Building Energy Center

Energy Analysis and Savings Opportunities For Habitat for Humanity 3 Bedroom Ranch House

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Meeting date: 3-30-2006
Issue date: 4-20-2006

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Disclaimer

The purpose of this assessment is to identify and approximately quantify savings opportunities. The report is not intended to provide detailed engineering plans or designs for implementing the recommendations. Estimates of savings and costs are based on the best information available to the University of Dayton Building Energy Analysis Center (UD BEAC) within the scope of the assessment. However, the UD BEAC makes no warranty with respect to the accuracy of the savings estimates or contents of the report. The client is encouraged to evaluate each opportunity and attain further engineering analysis, if desired, to verify or refine savings estimates.

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I. Executive Summary

On March 30, 2006 the University of Dayton Building Energy Analysis Center (UD BEAC) visited the offices of Dayton's Habitat for Humanity to discuss future collaborations and analysis. With the help of the staff, current construction techniques and materials were discussed. Discussion of the specific building characteristics of the house whose print had been provided earlier was also conducted.

Using this information, the building's energy use was simulated using hour-by-hour building energy simulation software. While calibration could not be conducted without actual utility data, comparison of varying material options was conducted.

Based on information gathered, we identified and quantified 2 energy savings opportunities with a total potential savings of $123.65 per year. The cost of implementation of the 2 recommendations would be about $472.24. These savings opportunities are summarized in the table below.

Implementation of these recommendations would reduce electricity use by 25 kWh per year. Predicted natural gas savings would be about 95 ccf per year, however current natural gas use is was simulated at only 791 ccf per year.

Summary of Assessment Recommendations (ARs)

AR		Annual Savings			Cost	Rate of Return	Simple Payback (months)
		Electrical Energy (kWh)	Natural Gas (mmBtu)	Dollars			
1	Substituting 2 by 6 framing for walls.	6	7.8	$98.	$314	31%	38
2	Using the increase R value insulation in attic.	19	1.7	$23.15	$764	14%	82
Totals		25	9.5	$123.65	$1,912	26%	45

II. Habitat for Humanity 3BR Ranch

Building Description

The house analyzed is a three bedroom ranch with one floor. We assumed that the house would contain five residents and a total of 1056 ft^2 conditioned floor space. In addition the attic and crawlspace are about 1056 ft^2 unconditioned floor space. Given this base for modeling varying assumptions were made in order to analyze the difference in material components which could be used.

House Layout

The DOHH – 3 BR Ranch Print was used in our analysis. As this document is rather lengthy and was provided to us by your agency we have omitted it under the assumption that is can be readily accessed as needed.

Numerical Utility Summary

Floor Area: 1,056 ft^2
Number of Occupants: 5

	Annual Usage	Annual Cost	Average Unit Cost	Cost/Area ($/ft2-yr)	Cost/Occupant ($/occ-yr)
Electricity	12227 kWh/yr	$1,222.70	$0.10 /kWh	$1.16	$244.54
Natural Gas	791 ccf/yr	$988.75	$1.25 / ccf	$0.94	$197.75
Total		$2,211.45		$2.09	$442.29

While we would note that while calculated yearly electricity usage of 1227 kWh/yr is above the Midwest average of 8,937 kWh per year, this data has also been derived without calibration of the model. So while this may indicate 36% more electricity than typical Midwest homes it cannot be verified without actual utility data.

The calculated usage of the natural gas for three bedroom ranch was 791 ccf of natural gas per year. The average annual natural gas use for homes in the Midwest is 910 ccf per year. While this implies it uses less than the Midwestern average, this numeric has also been generated without calibration and like the electricity usage requires calibration for verification.

