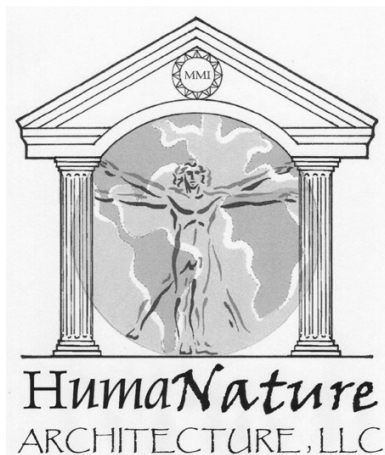


Energy Analysis for the Mobley House  
Colorado College  
Colorado Springs, Colorado  
March 2003



Prepared By:

James Plagmann, AIA

**HumaNature** Architecture, LLC

6110 Dudley St., Suite B1

Arvada, Colorado 80004-5465

Tel: 303-403-0342

E mail: [humanature\\_jp@msn.com](mailto:humanature_jp@msn.com)

## Introduction

Energy efficiency is considered to be the most important attribute of a sustainable building. Although the environmental impact of constructing a building can be significant, the accumulated impact of energy consumption, which repeats annually throughout the life of the building, usually adds up to 5 to 10 times the consequences of the initial construction. These impacts include on-site emissions resulting from the burning of fuel and off-site emissions at the power plant from generating the electricity that the building will use. It is well documented that annual energy consumption can be reduced by 40%-70% by employing energy-efficiency strategies. This calls for a whole building design approach, where various strategies are analyzed and integrated from the earliest phases of design.

Energy-10 is a conceptual design tool that aids in the creation of energy efficient buildings. Funded by the Department of Energy, the software was created in a collaborative effort by the National Renewable Energy Laboratory (NREL), the Sustainable Buildings Industry Council (SBIC), the Lawrence Berkeley National Laboratory (LBNL), and the Berkeley Solar Group (BSG). The program performs an hour-by-hour simulation for a typical year, using actual average weather data from specific cities; in this case, from Colorado Springs. Strategies that can be analyzed include daylighting, passive solar heating, shading, energy-efficient shell design and mechanical equipment. What makes Energy-10 so versatile is that every bit of necessary information is given a default value, so it can be used at the earliest stages of design, when little is known about the building. Then, as the project progresses, all of the information can be modified so that as the building becomes more defined and refined, so does the energy model. An important caveat regarding Energy-10 modeling is that it is not intended to predict actual energy consumption or actual energy costs, as there are far too many variables that cannot be accounted for, such as the actual weather from year to year, and energy related behavior of the building's occupants. What can be measured is the relative effectiveness of many strategies individually and in combination.

## Initial Information and Assumptions

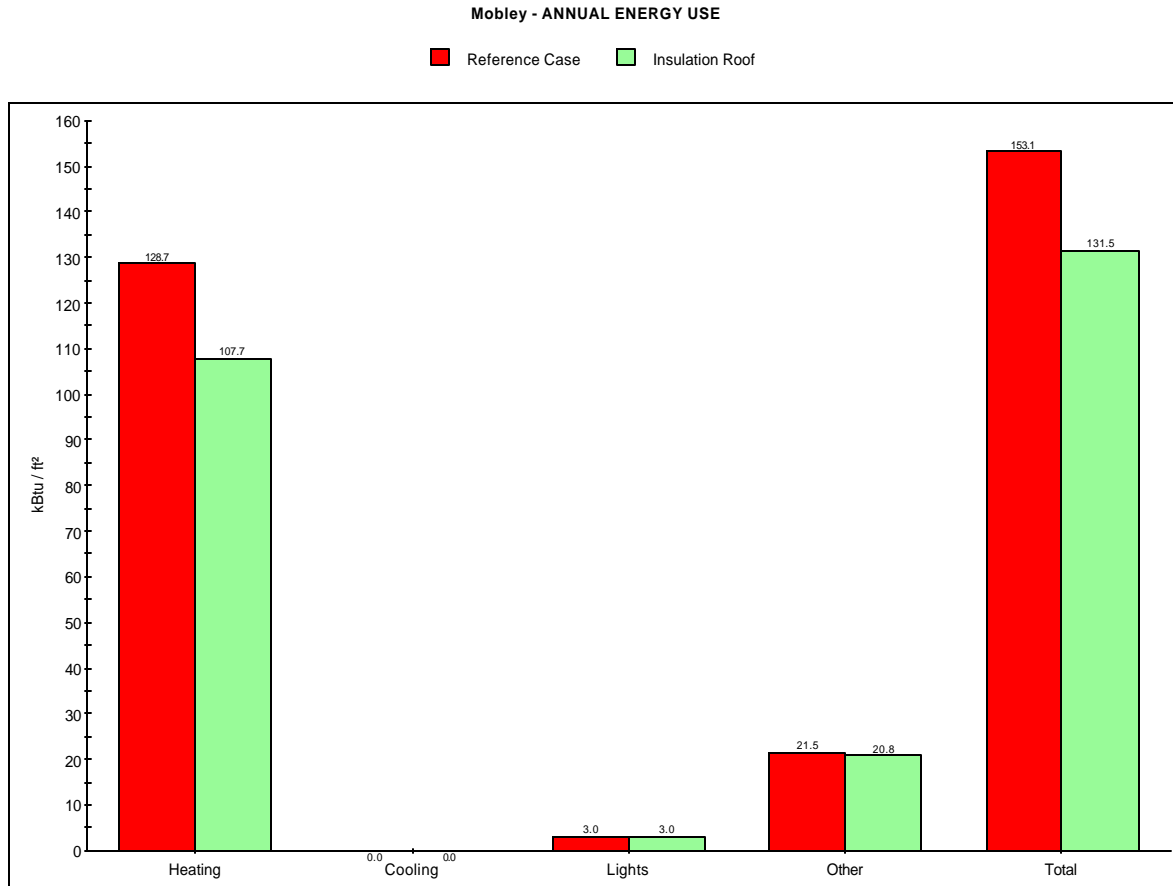
Information gathered about the Mobley House for use in this simulation included measurements of the main footprint of the house, vertical dimensions of the elevations and measurements of all of the windows and doors. The upper floor area has been estimated, as has the roof area, because of the many steps and variations in the upper floor plan and roof. These approximations are acceptable because the same measurements have been used in all of the simulation runs, so the results are based on the same relative areas. Inspection of the attic space revealed approximately 2 inches of mineral fiber insulation. It is assumed that the walls have no insulation in them, due to the age of the structure. Because measurement of the actual "effective leakage area" (cracks, seams and joints between and around architectural elements and penetrations) would be impossible, the default value was used. And, given the age of the mechanical system, it is assumed to be no more than 70% efficient. No air conditioning is currently installed in the residence. Finally, an electric rate of \$0.052/kwh and a gas rate of \$0.352/therm have been used in the calculations.

