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Sustainable Habitat

Reducing Energy Consumption through Evaluation, Efficiency, and Education

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science (Natural Resources and Environment) at the University of Michigan

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Abstract

Habitat for Humanity of Michigan (HFHM) seeks to improve energy efficiency and promote reduced energy consumption among Habitat homes through improved building science and education. Interviews with 21 HFH affiliates from around Michigan revealed best building and communication practices including installing Energy Star appliances, using LED lighting, and conducting partner family home walkthroughs. A survey of 115 Habitat families revealed attitudes on energy and the environment, experience in their home, and demographic trends. Electricity and natural gas consumption was analyzed for these homes and compared to energy consumption in similar non-Habitat homes from the US Energy Information Agency's Residential Energy Consumption Survey.

In general, Habitat homeowners correctly assessed the relative energy efficiency of their homes. On average, Habitat homes consumed 25.86% less natural gas and 15.94% less electricity annually compared to demographically similar non-Habitat homes when controlling for home size, number of household members, and climate. Our models indicated significant drivers of household energy use, which led us to identify the following areas for intervention: nighttime thermostat settings, installing smart power strips, quantifying monetary losses associated with the use of secondary freezers and electric space heaters to discourage the purchase of excess appliances, and exploring gift-in-kind partnerships for energy-efficient window air conditioning units. Little relationship was found between attitudinal variables, such as the extent to which self-reported environmental concerns motivate behavior, and energy consumption. Fostering more frequent and extensive communication between HFHM affiliates and partner families is also encouraged based on feedback from both parties.

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Introduction

Habitat for Humanity International (HFHI) is a non-profit organization that builds and renovates safe, affordable housing for low-income families around the world through local affiliate organizations. These affiliates sell homes to partner families at cost through zero-interest mortgage loans (Habitat for Humanity, 2014). Habitat for Humanity of Michigan (HFHM) is a State Support Organization (SSO) that works with over 70 Habitat affiliate chapters in Michigan to improve building design, secure and maintain funding, and interface with HFHI.

HFHM has made great strides in promoting energy efficiency for the houses that affiliates in Michigan build and renovate. However, HFHM wanted to determine how best to proceed to further reduce energy consumption in Habitat homes—thereby improving the financial security of Habitat partner families as well as reducing environmental impact. This project's purpose was to measure actual household energy consumption among Habitat households in Michigan, evaluate the performance of Habitat affiliates' energy efficiency efforts, and create recommendations for further reducing energy consumption in Habitat homes through a combination of building technology and education programs.

HFHM reaches a considerable target audience across the state. We hope that the strategy our team designed will be relevant to all affiliate chapters in Michigan, and perhaps the building industry more generally. As of 2012, Habitat for Humanity was the sixth largest homebuilder in the United States (Habitat for Humanity 2012); thanks to this industry clout, steps that Habitat affiliates take to improve their approach to affordable housing can improve homeowners' sustainability and livelihood at scale as well as reverberate throughout the homebuilding community, providing a model for other organizations devoted to affordable and sustainable housing.

Background

Although global energy poverty has been widely explored, energy poverty as it applies to low-income housing in the United States has not. This presented a research gap that we aimed to address through the course of our project. Energy expenditures comprise a disproportionately high share of total expenses in low-income households. Many families in the US, including Michigan, experience energy poverty, defined as devoting at least 10% of total household income to energy expenditures (Roberts, 2008). In comparison, higher-income households typically spend a much smaller proportion of their income on energy needs, averaging between 3% and 4% (Eisenberg, 2010).

Energy poverty is as much related to income as to the older and less energy-efficient housing infrastructure that low-income families generally inhabit. According to the 2009 Residential Energy Consumption Survey, average annual energy consumption per square foot for heating and cooling among Michigan households above 150% of the federal poverty level was approximately 40.72 MBtu/square foot, while average annual energy consumption for these purposes among households at or below 150% of the federal poverty level was approximately 66.37 Mbtu/square foot (U.S. Energy Information Administration, 2009).