Building Energy Simulation

Electricity and natural gas use of the three bedroom ranch was simulated using the hour-by-hour ESim building energy simulation program. To simulate energy use, building characteristics, operating schedules and energy using equipment data were entered into the building description file Habitat_baseline.SZB shown below. Simulating current building energy use gives us confidence in our understanding of building characteristics. Through a process of calibration to actual utility data we can better understand the characteristics of the building. We are quickly able to spot errors in building operation, and target areas for improvement.

```
"Building ID"    "Habitat_A_NS_ins"
"COOLING SET POINTS================================"
"Cooling str month"                                 5
"Cooling end month"                                10
"Cool set-point str hr - occ"                       1
"Cool set-point end hr - occ"                      24
"Cool set-point days/week - occ"                    7
"Cool set-point temp - occ"                        72
"Cool set-point temp - unocc"                      72
"HEATING SET POINTS================================"
"Heating str month"                                11
"Heating end month"                                 4
"Heat set-point str hr - occ"                       1
"Heat set-point end hr - occ"                      24
"Heat set-point days/week - occ"                    7
"Heat set-point temp - occ"                        72
"Heat set-point temp - unocc"                      72
"ROOF=============================================="
"East-West ceil length (ft)"                       44
"North-South ceil length (ft)"                     24
"Max attic height (0 for flat roofs) (ft)"          8
"Ridgeline: EW, NS, none"                        "NS"
"Solar absorptivity of roof: 0 to 1.0"             .8
"Rroof+ceil (hr ft2 F / Btu)"                    43.6
"Roof type: attic, steel, 2in-con, 6in-con" "attic"
"WALLS============================================="
"Rwall (hr ft2 F / Btu)"                         16.5
"Solar absorptivity of walls: 0 to 1.0"           0.5
"Wall type: steel,frame,block,12in-con"       "block"
"Awall n (ft2)"                                   410
"Awall s (ft2)"                                   395
"Awall e (ft2)"                                   240
"Awall w (ft2)"                                   216
"DOORS============================================="
"Rdoors (hr ft2 F / Btu)"                         2.5
"Adoors (ft2)"                                     42
"WINDOWS==========================================="
"R center-of-glass (hr ft2 F / Btu)"                2
"Area glass north (ft2)"                           30
"Area glass south (ft2)"                           45
"Area glass east (ft2)"                             0
"Area glass west (ft2)"                            24
"Solar heat gain coef(normal,beam): 0 to 1"       0.4
"Bldg's rotation from true NSEW (degrees)"          0
"Average ground reflectance (0 to 1.0)"            .2
"WINDOW OVERHANGS AND WINGS========================"
"Protrusion of overhang (ft)"                       0
"Gap between overhang and window (ft)"              1
"Height of window (ft)"                             5
"Protrusion of wing (ft)"                           0
