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Energy Design Guides for Army Barracks

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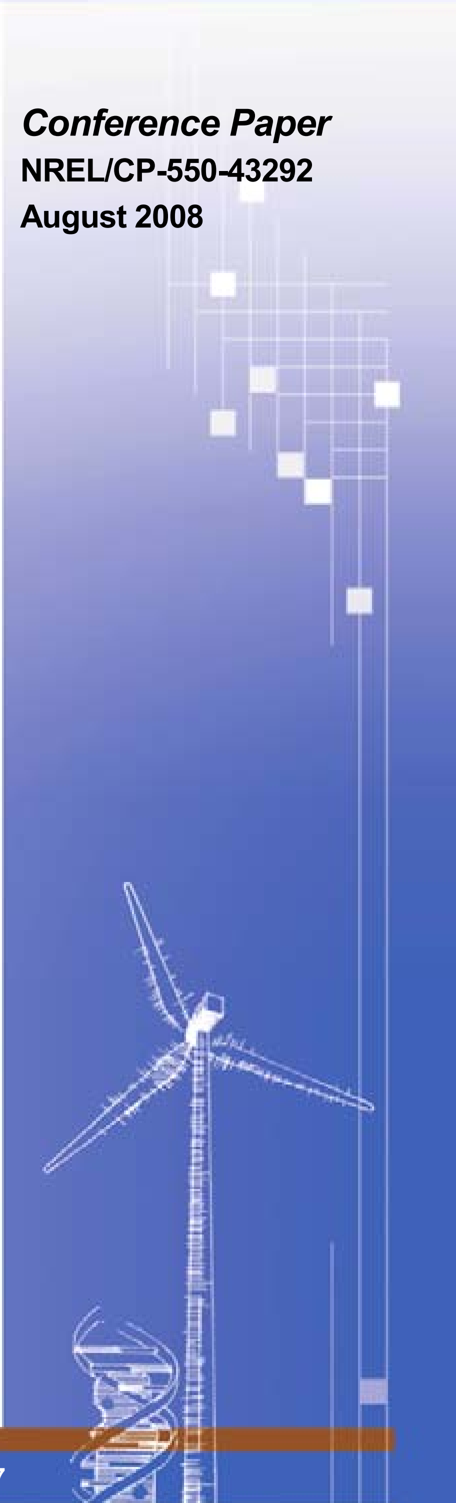

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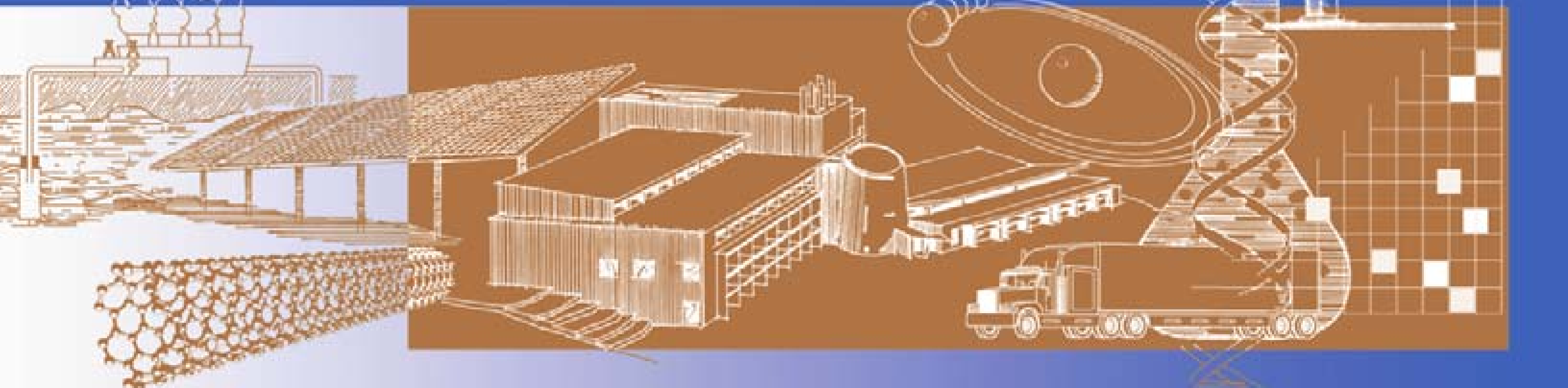

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Energy Design Guides for Army Barracks[1]

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ABSTRACT

The Energy Policy Act of 2005 requires federal facilities to be built to achieve 30% energy savings over the 2004 International Energy Code or American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 90.1-2004, as appropriate. The Engineer Research and Development Center of the U.S. Army Corps of Engineers and the National Renewable Energy Laboratory (NREL) are developing target energy budgets and design guides with a prescriptive path to achieve 30% energy savings over a baseline built to the minimum requirements of ANSI/ASHRAE/IESNA Standard 90.1-2004. This project covers eight building types in 15 U.S. climate zones. The building types include barracks, administrative buildings, a maintenance facility, a dining facility, a child development center, and an Army reserve center. All the design guides will be completed by the end of 2008. This paper focuses on the design guide for one type of barracks called unaccompanied enlisted personal housing (UEPH). The UEPH buildings are similar to apartment buildings with double occupancy units. For each building type, a baseline was established following typical Army construction and ASHRAE Standard 90.1 Appendix G modeling rules.

