# Energy Use and Efficiency Opportunities in Military Base Family Housing

*Rick Kunkle, Michael Lubliner, Luke Howard, Ken Eklund, Andrew Gordon, and Luke Mattheis, Washington State University Energy Program*
*Michael Blasnik, Blasnik and Associates*

**ABSTRACT**

The paper provides an analysis of metered and predicted (using BEopt and SIMPLE) gas and electric energy use in housing at Joint Base Lewis McChord. Results compare energy use for 2,276 housing units in six on-base communities and identify energy retrofit opportunities. In particular we compare the energy use of newer ENERGY STAR® homes in one community with the others and estimate the energy savings from high efficiency tankless water heaters in some of these new homes. Case studies based on field audits on a small sample of homes in these communities highlight the importance of taking a "systems approach" to energy retrofits. Examples of "lost opportunities" for energy efficiency include, 1) improving the thermal distribution system efficiency when replacing old furnaces, 2) installing new gas high efficiency water heating in homes with gas space heating, and 3) sealing attic air leakage prior to adding more insulation. The paper offers "lessons learned" and recommendations to the Department of Defense and its private contractors who own and manage these communities.

## Introduction

Equity Residential, the owner of the housing on Joint Base Lewis McChord (JBLM),[1] has taken a number of steps to improve the energy efficiency of new and existing housing on the base. Efficiency upgrades include high efficiency natural gas furnaces, new water heaters, new windows, efficient lighting, and some ENERGY STAR® appliances. Since 2005, more than 500 energy efficient modular homes have been constructed in the Fort Lewis portion of JBLM. These factory-built homes are constructed to Northwest ENERGY STAR® Home standards (Northwest Energy Efficiency Alliance 2006), featuring 90% AFUE furnaces, efficient windows, and ENERGY STAR® appliances and lighting (Lubliner 2010). Building America supported this work through the Industrialized Housing Partnership.

The purpose of the research described in this paper was to further assist the Department of Defense (DOD), JBLM command, and Equity Residential in improving the energy efficiency of housing at JBLM. The Building America Buildings Technologies Program supported the research.[2] Researchers from the Washington State University (WSU) Energy Program worked in partnership with Equity Residential and Minol, the company managing the base's utility billing. Energy use in homes in six JBLM communities was analyzed and compared to assess performance. Field testing was conducted in a sample of homes in the communities and energy models were developed to identify opportunities for future energy efficiency improvements.

The research covered 2,276 housing units in 6 communities: Beachwood, Broadmoor, Davis Hill, Discovery Village (including Miller Hill), Evergreen, and New Hillside. Equity

[1] JBLM is located approximately five miles south of Tacoma, Washington State.

[2] Pacific Northwest National Laboratory provided funding for this research. Dr. Subrato Chandra was the Technical Monitor. We dedicate this work in his memory in gratitude for the many years of guidance and wisdom he provided.

provided information about the characteristics of the housing units, occupancy data, and information about capital improvements. All housing in these communities had natural gas space heat and either natural gas or electric resistance hot water heat. **Table 1** provides some basic characteristics for each of these communities. The Northwest ENERGY STAR® homes are in the Discovery Village/Miller Hill community.

**Table 1. JBLM Community Characteristics**

| Community | Units | Typical Square Feet | Typical Vintage | Gas Hot Water Heat (units) | Electric Hot Water Heat (units) |
|---|---|---|---|---|---|
| Beachwood | 512 | 1220-1494 | 1959-1963/ 2003 | 129 | 383 |
| Broadmoor | 169 | 1900-2844 | Pre-1950 | 72 | 97 |
| Davis Hill | 433 | 1154-1262 | 1959-1963 | 224 | 209 |
| Discovery Village | 458 | 1700-2062 | 2005-2007 | 458 | 0 |
| Miller Hill (part of Discovery Village) | 34 | 1780-2062 | 2008 | 34 | 0 |
| Evergreen | 147 | 1464-1580 | 1984/1995 | 147 | 0 |
| New Hillside | 523 | 1220-1378 | 1959-1963 | 0 | 523 |
| Total | 2276 | - | - | 1064 | 1212 |

## Approach

Researchers used three approaches to analyze energy use and identify efficiency opportunities at JBLM: utility billing analysis, energy audits, and energy modeling.

