ESTCP Project Outbrief

Zero Energy Housing for Military Installations

EW-200814
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EW-200814: Zero Energy Housing for Military Installations

Technology

This project evaluated the design approach and operational performance of two zero energy housing (ZEH) units compared to two typically designed (baseline) housing units

Demonstration

Performance monitoring of four housing units was used to compare the energy, water, operations, occupant satisfaction, and life-cycle cost of the ZEHs compared to the baseline housing units

Technical & Economic Performance Results

- Sought:14 qualitative and quantitative objectives were pursued
- Achieved: 9 of the metrics were met

Project Hurdles

- Monitoring equipment failures

Technology Transfer Outlook

- Interest by Lend Lease to use the tools to inform its customers on how to reduce energy use

Performers:

Army, PNNL, Campbell Crossing/Lend Lease, Concurrent Technologies Corporation, National Association of Home Builders

Demonstration Site(s):

Fort Campbell, Tennessee/Kentucky

Project Team

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Pacific Northwest National Laboratory

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U.S. Army Installation Management Command, Southeast

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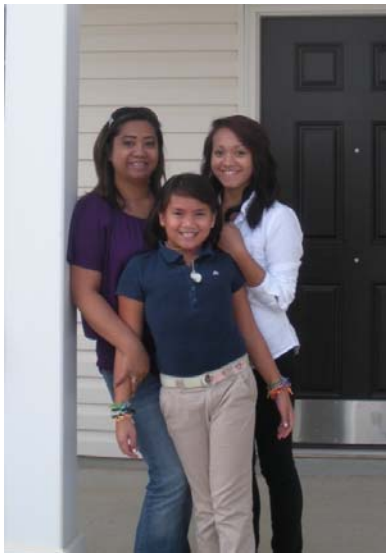
Campbell Crossing/Lend Lease

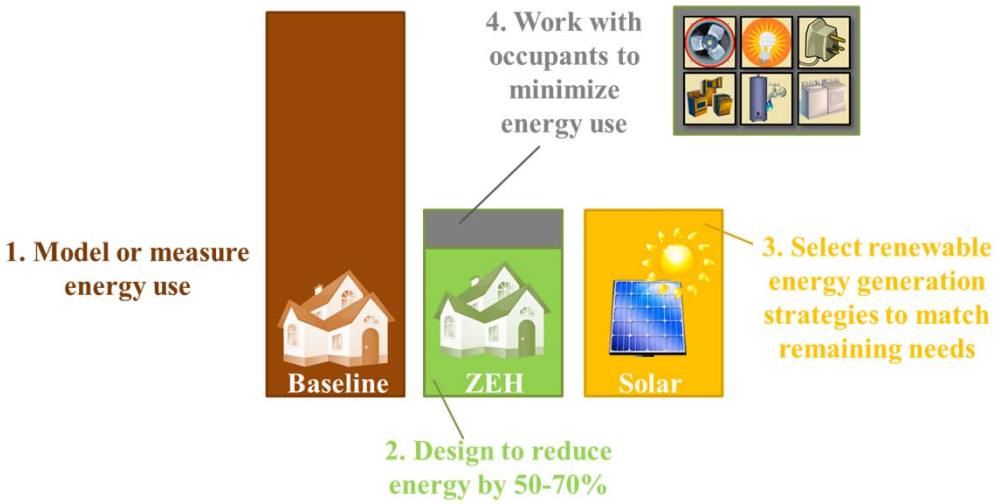
Heidi Anne Kaltenhauser
Concurrent Technologies Corporation

Joe Wiehagen
National Association of Home Builders

Background

- Residential homes use more than 20% of the energy consumed in the U.S.
- Net zero energy homes produce as much energy as they use over a given time
- Project Scope: Performance evaluation of two net zero energy homes at Ft. Campbell, Kentucky





Technical Objective

- Compare two net Zero-Energy Homes (ZEHs) to two baseline homes with respect to:
  - ♦ construction and O&M costs
  - ♦ energy efficiency
  - ♦ environmental impact
  - ♦ occupant comfort

