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An Evaluation of the Fort Polk Energy Savings Performance Contract

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ABSTRACT

The U.S. Army, in cooperation with an energy services company (ESCO), used private capital to retrofit 4,003 family housing units on the Fort Polk, Louisiana, military base with geothermal heat pumps (GHPs). The project was performed under an energy savings performance contract (ESPC) that provides for the Army and the ESCO to share the cost savings realized through the energy retrofit over the 20-year life of the contract. Under the terms of the contract, the ESCO is responsible for maintaining the GHPs and provides ongoing measurement and verification (M&V) to assure cost and energy savings to the Army. An independent evaluation conducted by the Department of Energy's Oak Ridge National Laboratory indicates that the GHP systems in combination with other energy retrofit measures have reduced annual whole-community electrical consumption by 33%, and natural gas consumption by 100%. These energy savings correspond to an estimated reduction in CO_2 emissions of 22,400 tons per year. Peak electrical demand has been reduced by 43%. The electrical energy and demand savings correspond to an improvement in the whole-community annual electric load factor from 0.52 to 0.62. As a result of the project, Fort Polk saves about $450,000 annually and benefits from complete renewal of the major energy consuming systems in family housing and maintenance of those systems for 20 years. Given the magnitude of the project, the cost and energy savings achieved, and the lessons learned during its design and implementation, the Fort Polk ESPC can provide a model for other housing-related energy savings performance contracts in both the public and private sectors.

Introduction

The Fort Polk Joint Readiness Training Center is a 200,000-acre facility in west-central Louisiana containing military offices, training centers, warehouses, a hospital, and housing for some 15,000 service members and their families. About 12,000 people live in Fort Polk family housing, which consists of 4,003 living units in 1,290 buildings. Family housing had been constructed in nine phases between 1972 and 1988 and as is often the case with conventional bid-from-spec government procurement, the installed space conditioning equipment was a mixture of minimum-efficiency models selected on low-bid and often misapplied in terms of sizing and quality of installation. In the face of rising maintenance requests, the base had been out-sourcing family housing maintenance to a series of private service contractors on a low-bid basis. For the most part, the experience with these contractors was less than satisfactory. Frequent service calls and the difficulty of stocking parts and training technicians for the hodge-podge of units overwhelmed the budgets of a succession of contractors, and the net result was poor service for the residents and financial diffficulties for some contractors. By the early 1990's all of these problems had become critical. A survey of maintenance records from the last year prior to retrofit (Shonder & Hughes, 1997a) indicated that in the worst month, July, there were about 90 service calls per day on average and over 100 on the worst days.

The deficit reduction mood in Congress meant that Fort Polk's $13 million annual energy budget (of which family housing accounted for a 40% share, and rising) would be flat at best, and any energy cost growth would have to come out of training or salary dollars. Further, the financial distress of the service contractors was clear evidence that the base would have to find more money to spend on maintenance if something wasn't done.

All of these factors led the base to consider the use of a shared energy savings contract, where the contractor would provide the financing and assume responsibility for the maintenance. Fort Polk paid a fee to the Army Corp of Engineers-Huntsville, the Army's Center of Excellence for performance contracting, to determine project feasibility, develop an RFP, solicit bids, support negotiations, award the contract, and provide support during implementation. The RFP conveyed Fort Polk's preference for GHPs but allowed offerors to propose optional systems. The RFP also encouraged proposals to include other energy cost saving measures. The winning proposal, the only one received, was centered on GHPs.

Installed Equipment

Before the retrofits, about 80% of the residences in Fort Polk's family housing were served by air-source heat pumps and electric water heaters, with the remaining 20% using central air conditioning and gas-fired forced-air furnaces. The residences with gas heat also had gas-fired water heaters. The ESCO replaced all existing heating and cooling equipment with geothermal heat pumps in sizes of 1.5, 2, and 2.5 nominal tons depending on the load, with one heat pump per living unit. A total capacity of 6593 tons was installed, an average of about 1.65 tons per residence. By the time crews installed the last of the heat pumps at the end of summer 1996, they had drilled a total of 1.8 million feet of 4-1/8-inch bore and had installed 3.6 million feet of 1-inch SDR-11 high-density polyethylene pipe—about 686 miles' worth—in the bores, which were backfilled with standard bentonite-based grout. Each of the 4,003 GHPs has its own ground heat exchanger, consisting of two vertical, U-shaped pipe loops placed in separate bore holes and connected in parallel. The average for the entire project was 275 bore feet per ton of installed capacity. Common loop systems were considered for the multiple-family residences, but the difficulty of installing a common header and associated controls in existing buildings made it more feasible to install one loop per apartment.