## **Strategies Simulated**

Energy-10 has the ability to analyze windows, insulation, air leakage control, daylighting, shading, energy efficient lights, passive solar heating, thermal mass, high efficiency HVAC, economizer cycles, HVAC controls and duct leakage. Because of the historic nature of the building, and because of the typically small impact of daylighting in a residence, daylighting and shading have not been analyzed. Also, because this is an existing structure, passive solar heating strategies (which primarily involves placement of windows) and thermal mass have not been studied. Strategies that have been simulated include insulating the walls and roof, decreasing the air leakage through the building shell, replacing the windows, and improving HVAC performance.

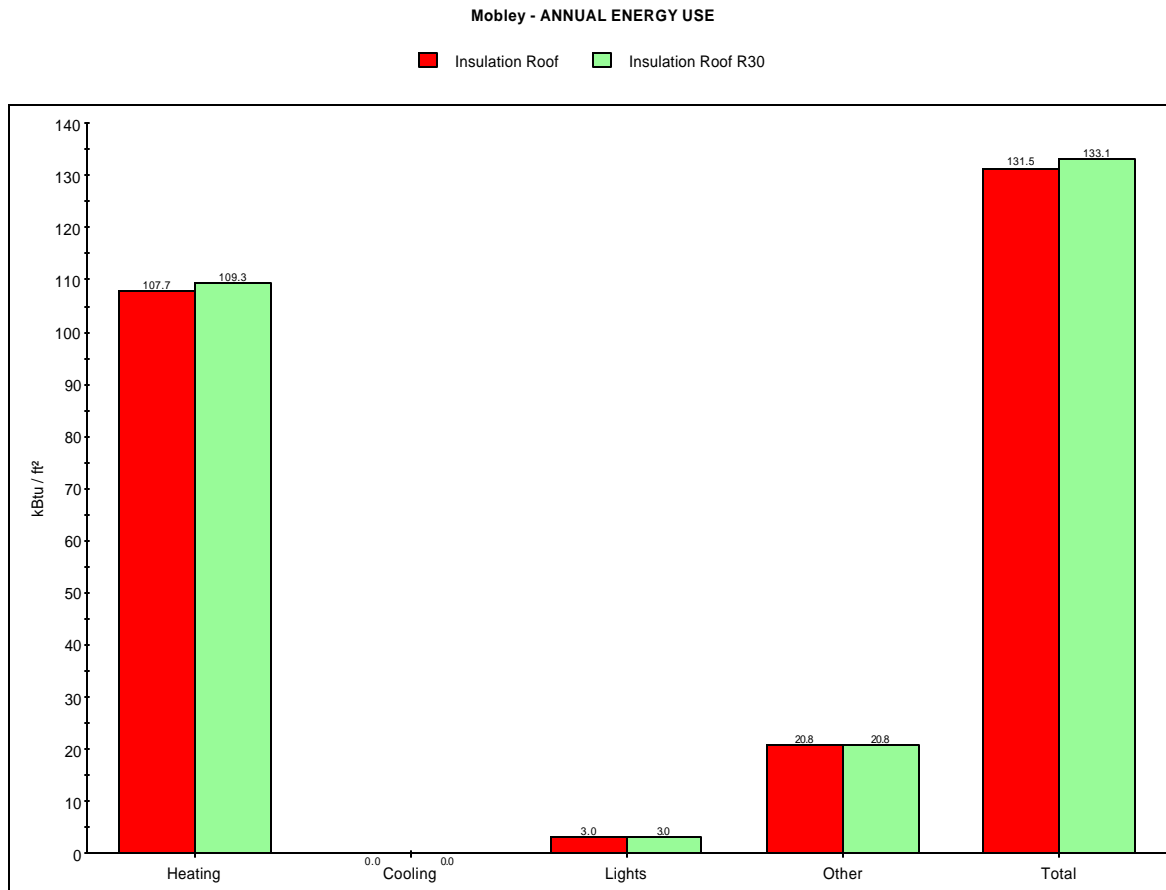
## Simulation Results

The first simulation compared the existing building, termed the Reference Case, or Building 1, with the same building (Building 2) having increased roof insulation (from R6 to R40). The total annual energy use graph is shown below:



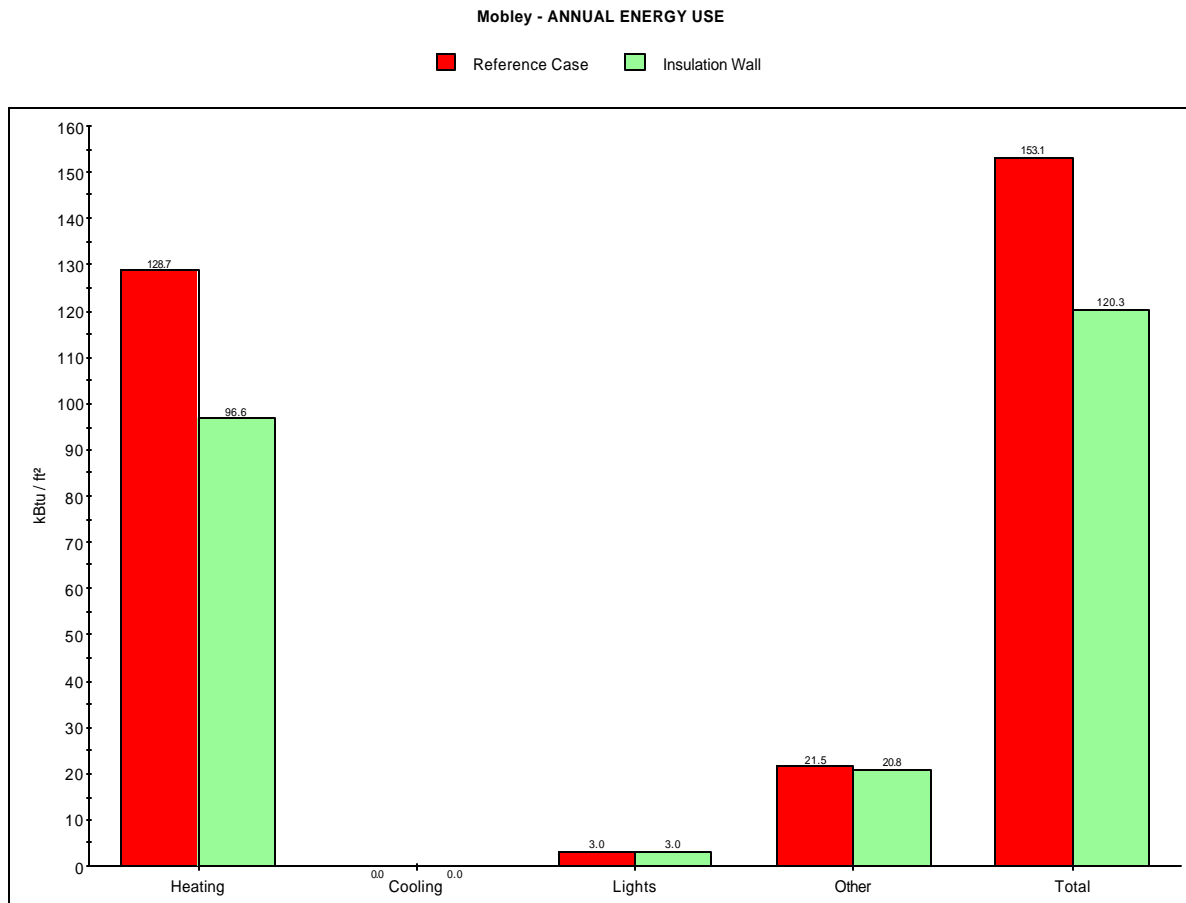
This shows a total annual savings of just over 14%.