"Gap between wing and window (ft)"                  1
"Width of window (ft)"                              3
"FLOOR============================================="
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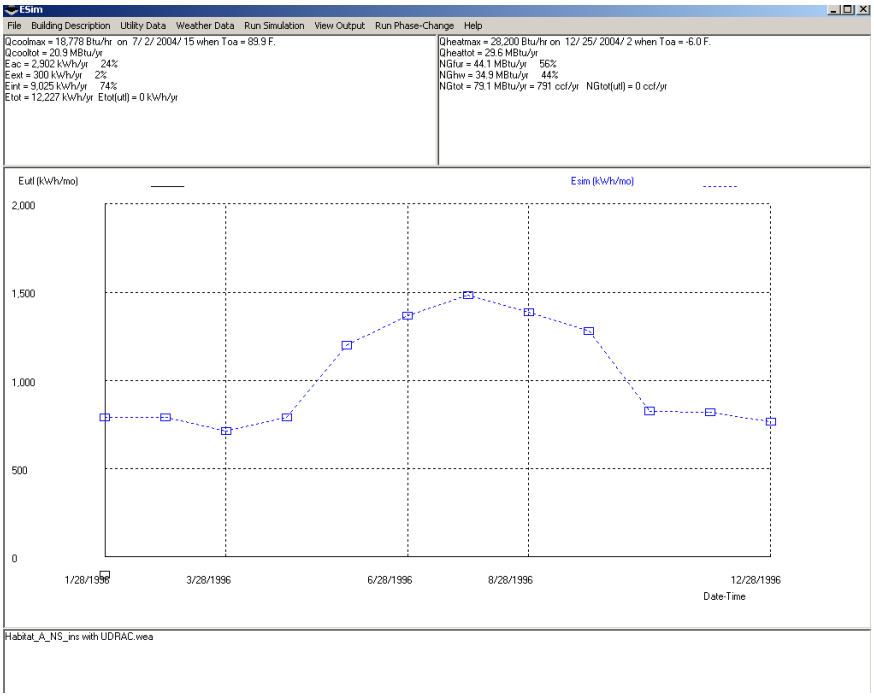
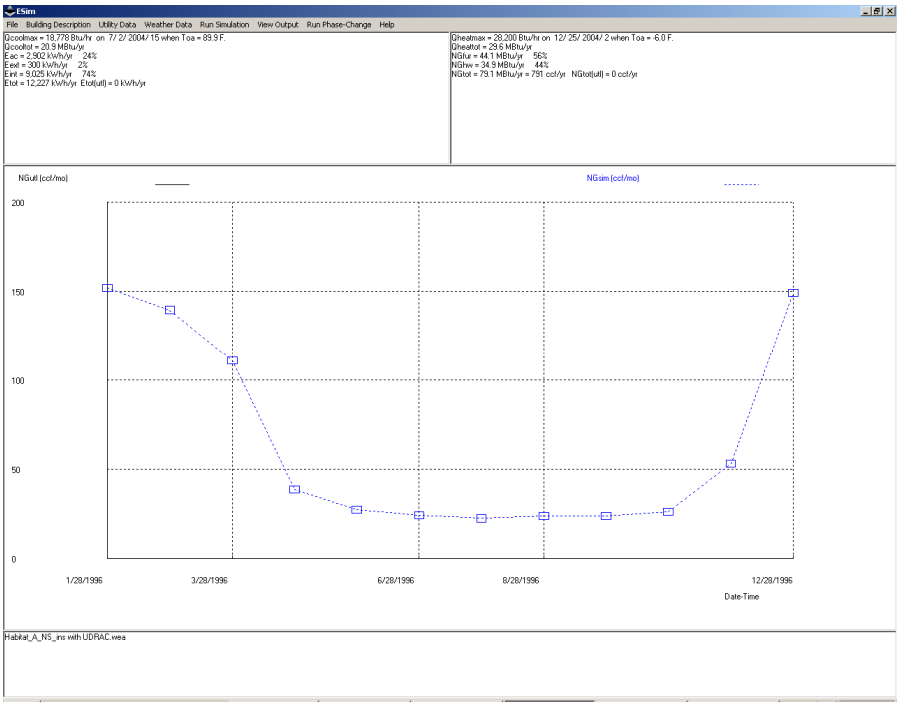
```
"Floor type: slab;hbase;unhbase"                "slab"
"Floor weight: wood;3in-con;8in-con"        "3in-con"
"Perim (ft)"                                      136
"Afloor (ft2)"                                   1056
"Rfloor (hr ft2 F / Btu)"                           5
"Rperim-insul (hr ft2 F / Btu)"                    10
"INFILTRATION======================================"
"Infiltration (air changes per hour)"             1.5
"Volume conditioned area (ft3)"                  8448
"HOT WATER========================================="
"Vol HW (gal/hr)"                                   3
"Temp HW (F)"                                     140
"Efficiency"                                      .55
"Fuel: elec; ng"                                 "ng"
"SZB INTERNAL LOADS AND ELEC USE=================="
"Avg (non-AC) elec cons (kWh/mo)"                 750
"Avg num people"                                    5
"Eoccupied / Eunoccupied"                           1
"OTHER ENERGY CONSUMPTION========================="
"Exterior elec cons (kWh/mo)"                      25
"Other ng cons (ccf/mo)"                            0
"SZB COOLING AND HEATING EQUIP===================="
"System type: sd, sdcont, dd or hp"              "sd"
"SEER of air cond (Btu/hrW)"                        6
"Efficiency of heating unit"                     0.67
"HSPF of heatpump (Btu/W-hr)"                     8.3
"Minimum fraction outdoor air"                      0
"Economizer: none, temp, enthalpy"             "none"
"Temp of air leaving cooling coil (F)"             60
"Temp of air leaving heating coil (F)"            120
"Total supply air {about 1 cfm/ft2} (cfm)"       7200
"Cooling coil: on, off"                          "on"
"Heating coil: on, off"                          "on"
"END CODE=========================================="
"End code"                                        -99
```

Daily occupancy data if often generated in collaboration with utility data based upon that structures actual residence information. This is then used in calibration. This information would allow us to conduct further analysis of the operation and potential savings associated with design changes and/or structural retrofits.

One year of hourly meteorological data which can be matched to any utility data provided is then used to generate energy use data synthesized from actual average daily temperatures during this period and typical correlations between solar radiation, humidity and air temperature from nearby Dayton, OH. For our current analysis we chose to use local data correlating to the past year. The actual average daily temperatures were from the UD/EPA Average Daily Temperature Archive at www.engr.udayton.edu/weather. The typical correlations between solar radiation, humidity and air temperature were derived from Typical Meteorological Year data from http://rredc.nrel.gov/solar/old_data/nsrdb/tmy2/. The resulting hourly weather file was called UD_2004_2005.wea.