In order to standardize the equipment which would have to be maintained in the future, the gas-fired water heaters were replaced with electric units. Residences served by natural gas represented the oldest housing at the facility, and many of the water heaters were thought to be nearing the end of their service life. Seventy-five percent of the new heat pumps utilize desuperheaters, which recover waste heat from the GHPs when they run for heating or cooling, and transfer it to the water heater. In the other 25% of the living units, the heat pumps and water heaters were too far apart to make desuperheater installation practical. Other retrofits included additional attic insulation (where needed), low-flow shower heads, and compact fluorescent lights. Weather-stripping and storm windows were not installed because the housing units were already fairly tight and the potential energy savings did not justify the additional investment. So, too, with duct sealing work, except in cases where there were leaks large enough to cause serious performance or comfort problems.

Engineering the Project

Developing models of energy consumption and performing design calculations to size heat pumps and ground heat exchangers for 4,003 apartments, engineering the other retrofits for each apartment, and estimating overall energy savings, represented a major undertaking. However, unlike most private housing, military family housing is centrally managed and existing technical records and plan vaults enable economies of scale in the engineering of retrofits. In this project the archived information enabled the identification of 64 unique "building block" housing units that describe the entire housing population. All housing units represented by the same "building block" are identical from the point of view of heating and cooling design load calculations (same floor plan, same wall/roof/floor/window/door constructions and exposures to outdoor air) except for compass orientation. Pre-calculation of design loads for each "building block" and orientation created the equivalent of a spreadsheet-based lookup table for each of the 4,003 apartments.

The housing characteristics of each "building block" are determined by carefully overlaying the construction contract history determined from the technical records and plan vaults. The starting point is the construction documents for each phase of the original construction. Older housing often has already had energy-related retrofits since the original construction (attic insulation, window upgrades, etc.). The objective is to build characteristics files that describe the currently existing apartments, and then make any modifications related to ECMs that will be installed along with the GHPs (in this case, for example, heating/cooling load calculations were affected by lighting retrofits in all units, whereas attic insulation only impacted the loads in upper-floor units).

The "after" characteristics are documented in the form of input files to the heating/cooling design load calculations used to size the GHPs. In addition the "before/after" characteristics are documented in the form of input files to the energy analysis program used to estimate the energy savings of the project. Depending on the method used, ground heat exchanger sizing may involve use of design load and energy analysis results. The designs are then documented in the spreadsheet-based lookup table for each building block and orientation. The spreadsheet defines all 4,003 apartments by building block and orientation, design loads, GHP size, ground heat exchanger size, lighting fixture count and change, building number, and serving electric distribution feeder. Details of the method are presented in Shonder & Hughes., 1997b.

When the Fort Polk project was engineered, vertical borehole ground heat exchanger design was largely experience-based. A small cadre of experienced designers could develop effective designs by adjusting the outputs of the methods they used based on experience. Because of the uncertainty and the severe consequences of undersizing, the ESCO obtained multiple opinions from among this experienced group (Thornton et.al., 1997). Since then the industry has had more experience and methods have improved so that future projects will not have to support the cost of this design redundancy.

Project Evaluation Methodology

An independent evaluation of the Fort Polk ESPC was performed by the Oak Ridge National Laboratory (Hughes et al., 1997). The objectives of the evaluation were to: 1) determine statistically-valid energy, demand, and O&M impacts of GHPs applied to military family housing at Fort Polk, and 2) to improve the capability to evaluate, design, install, operate, and maintain GHPs in military family housing. The evaluation approach, shown schematically in Figure 1, included three interrelated levels of field data collection (Levels 1, 2, and 3). A fourth level of data collection (Energy Balance data) supported the advancement of GHP system design and energy estimating methods.