Then, to analyze the value of varying levels of insulation, a simulation was run comparing R40 versus R30 insulation in the roof:



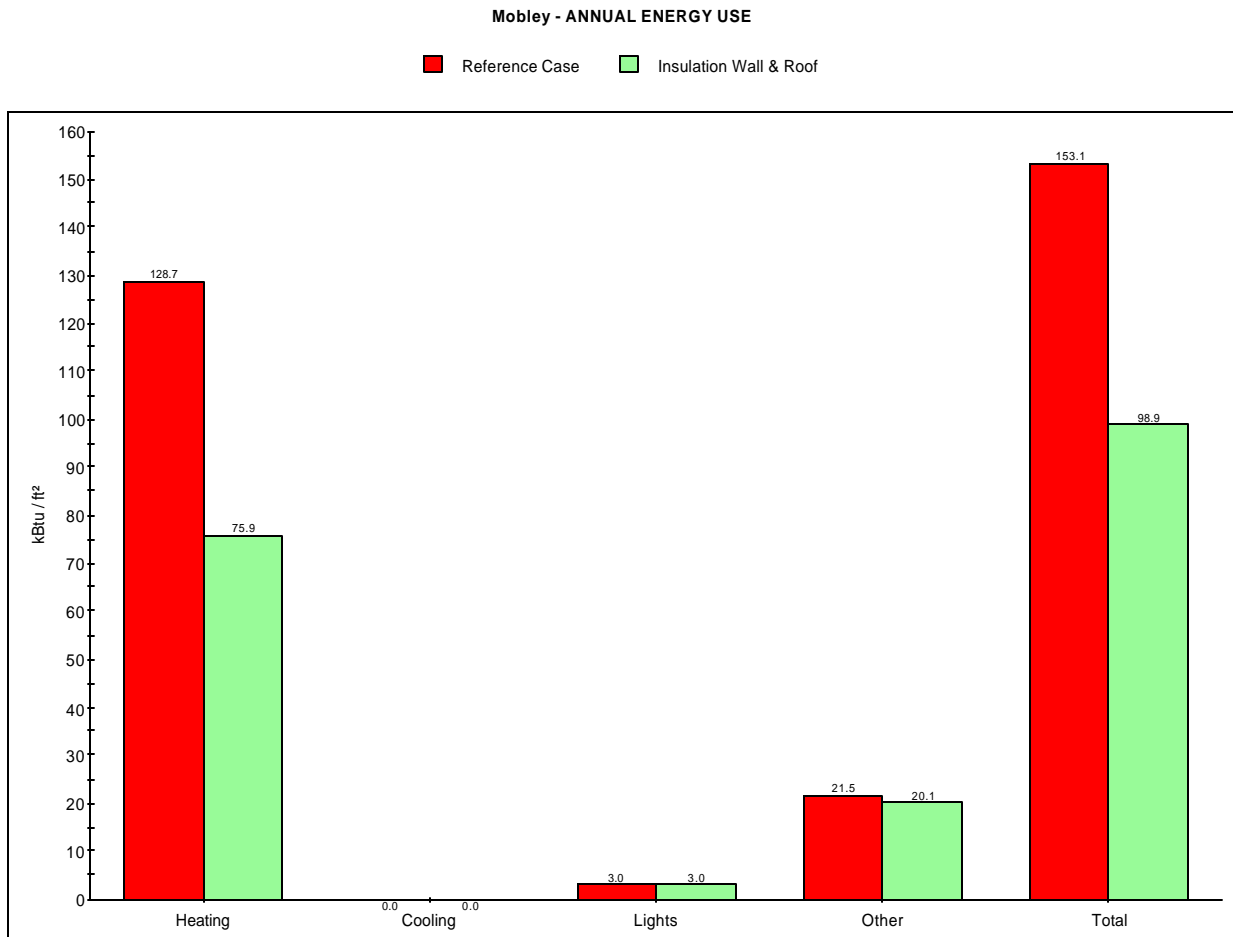
As indicated, decreasing the insulation from R40 to R30 only diminishes the performance by a little over 1%, so it is unlikely that the increased insulation is worth the additional expense.

The next run compared the Reference Case with the same building having insulation added to the walls:



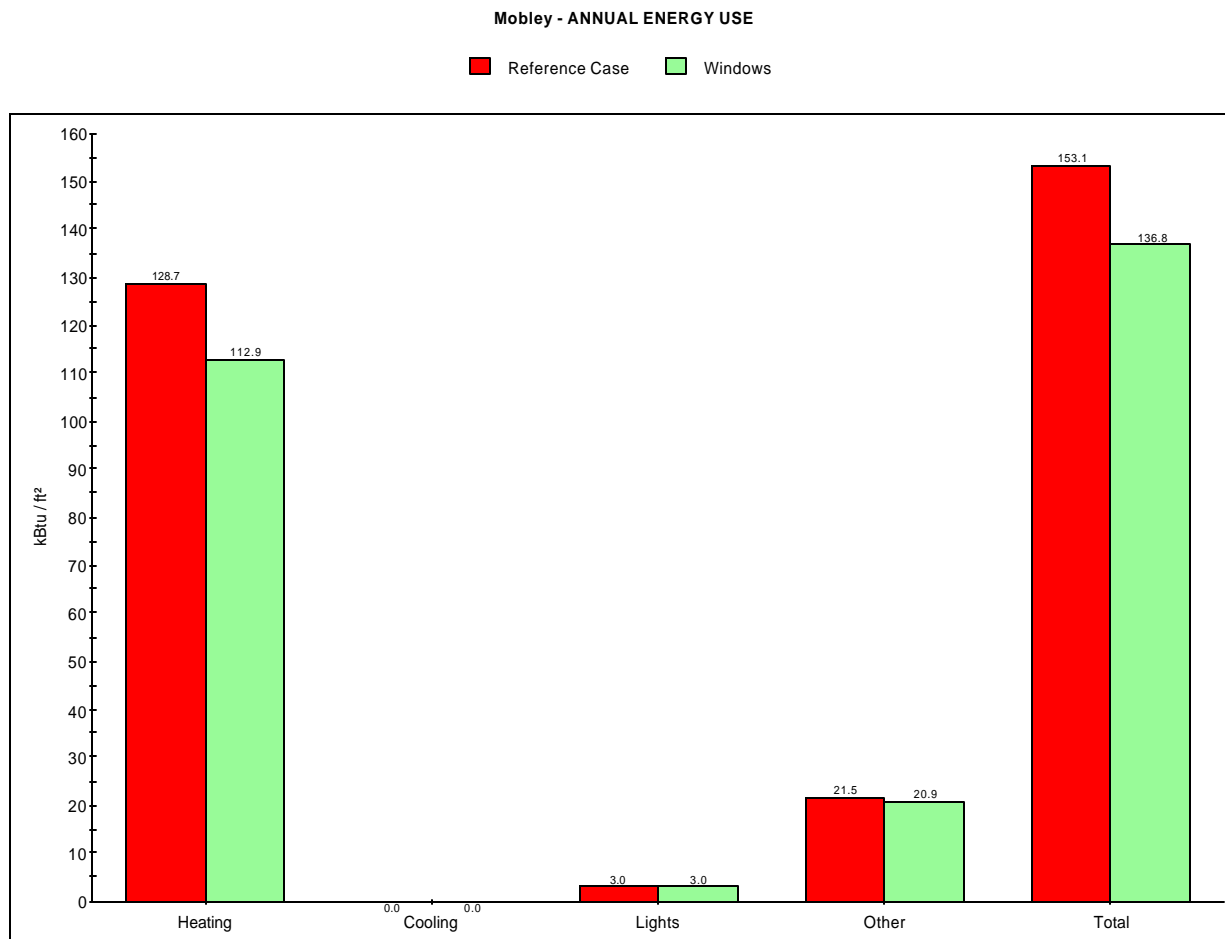
In this case, the savings are approximately 21.5%, half again as much as the efficacy of adding insulation to the roof.