- Billing Analysis: Minol provided utility billing data in groups of 23 spreadsheets for each billing period for all the housing units in each community. The data covered the period from January 2009 to December 2010. Researchers entered the data into a database and matched it with unit characteristics data. Once the data was sorted, filtered, and organized, two analyses were conducted: an aggregate analysis of the actual energy use data for each community, and a regression analysis of the billing data to produce estimated energy use statistics for each community. The actual aggregate analysis calculated energy statistics for 12 annual periods for each community. The regression analysis estimated baseload and total electric and natural gas use under typical weather conditions (Typical Meteorological Year 3 (TMY3) weather data) using the utility billing data for each housing unit. Statistics for each community were calculated from the regression analysis. Regression models were also developed to analyze electric baseload, tankless gas water heaters, and annual natural gas use by community. During the analysis, researchers identified data quality issues that created challenges that were dealt with in the analysis: significant turnover in military housing (on the order of 50%) and a significant number of estimated utility readings.
- Energy Audits: Researchers conducted full energy audits in at least two unoccupied homes in each of the five non-ENERGY STAR communities. The audits included diagnostic testing along with visual inspections of the envelope and equipment. Three additional audits were conducted in homes with high bill complaints. Two of the bill complaint homes were in the five non-ENERGY STAR communities and one was in

Discovery Village. The audit protocol in these homes was the same except that a homeowner's survey was conducted in the three occupied homes.

- Energy modeling: The programs SIMPLE[3] and BEopt (Building Efficiency optimization)[4] were used. Performing the energy modeling served several purposes. By running both programs on each house, the results could be compared against one another and against the utility bills. More importantly, the results of the models also provided information on energy efficiency opportunities, which will allow JBLM to make better-informed decisions about future building retrofits and new construction.

## What We Learned

The results of the research highlight that the ENERGY STAR housing is performing well and that there are opportunities for energy efficiency improvement in the older communities. The results are presented for each part of the research (billing analysis, energy audits, and energy modeling).

### Billing Analysis

The billing analysis presented in this report compares the electric, gas and total annual energy use in six JBLM communities. The billing analysis also considers the performance of natural gas tank water heaters in a subset of homes in Discovery Village (called Miller Hill).

**The ENERGY STAR homes use less energy than the homes in the other communities.** Natural gas use is 40 to 60 percent lower except for a small group of newer non-ENERGY STAR homes where the difference is around 13 percent.[5] **Figure 1** shows the percentage natural gas savings per square foot relative to Discovery Village/Miller Hill (ENERGY STAR) for the 12 billing annual billing periods based on the actual aggregate energy use statistics. The four communities with natural gas heating and water heating are compared. Note the consistent differences between Davis Hill, Evergreen and Beachwood. Davis Hill was constructed in the 1960s, prior to any energy code. Evergreen was constructed in two stages; the first stage was constructed in 1984, prior to the adoption of the Washington State Energy Code (WSEC), and part in 1995 after the WSEC went into effect. The Beachwood units with natural gas water heating were built in 2003. The WSEC was the first statewide energy code to implement the Model Conservations Standards of the Northwest Power and Conservation Council. It has been upgraded regularly since its adoption in 1991. It is the key factor in explaining the across-the-board difference in energy use between these non-ENERGY STAR developments. It is national

