allow the air to be pre-cooled with the indirect and direct sections and then cooled down to whatever the required air temperature is needed to satisfy the building load. This would allow for a much smaller DX section and would therefore save energy.

6.2.1.3 Energy Savings

Since the trend on the installation is to replace all evaporative cooling units with DX cooling, savings have been calculated to reflect the difference between what is currently being installed and what the team is proposing. The savings for an example building have been calculated below. Assumptions used for savings calculations are:

- a large replacement DEC unit is 10,000 cfm with 90 percent effectiveness
- an IDEC-DX unit is sized for 10,000 cfm with 75 percent indirect effectiveness, and 90 percent direct effectiveness, using outside air as the secondary air stream.

The actual size of the replacement equipment would have to be determined by performing a load calculation for each building. Since this is beyond the scope of this project, 10,000 cfm was used in the example only. The weather bin data (listed in Table 8) was used for Fort Bliss, TX. The unit cost for electricity is $96/MWhr during peak rates (between 10:00 and 21:00 June through September). This is the majority of the time cooling would be needed.

Table 8. Temperature bin data, Fort Bliss, TX.

°F DB	°F WB	hrs/yr
102	70	30
97	65	159
92	63	404
87	62	570
82	60	720
77	58	896
72	56	967
67	52	844
62	48	778
57	44	731
52	41	672
47	38	614
42	35	502
37	31	396

$$Q_{MBTU\ Saved} = 1.08 * \Delta T * Evaporative\ Cooler\ Effectiveness * Volumetric\ Air\ Flowrate * Hours$$

$$Q_{MBTU\ Saved} = 1.08 * (T_{outside,DB} - T_{outside,WB}) * 90\% * 10{,}000\ cfm * Annual\ Run\ Hours\ at\ Each\ Temp\ Bin =$$

1,102 MMBTU/yr

$Q_{MBTU\ Saved} =$ 1,102.3 MMBTU for a 10,000 cfm DEC unit in Fort Bliss, TX over a traditional DX system

This equals $22,600 in energy cost savings, calculated by:

1,102.3 MMBTU * $0.096/kWh * 293 kWh/MMBTU = $31,005.

The savings for an IDEC-DX unit versus a DX-only unit are calculated as:

$$Q_{MBTU\ Saved\ IEC} = 1.08 * \Delta T * IEC\ Cooler\ Effectiveness * Volumetric\ Air\ Flowrate * Hours$$

$$Q_{MBTU\ Saved\ DEC} = 1.08 * \Delta T * DEC\ Cooler\ Effectiveness * Volumetric\ Air\ Flowrate * Hours$$

$$Q_{MBTU\ Saved\ Total} = Q_{MBTU\ Saved\ IEC} + Q_{MBTU\ Saved\ DEC}$$

where:

$$Q_{MBTU\ Saved\ IEC} = 1.08 * (T_{outside,DB} - T_{outside,WB}) * 75\% * 10{,}000\ cfm * Annual\ Run\ Hours\ at\ Each\ Temp\ Bin$$

$$Q_{MBTU\ Saved\ IEC} = 918.6 \text{ MMBTU for the 10,000 cfm IEC module}$$

$$Q_{MBTU\ Saved\ DEC} = 1.08 * (T_{IEC\ Discharge,DB} - T_{IEC\ Discharge,WB}) * 90\% * 10{,}000\ cfm * Annual\ Run\ Hours$$

= 592 MMBTU/yr

$$Q_{MBTU\ Saved\ DEC} = 591.9 \text{ MMBTU for the 10,000 cfm DEC module}$$

Therefore,

$Q_{MBTU\ Saved\ Total} = Q_{MBTU\ Saved\ IEC} + Q_{MBTU\ Saved\ DEC}$ = 918.6 MMBTU + 591.9 MMBTU = 1,510 MMBTU (for a 10,000 cfm IDEC-DX unit in Fort Bliss, TX, over a traditional DX system)

Savings = 1,510 MMBTU * $0.096 kW/h * 293 kWh/MMBTU = $42,473.

6.2.1.4 Investment

Evaporative cooling units can cost more than traditional cooling units. There are a few manufacturers that stock standard sized units, but most of the hybrid units are custom engineered products. The cost of a large 10,000 cfm DEC unit installed is approximately $25,000. The cost of a hybrid 10,000 cfm IDEC-DX unit is between $45,000 and $50,000.

6.2.1.5 Payback

The simple payback for a larger DEC unit is:

$25,000 /$31,005/yr = 0.8 yrs

The simple payback for a hybrid IDEC-DX unit is:

$50,000/$42,473 = 1.2 yrs.

Table 9. Savings summary for one large replacement DEC unit.

Bldg.	Estimated Investment Cost	Savings MWh	Savings $	Simple Payback (yrs)
11108	$62,500	807	$77472	0.8
2415	$12,500	161	$15,456	0.8
2497	$12,500	161	$15,456	0.8
2910	$12,500	161	$15,456	0.8
2911	$12,500	161	$15,456	0.8
2912	$12,500	161	$15,456	0.8
2915	$12,500	161	$15,456	0.8
2916	$12,500	161	$15,456	0.8
2918	$12,500	161	$15,456	0.8
2919	$12,500	161	$15,456	0.8
2920	$12,500	161	$15,456	0.8
Total	*$187500*	*2417*	*$232,032*	*0.8*

6.2.2 EC #2—Provide Indirect and Direct Evaporative Cooling (IDEC)—DX Units Instead of DX Only Units

The buildings surveyed that had large direct evaporative coolers were Bldg. 2, Bldg. 1001, Bldg. 1007, Bldg. 2416, and Bldg. 2419.

6.2.2.1 Existing Conditions/Problems

All of the units serving these buildings suffered from clogged media, improper controls, no controls, by-passed controls, broken sump pumps and drains, no mist eliminators, and undersized exhaust fans. The media was clogged to a point that the units were estimated to be operating at 20 to 30 percent of their design capacity. This has led to poor QoL and uncomfortable space conditions.

Table 9 lists the potential savings and payback for all buildings in this category based on the above analysis. These numbers are estimates only. Without performing actual load calculations for each individual building it is impossible to accurately determine how much cooling/heating is needed for each building listed.

6.2.2.2 *Solutions*

As has been stated throughout this report, evaporative cooling that is maintained and operated properly can provide QoL comfort cooling. Replacing the media in these units will improve the space conditions dramatically. Proper controls that allow media blow down and sump dumps will keep the new media from clogging as fast as it is now. This media, which is 4–6 in. deep, needs to be replaced every 5 to 7 yrs; performing these replacements will keep the units running efficiently. Mist eliminators will decrease the amount of water carry-over from the media into the air stream. This will help reduce the amount of humidity in the air that is delivered to the space.

It has been determined that these units will be replaced with traditional DX cooling by the staff at Fort Bliss. This team recommends providing IDEC-DX units instead of DX only units. Significant energy savings can be achieved by passing the maintenance schedules and requirements onto the installation maintenance contractor and requiring them to do these tasks.

6.2.2.3 *Energy Savings*

Many of the units serving these buildings were 35,000 cfm and 40,000 cfm. The same equations and methods used to calculate the energy savings can be applied to any sized unit to demonstrate the savings potential for units of this size.

The energy savings for a 35,000 cfm IDEC-DX unit versus a DX only unit are calculated by the same equations used in the example above. The total energy saved is 1,549MWHr (5,287 MMBTU) and the total cost savings would be $148,713. The total energy savings for a 40,000 cfm IDEC-DX unit versus a DX only unit is 1,770 MWh (6,042 MMBTU) and the total cost savings is $169,920.

6.2.2.4 *Investment*

The investment costs for a 35,000 cfm IDEC-DX unit is $210,000 installed; and for a 40,000 cfm unit is $240,000 installed.

6.2.2.5 Payback

The simple paybacks for these sized units are:

35,000 cfm → $210,000/$148,713 = 1.4 yrs

40,000 cfm → $240,000/$169,920 = 1.4 yrs

Table 10 lists the potential savings and payback for all buildings in this Category based on the above analysis. These numbers are estimates only. Without performing actual load calculation for each individual building, it is impossible to accurately determine how much cooling/heating is needed for each building listed.

6.2.3 EC #3—Replace Direct Evaporative Cooling Units

The buildings surveyed that had indirect/direct evaporative cooling units that were converted to direct evaporative cooling units were 1003, 2416, and 2418.

6.2.3.1 Existing Conditions/Problems

Several of the surveyed buildings had IDEC units that had been converted to DEC only. These units suffered the same type of problems seen in the other surveyed buildings, plugged media, improper controls, etc. In addition to these problems, the indirect section had been bypassed or removed entirely. Most of the units had an additional direct evaporative media installed where the heat exchanger used to be mounted. By removing the indirect heat exchanger, the units' ability to perform as it was designed is greatly reduced. The discharge air temperatures from a DEC only unit are much higher than they would be from an IDEC unit.

Table 10. Savings summary for three -stage hybrid IDEC-DX unit.

Bldg.	Estimated Investment Cost	Savings MWh	Savings $	Simple Payback (yrs)
2	$2,880,000	18,583	$1,783,968	1.6
1001	$630,000	4,646	$446,016	1.4
1007	$630,000	4,646	$446,016	1.4
2416	$270,000	1,742	$167,232	1.6
2419	$210,000	1,549	$148,704	1.4
Total	***$4620000***	***31,166***	***$2,991,936***	***1.5***

If the airflow remains constant, as in these cases it had, then the amount of cooling achievable from the units is decreased. In addition, some units had secondary air fans, which were no longer needed, running 24/7.

6.2.3.2 Solutions

The obvious solution is to convert these modified units back into their proper configuration. However, due to the interior and exterior condition of the units, the team recommends that they be replaced entirely. Most of the enclosures were rusted inside and out, to the point where they required replacement. Two of the units had trees growing directly above the intake sections of the units. These trees should be removed, or the units should be relocated. These units had extremely dirty intake filters and screens. There were also noticeable biological organisms growing in the sumps. This can lead to poor leaving air quality.

The units found were either 5,000 cfm or 21,000 cfm. There were similar age/function buildings around these buildings that had been converted to DX. The energy savings calculated below will demonstrate the savings potential if these buildings are converted from DX to IDEC.

6.2.3.3 Energy Savings

The energy savings for the 5,000 cfm and 21,000 cfm units is calculated in the same way as was done for the other examples above. The energy and cost savings are calculated to be:

5,000 cfm → 755 MMBTU and $21,237/yr

21,000 cfm → 3,200 MMBTU and $90,010/yr

6.2.3.4 Investment

The investment costs for a 5,000 cfm IDEC unit is $23,000 installed and for a 21,000 cfm unit, $118,000 installed.

6.2.3.5 Payback

The simple paybacks for these sized units are:

5,000 cfm → $23,000/$21,237 = 1.1 yrs

40,000 cfm → $118,000/$90,010 = 1.3 yrs

Table 11 lists the potential savings and payback for all buildings in this category based on the above analysis. These numbers are estimates only. Without performing actual load calculations for each individual building it is impossible to accurately determine how much cooling/heating is needed for each building listed.

Table 11. Savings summary for two -stage hybrid IDEC unit.

Bldg.	Estimated Investment Cost	Savings MWh	Savings $	Simple Payback (yrs)
1003	$354,000	2,786	$267,456	2.0
2416	$23,000	221	$21,216	1.6
2418	$23,000	221	$21,216	1.6
Total	*$400000*	*3,228*	*$309,888*	*1.3*

Table 12 lists the simple payback calculated for the Evaporative Cooling ECMs.

Table 12. Simple payback calculated for Evaporative Cooling ECMs.

ECM	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec. Demand, Thermal, and Maint. $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
EC #1	Replace small existing direct evaporative cooling units with one larger unit	8247	0	$232,032	0	0	0	232032	187,500	0.8
EC #2	Provide indirect and direct evaporative cooling (IDEC) - DX units Instead of DX only units	106338	0	$2,991,936	0	0	0	2991936	4,620,000	1.5
EC #3	Replace direct evaporative cooling units	11014	0	$309,888	0	0	0	309888	400,000	1.3
Totals		*125599*	*0*	*$3,533,856*	*0*	*0*	*0*	*3533856*	*5207500*	*1*

7 Electrical ECM

7.1 EL #1—Use Energy Efficient Electric Motors, Bldgs. 525, 1060, 4600

7.1.1 Existing Conditions

Electric motors are required to power a wide range of equipment and devices. The loads on the motors can vary or be relatively constant. When selecting a motor, it is best to match the process load to the proper motor size. A partially loaded motor operates at a lower efficiency than one fully loaded.

Motor efficiency ranges from 75 percent for a standard 1 hp, three-phase induction motor operating at full load to 90 percent for a standard 50 hp motor. In 1992, the Energy Policy Act was passed that required most motors manufactured after October 1997 to meet higher efficiency standards. The efficiency set for 1 and 50 hp motors are 82.5 percent and 93 percent, respectively. Later, premium efficiency motors became available at extra cost with efficiencies that range from 85.5 to 94.13 percent for the same size motors. Single phase motors are normally 5 to 10 percent lower in efficiency. Another benefit of the higher efficiency motors is they run cooler and should provide a longer service life.

Electric motors have a limited life. When they become inoperable, they can typically be repaired by rewinding. A downside to this repair is a loss in efficiency. It is often more economical to replace a burnt out motor with a new premium motor than to rewind it. The cost difference between operating the two motors will easily pay for the extra cost of the new one. Table 13 lists simple payback calculated for this electrical ECM.

7.1.2 Solution

Electric motors found at Fort Bliss were not of the premium efficiency type. Pumps and air compressors were powered by low efficiency 20 and 25 hp motors. It is recommended to replace these motors with premium efficiency motors when they fail and need replacement. Tables 13 and 14 list the annual savings and the cost of the premium motors compared to the use of standard efficiency motors. An analysis of the data shown in Tables 13 and 14 assumes that the motors operate continuously and are fully loaded. The cost used in the simple payback calculation is half the premium cost, which approximates the cost of a new motor compared to rewinding a failed motor.

If this motor replacement program is not implemented, energy will continue to be wasted since the present system uses inefficient equipment.

7.1.3 Savings

Tables 13 and 14 list the estimated savings of operating premium efficiency motors instead of less efficient ones based on continuous operation.

Table 13. Comparison of premium efficiency with standard motors.

Motor Size	Existing Efficiency (%)	Proposed Efficiency (%)	Energy Saved (kWh/yr)	Energy Cost Savings ($/yr)	Total Cost Premium ($)	Additional Cost of New Motor vs. Rewinding	Simple Payback (yrs)
25	89%	93.6%	7,515	$526	$975	$488	0.9
20	88%	93.6	7319	$512	$850	$425	0.9
10	86%	91.7%	3,725	$260	$520	$260	1.0
5	85%	89.5%	1,470	$103	$295	$144	1.4
3	82%	89.5%	1,470	$103	$230	$115	1.1
1	76%	85.5%	621	$44	$185	$93	2.1

Table 14. Comparison of premium efficiency with post-1997 motors.

Motor Size	Existing Efficiency (%)	Proposed Efficiency (%)	Energy Saved (kWh/yr)	Energy Cost Savings ($/yr)	Total Cost Premium ($)	Additional Cost of New Motor vs. Rewinding	Simple Payback (yrs)
25	91.7%	93.6%	3,104	$217	$975	$488	2.2
20	91.0%	93.6%	3,398	$238	$850	$425	1.8
10	89.5%	91.7%	1,438	$101	$520	$260	2.6
5	87.5%	89.5%	653	$46	$295	$144	3.2
3	86.5%	89.7%	588	$41	$230	$115	2.8
1	82.5%	85.5%	196	$14	$185	$93	6.6

7.1.4 Investments

Tables 13 and 14 list the cost of new premium efficiency motors. Simple payback calculations assume that the cost of rewinding an old motor is half the cost of a new premium efficiency motor.

7.1.5 Payback

Tables 13 and 14 also list the simple payback of installing new premium efficiency motors. The resulting payback period ranges from 0.9 to 6.6 yrs.

8 Heating, Ventilating, and Air Conditioning ECMs

8.1 HVAC #1—Schedule Air Handling Units To Match Building Usage

8.1.1 Existing Conditions/Problems

Many AHUs are scheduled to operate 24/7 (or nearly that much). This is not necessary since admin spaces, motor pools, and other mission-related buildings at Fort Bliss are not normally used more than 8–12 hrs/day, 5 days/wk. Some secure areas may run for longer periods, but in most cases, not continuously. Running an AHU for more hours than necessary means that energy is wasted for heating, for cooling, and for running fan motors, even though some AHUs have variable frequency drives (VFDs).

8.1.2 Solution

Use one of the existing energy management systems (EMS) (Trane Tracer Summit, Williams Electronics or Web Controls), to adjust the operating time for every single AHU to match the hours that people actually occupy the building or portion of the building. For AHUs, which cannot feasibly be interfaced to an EMS, install programmable timers with weekly schedules. There is an ongoing project to replace the existing EMSs and also to increase the number of buildings that can be controlled with a new system. Until this system is operational the excessive energy costs for unnecessarily running AHUs will continue.

8.1.3 Savings

Reducing the running hours for an air handling unit with normal functions (i.e., everything works as it is intended to after fixing malfunctioning equipment) see ECM COM #1 paragraph 4.1.2, p 34), from 168 hrs/wk (24/7) to 60 hrs/wk (12/5), with 20,000 cfm, 30 percent outdoor air in both winter and summer for economizing reasons, and with a 10 hp supply air fan and 8 hp return air fan, the savings can be calculated:

Heating savings, Fort Bliss climate (2761 heating degree days °F = 1534 degree days °C): 124 MWh/yr (423 MMBtus), $5,500/yr with 70% boiler plus heat distribution system efficiency (604 MMBtus gross) (30% OA = 6,000 cfm = 2.8 m^3/s. Heating : 2.8 m^3/s * 1.2 kJ/kg, °C * 1534 degree days * 24 hrs = 123,700 kWh)

Cooling savings, Fort Bliss climate (2109 cooling degree days °F = 1172 degree days °C): 31 MWh electricity/yr, $2,050/yr (COP = 3.0). (Cooling: 2.8 m^3/s * 1.2 kJ/kg, °C * 1172 degree days* 24 hrs/3.0 (=COP) = 31,500 kWh)

Motor savings: (10 + 8 hp) * 0.746 * (168 – 60 hrs) * 52 wks = 75 MWh/yr, $4,875/yr

Total savings then equal $12,400/yr

Since most of the AHUs are on 24/7 operation at present it is not overestimating to believe that AHUs totaling at least 200,000 cfm are possible to schedule to 12/5, indicating total savings of $124,000/yr.

Additional savings will be achieved in the form of lower water bills in buildings where evaporative coolers are used. Also, the maintenance costs in all buildings can be significantly reduced due to reduced operational hours per year.

8.1.4 Investment

Investment costs should normally be included in the UMCS operator daily routines, if EMS are operable, unless new programmable timers are needed.

8.1.5 Payback

Payback will occur immediately.

8.2 HVAC #2—Install Solar Heating for Domestic Hot Water at Selected Buildings

8.2.1 Existing Conditions/Problems

The sun shines almost all year around in El Paso. In a warehouse at Fort Bliss there are close to 200 solar panels in good shape that were collected from the hospital when it was renovated a couple of years ago. Meanwhile, some very good candidates for solar heating were found (buildings that use large amounts of hot water that today is heated by gas boilers or in some cases during the summer also by electric heaters). The following buildings are good candidates for solar heating of domestic hot water: Bldgs. 2457 and 906 (dining facilities that serve breakfast, lunch and dinner), Bldg. 2499 (fitness center) and Bldg. 5035 (indoor swimming pool).

8.2.2 Solution

Hire a designer to do the following:

- examine existing domestic hot water heating system, boilers, pipes, and controls
- design new piping to connect to solar panels
- design new controls to make solar panels and boilers for backup (cloudy days) work together, with first priority on solar heating
- calculate necessary quantities of the existing solar panels to be installed for the buildings, respectively.

Hire a contractor to do the installation, including commissioning and verification of results.

8.2.3 Savings

At this level of assessment, access to water consumption data per building was unavailable. Therefore, it is not possible to predict annual savings.

8.2.4 Investment

Since Fort Bliss already possesses the solar panels the investment ought to be quite moderate. An estimate of the above described work, including material (doing all four buildings at the same time with the same contractor) and labor is that the costs should be in the range of 50 cents/sq ft of building area. This transforms to the following costs:

- Bldg. 906: $12,000
- Bldg. 2457: $12,000
- Bldg. 2499: $10,000
- Bldg. 5035: $14,000.

8.2.5 Payback

With the El Paso climate and annual sun hours (normally 1000 W/m^2 of solar panel from the sun), and with existing solar panels, the payback time is estimated to be less than 2 yrs for the proposed solution.

8.3 HVAC #3—Replace Warm Air Heating System In Vehicle Maintenance Areas with Radiant Heating, Bldg. 2588

8.3.1 Existing Conditions

In some vehicle maintenance shops, warm air unit heaters are used to provide winter time building heating. These heaters contribute to temperature stratification in these spaces, which causes some energy waste. Also, when large truck doors open it takes some time for the building temperature to return to normal.

8.3.2 Solution

Radiant heaters placed above work areas can replace the warm air heaters. These heaters heat the floor, which in turn warms the people in those areas. Very little air stratification takes place and the infiltration of outside air has less cooling effect to the workspace. The gas-fired radiant heaters would be hung from the upper framing of the building and would be controlled by area thermostats much like other heaters. A natural gas distribution piping system will be needed to supply energy to the heaters.

8.3.3 Savings

It is estimated that radiant heating will save 20 percent of the energy used by a warm air heating system. Using a maintenance area of approximately 42,000 sq ft, the estimated annual heating energy use is 5,000 million Btu. The use of radiant heaters will save approximately 20 percent of this energy or 1,000 million Btu, which would be worth $9,084/yr.

8.3.4 Investments

Using heaters that can provide 100,000 Btuh each, approximately 40 will be required to heat this building area. The estimated cost to install a 100,000 Btuh radiant gas-fired heater is $3,000 each. Thus the total installed cost is $120,000.

8.3.5 Payback

The resulting simple payback is 13.2 yrs.

8.4 HVAC #4—Install Radiant Cooling in Barracks Areas

8.4.1 Existing Conditions

There are several barracks (Bldgs. 1001, 1002, 1005, 1006, 1009 – 1014 and 2419) that need to be renovated to provide 1 + 1 soldier housing. Part of the renovation is the installation of a new HVAC system. Three types of air-conditioning systems have been used for this application:

1. Fan coil units installed in each room
2. Heat pump units with one for each room
3. Central air-conditioning system with air ducted to each room. These systems perform fairly well, but have difficulty controlling humidity.

The best way to control humidity in barracks buildings is to install a dedicated outdoor air supply (DOAS) unit that delivers dry air to all building spaces. This dry air will have a dew point of 45 °F or less, which will be low enough to absorb moisture generated in the rooms created by showers, cooking, etc. Since the DOAS unit controls the space's humidity and ventilation requirements, only temperature control remains to be satisfied.

Barracks Bldg. 1002 has been chosen as representative of this building group. This building has an area of 47,649 sq ft, which is assumed to be the average of the 11 buildings in the group.