The subsequent run combined the wall and roof insulation:



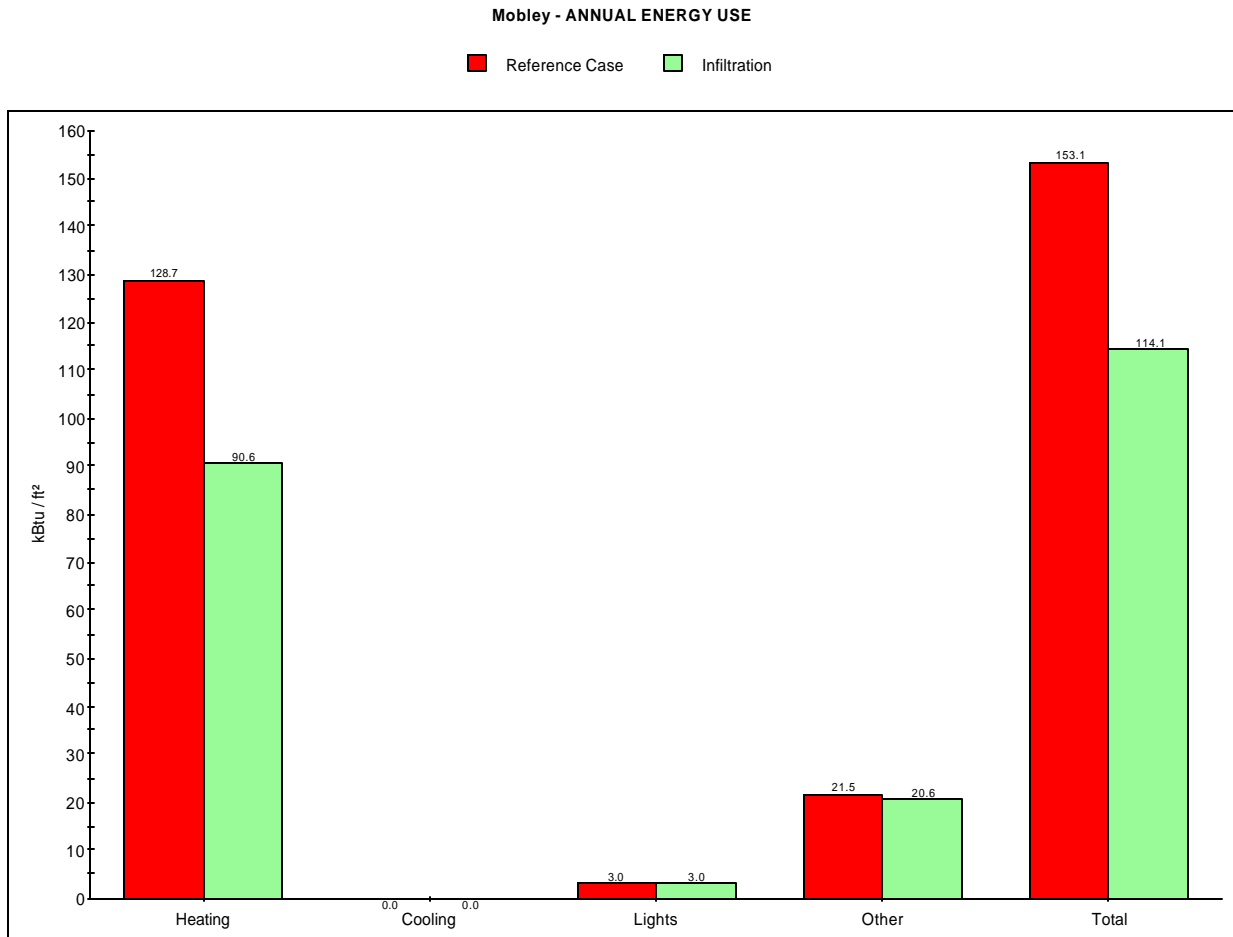
The total annual energy use is reduced by 35.5%, or the combined value of the roof and wall savings from the previous runs.

Next, the value of replacing all of the existing windows with double pane, low-e windows was analyzed:



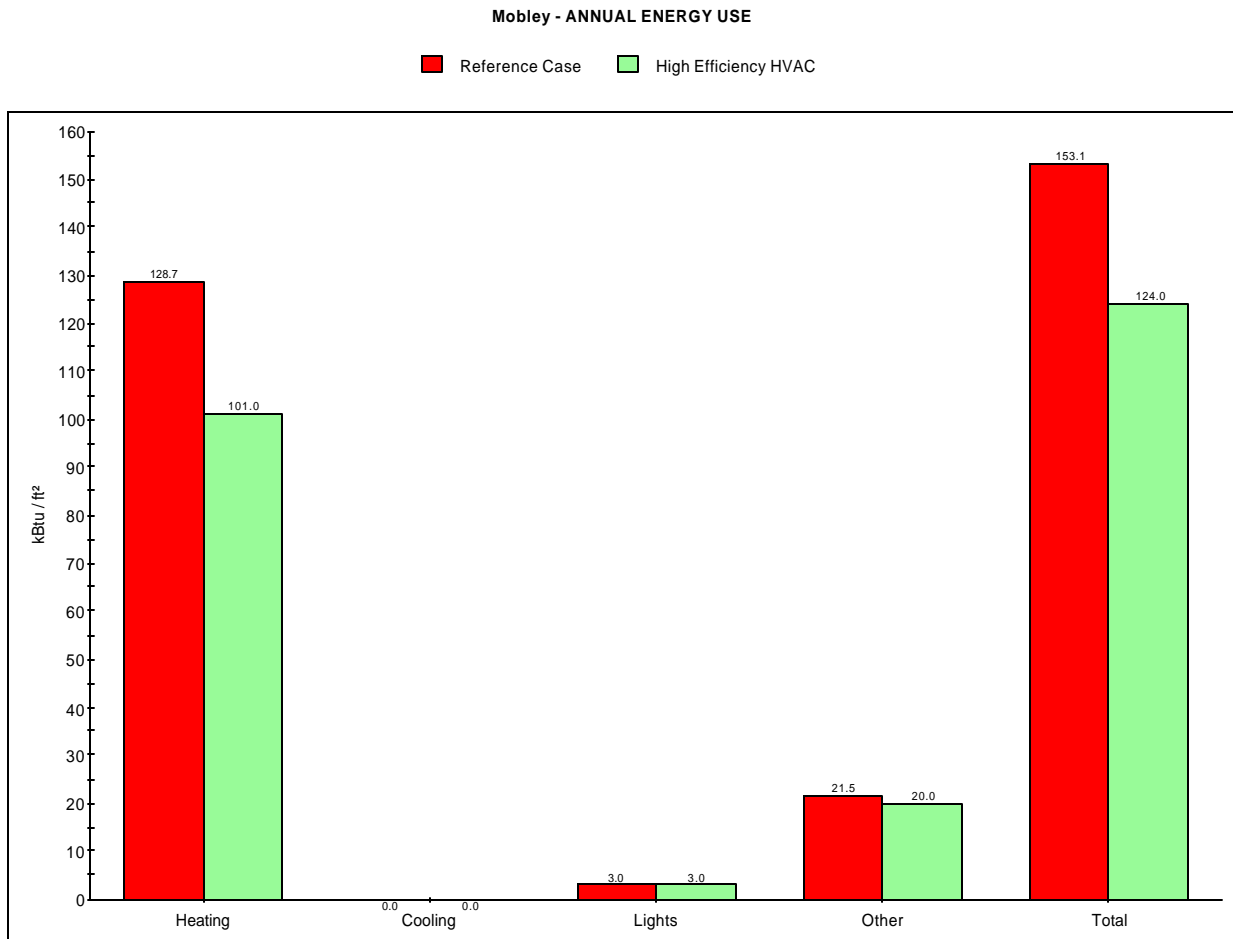
Interestingly, the savings is only around 11%, and given the high cost of windows, the payback period would be very long.

The next strategy studied was to decrease the infiltration losses and gains. Infiltration is basically all of the cracks, seams and joints between elements such as between roof and walls, around windows and penetrations such as outlets, etc. that allow air to flow into or out of the building.



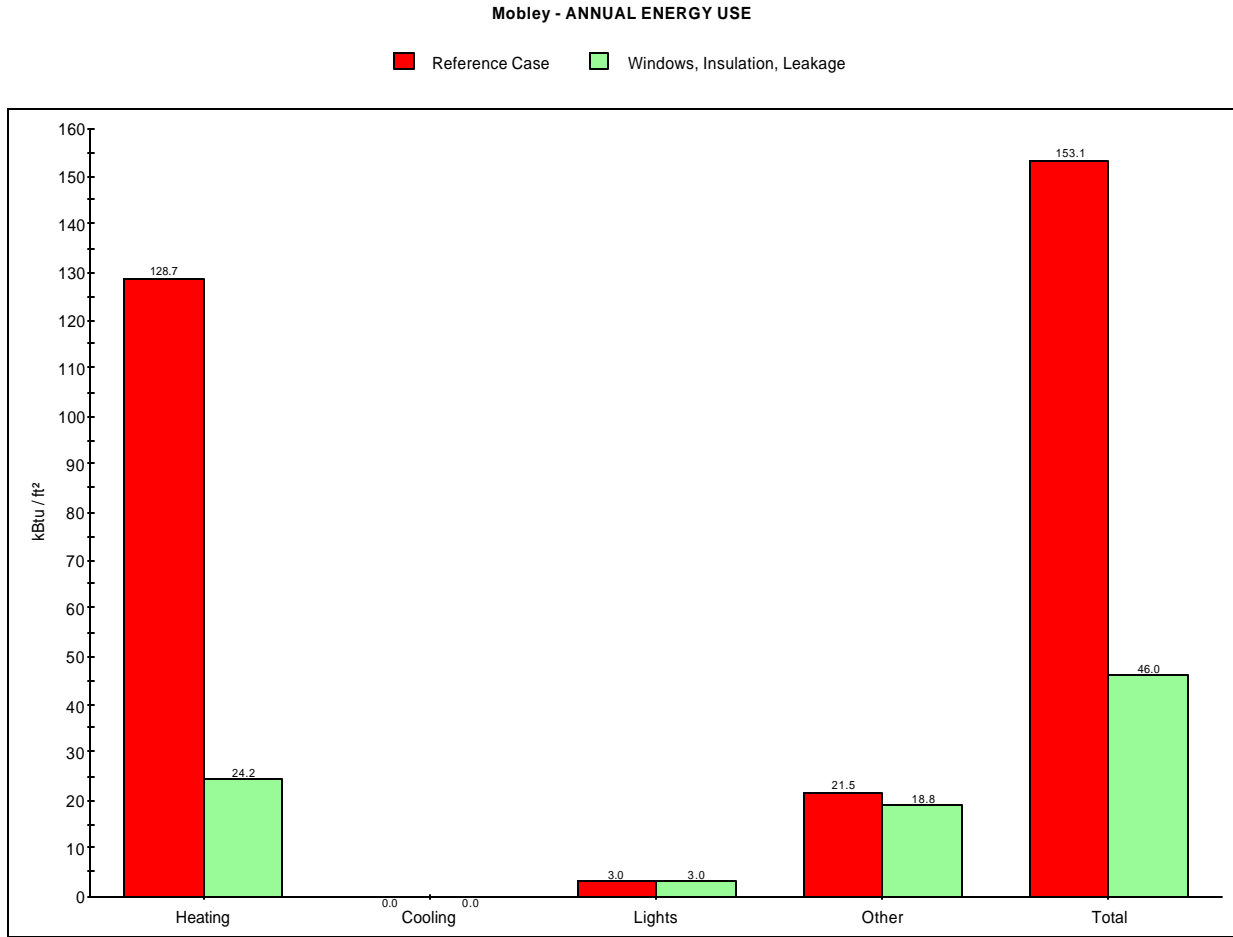
The savings here is the largest from any one strategy; approximately 25.5%. And this strategy is one of the least expensive to implement.