Level 1 addressed the aggregate of the 4,003 housing units: data on electrical demand and consumption were collected at fifteen minute intervals from submeters on fourteen of the sixteen electrical feeders that supply electricity to the family housing areas of the Fort (the original intent was to monitor all feeders, but the project's recording equipment could not be interfaced with existing metering on two feeders). Temperature and humidity data were also collected at fifteen-minute intervals at four different locations within the family housing area.

Level 2 data collection focused on a sample of 42 individual housing units in 16 buildings. Total premise energy use and the energy use of the heat pump (or of the air conditioner/gas furnace combination in some of the pre-retrofit units) were collected at fifteen-minute intervals. In Level 3, more detailed energy use data were collected on a subsample of 18 of the 42 Level 2 units (7 of the 16 buildings). In addition to total premise and space conditioning energy, fifteen-minute interval data were collected to isolate the energy use of the hot water heater, the air handling system, and the furnace in the pre-retrofit condition.

Data were collected for approximately one year before and one year after the retrofits. Figure 2 presents the daily energy consumption for a typical electrical feeder serving 1,220 apartments in 416 buildings. Pre- and post-retrofit daily energy consumption data were fit to dual-changepoint functions of daily average temperature of the following form:

$$E = \begin{cases} E_0 + m_h(T-T_h) & T<T_h \\ E_0 & T_h<=T<=T_c \\ E_0 + m_c(T-T_c) & T>T_c \end{cases} \qquad (1)$$

where E_0 is the baseline daily energy use, m_h and m_c are the heating and cooling slopes, T_h and T_c are the heating and cooling breakpoint temperatures, and T is the daily average temperature (for feeders serving housing with gas furnaces, a single changepoint model was used). Pre- and post-retrofit energy consumption were normalized to a typical meteorological year (TMY). The energy savings due to the retrofits were estimated as the difference between pre-retrofit TMY consumption and post-retrofit TMY consumption. Additional details of these models are provided in Hughes & Shonder, 1998.