Performance Objectives: Design

Performance Objective	Metric	Success Criteria	Results
Quantitative Performance Objectives			
1. Reduce modeled energy use of ZEH design compared to typically designed unit (*Energy*)	Modeled annual energy use per unit area	ZEH model shows 50% less annual energy use (kBtu per square foot) than typically designed unit	ZEH model showed 52% less energy use than typically designed unit
2. Reduce modeled energy use of ZEH design compared to national standards (*Energy*)	Modeled annual energy use per unit area	ZEH model shows 60% less annual energy use (kBtu per square foot) than the national average	ZEH model showed 72% less energy use than the national average
3. Modeled on-site energy generation is equal or greater than modeled energy use (*Energy*)	Modeled net energy use per year	ZEH model shows energy generation (kBtu per year) is equal to or greater than design energy use	ZEH model showed 8% more energy generation than design energy use
4. Reduce modeled potable water use of ZEH design compared to typically designed unit (*Water*)	Modeled annual water use per occupant	ZEH design includes more efficient fixtures and fittings than typically designed unit	Rated performance of ZEH toilets were 22% more efficient than the typically designed unit; lavatory faucets were 32% more efficient, and showers were 30% more efficient

Performance Objectives: Measured

Performance Objective	Metric	Success Criteria	Results
Quantitative Performance Objectives			
5. Reduce measured energy use of ZEH compared to typically designed unit (*Energy*)	Measured annual energy use per unit area	ZEH design includes more efficient fixtures and fittings than typically designed unit	Rated performance of ZEH toilets were 22% more efficient than the typically designed unit; lavatory faucets were 32% more efficient, and showers were 30% more efficient
5. Reduce measured energy use of ZEH compared to typically designed unit (*Energy*)	Measured annual energy use per unit area	ZEH shows 50% less energy use (kBtu per square foot) than a typically designed unit and Fort Campbell unit complex average	ZEH A: energy use was 29% less than average typically designed unit and 40% less than average Fort Campbell unit complex ZEH B: energy use was 19% less than average typically designed unit and 31% less than average Fort Campbell unit complex
6. Reduce measured energy use of ZEH compared to national standard (*Energy*)	Measured annual energy use per unit area	ZEH shows 60% less energy use (kBtu per square foot) than national average	ZEH A: energy use was 63% less than national average ZEH B: energy use was 58% less than national average

Performance Objectives: Measured

Performance Objective	Metric	Success Criteria	Results
Quantitative Performance Objectives			
7. Annual measured on-site energy generation is equal to or greater than annual measured energy use (*Energy*)	Measured net energy use per year	Annual ZEH energy generation (kBtu per year) is equal or greater than its energy use	ZEH A: energy generation was 79% of energy use ZEH B: energy generation was 67% of energy use
8. Reduce measured HVAC system energy use compared to typically designed unit (*Energy*)	Metered HVAC system energy use per year	ZEH HVAC system shows 60% less energy use (kBtu per year) than the HVAC system in the typically designed unit	ZEH A: HVAC system energy use was 26% less than average typically designed unit ZEH B: HVAC system energy use was 33% less than average typically designed unit
9. Reduce measured ZEH hot water energy use compared to typically designed unit (*Energy*)	Metered annual hot water use per occupant	ZEH hot water system shows 60% less energy use (kBtu per occupant per year) than hot water system of typically designed unit	ZEH A: hot water system energy use was 39% less than average typically designed unit ZEH B: hot water system energy use was 3% less than average typically designed unit

Performance Objectives: Measured

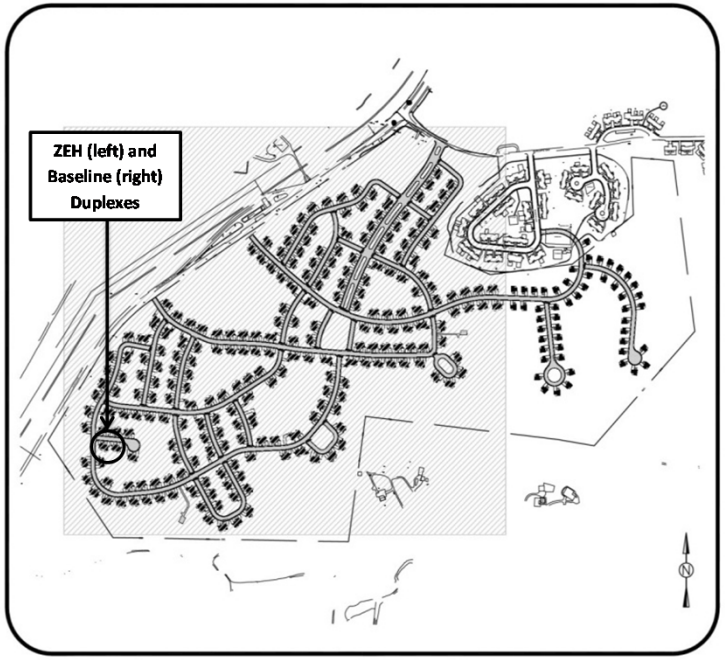
Performance Objective	Metric	Success Criteria	Results
Quantitative Performance Objectives			
10. Reduce measured ZEH lighting, plug load, and appliance energy use compared to typically designed unit (*Energy*)	Metered annual energy use associated with lighting, plug load, and appliances	ZEH shows 10% less annual energy use (kBtu per occupant) for lighting, 10% less annual energy use for plug loads, and 20% less energy use for appliances compared to typically designed unit	ZEH A: lighting energy use was 33% less than average typically designed unit ZEH B: lighting energy use was 16% less ZEH A: plug load energy use was 4% less than average typically designed unit ZEH B: plug load energy use was 3% less ZEH A: appliance energy use was 32% less than average typically designed unit ZEH B: appliance energy use was 19% less
11. Reduce measured ZEH potable water consumption compared to typically designed unit (*Water*)	Metered annual water use per occupant	ZEH shows 30% less water use (gallons per occupant) than typically designed unit	ZEH A water use was 51% less than Baseline B. Sufficient data were not available to compare ZEH B water use.
12. Reduce ZEH air emissions associated with measured electricity use (*Air Quality*)	Calculated emissions from energy generation sources using CO_2 equivalents as the indicator metric	ZEH related net emissions (CO_2 equivalents per year) are 100% lower than typically designed unit	ZEH A: emissions were 85% less than the average typically designed unit ZEH B: emissions were 75% less