8.4.2 Solution

Radiant cooling systems (Figure 26) have been successfully used in Europe. This type of system cools the ceiling above the occupied spaces. The cool ceiling in turn cools the occupants mainly by the transfer of radiant energy. An advantage of this type of system is a warmer chilled water can be used (approximately 61 °F. The system has a low energy use since required fan horsepower is reduced. The space needed by the system is small since the cooling panels are part of the ceiling. Fort Bliss is felt ideal for this type of application since outdoor conditions are always quite dry thus there is little concern with condensation on the cooling panels.

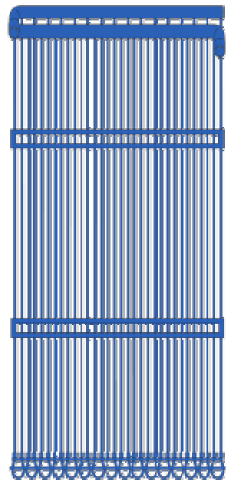

Figure 26. Radiant cooling panel.

The radiant cooling system consists of cooling panels made of a series of small tubes through which the chilled water flows. These panels can be attached to the surface of the ceiling and then buried in a thin plaster layer for protection and appearance. The radiant cooling panels can also be placed behind a gypsum board. The cooling potential with a plaster ceiling is approximately 25 Btuh/sq ft using a 61 °F entering water temperature. If the radiant panel is placed behind a heavier gypsum board, the cooling potential drops to approximately 21 Btuh/sq ft. At the rate of cooling required for a barracks room, the entire ceiling would need to be covered with cooling panels.

If this system is not provided, energy will be wasted since Fort Bliss does not have the most efficient available cooling systems. Also, an opportunity to demonstrate the benefits of this system will be lost.

8.4.3 Savings

This system will save approximately 40 percent of the cooling energy required by the barracks building. This amounts to 40 tons at peak conditions and would result in a electrical saving of approximately 100,000 kWh/yr. The annual electrical cost saving is $6,500. The radiant cooling system is very simple and will save maintenance costs when compared to a fan coil system. The estimated maintenance cost savings is $5,000/yr. The estimated savings for the 11 building group is $71,500 for energy and $55,000 for maintenance.

8.4.4 Investments

The estimated sensible cooling load that the cooling panel would handle is 6,000 Btuh or 0.5 tons of cooling. Using a cost of $18 per sq ft, the estimated cost for the ceiling panel in a soldier's room is $4,500. A comparable fan coil unit would cost approximately $5,000. The central cooling system with the radiant cooling would be a little smaller saving $25,000 for a barracks building being renovated. The net result is the radiant cooling system would be slightly less costly, $40,000 to $70,000/building or $440,000 to $770,000 for the 11 building group.

8.4.5 Payback

The estimated payback period is immediate since the radiant cooling system appears to be less costly.

It is recommended that a detailed design of a radiant cooling system be performed so that the actual costs of installation can be determined and a better estimate of cost saving can be developed. Also, to achieve the desired cooling all the ceiling space is required so the required radiant cooling panel size needs to be confirmed. It is suggested that the barrack's building shell be greatly improved with new windows, reduced window area, shading, and improved wall insulation. The new cooling and heating loads should take this into account.

8.5 HVAC #5—Replace Existing Chillers with High Efficiency Chillers

8.5.1 Existing Conditions/Problems

Existing cooling technologies at Fort Bliss are not as efficient as they could be. Water-cooled chillers are more efficient than air-cooled chillers, and if providing a large amount of cooling for extended periods of time, more efficient chillers can provide significant savings.

8.5.2 Solution

Replace large, air-cooled chillers with water-cooled reciprocating chillers and cooling towers (Table 15). These are based on building groupings resulting from a FEDS model of Fort Bliss. Appendix A to this report lists the buildings corresponding to "Building Designation."

Table 15. HVAC #5—Replace chillers with high-efficiency chillers.

ECM	Current Technology	Retrofit Technology	Current COP/ Eff. Value	Retrofit COP/ Eff. Value	Investment $	Savings $/yr	Simple Payback yrs
HV_5A	Electric water-cooled recip-rocating chiller {C1}	Water-cooled centrifugal electric chiller (ultra high efficiency)	3.3859	5.2378	$378,876	$27,645	13.7
HV_5B	Electric air-cooled chiller {C1}	Water-cooled reciprocating electric chiller (high efficiency) and cooling tower	2.33	3.5195	$439,865	$34,758	12.7
HV_5C	Electric air-cooled chiller {C1}	Water-cooled reciprocating electric chiller (very high efficiency) and cooling tower	2.3396	3.6734	$351,479	$30,863	11.4

8.5.3 Energy Savings

According to FEDS calculations, replacing older cooling systems with new more efficient systems would save 2,431 MMBtu/yr, for a savings of $88K/yr.

8.5.4 Additional Benefits

Maintenance savings for replacing the above systems is $4.8K/yr.

8.5.5 Investment

The new systems and their installation costs $1,170K.

8.5.6 Payback

The simple payback is 12.5 yrs.

8.6 HVAC #6—Replace Existing Boilers with High Efficiency Boilers

8.6.1 Existing Conditions/Problems

Some boilers on site are old and inefficient, with efficiencies ranging from 60 to 75 percent. Figure 27 shows the existing boiler in Bldg. 622.

8.6.2 Solution

Replace older boilers with new natural gas boilers, with efficiencies ranging from 80 to 84 percent (see Table 16). These are based on building groupings resulting from a FEDS model of Fort Bliss.

Appendix A to this report lists the buildings corresponding to “Building Designation.”

Figure 27. Boiler in Bldg. 622.

Energy Savings

According to FEDS calculations, replacing existing boilers with new more efficient gas boilers would save 4,591 MMBtu/yr, for a savings of $41.3K/yr.

8.6.3 Additional Benefits

Maintenance cost savings will be $4.2K/yr with new boilers.

Table 16. HVAC #6—Replace existing boilers with high efficiency boilers.

ECM	Current Technology	Retrofit Technology	Current COP/ Eff. Value	Retrofit COP/ Eff. Value	Investment $	Savings $/yr	Simple Payback yrs
HV_6A	Natural gas conventional boiler {H1}	Conventional gas boiler - 80% combustion efficiency	0.721	0.78	$12,217	$817	15.0
HV_6B	Natural gas conventional boiler {H1}	Conventional gas boiler - 80% combustion efficiency	0.7795	0.78	$36,456	$3,765	9.7
HV_6C	Natural gas conventional boiler {H1}	Conventional gas boiler - 84% combustion efficiency	0.5964	0.82	$122,501	$20,738	5.9

ECM	Current Technology	Retrofit Technology	Current COP/ Eff. Value	Retrofit COP/ Eff. Value	Investment $	Savings $/yr	Simple Payback yrs
HV_6D	Natural gas conventional boiler {H1}	Conventional gas boiler - 84% combustion efficiency	0.6356	0.82	$96,607	$20,638	4.7

8.6.4 Investment

The new systems and their installation costs $268K.

8.6.5 Payback

The simple payback is 5.9 yrs.

8.7 HVAC #7—Replace Existing Heating and Cooling Systems with Air Source Heat Pumps

8.7.1 Existing Conditions/Problems

Older, less efficient heating and cooling systems use energy unnecessarily to keep a building comfortable. These include gas boilers, oil boilers, electric furnaces, and central steam systems.

8.7.2 Solution

Replace existing heating and cooling systems with new, efficient air source heat pumps. The heat pumps have a COP of 3.2 on the heating side, and 2.96 on the cooling side (see Table 17). These are based on building groupings resulting from a FEDS model of Fort Bliss. Appendix A to this report lists the buildings corresponding to “Building Designation.”

Table 17. HVAC #7—Replace existing heating/cooling with air-source heat pump.

ECM	Current Technology	Retrofit Technology	Current COP/ Eff. Value	Retrofit COP/ Eff. Value	Investment $	Savings $/yr	Simple Payback yrs
HV_7A	Natural gas conventional boiler {H1}	High efficiency electric air source heat pump (commercial)	0.7657	3.2	$200,406	$43,664	4.6
HV_7B	Electric air-cooled chiller {C1}	High efficiency electric air source heat pump (commercial)	2.33	2.96	Same	Same	Same

8.7.3 Energy Savings

According to FEDS calculations, replacing existing heating and cooling systems with air source heat pumps would yield an energy savings of 855 MMBtu/yr, or $8.3K/yr in savings.

8.7.4 Additional Benefits

The maintenance savings for this ECM are due to the number of pieces of equipment needing maintenance being cut in half. This ECM saves $35.3K/yr.

8.7.5 Investment

The heat pumps cost $200K with installation.

8.7.6 Payback

The simple payback is 4.6 yrs.

8.8 HVAC #8—Replace Existing Water Heaters with High Efficiency Water Heaters

8.8.1 Existing Conditions/Problems

Many gas water heaters that provide domestic hot water to various facilities at Fort Bliss are old and inefficient. Figure 28, for example, shows uninsulated hot water piping in Bldg. 5041. In many cases, the equipment is not efficient in heating water for a large building.

Figure 28. Uninsulated hot water piping, Bldg. 5041.

8.8.2 Solution

Replace existing water heaters with more efficient gas boilers. Wrap the tank with R-11 insulation, and make sure faucet aerators and low-flow showerheads are installed in the restrooms. Installing low-flow shower-heads reduce flow rate from 4.8 to 2.0 gal/minute. Table 18 lists the before and after conditions, based on building groupings resulting from a FEDS model of Fort Bliss.

Appendix A to this report lists the buildings corresponding to "Building Designation."

Table 18. HVAC #8—Replace existing water heaters with high efficiency heaters.

ECM	Current Technology	Retrofit Technology	Current R-Value	Retrofit R-Value	Investment $	Savings $/yr	Simple Payback yrs
HV_8A	Natural gas central boiler	Condensing gas boiler - 91% combustion efficiency, wrap tank, aerators	0.721	0.89	$10,732	$4,201	2.6
HV_8B	Natural gas central boiler	Conventional gas boiler - 84% combustion efficiency, wrap tank, aerators	0.721	0.82	$3,433	$1,677	2.0
HV_8C	Natural gas central boiler	Conventional gas boiler - 84% combustion efficiency, wrap tank, aerators	0.721	0.82	$20,714	$10,089	2.1
HV_8D	Natural gas central boiler	Conventional gas boiler - 84% combustion efficiency, wrap tank, LFSHs	0.721	0.82	$21,104	$12,168	1.7
HV_8E	Natural gas central boiler	Conventional gas boiler - 84% combustion efficiency, wrap tank, LFSHs, aerators	0.721	0.82	$48,922	$8,472	5.8
HV_8F	Natural gas central boiler	Conventional gas boiler - 84% combustion efficiency, wrap tank, LFSHs, aerators	0.721	0.82	$32,312	$5,574	5.8
HV_8G	Natural Gas Central Boiler	Conventional Gas Boiler - 84% Combustion Efficiency, Wrap Tank, LFSHs, Aerators	0.721	0.82	$34,076	$5,751	5.9
HV_8H	Natural Gas Central Boiler	Conventional Gas Boiler - 84% Combustion Efficiency, Wrap Tank, LFSHs, Aerators	0.721	0.82	$66,176	$11,296	5.9
HV_8I	Natural Gas Central Boiler	Conventional Gas Boiler - 84% Combustion Efficiency, Wrap Tank, LFSHs, Aerators	0.721	0.82	$46,295	$23,221	2.0

8.8.3 Energy Savings

According to FEDS calculations, replacing these water heaters, insulating the tanks, and installing low-flow fixtures would result in energy savings of 9,165 MMBtu/yr, for a cost savings of $83.2K/yr.

8.8.4 Additional Benefits

Maintenance cost would increase $805/yr if this ECM were implemented.

8.8.5 Investment

This ECM would cost $284K.

8.8.6 Payback

With a total savings of $82K/yr, the simple payback is 3.4 yrs.

8.9 HVAC #9—Insulate Water Heater Tank, Insulate Pipes near Tank, Lower Tank Temperature, Install Low-Flow Showerheads, Install Faucet Aerators

8.9.1 Existing Conditions/Problems

Almost every building could use some improvement on its potable water system. Many buildings were built before the current legislation came into effect limiting maximum flow rates on end uses. Heat from potable hot water is wasted through poorly insulated or uninsulated tanks, excess flow from faucets (2.5–3 gpm) and showerheads (3–5 gpm), and unnecessarily high hot water temperature setpoints (140 °F).

8.9.2 Solution

Simple, low-cost improvements include insulating the hot water tank to R-11, installing faucet aerators to ensure a 2.0 gpm flow rate, installing low-flow showerheads for a 2.0 gpm flow rate, and turning down the tank temperature. (Water above 120 °F is too hot for human contact and can burn.) These measures should be taken in all buildings where not already implemented. Table 19 lists the before and after results, based on building groupings resulting from a FEDS model of Fort Bliss.

Appendix A to this report lists the buildings corresponding to "Building Designation."

Table 19. HVAC #9—Insulate water heater tank, insulate pipes near tank, lower tank temperature, install low-flow showerheads, install faucet aerators.

ECM	Current Technology	Retrofit Technology	Current R-Value	Retrofit R-Value	Investment $	Savings $/yr	Simple Payback yrs
HV_9A	Natural gas water heater	Wrap tank with insulation	0.76	0.76	$1,030	$299	3.4
HV_9B	Natural gas water heater	Wrap tank with insulation	0.76	0.76	$3,766	$1,091	3.5
HV_9C	Natural gas central boiler	Wrap tank with insulation	0.7838	0.7838	$5,949	$47,257	0.1

ECM	Current Technology	Retrofit Technology	Current R-Value	Retrofit R-Value	Investment $	Savings $/yr	Simple Payback yrs
HV_9D	Natural gas water heater	Wrap tank with insulation	0.76	0.76	$426	$124	3.4
HV_9E	Natural gas water heater	Wrap tank with insulation	0.76	0.76	$4,406	$1,276	3.5
HV_9F	Natural gas water heater	Wrap tank with insulation	0.76	0.76	$124	$36	3.4
HV_9G	Natural gas water heater	Wrap tank with insulation	0.76	0.76	$107	$31	3.5
HV_9H	Natural gas central boiler	Wrap tank with insulation	0.7795	0.7795	$310	$3,663	0.1
HV_9I	Natural gas water heater	Wrap tank with insulation	0.76	0.76	$1,918	$556	3.4
HV_9J	Natural gas water heater	Wrap tank with insulation	0.76	0.76	$568	$165	3.4
HV_9K	Natural gas central boiler	Wrap tank with insulation, aerators	0.721	0.721	$1,218	$8,399	0.1
HV_9L	Natural gas central boiler	Wrap tank with insulation, aerators	0.721	0.721	$6,652	$63,693	0.1
HV_9M	Natural gas water heater	Wrap tank with insulation, aerators, lower tank temperature	0.76	0.76	$284	$107	2.7
HV_9N	Natural gas water heater	Wrap tank with insulation, aerators, lower tank temperature	0.76	0.76	$536	$275	1.9
HV_9O	Natural gas water heater	Wrap tank with insulation, aerators, lower tank temperature	0.76	0.76	$167	$92	1.8
HV_9P	Natural gas water heater	Wrap tank with insulation, aerators, lower tank temperature	0.76	0.76	$364	$139	2.6
HV_9Q	Natural gas water heater	Wrap tank with insulation, aerators, lower tank temperature	0.76	0.76	$460	$201	2.3
HV_9R	Natural gas water heater	Wrap tank with insulation, aerators, lower tank temperature	0.76	0.76	$853	$343	2.5
HV_9S	Natural gas water heater	Wrap tank with insulation, aerators, lower tank temperature	0.76	0.76	$481	$174	2.8
HV_9T	Natural gas water heater	Wrap tank with insulation, aerators, lower tank temperature	0.76	0.76	$197	$111	1.8
HV_9U	Natural gas water heater	Wrap tank with insulation, aerators, lower tank temperature	0.76	0.76	$2,876	$1,348	2.1
HV_9V	Central steam heat ex-changer	Wrap tank with insulation, LFSHs	1	1	$3,859	$29,827	0.1
HV_9W	Natural gas central boiler	Wrap tank with insulation, LFSHs	0.7704	0.7704	$933	$8,256	0.1
HV_9X	Natural gas central boiler	Wrap tank with insulation, LFSHs, aerators	0.7393	0.7393	$524	$2,396	0.2
HV_9Y	Natural gas water heater	Wrap tank with insulation, LFSHs, aerators	0.76	0.76	$2,426	$884	2.7
HV_9Z	Natural gas water heater	wrap tank with insulation, LFSHs, lower tank temperature	0.76	0.76	$3,525	$1,252	2.8

8.9.3 Energy Savings

According to FEDS calculations, these miscellaneous domestic hot water retrofits would save 20,928 MMBtu/yr, which equates to a cost savings of approximately $199K/yr.

8.9.4 Additional Benefits

No maintenance savings are involved here, but reducing hot water temperatures to 120 °F eliminates the risk of burns from a faucet.

8.9.5 Investment

These measures would cost $53,319.

8.9.6 Payback

The simple payback is 0.3 yrs (Table 20).

Table 20. Simple payback calculated for HVAC ECMs.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
HVAC #1	Schedule air handling units to match building usage	1,065,000	0	$69,225	6040	$55,000	$–	$124,225	$–	0.0
HVAC #2	Install solar heating for domestic hot water at selected buildings	0	0	$–	0	$–	$–	$–	$–	0.0
HVAC #3	Replace warm air heating system in vehicle maintenance areas with radiant	0	0	$–	1000	$9,084	$–	$9,084	$120,000	13.2
HVAC #4*	Install radiant cooling in barracks areas	1,100,000	0	$71,500	0	$–	$55,000	$126,500	–$605,000	0.0
HVAC #5*	Replace existing chillers with high–efficiency chillers	712,456	–460	$88,462	0	$–	$4,804	$93,266	$1,170,220	12.5
HVAC #6*	Replace existing boilers with high–efficiency boilers	0	0	$–	4591	$41,708	$4,250	$45,958	$267,781	5.8
HVAC #7*	Replace existing heating and cooling systems with air source heat pumps	–31,359	–14	–$1,346	962	$8,740	$35,322	$42,716	$200,406	4.7
HVAC #8*	Condensing gas boiler – 91% combustion efficiency, wrap tank, aerators	0	0	$–	9165	$83,254	–$805	$82,449	$283,764	3.4
HVAC #9*	Replace existing water heaters with high efficiency heaters	0	0	$–	20528	$198,673	$–	$198,673	$53,319	0.3
Totals		*2,846,097*	*–474*	*$227,841*	*42286*	*$396,459*	*$98,571*	*$722,871*	*$1,490,490*	*2.1*
*Note that the HVAC group includes HVAC #4 which takes a $605,000 avoided cost credit.										

9 Lighting ECMs

9.1 LI #1—Provide Daylighting in Medical Warehouse (Bldg. 11156) and in Parts of Bldg. 2592

9.1.1 Existing Conditions/Problems

9.1.2 Medical Warehouse

At Fort Bliss, some buildings have few or no windows to let daylight in. Consequently, electric energy for lighting is a major operating cost of these buildings. Examples of such buildings are the medical warehouse (Bldg. 11156) and the warehouse portion of Bldg. 2592. The northern wing of Bldg. 2592 (Vehicle Maintenance) has windows placed up high close to the ceiling, without sufficient area to allow artificial lighting to be switched off during the day.

9.1.3 Solution

Install daylighting fixtures that direct the daylight into the buildings (this type of fixture is sometimes referred to as “solar tubes”) so that the existing, energy-consuming lights can be switched off when daylight is sufficient. This should be the case in most of the hours that these buildings are in use.

9.1.4 Savings

The solar tubes are intended to be installed in portions of Bldg. 2592 (warehouse, approximately 11,000 sq ft) and in the entire Bldg. 11156 (Medical warehouse, approximately 45,000 sq ft) except the office section at the center of the building.

These calculations presume that lights are switched off when people do not occupy the buildings. If not, the actual savings will be even higher.

Bldg. 2592 savings: 8 kW * 8 hrs/day * 260 days/yr = 16,640 kWh/yr.

At 6.5 cents/kWh the savings are worth $1,100/yr.

Avoided costs for maintenance, light bulb changes, etc. estimated at $750/yr, which gives total savings of $1,850/yr.

Bldg. 11156 savings: 26 kW * 8 hrs/day * 260 days/yr = 54,000 kWh/yr.

At 6.5 cents/kWh the savings are worth $3,500/yr.

Avoided costs for maintenance, light bulb change, etc. estimated to $2,500/yr, which gives total savings of $6,000/yr.

Some additional benefits are improved lighting standards. Figures 29 and 30 show that some parts are currently very dark even with artificial lighting.

Figure 29. Interior of Medical Warehouse (Bldg. 11156) is very dark, even with artificial lighting.

Figure 30. Interior of portions of Bldg. 2592 are very dark, even with artificial lighting.

9.1.5 Investment

The investment for Bldg. 2592 would amount to $34K for installation of 16 SunTracker One units.

The investment for Bldg. 11156 would amount to $139K for installation of 66 SunTracker One units.

Additional investment costs were based on information provided by Fernando Espinosa at ATEE* Corp. regarding “Applied Energy Efficiency.” More information is available on their website through URL:

http://www.natures-lighting.com/products.php?pid=2100

Perhaps less expensive solar tube units can be found. The investment costs quoted here are very preliminary since the information provider had no opportunity to study the buildings in question.

9.1.6 Payback

For Bldg. 2592, payback will occur in 16 yrs.

For Bldg. 11156, payback will occur in 21 yrs.

* ATEE Corporation, 7362 Remcon Circle El Paso, Texas 79912, tel. (915) 996-9432.

9.2 LI #2—Install Daylight Sensors (Photocells) To Control Artificial Lighting in Vehicle Maintenance Areas

9.2.1 Existing Conditions/Problems

Some buildings at Fort Bliss have large areas of windows to let daylight in. In other cases large doors are open. Despite this fact, and the fact that there is no visible difference in lighting levels when the electric lights are switched off during daytime, the electric lights are left on. Examples of such buildings are mainly the vehicle maintenance shops: Bldgs. 2592, 2588, 2643, 2462, 2466, 2484, 2624, 2629, and 2488. This makes electric energy for lighting a major operating cost in these buildings. Figure 31 shows one such building with electric lighting in use during periods when daylighting is available.

9.2.2 Solution

Install daylight sensors (photocells) that automatically switch light off when daylight is sufficient. This should be the case in most of the hours that these buildings are occupied.

9.2.3 Savings

In Bldg. 2643, for example, approximately 30 high pressure sodium lamps illuminated at 300 W each (a total of 9 kW) were found. Running these lights unnecessarily for 8 hrs/day, 5 days/wk, 52 wks/yr consumes 18,700 kWh worth $1,200/yr. Multiplying that saving with 10 similar buildings gives $12K worth of savings/yr (187 MWh/yr). The Fort Bliss peak load can also be reduced by 90 kW for 10 such buildings.

9.2.4 Investment

The investment for this ECM would amount to $2K/building or $20K in total.

9.2.5 Payback

Payback will occur in 1.7 yrs.

