Energy Consumption Study for Habitat for Humanity of the Chesapeake

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Habitat for Humanity of the Chesapeake (HHC) builds simple, decent and affordable homes for the working poor. HHC has employed green building practices for many years in so far as it – unlike most Habitat affiliates – has focused on reclaiming and renovating old row houses. This focus on material reuse and sustainable site selection (i.e. selection of sites in dense, urban areas) is commendable. In recognition of the connection between energy efficiency and affordability, HHC has expanded its green building initiatives to include a focus on improved energy performance. *This study confirmed that HHC-renovated row houses are using less energy than other row homes of similar size in Baltimore, thereby saving Habitat homeowners money on utility bills and reducing the organization's carbon footprint.*

I. Why is building high-performance, energy efficient affordable housing important?

1) Energy prices are forecast to rise

The Energy Information Administration predicts that energy prices will continue to rise for the foreseeable future (see Figure 58[i] and Figure 65[ii]). If a price is put on carbon in the US in the form of a carbon tax or cap-and-trade legislation, it is expected that the cost of energy to consumers will increase further still.

2) *Low-income households are disproportionately burdened when energy prices rise*

Often low-income households can afford neither energy efficient products, such as ENERGY STAR® appliances, nor new windows, insulation, and other weatherization retrofits. Moreover, because the share of annual expenditures for energy make up a larger percentage of the budget in a low-income household, and because energy costs have increased at a rate that outpaced increases in low-income wages in recent years, low-income households are disproportionately hurt when energy prices rise, relative to their higher-income counterparts.[iii] A December 2007 study by the Oak Ridge National Laboratory[iv], found that from 2001 to 2005 the average residential energy burden (ratio of energy expense over household income) rose for low-income households from 12.6 to 14.6% of income. The burden for non-low-income households rose from 3.1 to 3.2%.

Figure 65. Lower 48 wellhead natural gas prices in five cases, 1990-2030 (2007 dollars per thousand cubic feet)

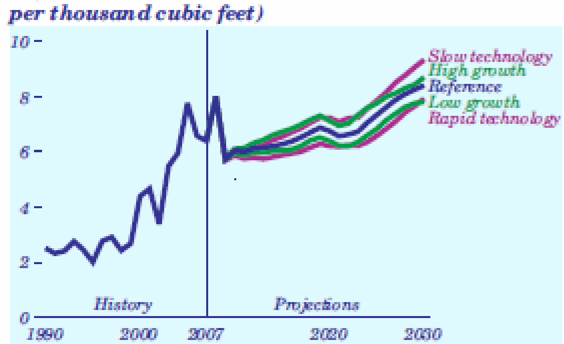
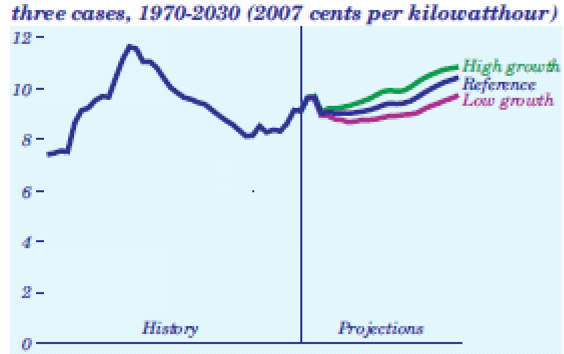


Figure 58. Average U.S. retail electricity prices in three cases, 1970-2030 (2007 cents per kilowatthour)



3) High residential energy burdens for low-income households lead to dire, unsafe tradeoffs

As a result of high energy burdens, millions of low-income households are (or will be in the future) challenged to keep the heat on and the lights lit. Indeed, many low-income households may be forced to make desperate tradeoffs between heat and electricity and other basic needs. The National Energy Assistance Directors' Association conducted a survey in 2008 that found that 70% of low-income households reported that they reduced spending on food, 31% reduced spending on medicine, and 19% changed plans for their education or their children's education in order to pay energy bills.[v] In an effort to reduce energy costs, families often resort to unsafe home heating sources such as space heaters, which are a fire hazard. The US Consumer Product Safety Commission estimates that roughly 25,000 residential fires are caused by space heaters every year in the US.[vi] Other families, in an effort to cut costs, set the thermostat unhealthily high or low, leading to hypothermia and heightened susceptibility to illnesses or hyperthermia (heat-related illnesses and death).[vii] Perhaps most concerning for Habitat is evidence that households with high-energy burdens have difficulty meeting mortgage loan obligations. A survey of households that received federal home energy assistance found that 25% of households failed to fully pay rent or their mortgage as a result of home energy costs.[viii]

