Executive Summary

Background

Fort Carson is a historic, 72-year-old Army base in Colorado with major environmental accomplishments and ambitions. As a flagship in the Army's Net Zero Initiative, Fort Carson has set goals of net zero energy (NZE),[1] water and waste for the entire base by the year 2020. Fort Carson's progress to date in meeting these goals includes the construction of over 70 LEED-certified green buildings on base. The base's sustainability goals dovetail with the objectives of the U.S. General Services Administration (GSA) Office of Federal High-Performance Green Buildings to improve understanding of how sustainable technologies and approaches can enhance building performance.

Figure 1 LEED-rated 4th Brigade Combat Team Brigade Battalion Headquarters, Fort Carson, Colorado

[1] For purposes of this report, an NZE building or installation is one that produces as much energy as it uses over the course of a year.

GSA partnered with Fort Carson, the U.S. Department of Energy and two National Laboratories to conduct the Fort Carson Energy Research Project from 2011 to 2013. The project goal was to identify the most lifecycle cost-effective strategies, on both the building and portfolio levels, to achieve NZE performance.

The project targeted six different Army building types and identified four areas of opportunity for the buildings to achieve energy efficiency breakthroughs. Three of the opportunities involved improving building systems and the fourth targeted the impact of building occupant behavior on energy performance. As a whole, this research project demonstrated effective ways to

What is Net Zero Energy?

- The most commonly used definition of an NZE building is: "for every unit of energy the building consumes over a year, it must generate a unit of energy."[2]
- Although not technically an NZE goal, the Energy Independence and Security Act of 2007 (EISA) requires that Federal buildings reduce fossil fuel-generated energy consumption by 100% by 2030.
- The Army defines a Net Zero Energy Installation (NZEI) as: "an installation that produces as much energy on-site as it uses, over the course of a year. To achieve this goal, installations must first implement aggressive conservation and efficiency efforts while benchmarking energy consumption to identify further opportunities. […] The balance of energy needs then are reduced and can be met by renewable energy projects."[3]

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[2] Whole Building Design Guide http://www.wbdg.org/resources/netzeroenergybuildings.php

[3] Army Vision for Net Zero, http://www.asaie.army.mil/Public/ES/netzero/docs/4Oct11_NET_ZERO_White_Paper.pdf

drive down building energy use and thereby save money and achieve ambitious energy and climate change goals.

The most effective approach to achieving NZE is to first reduce energy use to the greatest extent possible and then focus on renewable energy development for remaining energy needs. The project focused on the critical first step, aiming to identify energy reduction strategies with the highest return over the lifecycle of the buildings studied, including both building systems investments and occupant behavior change.

> An NZE building is one that produces as much energy as it uses over the course of a year.

The National Renewable Energy Laboratory (NREL) led the building systems research, while the Pacific Northwest National Laboratory (PNNL) led the occupant behavior research. The research teams identified the following research questions to guide their work:

GSA Demonstration Projects

GSA's Office of Federal High-Performance Green Buildings conducts research to demonstrate how Federal buildings can improve their energy and environmental performance. More information on GSA demonstration projects, including reports from completed projects, is available at GSA's Building Research webpage: www.gsa.gov/buildingresearch.

Research Questions

1. How can thermal envelope construction be optimized for lifecycle energy savings?

2. How well are the daylighting and lighting systems performing now, and how can their performance be maximized?

3. What sets of efficiency solutions are available at optimal energy lifecycle cost for common retrofits?

4. Which occupant behaviors have the greatest potential to reduce energy use in buildings, and what approaches can motivate and maintain these behaviors?

This report documents the project teams' methods, findings and recommendations in pursuit of each of these research questions.

Key Research Findings

Thermal Envelope Optimization

The research incorporated actual performance and cost data into energy models to compare a variety of wall, roof and window envelope assemblies in five of the Fort Carson building types. NREL employed net present value analysis to determine the most cost-effective solutions over 30-year building lifecycles, compared to the building energy code baseline (ASHRAE Standard 90.1-2007). The lab also studied opportunities to save energy when troops are deployed, by zoning and partially shutting down unused building sections. We found that:

1. Envelope optimization in new buildings at Fort Carson can yield savings up to 25% over the code baseline with net present value up to $350,000 and simple payback as low as seven years.

2. Results vary widely by building type; e.g., envelope improvements are a key component of NZE design for buildings with large heating loads, but may be less helpful for buildings that are dominated by equipment loads.