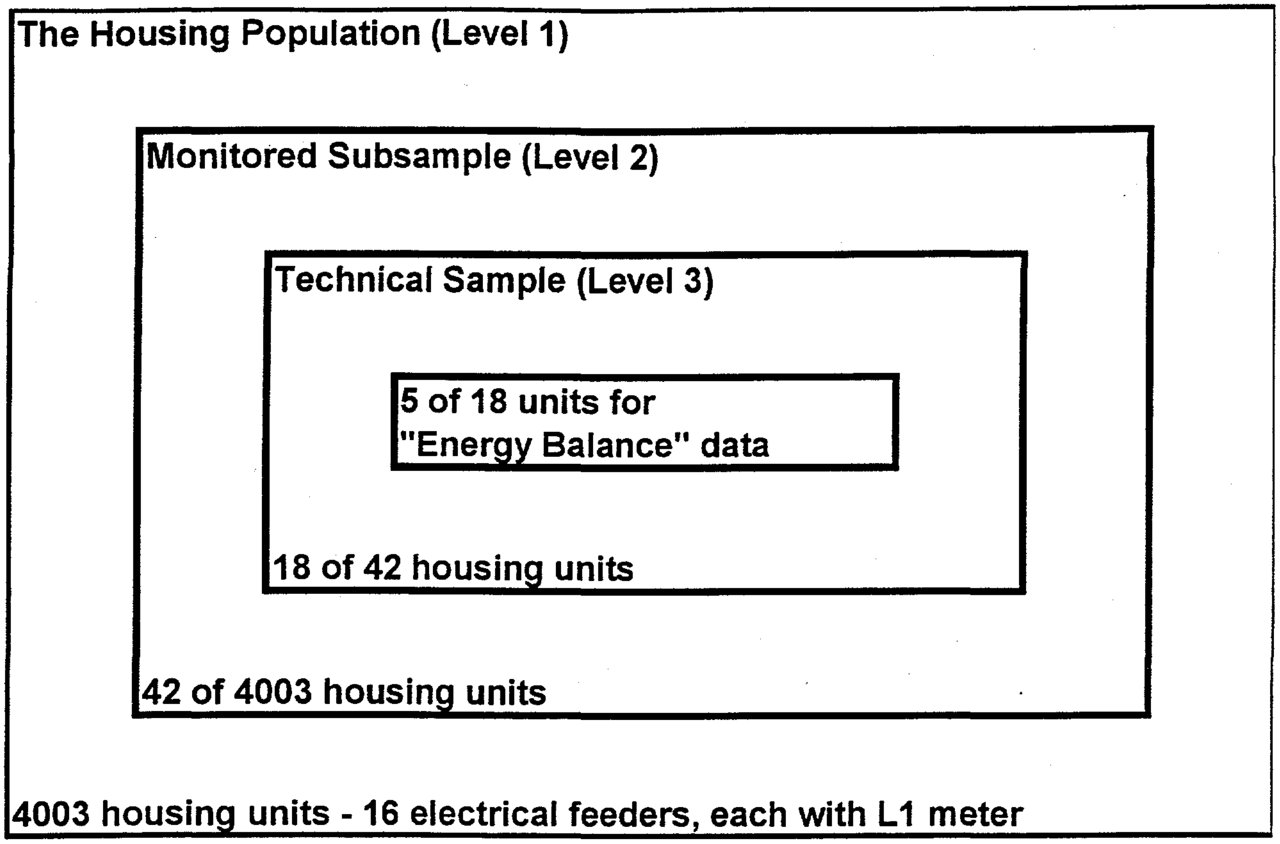

Figure 1: Evaluation methodology

In level 2, energy use data were collected from a statistically valid subsample of buildings from the family housing population. Figure 3 presents the pre- and post-retrofit daily energy consumption vs. daily average temperature for a typical level 2 site, a five-plex in the North Fort housing area. As with the feeder-level data, daily energy use was fit to a dual-changepoint function of daily average temperature, and savings was determined by normalizing pre- and post-retrofit consumption to a typical meteorological year.

Energy and Demand Savings

Table 1 presents the results of the analysis of the level 1 data. For a typical meteorological year the project results in an energy savings of approximately 25.8 million kWh, which is about 32.5% of the pre-retrofit electrical energy use in Fort Polk's family housing. Using standard emission factors for the Southeastern U.S. (Sand et. al., 1997), the savings corresponds to a reduction in CO_2 emissions of 20,900 tons per year.

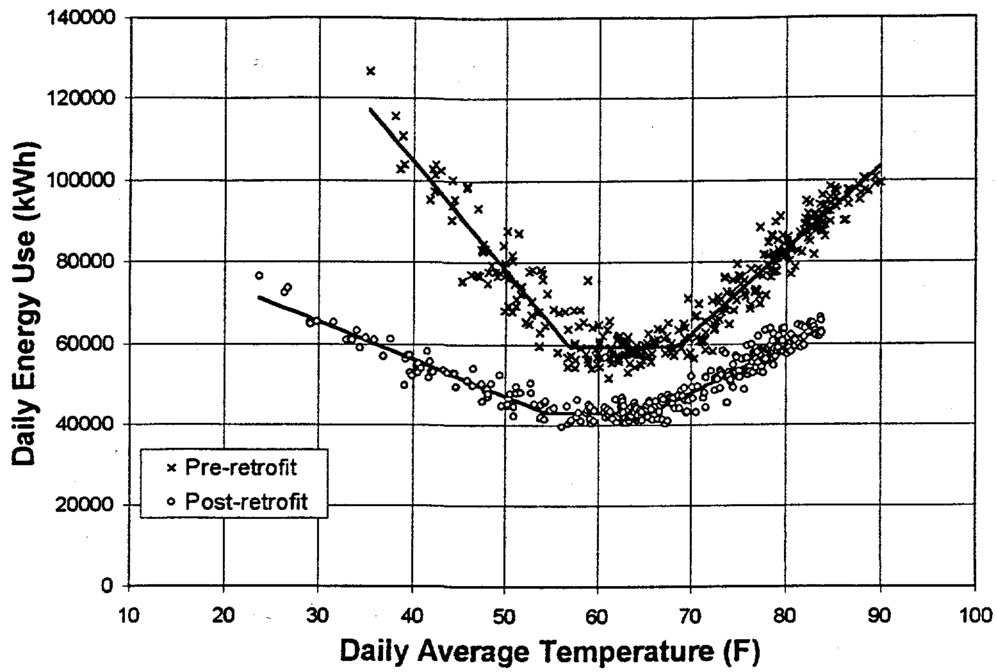

Figure 2: Pre- and post-retrofit daily electrical energy consumption vs. daily average temperature for a typical electrical feeder at Ft. Polk.