Performance Objectives: Measured

Performance Objective	Metric	Success Criteria	Results
Qualitative Performance Objectives			
13. ZEH maintenance is equal or less than typically designed unit maintenance *(Maintenance)*	Number of maintenance activities and time associated with these activities	ZEH maintenance activities are equal or less than the typically designed unit maintenance activities	ZEH preventative maintenance activities were more than the typically designed unit. ZEH emergency maintenance activities were approximately the same as the typically designed unit
14. ZEH occupant satisfaction is equal to or higher than typically designed unit (*IEQ*)	Building occupant satisfaction feedback from occupant interviews	ZEH shows equal or higher satisfaction as compared to the typically designed unit	ZEH satisfaction was equal to typically designed unit

Technical Approach: ZEH Design

- Energy modeling
- Strategies to reduce energy demand 50-70%
- Strategies for renewables



SITE MAP

ZEH and Baseline
Notable Design Differences

Baseline Design	ZEH Design
Air Source Heat Pump	Ground Source Heat Pump
Electric Water Heater	Solar Water Heater
2x4 Metal Stud Exterior Walls	2x6 Wood Stud Exterior Walls
R-15 Wall Insulation R-49 Ceiling Insulation R-0.5 Sheathing	R-19.8 Wall Insulation R-60 Ceiling Insulation R-5 Sheathing
Occupant-provided Clothes Washer and Dryer	Project-provided High Efficiency Clothes Washer and Dryer
No Envelope Sealant	Envelope Perimeter Sealant

Technical Approach: Whole Building Performance

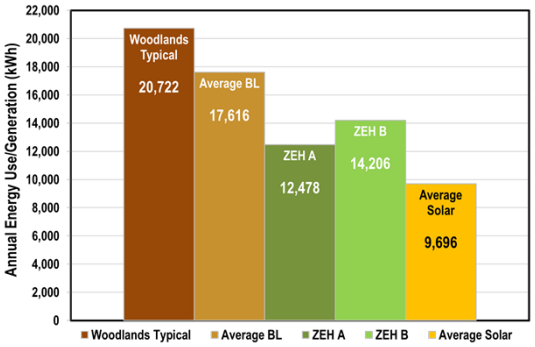
- Matched Pairs Analysis between ZEHs and baseline homes
  - Energy and water consumption, cost and use patterns
  - Maintenance costs and man-hours