The figures below show simulated (dashed line) electricity and natural gas use. It would also display actual (solid line) monthly data once obtained in order to compare the two. Relatively good agreement between simulated and actual electricity and natural gas use increases confidence in the simulation model. By modifying the building characteristic file, building improvements can be modeled and savings predicted. ESim can predict savings for many retrofit measures. ESim can predict savings for temperature setbacks, higher insulation, reduced infiltration, and increasing furnace, water heater, or air conditioner efficiency.



Simulated Monthly Electricity Use



Simulated Monthly Natural Gas Use

III. Assessment Recommendations (ARs)

The primary goal of our assessment is to help you reduce your energy costs. The Assessment Recommendations (ARs) that follow include descriptions of specific conservation measures and our estimates of the savings and cost of each recommendation. These recommendations do not constitute detailed engineering plans or designs. Additional engineering services may be necessary to implement certain recommendations.

AR 1: Frame walls with 2 by 6, 24" on the center.

	Annual Savings			Project Cost	Rate of Return
	Resource	CO_2 (lb)	Dollars	Total	
Natural Gas	7.8 mmBtu	881	$97.5	$313.84	31%

Analysis

After discussion with Habitat for Humanity Staff we decided to conduct some simulations and analysis of the use of 2 by 6 framing instead of the currently used 2 by 4 framing method. This allowed us to look at the energy savings associated with this change and then compare it to the implementation costs associated to this alternative.

Recommendation

We recommend using 2 by 6 frame construction rather than the currently used method.

Estimated Savings

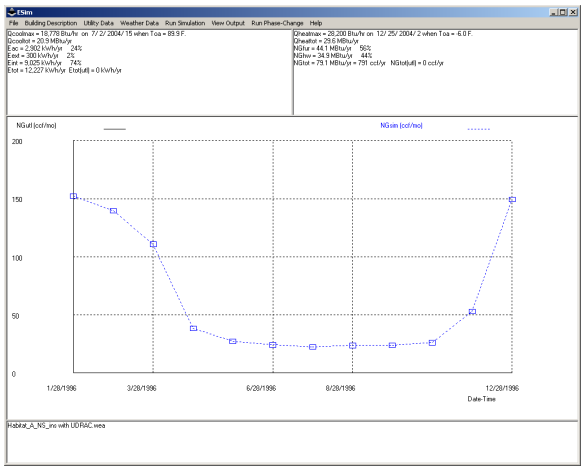
The R-value of the house walls is calculated using CalculateRvalue.xls using material properties and wall dimensions. Typical wood frame construction uses 2 x 4 wood studs, 16-inches on center. The material properties, wall dimensions and calculations are shown in the figure below. The calculated wall R-value is about 3.6 hr-ft2-F/Btu. We conservatively estimate a wall R-value of 4 hr-ft2-F/Btu. CalculateRvalue.xls was used to estimate the proposed R-value of the wall with blown cellulose insulation installed. The material properties, wall dimensions and calculations are shown in the figure below. The wall R-value with blown insulation would be about 13.5 hr-ft2-F/Btu.

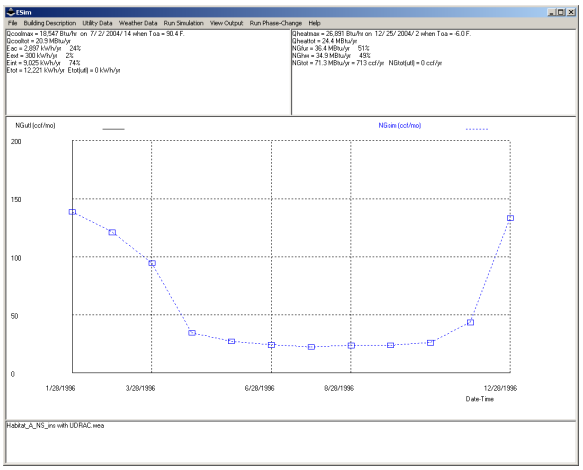
CalculateRvalue.xls	
Input Values	
Distance Between Stud	16
Stud Length (inches)	4
Stud Width (inches)	2
Kstud (hr-ft2-F/Btu-in)	0.833
Rsiding (hr-ft2-F/Btu)	0.81
Rspace (hr-ft2-F/Btu)	1.01
Rfinishing (hr-ft2-F/Btu)	0.32
ho	5
hi	1
Calculations	
Rstudpath (hr-ft2-F/Btu)	7.1
Ropenpath (hr-ft2-F/Btu)	3.34
Astudpath	0.125
Aopenpath	0.875
Total Rvalue	3.6

CalculateRvalue.xls	
Input Values	
Distance Between Stud	16
Stud Length (inches)	4
Stud Width (inches)	2
Kstud (hr-ft2-F/Btu-in)	0.833
Rsiding (hr-ft2-F/Btu)	0.81
Rcellulose (hr-ft2-F/Btu)	13.2
Rfinishing (hr-ft2-F/Btu)	0.32
ho	5
hi	1
Calculations	
Rstudpath (hr-ft2-F/Btu)	7.1
Rinspath (hr-ft2-F/Btu)	15.53
Astudpath	0.125
Ainspath	0.875
Total Rvalue	13.5

In the Building Energy Simulation section of the report, we created a model using current building characteristics. The building model is calibrated to actual utility bills. Simulated annual natural gas