Energy inefficiency among low-income households has a wide range of negative impacts. It increases the likelihood of financial and housing instability since families are forced to make difficult allocation decisions with limited resources. Energy poverty also leads to documented negative health impacts, particularly among children. Battacharya, *et al.* (2002) observed a phenomenon known as the "heat or eat dilemma," wherein as a response to unusually cold weather, poorer families reduced their expenditures on food by approximately the same amount that they increased their expenditures on energy. On the other hand, higher income families increased both their food and fuel expenditures when faced with the same situation. Additionally, investigators observed that children from lower income families consumed an average of 197 fewer calories/day during the winter than during the summer.

Furthermore, residential energy inefficiency has substantial environmental impacts. Approximately 54% of Michigan's electricity generation is fueled by coal (U.S. Energy Information Administration, 2013) and nearly 90% of Michigan households are heated with natural gas or propane (U.S. Energy Information Administration, 2009). Thus, inefficient housing contributes significantly to greenhouse gas emissions and climate disruption as well as emissions of other air pollutants including sulfur dioxide, nitrous oxides, particulate matter, and mercury.

The incorporation of sustainability principles into building science to address these challenges is fairly new, with the first green building programs launching in the early 1990s (EPA, 2012). Initially, "green" housing was aimed more affluent families with higher levels of disposable income. However, sustainable building techniques have been more recently applied to low-income housing in addition to upper-income housing and commercial buildings (EPA, 2011).

Included in this movement is HFHM, who has identified energy efficiency as a way to better serve partner families by improving the economic, social, and environmental sustainability of the houses they build and renovate. As an example of HFHM's success in adopting sustainable practices, by 2013 all participating new and renovated Habitat homes in Michigan achieved ENERGY STAR certification or equivalent. However, next steps toward cost-effective energy efficiency and conservation remain unclear, as this is relatively new territory in affordable housing.

One of the key strategies for further reducing energy consumption among Habitat homes is to install cost-effective, durable energy efficiency improvements as part of the building infrastructure. Existing retrofit programs show that reductions in energy consumption of up to 50% are possible through certain energy efficiency measures, and the costs of these measures are continually decreasing with improvements in building, appliance, and equipment technology. However, these deep retrofit programs can still be cost prohibitive and inappropriate in the affordable housing sector (Cluett and Amann, 2014). Therefore, one element of HFHM's strategy to further reduce energy consumption in Habitat homes is to identify cost-effective efficiency improvements that consistently deliver energy savings to partner families and pay for themselves relatively quickly.

Still, at their core most environmental problems are human problems. Even with technological gains that make cost-effective energy efficiency improvements more accessible, energy consumption may not change substantially in the long run due to continued consumption behaviors and the rebound effect, wherein the decreased cost of energy through improved efficiency yields increased consumption (Owen, 2010). To ensure the maximum amount of energy savings, steps to reduce consumption through behavior change are needed alongside improvements in energy efficiency. Several existing programs addressing behavior and education have been successful in reducing household energy consumption (Allcott, 2011; Osbaldiston, 2011).

Since HFHM recognizes that energy consumption is determined as much by individual and family conservation behaviors as by physical infrastructure, pairing families with ENERGY STAR certified or equivalent homes is an important first step in a greater trajectory aimed at fostering durable, pro-environmental, and sustainability habits. For this reason, HFHM wishes to collaborate with partner families in defining and understanding their role as environmental actors. This action is especially important as families move into and adjust to their new homes, since contextual changes are some of the best times to modify behavior (Verplanken et al., 2008). Based on survey and interview data, we developed behavior change recommendations and messaging strategies that encourage long-term energy conservation related to homeownership. These materials may serve as a behavior-change model for Habitat affiliates in the state as well as at the national level.