Figure 31. Electric lights in use when natural daylighting is available.

9.3 LI #3—Replace Incandescent Lights with Compact Fluorescent Lights

9.3.1 Existing Conditions/Problems

Incandescent lights are extremely inefficient; they produce very few lumens per watt consumed. In addition, they get very hot and produce excess heat in the building, burn out quickly, and need to be replaced often. While some have been replaced at Fort Bliss, a number of incandescent are still in use in various installation buildings. Some are used for exterior lighting, while others are used for interior lighting in administration, lodging, and service/morale, welfare, and recreation (MWR) facilities.

9.3.2 Solution

Replace all remaining incandescent lights with compact fluorescent lights (CFLs). CFLs use 65 to 80 percent less energy than incandescents with the same light output. They also last 7-10 times longer, reducing the need for maintenance hours and replacement bulbs. They are designed similarly to incandescents, allowing an easy switch of bulbs, rather than a complicated retrofit. Table 21 lists the before and after results, based on building groupings resulting from a FEDS model of Fort Bliss.

Appendix A to this report lists the buildings corresponding to “Building Designation.”

Table 21. LI #3—Replace incandescent lights with compact fluorescent lights.

ECM	Current Technology	Retrofit Technology	Current Wattage	Retrofit Wattage	Investment $	Savings $/yr	Simple Payback (yrs)
LI_3A	IN8: INC 75 CEIL	CF5: CFL 18 integral unit ELC	75	18	$43,498	$29,710	1.5
LI_3B	IN8: INC 75 CEIL	CF5: CFL 18 integral unit ELC	75	18	$133,037	$90,032	1.5
LI_3C	IN8: INC 75 CEIL	CF5: CFL 18 integral unit ELC	75	18	$59,940	$12,428	4.8
LI_3D	IN36: INC 60 FLD	CF5: CFL 18 integral unit ELC	60	18	$15,831	$75,406	0.2
LI_3E	IN37: INC 75 FLD	CF7: CFL 23 integral unit ELC	75	23	$1,978	$12,189	0.2
LI_3F	IN11: INC 100 CEIL	CF9: CFL 26 integral unit ELC	100	26	$16,937	$26,235	0.6

9.3.3 Energy Savings

Replacing all of these lights would result in 2,435,127 KWh/yr in electrical savings and 448 KW in demand savings, for a total savings of $246K/yr.

9.3.4 Additional Benefits

This ECM would also yield significant maintenance savings since CFLs last so much longer than incandescents. It would save $113K/yr in maintenance costs.

9.3.5 Investment

Replacing these lights would cost $271K.

9.3.6 Payback

The simple payback would be 1.1 yrs.

9.4 LI #4—Replace Exit Signs with Electroluminescent Exit Signs or Retrofit Kits

9.4.1 Existing Conditions/Problems

Most exit signs at Fort Bliss have been replaced with 2-watt LED exit signs. A few exit signs still use 40-watt incandescents. Since exit signs are never turned off, the smallest wattage sign will almost always be cost-effective.

9.4.2 Solution

Electroluminescent exit signs use only 0.2 watts. Therefore, it is cost-effective to replace all exit signs with these, using 10-200 times less energy than the current sign. Table 22 lists the before and after results, based on building groupings resulting from a FEDS model of Fort Bliss.

Appendix A to this report lists the buildings corresponding to "Building Designation."

Table 22. LI #4—Replace existing exit signs with electroluminescent exit signs.

ECM	Current Technology	Retrofit Technology	Current Wattage	Retrofit Wattage	Investment $	Savings $/yr	Simple Payback (yrs)
LI_4A	EX6: Exit - LED	EX11: Exit – electroluminescent panel	2	0.2	$14,702	$2,613	5.6
LI_4B	EX6: Exit - LED	EX11: Exit – electroluminescent panel	2	0.2	24,359	$4,144	5.9
LI_4C	EX6: Exit - LED	EX11: Exit – electroluminescent panel	2	0.2	$2,828	$467	6.1
LI_4D	EX1: EXIT - inc (2x20)	EX11: Exit – electroluminescent panel	40	0.2	$1,148	$1,096	1.0
LI_4E	EX6: EXIT – LED	EX11: Exit – electroluminescent panel	2	0.2	$16,216	$2,686	6.0
LI_4F	EX1: EXIT - inc (2x20)	EX11: Exit – electroluminescent panel	40	0.2	$16,180	$14,955	1.1
LI_4G	EX6: EXIT – LED	EX11: Exit – electroluminescent panel	2	0.2	$12,180	$2,008	6.1
LI_4H	EX6: EXIT – LED	EX11: Exit – electroluminescent panel	2	0.2	$9,657	$1,663	5.8
LI_4I	EX6: EXIT – LED	EX11: Exit – electroluminescent panel	2	0.2	$17,225	$2,899	5.9
LI_4J	EX6: EXIT – LED	EX11: Exit – electroluminescent panel	2	0.2	$2,492	$415	6.0
LI_4K	EX6: EXIT – LED	EX11: Exit – electroluminescent panel	2	0.2	$2,204	$362	6.1
LI_4L	EX6: EXIT – LED	EX11: Exit – electroluminescent panel	2	0.2	$3,830	$679	5.6
LI_4M	EX6: EXIT – LED	EX11: Exit – electroluminescent panel	2	0.2	$18,234	$3,119	5.8
LI_4N	EX6: EXIT – LED	EX11: Exit – electroluminescent panel	2	0.2	$24,289	$4,012	6.1
LI_4O	EX6: EXIT – LED	EX11: Exit – electroluminescent panel	2	0.2	$16,216	$2,645	6.1
LI_4P	EX6: Exit - LED	EX11: Exit – electroluminescent panel	2	0.2	$18,234	$3,157	5.8
LI_4Q	EX6: Exit - LED	EX11: Exit – electroluminescent panel	2	0.2	$34,381	$5,932	5.8
LI_4R	EX6: Exit - LED	EX11: Exit – electroluminescent panel	2	0.2	$5,452	$883	6.2
LI_4S	EX1: EXIT - inc (2x20)	EX11: Exit – electroluminescent panel	40	0.2	$8,143	$7,154	1.1
LI_4T	EX1: EXIT - inc (2x20)	EX11: Exit – electroluminescent panel	40	0.2	$21,262	$18,729	1.1
LI_4U	EX1: EXIT - inc (2x20)	EX11: Exit – electroluminescent panel	40	0.2	$9,152	$9,797	0.9
LI_4V	EX6: Exit - LED	EX11: Exit – electroluminescent panel	2	0.2	$19,244	$3,238	5.9
LI_4W	EX6: Exit - LED	EX11: Exit – electroluminescent panel	2	0.2	$4,106	$680	6.0
LI_4X	EX1: EXIT - inc (2x20)	EX11: Exit – electroluminescent panel	40	0.2	$18,066	$17,389	1.0
LI_4Y	EX6: Exit - LED	EX11: Exit – electroluminescent panel	2	0.2	$10,834	$1,854	5.8
LI_4Z	EX6: Exit - LED	EX11: Exit – electroluminescent panel	2	0.2	$8,728	$1,477	5.9
LI_4AA	EX1: EXIT - inc (2x20)	EX11: Exit – electroluminescent panel	40	0.2	$5,620	$5,507	1.0

ECM	Current Technology	Retrofit Technology	Current Wattage	Retrofit Wattage	Investment $	Savings $/yr	Simple Payback (yrs)
LI_4AB	EX6: Exit - LED	EX11: Exit – electroluminescent panel	2	0.2	$8,412	$1,413	6.0
LI_4AC	EX6: Exit - LED	EX11: Exit – electroluminescent panel	2	0.2	$1,953	$315	6.2
LI_4AD	EX1: EXIT - inc (2x20)	EX11: Exit – electroluminescent panel	40	0.2	$1,485	$1,313	1.1
LI_4AE	EX6: Exit - LED	EX11: Exit – electroluminescent panel	2	0.2	$2,340	$2,191	1.1
LI_4AF	EX1: EXIT - inc (2x20)	EX11: Exit – electroluminescent panel	40	0.2	$9,152	$8,875	1.0
LI_4AG	EX3: EXIT - FL 1-PL9	EX11: Exit – electroluminescent panel	13	0.2	$1,583	$794	2.0
LI_4AH	EX6: Exit - LED	EX11: Exit – electroluminescent panel	2	0.2	$10,161	$1,681	6.0
LI_4AI	EX6: Exit - LED	EX11: Exit – electroluminescent panel	2	0.2	$14,198	$2,421	5.9
LI_4AJ	EX6: Exit - LED	EX11: Exit – electroluminescent panel	2	0.2	$4,611	$768	6.0
LI_4AK	EX1: EXIT - inc (2x20)	EX11: Exit – electroluminescent panel	40	0.2	$1,415	$1,170	1.2

9.4.3 Energy Savings

Replacing all of these lights would result in 945 MWh/yr in electrical savings of, 93 KW in demand savings, and $89K/yr in maintenance savings , for a total savings of $141K/yr.

9.4.4 Additional Benefits

Electroluminescent exit signs have a much longer lifetime than incandescents and even LEDs. Therefore maintenance savings is significant – $90.8K/yr.

9.4.5 Investment

Installation of the new exit signs would cost $400K.

9.4.6 Payback

The simple payback would be 2.8 yrs.

9.5 LI #5—Replace Existing Lighting in High Bay Areas with T5 Fluorescent Lighting Systems

9.5.1 Existing Conditions/Problems

High bay areas are somewhat difficult to light since the light source is so far away from where it is being used. High output lights are needed in these areas for an efficient, well-lit space. Some buildings at Fort Bliss use large incandescent lights suspended from the ceiling, which is a waste of energy and does not provide good light. Others use metal halide lamps, which work well and are common, but are not the most efficient choice.

9.5.2 Solution

Use T5 fluorescent lights in high bay areas. These have a high output and are some of the most efficient options on the market. Replace smaller incandescent lamps with 2-bulb, 2-ft fixtures with reflectors. Replace larger incandescent lamps with 1-bulb, 4-ft fixtures with reflectors. Replace smaller metal halides with 1-bulb, 4-ft fixtures. Replace larger metal halides with 2-bulb, 4-ft fixtures with reflectors. Table 23 lists the before and after results, based on building groupings resulting from a FEDS model of Fort Bliss.

Appendix A to this report lists the buildings corresponding to "Building Designation."

Table 23. LI #5—Replace metal halide high-bay lighting with T5HO lighting.

ECM	Current Technology	Retrofit Technology	Current Wattage	Retrofit Wattage	Investment $	Savings $/yr	Simple Payback (yrs)
LI_5A	MH4: MH 175 PEND	FL269: FL 2X4 4F28T5 ELC4 REF	210	128	$145,945	$21,694	6.7
LI_5B	MH4: MH 175 PEND	FL269: FL 2X4 4F28T5 ELC4 REF	210	128	$270,313	$37,997	7.1
LI_5C	MH4: MH 175 PEND	FL269: FL 2X4 4F28T5 ELC4 REF	210	128	$829,400	$144,348	5.7

9.5.3 Energy Savings

According to FEDS calculations, replacing existing lighting in high bay areas with T5 fluorescent lighting systems would yield 4543 MWh/yr in electrical savings, 971 KW in demand savings, and $86K/yr in maintenance savings, for a total savings of $118K/yr.

9.5.4 Additional Benefits

There would also be a maintenance savings of $204K/yr.

9.5.5 Investment

This ECM would cost $1,246K to implement.

9.5.6 Payback

The simple payback would be 6.1 yrs.

9.6 LI #6—Replace T8 Lamps with Super T8 Lamps

9.6.1 Existing Conditions/Problems

Most buildings on site use T8 fluorescent fixtures to light offices, hallways, labs, and other work areas. While not terribly inefficient, there are better options for general lighting.

9.6.2 Solution

Super T8 lights are similar to T8s, but are more efficient. They are the same size, and so the replacement is easy:

- Replace 32W 2-bulb T8s with 25W 2-bulb super T8s with reflectors.
- Replace 32W 3-bulb T8s with 25W 3-bulb super T8s with reflectors.
- Replace 32W 4-bulb T8s with 30W 4-bulb super T8s with reflectors.
- Replace 32W 4-bulb T8s with 32W 3-bulb super T8s with reflectors.
- Replace 96W 8-ft, 2-bulb T8s with 28W 4-ft, 3-bulb super T8s.

Table 24 lists the before and after results, based on building groupings resulting from a FEDS model of Fort Bliss. Appendix A to this report lists the buildings corresponding to "Building Designation."

Table 24. LI #6—Replace T8 lighting with super T8 lighting.

ECM	Current Technology	Retrofit Technology	Current Wattage	Retrofit Wattage	Investment $	Savings $/yr	Simple Payback yrs
LI_6A	FL236: FL 2X4 3F32T8 ELC3	FL279: FL 2X4 2F32ST8 ELC2 REF	93	54	$423,889	$71,956	5.9
LI_6B	FL236: FL 2X4 3F32T8 ELC3	FL279: FL 2X4 2F32ST8 ELC2 REF	93	54	$112,770	$12,760	8.8
LI_6C	FL236: FL 2X4 3F32T8 ELC3	FL279: FL 2X4 2F32ST8 ELC2 REF	93	54	$37,473	$6,111	6.1
LI_6D	FL236: FL 2X4 3F32T8 ELC3	FL279: FL 2X4 2F32ST8 ELC2 REF	93	54	$484,069	$61,682	7.8
LI_6E	FL236: FL 2X4 3F32T8 ELC3	FL279: FL 2X4 2F32ST8 ELC2 REF	93	54	$104,239	$9,160	11.4
LI_6F	FL236: FL 2X4 3F32T8 ELC3	FL279: FL 2X4 2F32ST8 ELC2 REF	93	54	$429,196	$99,876	4.3
LI_6G	FL236: FL 2X4 3F32T8 ELC3	FL279: FL 2X4 2F32ST8 ELC2 REF	93	54	$315,906	$19,958	15.8
LI_6H	FL236: FL 2X4 3F32T8 ELC3	FL279: FL 2X4 2F32ST8 ELC2 REF	93	54	$206,243	$12,717	16.2
LI_6I	FL236: FL 2X4 3F32T8 ELC3	FL279: FL 2X4 2F32ST8 ELC2 REF	93	54	$201,378	$15,405	13.1
LI_6J	FL236: FL 2X4 3F32T8 ELC3	FL279: FL 2X4 2F32ST8 ELC2 REF	93	54	$405,577	$30,360	13.4
LI_6K	FL236: FL 2X4 3F32T8 ELC3	FL279: FL 2X4 2F32ST8 ELC2 REF	93	54	$278,374	$20,198	13.8
LI_6L	FL236: FL 2X4 3F32T8 ELC3	FL279: FL 2X4 2F32ST8 ELC2 REF	93	54	$51,536	$6,220	8.3
LI_6M	FL236: FL 2X4 3F32T8 ELC3	FL279: FL 2X4 2F32ST8 ELC2 REF	93	54	$29,310	$3,759	7.8
LI_6N	FL236: FL 2X4 3F32T8 ELC3	FL279: FL 2X4 2F32ST8 ELC2 REF	93	54	$70,276	$7,618	9.2
LI_6O	FL236: FL 2X4 3F32T8 ELC3	FL279: FL 2X4 2F32ST8 ELC2 REF	93	54	$121,470	$18,620	6.5
LI_6P	FL236: FL 2X4 3F32T8 ELC3	FL279: FL 2X4 2F32ST8 ELC2 REF	93	54	$113,834	$15,960	7.1
LI_6Q	FL236: FL 2X4 3F32T8 ELC3	FL279: FL 2X4 2F32ST8 ELC2 REF	93	54	$30,590	$3,045	10.0

Energy Savings

Replacing T8s with super T8s would yield 4,543 MWh/yr in electrical savings of, 971 KW in demand savings, $83K/yr in maintenance savings, for a total savings of $415K/yr.

9.6.3 Additional Benefits

There would also be a maintenance savings of $111K/yr.

9.6.4 Investment

This ECM would cost $4,240K to implement.

9.6.5 Payback

The simple payback would be 7.5 yrs.

9.7 LI #7—Replace T12 with Super T8 Lighting

9.7.1 Existing Conditions/Problems

Although it is common to replace the older T12 lights with T8 lights, in certain applications, the more efficient super T8s are a better replacement.

9.7.2 Solution

Super T8 lights are similar to T8s, but are more efficient. They are the same size, and so the replacement is easy. Replace 40W 4-bulb T12s with 32W 3-bulb super T8s with reflectors. Table 25 lists the before and after results, based on building groupings resulting from a FEDS model of Fort Bliss.

Appendix A to this report lists the buildings corresponding to "Building Designation."

Table 25. LI #7—Replace T12 with super T8 lighting.

ECM	Current Technology	Retrofit Technology	Current Wattage	Retrofit Wattage	Investment $	Savings $/yr	Simple Payback yrs
LI_7A	FL1: FL 2X4 4F40T12 STD2	FL280: FL 2X4 3F32ST8 ELC3 REF (FIX REPL)	192	81	$613,566	$152,957	4.0
LI_7B	FL1: FL 2X4 4F40T12 STD2	FL280: FL 2X4 3F32ST8 ELC3 REF (FIX REPL)	192	81	$718,057	$163,873	4.4
LI_7C	FL1: FL 2X4 4F40T12 STD2	FL280: FL 2X4 3F32ST8 ELC3 REF (FIX REPL)	192	81	$570,655	$137,753	4.1
LI_7D	FL1: FL 2X4 4F40T12 STD2	FL280: FL 2X4 3F32ST8 ELC3 REF (FIX REPL)	192	81	$30,306	$6,436	4.7

ECM	Current Technology	Retrofit Technology	Current Wattage	Retrofit Wattage	Investment $	Savings $/yr	Simple Payback yrs
LI_7E	FL1: FL 2X4 4F40T12 STD2	FL280: FL 2X4 3F32ST8 ELC3 REF (FIX REPL)	192	81	$80,133	$18,790	4.3
LI_7F	FL1: FL 2X4 4F40T12 STD2	FL280: FL 2X4 3F32ST8 ELC3 REF (FIX REPL)	192	81	$34,106	$3,973	8.6
LI_7G	FL3: FL 2X4 2F40T12 STD2	FL283: FL 2X4 2F30ST8 ELC2 (FIX REPL)	96	52	$108,474	$8,138	13.3
LI_7H	FL3: FL 2X4 2F40T12 STD2	FL303: FL 2X4 2F25ST8 ELC2 REF (FIX REPL)	96	44	$39,129	$4,809	8.1
LI_7I	FL3: FL 2X4 2F40T12 STD2	FL303: FL 2X4 2F25ST8 ELC2 REF (FIX REPL)	96	44	$23,518	$2,140	11.0
LI_7J		FL303: FL 2X4 2F25ST8 ELC2 REF (FIX REPL)			$17,146	$2,470	6.9
LI_7K		FL303: FL 2X4 2F25ST8 ELC2 REF (FIX REPL)			$17,146	$10,620	4.8
LI_7L		FL304: FL 2X4 3F25ST8 ELC3 REF			$675,395	$107,909	6.3

9.7.3 Energy Savings

Replacing T12 with Super T8 lighting would yield 6,212 MWh/yr in electrical savings are, 1,449 KW in demand savings, and $114K/yr in maintenance savings, for a total savings of $620K/yr.

9.7.4 Additional Benefits

There would also be a maintenance savings of $85.6K/yr.

9.7.5 Investment

This ECM would cost $ 2,120K to implement.

9.7.6 Payback

The simple payback would be 4.3 yrs.

9.8 LI #8—Replace Metal Halide High-Bay Lighting with Biaxial Super T8

9.8.1 Existing Conditions/Problems

High bay areas are somewhat difficult to light since the light source is so far away from where it is being used. High output lights are needed in these areas for an efficient, well-lit space. Some buildings at Fort Bliss use large incandescent lights suspended from the ceiling, which is a waste of energy and does not provide good light. Others use metal halide lamps, which work well and are common, but are not the most efficient choice.

9.8.2 Solution

Use biaxial Super T8 lighting fixtures, which have a high output and are some of the most efficient options on the market. Table 26 lists the before and after results, based on building groupings resulting from a FEDS model of Fort Bliss. Appendix A to this report lists the buildings corresponding to “Building Designation.”

Table 26. LI #8—Replace metal halide high-bay lighting with biaxial Super T8.

ECM	Current Technology	Retrofit Technology	Current Wattage	Retrofit Wattage	Investment $	Savings $/yr	Simple Payback yrs
LI_8A	MH5: MH 250 PEND	FL309: FL 2X3 6F40BX ELC2 REF	294	213	$250,747	$28,044	8.9
LI_8B	MH5: MH 250 PEND	FL309: FL 2X3 6F40BX ELC2 REF	294	213	$213,236	$26,833	7.9

9.8.3 Energy Savings

Replacing metal halide high-bay lighting with biaxial super T8 lighting would yield 490 MWh/yr in electrical savings and $14K/yr in maintenance savings, for a total savings of $55K/yr.

9.8.4 Additional Benefits

There would also be a maintenance savings of $14.3K/yr.

9.8.5 Investment

This ECM would cost $464K to implement.

9.8.6 Payback

The simple payback would be 8.5 yrs.

9.9 LI #9—Replace T12 U-Tube Fixtures with T8 U-Tube Fixtures

9.9.1 Existing Conditions/Problems

T12 lights are older and inefficient.

9.9.2 Solution

Replace 40-watt T12 2-bulb “U” tube 2x2 fixtures with 32-watt T8 “U” tube 2x2 fixtures with electronic ballasts. Table 27 lists the before and after results, based on building groupings resulting from a FEDS model of Fort Bliss.

Appendix A to this report lists the buildings corresponding to “Building Designation.”

Table 27. LI #9—Replace T12 U-tube fixtures with T8 U-tube fixtures.

ECM	Current Technology	Retrofit Technology	Current Wattage	Retrofit Wattage	Investment $	Savings $/yr	Simple Payback yrs
LI_9A	FL6: FL 2X2 2F40T12U STD2	FL54: FL 2X2 2F32T8U ELC2	96	62	$92,121	$10,416	8.8

9.9.3 Energy Savings

According to FEDS calculations, retrofitting these exterior lights would yield 225 MMBtu/yr in energy savings, for a cost savings of $5.8K/yr.

9.9.4 Additional Benefits

There would also be a maintenance savings of $4.6K/yr.

9.9.5 Investment

This ECM would cost $10.4K to implement.

9.9.6 Payback

The simple payback would be 8.8 yrs.

9.10 LI #11- Switch Off External Lights During Daytime

9.10.1 Existing Conditions/Problems

During the assessment visit, several buildings were found with external lights on during the daytime, e.g., building 2624 (17 lights ON), hangar 11108 north side, and medical warehouse 11156 (seven lights ON).

9.10.2 Solution

Install daylight sensors (photocells) that automatically switch external lights off when daylight is sufficient. Alternatively, repair or replace existing sensors that apparently do not work.

9.10.3 Savings

In Bldg. 2624, for example, with 17 lights on, and assuming 50W per fixture for a total of 850W unnecessarily ON for 10 hrs/day, 7 days/wk, 52 wks/yr, yields an energy consumption of:

0.85 kW* 10 hrs * 7 days * 52 wks = 3,100 kWh/yr, worth $200/yr.