Performance Monitoring

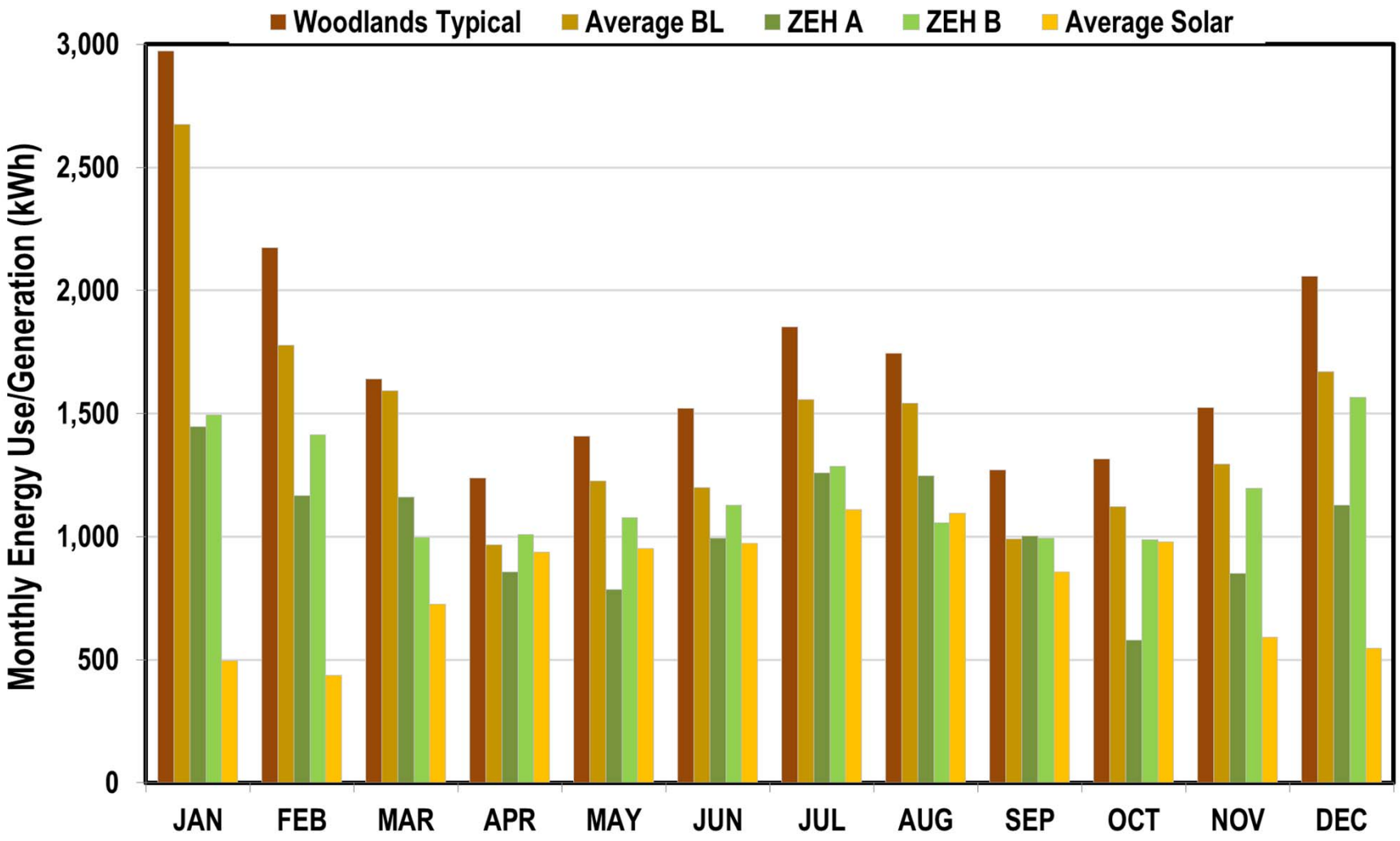
- 50 monitoring points including:
  - Electricity meters
  - End use meters
  - Water meters
  - Indoor and outdoor temperature and humidity
  - Solar hot water
  - Photovoltaic panels
- TED – The Energy Detective
- ShowerMinders
- In-home photovoltaic monitor