There has been a recent intellectual shift in the way experts think about and design environmental education and behavior change programs. In the past, information about and exposure to environmental problems was considered key to pro-environmental behavior change. After years of psychological research, it is now accepted that the relationship between information and action can be weak and uncertain (Osbaldiston and Schott, 2011). Thus, experts have been experimenting with a wider range of behavior change techniques (i.e. intention mapping, goal-setting, social norm marketing, prompts, intrinsic motivation, etc.), often with greater and more durable success than with information alone. However, no single strategy is sufficient for change, and many social scientists now recognize the power in employing varying and complementary methodological combinations (Abrahamse et al., 2005). Although promising, few programs have been developed that incorporate more than two change strategies and therefore little scientific evaluation has been done on which combinations are the most effective and under what circumstances. Using literature in this area, we explored some of these behavior change strategies in designing a home energy consumption survey and recommending educational materials for Habitat families.

Continued and regular interaction with Habitat partner families after move-in can have positive effects beyond reducing energy consumption. As home systems become increasingly complex (particularly for highly efficient homes), it can be difficult for first-time homeowners to keep track of the maintenance necessary to ensure the proper functionality and safety of infrastructure and equipment. For example, proper ventilation was not traditionally a concern in older homes since the building envelope was not tight and air could pass relatively freely through the home. Today, however, highly efficient homes require complex ventilation systems to ensure proper airflow through a tightly-sealed interior. If families are not equipped to maintain this ventilation system, they risk serious indoor air quality issues, including excess mold (Manuel, 2011). Thus, continuing interaction with families after move-in can help families properly maintain the health and livability of their homes, as well as reduce their monthly energy expenditures.

Objectives and Scope

The principle goal of our project involved meeting the requests of our client by identifying low-income residential energy efficiency strategies that can be applied within and beyond HFHM.

Our overall aim was to establish a plan to inform HFHM and Habitat affiliates in Michigan as they move forward with energy efficiency and sustainability measures. HFHM and many Michigan affiliates have already addressed "low-hanging fruit" in terms of energy efficiency, but realize that there is room for improvement. Regrettably, budgetary constraints among many affiliates make ambitious or sweeping overhauls difficult. Thus, we wanted to assess the effectiveness of current efficiency improvements and identify other viable measures Habitat could take to further increase energy efficiency. Moreover, our project will help families living in Habitat's finished homes to continue saving energy, which not only provides an environmental sustainability component, but also a social justice component as these measures will help reduce energy costs for low-income families.

A secondary goal of this project was to develop our team's professional and intellectual skills. Through this project, we built collaborative teamwork skills and learned to effectively interact with a large number of external stakeholders. Furthermore, our group augmented our knowledge of energy efficiency measures for buildings, the functioning of a multinational non-profit, and the development and evaluation of a behavior change intervention package. This project also allowed us to engage in a long-term consulting project, which aided in developing our computational and data analysis skills, as well as methods for distilling complex concepts into digestible recommendations for our client.

A third goal relates to the scalability of the project, specifically how strategies for encouraging energy conservation among the lower-income residential sector can be applied outside the operations of HFHM affiliates. Residential energy efficiency has the potential to mitigate energy poverty and significantly reduce the environmental damages associated with combustion of fossil fuels across many sectors and industries. Therefore, our client and team identified promoting energy efficiency more broadly in the lower-income sector as a key component of the project. The recommendations provided are applicable not only to HFHM affiliates, but also can be applied by other low-income housing developers in general.