Improvements in energy performance were achieved for the envelope using the NREL optimization platform for commercial buildings and previous ASHRAE design guides. Credit was also taken for tightening the building envelope by using proposed envelope leakage rates from ASHRAE and the Army. Two HVAC systems, including a dedicated outdoor air system, were considered. The final results achieved 29% site energy savings in two climates and greater than 30% site energy savings in all other climates.

Results of this study were implemented in the Army's standard RFP process for new UEPH barracks construction in late 2007. New UEPH design/construction begun in 2008 and beyond will require the contractor to design and construct a UEPH facility that meets the target energy budget developed in this study using either a custom design or the design guide's prescriptive path developed as part of this study.

Introduction

Section 109 of the Energy Policy Act of 2005 (EPAct 2005) states that for new federal facilities "the buildings be designed to achieve energy consumption levels that are at least 30 percent below the levels established in the version of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard or the International Energy

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Conservation Code, as appropriate" (U.S. Congress 2005). The energy efficient designs must be life cycle cost effective; however, "cost effective" is not defined in the law and left up to each federal agency to define. The U.S. Department of Energy (DOE) issued additional guidance in the Federal Register (NARA 2006), which states that savings calculations should not include the plug loads and implies that the savings shall be determined through energy cost savings. The U.S. Army decided it would use site energy for the HVAC, lighting, and hot water loads to determine the energy savings.

The U.S. Army constructs buildings across the country and wanted to streamline the process of meeting the energy savings requirements. The U.S. Army Corps of Engineers (USACE) worked with the National Renewable Energy Laboratory (NREL) to develop baseline and target energy budgets and design guides with one prescriptive path for achieving 30% or more energy savings. ASHRAE is providing expert review of the design guides. The project covers eight building types over all U.S. climate zones: basic training barracks, unaccompanied enlisted personal housing (UEPH), battalion headquarters, tactical equipment maintenance facilities, dining facilities, child development centers, Army reserve centers, and company operations. This paper focuses on the UEPH design guide; however, the process for developing all the design guides is similar.

The model for these design guides was adapted from the Advanced Energy Design Guides (AEDGs) from ASHRAE (2008). Each AEDG was developed for a specific building type and provides recommendation tables for each of the eight major climate zones and a "how-to" section on implementing the recommendations. The AEDGs do not provide baseline and target energy budgets, which are used by the Army in its requests for proposals.

Approach

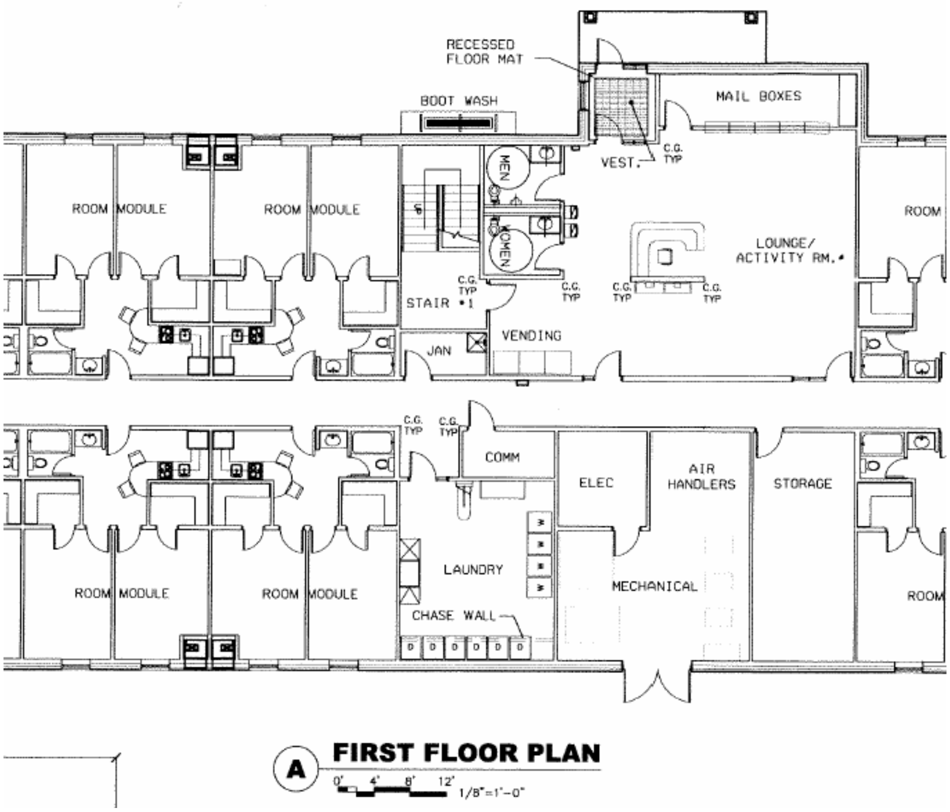
All energy simulations for the UEPH were carried out with EnergyPlus version 2.0 (DOE 2008). NREL is part of the EnergyPlus development team and has developed additional programs that work with EnergyPlus. These programs work together to create input files, manage the numerous simulations, provide optimization, and post process the results. The optimization engine, called Opt-E-Plus, is used to help optimize building designs based on energy performance, energy cost performance, or life cycle cost performance.