9.10.4 Investment

$100 per building.

9.10.5 Payback

Within 6 months

Table 28. Simple payback calculated for Lighting ECMs.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yes
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
LI #1	Provide daylighting in Medical Warehouse (Bldg. 11156) and in parts of Bldg. 2592	70,640	0	$4,592	0	$–	$4,350	$8,942	$173,000	19.3
LI #2	Install daylight sensors (photocells) to control artificial lighting in vehicle maintenance areas	187,000	0	$12,155	0	$–	$–	$12,155	$20,000	1.6
LI #3*	Replace incandescent lights with compact fluorescent lights	2,435,127	448	$161,692	–3,399	–$28,855	$113,251	$246,088	$271,221	1.1
LI #4*	Replace existing exit signs with electroluminescent exit signs	944,861	93	$61,767	–1,026	–$10,026	$88,760	$140,501	$400,292	2.8
LI #5*	Replace metal halide high-bay lighting with T5HO lighting	1,402,345	325	$126,671	–920	–$8,358	$85,726	$204,039	$1,245,658	6.1
LI #6*	Replace T8 lighting with super T8 lighting	4,542,602	971	$360,052	141	–$28,078	$83,431	$415,405	$3,416,130	8.2
LI #7*	Replace T12 with super T8 lighting	6,211,934	1,449	$537,387	–1,045	–$31,261	$113,742	$619,868	$2,961,179	4.8
LI #8*	Replace metal halide high-bay lighting with biaxial super T8	489,722	–123	$44,916	–474	–$4,305	$14,265	$54,876	$463,983	8.5
LI #9*	Replace T12 U-tube fixtures with T8 U-Tube fixtures	70,630	–17	$5,962	–16	–$145	$4,599	$10,416	$92,121	8.8
Totals		*16,354,861*	*3,146*	*$1,315,194*	*–6,739*	*–111028*	*$508,124*	*$1,712,290*	*$9,043,584*	*5.3*

10 Renewables ECM

10.1 REN #1—Shower Gray Water Heat Recovery

10.1.1 Existing Conditions

In the barracks, there are two high water use periods when the soldiers are taking showers. The first is after physical training (PT) about 7:30 a.m. to 8:00 a.m. The other period is in the late afternoon and early evening. During these times, there is a high energy use for heating domestic hot water that is used in taking showers. Currently, the warm shower water is collected and drained away using the sewer drainage system. There is no attempt to recover the heat from this waste stream.

10.1.2 Solution

Heat can be recovered from the sewer drainage system when soldiers are showering. This energy could then be used to preheat the shower cold water, which would reduce the hot water requirements. This can be accomplished by installing a shower drain heat recovery unit, which consists of a copper tube wound around the shower drain line for about 4 ft in length. Figure 32 shows this heat recovery unit. The installation of this heat exchanger requires replumbing of the shower's incoming cold water line. The cold water supply pipe must be connected to the heat exchanger so that the warmed cold water is immediately used by those taking showers. The use of this warmer cold water reduces the demand on the hot water flow.

Installing this heat recovery unit can be best done in conjunction with a building renovation project that changes the barrack's room layout to a 1 + 1 style where soldiers gets their own individual living quarters with a shared shower and kitchen area. This renovation is required in some of the old barracks at Fort Bliss, when new bathrooms would be installed for all rooms. It would be easy to install a shower drain heat recovery unit as part of this major change in the building's plumbing.

If this hot water heat recovery unit is not installed in the barracks, the current inefficient system will continue to waste energy.

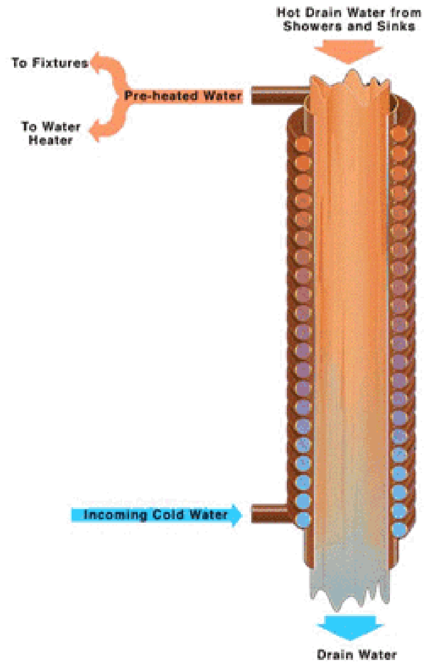

Figure 32. Shower drain heat recovery unit.

10.1.3 Savings

It is estimated every soldier takes 1½, 10-minute showers each day. The temperature rise of the hot water is from 60 °F to 140 °F or a 80 °F temperature rise. Since the population in the barracks is 216 people, the heat recovery unit will save 25 percent:

Q = 216 people * 1.5 * 365 days/yr * 10 min * 1.5 gal/min * 8 °F
* 8.3 lb/gal * 0.25 /0.8 eff. = 368 million Btu/yr

Energy cost savings = 368 million Btu/yr x $9.0839/million Btu = $3,343/yr

10.1.4 Investments

The estimated cost to install a heat recovery unit on a 4-in. drain is $1,000/drain. The shower rooms are adjacent to each other and they drain showers for the three stories of living areas. There are 18 shower drains required in the barracks building for a total cost of $18,000.

10.1.5 Payback

The resulting simple payback is 5.4 yrs.

11 Summary, Recommendations, and Lessons Learned

11.1 Summary

This project conducted an Energy Optimization Assessment at Fort Bliss as a part of the Annex 46 showcase studies to identify energy inefficiencies and wastes and to propose energy-related projects with applicable funding and methods of execution that could enable the installation to better meet the energy reduction requirements mandated by Executive Order 13423 and EPACT 2005.

The study was conducted by a team of researchers from the Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL), the Pacific Northwest National Laboratory (PNNL) and Subject Matter Experts (SMEs), and was limited to a "Level I" assessment. The scope of this study included an analysis of building envelopes, ventilation air systems, controls, interior and exterior lighting, and an evaluation of opportunities to use renewable energy resources.

The study identified a total of 214 different potential energy conservation measures (ECMs), 210 of which were economically quantified (cf. Appendix A). These ECMs (summarized in Table 29) are organized into six categories:

- Building Envelope
- Controls
- Evaporative Cooling
- HVAC
- Lighting
- Renewables.

If all these ECMs were implemented, they would yield savings of approximately $7.9 million/yr (65 MWh/yr in electrical energy savings, 170 MMBtu/yr in thermal savings (mostly natural gas), and $552K/yr in maintenance savings. Implementation of these projects would require investment of $23.4 million, and would achieve an average simple payback in 2.9 yrs.

Table 29. Summary of all ECMs.

ECM Group	Report Chapter	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec. Demand, Thermal, and Maint. $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
Building Envelope	3	5,883,905	1,966	$603,758	134,108	1193809	0	$1,797,567	$7,561,243	4.2
Controls	5	2,730,000	0	$177,450	0	0	0	$177,450	$100,000	0.6
Evaporative Cooling	6	36,811,000	0	$3,533,856	0	0	0	$3,533,856	$5,207,500	1.5
HVAC*	8	2,846,097	-474	$227,841	42,286	396459	43571	$667,871	$1,490,490	3.1
Lighting	9	16,354,861	3,146	$1,315,194	-6,739	-111028	508124	$1,712,290	$9,043,584	5.3
Renewables	10	0	0	$0	368	3343	0	$3,343	$18,000	5.4
Totals		*64,625,864*	*4,638*	*$5,858,099*	*170,023*	*1482583*	*551695*	*$7,892,377*	*$23,420,817*	*2.9*

*Note that the HVAC group includes HVAC #4 which takes a $605,000 avoided cost credit.

Thirty-four of these ECMs resulted from an SME analysis, which included a survey of the specific buildings to which each ECM applies. The other 180 ECMs resulted from modeling the installation's energy use using the Facility Energy Decision System (FEDS) tool. Because the FEDS analyses did not involve a visit to each building an ECM is proposed for, the FEDS analyses (and the resultant ECMs) were less thorough than the SME analyses and ECMs. The FEDS ECMs were divided into subsets of ECMs (cf. Chapters 3 [p 13] to 10 [p 102]). Note that, in Tables 30 through 33, ECM summaries resulting from FEDS analysis are indicated by an asterisk.

The **Building Envelope** category consists of 61 ECMs (summarized in Table 30). BE #4 through BE #7 are summarize ECMs for groups of buildings; these resulted from a FEDS analysis and can be broken into smaller projects. (Chapters 3.4 (p 24) through 3.7 (p 30) give a detailed description.) If all Building Envelope ECMs were implemented, they would save 5,888 MWh/yr and 134,108 MBtu/yr in thermal savings (mostly natural gas), resulting in savings of $1.8 million/yr. The investment cost of $7.6 million would achieve simple payback in 4.2 yrs.

Table 30. Summary of building envelope ECMs.

ECM	ECM Description	Electrical Savings			Thermal		Plant Energy Savings		Maintenance	Total Savings: Electrical Use, Elec. Demand, Thermal, and Maint.	Investment	Simple Payback
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr	MBtu/yr	$/yr	$/yr	$/yr	$	yrs
BE #1	Establish a strategic approach for re-roofing projects, incorporating the use of cool roof materials	1,014,000	0	$65,910	−480	−$4,360	0	0	0	$61,550	$–	0.0
BE #2	Place transparent panels behind windows in vehicle maintenance buildings and barracks	0	0	$–	609	$5,532	0	0	0	$5,532	$124,560	22.5
BE #3A	Install exterior shading for windows in barracks and administrative areas	72,800	0	$4,732	379	$3,443	0	0	0	$8,175	$132,000	16.1
BE #3B	Install exterior shading for windows in barracks and administrative areas with avoided cooling capacity	72,800	0	$4,732	379	$3,443	0	0	0	$8,175	$66,000	8.1
BE #4 *	Install foundation insulation	116,642	106	$15,074	5,672	$51,506	4513	41244	0	$66,580	$607,256	9.1
BE #5*	Insulate roofs, ceilings, and attics	2,747,248	1,357	$355,246	82,353	$723,687	81082	705238	0	$1,078,933	$3,809,632	3.5
BE #6*	Install wall insulation	1,269,584	161	83,880	41,007	372,504	40,449	367,437	0	456,384	1,894,324	4.2
BE #7*	Replace inefficient metal frame windows	590,831	342	74,184	4,189	38,055	4,189	38,055	0	112,239	927,471	8.3
Totals		*5,883,905*	*1,966*	*$603,758*	*134,108*	*$1,193,809*	*130233*	*1151974*	*0*	*$1,797,567*	*$7,561,243*	*4.2*

* Indicates that the ECM is a result of FEDS analysis. These are broken down into groups of buildings in Chapter 3.

The **Controls** category consists of two ECMs. Establishing and maintaining a uniform setpoint for all space temperatures would save 9,315 KWh/yr, resulting in savings of $177K/yr. The investment cost of $100K would achieve a quick simple payback in 0.6 yrs. The second Controls ECM, of expanding the base wide control system, was not economically analyzed in this effort, but is being pursued separately.

The **Evaporative Cooling** ECM group consists of three types of ECMs, which include a total of 19 ECMs (Table 31). Eleven buildings were identified in which EC #1 could be applied; implementation would save 8,247 KWh/yr resulting in savings of $232K/yr. The investment cost of $188K would achieve simple payback in 0.8 yrs. Five buildings were identified in which EC #2 could be applied; implementation would save 106,338 KWh/yr, resulting in savings of $3 million/yr. The investment cost of $4.6 million would achieve simple payback in 1.5 yrs. Three buildings were identified in which EC #3 could be applied; implementation would save 11,014 KWh/yr resulting in savings of $310K/yr. The investment cost of $400K would achieve simple payback in 1.3 yrs.

Table 31. Summary of evaporative cooling ECMs.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec. Demand, Thermal, and Maint. $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
EC #1	Replace small existing direct evaporative cooling units with one larger unit	2,417,000	0	$232,032	0	0	0	$232,032	$187,500	0.8
EC #2	Provide indirect and direct evaporative cooling (IDEC) - DX units instead of DX only units	2,417,000	0	$2,991,936	0	0	0	$2,991,936	$4,620,000	1.5
EC #3	Replace direct evaporative cooling units	3,228,000	0	$309,888	0	0	0	$309,888	$400,000	1.3
Totals		*36,811,000*	*0*	*$3,533,856*	*0*	*0*	*0*	*$3,533,856*	*$5,207,500*	*1*

The **HVAC** ECM group consists of 48 ECMs (summarized in Table 32). HVAC #5 through HVAC #10 summarize ECMs for groups of buildings that resulted from a FEDS analysis, and that can be broken into smaller projects (cf. Chapters 8.5 [p 77] through 8.9 [p 83]). Implementation of all HVAC ECMs would save 688,484 KWh/yr and 42,286 MBtu/yr in thermal costs (mostly natural gas), and $44K in maintenance costs, resulting in a total savings of $668K/yr. The investment cost of $2.1 million would achieve simple payback in 3.1 yrs.

The **Lighting** ECM group consists of 80 ECMs (summarized in Table 33). LI #3 through LI #10 summarize ECMs for groups of buildings that resulted from a FEDS analysis, and that can be broken into smaller projects. (For details, see Chapters 9.3 [p 91] through 9.10 [p 100].) Implementation of all Lighting ECMs would save 16 million KWh/yr, have a 6,739 MBtu/yr thermal penalty, and reduce maintenance costs by $508K, resulting in total savings of $1.7 million/yr. The investment cost of $9 million would achieve simple payback in 5.3 yrs.

One **Renewable** type of ECM was identified. Shower water heat recovery would save 368 MBTU/yr for a savings of $3,343/yr. The investment cost of $18K would achieve simple payback in 5.4 yrs.

Several **Miscellaneous** ECMs, involving commissioning and electrical motors, were also identified. These were not analyzed economically.

The Level I analyses of multiple complex systems conducted during the Energy Optimization Assessment are not intended to be (nor should they be) precise. The quantity and quality of the systems improvements identified suggests that significant potential exists.

Table 32. Summary of HVAC ECMs.

ECM	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec. Demand, Thermal, and Maint. $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
HVAC #1	Schedule air handling units to match building usage	1,065,000	0	$69,225	0	$55,000	$–	$124,225	$–	0.0
HVAC #2	Install solar heating for domestic hot water at selected buildings	0	0	$–	6040	$–	$–	$–	$–	0.0
HVAC #3	Replace warm air heating system in vehicle maintenance areas with radiant	0	0	$–	0	$9,084	$–	$9,084	$120,000	13.2
HVAC #4**	Install radiant cooling in barracks areas	1,100,000	0	$71,500	1000	$–	$55,000	$126,500	$–605,000	0.0
HVAC #5*	Replace existing chillers with high-efficiency chillers	712,456	–460	88,462	0	0	4,804	93,266	1,170,220	12.5
HVAC #6*	Replace existing boilers with high-efficiency boilers	0	0	0	4,591	41,708	4,250	45,958	267,781	5.8
HVAC #7*	Replace existing heating and cooling systems with air source heat pumps	–31,359	–14	–1,346	962	8,740	35,322	42,716	200,406	4.7
HVAC #8*	Condensing gas boiler - 91% combustion efficiency, wrap tank, aerators	0	0	0	9,165	83,254	–805	82,449	283,764	3.4
HVAC #9*	Replace existing water heaters with high efficiency heaters	0	0	$0	20528	$198,673	$0	$198,673	$53,319	0.3
Totals		*0*	*–474*	*$227,841*	*42286*	*$396,459*	*$98,571*	*$722,871*	*$1,490,490*	*2.9*

* Indicates that the ECM is a result of FEDS analysis. These are broken down into groups of buildings in Chapter 8.

**Note that HVAC #4 takes a $605,000 avoided cost credit.

Table 33. Summary of Lighting ECMs.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec. Demand, Thermal, and Maint. $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
LI #1	Provide daylighting in Medical Warehouse (Bldg. 11156) and in parts of Bldg. 2592	70,640	0	$4,592	0	$0	$4,350	$8,942	$173,000	19.3
LI #2	Install daylight sensors (photo-cells) to control artificial lighting in vehicle maintenance areas	187,000	0	$12,155	0	$0	$0	$12,155	$20,000	1.6
LI #3*	Replace incandescent lights with compact fluorescent lights	2,435,127	448	$161,692	–3,399	–$28,855	$113,251	$246,088	$271,221	1.1
LI #4*	Replace existing exit signs with electroluminescent exit signs	944,861	93	$61,767	–1,026	–$10,026	$88,760	$140,501	$400,292	2.8
LI #5*	Replace metal halide high-bay lighting with T5ho lighting	1,402,345	325	$126,671	–920	–$8,358	$85,726	$204,039	$1,245,658	6.1
LI #6*	Replace T8 lighting with super T8 lighting	4,542,602	971	$360,052	141	–$28,078	$83,431	$415,405	$3,416,130	8.2
LI #7*	Replace T12 with super T8 lighting	6,211,934	1,449	$537,387	–1,045	–$31,261	$113,742	$619,868	$2,961,179	4.8
LI #8*	Replace metal halide high-bay lighting with biaxial super T8	489,722	–123	$44,916	–474	–$4,305	$14,265	$54,876	$463,983	8.5
LI #9*	Replace T12 U-tube fixtures with T8 U-tube fixtures	70,630	–17	$5,962	–16	–$145	$4,599	$10,416	$92,121	8.8
Totals		*16,354,861*	*3,146*	*$1,315,194*	*–6,739*	*–111028*	*$508,124*	*$1,712,290*	*$9,043,584*	*5.3*

* Indicates that the ECM is a result of FEDS analysis. These are broken down into groups of buildings in Chapter 9.

11.2 Recommendations

11.2.1 Policy Related Measures

The following measures require virtually no additional capitol investment. These low cost/low-risk (so-called “slam dunk” measures) can be implemented quickly and should be funded internally as soon as possible. While the estimated cost of establishing installation wide setpoints is $100K, this could be implemented as part of the planned expansion of the installation wide building control system at virtually no additional cost:

- cool roof strategy
- establishment of an installation wide building temperature setpoint.

11.2.2 Low to Moderate Cost Projects

The 56 ECMs summarized in Table 34 were found to have an investment of $20K or less and to result in a simple payback of less than 6 yrs. All 56 ECMs could be implemented as a group for a total of $357K; if implemented, they would save $620K/yr and result in a simple payback of just over 6 months. Fort Bliss should seek internal funding for these projects.

11.2.3 Re-Commissioning

Although re-commissioning of HVAC systems was not economically analyzed, an aggressive re-commissioning of HVAC systems is recommended because numerous opportunities that typically have a very short payback period were noted throughout the installation. It is recommended that Fort Bliss pursue this through third party financing such as ESPC.

11.2.4 Demonstration Projects

Two ECMs were identified at Fort Bliss as potential demonstration projects and submitted as candidate Installation Technology Transition Project (ITTP) projects at either Fort Bliss or other army installations. The first is entitled “Grey Water Heat Recovery From Showers” as described in ECM “REN #1.” The second is an evaporative cooling demonstration entitled “Hybrid Air Cooling for the Army Facilities.”

Table 34. ECMs with investment less than $20K and simple payback less than 6 yrs.

ECM #	ECM Description	Electricity Savings				Thermal		Maint	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint	Investment	Simple Payback
		MBtu/yr	KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr	$/yr	$/yr	$	yrs
BE #1	Establish a strategic approach for re-roofing projects, incorporating the use of cool roof materials	3,460	1,014,000		65910	–480	–$4,360	$0	$61,550	$0	0.0
HVAC #1	Schedule air handling units to match building usage	3,634	1,065,000		$69,225	6,040	$55,000		$124,225	–	0.0
HV_9G	Wrap tank with insulation	0	–	0	$0	403	$3,663	–	$3,663	310	0.1
HV_9L	Wrap tank with insulation, aerators	0	–	0	$0	7,012	$63,693	–	$63,693	6,652	0.1
HV_9W	Wrap tank with insulation, LFSHS	0	–	0	$0	909	$8,256	–	$8,256	933	0.1
HV_9C	Wrap tank with insulation	0	–	0	$0	5,202	$47,257	–	$47,257	5,949	0.1
HV_9V	Wrap tank with insulation, LFSHs	0	–	0	$0	4,392	$52,084	–	$52,084	6,655	0.1
HV_9K	Wrap tank with insulation, aerators	0	–	0	$0	925	$8,399	–	$8,399	1,218	0.1
LI_3E	CF7: CFL 23 integral unit ELC	116	33,996	7	$3,199	104	$2,879	$6,111	$12,189	$1,978	0.2
LI_3D	CF5: CFL 18 integral unit ELC	703	206,029	47	$17,118	–45	–$405	$58,693	$75,406	$15,831	0.2
HV_9X	Wrap tank with insulation, LFSHs, aerators	0	–	0	$0	534	$4,853	–	$4,853	1,048	0.2
LI_3F	CF9: CFL 26 integral unit ELC	830	243,249	65	$23,704	–132	–$1,109	$3,729	$26,324	$16,937	0.6
LI_4U	EX11: Exit – electroluminescent panel	275	80,595	9	$5,510	138	$–	$4,287	$9,797	$9,152	0.9
LI_4D	EX11: Exit – electroluminescent panel	36	10,551	0	$746	–14	–$126	$476	$1,096	$1,148	1.0
LI_4AA	EX11: Exit – electroluminescent panel	163	47,771	5	$3,169	–31	–$282	$2,620	$5,507	$5,620	1.0
LI_4AF	EX11: Exit – electroluminescent panel	290	84,991	9	$5,332	–82	–$744	$4,287	$8,875	$9,152	1.0
LI_4X	EX11: Exit – electroluminescent panel	526	154,155	17	$9,964	–118	–$1,069	$8,494	$17,389	$18,066	1.0
LI_4AE	EX11: Exit – electroluminescent panel	77	22,566	2	$1,382	–29	–$263	$1,072	$2,191	$2,340	1.1
LI_4AD	EX11: Exit – electroluminescent panel	40	11,723	1	$743	–8	–$65	$635	$1,313	$1,079	0.8
LI_4S	EX11: Exit – electroluminescent panel	232	67,992	8	$4,413	–118	–$1,070	$3,811	$7,154	$8,143	1.1
LI_4AK	EX11: Exit – electroluminescent panel	40	11,723	1	$755	–24	–$220	$635	$1,170	$1,415	1.2
HV_9O	Wrap tank with insulation, aerators, lower tank temperature	0	–	0	$0	24	$217	–	$217	314	1.4
BE_5G	Attic ceiling: Increase insulation by R-30 (blow-in cellulose)	141	41,323	32	6308	172	$1,563	$0	$7,871	$11,824	1.5