4) Green building initiatives can improve energy performance and deliver financial benefits

Research using the life-cycle approach[1] reveals that green affordable housing is more cost effective than conventional affordable housing in net present value terms.[ix] ENERGY STAR® qualified homes can improve energy efficiency by 30% and achieve energy savings of up to $400 annually, relative to conventional homes.[x] Given that the premium paid upfront to meet ENERGY STAR® standards for the average Habitat for Humanity home is roughly $3,000[xi], this is a healthy return. To the extent that green building reduces utility expenses, HHC homeowners will be more able to meet their mortgage loan obligations and cover other expenses of daily living.

5) Improving energy performance in affordable housing helps to mitigate climate change

According to the EIA, 21% of green house gases emitted in the US are attributed to residential energy use.[xii] Older homes are to blame more so than newer homes. According to the Joint Center for Housing Studies of Harvard University, homes built before 1970 ("older homes") in the Northeast use 30% more energy per square foot than homes built after 1990 ("newer homes"). Similar trends are observed in the Southeast where older homes use 25% more energy than their newer counterparts.[xiii] For homes that are even older, as are most row homes in Baltimore, MD, where HHC operates, the energy use differential is even more pronounced. Clearly, retrofitting row homes is akin to pursuing low hanging fruit: The HHC retrofits address a significant contributor to green house gas emissions in the US (older, inefficient homes) and make a long-term fix.

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[1] Life-cycle cost analysis (LCA) is a means of assessing the total cost of building ownership. It takes into account all acquisition/construction, ownership, maintenance, and disposal costs. LCA is useful when deciding between two project alternatives that differ with respect to initial costs and operating costs.

II. What are the challenges/costs specific to green affordable housing?

1) Developers and homeowners receive different life cycle costs and benefits

The benefits and costs do not accrue equally to all parties. While the overall life cycle costs of green building result in a positive net present value, the increased capital expenditures are incurred by the developer (i.e. HHC) whereas the benefits related to the long-term decrease in maintenance and operational costs accrue largely to the homeowners.[xiv]

2) Conventional developers can recoup increased capital costs; Habitat cannot

Habitat seeks to fulfill its mission of providing low- and moderate-income families with affordable places to live. As a result, the approach that HHC takes to development differs slightly from conventional development: While conventional developers can recoup increased capital costs by way of a higher sales price, Habitat often cannot due to its emphasis on affordability.

3) Scarce resources lead to a tension between building more and building green

All else equal, Habitat seeks to serve as many low- and moderate-income families as possible. Indeed, the number of homes built is a first-order measure of productivity. Given that funding is a scarce resource, there is tension between Habitat's mission to build as many units as possible - which requires allocating scarce dollars to projects with the lowest first cost - and its desire to build green homes - which are more costly initially, but more "affordable" long-term.

4) It is difficult to quantify benefits, especially soft benefits

It is difficult to quantify the benefits of investing in energy efficiency because there are many confounding variables at play. While there is a direct link between energy efficiency and energy conservation, variables such as variance in the performance of green building elements, variance in occupant behavior, and variance in the number of occupants can change the strength and even the direction of the relationship. Moreover, not only is it difficult to quantify and put a value on how much energy is conserved as a result of green building efforts, there are also many "soft" benefits (e.g. improved occupant health and productivity) that accrue to homeowners. Research suggests that people living in homes with sufficient heating and cooling suffer fewer colds and illnesses, resulting in lower absenteeism at work and school.[xv] Studies of students in schools and workers in office buildings indicate that improved comfort levels increase productivity and school performance.[xvi] The challenging question is: what is the value of these "soft" benefits?

III. Case Study

HHC has recently rehabilitated 36 old row houses using construction techniques and materials meant to improve energy performance. Because the HHC-rehabbed homes (the treatment group) are surrounded by neighborhoods filled with hundreds of row homes that are nearly identical in size and design to the treatment group save for the lack of rehabilitation, there is a readily available control group. ANOVA analysis was used to compare average daily energy consumption between HHC-renovated homes and the control group.