The first step in this type of whole building energy simulation project is to define the baseline building models, which in this case meet the requirements of ASHRAE Standard 90.1-2004 following the Appendix G guidelines (ASHRAE 2004a). We followed Appendix G with three exceptions, which were approved by DOE. The first is to use site energy without plug loads as our metric for savings. This exception is a combination of the EPAct 2005 guidance from DOE to not include plug loads and a decision by the Army to use site energy. The second exception is to use the nonresidential tables for all buildings including barracks. A three story barracks falls under the residential requirements of Standard 90.1-2004; however, the Army builds some barracks four or more stories, which is included in the nonresidential portion of the standard. Finally, Standard 90.1-2004 does not contain building air leakage and infiltration levels. We define a baseline air leakage rate and an energy efficient leakage rate and include this in our energy efficiency strategies.

Building Description

The UEPH barracks are similar to apartment buildings. The model used for this study contained 78 double occupancy units for a total capacity of 156 personnel. Each apartment unit has two bedrooms with a storage area, a bathroom, and a kitchen as shown in Figure 1. The first floor has 24 units, a laundry room, a common area, a large mechanical room, and a storage area. The second and third floors have 27 units and a laundry room. Each floor is 18,403 ft^2 and the building is 55,209 ft^2. A rendering of the baseline computer model is shown in Figure 2.

Figure 1 Section of the first floor plan for the UEPH barracks



Locations

Fifteen locations were selected to represent 15 climate zones in the United States (Briggs et al. 2003). We selected Colorado Springs for climate zone 5B instead of Boise, Idaho, to more closely align with the installations at Fort Carson. The 15 climate zones and the cities used to represent the climate zones are shown in Table 2.

Energy Modeling

The energy simulations were completed using EnergyPlus version 2.0 (DOE 2008). All simulations were completed with the NREL analysis platform that manages EnergyPlus simulations. The modeling assumptions used in the baseline and energy efficient models are shown in Table 1.

The approach to modeling the energy efficiency improvements was to add one improvement at a time starting with the envelope then infiltration and HVAC. The approach to modeling each of these areas is presented in the following sections.