3. Thermal zoning and ventilation setback when troops are deployed can yield energy savings up to 23%.

Daylighting and Lighting System Performance

To evaluate performance and identify opportunities for Fort Carson buildings to provide superior lighting with minimal energy use, NREL observed occupancy, lighting and daylighting patterns at four building types, modeled alternative solutions where appropriate, and translated lessons learned into recommendations for improvement. Findings include:

1. Fort Carson is using up to 50% less lighting energy than buildings meeting minimum energy code requirements.

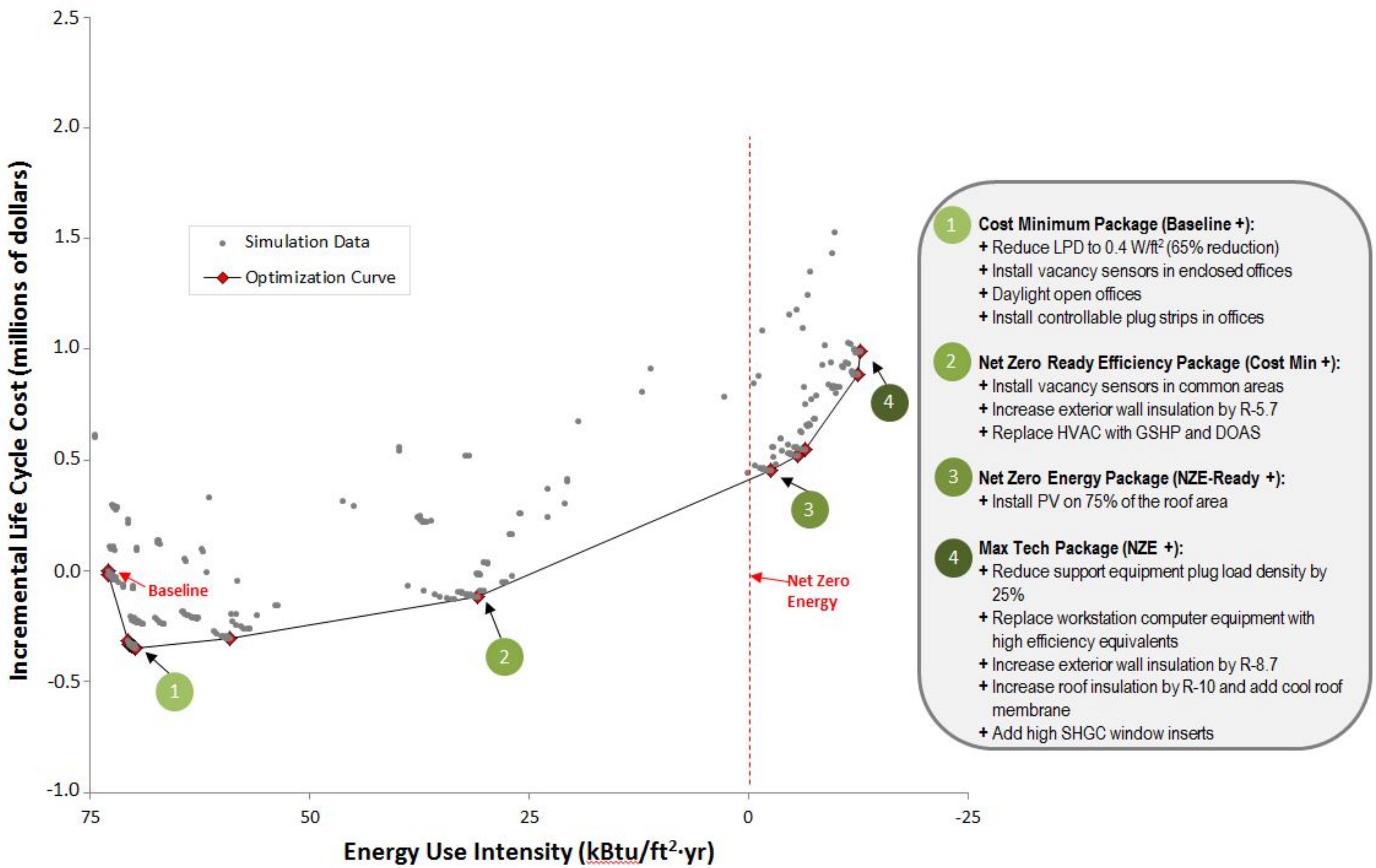
2. The base has further opportunities to optimize lighting quality and efficiency while reducing consumption to levels 90% lower than required by code.

Net Zero Retrofit Optimization

The research team used an office building on the base that had been renovated from a former barracks as the basis for a study to identify a lifecycle-cost-effective pathway to achieve energy reduction performance up to NZE for retrofit projects. NREL sought to demonstrate the feasibility of NZE retrofit planning primarily using open source on-line modeling tools. Findings include:

1. Fort Carson office building retrofits have a clear, low-risk investment path of bundled energy technology solutions from lowest life-cycle cost to NZE. (See output of the modeling exercise in Figure 2 below.)