1. Description of HHC Building Phases

a) Phase I: "Historical baseline" homes
- 7 row homes purchased by homeowners between January 2004 and June 2005
- Green building elements: high efficiency furnace, conditioned crawlspaces, ducting and hot water systems redesigned for higher efficiency, increased insulation (exceeded code requirements), and Energy Star appliances

b) Phase II: "Stepped-up efficiency" homes
- 14 row homes purchased by homeowners between June 2006 and June 2008
- Green building elements: in addition to the elements that were incorporated during the "Historical baseline" phase, this phase also implemented Low-e windows, sealed combustion water heaters, mastic sealed ducts, improved air sealing techniques (spray foam, rigid foam board, and caulk), compact florescent lighting, fiber cement siding (as opposed to vinyl), blower door testing, and tankless water heaters[2]

c) Phase III: "ENERGY STAR®" homes
- 15 row homes purchased by homeowners between October 2008 to May 2009
- Green building elements: in addition to the elements that were incorporated during the "Historical baseline" phase and the "Stepped-up efficiency" phase, this phase also implemented new insulation and air sealing techniques (blown-in, fiberglass batts, high expansion spray foam, and rigid foam), programmable thermostats, and improved HVAC load calculations

2. Data Collection

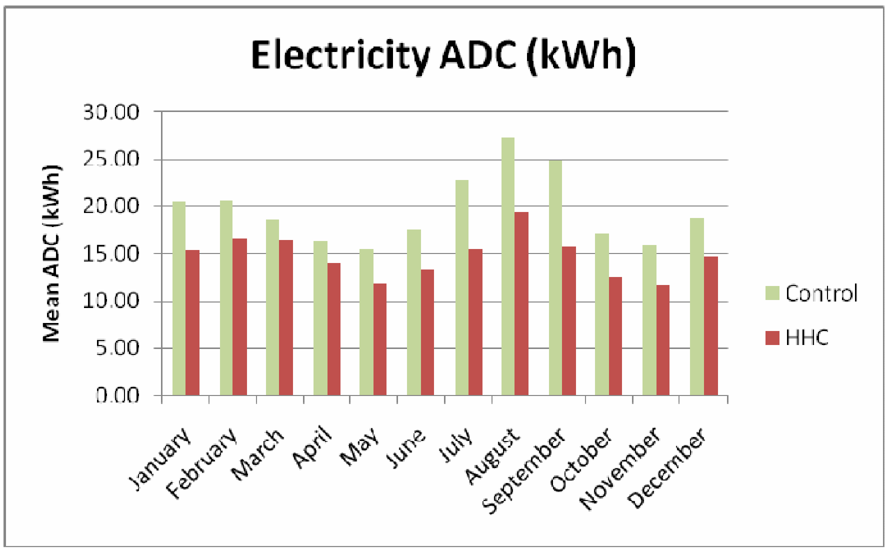
Baltimore Gas and Electric (BGE) provided monthly *electricity usage* (ELE) and *gas usage* (GAS) for the period September 2008 to August 2009, measured in kilo-watt-hours (kWh) and therms (ths) respectively. Because BGE does not read all meters on the same read-date each month, the number of days in a billing cycle can vary by account. BGE provided the number of *billing days* (BD), which is the number of calendar days during the billing cycle over which the usage amount accumulated. Using these variables, *average daily consumption* (ADC) was

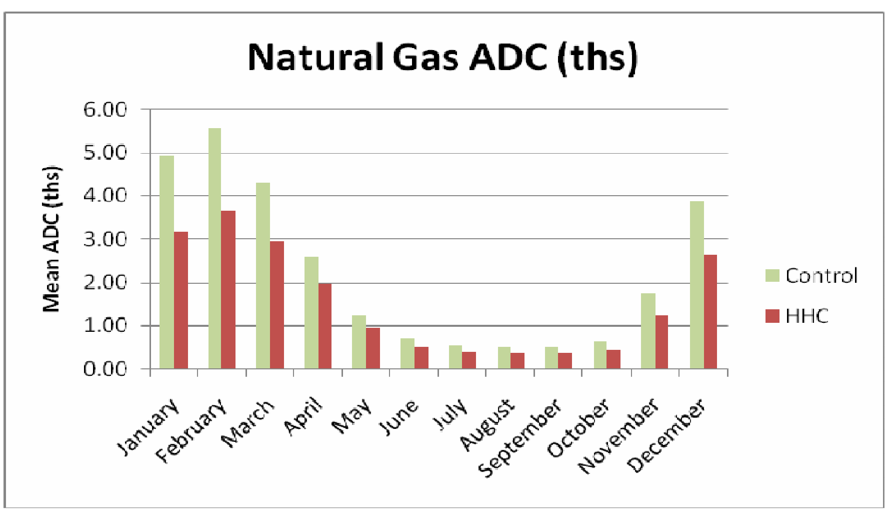
[2] Tankless water heaters were installed in some, but not all, of the "Stepped-up Efficiency" homes; they were not installed in the homes in the "Energy Star" phase.