Figure 2 Rendering of the baseline energy simulation model

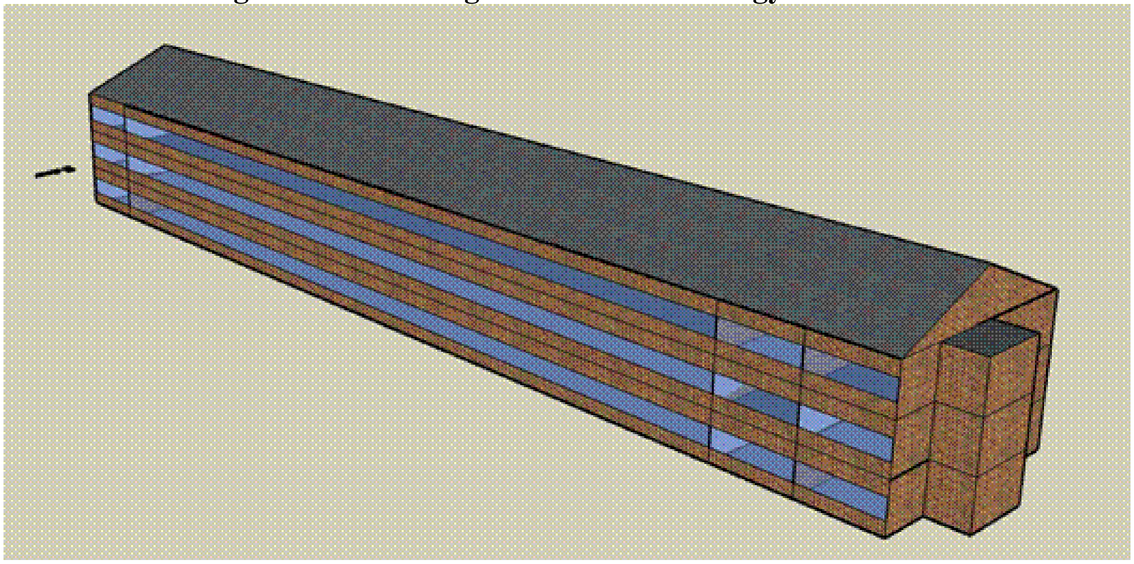


Table 1 Model Assumptions

Building Component	Baseline Building Model	Efficient Building Model
Area	55,209 ft^2 (5,088 m^2)	Same as baseline
Floors	3	Same as baseline
Aspect ratio	2.0	Same as baseline
Orientation	Long axis running east and west	Same as baseline
Window to wall ratio	19% on north and south facades	Same as baseline
Window type	Standard 90.1-2004	See Table 2
Wall construction	Steel frame	Same as baseline
Wall insulation	Standard 90.1-2004	See Table 2
Roof construction	Sloped roof and attic with insulation at the roof level	Sloped metal roof and attic with insulation at the ceiling level
Roof insulation	Standard 90.1-2004 equal to the "insulation entirely above deck"	See Table 2
Roof albedo	0.08	0.3
Infiltration	0.40 cfm/ft^2 @ 0.3 in w.g.	0.25 cfm/ft^2 @ 0.3 in w.g.
Lighting	Rooms - 1.0 W/ft^2 (10.8 W/m^2) Corridors: 0.6 W/ft^2 (6.5 W/m^2)	Same as baseline
Plug loads	1.7 W/ft^2 plus refrigerator and range	Same as baseline
Temp set points	70ºF heating; 75ºF cooling, no set back	Same as baseline
HVAC	PSZ with DX-AC (3.0 COP) and gas furnace (0.8 E_t)	Sys. 1: PSZ with DX-AC (3.5 COP) and gas furnace (0.9 Et) Sys. 3: DOAS with DX dehumidification (3.5 COP), gas heating coil (0.9 Et), ERV (70% effectiveness), 4-pipe FCUs for zone temperature control.
DHW	Natural gas boiler (0.8 E_t)	Natural gas boiler (0.9 E_t)

Envelope

As stated in the Approach section, the Army decided to use the nonresidential portion of Standard 90.1 for all its building types, even though the building used for this study falls under the residential requirements. The nonresidential envelope insulation levels are slightly lower than the residential insulation levels. Simulations were completed comparing the residential IECC-2004 requirements and Standard 90.1-2004 nonresidential energy requirements for this building. Annual energy use in the nonresidential Standard 90.1-2004 compliant building ranged from 2% lower in San Francisco to 15% higher in Duluth with an average difference over 14 locations of 7% more energy required in the Standard 90.1-2004 compliant building than in the IECC-2004 compliant building.

The first steps to determine the optimal envelope improvements were completed using the NREL optimization platform, Opt-E-Plus. The program finds the optimal solutions of a large set of selected envelope features based on initial capital costs, operational energy costs, and maintenance costs over a defined time period. The capital and maintenance cost data are based on the information used by ASHRAE for Standard 90.1 development. The utility costs are based on typical utility costs for each location, which are probably higher than the rates used by the Army; however, the Army rates for each location were not known. Higher energy costs would lead to more energy efficient strategies, which was taken into account when reviewing the results. The analysis period was set to 30 years.

Optimization runs for wall and roof insulation levels and window types were carried out for five locations for the training barracks and UEPH and nine locations for the battalion headquarters (BHQ). Solutions were selected by location that produced high energy savings and maintained low capital cost increases. The optimization results for the BHQ in Houston are shown Figures 3 and 4. Each dot represents one simulation with a different combination of features. The results are shown for the effects on the capital costs as well as the capital, energy, and maintenance costs over 30 years. The minimum 30 year cost point provides about a 5% energy savings; the optimal point provides more than 8% savings, but at a much higher first cost. Figure 4 shows how a group of near optimal solutions was selected that produced the highest savings and kept the increase in first costs to less than 1.5%. The final solutions were manually selected from these near optimal solutions for each optimized location in a way that kept consistency in the insulation and windows across the climate zones. The results for these locations were applied to the other locations based on similar heating and cooling degree days and the need to keep the results simple and easy to implement.

All optimization runs were completed with an attic roof construction and generic wall constructions using an effective overall R-value. The final recommendations were determined from a review of the optimization results. The final recommendations shown in Table 2 were selected to have the lowest first cost increase with good performance. A large part of the performance improvement comes from changing the construction of the roof from "insulation entirely above deck," as required for the baseline in Standard 90.1-2004 Appendix G, to the vented attic with the insulation at the ceiling level.

Figure 3 **Envelope optimization results for Houston showing change in cost with energy savings**