Next, a simulation was run to analyze the effectiveness of increasing the HVAC efficiency from 70% to 90%:



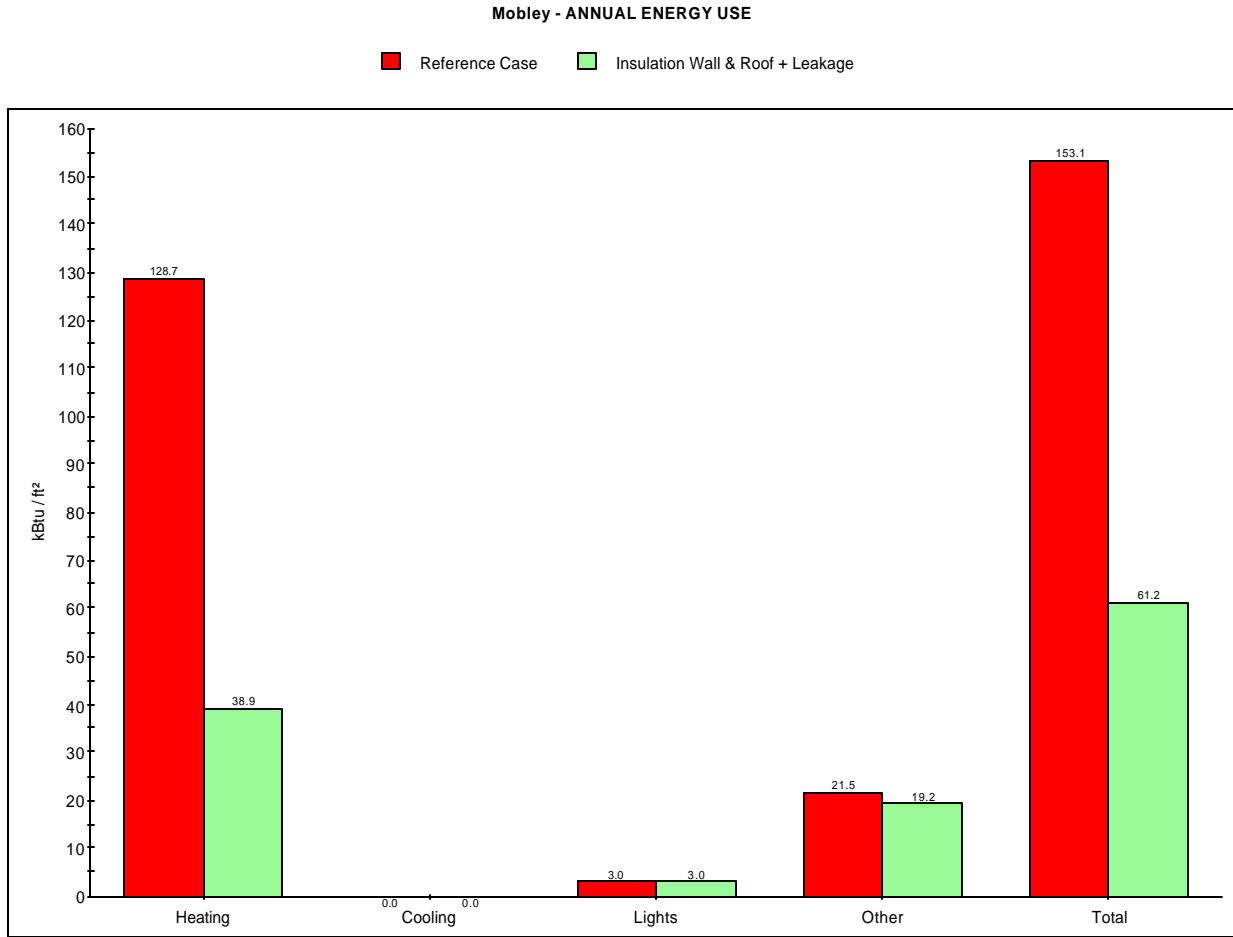
This results in a savings of around 19%. It is worth noting that the only modification to building 2 for this simulation was the upgraded HVAC efficiency. Before running the simulation, Energy 10 performs an “Auto-sizing” of the HVAC system. In this case, the rated output of the system is 114 kBtu/Hr. This item will be revisited later in the report.

Next, simulations were run with combinations of strategies. First, wall and roof insulation, windows and leakage control were combined with the following results:



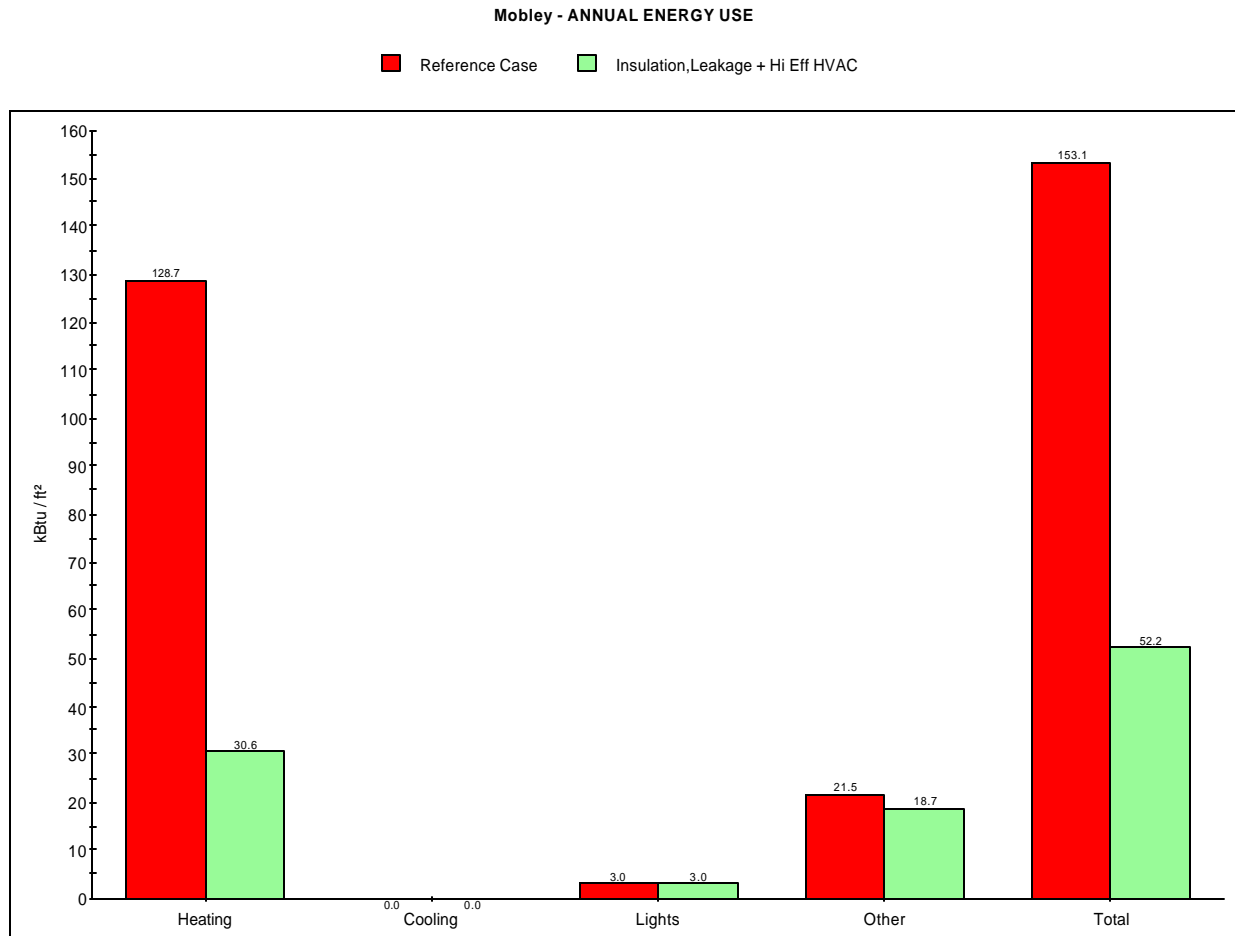
Here, we see a savings of 70% as compared to the Reference Case.