use is 791 ccf. Assuming the wall R-value would increase from 4 to 13.5 hr-ft2-F/Btu natural gas use would be about 713 ccf per year. Simulated natural gas use is shown in the figure below.





Predicted natural gas use is compared to current simulated natural gas use. Natural gas savings from changing wall construction methods is:

791 ccf/yr – 713 ccf/yr = 78 ccf/yr
865 ccf/yr x $1.25 /ccf = $97.50 /yr

The reduction in CO_2 emissions would be about:

78 ccf/year x 11.3 lbs CO_2/ccf = 881 lbs CO_2

Estimated Implementation Cost
Using the cost analysis provided by Habitat personnel, the difference in cost for changing wall construction from 2 by 4 to 2 by 6 is $313.84.

The total cost of implementation would be about:

$313.84

Estimated Rate of Return and Simple Payback
($98.10 /year / $313.84) = 31%
($313.84 / $98.10 /year) x 12 months/year = 38 months

AR 2: Increase R Value of Ceiling Insulation

	Annual Savings			Project Cost	Rate of Return
	Resource	CO_2 (lb)	Dollars	Total	
Natural Gas	1.7 mmBtu	192	$21.25	$158.40	14.6%

Analysis

Currently the building standard for insulating the between the living space and the attic is an insulation of R-Value 38 . During our discussion an alternative insulation of R-Value49 was qouted which could be installed at an increased cost of $0.15 per square foot.

Change the type of Insulation used in Habitat Ceiling

Recommendation

We recommend using the higher R value insulation in future Habitat projects using this design.

Estimated Savings

To estimate the savings from adding insulation, we use Esim software (Carpenter and Kissock, 2005), available free of charge from the University of Dayton Industrial Assessment Center Website. (http://www.engr.udayton.edu/udiac)

Analysis consisted of adjusting the initial building description file to reflect the change in R-value for the insulation within the building characteristics. This file was then run using Esim to generate a new model of heating and cooling requirements for the weather data used on the initial model. In comparing the difference in energy requirements from the initial analysis to this adjusted trial we can approximate the savings expected from this change.

We would note that since no actual utility data was available for use in calibration this analysis is not as accurate as it would be if this information was to be included.

Annual savings would be about:

1.7 mmBtu/yr x $12.50 /mmBtu = $21.25 /yr

Annual CO_2 savings would be about:

1.7 mmBtu/yr x 113 lb CO_2 /mmBtu = 192 lb CO_2 /year

Estimated Implementation Cost

According to your quoted cost, the increase in cost of insulation is about $0.15 per square foot.
The print provided us shows the insulated area between the attic and the living space to be 1056 square feet.

The estimated implementation cost is:

$\$0.15/ft^2$ x 1056 ft^2 = $158.40

Estimated Rate of Return and Simple Payback
$21.25 /yr / $158.40 = 14.6%
$158.40 / $21.25 /year x 12 months/year = 82 months

V. CO_2 Emission Factors

2.3 lb. CO_2/kWh is DPL average from "Benchmarking Air Emissions of Electric Utility Generators in the U.S.", National Resources Defense Council, www.nrdc.org, June, 1998.

11.3 lb.CO_2/ccf natural gas is from combustion equation for stoichiometric combustion of methane

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