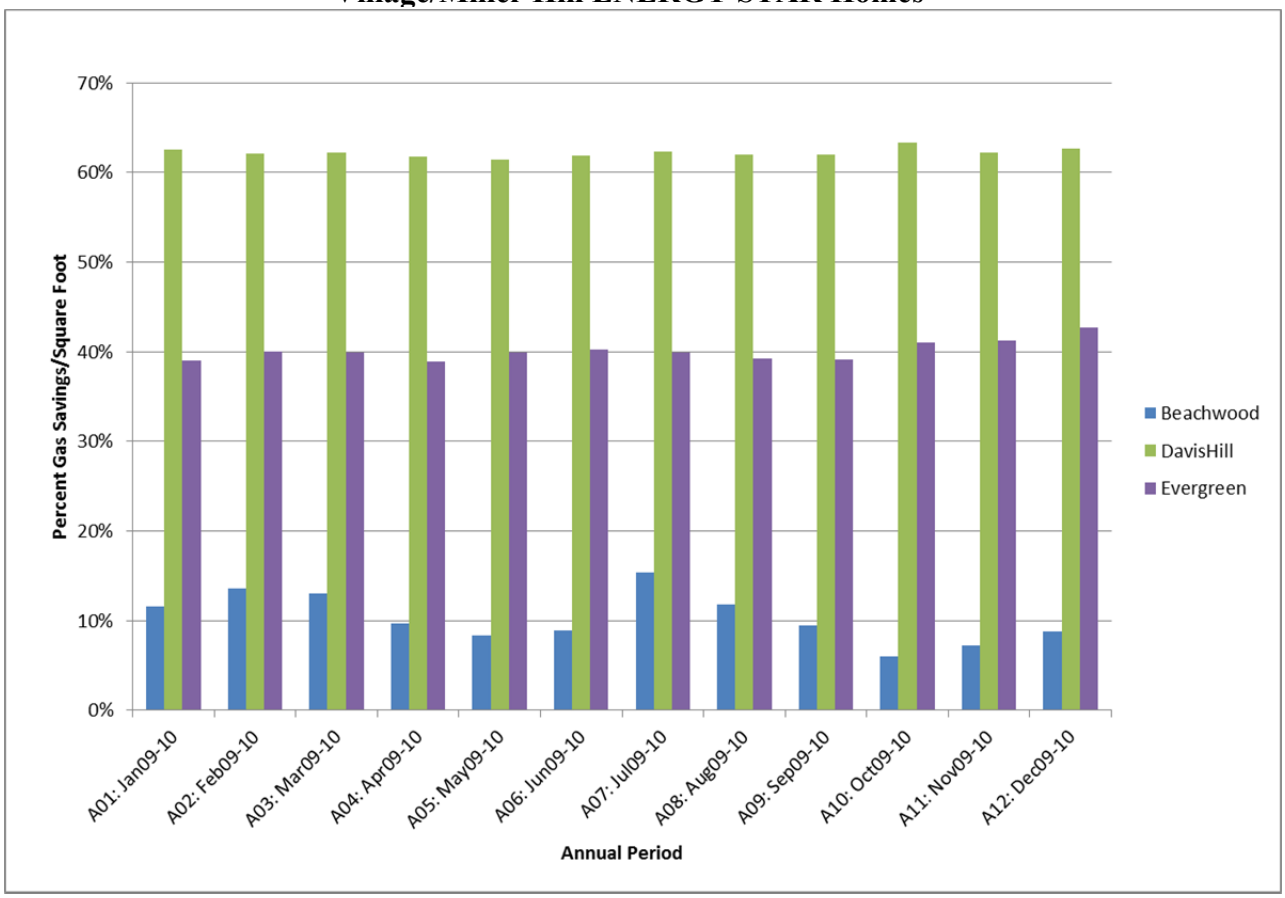
[3] **SIMPLE** is a spreadsheet designed by Michael Blasnik to allow the input of qualitative data to generate estimated household energy use. The values given to the qualitative model entries are drawn from extensive analyses of energy consumption from all over the country and represent averaged values of those qualitatively described inputs.

[4] **BEopt** is a software program (available at http://beopt.nrel.gov/ ) developed by the National Renewable Energy Laboratory (NREL) with the goal of "optimal building designs along the path to highly efficient buildings". BEopt possesses a large variety of options with which to customize a representative model and is constructed to simulate energy usage through integrated calculations and formulas.

[5] The Discovery Village/Miller Hill housing units are larger than the other communities. These savings adjust for square footage. The non-adjusted savings are 30-40 percent and less than 10 percent for the newer non-ENERGY STAR homes.

policy for the DOD and Department of Homeland Security to construct military rental housing to state building code requirements (see 10 U.S.C. § 2836 (c) (4) (A).

**Figure 1. Differences in Annual Natural Gas Use per Square Foot Relative to Discovery Village/Miller Hill ENERGY STAR Homes**