However, since replacing the windows may be cost-prohibitive, another run was generated with only the insulation and leakage control incorporated:



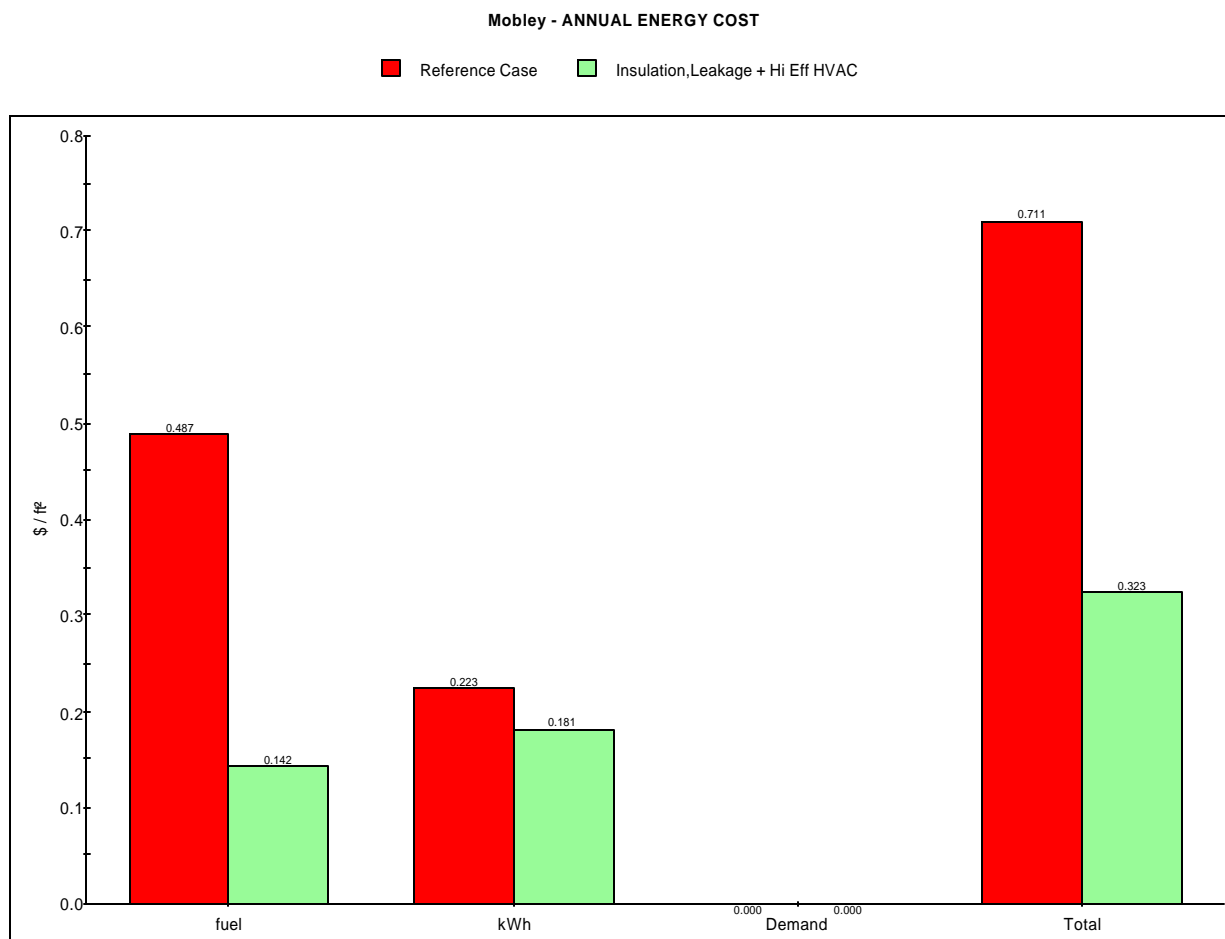
Here we see a savings of 60%, which is in congruence with the previous run showing replaced windows saving 11%. Therefore, as determined previously, it may not be cost effective to replace the windows.

Based on the results of the simulations so far, a final run was performed incorporating the most effective strategies: roof and wall insulation, leakage control, and high-efficiency HVAC:



We now have an energy saving of 66%. And, equally important, the HVAC system sizing has dropped from 114kBtu/hr to only 49kBtu/hr, a decrease of 57%. Thus, a much smaller HVAC system can accommodate the substantially decreased heating load, and, of course, the much smaller system equates to a much smaller price tag.