calculated for electricity and gas usage for each account. The above-described data was provided for all accounts included in one of the three HHC building phases. As well, for each phase, BGE provided the same data for a group of nearby accounts (the control group) as identified by matching *gridcode* (GRID). Gridcode is a code assigned to an area of BGE territory. Each gridcode equates to approximately one square quarter of a mile. The data was screened to eliminate outliers and focus on the most regular bills.

3. *Exploring the Data*

Based on a simple comparison of average daily consumption (ADC) for electricity and gas, it appears that the HHC homes as a group are using less energy than the homes in the control group. See Bar Charts below. Further analysis is required to determine if the difference between the means is evidence that the groups are in fact different (ie. the difference between the means is not due to "chance").





4. Variables

There are many variables that affect home energy use. Among them, the four primary drivers of variance include weatherization of home and efficiency of appliances/systems, weather, number of occupants, and intensity of occupant energy use. All homes, both HHC and non-HHC, should have been subject to the same general weather patterns, given their close proximity; hence, month is a good proxy for weather and can be entered as an explanatory variable. The number of occupants and the intensity of energy use are two variables for which data is unavailable. However, it was assumed that the distribution of outcomes for each variable was similar for both the treatment group and the control group. In other words, there is no reason to believe the HHC households have more or fewer occupants than non-HHC households in the same neighborhood. Similarly, there is no reason to believe that HHC households use energy any more or less intensely than non-HHC households in the same neighborhood. To account for differences between neighborhoods (differences in house size, demographic and/or socioeconomic differences, differences in billing cycle) gridcode (GRID) was entered as an explanatory variable.

5. Energy Impact Analysis

To determine if the difference in mean ADC between the control group and the treatment group is evidence that the control group is in fact different from the treatment group, an analysis of variance (ANOVA) test was run followed by an ANOVACONTRAST test. We presume that the mean energy usage for the control group is not significantly different from the mean energy usage for the treatment group (and any variance is due to random chance). If this hypothesis is rejected, then we can presume that there is a statistically significant difference between two or more mean values. To check the results given by the analysis above, a linear regression model was used to confirm the relationship between average daily consumption and phase.

6. Results

ANOVA analysis confirmed that there is a statistically significant difference in mean daily energy performance between the treatment group and the control group. A complex contrast analysis (ANOVACONTRAST) revealed that HHC-renovated homes use *less* electricity and *less* natural gas on average relative to the control group. Furthermore, on average, HHC-renovated homes use approximately 25% less electricity per day and 33% less natural gas per day relative to the control group. A regression analysis was used as a robustness check and it confirmed the direction of this relationship: HHC-renovated homes use *less* electricity and *less* natural gas on average than the control group.

It is noteworthy that weather and neighborhood (as described by gridcode) explain the lion share of the variation in ADC. This is not unexpected because weather dictates the need for heating and cooling, and neighborhood is likely correlated with size of house, age of occupants, and other such variables. Nevertheless, HHC-renovations account for some of the variation in energy consumption and there is statistical significance associated with the difference.

Table 1: Percent Savings, by Phase

	Electricity	Gas
All HHC	25%	33%
Phase 1	11%	17%
Phase 2	32%	55%
Phase 3	25%	29%

IV. Conclusion

Homes rehabilitated by HHC use less energy than comparable un-renovated homes. The results are statistically significant and confirmed by more than one type of analysis. This is good news for HHC. Because there is some disparity between the models with regards to "how much less" energy the HHC-rehabbed homes are using, these numbers may not be a precise measurement of energy savings; however, they are a good estimate. While further study is advisable, we can say with confidence that Habitat's work in Baltimore is saving Habitat homeowners money on utility bills, making homeownership more affordable, and reducing the organization's carbon footprint. Because initial results are trending in the right direction, Habitat should continue to implement green building techniques going forward.

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