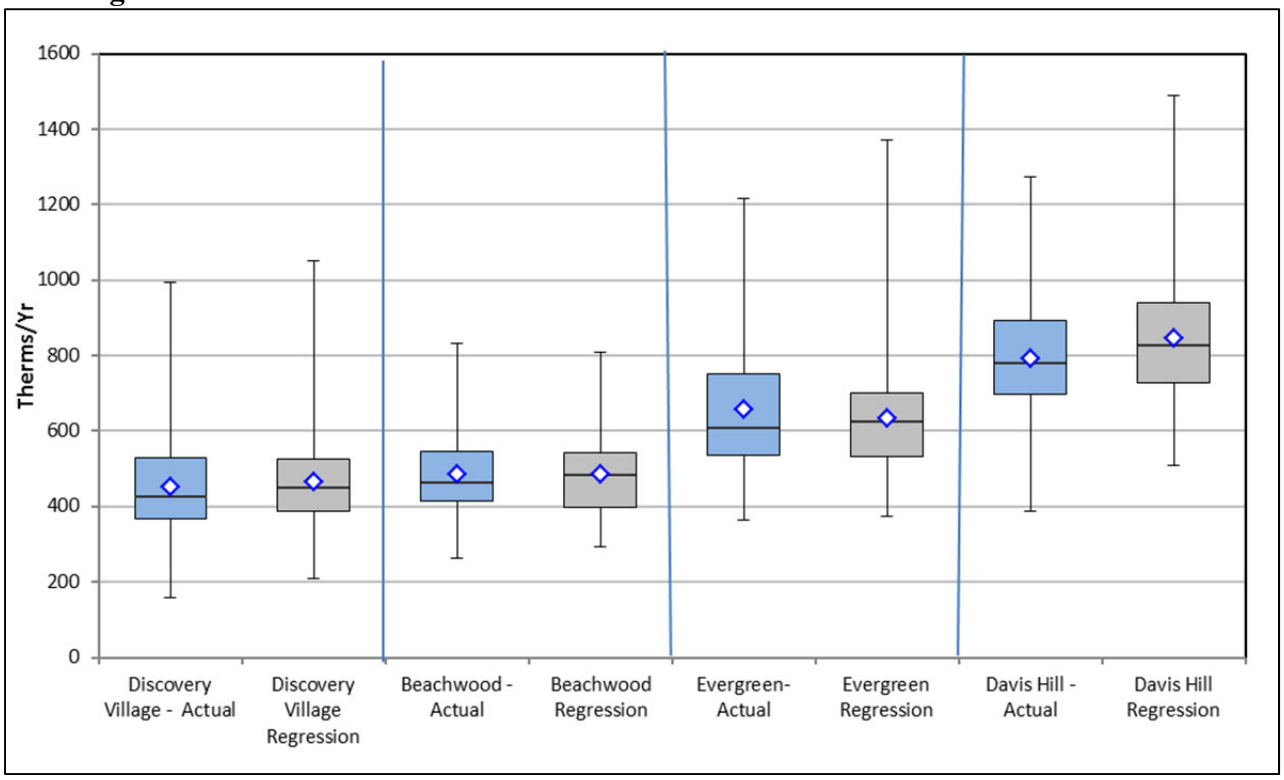



**Energy use varied significantly across housing units. Figure 2** graphically displays the natural gas energy use ranges for communities with natural gas heating and water heating[6]. For each of the four communities there is a box plot based on the actual aggregate annual energy use statistics and the regression analysis. The results for the actual natural gas use and regression natural gas use are close. Discovery Village/Miller Hill and Beachwood have similar natural gas use[7], while the older Evergreen and Davis Hill communities have higher use. There is a fairly wide range in the natural gas use in the housing units within each community. Even some of the Discovery Village homes have high natural gas use[8]. This may reflect changes in occupancy in units due to the nature of military service (even though a unit is occupied) as well as differences in occupant behavior. The shaded boxes are a good reflection of the energy use in each

[6] The box plot shows the median value, (the line across the box), average (the diamond), 25th and 75th percentile (the box) and maximum and minimum range (whiskers) in natural gas use.
[7] Note these values are not adjusted for square footage as in Figure 1. The Discovery Village homes are larger than the other housing units.
[8] The higher energy use in the Discovery Village home that was audited due to a high bill complaint seemed to be due to increased occupancy because one of the occupants left their job.

community. This variation in energy use is also evident in the electricity use within the communities.

**Figure 2. Total Natural Gas Use for Communities with Natural Gas Water Heat**




**Natural gas energy use in the historic Broadmoor neighborhood was substantially higher than the other neighborhoods.** Many of these homes were built between 1929 and 1939, with some duplexes built in 1948 and a few single-family homes built around 1960. They all have natural gas heat (gas boilers and radiators). The natural gas use in the Broadmoor homes is three to five times greater than the other communities (**Table 2**). Because the historical homes have less efficient building envelopes and heating systems and are larger than the homes in other communities, higher energy use is expected. It is possible that the high energy use is not representative of Broadmoor as a whole because of the small sample size[9] for the analysis. However, the usage still seems to be excessive and opportunities to reduce natural gas consumption should be explored, although historic preservation restrictions limit the options Equity Residential has in regard to the oldest of these buildings.