ECM #	ECM Description	Electricity Savings				Thermal		Maint $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		MBtu/yr	KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
LI_4F	EX11: Exit – electroluminescent panel	490	143,605	6	$9,464	–300	–$2,047	$7,538	$14,955	$16,180	1.1
LI #2	Install daylight sensors (photocells) to control artificial lighting in vehicle maintenance areas	638	187,000	0	$12,155		$–		$12,155	$20,000	1.6
HV_9T	Wrap tank with insulation, aerators, lower tank temperature	0	–	0	$0	12	$111	–	$111	197	1.8
HV_9N	Wrap tank with insulation, aerators, lower tank temperature	0	–	0	$0	57	$517	–	$517	959	1.9
LI_4AG	EX11: Exit – electroluminescent panel	17	4,982	1	$333	–2	–$15	$476	$794	$1,583	2.0
HV_8B	Conventional gas boiler - 84% combustion efficiency, wrap tank, aerators	0	–	0	$0	185	$1,679	–$2	$1,677	3,433	2.0
HV_9U	Wrap tank with insulation, aerators, lower tank temperature	0	–	0	$0	148	$1,348	–	$1,348	2,876	2.1
HV_9Q	Wrap tank with insulation, aerators, lower tank temperature	0	–	0	$0	22	$201	–	$201	460	2.3
HV_9R	Wrap tank with insulation, aerators, lower tank temperature	0	–	0	$0	78	$705	–	$705	1,662	2.4
HV_8A	Condensing gas boiler - 91% combustion efficiency, wrap tank, aerators	0	–	0	$0	482	$4,380	–$179	$4,201	10,732	2.6
HV_9M	Wrap tank with insulation, aerators, lower tank temperature	0	–	0	$0	116	$1,049	–	$1,049	2,725	2.6
HV_9P	Wrap tank with insulation, aerators, lower tank temperature	0	–	0	$0	15	$139	–	$139	364	2.6
HV_9S	Wrap tank with insulation, aerators, lower tank temperature	0	–	0	$0	36	$333	–	$333	890	2.7
HV_9Y	Wrap tank with insulation, LFSHS, aerators	0	–	0	$0	97	$884	–	$884	2,426	2.7
HV_9Z	Wrap tank with insulation, LFSHs, lower tank temperature	0	–	0	$0	138	$1,252	–	$1,252	3,525	2.8
HV_9D	Wrap tank with insulation	0	–	0	$0	14	$124	–	$124	426	3.4
HV_9J	Wrap tank with insulation	0	–	0	$0	18	$165	–	$165	568	3.4
HV_9F	Wrap tank with insulation	0	–	0	$0	2	$18	–	$18	62	3.4
HV_9A	Wrap tank with insulation	0	–	0	$0	33	$299	–	$299	1,030	3.4
HV_9H	Wrap tank with insulation	0	–	0	$0	61	$556	–	$556	1,918	3.4
HV_9B	Wrap tank with insulation	0	–	0	$0	120	$1,091	–	$1,091	3,766	3.5
HV_9E	Wrap tank with insulation	0	–	0	$0	70	$638	–	$638	2,203	3.5
REN #1	Shower gray water heat recovery	0			0	368	$3,343		$3,343	18,000	5.4

ECM #	ECM Description	Electricity Savings				Thermal		Maint $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		MBtu/yr	KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
LI_4A	EX11: Exit – electroluminescent panel	24	7,034	1	$467	0	$–	$2,146	$2,613	$14,702	5.6
LI_4L	EX11: Exit – electroluminescent panel	6	1,758	0	$128	0	$–	$551	$679	$3,830	5.6
LI_4P	EX11: Exit – electroluminescent panel	29	8,499	1	$601	–12	–$108	$2,664	$3,157	$18,234	5.8
LI_4H	EX11: Exit – electroluminescent panel	15	4,396	1	$308	–6	–$51	$1,406	$1,663	$9,657	5.8
LI_4Y	EX11: Exit – electroluminescent panel	14	4,103	0	$276	0	–$1	$1,579	$1,854	$10,834	5.8
LI_4M	EX11: Exit – electroluminescent panel	24	7,034	1	$455	17	$–	$2,664	$3,119	$18,234	5.8
LI_4AI	EX11: Exit – electroluminescent panel	21	6,154	1	$433	–9	–$84	$2,072	$2,421	$14,198	5.9
LI_4Z	EX11: Exit – electroluminescent panel	12	3,517	0	$230	–3	–$23	$1,270	$1,477	$8,728	5.9
LI_4I	EX11: Exit – electroluminescent panel	24	7,034	1	$445	–7	–$62	$2,516	$2,899	$17,225	5.9
LI_4V	EX11: Exit – electroluminescent panel	25	7,327	1	$470	–5	–$44	$2,812	$3,238	$19,244	5.9
Total			*3,488,107*	*217*	*$243,243*	*26,519*	*$254,548*	*122,363*	*$620,154*	*$356,635*	*0.6*

11.2.5 Evaporative Cooling

Fort Bliss has an ideal climate for cooling by evaporation. There are numerous evaporative coolers currently installed. However, many of these units are in poor condition and are operating at less than ideal condition. This results in overly humidified air and resulting problems such as mold and uncomfortable working environments. This has resulted in a general trend at Fort Bliss of replacing evaporative cooling with direct expansion (DX) cooling, which is much more costly to operate. If this trend is allowed to continue the additional electrical demand will be considerable. Three types of evaporative cooling were identified and the energy consequences of each analyzed. It is recommended that Fort Bliss pursue a Level II analysis to determine the type of evaporative cooling that will meet each building's cooling requirements and produce a 20 percent design.

11.2.6 Good Payback and Moderate Investment Projects

Table 35 lists ECMs that would yield a simple payback of less than 10 yrs, but that would require moderate investments of between $20K and $200K. These 53 ECMs together would yield annual savings of $1.4 million at a cost of $3.7 million for a simple payback of 2.7 yrs. Due to their size and complexity (for example EC #1), some may need to be developed further by an Energy Optimization Assessment Level II effort.

11.2.7 Good Payback and Significant Investment Projects

Table 36 lists ECMs that would yield a simple payback of less than 6 yrs, but that would also require significant investments of over $200K each. At a cost of $11 million, these 16 ECMs would together yield annual savings of $5 million, resulting in a simple payback of 2.2 yrs. Due to their size and complexity, most need to be developed further by an Energy Optimization Assessment Level II effort, which is geared toward funds appropriation.

11.2.8 Level II Analysis Candidates

Some of the ripest opportunities for savings come from the moderate and high cost ECMs identified. These often require a combination of in-house and outside support.

Table 35. ECMs with investments between $20K and $200K and simple payback of less than 10 yrs.

ECM #	ECM Description	Electricity Savings				Thermal		Maint $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		MBtu/yr	KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
BE_5A	Add insulation to interior surface of metal roof: 4-in. fiberglass	1,828	535,734	306	65092	2,919	$26,517	$0	$91,609	$31,685	0.3
CON #1	Establish and maintain a uniform and general set point for space temperature in all buildings	9,315	2,730,000		177,450		$—		177,450	100,000	0.6
EC #1	Replace small existing direct evaporative cooling units with one larger unit	8,247	2,417,000		232032		$—		$232,032	$187,500	0.8
LI_4T	EX11: Exit – electroluminescent panel	609	178,480	20	$11,595	–316	–$2,869	$10,003	$18,729	$21,262	1.1
BE_5C	Add insulation to interior surface of metal roof: 4-in. fiberglass	1,649	483,274	0	41896	16,361	$146,362	$0	$188,258	$385,859	2.0
LI_3A	CF5: CFL 18 integral unit ELC	1,518	444,882	77	$26,646	–773	–$7,023	$10,086	$29,709	$43,498	1.5
LI_3B	CF5: CFL 18 integral unit ELC	4,630	1,356,919	235	$81,343	–2,439	–$22,160	$30,849	$90,032	$133,037	1.5
BE_5H	Attic ceiling: Increase insulation by R-38 (blow-in cellulose)	405	118,694	78	16225	620	$5,630	$0	$21,855	$35,422	1.6
LI #2	Install daylight sensors (photocells) to control artificial lighting in vehicle maintenance areas	638	187,000	0	$12,155		$—		$12,155	$20,000	1.6
HV_8D	Conventional gas boiler - 84% combustion efficiency, wrap tank, LFSHs	0	–	0	$0	1,341	$12,182	–$14	$12,168	21,104	1.7
BE_6J	Add interior metal wall surface insulation: 4-in. Fiberglass	677	198,409	23	20184	7,913	$71,885	$0	$92,069	$172,148	1.9
HV_8I	Conventional gas boiler - 84% combustion efficiency, wrap tank, LFSHs, aerators	0	–	0	$0	2,567	$23,322	–$101	$23,221	46,295	2.0
HV_8C	Conventional gas boiler - 84% combustion efficiency, wrap tank, aerators	0	–	0	$0	1,112	$10,099	–$10	$10,089	20,714	2.1
BE_5F	Attic ceiling: increase insulation by r-19 (blow-in cellulose)	9	2,638	0	119	1,050	$9,534	$0	$9,653	$33,242	3.4
LI_7E	FL280: FL 2X4 3F32ST8 ELC3 REF (FIX REPL)	623	182,583	47	$16,843	–148	–$1,349	$3,296	$18,790	$80,133	4.3
HV_6D	Conventional gas boiler — 84% Combustion efficiency	0	–	0	$0	2,264	$20,569	69	$20,638	96,607	4.7
LI_7D	FL280: FL 2X4 3F32ST8 ELC3 REF (FIX REPL)	182	53,339	17	$5,638	–36	–$324	$1,122	$6,436	$30,306	4.7
LI_7K	FL303: FL 2X4 2F25ST8 ELC2 REF (FIX REPL)	431	126,314	23	$9,375	–31	–$282	$1,527	$10,620	$50,694	4.8
LI_3C	CF5: CFL 18 integral unit ELC	512	150,052	17	$9,682	–114	–$1,037	$3,783	$12,428	$59,940	4.8
BE_5E	Attic ceiling: Increase insulation by R-19 (blow-in cellulose)	209	61,252	64	10730	0	$—	$0	$10,730	$59,504	5.5

ECM #	ECM Description	Electricity Savings				Thermal		Maint $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		MBtu/yr	KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
BE_4M	Insulate perimeter of slab on grade: Increase insulation by R-15	122	35,755	30	4401	509	$4,621	$0	$9,022	$52,024	5.8
HV_8E	Conventional gas boiler - 84% combustion efficiency, wrap tank, LFSHs, aerators	0	–	0	$0	948	$8,610	–$138	$8,472	48,922	5.8
LI_4Q	EX11: Exit – electroluminescent panel	54	15,826	2	$1,126	–25	–$226	$5,032	$5,932	$34,381	5.8
HV_8F	Conventional gas boiler - 84% combustion efficiency, wrap tank, LFSHs, aerators	0	–	0	$0	624	$5,665	–$91	$5,574	32,312	5.8
HV_8H	Conventional gas boiler - 84% combustion efficiency, wrap tank, LFSHs, aerators	0	–	0	$0	1,263	$11,475	–$179	$11,296	66,176	5.9
LI_4B	EX11: Exit – electroluminescent panel	32	9,378	1	$620	–3	–$28	$3,552	$4,144	$24,359	5.9
HV_6C	Conventional gas boiler - 84% combustion efficiency	0	–	0	$0	2,288	$20,783	–$45	$20,738	122,501	5.9
HV_8G	Conventional gas boiler - 84% combustion efficiency, wrap tank, LFSHs, aerators	0	–	0	$0	643	$5,842	–$91	$5,751	34,076	5.9
LI_4N	EX11: Exit – electroluminescent panel	33	9,671	1	$617	–17	–$157	$3,552	$4,012	$24,289	6.1
LI_6C	FL279: FL 2X4 2F32ST8 ELC2 REF	208	60,959	18	$6,067	–59	–$540	$584	$6,111	$37,473	6.1
BE_4L	Insulate perimeter of slab on grade: Increase insulation by R-15	62	18,170	15	2225	229	$2,078	$0	$4,303	$26,673	6.2
BE_5L	Insulate built-up roof surface (R-20) and re-roof	142	41,616	25	5433	168	$1,526	$0	$6,959	$44,133	6.3
LI_6O	FL279: FL 2X4 2F32ST8 ELC2 REF	633	185,514	61	$18,427	–187	–$1,699	$1,892	$18,620	$121,470	6.5
LI_5A	FL269: FL 2X4 4F28T5 ELC4 REF	517	151,518	30	$12,305	–93	–$847	$10,236	$21,694	$145,945	6.7
BE_4N	Insulate perimeter of slab on grade: Increase insulation by R-15	–5	–1,465	0	–63	529	$4,803	$0	$4,740	$32,241	6.8
BE_4F	Insulate perimeter of slab on grade: Increase insulation by R-15	41	12,016	13	1637	228	$2,073	$0	$3,710	$26,048	7.0
LI_6P	FL279: FL 2X4 2F32ST8 ELC2 REF	556	162,948	50	$16,010	–201	–$1,823	$1,773	$15,960	$113,834	7.1
BE_4D	Insulate perimeter of slab on grade: Increase insulation by R-15	21	6,154	14	1477	267	$2,422	$0	$3,899	$28,634	7.3
BE_5K	Insulate built-up roof surface (R-10) and re-roof	108	31,652	0	1359	2,138	$19,424	$0	$20,783	$157,904	7.6
LI_6M	FL279: FL 2X4 2F32ST8 ELC2 REF	144	42,202	10	$3,768	–51	–$466	$457	$3,759	$29,310	7.8
BE_5P	Suspended ceiling: increase insulation by R-19	139	40,737	26	5293	211	$1,913	$0	$7,206	$57,110	7.9
BE_4I	Insulate perimeter of slab on grade: Increase insulation by R-15	161	47,184	17	3841	0	$–	$0	$3,841	$30,476	7.9

ECM #	ECM Description	Electricity Savings				Thermal		Maint $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		MBtu/yr	KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
BE #3B	Install exterior shading for windows in barracks and administrative areas with avoided cooling capacity	248	72,800		4732	379	$3,443	$0	$8,175	$66,000	8.1
LI_7H	FL283: FL 2X4 2F30ST8 ELC2 (FIX REPL)	177	51,874	10	$4,212	–32	–$286	$883	$4,809	$39,129	8.1
LI_6L	FL279: FL 2X4 2F32ST8 ELC2 REF	183	53,632	18	$5,735	–36	–$326	$811	$6,220	$51,536	8.3
LI_7F	FL280: FL 2X4 3F32ST8 ELC3 REF (FIX REPL)	276	80,888	20	$3,482	–100	–$912	$1,403	$3,973	$34,106	8.6
LI_6B	FL279: FL 2X4 2F32ST8 ELC2 REF	474	138,916	33	$12,487	–192	–$1,737	$2,010	$12,760	$112,770	8.8
BE_7B	Install thermal break aluminum frame double pane argon/super low-E window	161	47,184	32	6604	307	$2,788	$0	$9,392	$81,841	8.7
LI_9A	FL54: FL 2X2 2F32T8U ELC2	241	70,630	–17	$5,962	–16	–145	$4,599	$10,416	$92,121	8.8
LI_6N	FL279: FL 2X4 2F32ST8 ELC2 REF	290	84,991	21	$7,807	–136	–$1,234	$1,045	$7,618	$70,276	9.2
BE_5R	Suspended ceiling: increase insulation by R-19	429	125,727	49	11721	0	$—	$0	$11,721	$108,863	9.3
BE_7C	Install thermal break aluminum frame double pane argon/super low-E window	147	43,081	9	4229	222	$2,019	$0	$6,248	$59,271	9.5
HV_6B	Conventional gas boiler - 80% combustion efficiency	0	–	0	$0	–	$4	3,761	$3,765	36,456	9.7
Total			*10,866,128*	*1,395*	*$888,519*	*42,095*	*$380,119*	*101,656*	*$1,370,294*	*$3,671,610*	*2.7*

Table 36. ECMs requiring investment greater than $200K and simple payback less than 6 yrs.

ECM	ECM Description	Electricity Savings				Thermal		Maint $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		MBtu/yr	KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
HVAC #4	Install Radiant Cooling in Barracks Areas	3,753	1,100,000		$71,500		$–	55,000	$126,000	–605,000	0.0
BE_5B	Add insulation to interior surface of metal roof: 4-in. fiberglass	–159	–46,598	0	–2007	35,992	$326,947	$0	$324,940	$413,002	1.3
EC #3	Replace direct evaporative cooling units	11,014	3,228,000		309888		$–		$309,888	$400,000	1.3
EC #2	Provide indirect and direct evaporative cooling (IDEC)-DX units instead of DX only units	106,338	31,166,000		2991936		$–		$2,991,936	$4,620,000	1.5
BE_5S	Suspended ceiling: increase insulation by R-19	1,100	322,378	170	43942	4,391	$39,891	$0	$83,833	$210,900	2.5
BE_6I	Add interior metal wall surface insulation: 4 in. fiberglass	2,493	730,626	0	31502	16,863	$153,185	$0	$184,687	$549,482	3.0
BE_6H	Add interior metal wall surface insulation: 4 in. fiberglass	0	0	0	0	9,032	$82,043	$0	$82,043	$281,878	3.4
LI_7A	FL280: FL 2X4 3F32ST8 ELC3 REF (FIXREPL)	4,722	1,383,882	369	$130,960	–357	–$3,242	$25,239	$152,957	$613,566	4.0
LI_7C	FL280: FL 2X4 3F32ST8 ELC3 REF (FIXREPL)	4,486	1,314,717	348	$123,992	–1,070	–$9,713	$23,474	$137,753	$570,655	4.1
LI_6F	FL279: FL2X42 F32ST8 ELC2 REF	4,507	1,320,871	163	$88,571	2,965	$–	$11,305	$99,876	$429,196	4.3
LI_7B	FL280: FL2X43 F32ST8 ELC3 REF (FIXREPL)	5,428	1,590,790	413	$149,034	–1,618	–$14,698	$29,537	$163,873	$718,057	4.4
HV_7A	High efficiency electric air source heat pump (commercial)	–107	–$31,359	–14	–$1,346	962	$8,740	35,322	$42,716	200,406	4.7
BE_6G	Add interior metal wall surface insulation: 4 in. Fiberglass	0	0	0	0	5,720	$51,961	$0	$51,961	$269,463	5.2
BE_5N	Insulate built-up roof surface (R-20) and re-roof	2,207	646,808	365	82600	2,598	$23,604	$0	$106,204	$605,727	5.7
LI_5C	FL269: FL 2X4 4F28T5 ELC4 REF	3,530	1,034,541	224	$91,275	–688	–$6,249	$59,322	$144,348	$829,400	5.7
LI_6A	FL279: FL 2X4 2F32ST8 ELC2 REF	2,323	680,804	199	$65,353	0	$–	$6,603	$71,956	$423,889	5.9
Total			*44,441,460*	*2,237*	*$4,177,200*	*74,790*	*$652,469*	*245,802*	*$5,075,471*	*$10,530,621*	*2.1*

It is recommended that Fort Bliss pursue Level II of this Energy Optimization Assessment for:

- evaporative cooling
- grey water heat recovery.

Recommendations for the scope of the Level II study can be based on the Level I and demonstration project results. A specific Level II scope will be jointly developed by the CERL and Fort Bliss teams through review and discussion of results documented in this Level I report. The Level II report will include an analysis that “guesses at nothing – measures everything.” The results will be a set of demonstrated process and systems improvements based on hard numbers. CERL and expert consultants will provide guidance and further assistance in identifying a specific Level II scope of work, respective roles, and the most expeditious implementation path. This will begin with a formal review of this (Level I) report, combined with a planning session to organize the Level II program.

11.2.9 Significant Maintenance Savings Projects

Table 37 lists the ECMs that offer the greatest maintenance savings. It is recommended that Fort Bliss review these projects along with its maintenance program to determine the suitability of these ECMs as projects, or as modifications to maintenance contracts (or both).

Table 37. ECMs with greatest maintenance savings.

ECM	ECM Description	Electricity Savings				Thermal		Maint. $/yr	Total Savings: Electrical Use, Elec. Demand, Thermal, and Maint. $/yr	Investment $	Simple Payback yrs
		MBtu/yr	KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
LI_4T	EX11: Exit - electroluminescent panel	609	178,480	20	$11,595	−316	−$2,869	$10,003	$18,729	$21,262	1.1
LI_6G	FL279: FL 2X4 2F32ST8 ELC2 REF	757	221,855	38	$13,295	−375	−$3,409	$10,072	$19,958	$315,906	15.8
LI_3A	CF5: CFL 18 integral unit ELC	1,518	444,882	77	$26,646	−773	−$7,023	$10,086	$29,709	$43,498	1.5
LI_5A	FL269: FL 2X4 4F28T5 ELC4 REF	517	151,518	30	$12,305	−93	−$847	$10,236	$21,694	$145,945	6.7
LI_6F	FL279: FL 2X4 2F32ST8 ELC2 REF	4,507	1,320,871	163	$88,571	2,965	$—	$11,305	$99,876	$429,196	4.3
LI_6J	FL279: FL 2X4 2F32ST8 ELC2 REF	1,176	344,652	74	$22,212	−527	−$4,783	$12,931	$30,360	$405,577	13.4
LI_5B	FL269: FL 2X4 4F28T5 ELC4 REF	738	216,286	71	$23,091	−139	−$1,262	$16,168	$37,997	$270,313	7.1
LI_7C	FL280: FL 2X4 3F32ST8 ELC3 REF (FIX REPL)	4,486	1,314,717	348	$123,992	−1,070	−$9,713	$23,474	$137,753	$570,655	4.1
LI_7L	FL304: FL 2X4 3F25ST8 ELC3 REF	4,269	1,251,120	156	$84,278	2,397	$—	$23,631	$107,909	$675,395	6.3
LI_7A	FL280: FL 2X4 3F32ST8 ELC3 REF (FIX REPL)	4,722	1,383,882	369	$130,960	−357	−$3,242	$25,239	$152,957	$613,566	4.0
LI_7B	FL280: FL 2X4 3F32ST8 ELC3 REF (FIX REPL)	5,428	1,590,790	413	$149,034	−1,618	−$14,698	$29,537	$163,873	$718,057	4.4
LI_3B	CF5: CFL 18 integral unit ELC	4,630	1,356,919	235	$81,343	−2,439	−$22,160	$30,849	$90,032	$133,037	1.5
HV_7A	High efficiency electric air source heat pump (commercial)	−107	−$31,359	−14	−$1,346	962	$8,740	35,322	$42,716	200,406	4.7
LI_3D	CF5: CFL 18 integral unit ELC	703	206,029	47	$17,118	−45	−$405	$58,693	$75,406	$15,831	0.2
LI_5C	FL269: FL 2X4 4F28T5 ELC4 REF	3,530	1,034,541	224	$91,275	−688	−$6,249	$59,322	$144,348	$829,400	5.7
Total			*10,985,183*	*2,251*	*$874,369*	*−2,116*	*−$67,920*	*$366,868*	*$1,173,317*	*$5,388,044*	*4.6*

11.3 Lessons Learned

An EPOA is a complex undertaking. Several key elements require significant attention to guarantee success:

1. The involvement of key facility personnel who know what the problems are, where they are, and have thought of many solutions
2. The facility personnel's sense of "ownership" of the ideas, which in turn develops a commitment for implementation
3. The EPOA focus on site-specific, critical cost issues, which, if solved, will make the greatest possible economic contribution to the installation's facility's bottom-line.