Results

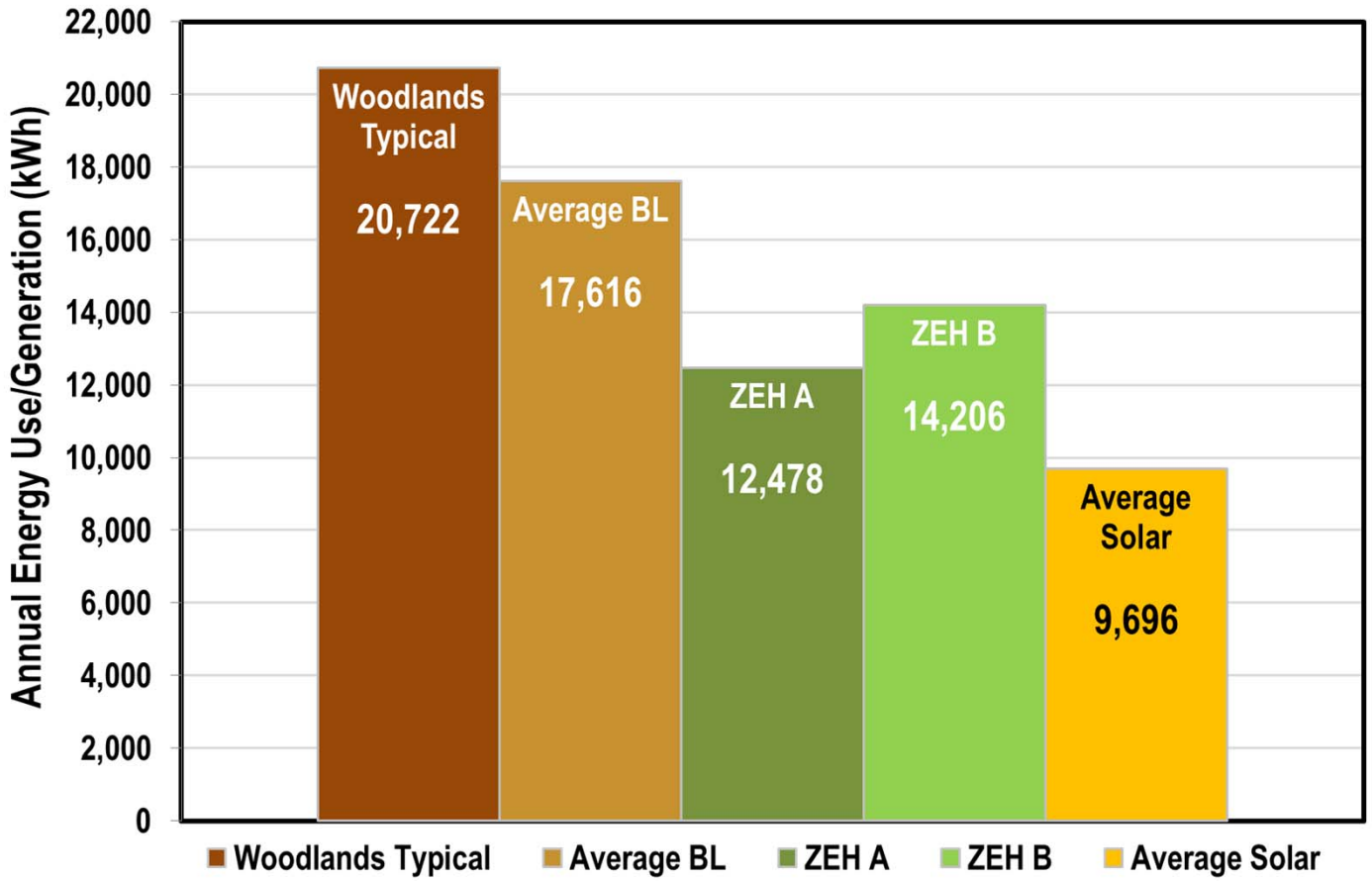
- ZEH units used
  - 24% less energy than 2 baseline units
  - 35% less energy than other homes in Woodlands Community
  - 51% less water/occupant than baseline units
- Baseline homes used
  - 15% less energy than other homes in Woodlands Community
- ZEH energy generation:
  - ZEH A: energy generation was 79% of energy use
  - ZEH B: energy generation was 67% of energy use
- Minimal maintenance differences during study period
- No notable differences in occupant satisfaction