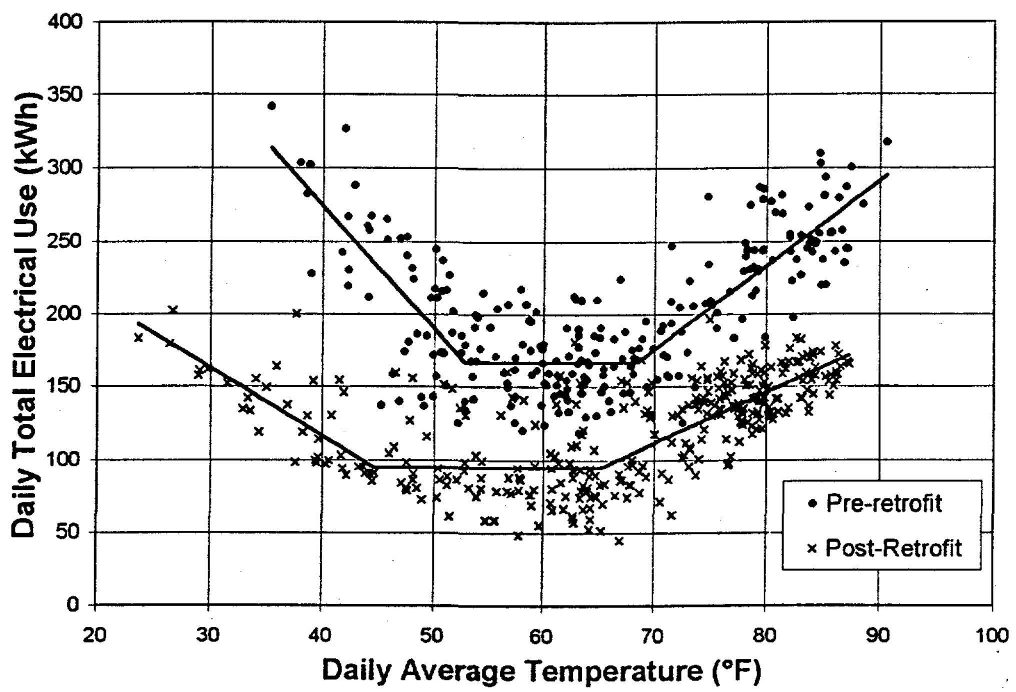

Figure 3: Pre- and post-retrofit daily energy consumption vs. daily average temperature for a typical level 2 site, a five-apartment building.

Table 1 : Pre- and post-retrofit energy consumption for the 16 family housing electrical feeders, normalized to a typical meteorological year.

	Pre-Retrofit			Post-retrofit			Savings	
Feeder	Annual kWh	Annual kWh/ft^2	Daily kWh/unit	Annual kWh	Annual kWh/ft^2	Daily kWh/unit	Total kWh	Percent Savings
1	2873622	12.43	39.36	2009882	8.69	27.53	863741	30.1%
2	27722779	15.92	62.26	18957249	10.89	42.57	8765530	31.6%
3	1273011	16.98	87.19	977428	13.04	66.95	295583	23.2%
4	170119	14.17	77.68	176601	14.71	80.64	-6482	-3.8%
5	1299381	8.69	35.60	1301949	8.71	35.67	-2568	-0.2%
6	1551831	14.27	53.14	999095	9.19	34.22	552736	35.6%
7	13918902	15.35	66.78	6217805	6.86	29.83	7701097	55.3%
11	2278945	10.74	41.08	1912352	9.01	34.47	366593	16.1%
12	2002139	10.82	38.63	1678039	9.07	32.38	324100	16.2%
13	2216799	10.97	37.49	1852790	9.16	31.33	364009	16.4%
14	2530362	10.12	34.66	2076470	8.30	28.44	453892	17.9%
15	4137766	14.95	56.68	2687859	9.71	36.82	1449907	35.0%
16	6112001	15.76	54.72	4763891	12.29	42.65	1348110	22.1%
17	4015635	11.41	40.01	3049713	8.67	30.38	965922	24.1%
18	3466581	14.72	56.53	2330801	9.90	38.01	1135781	32.8%
19	3843615	14.88	58.18	2604372	10.08	39.42	1239243	32.2%
TOTAL (TMY)	**79413489**	**14.22**	**54.35**	**53596295**	**9.60**	**36.68**	**25817194**	**32.5%**