Major cost issues are:

- facility utilization (bottlenecks)
- maintenance and repair optimization (off spec, scrap, rework)
- labor (productivity, planning/scheduling)
- energy (steam, electricity, compressed air)
- waste (air, water, solid, hazardous)
- equipment (outdated or state-of-the-art), etc.

From a cost perspective, facility capacity, materials, and labor utilization are far more significant than energy and environmental concerns. However, all of these issues must be considered together to achieve DOD's mission of military readiness in the most efficient, cost-effective way. The Energy Assessment Protocol developed by CERL in collaboration with a number of government, institutional, and private sector parties is based on the analysis of the information available from literature, training materials, documented and undocumented practical experiences of contributors, and successful showcase energy assessments conducted by a diverse team of experts at U.S. Army facilities. The protocol addresses both technical and nontechnical, organizational capabilities required to conduct a successful assessment geared to identifying measures that can reduce energy and other operating costs without adversely impacting product quality, safety, morale, or the environment.

Expertise in energy auditing is not an isolated set of skills, methods, or procedures; it requires a combination of skills and procedures from different fields. However, an energy and process audit requires a specific talent for putting together existing ways and procedures to show the overall energy performance of a building and the processes it houses, and how the energy performance of that building can be improved. A well grounded energy and process audit team should have expertise in the fields of HVAC, structural engineering, electrical and automation engineering—and the team should also have a good understanding of production processes.

Most of the knowledge necessary for an energy audit is a part of already existing expertise. Designers, consultants, contractors, and material and equipment suppliers should be familiar with the energy performance of the specific field in which they are experts. Structural designers and consultants should be familiar with heat losses through the building shell and what insulation should be added. Heating and ventilation engineers should be familiar with the energy performance of heating, ventilation, compressed air, and heat recovery systems. Designers of electrical systems should know energy performance of different motors, variable frequency drive (VFD) drives, and lighting systems. An industrial process and energy audit requires knowledge of process engineers specialized in certain processes.

Critical to any energy and process audit team member is the ability to apply a “holistic” approach to the energy sources and sinks in the audited target (installation, building, system, or their elements), and the ability to “step outside the box.” This ability presumes a thorough understanding of the processes performed in the audited building, and of the needs of the end users. For this reason, the end users themselves are important members of the team. It is critical for management, production, operations and maintenance (O&M) staff, energy managers, and on-site contractors to “buy in” to the implementation by participating in the process, sharing their knowledge and expertise, gathering information, and developing ideas.

Acronyms and Abbreviations

Term	Spellout
ACSIM	Assistant Chief of Staff for Installation Management
AHU	air handling unit
CEERD	U.S. Army Corps of Engineers, Engineer Research and Development Center
CERL	Construction Engineering Research Laboratory
CFL	compact fluorescent lamp
CFR	Code of the Federal Regulations
COP	coefficient of performance
DB	dry bulb
DDC	direct digital control
DEC	direct evaporative cooling
DOAS	dedicated outdoor air supply
DPW	Directorate of Public Works
DX	direct expansion
ECBCS	Energy Conservation in Buildings and Community Systems
ECM	energy conservation measure
EMC	energy management control
EMCS	energy management control system
EMS	energy management system
USEPA	U.S. Environmental Protection Agency
EPACT	Energy Policy Act
EPOA	energy and process optimization assessment
ERDC	Engineer Research and Development Center
ESPC	energy savings performance contract
FEDS	Facility Energy Decision System
HQ	headquarters
HVAC	heating, ventilating, and air-conditioning
IDEC	Indirect and Direct Evaporative Cooling
IEA	International Energy Agency
IEC	indirect evaporative cooling
HQ-IMCOM	Headquarters, Installation Management Command
IR	infrared radiant
kW	kilowatt
LED	light emitting diode
MMBtu	million Btus
MW	megawatt
MWh	megawatt hour

Term	Spellout
MWR	morale, welfare, and recreation
NPV	net present value
OA	outside air
OWS	operator workstation
PC	personal computer
PNNL	Pacific Northwest National Laboratory
PT	physical training
RA	return air
SBS	sick building syndrome
SIR	savings to investment ratio
SME	subject matter expert
TMY	typical meteorological year
TNT	trinitrotoluene
UESC	utility energy services contract
UMCS	utility monitoring and control system
VAV	variable air volume
VFD	variable frequency drive
WWW	World Wide Web

Appendix A: Summary of All ECMs

Table A1. Summary of all ECMs.

ECM #	ECM Description	Electricity Savings				Thermal		Maint $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint ($/yr)	Investment $	Simple Payback yrs
		MBtu/yr	KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
BE #1	Establish a strategic approach for re–roofing projects, incorporating the use of cool roof materials	3,460	1,014,000		65910	–480	–$4,360	$0	$61,550	$0	0.0
BE #2	Place transparent panels behind windows in vehicle maintenance buildings and barracks	0			0	609	$5,532	$0	$5,532	$124,560	22.5
BE #3A	Install exterior shading for windows in barracks and administrative areas	248	72,800		4732	379	$3,443	$0	$8,175	$132,000	16.1
BE #3B	Install exterior shading for windows in barracks and administrative areas with avoided cooling capacity	248	72,800		4732	379	$3,443	$0	$8,175	$66,000	8.1
BE_4A	Insulate perimeter of slab on grade: Increase insulation by R–10	0	0	0	0	29	$263	$0	$263	$3,520	13.4
BE_4B	Insulate perimeter of slab on grade: Increase insulation by R–15	–5	–1,465	0	–58	259	$2,351	$0	$2,293	$26,299	11.5
BE_4C	Insulate perimeter of slab on grade: Increase insulation by R–15	–17	–4,982	5	229	1,225	11,121	0	11,350	125,425	11.1
BE_4D	Insulate perimeter of slab on grade: Increase insulation by R–15	21	6,154	14	1477	267	$2,422	$0	$3,899	$28,634	7.3
BE_4E	Insulate perimeter of slab on grade: Increase insulation by R–15	3	879	1	151	18	$164	$0	$315	$2,565	8.1
BE_4F	Insulate perimeter of slab on grade: Increase insulation by R–15	41	12,016	13	1637	228	$2,073	$0	$3,710	$26,048	7.0
BE_4G	Insulate perimeter of slab on grade: Increase insulation by R–15	11	3,224	5	575	161	$1,460	$0	$2,035	$18,613	9.1
BE_4H	Insulate perimeter of slab on grade: Increase insulation by R–15	2	586	1	105	10	$92	$0	$197	$1,428	7.2
BE_4I	Insulate perimeter of slab on grade: Increase insulation by R–15	161	47,184	17	3841	0	$–	$0	$3,841	$30,476	7.9
BE_4J	Insulate perimeter of slab on grade: Increase insulation by R–15	–4	–1,172	0	–52	359	$3,260	$0	$3,208	$38,575	12.0
BE_4K	Insulate perimeter of slab on grade: Increase insulation by R–15	–3	–879	0	–42	241	$2,190	$0	$2,148	$25,449	11.8
BE_4L	Insulate perimeter of slab on grade: Increase insulation by R–15	62	18,170	15	2225	229	$2,078	$0	$4,303	$26,673	6.2
BE_4M	Insulate perimeter of slab on grade: Increase insulation by R–15	122	35,755	30	4401	509	$4,621	$0	$9,022	$52,024	5.8
BE_4N	Insulate perimeter of slab on grade: Increase insulation by R–15	–5	–1,465	0	–63	529	$4,803	$0	$4,740	$32,241	6.8
BE_4O	Insulate perimeter of slab on grade: Increase insulation by R–15	–3	–879	0	–39	164	$1,494	$0	$1,455	$18,774	12.9
BE_4P	Insulate perimeter of slab on grade: Increase insulation by R–15	–3	–879	0	–44	316	$2,866	$0	$2,822	$35,464	12.6
BE_4Q	Insulate perimeter of slab on grade: Increase insulation by R–15	–1	–293	0	–7	19	$171	$0	$164	$2,036	12.4
BE_4R	Insulate perimeter of slab on grade: Increase insulation by R–15	20	5,861	4	665	101	$920	$0	$1,585	$13,181	8.3
BE_4S	Insulate perimeter of slab on grade: Increase insulation by R–15	–9	–2,638	0	–112	751	$6,823	$0	$6,711	$71,060	10.6
BE_4T	Insulate perimeter of slab on grade: Increase insulation by R–15	1	293	0	12	126	$1,142	$0	$1,154	$12,105	10.5
BE_4U	Insulate perimeter of slab on grade: Increase insulation by R–7.5	4	1,172	1	173	131	$1,192	$0	$1,365	$16,666	12.2
BE_5A	Add insulation to interior surface of metal roof: 4 inches fiberglass	1,828	535,734	306	65092	2,919	$26,517	$0	$91,609	$31,685	0.3
BE_5B	Add insulation to interior surface of metal roof: 4 inches fiberglass	–159	–46,598	0	–2007	35,992	$326,947	$0	$324,940	$413,002	1.3

ECM #	ECM Description	Electricity Savings				Thermal		Maint $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint ($/yr)	Investment $	Simple Payback yrs
		MBtu/yr	KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
BE_5C (hanger	Add insulation to interior surface of metal roof: 4 inches fiberglass	1,470	430,814	–$23	39631	14,096	128,046		$167,677	357,797	2.1
BE_5C (offices	Add insulation to interior surface of metal roof: 4 inches fiberglass	179	52,460	23	2265	2,265	$18,316	$0	$20,581	$28,062	1.4
BE_5D	Attic ceiling: Increase insulation by R–13 (Blow–in Cellulose	–92	–26,963	0	–1166	550	$4,993	$0	$3,827	$47,024	12.3
BE_5E	Attic ceiling: Increase insulation by R–19 (Blow–in Cellulose	209	61,252	64	10730	0	$–	$0	$10,730	$59,504	5.5
BE_5F	Attic ceiling: Increase insulation by R–19 (Blow–in Cellulose	9	2,638	0	119	1,050	$9,534	$0	$9,653	$33,242	3.4
BE_5G	Attic ceiling: Increase insulation by R–30 (Blow–in Cellulose	141	41,323	32	6308	172	$1,563	$0	$7,871	$11,824	1.5
BE_5H	Attic ceiling: Increase insulation by R–38 (Blow–in Cellulose	405	118,694	78	16225	620	$5,630	$0	$21,855	$35,422	1.6
BE_5I	Insulate built–up roof surface (R–10 and Re–Roof	–118	–34,582	0	–1495	6,202	$56,341	$0	$54,846	$535,848	9.8
BE_5J	Insulate built–up roof surface (R–10 and Re–Roof	126	36,927	0	1598	4,902	$44,528	$0	$46,126	$362,760	7.9
BE_5K	Insulate built–up roof surface (R–10 and Re–Roof	108	31,652	0	1359	2,138	$19,424	$0	$20,783	$157,904	7.6
BE_5L	Insulate built–up roof surface (R–20 and Re–Roof	142	41,616	25	5433	168	$1,526	$0	$6,959	$44,133	6.3
BE_5M	Insulate built–up roof surface (R–20 and Re–Roof	1,028	301,277	182	40317	1,026	$9,322	$0	$49,639	$300,756	6.1
BE_5N	Insulate built–up roof surface (R–20 and Re–Roof	2,207	646,808	365	82600	2,598	$23,604	$0	$106,204	$605,727	5.7
BE_5O	Suspended Ceiling: Increase Insulation by R–11	–58	–16,998	0	15085	2,437	$–	$0	$15,085	$185,626	12.3
BE_5P	Suspended Ceiling: Increase Insulation by R–19	139	40,737	26	5293	211	$1,913	$0	$7,206	$57,110	7.9
BE_5Q	Suspended Ceiling: Increase Insulation by R–19	152	44,547	35	6556	495	$4,494	$0	$11,050	$131,966	11.9
BE_5R	Suspended Ceiling: Increase Insulation by R–19	429	125,727	49	11721	0	$–	$0	$11,721	$108,863	9.3
BE_5S	Suspended Ceiling: Increase Insulation by R–19	1,100	322,378	170	43942	4,391	$39,891	$0	$83,833	$210,900	2.5
BE_5T	Suspended Ceiling: Increase Insulation by R–19	114	33,410	23	5125	106	$965	$0	$6,090	$84,714	13.9
BE_5U	Suspended Ceiling: Increase Insulation by R–19	15	4,396	2	515	15	$133	$0	$648	$5,763	8.9
BE_6A	Add interior masonry surface insulation: R–12.4	59	17,291	13	2102	158	$1,431	$0	$3,533	$44,503	12.6
BE_6B	Add interior masonry surface insulation: R–12.4	164	48,064	41	6431	558	$5,067	$0	$11,498	$152,625	13.3
BE_6C	Add interior masonry surface insulation: R–12.4	60	17,584	12	2001	126	$1,148	$0	$3,149	$41,317	13.1
BE_6D	Add interior masonry surface insulation: R–12.4	240	70,337	49	8026	584	$5,306	$0	$13,332	$175,869	13.2
BE_6E	Add interior masonry surface insulation: R–12.4	26	7,620	5	976	53	$478	$0	$1,454	$18,422	12.7
BE_6F	Add interior metal wall surface insulation: 4-in. fiberglass	613	179,653	18	12658	0	$–	$0	$12,658	$188,617	14.9
BE_6G	Add interior metal wall surface insulation: 4-in. fiberglass	0	0	0	0	5,720	$51,961	$0	$51,961	$269,463	5.2
BE_6H	Add interior metal wall surface insulation: 4-in. fiberglass	0	0	0	0	9,032	$82,043	$0	$82,043	$281,878	3.4
BE_6I	Add interior metal wall surface insulation: 4-in. fiberglass	2,493	730,626	0	31502	16,863	$153,185	$0	$184,687	$549,482	3.0

ECM #	ECM Description	Electricity Savings				Thermal		Maint $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint ($/yr)	Investment $	Simple Payback yrs
		MBtu/yr	KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
BE_6J	Add interior metal wall surface insulation: 4-in. fiberglass	677	198,409	23	20184	7,913	$71,885	$0	$92,069	$172,148	1.9
BE_7A	Install thermal break aluminum frame double pane argon/super low–E window	43	12,602	8	1668	58	$525	$0	$2,193	$18,676	8.5
BE_7B	Install thermal break aluminum frame double pane argon/super low–E window	161	47,184	32	6604	307	$2,788	$0	$9,392	$81,841	8.7
BE_7C	Install thermal break aluminum frame double pane argon/super low–E window	147	43,081	9	4229	222	$2,019	$0	$6,248	$59,271	9.5
BE_7D	Install thermal break aluminum frame double pane argon/super low–E window	174	50,994	17	4623	0	$–	$0	$4,623	$47,909	10.4
BE_7E	Install thermal break aluminum frame double pane argon/super low–E window	604	177,015	102	23034	856	$7,775	$0	$30,809	$243,954	7.9
BE_7F	Install thermal break aluminum frame double pane argon/super low–E window	887	259,954	174	34026	2,746	$24,948	$0	$58,974	$475,820	8.1
COM #1	Retrocommission building controls and EMS (energy management system in most buildings	0			0		$–		$0		
CON #1	Establish and maintain a uniform and general set point for space temperature in all buildings	9,315	2,730,000		177,450		$–		177,450	100,000	0.6
CON #2	Connect all major buildings at fort bliss to a central monitoring and control system	0			0		$–		$0		
DIN #1	More efficient dining facility operations	0			0		$–		$0		
EC #1	Replace small existing direct evaporative cooling units with one larger unit	8,247	2,417,000		232032		$–		$232,032	$187,500	0.8
EC #2	Provide indirect and direct evaporative cooling (IDEC – DX units instead of DX only units	106,338	31,166,000		2991936		$–		$2,991,936	$4,620,000	1.5
EC #3	Replace direct evaporative cooling units	11,014	3,228,000		309888		$–		$309,888	$400,000	1.3
EL #1	Use energy efficient electric motors, Bldg. 4600, 1060, 525	0			$0		$–		$0		
HVAC #1	Schedule air handling units to match building usage	3,634	1,065,000		$69,225	6,040	$55,000		$124,225	–	0.0
HVAC #2	Install solar heating for domestic hot water at selected buildings	0			$0		$–		$0		
HVAC #3	Replace warm air heating system in vehicle maintenance areas with radiant	0			$0	1,000	$9,084		$9,084	120,000	13.2
HVAC #4	Install radiant cooling in barracks areas	3,753	1,100,000		$71,500		$–	55,000	$126,500	–605,000	0.0
HV_5A	Water–cooled centrifugal electric chiller (ultra high efficiency	638	186,979	–109	$22,929	–	$–	4,716	$27,645	378,876	13.7
HV_5B	Water–cooled reciprocating electric chiller (high efficiency and cooling tower	862	252,627	–205	$35,296	–	$–	–$538	$34,758	439,865	12.7
HV_5C	Water–cooled reciprocating electric chiller (very high efficiency and cooling tower	931	272,849	–146	$30,237	–	$–	626	$30,863	351,479	11.4
HV_6A	Conventional gas boiler – 80% combustion efficiency	0	–	0	$0	39	$352	465	$817	12,217	15.0
HV_6B	Conventional gas boiler – 80% combustion efficiency	0	–	0	$0	–	$4	3,761	$3,765	36,456	9.7
HV_6C	Conventional gas boiler – 84% combustion efficiency	0	–	0	$0	2,288	$20,783	–$45	$20,738	122,501	5.9
HV_6D	Conventional gas boiler – 84% combustion efficiency	0	–	0	$0	2,264	$20,569	69	$20,638	96,607	4.7
HV_7A	High efficiency electric air source heat pump (commercial	–107	–$31,359	–14	–$1,346	962	$8,740	35,322	$42,716	200,406	4.7
HV_7B	High efficiency electric air source heat pump (commercial	0	–	0	$0	–	$–	–	$0	Same	

ECM #	ECM Description	Electricity Savings				Thermal		Maint $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint ($/yr)	Investment $	Simple Payback yrs
		MBtu/yr	KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
HV_8A	Condensing gas boiler – 91% combustion efficiency, wrap tank, aerators	0	–	0	$0	482	$4,380	–$179	$4,201	10,732	2.6
HV_8B	Conventional gas boiler – 84% combustion efficiency, wrap tank, aerators	0	–	0	$0	185	$1,679	–$2	$1,677	3,433	2.0
HV_8C	Conventional gas boiler – 84% combustion efficiency, wrap tank, aerators	0	–	0	$0	1,112	$10,099	–$10	$10,089	20,714	2.1
HV_8D	Conventional gas boiler – 84% combustion efficiency, wrap tank, LFSHS	0	–	0	$0	1,341	$12,182	–$14	$12,168	21,104	1.7
HV_8E	Conventional gas boiler – 84% combustion efficiency, wrap tank, LFSHS, aerators	0	–	0	$0	948	$8,610	–$138	$8,472	48,922	5.8
HV_8F	Conventional gas boiler – 84% combustion efficiency, wrap tank, LFSHS, aerators	0	–	0	$0	624	$5,665	–$91	$5,574	32,312	5.8
HV_8G	Conventional gas boiler – 84% combustion efficiency, wrap tank, LFSHs, aerators	0	–	0	$0	643	$5,842	–$91	$5,751	34,076	5.9
HV_8H	Conventional gas boiler – 84% combustion efficiency, wrap tank, LFSHs, aerators	0	–	0	$0	1,263	$11,475	–$179	$11,296	66,176	5.9
HV_8I	Conventional gas boiler – 84% combustion efficiency, wrap tank, LFSHs, aerators	0	–	0	$0	2,567	$23,322	–$101	$23,221	46,295	2.0
HV_9A	Wrap tank with insulation	0	–	0	$0	33	$299	–	$299	1,030	3.4
HV_9B	Wrap tank with insulation	0	0	0	0	120	1,091	0	1,091	3,766	3.5
HV_9C	Wrap tank with insulation	0	–	0	$0	5,202	$47,257	–	$47,257	5,949	0.1
HV_9D	Wrap tank with insulation	0	–	0	$0	14	$124	–	$124	426	3.4
HV_9E	Wrap tank with insulation	0	–	0	$0	140	$1,276	–	$1,276	4,406	3.5
HV_9F	Wrap tank with insulation	0	–	0	$0	4	$36	–	$36	124	3.4
HV_9G	Wrap tank with insulation	0	–	0	$0	403	$3,663	–	$3,663	310	0.1
HV_9H	Wrap tank with insulation	0	–	0	$0	61	$556	–	$556	1,918	3.4
HV_9I	Wrap tank with insulation	0	–	0	$0	18	$165	–	$165	1,918	11.6
HV_9J	Wrap tank with insulation	0	–	0	$0	18	$165	–	$165	568	3.4
HV_9K	Wrap tank with insulation, aerators	0	–	0	$0	925	$8,399	–	$8,399	1,218	0.1
HV_9L	Wrap tank with insulation, aerators	0	–	0	$0	7,012	$63,693	–	$63,693	6,652	0.1
HV_9M	Wrap tank with insulation, aerators, lower tank temperature	0	–	0	$0	116	$1,049	–	$1,049	2,725	2.6
HV_9N	Wrap tank with insulation, aerators, lower tank temperature	0	–	0	$0	57	$517	–	$517	959	1.9
HV_9O	Wrap tank with insulation, aerators, lower tank temperature	0	–	0	$0	24	$217	–	$217	314	1.4
HV_9P	Wrap tank with insulation, aerators, lower tank temperature	0	–	0	$0	15	$139	–	$139	364	2.6
HV_9Q	Wrap tank with insulation, aerators, lower tank temperature	0	–	0	$0	22	$201	–	$201	460	2.3
HV_9R	Wrap tank with insulation, aerators, lower tank temperature	0	–	0	$0	78	$705	–	$705	1,662	2.4
HV_9S	Wrap tank with insulation, aerators, lower tank temperature	0	–	0	$0	36	$333	–	$333	890	2.7
HV_9T	Wrap tank with insulation, aerators, lower tank temperature	0	–	0	$0	12	$111	–	$111	197	1.8
HV_9U	Wrap tank with insulation, aerators, lower tank temperature	0	–	0	$0	148	$1,348	–	$1,348	2,876	2.1