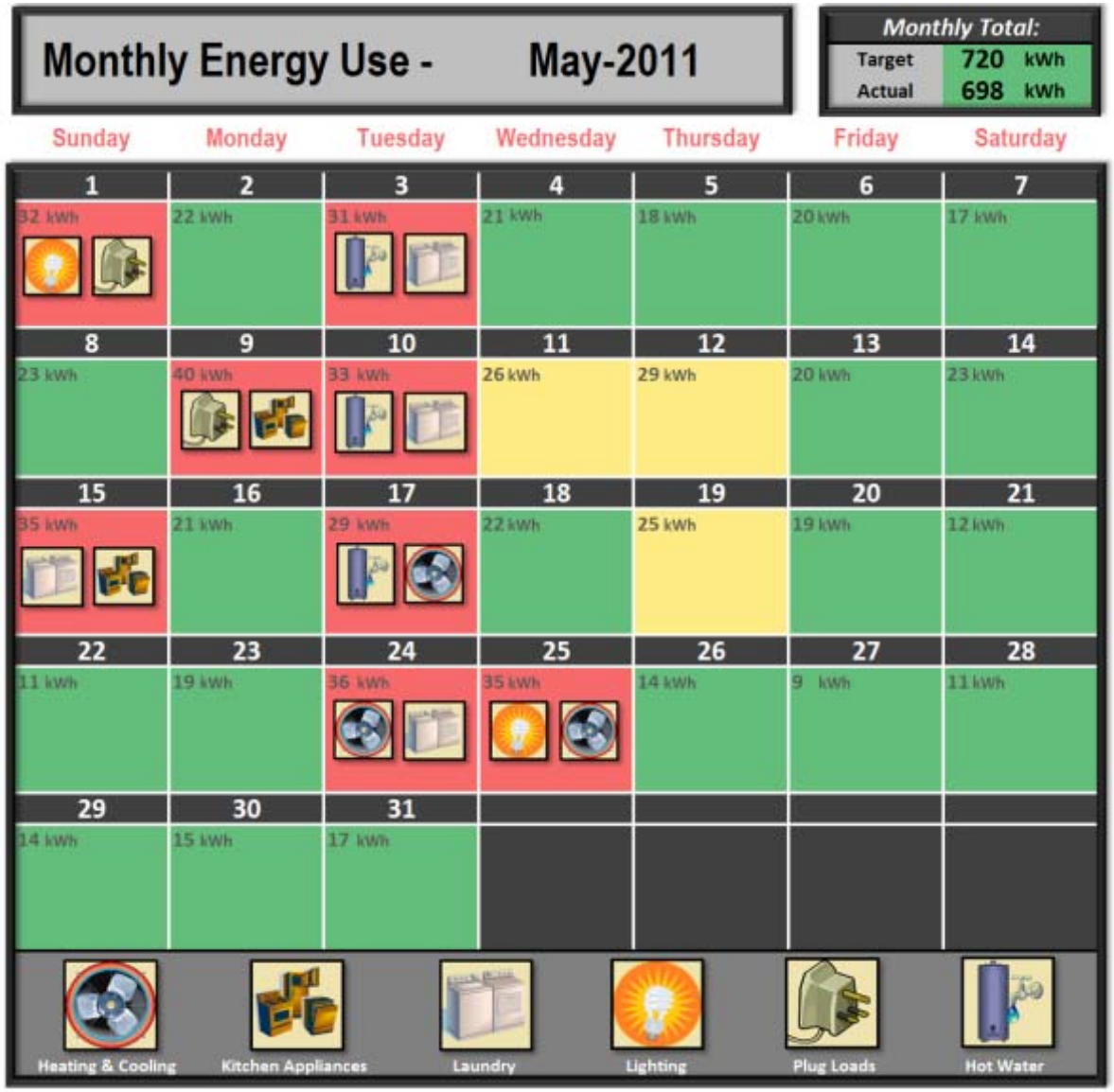
Monthly Energy Use

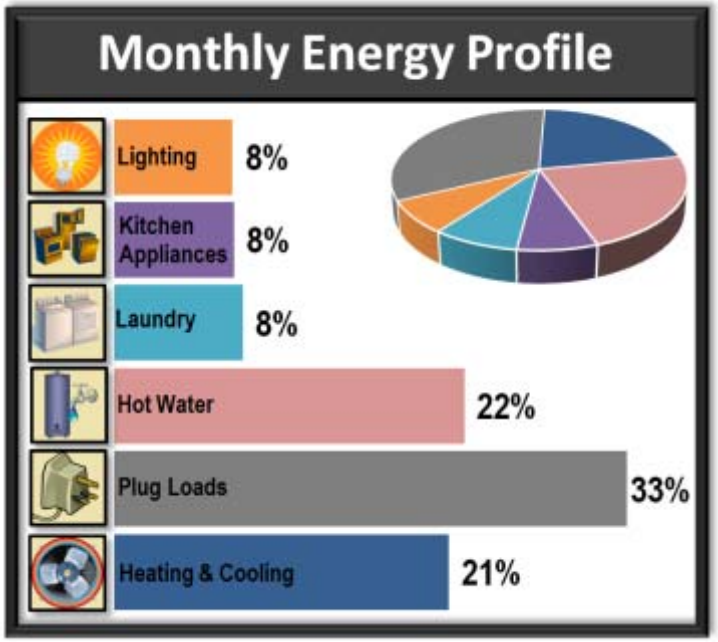


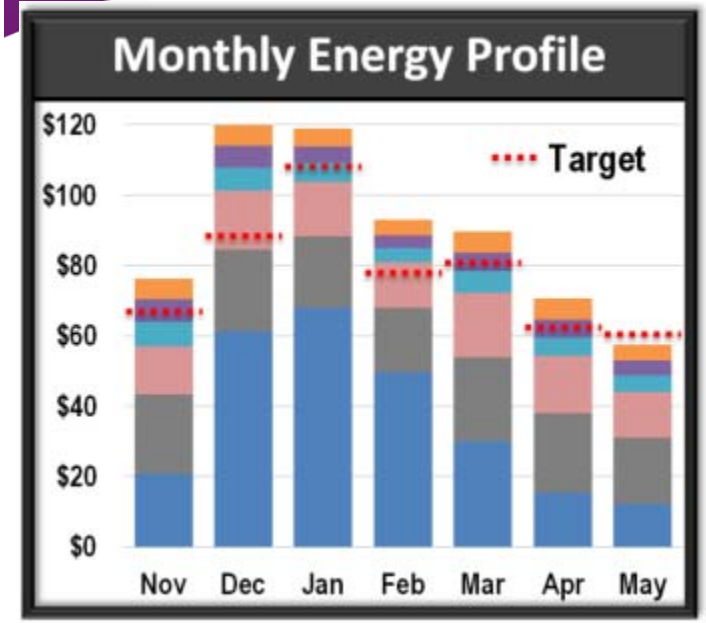
Annual Energy Use

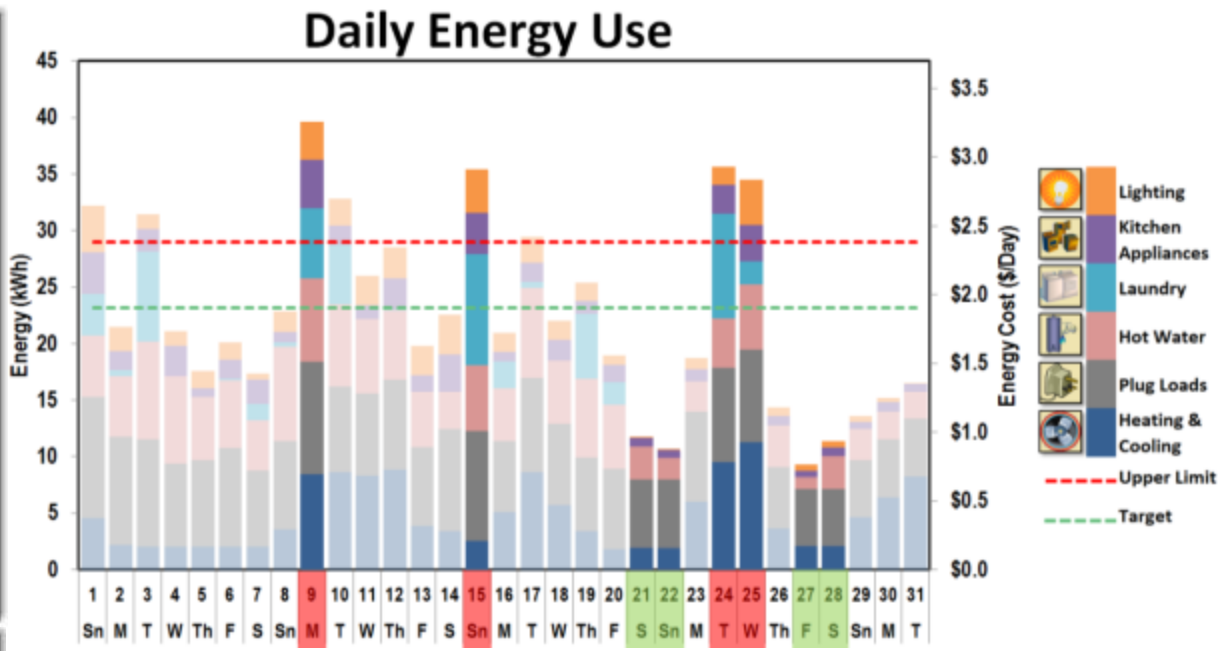


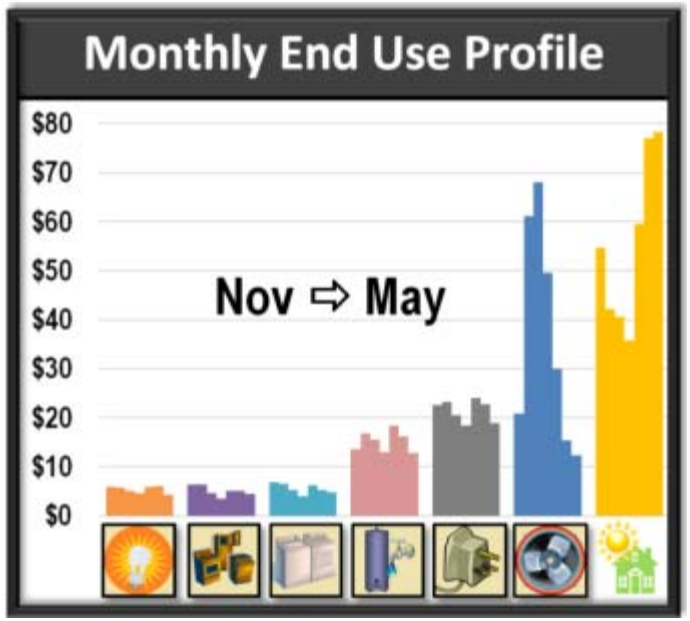
Occupant Interaction

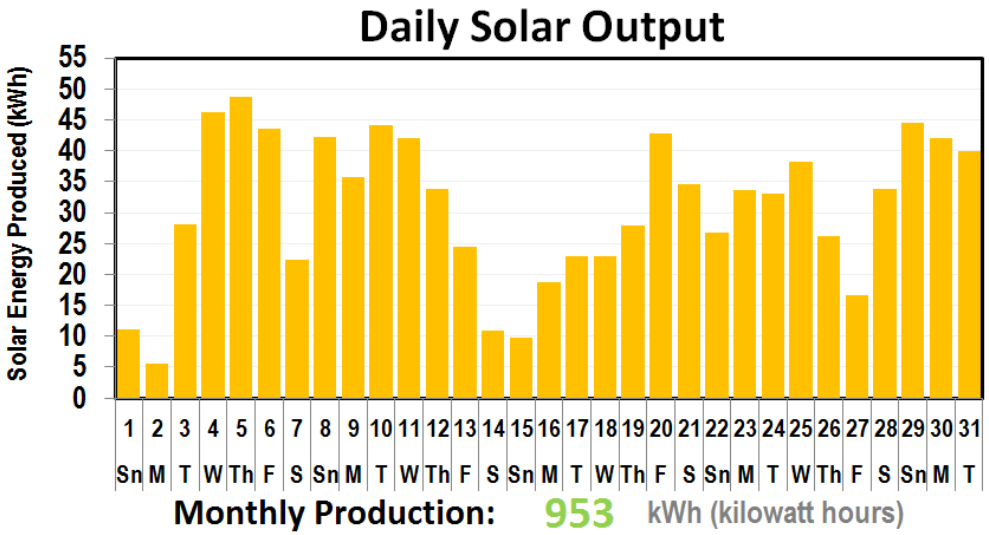





Monthly Energy Profile
$120
$100
$80
$60
$40
$20
$0
Target
Nov
Dec
Jan
Feb
Mar
Apr
May


Daily Energy Use
Energy (kWh)
Energy Cost ($/Day)
Lighting
Kitchen Appliances
Laundry
Hot Water
Plug Loads
Heating & Cooling
Upper Limit
Target


Monthly End Use Profile
Nov ⇨ May


Daily Solar Output
Solar Energy Produced (kWh)
Monthly Production: 953 kWh (kilowatt hours)

Issues/Lessons Learned

- Occupant feedback technologies and strategies have an impact on reducing energy use
- Greater emphasis on energy conservation and occupant behavior may be required
- ZEH designs may be more successful and cost-effective in areas such as California where energy costs are higher, renewable energy resource potential is greater, and designs are more adaptable
- Monitoring equipment failures

Technology Transfer

- Presentations to buildings community
  - ♦ Design, operations & occupant engagement strategies
- Lend Lease
  - ♦ Monitoring system/data analysis transfer attempt
  - ♦ Future home design modifications
  - ♦ Future occupant engagement
- ♦ DoD
  - ♦ GTMO: monitoring system, design, and operation lessons learned and recommendations

Publications

- US Green Building Council's Greenbuild – Oct 2011
- West Coast Energy Management Congress – June 2011
- US Green Building Council's Greenbuild Residential Summit – Nov 2009
- Fort Polk – August 09
- Army Monthly Sustainability Information Exchange – May 09
- Fort Lewis and Seattle COE District – February 09
- COE Net Zero Energy Conference – February 09
- SERDP/ESTCP Symposium – December 08
- Joint Services Environmental Management Conference – May 08
- HQ Army RCI conference – April 08