As expected, the savings were somewhat lower on feeders with housing previously served by gas furnaces and gas-fired water heaters (Feeders 5, 11, 12, 13 and 14); on average these feeders saved 16.7% of their pre-retrofit electrical use, as opposed to 35.3% for feeders which were all-electric prior to the retrofits. However the replacement of gas-fired equipment with electrical equipment effectively eliminated the use of natural gas in Fort Polk family housing, resulting in an additional savings of approximately 260,000 therms of natural gas per year. Using standard emission factors for gas-fired equipment, this savings corresponds to a reduction of 1500 tons per year in CO_2 emissions. With the reduction in electrical energy use, the total reduction in CO_2 emissions as a result of the retrofits is about 22,400 tons per year.

It should be noted that the apparent energy savings presented here may not correspond to the "contracted" savings for which the ESCO receives payment under the terms of the performance contract, even in a typical year. Operational deviations such as changes in occupancy, plug load growth, and changes in comfort setpoints, can cause higher or lower apparent energy savings, and in general such changes require baseline adjustments to correct for deviations which are beyond the control and responsibility of the ESCO.

In addition to the electrical energy savings, comparison of pre- and post-retrofit feeder-level electrical demand indicates that peak-day electrical demand in the family housing areas of Fort Polk has been reduced by 7.55 MW, which is 43.5% lower than the pre-retrofit peak demand. As a result of the reduction in demand, the load factor for family housing increased from 0.52 to 0.62. Table 2 presents the pre- and post retrofit peak demand and load factor for each of the 16 feeders.

Table 2: Estimated pre- and post-retrofit peak day electrical demand and annual load factor for the sixteen family housing electrical feeders.

	Pre-Retrofit			Post-Retrofit			Demand	Percent
Feeder	peak kW	Annual kWh	load factor	peak kW	Annual kWh	load factor	Reduction	Reduction
1	600	2873622	0.55	405	2001455	0.56	194	32.4%
2	5639	27722779	0.56	3376	18957249	0.64	2263	40.1%
3	248	1273011	0.59	213	977428	0.52	35	14.1%
4	54	170119	0.36	28	176601	0.73	26	48.6%
5	499	1299381	0.30	287	1301949	0.52	212	42.5%
6	276	1551831	0.64	200	999095	0.57	75	27.3%
7	2490	13918902	0.64	1125	6217805	0.63	1366	54.8%
11	774	2278945	0.34	395	1912352	0.55	379	49.0%
12	603	2002139	0.38	354	1678039	0.54	249	41.3%
13	702	2216799	0.36	341	1852790	0.62	361	51.4%
14	865	2530362	0.33	438	2076470	0.54	427	49.3%
15	782	4137766	0.60	448	2687859	0.68	334	42.7%
16	1475	6112001	0.47	809	4763891	0.67	666	45.2%
17	900	4015635	0.51	493	3049713	0.71	408	45.3%
18	694	3466581	0.57	429	2330146	0.62	265	38.2%
19	770	3843615	0.57	479	2603741	0.62	290	37.7%
Total	**17371**	**79413489**	**0.52**	**9820**	**53586583**	**0.62**	**7551**	**43.5%**

(1) Pre- and post-retrofit annual consumption and demand estimated for feeders 18 and 19.

(2) Post-retrofit demand estimated for feeder 13 due to equipment failure during peak cooling season.

The 13 Level 2 buildings (which included a total of 42 apartments) are a random sample of the family housing population, and as such the energy savings for the sample should be representative of the savings achieved across the entire population. Table 3 below presents the pre- and post-retrofit annual energy consumption for these buildings, normalized to a typical meteorological year. The annual electrical energy savings from the subsample was 308,016 kWh, or 35.8% of the pre-retrofit annual electrical energy savings. Since the Level 2 subsample did not include any residences which were heated by natural gas prior to the retrofits, this energy savings can be compared with the average savings on electrical feeders 1,2,3,6,7,15,16,17, 18 and 19. As stated above, this was 35.3%, thus there is excellent agreement between the feeder level data and the monitored subsample.