ECM #	ECM Description	Electricity Savings				Thermal		Maint $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint ($/yr)	Investment $	Simple Payback yrs
		MBtu/yr	KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
HV_9V	Wrap tank with insulation, LFSHs	0	–	0	$0	4,392	$52,084	–	$52,084	6,655	0.1
HV_9W	Wrap tank with insulation, LFSHs	0	–	0	$0	909	$8,256	–	$8,256	933	0.1
HV_9X	Wrap tank with insulation, LFSHs, aerators	0	–	0	$0	534	$4,853	–	$4,853	1,048	0.2
HV_9Y	Wrap tank with insulation, LFSHs, aerators	0	–	0	$0	97	$884	–	$884	2,426	2.7
HV_9Z	Wrap tank with insulation, LFSHs, lower tank temperature	0	–	0	$0	138	$1,252	–	$1,252	3,525	2.8
LI #1	Provide daylighting in medical warehouse (Bldg. 11156 and in parts of Bldg. 2592	241	70,640	0	$4,592		$–	$4,350	$8,942	$173,000	19.3
LI #2	Install daylight sensors (photocells to control artificial lighting in vehicle maintenance areas	638	187,000	0	$12,155		$–		$12,155	$20,000	1.6
LI_3A	CF5: CFL 18 integral unit ELC	1,518	444,882	77	$26,646	–773	–$7,023	$10,086	$29,709	$43,498	1.5
LI_3B	CF5: CFL 18 integral unit ELC	4,630	1,356,919	235	$81,343	–2,439	–$22,160	$30,849	$90,032	$133,037	1.5
LI_3C	CF5: CFL 18 integral unit ELC	512	150,052	17	$9,682	–114	–$1,037	$3,783	$12,428	$59,940	4.8
LI_3D	CF5: CFL 18 integral unit ELC	703	206,029	47	$17,118	–45	–$405	$58,693	$75,406	$15,831	0.2
LI_3E	CF7: CFL 23 integral unit ELC	116	$33,996	7	$3,199	$104	$2,879	$6,111	$12,189	$1,978	0.2
LI_3F	CF9: CFL 26 integral unit ELC	830	243,249	65	$23,704	–132	–$1,109	$3,729	$26,324	$16,937	0.6
LI_4A	EX11: Exit – electroluminescent panel	24	7,034	1	$467	0	$–	$2,146	$2,613	$14,702	5.6
LI_4B	EX11: Exit – electroluminescent panel	32	9,378	1	620	–3	–28	3,552	$4,144	24,359	5.9
LI_4C	EX11: Exit – electroluminescent panel	4	1,172	0	$68	–1	–$5	$404	$467	$2,828	6.1
LI_4D	EX11: Exit – electroluminescent panel	36	10,551	0	746	–14	–126	476	1,096	1,148	1.0
LI_4E	EX11: Exit – electroluminescent panel	21	6,154	1	$404	–10	–$86	$2,368	$2,686	$16,216	6.0
LI_4F	EX11: Exit – electroluminescent panel	$490	$143,605	$6	$9,464	–$300	–$2,047	$7,538	$14,955	$16,180	1.1
LI_4G	EX11: Exit – electroluminescent panel	16	4,689	1	$298	–8	–$66	$1,776	$2,008	$12,180	6.1
LI_4H	EX11: Exit – electroluminescent panel	15	4,396	1	$308	–6	–$51	$1,406	$1,663	$9,657	5.8
LI_4I	EX11: Exit – electroluminescent panel	24	7,034	1	$445	–7	–$62	$2,516	$2,899	$17,225	5.9
LI_4J	EX11: Exit – electroluminescent panel	4	1,172	0	$68	–1	–$8	$355	$415	$2,492	6.0
LI_4K	EX11: Exit – electroluminescent panel	3	879	0	$54	0	–$5	$313	$362	$2,204	6.1
LI_4L	EX11: Exit – electroluminescent panel	6	1,758	0	$128	0	$–	$551	$679	$3,830	5.6
LI_4M	EX11: Exit – electroluminescent panel	24	7,034	1	$455	17	$–	$2,664	$3,119	$18,234	5.8
LI_4N	EX11: Exit – electroluminescent panel	33	9,671	1	$617	–17	–$157	$3,552	$4,012	$24,289	6.1
LI_4O	EX11: Exit – electroluminescent panel	21	6,154	1	$397	–13	–$120	$2,368	$2,645	$16,216	6.1
LI_4P	EX11: Exit – electroluminescent panel	29	8,499	1	$601	–12	–$108	$2,664	$3,157	$18,234	5.8
LI_4Q	EX11: Exit – electroluminescent panel	54	15,826	2	$1,126	–25	–$226	$5,032	$5,932	$34,381	5.8

ECM #	ECM Description	Electricity Savings				Thermal		Maint $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint ($/yr)	Investment $	Simple Payback yrs
		MBtu/yr	KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
LI_4R	EX11: Exit – electroluminescent panel	7	2,051	0	$133	–4	–$39	$789	$883	$5,452	6.2
LI_4S	EX11: Exit – electroluminescent panel	232	67,992	8	$4,413	–118	–$1,070	$3,811	$7,154	$8,143	1.1
LI_4T	EX11: Exit – electroluminescent panel	609	178,480	20	$11,595	–316	–$2,869	$10,003	$18,729	$21,262	1.1
LI_4U	EX11: Exit – electroluminescent panel	275	80,595	9	$5,510	138	$–	$4,287	$9,797	$9,152	0.9
LI_4V	EX11: Exit – electroluminescent panel	25	7,327	1	$470	–5	–$44	$2,812	$3,238	$19,244	5.9
LI_4W	EX11: Exit – electroluminescent panel	5	1,465	0	$99	–1	–$11	$592	$680	$4,106	6.0
LI_4X	EX11: Exit – electroluminescent panel	526	154,155	17	$9,964	–118	–$1,069	$8,494	$17,389	$18,066	1.0
LI_4Y	EX11: Exit – electroluminescent panel	14	4,103	0	$276	0	–$1	$1,579	$1,854	$10,834	5.8
LI_4Z	EX11: Exit – electroluminescent panel	12	3,517	0	$230	–3	–$23	$1,270	$1,477	$8,728	5.9
LI_4AA	EX11: Exit – electroluminescent panel	163	47,771	5	$3,169	–31	–$282	$2,620	$5,507	$5,620	1.0
LI_4AB	EX11: Exit – electroluminescent panel	11	3,224	0	$217	–3	–$27	$1,223	$1,413	$8,412	6.0
LI_4AC	EX11: Exit – electroluminescent panel	2	586	0	$46	–1	–$7	$276	$315	$1,953	6.2
LI_4AD	EX11: Exit – electroluminescent panel	$40	$11,723	$1	$743	–$8	–$65	$635	$1,313	$1,485	1.1
LI_4AE	EX11: Exit – electroluminescent panel	77	22,566	2	$1,382	–29	–$263	$1,072	$2,191	$2,340	1.1
LI_4AF	EX11: Exit – electroluminescent panel	290	84,991	9	$5,332	–82	–$744	$4,287	$8,875	$9,152	1.0
LI_4AG	EX11: Exit – electroluminescent panel	17	4,982	1	$333	–2	–$15	$476	$794	$1,583	2.0
LI_4AH	EX11: Exit – electroluminescent panel	15	4,396	0	$269	–7	–$68	$1,480	$1,681	$10,161	6.0
LI_4AI	EX11: Exit – electroluminescent panel	21	6,154	1	$433	–9	–$84	$2,072	$2,421	$14,198	5.9
LI_4AJ	EX11: Exit – electroluminescent panel	7	2,051	0	$132	–3	–$30	$666	$768	$4,611	6.0
LI_4AK	EX11: Exit – electroluminescent panel	40	11,723	1	$755	–24	–$220	$635	$1,170	$1,415	1.2
LI_5A	FL269: FL 2X4 4F28T5 ELC4 REF	517	151,518	30	$12,305	–93	–$847	$10,236	$21,694	$145,945	6.7
LI_5B	FL269: FL 2X4 4F28T5 ELC4 REF	738	216,286	71	$23,091	–139	–$1,262	$16,168	$37,997	$270,313	7.1
LI_5C	FL269: FL 2X4 4F28T5 ELC4 REF	3,530	1,034,541	224	$91,275	–688	–$6,249	$59,322	$144,348	$829,400	5.7
LI_6A	FL279: FL 2X4 2F32ST8 ELC2 REF	2,323	680,804	199	$65,353	0	$–	$6,603	$71,956	$423,889	5.9
LI_6B	FL279: FL 2X4 2F32ST8 ELC2 REF	$474	$138,916	$33	$12,487	–$192	–$1,737	$2,010	$12,760	$112,770	8.8
LI_6C	FL279: FL 2X4 2F32ST8 ELC2 REF	208	60,959	18	$6,067	–59	–$540	$584	$6,111	$37,473	6.1
LI_6D	FL279: FL 2X4 2F32ST8 ELC2 REF	2,167	635,085	171	$60,395	–774	–$7,029	$8,316	$61,682	$484,069	7.8
LI_6E	FL279: FL 2X4 2F32ST8 ELC2 REF	290	84,991	12	$5,930	0	$–	$3,230	$9,160	$104,239	11.4
LI_6F	FL279: FL 2X4 2F32ST8 ELC2 REF	4,507	1,320,871	163	$88,571	2,965	$–	$11,305	$99,876	$429,196	4.3
LI_6G	FL279: FL 2X4 2F32ST8 ELC2 REF	757	221,855	38	$13,295	–375	–$3,409	$10,072	$19,958	$315,906	15.8

ECM #	ECM Description	Electricity Savings				Thermal		Maint $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint ($/yr)	Investment $	Simple Payback yrs
		MBtu/yr	KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
LI_6H	FL279: FL 2X4 2F32ST8 ELC2 REF	492	144,191	25	$8,650	−276	−$2,509	$6,576	$12,717	$206,243	16.2
LI_6I	FL279: FL 2X4 2F32ST8 ELC2 REF	586	171,740	37	$11,122	−235	−$2,138	$6,421	$15,405	$201,378	13.1
LI_6J	FL279: FL 2X4 2F32ST8 ELC2 REF	1,176	344,652	74	$22,212	−527	−$4,783	$12,931	$30,360	$405,577	13.4
LI_6K	FL279: FL 2X4 2F32ST8 ELC2 REF	626	183,462	34	$11,822	267	$–	$8,376	$20,198	$278,374	13.8
LI_6L	FL279: FL 2X4 2F32ST8 ELC2 REF	183	53,632	18	$5,735	−36	−$326	$811	$6,220	$51,536	8.3
LI_6M	FL279: FL 2X4 2F32ST8 ELC2 REF	144	42,202	10	$3,768	−51	−$466	$457	$3,759	$29,310	7.8
LI_6N	FL279: FL 2X4 2F32ST8 ELC2 REF	290	84,991	21	$7,807	−136	−$1,234	$1,045	$7,618	$70,276	9.2
LI_6O	FL279: FL 2X4 2F32ST8 ELC2 REF	633	185,514	61	$18,427	−187	−$1,699	$1,892	$18,620	$121,470	6.5
LI_6P	FL279: FL 2X4 2F32ST8 ELC2 REF	556	162,948	50	$16,010	−201	−$1,823	$1,773	$15,960	$113,834	7.1
LI_6Q	FL279: FL 2X4 2F32ST8 ELC2 REF	88	25,790	7	$2,401	−42	−$385	$1,029	$3,045	$30,590	10.0
LI_7A	FL280: FL 2X4 3F32ST8 ELC3 REF (FIX REPL	4,722	1,383,882	369	$130,960	−357	−$3,242	$25,239	$152,957	$613,566	4.0
LI_7B	FL280: FL 2X4 3F32ST8 ELC3 REF (FIX REPL	5,428	1,590,790	413	$149,034	−1,618	−$14,698	$29,537	$163,873	$718,057	4.4
LI_7C	FL280: FL 2X4 3F32ST8 ELC3 REF (FIX REPL	4,486	1,314,717	348	$123,992	−1,070	−$9,713	$23,474	$137,753	$570,655	4.1
LI_7D	FL280: FL 2X4 3F32ST8 ELC3 REF (FIX REPL	182	53,339	17	$5,638	−36	−$324	$1,122	$6,436	$30,306	4.7
LI_7E	FL280: FL 2X4 3F32ST8 ELC3 REF (FIX REPL	623	182,583	47	$16,843	−148	−$1,349	$3,296	$18,790	$80,133	4.3
LI_7F	FL280: FL 2X4 3F32ST8 ELC3 REF (FIX REPL	276	80,888	20	$3,482	−100	−$912	$1,403	$3,973	$34,106	8.6
LI_7G	FL280: FL 2X4 3F32ST8 ELC3 REF Total	453	132,761	36	$5,724	−31	−$287	$2,701	$8,138	$108,474	13.3
LI_7H	FL283: FL 2X4 2F30ST8 ELC2 (FIX REPL	177	51,874	10	$4,212	−32	−$286	$883	$4,809	$39,129	8.1
LI_7I	FL303: FL 2X4 2F25ST8 ELC2 REF	69	20,222	5	$1,828	−15	−$132	$444	$2,140	$23,518	11.0
LI_7J	FL303: FL 2X4 2F25ST8 ELC2 REF (FIX REPL	80	23,446	5	$2,021	−4	−$36	$485	$2,470	$17,146	6.9
LI_7K	FL303: FL 2X4 2F25ST8 ELC2 REF (FIX REPL	431	126,314	23	$9,375	−31	−$282	$1,527	$10,620	$50,694	4.8
LI_7L	FL304: FL 2X4 3F25ST8 ELC3 REF	4,269	1,251,120	156	$84,278	2,397	$–	$23,631	$107,909	$675,395	6.3
LI_8A	FL309: FL 2X3 6F40BX ELC2 REF	800	234,457	−62	$22,112	−228	−$2,070	$8,002	$28,044	$250,747	8.9
LI_8B	FL309: FL 2X3 6F40BX ELC2 REF	871	255,265	−61	$22,804	−246	−$2,235	$6,263	$26,832	$213,236	7.9
LI_9A	FL54: FL 2X2 2F32T8U ELC2	241	70,630	−17	$5,962	−16	−145	$4,599	$10,416	$92,121	8.8
REN #1	Shower gray water heat recovery	0			0	368	$3,343		$3,343	18,000	5.4
Total			*64,625,864*	*4,638*	*$5,858,094*	*170,023*	*$1,482,583*	*$551,695*	*$7,982,377*	*$24,025,817*	*3.0*

Appendix B: Affected Buildings, Listed by ECMs

Table B1. Affected buildings, by Building Envelope ECM.

ECM	Buildings Affected
BE_4A	11108, 11202, 11304
BE_4B	616, 620, 639, 618, 641, 627, 629, 631, 632, 611
BE_4C	622, 624, 614
BE_4D	59, 299, 505, 617, 744, 751, 772, 1016, 1017, 1022, 1023, 1025, 1026, 1029, 1030, 1031, 1045, 1091, 1095, 1658, 1660, 1771, 1871, 2400, 2401, 2402, 2403, 2404, 2405, 2406, 2407, 2409, 2415, 2422, 2432, 2436, 2437, 2438, 2439, 2440, 2441, 2453, 2454, 2470, 2481, 2492, 2493, 2497, 2525, 2601, 2602, 2605, 2606, 2608, 2627, 2636, 2910, 2911, 2912, 2913, 2914, 2915, 2916, 2917, 2918, 2919, 2920, 2938, 2939, 2947, 2967, 3600, 3671, 3679, 3688, 5271, 5801, 5810, 5811, 5848, 5849, 5850, 5854, 5859, 5863, 5864, 5880, 5898, 6907, 11000, 11141, 11143, 11148, 11176, 11210, 11274, 11276, 11306, 11518, 11520, 5352G, 5447G, 5448G, 5452G, 5453G, 5454G
BE_4E	60, 777, 1001, 1009, 2446, 2494, 6380
BE_4F	1079, 1083, 1320, 1321, 1872, 2071, 2465, 2486, 2612, 2613, 2617, 2625, 2633, 2641, 2655, 2999, 3720, 3791, 5395, 5401, 5402, 5411, 5471, 5894, 6901, 6917, 7782, 11009, 11027, 11032, 11041, 11053, 11056, 11060, 11112, 11181, 11235, 11242, 11243, 11244, 11245, 11286, 11287, 11288, 11289, 11303, 11322, 11556, 1060G, 5096G, 5308G, 5309G, 5317G, 5318G, 5319G, 5320G, 5449G
BE_4G	11055, 11291, 11293, 11294
BE_4H	2
BE_4I	45, 46, 49, 2496, 2954, 6077, 7124, 7136, 7166, 7167, 7304, 7360, 11519
BE_4J	1002, 1005, 1006, 1010, 1011, 1012, 1013, 1014, 2416, 2417, 2419, 2442
BE_4K	1003, 1004, 1007, 2418, 2420, 2447, 2904, 2905
BE_4L	2414, 2421, 2444, 2445, 2449, 2450, 2471, 2476, 2480
BE_4M	1008, 2410, 2411, 2412, 2413, 2448, 2452, 2472, 2473, 2474, 2475, 2477, 2478, 2479, 2901, 2902, 2903
BE_4N	213, 220, 223, 628, 633, 7157, 7158, 7159, 11144, 11147, 11150, 11151, 11152, 11153, 11285, 11354
BE_4O	5023, 5039, 5040, 5041, 5042, 5043, 5044, 5045
BE_4P	243, 5015, 5016, 5017, 5018, 5019, 5020, 7309, 11174, 11175, 11265, 11266, 11332, 11340
BE_4Q	2592
BE_4R	906, 2457, 11199
BE_4S	53, 199, 253, 315, 448, 452, 649, 650, 1126, 1128, 1441, 1542, 1742, 1983, 2009, 2010, 2014, 2498, 2968, 3005, 3006, 3095, 3192, 3512, 3514, 3619, 3631, 3734, 4130, 4131, 4132, 5051, 5052, 5053, 5054, 5055, 5312, 5363, 5815, 5839, 5847, 5891, 6921, 6925, 7134, 7155, 7289, 11214, 11275, 11283, 11331, 11338, 11380, 11388, 11389, 11392, 11404, 5322G, 5450G
BE_4T	311, 2495, 7152, 11292
BE_4U	11108, 11202, 11304
BE_5A	1079, 1083, 1320, 1321, 1872, 2071, 2465, 2486, 2612, 2613, 2617, 2625, 2633, 2641, 2655, 2999, 3720, 3791, 5395, 5401, 5402, 5411, 5471, 5894, 6901, 6917, 7782, 11009, 11027, 11032, 11041, 11053, 11056, 11060, 11112, 11181, 11235, 11242, 11243, 11244, 11
BE_5B	1547, 1730, 2042, 2043, 2607, 2615, 2638, 3500, 3621, 4100, 5400, 5808, 6908, 6909, 6918, 6919, 6920, 6926, 6928, 6949, 11068, 11305, 11307, 1033A, 1033B, 1034A, 1034B, 1036A, 1036B, 5323G, 5328G, 5329G, 5354G, 5355G, 5433G, 5446G, 5456G, A0401, A0402, A0
BE_5C	11108, 11202, 11304
BE_5D	4, 8, 9, 11, 12, 13, 15, 19, 48, 50, 51, 55, 111, 112, 113, 114, 115, 117, 118, 122, 123, 128, 241, 251, 273, 440, 442, 443, 444, 449, 450, 451, 762, 801, 1480, 2004, 2021, 2637, 3654, 7000, 7113, 7125, 7137, 7151, 7175, 11169, 11240, 11301
BE_5E	56, 58, 724, 725, 730, 1043, 1044, 1093, 2950, 2951, 2952, 2953, 3390, 3693, 3785, 5800, 5838, 5843, 5853, 5855, 5865, 5867, 6905, 11007, 11107, 11115, 11205, 11236, 11269
BE_5F	616, 620, 639, 618, 641, 627, 629, 631, 632, 611

ECM	Buildings Affected
BE_5G	4, 8, 9, 11, 12, 13, 15, 19, 48, 50, 51, 55, 111, 112, 113, 114, 115, 117, 118, 122, 123, 128, 241, 251, 273, 440, 442, 443, 444, 449, 450, 451, 762, 801, 1480, 2004, 2021, 2637, 3654, 7000, 7113, 7125, 7137, 7151, 7175, 11169, 11240, 11301
BE_5H	622, 624, 614
BE_5I	54, 116, 125, 127, 198, 250, 1015, 1109, 1110, 1456, 1610, 1724, 1743, 2011, 2408, 2433, 2969, 2996, 4116, 5095, 7162, 7311, 10020, 11131, 11142, 11211, 11284
BE_5J	53, 199, 253, 315, 448, 452, 649, 650, 1126, 1128, 1441, 1542, 1742, 1983, 2009, 2010, 2014, 2498, 2968, 3005, 3006, 3095, 3192, 3512, 3514, 3619, 3631, 3734, 4130, 4131, 4132, 5051, 5052, 5053, 5054, 5055, 5312, 5363, 5815, 5839, 5847, 5891, 6921, 6925,
BE_5K	311, 2495, 7152, 11292
BE_5L	60, 777, 1001, 1009, 2446, 2494, 6380
BE_5M	2414, 2421, 2444, 2445, 2449, 2450, 2471, 2476, 2480
BE_5N	1008, 2410, 2411, 2412, 2413, 2448, 2452, 2472, 2473, 2474, 2475, 2477, 2478, 2479, 2901, 2902, 2903
BE_5O	7777, 7776, 7779, 7781
BE_5P	59, 299, 505, 617, 744, 751, 772, 1016, 1017, 1022, 1023, 1025, 1026, 1029, 1030, 1031, 1045, 1091, 1095, 1658, 1660, 1771, 1871, 2400, 2401, 2402, 2403, 2404, 2405, 2406, 2407, 2409, 2415, 2422, 2432, 2436, 2437, 2438, 2439, 2440, 2441, 2453, 2454, 2470,
BE_5Q	11055, 11291, 11293, 11294
BE_5R	45, 46, 49, 2496, 2954, 6077, 7124, 7136, 7166, 7167, 7304, 7360, 11519
BE_5S	28, 447, 615, 690, 907, 1252, 1330, 1364, 1998, 2451, 2464, 2491, 2509, 2595, 2598, 2620, 2634, 2642, 2654, 2656, 2931, 2932, 2940, 2941, 2942, 2956, 2961, 2962, 2970, 2971, 2984, 2990, 2994, 3002, 3004, 3007, 3196, 3636, 3655, 3661, 3662, 3699, 3795, 410
BE_5T	906, 2457, 11199
BE_5U	2
BE_6A	622, 624, 614
BE_6B	59, 299, 505, 617, 744, 751, 772, 1016, 1017, 1022, 1023, 1025, 1026, 1029, 1030, 1031, 1045, 1091, 1095, 1658, 1660, 1771, 1871, 2400, 2401, 2402, 2403, 2404, 2405, 2406, 2407, 2409, 2415, 2422, 2432, 2436, 2437, 2438, 2439, 2440, 2441, 2453, 2454, 2470
BE_6C	60, 777, 1001, 1009, 2446, 2494, 6380
BE_6D	1079, 1083, 1320, 1321, 1872, 2071, 2465, 2486, 2612, 2613, 2617, 2625, 2633, 2641, 2655, 2999, 3720, 3791, 5395, 5401, 5402, 5411, 5471, 5894, 6901, 6917, 7782, 11009, 11027, 11032, 11041, 11053, 11056, 11060, 11112, 11181, 11235, 11242, 11243, 11244, 11
BE_6E	2
BE_6F	45, 46, 49, 2496, 2954, 6077, 7124, 7136, 7166, 7167, 7304, 7360, 11519
BE_6G	5, 242, 248, 275, 612, 613, 645, 651, 888, 889, 890, 1125, 1127, 1177, 1178, 1179, 1180, 1181, 1270, 1271, 1273, 1275, 1276, 1277, 1278, 1279, 1361, 2019, 2020, 2022, 5358, 7133, 7139, 7178, 11121, 11200, 11220, 11225
BE_6H	21, 1101, 1102, 1103, 1104, 1105, 1106, 1107, 1108, 1111, 1112, 1113, 1114, 1115, 1116, 1117, 1119, 1120, 1121, 1122, 1123, 1124, 11005, 11116
BE_6I	619, 623, 644, 721, 735, 749, 750, 771, 1077, 1078, 1087, 1088, 1096, 1097, 1099, 1249, 1726, 1727, 1728, 1729, 1731, 1732, 2034, 2320, 2321, 2322, 2323, 2330, 2331, 2332, 2333, 2340, 2341, 2342, 2343, 2350, 2351, 2352, 2353, 2460, 2467, 2482, 2490, 2527,
BE_6J	11108, 11202, 11304
BE_7A	622, 624, 614
BE_7B	59, 299, 505, 617, 744, 751, 772, 1016, 1017, 1022, 1023, 1025, 1026, 1029, 1030, 1031, 1045, 1091, 1095, 1658, 1660, 1771, 1871, 2400, 2401, 2402, 2403, 2404, 2405, 2406, 2407, 2409, 2415, 2422, 2432, 2436, 2437, 2438, 2439, 2440, 2441, 2453, 2454, 2470,
BE_7C	2
BE_7D	45, 46, 49, 2496, 2954, 6077, 7124, 7136, 7166, 7167, 7304, 7360, 11519
BE_7E	2414, 2421, 2444, 2445, 2449, 2450, 2471, 2476, 2480
BE_7F	1008, 2410, 2411, 2412, 2413, 2448, 2452, 2472, 2473, 2474, 2475, 2477, 2478, 2479, 2901, 2902, 2903

Table B2. Affected buildings, by HVAC ECM.