Methodology

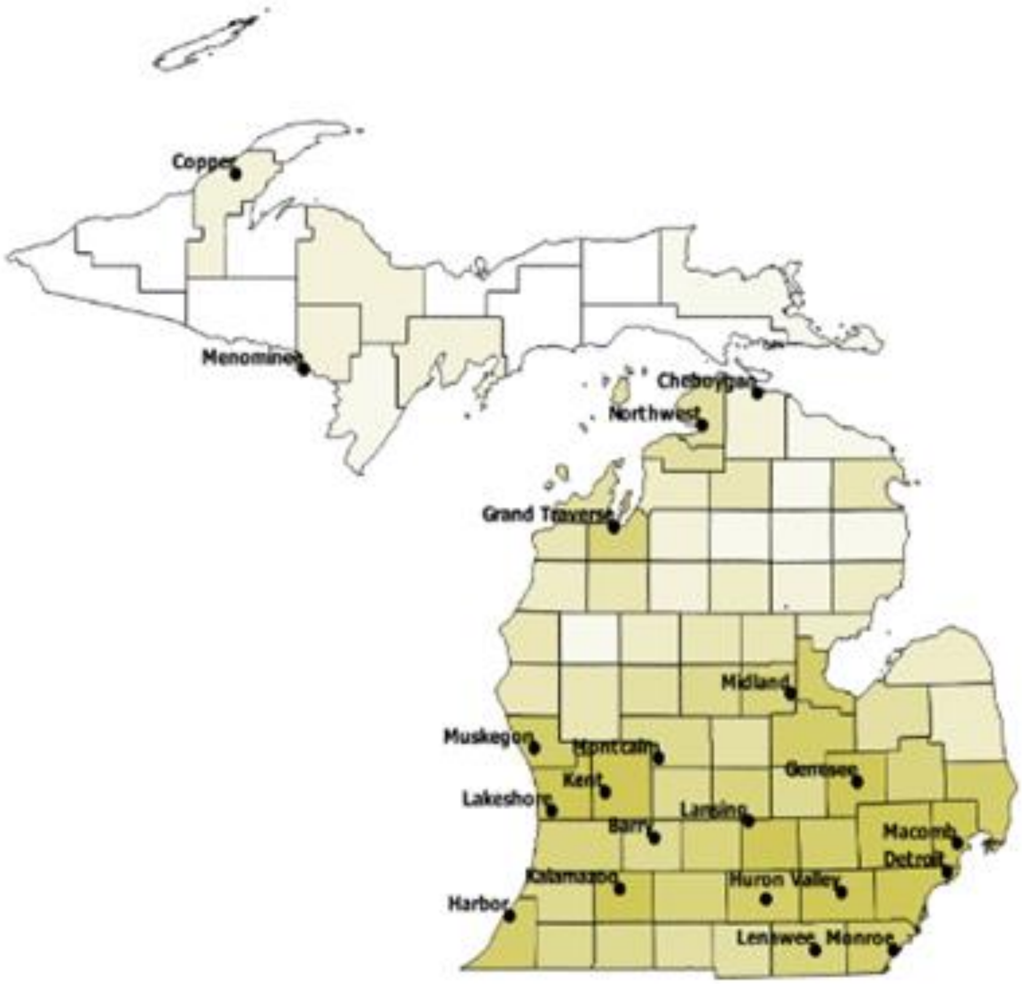
Many factors affect the ultimate energy use of a particular household: building characteristics; appliances; heating, cooling, and ventilation systems; the number of residents; the age and health of residents; how often residents are home; and energy consumption behavior are just a few key determinants of total energy usage. These drivers of energy consumption can be addressed via two components. The first component is identification of the best technology available to reduce energy intensity in a cost-effective manner. The second major component is to identify how Habitat families' behaviors, attitudes, and intentions affect their energy consumption, and how educational outreach can be designed to influence these behaviors, attitudes, and intentions in a positive manner and motivate families to conserve energy and properly maintain their homes.

Affiliate Interviews

Before collecting information on Habitat households themselves, we conducted qualitative interviews with construction managers, executive directors, and other key stakeholders at participating Habitat affiliates. The goal of these interviews was to better understand motivations behind sustainability, best practices in construction and communication, and challenges faced when pursuing efficiency in homes. In addition to data collection, these interviews helped inform our Habitat household survey and establish trust between our research team and Michigan Habitat affiliates. It was made clear that the point of our research was not to rank or scrutinize affiliate performance.

We targeted affiliates based on their size and relationship with HFHM. After HFHM notified affiliates of the project, we arranged calls with representatives of 21 affiliates between March and May of 2014. A map of these affiliates is shown in Figure 1 below. Interviews lasted approximately 45 minutes and were semi-structured, with each team member following a question guide while allowing for follow-up questions and free discussion as needed. In most cases at least two members of the SNRE team were present in order to ensure a balance of note taking and discussion. The interview consisted of four sections: construction, systems, communication, and general questions. An important component of the interview was asking which affiliates were viewed as top performers in the state, in order to identify successful partners.