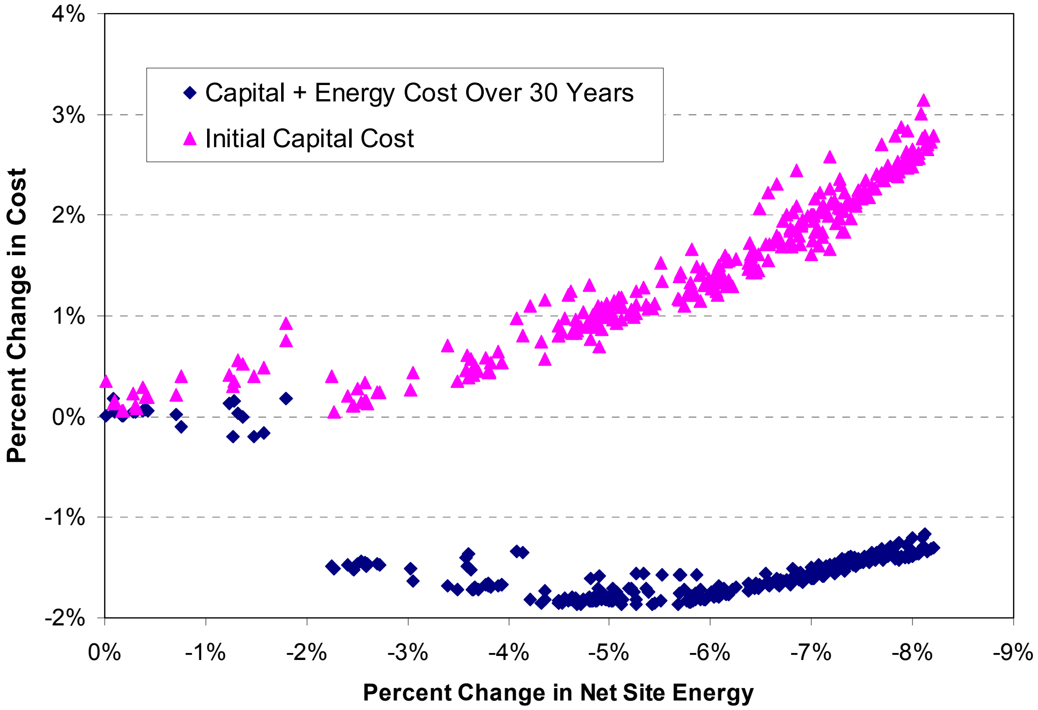


Figure 4 **Envelope optimization results for Houston showing optimal solutions**

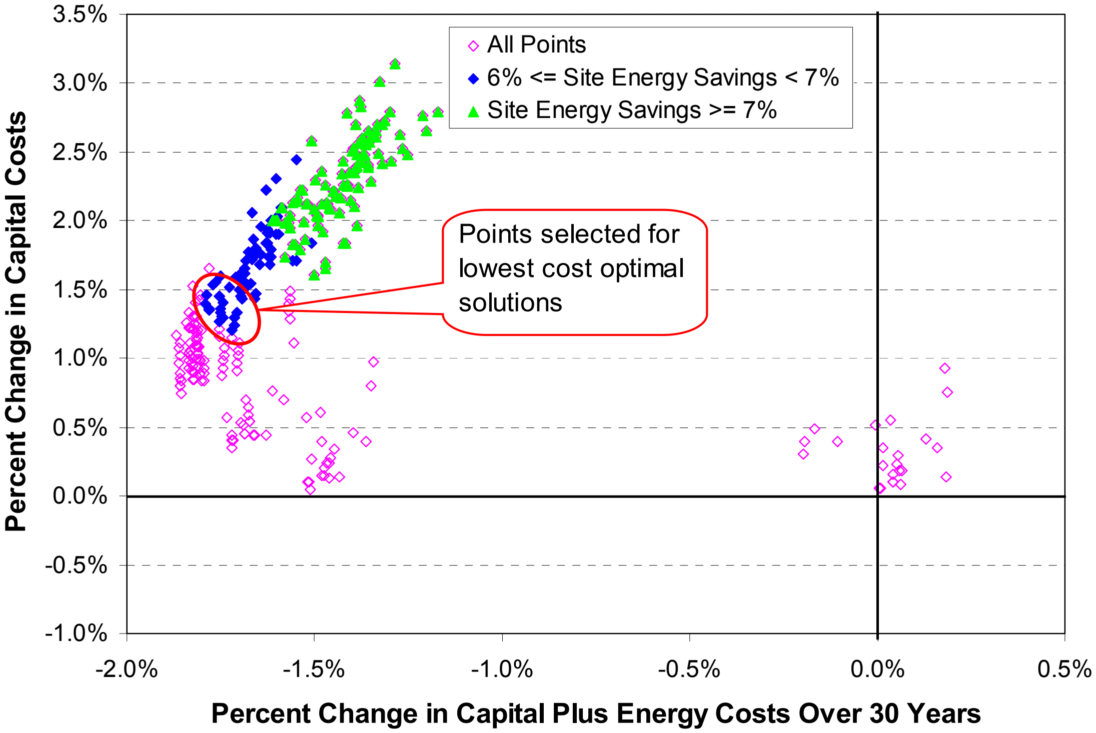


Table 2 Recommended Envelope Energy Conservation Measures

Zone	City	Total Wall Ins. ($ft^2·h·F$ /Btu)	Attic Ins. ($ft^2·h·F$ /Btu)	Slab Ins. ($ft^2·h·F$ /Btu)	Window	
					U-Btu/ $ft^2·h·F$	SHGC
1A	Miami, FL	20	40	0	0.45	0.31
2A	Houston, TX	20	40	0	0.45	0.31
2B	Phoenix, AZ	20	40	0	0.45	0.31
3A	Memphis, TN	20	40	0	0.45	0.31
3B	El Paso, TX	20	40	0	0.45	0.31
3C	San Francisco, CA	20	40	0	0.45	0.31
4A	Baltimore, MD	25	50	0	0.42	0.46
4B	Albuquerque, NM	25	50	0	0.42	0.46
4C	Seattle, WA	25	50	0	0.42	0.46
5A	Chicago, IL	25	50	0	0.42	0.46
5B	Colorado Springs, CO	25	50	0	0.42	0.46
6A	Burlington, VT	30	60	0	0.42	0.46
6B	Helena, MT	30	60	0	0.42	0.46
7A	Duluth, MN	30	60	0	0.33	NR
8A	Fairbanks, AK	30	60	10	0.33	NR

Infiltration

It is difficult to obtain good data and develop detailed models of infiltration. Every building has different leakage characteristics, and the infiltration varies with operation of the building and ambient conditions. Most often, we use an average constant infiltration rate in the energy model. A proposal to ASHRAE to include building air tightness in Standard 90.1-2004 includes a maximum building leakage rate of 0.4 cfm/ft^2 at 0.3 in w.g. (2.0 $L/s·m^2$ at 75 Pa) as determined by a building pressurization test. This air tightness was assumed to be the baseline leakage rate. The U.S. Army has proposed in its new construction regulations that the leakage rate for its new buildings not exceed 0.25 cfm/ft^2 at 0.3 in w.g. (1.3 $L/s·m^2$ at 75 Pa), which was assumed for the energy efficient building models.