ECM	Buildings Affected
HV_5A	11055, 11291, 11293, 11294
HV_5B	1735, 2930, 2949
HV_5C	2457, 11199
HV_6A	622, 624, 614
HV_6B	906, 2457, 11199
HV_6C	195, 635, 756, 820, 1301, 2499, 3191, 3508, 3730, 4797, 5035, 7061, 7153, 11251
HV_6D	1735, 2930, 2949
HV_7A	45, 46, 49, 2496, 2954, 6077, 7124, 7136, 7166, 7167, 7304, 7360, 11519
HV_7B	45, 46, 49, 2496, 2954, 6077, 7124, 7136, 7166, 7167, 7304, 7360, 11519
HV_8A	2
HV_8B	777
HV_8C	60, 1001, 1009, 2446, 2494, 6380
HV_8D	5023, 5039, 5040, 5041, 5042, 5043, 5044, 5045
HV_8E	1002, 1005, 1006, 1010, 1011, 1012, 1013, 1014, 2416, 2417, 2419, 2442
HV_8F	1003, 1004, 1007, 2418, 2420, 2447, 2904, 2905
HV_8G	2414, 2421, 2444, 2445, 2449, 2450, 2471, 2476, 2480
HV_8H	1008, 2410, 2411, 2412, 2413, 2448, 2452, 2472, 2473, 2474, 2475, 2477, 2478, 2479, 2901, 2902, 2903
HV_8I	243, 5015, 5016, 5017, 5018, 5019, 5020, 7309, 11174, 11175, 11265, 11266, 11332, 11340
HV_9A	56, 58, 724, 725, 730, 1043, 1044, 1093, 2950, 2951, 2952, 2953, 3390, 3693, 3785, 5800, 5838, 5843, 5853, 5855, 5865, 5867, 6905, 11007, 11107, 11115, 11205, 11236, 11269
HV_9B	59, 299, 505, 617, 744, 751, 772, 1016, 1017, 1022, 1023, 1025, 1026, 1029, 1030, 1031, 1045, 1091, 1095, 1658, 1660, 1771, 1871, 2400, 2401, 2402, 2403, 2404, 2405, 2406, 2407, 2409, 2415, 2422, 2432, 2436, 2437, 2438, 2439, 2440, 2441, 2453, 2454, 2470,
HV_9C	1547, 1730, 2042, 2043, 2607, 2615, 2638, 3500, 3621, 4100, 5400, 5808, 6908, 6909, 6918, 6919, 6920, 6926, 6928, 6949, 11068, 11305, 11307, 1033A, 1033B, 1034A, 1034B, 1036A, 1036B, 5323G, 5328G, 5329G, 5354G, 5355G, 5433G, 5446G, 5456G, A0401, A0402, A0
HV_9D	11055, 11291, 11293, 11294
HV_9E	28, 447, 615, 690, 907, 1252, 1330, 1364, 1998, 2451, 2464, 2491, 2509, 2595, 2598, 2620, 2634, 2642, 2654, 2656, 2931, 2932, 2940, 2941, 2942, 2956, 2961, 2962, 2970, 2971, 2984, 2990, 2994, 3002, 3004, 3007, 3196, 3636, 3655, 3661, 3662, 3699, 3795, 410
HV_9F	2462, 2466, 2484, 2488, 2624, 2629, 2643
HV_9G	2592
HV_9H	906, 2457, 11199
HV_9I	1735, 2930, 2949
HV_9J	311, 2495, 7152, 11292
HV_9K	1, 500, 503, 504, 512, 515, 516, 7115
HV_9L	54, 116, 125, 127, 198, 250, 1015, 1109, 1110, 1456, 1610, 1724, 1743, 2011, 2408, 2433, 2969, 2996, 4116, 5095, 7162, 7311, 10020, 11131, 11142, 11211, 11284
HV_9M	4, 8, 9, 11, 12, 13, 15, 19, 48, 50, 51, 55, 111, 112, 113, 114, 115, 117, 118, 122, 123, 128, 241, 251, 273, 440, 442, 443, 444, 449, 450, 451, 762, 801, 1480, 2004, 2021, 2637, 3654, 7000, 7113, 7125, 7137, 7151, 7175, 11169, 11240, 11301
HV_9N	616, 620, 639, 618, 641, 627, 629, 631, 632, 611
HV_9O	622, 624, 614
HV_9P	5, 242, 248, 275, 612, 613, 645, 651, 888, 889, 890, 1125, 1127, 1177, 1178, 1179, 1180, 1181, 1270, 1271, 1273, 1275, 1276, 1277, 1278, 1279, 1361, 2019, 2020, 2022, 5358, 7133, 7139, 7178, 11121, 11200, 11220, 11225
HV_9Q	21, 1101, 1102, 1103, 1104, 1105, 1106, 1107, 1108, 1111, 1112, 1113, 1114, 1115, 1116, 1117, 1119, 1120, 1121, 1122, 1123, 1124, 11005, 11116
HV_9R	736, 737, 741, 742, 748, 1018, 1046, 1063, 1069, 1070, 1071, 1085, 1090, 1170, 1319, 1780, 1798, 2033, 2427, 2431, 2599, 2660, 2673, 3659, 3695, 3696, 3697, 3698, 3700, 3796, 3797, 3798, 4318, 5885, 6915, 6951, 6960, 7094, 7142, 7177, 7181, 7242, 11006, 1

ECM	Buildings Affected
HV_9S	720, 722, 723, 738, 739, 740, 743, 745, 746, 747, 754, 755, 769, 1080, 1081, 1082, 1092, 1094, 1118, 1250, 1334, 1336, 1656, 2588, 3672
HV_9T	11108, 11202, 11304
HV_9U	53, 199, 253, 315, 448, 452, 649, 650, 1126, 1128, 1441, 1542, 1742, 1983, 2009, 2010, 2014, 2498, 2968, 3005, 3006, 3095, 3192, 3512, 3514, 3619, 3631, 3734, 4130, 4131, 4132, 5051, 5052, 5053, 5054, 5055, 5312, 5363, 5815, 5839, 5847, 5891, 6921, 6925,
HV_9V	7777, 7776, 7779, 7781
HV_9W	900, 909, 919, 1744, 7060, 11345
HV_9X	45, 46, 49, 2496, 2954, 6077, 7124, 7136, 7166, 7167, 7304, 7360, 11519
HV_9Y	213, 220, 223, 628, 633, 7157, 7158, 7159, 11144, 11147, 11150, 11151, 11152, 11153, 11285, 11354
HV_9Z	195, 635, 756, 820, 1301, 2499, 3191, 3508, 3730, 4797, 5035, 7061, 7153, 11251

Table B3. Affected buildings, by Lighting ECMs.

ECM	Buildings Affected
LI_3A	5023, 5039, 5040, 5041, 5042, 5043, 5044, 5045
LI_3B	243, 5015, 5016, 5017, 5018, 5019, 5020, 7309, 11174, 11175, 11265, 11266, 11332, 11340
LI_3C	619, 623, 644, 721, 735, 749, 750, 771, 1077, 1078, 1087, 1088, 1096, 1097, 1099, 1249, 1726, 1727, 1728, 1729, 1731, 1732, 2034, 2320, 2321, 2322, 2323, 2330, 2331, 2332, 2333, 2340, 2341, 2342, 2343, 2350, 2351, 2352, 2353, 2460, 2467, 2482, 2490, 2527,
LI_3D	906, 2457, 11199
LI_3E	4, 8, 9, 11, 12, 13, 15, 19, 48, 50, 51, 55, 111, 112, 113, 114, 115, 117, 118, 122, 123, 128, 241, 251, 273, 440, 442, 443, 444, 449, 450, 451, 762, 801, 1480, 2004, 2021, 2637, 3654, 7000, 7113, 7125, 7137, 7151, 7175, 11169, 11240, 11301
LI_3F	720, 722, 723, 738, 739, 740, 743, 745, 746, 747, 754, 755, 769, 1080, 1081, 1082, 1092, 1094, 1118, 1250, 1334, 1336, 1656, 2588, 3672
LI_4A	56, 58, 724, 725, 730, 1043, 1044, 1093, 2950, 2951, 2952, 2953, 3390, 3693, 3785, 5800, 5838, 5843, 5853, 5855, 5865, 5867, 6905, 11007, 11107, 11115, 11205, 11236, 11269
LI_4B	4, 8, 9, 11, 12, 13, 15, 19, 48, 50, 51, 55, 111, 112, 113, 114, 115, 117, 118, 122, 123, 128, 241, 251, 273, 440, 442, 443, 444, 449, 450, 451, 762, 801, 1480, 2004, 2021, 2637, 3654, 7000, 7113, 7125, 7137, 7151, 7175, 11169, 11240, 11301
LI_4C	616, 620, 639, 618, 641, 627, 629, 631, 632, 611
LI_4D	622, 624, 614
LI_4E	1, 500, 503, 504, 512, 515, 516, 7115
LI_4F	59, 299, 505, 617, 744, 751, 772, 1016, 1017, 1022, 1023, 1025, 1026, 1029, 1030, 1031, 1045, 1091, 1095, 1658, 1660, 1771, 1871, 2400, 2401, 2402, 2403, 2404, 2405, 2406, 2407, 2409, 2415, 2422, 2432, 2436, 2437, 2438, 2439, 2440, 2441, 2453, 2454, 2470,
LI_4G	60, 777, 1001, 1009, 2446, 2494, 6380
LI_4H	1079, 1083, 1320, 1321, 1872, 2071, 2465, 2486, 2612, 2613, 2617, 2625, 2633, 2641, 2655, 2999, 3720, 3791, 5395, 5401, 5402, 5411, 5471, 5894, 6901, 6917, 7782, 11009, 11027, 11032, 11041, 11053, 11056, 11060, 11112, 11181, 11235, 11242, 11243, 11244, 11
LI_4I	1547, 1730, 2042, 2043, 2607, 2615, 2638, 3500, 3621, 4100, 5400, 5808, 6908, 6909, 6918, 6919, 6920, 6926, 6928, 6949, 11068, 11305, 11307, 1033A, 1033B, 1034A, 1034B, 1036A, 1036B, 5323G, 5328G, 5329G, 5354G, 5355G, 5433G, 5446G, 5456G, A0401, A0402, A0
LI_4J	11055, 11291, 11293, 11294
LI_4K	2
LI_4L	45, 46, 49, 2496, 2954, 6077, 7124, 7136, 7166, 7167, 7304, 7360, 11519
LI_4M	7777, 7776, 7779, 7781
LI_4N	1002, 1005, 1006, 1010, 1011, 1012, 1013, 1014, 2416, 2417, 2419, 2442
LI_4O	1003, 1004, 1007, 2418, 2420, 2447, 2904, 2905
LI_4P	2414, 2421, 2444, 2445, 2449, 2450, 2471, 2476, 2480
LI_4Q	1008, 2410, 2411, 2412, 2413, 2448, 2452, 2472, 2473, 2474, 2475, 2477, 2478, 2479, 2901, 2902, 2903
LI_4R	213, 220, 223, 628, 633, 7157, 7158, 7159, 11144, 11147, 11150, 11151, 11152, 11153, 11285, 11354
LI_4S	5023, 5039, 5040, 5041, 5042, 5043, 5044, 5045
LI_4T	243, 5015, 5016, 5017, 5018, 5019, 5020, 7309, 11174, 11175, 11265, 11266, 11332, 11340
LI_4U	900, 909, 919, 1744, 7060, 11345

ECM	Buildings Affected
LI_4V	5, 242, 248, 275, 612, 613, 645, 651, 888, 889, 890, 1125, 1127, 1177, 1178, 1179, 1180, 1181, 1270, 1271, 1273, 1275, 1276, 1277, 1278, 1279, 1361, 2019, 2020, 2022, 5358, 7133, 7139, 7178, 11121, 11200, 11220, 11225
LI_4W	21, 1101, 1102, 1103, 1104, 1105, 1106, 1107, 1108, 1111, 1112, 1113, 1114, 1115, 1116, 1117, 1119, 1120, 1121, 1122, 1123, 1124, 11005, 11116
LI_4X	619, 623, 644, 721, 735, 749, 750, 771, 1077, 1078, 1087, 1088, 1096, 1097, 1099, 1249, 1726, 1727, 1728, 1729, 1731, 1732, 2034, 2320, 2321, 2322, 2323, 2330, 2331, 2332, 2333, 2340, 2341, 2342, 2343, 2350, 2351, 2352, 2353, 2460, 2467, 2482, 2490, 2527,
LI_4Y	590, 591, 592, 593, 594, 595, 596, 597, 598, 1048, 1058, 1065, 1075, 1235, 1251, 2425, 2430, 2461, 2483, 2515, 2517, 2590, 2623, 2630, 2640, 2658, 2665, 2671, 2678, 2684, 2935, 2945, 2965, 2975, 2982, 2992, 3664, 3673, 5813, 11105, 11186, 11500, 11505, 11
LI_4Z	736, 737, 741, 742, 748, 1018, 1046, 1063, 1069, 1070, 1071, 1085, 1090, 1170, 1319, 1780, 1798, 2033, 2427, 2431, 2599, 2660, 2673, 3659, 3695, 3696, 3697, 3698, 3700, 3796, 3797, 3798, 4318, 5885, 6915, 6951, 6960, 7094, 7142, 7177, 7181, 7242, 11006, 1
LI_4AA	720, 722, 723, 738, 739, 740, 743, 745, 746, 747, 754, 755, 769, 1080, 1081, 1082, 1092, 1094, 1118, 1250, 1334, 1336, 1656, 2588, 3672
LI_4AB	28, 447, 615, 690, 907, 1252, 1330, 1364, 1998, 2451, 2464, 2491, 2509, 2595, 2598, 2620, 2634, 2642, 2654, 2656, 2931, 2932, 2940, 2941, 2942, 2956, 2961, 2962, 2970, 2971, 2984, 2990, 2994, 3002, 3004, 3007, 3196, 3636, 3655, 3661, 3662, 3699, 3795, 410
LI_4AC	2462, 2466, 2484, 2488, 2624, 2629, 2643
LI_4AD	2592
LI_4AE	11108, 11202, 11304
LI_4AF	54, 116, 125, 127, 198, 250, 1015, 1109, 1110, 1456, 1610, 1724, 1743, 2011, 2408, 2433, 2969, 2996, 4116, 5095, 7162, 7311, 10020, 11131, 11142, 11211, 11284
LI_4AG	906, 2457, 11199
LI_4AH	53, 199, 253, 315, 448, 452, 649, 650, 1126, 1128, 1441, 1542, 1742, 1983, 2009, 2010, 2014, 2498, 2968, 3005, 3006, 3095, 3192, 3512, 3514, 3619, 3631, 3734, 4130, 4131, 4132, 5051, 5052, 5053, 5054, 5055, 5312, 5363, 5815, 5839, 5847, 5891, 6921, 6925,
LI_4AI	195, 635, 756, 820, 1301, 2499, 3191, 3508, 3730, 4797, 5035, 7061, 7153, 11251
LI_4AJ	1735, 2930, 2949
LI_4AK	311, 2495, 7152, 11292
LI_5A	5, 242, 248, 275, 612, 613, 645, 651, 888, 889, 890, 1125, 1127, 1177, 1178, 1179, 1180, 1181, 1270, 1271, 1273, 1275, 1276, 1277, 1278, 1279, 1361, 2019, 2020, 2022, 5358, 7133, 7139, 7178, 11121, 11200, 11220, 11225
LI_5B	21, 1101, 1102, 1103, 1104, 1105, 1106, 1107, 1108, 1111, 1112, 1113, 1114, 1115, 1116, 1117, 1119, 1120, 1121, 1122, 1123, 1124, 11005, 11116
LI_5C	736, 737, 741, 742, 748, 1018, 1046, 1063, 1069, 1070, 1071, 1085, 1090, 1170, 1319, 1780, 1798, 2033, 2427, 2431, 2599, 2660, 2673, 3659, 3695, 3696, 3697, 3698, 3700, 3796, 3797, 3798, 4318, 5885, 6915, 6951, 6960, 7094, 7142, 7177, 7181, 7242, 11006, 1
LI_6A	56, 58, 724, 725, 730, 1043, 1044, 1093, 2950, 2951, 2952, 2953, 3390, 3693, 3785, 5800, 5838, 5843, 5853, 5855, 5865, 5867, 6905, 11007, 11107, 11115, 11205, 11236, 11269
LI_6B	616, 620, 639, 618, 641, 627, 629, 631, 632, 611
LI_6C	622, 624, 614
LI_6D	59, 299, 505, 617, 744, 751, 772, 1016, 1017, 1022, 1023, 1025, 1026, 1029, 1030, 1031, 1045, 1091, 1095, 1658, 1660, 1771, 1871, 2400, 2401, 2402, 2403, 2404, 2405, 2406, 2407, 2409, 2415, 2422, 2432, 2436, 2437, 2438, 2439, 2440, 2441, 2453, 2454, 2470,
LI_6E	45, 46, 49, 2496, 2954, 6077, 7124, 7136, 7166, 7167, 7304, 7360, 11519
LI_6F	7777
LI_6G	1002, 1005, 1006, 1010, 1011, 1012, 1013, 1014, 2416, 2417, 2419, 2442
LI_6H	1003, 1004, 1007, 2418, 2420, 2447, 2904, 2905
LI_6I	2414, 2421, 2444, 2445, 2449, 2450, 2471, 2476, 2480
LI_6J	1008, 2410, 2411, 2412, 2413, 2448, 2452, 2472, 2473, 2474, 2475, 2477, 2478, 2479, 2901, 2902, 2903
LI_6K	900, 909, 919, 1744, 7060, 11345
LI_6L	21, 1101, 1102, 1103, 1104, 1105, 1106, 1107, 1108, 1111, 1112, 1113, 1114, 1115, 1116, 1117, 1119, 1120, 1121, 1122, 1123, 1124, 11005, 11116
LI_6M	11108, 11202, 11304

ECM	Buildings Affected
LI_6N	53, 199, 253, 315, 448, 452, 649, 650, 1126, 1128, 1441, 1542, 1742, 1983, 2009, 2010, 2014, 2498, 2968, 3005, 3006, 3095, 3192, 3512, 3514, 3619, 3631, 3734, 4130, 4131, 4132, 5051, 5052, 5053, 5054, 5055, 5312, 5363, 5815, 5839, 5847, 5891, 6921, 6925,
LI_6O	195, 635, 756, 820, 1301, 2499, 3191, 3508, 3730, 4797, 5035, 7061, 7153, 11251
LI_6P	1735, 2930, 2949
LI_6Q	311, 2495, 7152, 11292
LI_7A	4, 8, 9, 11, 12, 13, 15, 19, 48, 50, 51, 55, 111, 112, 113, 114, 115, 117, 118, 122, 123, 128, 241, 251, 273, 440, 442, 443, 444, 449, 450, 451, 762, 801, 1480, 2004, 2021, 2637, 3654, 7000, 7113, 7125, 7137, 7151, 7175, 11169, 11240, 11301
LI_7B	1, 500, 503, 504, 512, 515, 516, 7115
LI_7C	60, 777, 1001, 1009, 2446, 2494, 6380
LI_7D	21, 1101, 1102, 1103, 1104, 1105, 1106, 1107, 1108, 1111, 1112, 1113, 1114, 1115, 1116, 1117, 1119, 1120, 1121, 1122, 1123, 1124, 11005, 11116
LI_7E	2592
LI_7F	11108, 11202, 11304
LI_7G	2
LI_7H	5, 242, 248, 275, 612, 613, 645, 651, 888, 889, 890, 1125, 1127, 1177, 1178, 1179, 1180, 1181, 1270, 1271, 1273, 1275, 1276, 1277, 1278, 1279, 1361, 2019, 2020, 2022, 5358, 7133, 7139, 7178, 11121, 11200, 11220, 11225
LI_7I	1079, 1083, 1320, 1321, 1872, 2071, 2465, 2486, 2612, 2613, 2617, 2625, 2633, 2641, 2655, 2999, 3720, 3791, 5395, 5401, 5402, 5411, 5471, 5894, 6901, 6917, 7782, 11009, 11027, 11032, 11041, 11053, 11056, 11060, 11112, 11181, 11235, 11242, 11243, 11244, 11
LI_7J	2592
LI_7K	906, 2457, 11199
LI_7L	7777, 7776, 7779, 7781
LI_8A	2462, 2466, 2484, 2488, 2624, 2629, 2643
LI_8B	11108, 11202, 11304
LI_9A	906, 2457, 11199

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14. ABSTRACT

An Energy Optimization Assessment was conducted at Fort Bliss as a part of the “Annex 46 Holistic Assessment Toolkit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo)” initiative to identify energy inefficiencies and wastes and propose energy related projects with applicable funding and execution methods that could enable the installation to better meet the energy reduction requirements mandated by Executive Order 13123 and Energy Policy Act (EPAct) 2005. The assessment included a Level I study of energy conservation opportunities in a number of representative buildings including an analysis of their building envelopes, ventilation air systems, controls, interior and exterior lighting as well as opportunities to use renewable energy resources. The Annex 46 initiative at Fort Bliss did not include the evaluation of industrial or manufacturing processes. The study identified 210 different energy conservation measures (ECMs) that if implemented would reduce Fort Bliss's annual energy use by up to 65 MWH/yr electric and 170,023 MMBtu/yr thermal savings (mostly natural gas). Savings of $552K/yr in maintenance costs were also identified. The total energy and maintenance savings would be $7.9 million/yr. An investment of $23.4 million to implement the ECMs results in a simple payback of 3 yrs. These ECMs are presented in nine groups according to the system type that the ECM affects.

15. SUBJECT TERMS
energy efficient
Fort Bliss, TX
energy conservation utilities
Annex 46

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