FIGURE 1: PARTICIPATING HFH AFFILIATE MAP



Partner Family Survey

After interviewing affiliates to gain a better understanding of their operations, we developed a mail survey directed at Habitat partner families in order to assess attitudes and behaviors related to energy and the environment, experience in their home, interactions with HFH, energy consumption patterns, and demographic information. The survey was done via US Mail, as opposed to online, based on anecdotal evidence that suggested that Habitat partner families do not have regular Internet access. Note that we later discovered during our survey that many more families use the Internet regularly than initially expected, which is discussed in greater detail in the Results section below.

Survey Creation Process

The survey was designed in consultation with a number of social research experts, informed by a review of relevant literature (DeCicco, *et al*., 2013; Dillman, *et al.,* 2009; Schutt, 2001), and based partly on the type and style of questions asked within the EIA 2009 Residential Energy Consumption Survey (RECS). There were three primary sections:

1. Attitudes on energy and the environment
2. Home experience and energy use
3. Demographics

We consulted with faculty members from the University of Michigan while designing the survey: Dr. Avik Basu (SNRE), Dr. Grant Benson (Institute for Social Research), Dr. John DeCicco (former SNRE faculty), and Dr. Michael Moore (SNRE).

Survey Mailing Process

There are over 70 Habitat affiliates in Michigan, each with varying levels of annual home construction and renovation activity. Due to time and resource constraints, our team was not able to sample households from every Habitat affiliate in Michigan. Therefore, we used the same 21 affiliates who participated in qualitative interviews as the source population for our survey sample. These 21 affiliates, including both urban and rural affiliates, represented 67% of new builds and rehabilitations across the state from 2009 through 2013. Of these 21 affiliates, 13 agreed to provide names and mailing addresses for their partner families, three chose to mail out the surveys to their partner families themselves due to concerns over privacy, and five did not respond to our request. We asked that affiliates provide us with contact information for homes that had been occupied for at least two years and were not heated with propane in order to accurately compare natural gas consumption across homes.

Approximately three days before the physical surveys were distributed, a simple pre-notice letter was sent out to the families, which introduced our team, informed families about the goals of the project, and asked for their participation. We alerted families that they would be receiving a survey in the mail and included a contact phone number and e-mail address they could use to reach us with questions about the project or for assistance filling out the survey. These pre-notice letters were personalized for partner families that we contacted directly. For the three affiliates who sent out survey materials themselves, letters were not personalized.

Three days after distribution of the pre-notice letters, our team sent out 490 survey mailers that included a cover letter, survey booklet, stamped and self-addressed return envelope, and customer authorization forms for the electric and natural gas utilities that serviced their home. The mailer also included a $1 bill as an incentive to complete the survey, since prepaid monetary incentives have been shown to significantly increase response rates in mail surveys (Dillman, *et al.,* 2009; Singer, 2012). The cover letter reminded participants of the nature and goal of our project, thanked them for their participation, described instructions for returning materials to our team, and again provided contact information.

One week after distributing the survey materials, we mailed postcards to families for whom we had contact information. These postcards thanked participants for their assistance, reminded participants to complete and return their survey booklets and customer authorization forms, and again provided contact information for questions. For the three affiliates who did not share partner family contact information with our team, no postcards were distributed.

Due to delays in approving the language used in the DTE Energy customer authorization forms, survey materials were distributed in two batches. The first batch, which included all homes *not* serviced by DTE Energy, was distributed in August 2014. The second batch, which included all homes serviced by DTE Energy, was distributed in October 2014.

Survey Questions

For the complete list of questions in the partner family survey, refer to Appendix B.

Survey Error

As with all surveys, ours was not free from error or bias. We achieved a 25.1% response rate, indicating that 74.9% of the households who received a survey did not return it. In our analysis, we assume that this 25.1% is a representative sample of the Habitat partner family population in Michigan. However, it is possible that these 25.1% are not representative of Habitat families.