[9] The sample sizes were relatively low in Broadmoor due to missing natural gas data and the occupancy and data quality screens used in the analysis.

**Table 2. Total Energy Use for Broadmoor Single-family Units**

| | Natural Gas Hot Water Heat | | Electric Hot Water Heat | |
|---|---|---|---|---|
| | Natural Gas (therms) | Electricity (kWh) | Natural Gas (therms) | Electricity (kWh) |
| Annual Average Use | 2390 | 7951 | 2060 | 11517 |
| Annual Use 3/2009-3/2010 | 2496 | 7960 | 2039 | 9818 |
| Regression Average Annual Use | 2304 | 9014 | 1954 | 13711 |

The total electricity usage in the Broadmoor homes is comparable to the other communities. The regression analysis shows higher values, but this may be a data anomaly due to a small sample and some homes with high usage. When accounting for the higher square footage and number of bedrooms, electricity use in Broadmoor tends to be lower than the other communities. This counters one explanation for the high natural gas use – that the occupants of these homes are high energy users.

**Tankless natural gas water heaters save energy**. The newest housing units at JBLM were built in 2008 at Miller Hill (part of Discovery Village). These 34 units have high efficiency tankless natural gas hot water heaters (EF=0.82). To identify whether these tankless hot water heaters are generating any natural gas energy savings, researchers compared the natural gas use of Miller Hill units with similar units in Discovery Village. These Discovery Village units have power vented storage natural gas water heaters (EF=0.62).

Researchers used two methods to estimate the energy savings from the tankless hot water heaters. In one method researchers used a regression model to compare natural gas baseload in four bedroom Discovery Village units with Miller Hill, which are all four bedroom units. The result of this analysis was 51 therms lower baseload for Miller Hill, which was 22 percent of natural gas baseload. This reflects the estimated natural gas savings from the tankless water heaters. The 95 percent confidence interval is 20 to 82 therms. This range is relatively large due to the small sample size.

The second analysis method compared the actual natural gas use for summer months when minimal to no space heating was expected. Based on the average savings for four summer months (over two years), the annual energy savings for the tankless water heaters is estimated to be 54 therms per year, or about 20% of natural gas baseload.

The savings estimates for the two methods are similar at approximately 50 therms per year, slightly less than the 24 percent expected based on the EF values alone. This is in keeping with DOE's estimated savings for this technology (USDOE 2011). Caution should be used in interpreting these results, since the number of Miller Hill units with tankless water heaters is small.

## Energy Audits

The energy audits were conducted in the five non-ENERGY STAR homes communities to characterize the energy conditions in these homes and to recommend opportunities to improve energy performance. All these homes have been retrofitted with high efficiency (at or about an Annual Fuel Utilization Efficiency (AFUE) of .92) sealed combustion furnaces except for the Broadmoor development. New .82 AFUE boilers are being phased-in at Broadmoor. All these units have newer natural gas or electric tank type water heaters. Significant renovations have occurred in three communities that involved window replacement and lighting efficiency

upgrades. ENERGY STAR refrigerator and dishwashers have been installed in many units, but this has not been systematic.

The results of the energy audits highlighted the following opportunities (excluding Discovery Village/Miller Hill).

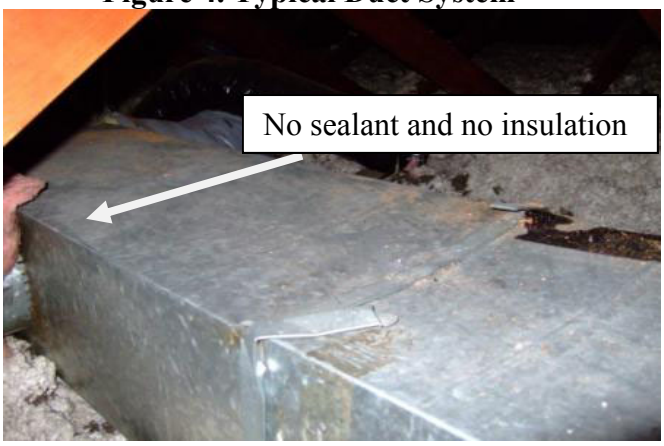
- Most homes had minimal attic insulation, at or about R-15. The insulation that was present was typically in poor condition with large areas of compression and incomplete and uneven coverage (**Figure 3)**. Homes would see significant improvement in occupant comfort and energy efficiency if ceilings are air sealed and insulated to a minimum of R-38; ideally to R-49.