Several assumptions still have to be made to go from these leakage rates to the simple infiltration model in the building simulation. The infiltration at these leakage rates and pressures were calculated based on the total wall and flat roof area of the building, then converted to a pressure of 5 Pa assuming a flow coefficient of 0.65. We assumed that the average pressure drop across the building envelop is 0.02 in w.g. (5 Pa). Wind pressure and temperature differentials across the building envelope drive the infiltration and these driving forces vary throughout the year; however, we are not modeling these variations in the simulations. We assume that a constant air changes per hour will model the average effects over the year and in different locations. This is a gross assumption, but one that is necessary without moving to more complicated flow network simulations. Table 3 shows the infiltration at these two leakage rates.

The mechanical ventilation system pressurizes the building by providing outside air equal to the building exhaust plus the air leakage at 0.02 in w.g. (5 Pa). Infiltration is often assumed to go to zero when buildings are pressurized. This assumption is usually made because there is a lack of evidence to about what really happens and how to model it in an energy simulation. We have assumed that the average uncontrolled infiltration when the building is pressurized is reduced to 10% of the value calculated at 0.02 in w.g. (5 Pa). The difference in the leakage rates between the two air tightness levels was accounted for in the outdoor ventilation rates for the baseline and energy efficient models.

Table 3 Infiltration Leakage Rates

	0.4 cfm/ft^2	**0.25 cfm/ft^2**
ACH at 0.3 in w.g. (75 Pa)	1.51	0.62
ACH at 0.02 in w.g. (5 Pa)	0.22	0.09
Excess ventilation flow at 0.02 in w.g. (cfm)	2,950	1,211
Excess ventilation flow at 5 Pa (L/s)	1,392	572

Ventilation

The ventilation was set to provide 90 cfm of outside air to each apartment unit to make up for the bathroom exhaust and control humidity, which is greater than the ventilation requirements from ASHRAE Standard 62.1-2004 (ASHRAE 2004b). This level of ventilation is based on experience with Army barracks. Additional outside air was added to the whole building to make up for the leakage rate at 0.02 in w.g. (5 Pa) pressurization as shown in Table 3.

Hot water

Hot water use was assumed to be 30 gal/day/occupant at 110ºF with a peak draw of 40 gal/h per unit from a 140ºF storage tank. The peak washing machine use per floor is assumed to be four loads per hour or 80 gal/h of 120ºF hot water, which is approximately 53 gal/h from a 140ºF storage tank.

Plug Loads

We assumed that each bedroom has a computer, stereo, television, and other smaller electronic devices for a plug load density of 1.7 W/ft^2. Each kitchen contains a refrigerator and an electric range. The refrigerator was assumed to be very efficient with an average power consumption of 76 W, and the range was assumed to have a peak power of 1,500 W. There are 14 washing machines in the building (4 on the first floor and 5 on the second and third floors). With a 90% occupancy rate for the building, there are 140 occupants. Three loads per occupant per week for 420 loads/week or 60 loads/day were assumed. ENERGY STAR® commercial washing machines use approximately 20 gallons of water per load and 0.60 kWh of electricity per load. The dryers were assumed to use 1.5 kWh of electricity per load.

HVAC and Hot Water

The baseline HVAC system uses packaged single zone air conditioning (PSZ-AC) units with a natural gas furnace in each zone. A high efficiency version of the baseline and a dedicated outdoor air system (DOAS) with fan coil units were considered for the energy efficient cases. The first system was modeled with an increase in coefficient of performance (COP) to 3.5, increased gas furnace efficiency to 0.9, and improved fan efficiency. In the second case, the DOAS provided the building ventilation air and zone level fan coil units were used to control zone loads. The DOAS included a packaged direct expansion coil for cooling and humidity control, hot water coil for heating energy, and an energy recovery ventilator (ERV). The ERV was modeled with sensible heat recovery only at 75% to 70% effectiveness at 75% to 100% air flow. Later simulations included latent heat recovery. Frost control for the ERV was handled with the exhaust only method in EnergyPlus, which bypasses the supply air around the ERV to avoid frost conditions. The system was operated with an outdoor air temperature (OAT) reset on supply air temperature (SAT). The SAT set point schedule was colder with higher OAT and warmer with colder OAT. The set point at high OAT was lower in the humid climates for better humidity control and higher in the dry climates for more energy savings. The space loads are met with 4-pipe fan coil units connected to a central chiller and boiler. The central chiller and boiler are assumed to be outside the building boundary and are not improved above minimum efficiencies; however, the energy use from these systems is included in the building total energy use and energy saving calculations. The central chiller is assumed to have a COP of 5 and the central boiler is assumed to have a thermal efficiency of 80%.