Language barriers presented another potential source of error. Due to resource constraints, only an English language version of our survey could be distributed to partner families. If some partner families were uncomfortable responding to an English language survey, their behaviors, attitudes, and energy use may not have been captured in our results, potentially biasing the results in favor of English-speaking households.

Energy Consumption Data

In addition to the social research on how Habitat families use and conserve energy in their homes, we also worked with partner families, HFH, and electric and natural gas utility companies to collect actual energy consumption data for Habitat homes.

Utility Consumption Data

In order to collect electricity and natural gas consumption data for participating households, our team used customer authorization forms which, when signed by participating households, authorized our team to collect these data directly from utilities. Forms were customized to each utility. For the two largest utilities, DTE Energy and Consumers Energy, we modeled the customer authorization form based on an authorization form that HFHM had used in a previous study. We then submitted these forms to the legal departments at these utilities for edits and approval. For all other utilities, we used the language that had been approved by Consumers Energy. A copy of the customer authorization for used for Consumers Energy can be found in Appendix C. Once we received signed authorization forms in the returned survey packets, we submitted them to their respective utilities and requested two years' worth of monthly electric and/or natural gas consumption data from June 2012 through May 2014.

We identified the utilities that serviced each address using www.allconnect.com, which allowed utility lookup by address in July 2014. However, as of April 2015, this tool is no longer effective for most Michigan residential addresses. This tool was generally effective for identifying the utilities that serviced each address at the time. However, there were certain instances where it could not identify any electric or gas utility, in which case we relied on qualitative information obtained from affiliate interviews to estimate the utility that serviced their partner families' homes. In the case that the online tool returned multiple utilities for one address, we included forms from each utility in the survey mailer and asked households to only complete and return forms for the utilities that actually serviced their home.

We found that the homes represented in our survey were serviced by a total of nine utilities: Cherryland Electric Cooperative, Consumers Energy, DTE Energy, Holland

Board of Public Works, Lansing Board of Water and Light, Michigan Gas Utilities, Midwest Energy Cooperative, We Energies, and Zeeland Board of Public Works. Of these utilities, our team was successful in collecting electricity and gas consumption data from every utility except We Energies, despite repeated follow-up requests. Overall, approximately 87% of households surveyed received electric and/or gas service from the two largest investor-owned utilities in the state, Consumers Energy and DTE Energy.

Collection of utility consumption data was the most time-consuming portion of this project. One utility in particular, DTE Energy, had an extensive approval process both for our customer authorization forms and for our data transfer, storage, and security plan. The approval process for our customer authorization form took three months, from July 2014 to October 2014. Due to this delay, we distributed household surveys in two batches as previously discussed.

DTE Energy also required our team to complete a complex data security questionnaire and a "terms and conditions" document that would eventually be rolled into a data security agreement. Working with University of Michigan Information and Technology Services and University of Michigan Office of Research and Sponsored Projects, we prepared our responses to the questionnaire and negotiated a data security agreement. This process took five months, from September 2014 through January 2015. Upon completion of the data security agreement, our team forwarded the completed customer authorization forms to DTE in February 2014 and received our requested consumption data in the same month.

Energy Consumption Data Error

There are several potential sources of error in the energy consumption data we collected from utilities. First, not all utilities included in our sample use smart meters, and not all utilities are able to collect accurate meter readings every month for every home. This means that some of the monthly energy consumption data collected were estimated rather than based on an actual meter reading. For some utilities, it was not made clear which data were estimated and which were based on actual meter readings. To help overcome this obstacle, we grouped energy consumption across several months or a full year for our analysis, instead of considering monthly energy use. This helped ensure that the energy consumption data included a majority of actual meter readings.

Another source of error was the uncertainty in the dates for each billing period. Many utilities' billing periods do not correspond with the beginning and end of calendar months. For example, the June 2012 billing period for one utility covers May 20 - June 19, while the June 2012 billing period for another utility covers June 5 - July 4. To overcome these differences, we considered usage by season or over the course of the entire year.