2. Publicly available open source tools can be used to identify much of this roadmap of bundled energy technology solutions.



Note: DOAS – dedicated outdoor air system, GSHP – Ground source heat pump, HVAC – heating, ventilation, and air conditioning, kBtu/ft^2·yr – thousand British thermal units per square foot per year, LPD – Lighting Power Density, PV – Photovoltaic, SHGC – Solar heat gain coefficient, W/ft^2 – watts per square foot

Figure 2 Retrofit Optimization Results: Simulation Output

Occupant Behavior

PNNL gathered data on the energy-related behaviors of Fort Carson civilian and military building occupants through surveys, group interviews and energy metering. Based on these data, the research team designed a three month intervention at five buildings to test the potential of the Army's Building Energy Monitor (BEM) program to motivate occupants to employ energy-saving behaviors. The intervention tested a model of change that integrates policy ("Rules"), identification of people in specific roles as linchpins ("Roles") and a variety of behavior change methods ("Tools"). In contrast to the Rules, Roles and Tools approach, typical behavior change interventions focus on single behaviors and do not include the organizational context. Findings:

1. Occupants increased energy-saving behaviors as part of the intervention, leading to energy reductions of approximately 2% in one building. Success rates varied across the five buildings. (Results of the effort to increase nightly computer shutdowns shown in Figure 3 below.)

2. Having an engaged BEM with reinforcement from leadership helped drive behavior change.

3. Occupant behavior can be influenced as part of a well-structured effort that includes considering the institutional context, targeting specific and relevant behaviors, providing social reinforcement, measuring results and incorporating feedback.

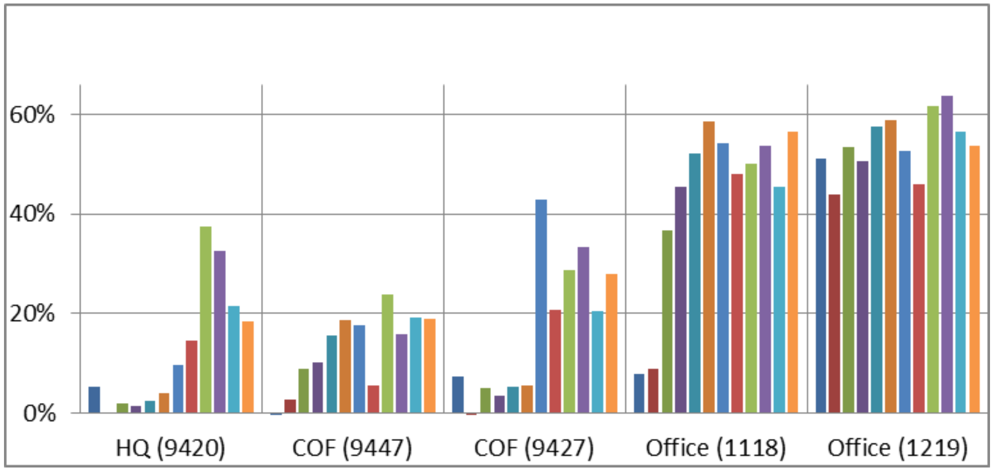


Figure 3 Percent of Computers Shut Down at Night during Research Intervention, by Building and Week

Recommendations Based on Research Findings

While the findings of this project are specific to the building types, systems, climate and population of Fort Carson, they also reveal lessons in integrating energy efficiency strategies applicable to other buildings:

- The building systems research conducted under this project demonstrated the value of taking a deep dive into how efficiently building systems (like lighting and envelope) are operating and identifying opportunities for improvements, up to NZE. Analyses that take lifecycle costs and benefits into account lay the groundwork for making the most rational decisions over the lifetime of a building.

- Best practices identified should be built into portfolio planning, standards, contract language and specifications. Solutions will need to be adapted to each individual building, at which point technologies and approaches can be bundled together to form the most lifecycle-cost-effective progression of investments.

- The behavioral research demonstrated opportunities to effectively engage building occupants in energy reduction. The research suggested the value of integrating building systems improvements with occupant engagement strategies, as both are needed to achieve NZE levels.

- Engaging occupants requires employing institutional approaches that integrate changes in policy and organizational roles with programs to influence specific occupant behaviors. Occupants need support to adopt energy-saving behaviors, and all relevant rules, roles and tools should be considered and adjusted to ensure that they receive such support. As a key example, local energy advocates need systems to monitor energy use and gain feedback from occupants while also informing occupants of energy use levels and how they can reduce them.

Attaining a high standard like NZE requires finding and using every tool in the toolbox. Yet even such an ambitious goal appears increasingly attainable as building professionals learn how to design and adapt building systems and work with occupants to make it happen.

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