**Figure 3. Attic Insulation Showing Compressed and Inconsistent Fill**

- Wall insulation was present in all homes except for those in the Broadmoor development, although no diagnostic testing of wall insulation was done. The homes in the Broadmoor development receive wall insulation when major interior renovation is done.
- Windows in all developments but Evergreen and Broadmoor were typically multi-paned and vinyl framed. Evergreen and the newer homes in the Broadmoor development had aluminum framed double-paned windows. The majority of the windows in the historic Broadmoor homes were original wood sash double hung single-pane units; during renovation, the windows were repainted, but no additional air sealing was completed; testing found significant air leakage at all sash rails. At the next major renovation, all windows in homes of this study should be replaced with code compliant units (U-factors of .3 to .34.)
- Performance testing of these homes showed that they all had very similar envelope infiltration rates, with all homes testing between 9.9 and 13.6 air changes per hour at 50 Pascals of depressurization ($ACH_{50}$); with average leakage of 11.9 $ACH_{50}$. Typical areas of leakage included: door and hatch weather seals, plumbing penetrations, light fixtures, switches and outlets, supply and return boot penetrations through exterior assemblies, and aluminum and wood frame windows (where present). Air sealing measures should be implemented in all homes with assumed infiltration greater than 7.0 $ACH_{50}$, which is the minimum ventilation level (MVL) used in the Pacific Northwest and in this study.

- Duct testing produced significantly varying results that were not directly attributable to any specific system design or vintage. Duct leakage rates to the exterior at 50 Pascals of pressurization varied from 6.9% to 39.7% of the conditioned floor area (CFA). No ducting had insulation (**Figure 4**). All homes except those in the older Broadmoor development (non-ducted heating) should have the duct work sealed and insulated.

**Figure 4. Typical Duct System**




- The homes were outfitted with source specific ventilation in the bathrooms and kitchens. Testing with a balometer identified significant variance in exhaust fan flow rates from home to home, from totally inoperable to 62 Cubic Feet per Minute (CFM). Bathroom and kitchen exhaust fans should be tested and all fans with insufficient (50 CFM is code) should be replaced.

**Energy Modeling**

The energy modeling allowed us to compare the estimates from two modeling programs, SIMPLE and BEopt, with actual energy use in the non-ENERGY STAR communities and to analyze individual energy efficiency measures and packages of measures. The energy audits provided inputs for the models.

BEopt tended to produce higher energy use estimates than SIMPLE. When comparing the model estimates to the actual community energy use, SIMPLE was more likely to underestimate energy use, while BEopt tended to overestimate energy use. **Table 3** shows the results of this comparison for all the communities except Broadmoor, which is not included because of small sample size and diversity of units. With a few exceptions, the modeled results were reasonably close to actual average community energy use.

We also compared the model results to the energy use of the specific housing units that were audited. The deviation of estimated and actual energy use was more significant. We believe this is due to the unique occupant behaviors in those homes, which tend to wash out when considering the average energy use in a community. This highlights the challenge of using a model to estimate the energy use of an occupied home.

BEopt was used to analyze different energy retrofit options. The individual energy efficiency measures considered were:

- Improve HVAC ductwork (duct sealing and insulation)
- Air sealing to 150% of MVL[10]
- Air sealing to 100% of MVL
- Air sealing to 50% of MVL, with the additional installation of an ASHRAE 62.2 compliant ventilation system
- Increase ceiling insulation from R15 to R49
- Convert older electric tank water heaters to tankless gas, and tankless gas condensing water heaters