The service water heating system in the baseline building models uses an 80% efficient boiler. The energy efficient models use a 90% efficient boiler and gray water heat recovery on the shower water with an assumed savings of 20% (FEMP 2005). The only way to make this measure economical is to gang six or more showers together per drain heat recovery unit, which may not be physically practical.

Results

The annual energy use intensity for each climate as simulated by EnergyPlus forms the baseline energy budget. The target energy budget is 70% of these baseline values. The site energy use intensities with and without plug loads for the baseline and target energy budgets are shown in Table 4 for each climate zone. Breakouts of the energy consumption by end use are shown in Figure 5.

The simulated results for the energy efficient designs including the envelope, infiltration, grey water heat recovery, and HVAC energy conservation measures are shown in Tables 5 and 6. Table 5 shows the savings for each efficiency measure. The improvements to the envelope and lighting were simulated together; therefore, there is one number. The DOAS with ERV system showed the best performance in all locations except Phoenix and El Paso, where the high efficiency PSZ-AC system had the best performance. The total site energy savings exceeded 30% for all locations except for Phoenix and El Paso, which showed 29% savings.

Table 4 Energy Budgets by Climate Zone with and without Plug Loads

Climate Zone	City	With Plug Loads		Without Plug Loads	
		Baseline (kBtu/ft^2)	Target (kBtu/ft^2)	Baseline (kBtu/ft^2)	Target (kBtu/ft^2)
1A	Miami, FL	102	72	82	58
2A	Houston, TX	102	72	82	57
2B	Phoenix, AZ	65	46	45	32
3A	Memphis, TN	91	64	71	50
3B	El Paso, TX	63	44	42	30
3C	San Francisco, CA	67	47	47	33
4A	Baltimore, MD	95	67	75	52
4B	Albuquerque, NM	68	48	48	34
4C	Seattle, WA	80	56	60	42
5A	Chicago, IL	97	68	77	54
5B	Colorado Springs, CO	75	52	54	38
6A	Burlington, VT	103	72	83	58
6B	Helena, MT	88	62	68	47
7A	Duluth, MN	111	78	91	64
8A	Fairbanks, AK	143	100	123	86

Figure 5 Energy use by end use for the baseline buildings

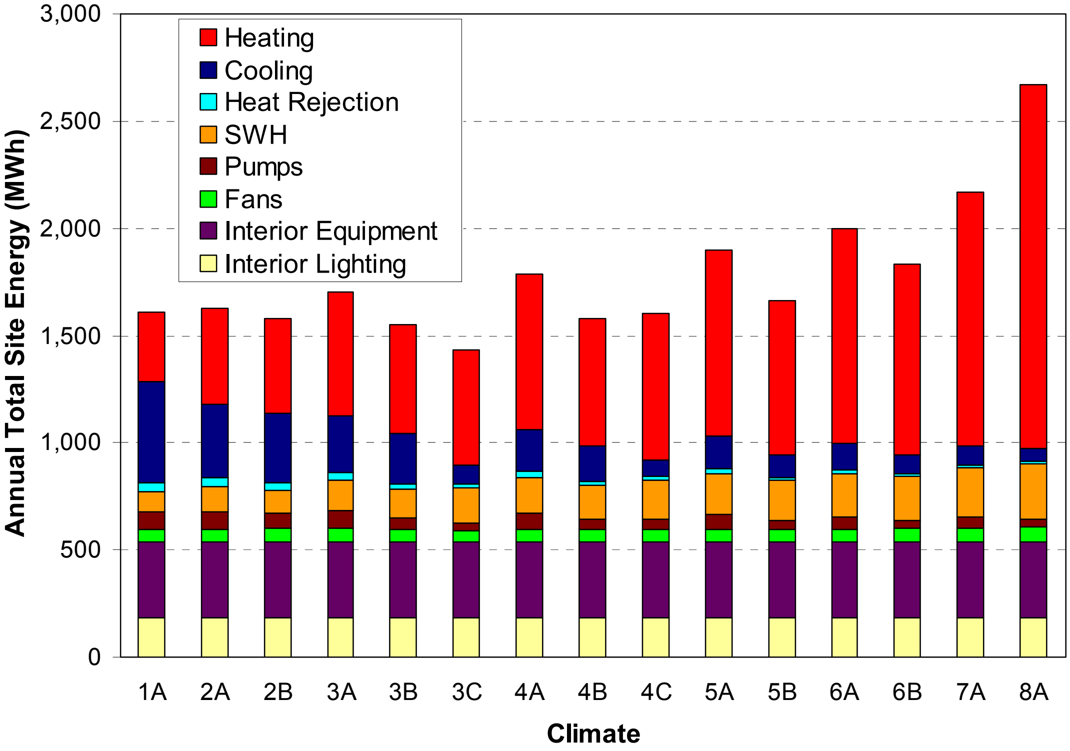


Table 5 Savings by Efficiency Measure without Plug Loads

Zone	City	Insulation, Windows, Infiltration, & Lighting	Grey Water HR	DOAS & ERV	High eff PSZ-AC
1A	Miami, FL	24%	1%	26%	8%
2A	Houston, TX	23%	2%	30%	8%
2B	Phoenix, AZ	18%	3%	5%	8%
3A	Memphis, TN	16%	2%	32%	9%
3B	El Paso, TX	17%	4%	5%	8%
3C	San Francisco, CA	19%	4%	19%	8%
4A	Baltimore, MD	17%	2%	35%	9%
4B	Albuquerque, NM	18%	4%	15%	8%
4C	Seattle, WA	19%	3%	31%	8%
5A	Chicago, IL	13%	3%	40%	9%
5B	Colorado Springs, CO	16%	4%	25%	8%
6A	Burlington, VT	12%	3%	42%	9%
6B	Helena, MT	15%	3%	34%	8%
7A	Duluth, MN	13%	3%	43%	9%
8A	Fairbanks, AK	13%	2%	44%	10%