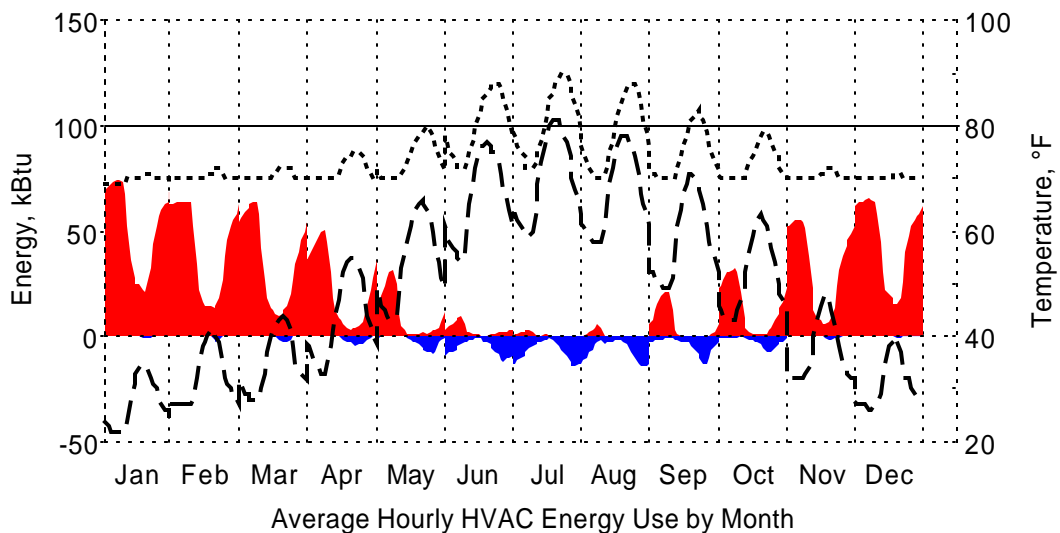
Below is a graph of the annual energy cost savings for the same simulation:



As indicated, the majority of the savings is realized in fuel cost: over 70%. Since the building is not air conditioned, the electrical savings are a more modest 19%, due to the decrease in fan energy because of lower heating requirements. And, because electricity is currently more expensive than natural gas, the total cost savings for the building is 55%, slightly less than the 60% annual energy savings.

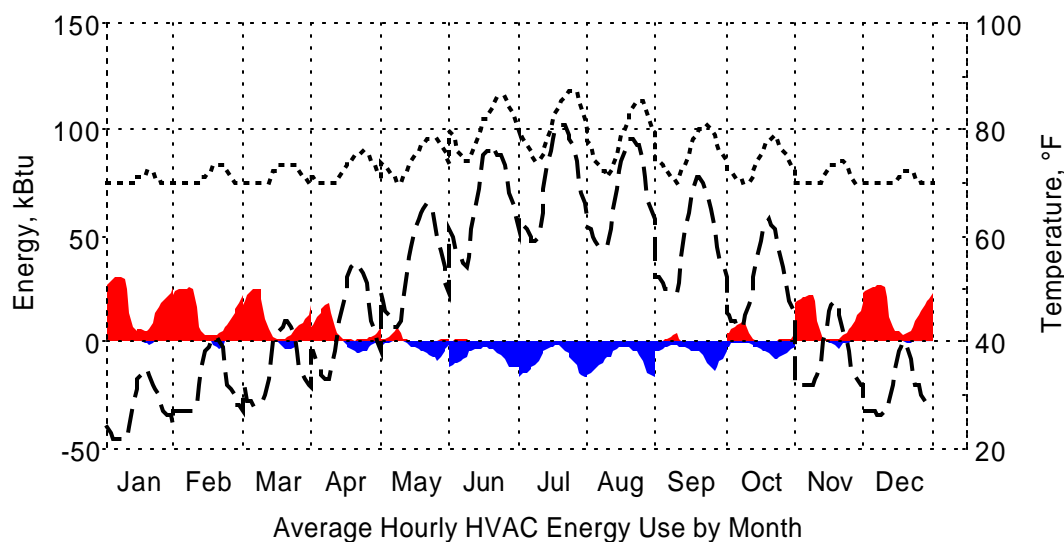
Next, a look at the average hourly energy use by month. This chart graphs the heating energy used in red, the cooling energy in blue (in this case, since there is no air conditioning, cooling is provided by fan ventilation only), the indoor and outdoor temperatures. Notice that the indoor temperature (the solid line) rises well above 80 degrees, even approaching 90 degrees in June, July and August. This would call for some type of cooling, heat prevention or exhaust in order to maintain an acceptable level of comfort during those months.

**Mobley - Reference Case**



HVAC +
  HVAC -
  Inside T
  Outside T

**Mobley - Insulation, Leakage + Hi Eff HVAC**



HVAC +
  HVAC -
  Inside T
  Outside T

## Recommendations

Based on the analyses above, the following energy efficiency strategies are recommended for the Mobley House:

1. **Install R30 insulation in the attic.** Blown-in cellulose insulation would be the environmentally preferable material.
2. **Fill wall cavities with insulation.** Given the fact that this is an existing building, and the relatively good condition of the plaster walls, the most effective type of insulation for this application would be Icynene™, a closed cell, water-based expanding foam insulation that remains soft after curing. This insulation is installed by pouring it into small holes at the top of the walls in between each stud. The advantages of this type of insulation is that it expands to fill every void in a wall cavity, thereby minimizing air leakage, another recommended strategy discussed below. It also remains soft as it cures, so that it will not damage the interior plaster or the exterior siding as it expands. Additionally, it does not support microbial growth, nor does it offgas VOC's because it is water based.
3. **Install storm windows on all windows, seal around all windows and consider low-e coatings on the storm windows.** Since the cost effectiveness of installing new windows throughout the house is low because of their high first cost, and because there are already storm windows on a few of the existing windows, the construction and installation of storm windows on the remaining windows is recommended. The new and existing storm windows should be provided with a sealing system to prevent air infiltration, and a hard-coat low-e coating on the inboard glass surface of the storm windows should be considered. Given the propensity for warm days even in the coldest winter months in Colorado, a system for partially opening the storm windows when they are in place should be devised. Also, since the storm windows will need to be removed and reinstalled each year, someone will have to be assigned to perform that task, and a storage location within the house should be provided.
4. **Provide comprehensive infiltration (air leakage) control.** This entails sealing all joints, cracks and seams, such as around window and door frames, at the foundation/wall connection, around wall outlets and at the operable window and doors openings. Low VOC caulk and expanding or fiber strips should be used.
5. **Install high efficiency HVAC.** It is unknown how old the current gas furnace is, but when it comes time to replace it, high efficiency (90% efficient) equipment should be installed. And it is important that the new equipment be sized accurately for loads based on the above upgrades, and not on "rule-of-thumb." When equipment is oversized, it operates less efficiently, plus capacity is paid for that is never used. Since this is a forced air system, air conditioning may be installed at that time, but evaporative cooling is significantly more efficient and less expensive to install and operate. When installing the system, the duct seams should be sealed with mastic.
6. **A whole house fan should be installed.** Moving air through the house during the cooling season will help to keep the temperatures down, especially if the fan is run at night to cool the house and mass with cooler night air.

7. **A set-back thermostat should be installed.** These are inexpensive and reliable, and can reduce energy use by up to 10%.
8. **Hot water pipes should be insulated.** Another inexpensive and effective strategy.
9. **Compact fluorescent lamps should be installed in all fixtures.** Although the first cost of these is high, they will pay for themselves in energy saved over their lifetimes.
10. **A radiant barrier should be installed in the attic, on the underside of the roof rafters.** This strategy cannot be modeled in Energy 10, but will contribute significantly to heat avoidance during the cooling season.
11. **Window coverings, such as operable blinds, should be installed on the interior of south and west facing windows.** This will also serve to prevent solar gain when undesirable.