Analysis of the Level 3 data (Shonder et. al., 1997) allowed determination of the relative impact of the conservation measures installed. As shown in Figure 4, the GHPs, including desuperheaters, accounted for 66% of the savings achieved; however the lighting retrofits played an important role as well. Lighting in each apartment was reduced from 1,845 W to 458 W through a combination of fixture delamping and compact fluorescent lighting.

Table 3 : Pre- and post-retrofit TMY energy use for the 13 Level-2 buildings.

Building	Pre-Retrofit			Post-Retrofit			Projected Savings		
	Annual kWh	Annual kWh/ft^2	Daily kWh/unit	Annual kWh	Annual kWh/ft^2	Daily kWh/unit	Annual kWh	Annual kWh/unit	Percent Savings
209	116223	16.57	79.60	76836	10.95	52.63	39387	9847	33.9%
210	67541	14.38	46.26	32347	6.89	22.16	35194	8799	52.1%
211	27865	15.53	76.34	18776	10.47	51.44	9089	9089	32.6%
213	55895	12.07	38.28	37289	8.05	25.54	18607	4652	33.3%
214	53435	15.46	73.20	37121	10.74	50.85	16314	8157	30.5%
215	87721	20.44	60.08	49484	11.53	33.89	38237	9559	43.6%
216	49545	14.59	67.87	40463	11.91	55.43	9083	4541	18.3%
217	55045	14.77	75.40	31548	8.46	43.22	23496	11748	42.7%
218	72639	16.92	49.75	62651	14.60	42.91	9988	2497	13.8%
219	84333	19.65	57.76	39891	9.29	27.32	44443	11111	52.7%
220	75753	12.06	41.51	43691	6.95	23.94	32062	6412	42.3%
221	76293	13.68	52.26	49597	8.89	33.97	26697	6674	35.0%
223	37277	14.66	51.06	31856	12.53	43.64	5420	2710	14.5%
Total:	**859565**	**15.35**	**56.07**	**551549**	**9.85**	**35.98**	**308016**	**7334**	**35.8%**

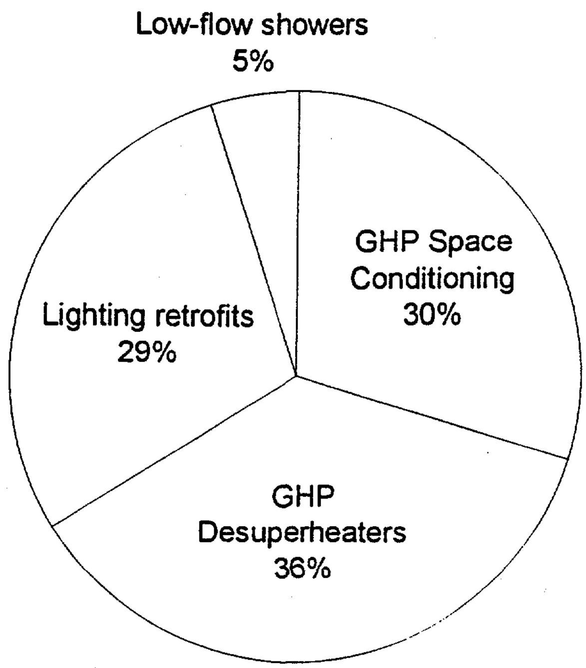

Figure 4 : Breakdown of energy savings by conservation measure.

Conclusions

As the result of an energy savings performance contract, the Fort Polk military base has reduced electrical consumption in family housing by 25.8 million kWh per year, which is about 33% of pre-retrofit energy use. Natural gas consumption has been reduced by about 260,000 therms per year. These energy savings correspond to an estimated reduction in CO_2 emissions of 22,400 tons per year. Peak electrical demand has been reduced by 7.6 MW. The electrical energy and demand savings correspond to an improvement in the whole-community annual electric load factor from 0.52 to 0.62. As a result of the project, Fort Polk saves about $450,000 annually and benefits from complete renewal of the major energy consuming systems in family housing and maintenance of those systems for 20 years. In return for a 77% share of future energy and maintenance savings, the project was carried out with private capital at no up-front cost to Fort Polk.

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