Table 6 Total Energy Efficient Design Solutions without Plug Loads

Zone	City	Baseline (kBtu/ft^2)	System 1: High Efficiency PSZ-AC		System 2: DOAS, ERV, 4-Pipe Fan Coil	
			(kBtu/ft^2)	Savings	(kBtu/ft^2)	Savings
1A	Miami, FL	82	55	34%	40	51%
2A	Houston, TX	82	55	33%	37	55%
2B	Phoenix, AZ	45	32	29%	34	25%
3A	Memphis, TN	71	52	27%	35	50%
3B	El Paso, TX	42	30	29%	31	26%
3C	San Francisco, CA	47	33	31%	27	42%
4A	Baltimore, MD	75	54	28%	34	55%
4B	Albuquerque, NM	48	34	30%	30	37%
4C	Seattle, WA	60	42	30%	28	53%
5A	Chicago, IL	77	58	24%	35	55%
5B	Colorado Springs, CO	54	39	28%	30	44%
6A	Burlington, VT	83	63	24%	36	57%
6B	Helena, MT	68	49	27%	32	53%
7A	Duluth, MN	91	68	25%	37	59%
8A	Fairbanks, AK	123	92	25%	49	60%

Conclusions

EPAct 2005 sets energy performance levels to reduce energy use in federal facilities. The USACE determined the best way to meet the requirements of the new law for the large number of new buildings it anticipates was to develop standard baseline buildings and set target energy budgets. USACE also wanted a prescriptive path to meet the energy savings requirements. The target energy budgets and the prescriptive recommendations are put in the requests for proposals for new buildings. Contractors may either follow the prescriptive path or do their own energy calculations to show compliance with the 30% energy savings.

Design guides for eight building types are being developed for the Army. This paper presents the results of developing target energy budgets and an energy design guide for a UEPH barracks. The approach used for the other seven building types is similar to that presented in this paper, with modifications based on the building systems and improvements based on knowledge gained from the previous design guides. The energy savings in two of the climates zones reached only 29%; however, energy savings of 50% or greater were shown possible in 10 climate zones for the UEPH barracks. The results are strongly dependent on the model assumptions and may or may not be realized in actual buildings.

Results of this study were implemented in the Army's standard RFP process for new UEPH barracks construction in late 2007. New UEPH design/construction begun in 2008 and beyond will require the Contractor to design and construct a UEPH facility that meets the target energy budget developed in this study using either a custom design or the design guide's prescriptive path developed as part of this study. Results for the other building types will be incorporated into the Army's RFP process in 2008 for 2009 and beyond for new construction.

References

ASHRAE (2004a). *Energy Standard for Buildings Except Low-Rise Residential Buildings.* ANSI/ ASHRAE/IESNA Standard 90.1-2004. Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

ASHRAE (2004b). *Ventilation for Acceptable Indoor Air Quality.* ANSI/ASHRAE Standard 62.1-2004. Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

ASHRAE (2008). *Advanced Energy Design Guides.* Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers. www.ashrae.org/publications/page/1604

Briggs, R.S., Lucas, R.G., and Taylor, T. (2003). *Climate Classification for Building Energy Codes and Standards: Part 2 - Zone Definitions*, Maps and Comparisons, Technical and Symposium Papers, ASHRAE Winter Meeting, Chicago, IL, January, 2003. Atlanta, GA: American Society of Heating Refrigerating, and Air-Conditioning Engineers.

DOE (2008). *EnergyPlus, Building Energy Simulation Software* web site. Washington, D.C.: U.S. Department of Energy. www.EnergyPlus.gov.

FEMP (2005). *Heat Recovery from Wastewater Using a Gravity-Film Heat Exchanger*. DOE/EE-0247 Revised, Federal Energy Management Program, Washington, D.C.: U.S. Department of Energy.

NARA (2006). Federal Register Vol. 71, No. 232. pp.70275-70284. Washington, D.C.: National Archives and Records Administration.

U.S. Congress (2005). *Energy Policy Act of 2005*, Pub. L. No. 109-58, 119 Stat. 594 (2005). Washington, D.C.

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The Engineer Research and Development Center of the U.S. Army Corps of Engineers and the National Renewable Energy Laboratory are developing target energy budgets and design guides with a prescriptive path to achieve 30% energy savings over a baseline built to the minimum requirements of ANSI/ASHRAE/IESNA Standard 90.1-2004. This project covers eight building types in 15 U.S. climate zones. The building types include barracks, administrative buildings, a maintenance facility, a dining facility, a child development center, and an Army reserve center. This paper focuses on the design guide for one type of barracks called unaccompanied enlisted personal housing, which are similar to apartment buildings with double occupancy units.

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