**Table 3. Percent Deviation of SIMPLE And BEopt from Community Mean Energy Use**

| Communities with Electric Water Heat | Mean Energy Use in MMBtus | Unit Number | SIMPLE Projections in MMBtus and % | BEopt Projections in MMBtus and % |
|---|---|---|---|---|
| Beachwood | 86.8 | 8450 | 80.6 (-7%) | 106.5 (22.7%) |
| | | 8636 | 99.6 (15%) | 101.7 (17%) |
| New Hillside | 97.7 | 6759 | 87.7 (-10%) | 112.7 (15%) |
| | | 6768 | 80.7 (-17%) | 103.8 (6%) |
| Davis Hill | 91.5 | 5428 | 85.3 (-7%) | 108.4 (18%) |
| Communities with Natural Gas Water Heat | Mean Energy Use in MMBtus | Unit Number | SIMPLE Projections in MMBtus and % | BEopt Projections in MMBtus and % |
| Davis Hill | 105.9 | 5959 | 98.7 (-7%) | 131.2 (24%) |
| Evergreen I | 96.7 | 9280 | 110.8 (15%) | 81.9 (-15%) |
| | | 9290 | 105.9 (10%) | 139.5 (44%) |

The analysis of measures suggests that three measures: air sealing, improving ductwork (duct sealing), and increasing attic insulation to R-49 produce the greatest energy savings for the lowest cost. Based on these results, three packages of measures were created:

A. Improve HVAC ductwork; Air sealing to 150% of MVL; and Attic Insulation from R15 to R49
B. Improve HVAC ductwork; Air sealing to 100% of MVL; and Attic Insulation from R15 to R49
C. Improve HVAC ductwork; Air sealing to 50% of MVL; and Attic Insulation from R15 to R49

[10] The MVL or Minimum Ventilation Level is 7 ACH at 50 Pascals, meaning that if the home's air leakage rate is lower than this, then mechanical whole house ventilation must be added. The only option considered that would trigger this requirement is to reduce leakage to 50% of MVL.

**Table 4** shows the analysis results for the three packages of measures for the five non-ENERGY STAR communities. The analysis uses the mean electricity rate for Washington ($0.08/kWh) and the natural gas rate JBLM pays ($9.86/1000 cu.ft.). It also includes default assumptions in BEopt including a 1% fuel escalation rate and a mortgage tax deduction. While the mortgage tax deduction does not apply to JBLM, it is illustrative to show the results as if they were being financed by a homeowner.

**Table 4. BEopt Analysis of Measure Packages**

| AVERAGE ESTIMATED | PACKAGE A: | PACKAGE B: | PACKAGE C: |
|---|---|---|---|
| Site Energy Savings in MMbtus/year | 17.9 | 24.8 | 26.4 |
| Site Energy Savings in $/year (gas + elec.) | $181 | $250 | $262 |
| Cost per measure package | $2,062 | $2,632 | $3,890 |
| Simple payback in years | 11.4 | 10.5 | 14.8 |
| Monthly savings in $ | $15.09 | $20.86 | $21.86 |
| Monthly cost at 7% over 30yrs | $14.44 | $18.42 | $27.23 |
| Monthly Cash Flow at 7% over 30yrs | $0.65 | $2.44 | -$5.37 |
| Monthly cost at 4% over 30yrs | $9.84 | $12.57 | $18.57 |
| Monthly Cash Flow at 4% over 30yrs | $5.25 | $8.29 | $3.29 |

Packages A and B possess strong potential to provide a good return on investment in a reasonable amount of time, given financing at 4% interest rate. While package C provides the highest degree of energy efficiency, it also includes the installation of mechanical ventilation to meet the household exhaust requirement of ASHRAE 62.2. The addition of mechanical ventilation and the higher price per square foot of air sealing a house to 3.5 $ACH_{50}$ produces greater costs and impacts the feasibility of implementing these measures. This package also had lower energy savings for the non-Broadmoor communities that had lower levels of air leakage.

## Recommendations

Based on the results of this research, the following recommendations were made to JBLM:

- ENERGY STAR homes use less energy than any other homes on the base, and the standard has become more stringent since the new homes analyzed in this study. Since Discovery Village and Miller Hill, JBLM has installed more ENERGY STAR homes and should continue this policy.
- Develop a strategic plan for energy efficiency upgrades including specifications and quality control protocols. To achieve maximum benefits approach the upgrades from a systems perspective rather than making piecemeal, incremental improvements. This plan should consider the following specific recommendations:

- → A package of energy efficiency upgrades that includes improving HVAC ductwork (duct sealing and insulation), air sealing, and ceiling insulation is recommended in existing housing at JBLM. Apply air sealing using skilled, equipped specialists and quality control. Areas to be sealed include attics, floors, rim joists in basements, window frames, chimneys, plumbing and electrical penetrations, hatches, doorways, and lighting fixtures. Insulate ceilings to a nominal (full depth where possible) R-49. Where practical, consider removing the existing insulation prior to sealing to allow for sealing the ceiling plane and to achieve maximum insulating effectiveness.
- → Replace leaky, aluminum, double-pane windows where they exist (Evergreen and the newer portion of Broadmoor) when possible (as part of renovations). New, highly efficient vinyl frame windows may be 3 times more efficient.
- → Explore additional opportunities[11] to improve the efficiency of the historic Broadmoor homes. These homes have no wall insulation and leaky, single-pane, double-hung windows. Historic preservation requirements need to be met. It may be possible to install dense-pack wall insulation from the inside of the homes by temporarily removing the baseboards. At a minimum, weather stripping should be installed on the windows to reduce air infiltration and improve comfort. Window replacement or other options that meet historic preservation requirements should be explored.
- → Most housing units have relatively new water heaters. Develop a strategic plan for water heater replacement with high efficiency units during the normal replacement cycle. If a unit has a natural gas water heater, upgrade to a tankless demand heater if the service allows. If not, upgrade to a condensing tank natural gas water heater.
- → Install CFLs in at least 75% of the sockets in homes where this has not already been done (e.g. historic Broadmoor and Evergreen). For classic fixtures with dimming capability, consider LED lamps.
- → It is recommended that all bathroom and kitchen exhaust fans be tested with a calibrated flow hood at time of occupant turnover to verify that fan flow rate is sufficient (50 CFM is code). Replace inadequate units with high efficiency, quiet fans with more sophisticated control strategies. Occupants should be educated about the operation of exhaust fans.

- The billing analysis identified significant variation in energy use within the communities at JBLM. The top energy users were sometimes using more than twice as much energy as the average. This presents opportunities to develop and implement strategies to reduce this high use. Residents do not pay their energy bills (USDOD 2005), but they are charged for over usage (above average) and refunded for under usage (below average). So some incentives already exist for residents to reduce their energy use. Strategies to improve and complement this billing incentive should be considered.

[11] In addition to the ceiling insulation and air sealing noted for existing housing. Heating for Broadmoor is hydronic, so HVAC ductwork improvements do not apply.

## Next Steps

Researchers discussed project results with representatives from Equity Residential in January 2012. This initial conversation focused on clarifications in the report. Several things came up regarding future opportunities and next steps.

- While there may be significant opportunities for energy savings in the Broadmoor community, historic preservation requirements can limit the opportunities for making energy efficiency improvements. State Historic Preservation Officers need to be consulted and it may not be possible to implement some of the recommendations.
- There is significant interest in creating green jobs at JBLM and providing career opportunities in the energy efficiency field for veterans ("green jobs for vets"). This may be an opportunity for moving forward with some of the recommendations from this project.
- There is interest in doing some pilot energy efficiency retrofit projects using the recommended systems approach and then conducting some research to verify whether the improvements are a good investment and should be expanded to more housing.
- Equity Residential owns the housing at JBLM. Any investments to improve the energy efficiency of the housing need to pencil out for Equity. Since housing has been privatized, there are barriers to the use of public money to make energy improvements. Fundamentally, livability of the housing is the priority, not energy efficiency. These issues need to be considered in any strategic plan to improve the energy efficiency of JBLM housing.

Conversations with Equity Residential about next steps in carrying out the recommendations in this research project will continue.

## References


Lubliner, M., M. Blasnik, R. Kunkle, A. Gordon. 2010. "Measured vs. Predicted Analysis of Energy Star Modular Permanent Military Housing: Fort Lewis Case Study." In *Proceedings of the 2010 ACEEE Summer Study on Energy Efficiency in Buildings*. Washington, D.C.: American Council for an Energy-Efficient Economy.

Northwest Energy Efficiency Alliance. (2006). *ENERGY STAR® Homes Northwest Specifications and Technical Reference for Single Family Site Built Homes*. Portland, Oregon: NEEA.

USDOD. 2005. Letter on requirements and billing information to Fort Lewis residents regarding Army's Residential Communities Utility Policy. United States Department of Defense.

USDOE 2011. "Energy Savers: Demand (Tankless or Instantaneous) Water Heaters." Retrieved November 7, 2011, from United States Department of Energy Office of Energy Efficiency and Renewable Energy: http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=12820