Heating and Cooling Degree Days

In order to account for energy consumption variations in different parts of the state due to differing latitudes and weather conditions, we collected heating and cooling degree days for areas around each affiliate included in the survey. A heating degree day (HDD) or cooling degree day (CDD) is a measure of how hot or cold a day is, on average, compared to a baseline indoor temperature (65 °F) in one day. For example, if a single day has an average temperature of 55 °F, that day will accrue 10 HDD. Five days with average temperatures of 55 °F each day will accrue 50 HDD in total. The equation used to calculate HDD is:

$$HDD\ for\ X\ days = (65 - Avg.\ Temp) \times X$$

We used the zip code of affiliates as the location for which to pull monthly HDD and CDD data from www.degreedays.net, and made the assumption that homes built by that affiliate would have a similar number of HDD and CDD. This assumption allowed us to pull data for a few zip codes, rather than data for each individual home. We verified this assumption by testing HDD data for two separate houses built by the same affiliate and found an average difference of 27 HDD (or less than one degree difference per day between the two locations) over 36 months.

Building Characteristics Data

Our team also collected information on the basic building characteristics for each home. While the number of building characteristic variables that we could have collected is practically endless - everything from home size to insulation values to directional orientation - we had to balance the need for comprehensive data with the availability of Habitat affiliates and their capacity to collect this information. Therefore, we only collect a relatively limited amount of data, focusing predominantly on building characteristics that were easily obtainable from build plans and that varied greatly across different affiliates. These characteristics included square footage, whether or not the home had a basement or crawlspace, number of bedrooms, type of build (new build, gut rehab, non-gut rehab, recycle), and the Home Energy Rating System (HERS) score, if available. For affiliates who did not respond to our request, we collected information on the square footage of the home and number of bedrooms using property tax records obtained through www.zillow.com and county clerk offices.

Analysis Methodology

Using data collected from household surveys and affiliate interviews, as well as household building characteristics and energy consumption information, we performed an evaluation of energy consumption across Habitat households using two methods.

First, we created multiple linear regression models explaining electricity and natural gas consumption among Habitat homes using household characteristics. Second, we compared energy consumption in Habitat homes with energy consumption in similar, nationally-representative non-Habitat homes to determine how energy efficient Habitat homes were compared with national averages. To do this, we used microdata from the 2009 Residential Energy Consumption Survey (RECS). The 2009 survey, conducted by the Energy Information Administration (EIA), was the thirteenth since 1978 and collected data from 12,083 households in housing units statistically selected to represent the 113.6 million housing units that are occupied as a primary residence. We specifically isolated homes that met the following characteristics:

- Single-family, detached;
- Owner-occupied;
- Less than 2,000 square feet of conditioned space;
- Heated with natural gas;
- Midwestern or Northeastern Climate Zone, specifically: Connecticut, Illinois, Indiana, Massachusetts, Maine, Michigan, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, and Wisconsin

Electricity and natural gas usage data from RECS was collected directly from energy suppliers and did not rely on household self-reports. Similarly, square footage in RECS was measured directly by survey administrators and was not self-reported by responding households. One weakness of using RECS data to compare with data from our survey is the time difference: RECS data was collected during 2009 and represents energy consumption during 2009, while our survey was administered during 2014 and represents energy consumption during 2013. While we attempted to control for differences in energy consumption between those years by including heating and cooling degree days, it is possible that, for other reasons, energy consumption might have been significantly different in 2009 than in 2013.

For all statistical confidence tests performed in our analysis, we used an alpha level of

0.1, indicating a 90% probability that the true population parameter was captured within the confidence interval around the means, differences in means, differences in proportions, or model coefficients identified in our results. This provides enough confidence to reasonably avoid determining statistical significance in error while also making the confidence interval narrow enough to make our findings operationally practical.

Challenges

Throughout the project our team faced various challenges that complicated and delayed project execution. In the most general sense these were related to communication and data procurement.

Communication Challenges

Fortunately, our team experienced no difficulty communicating with HFHM and challenges related to communication were limited to select affiliates and partner families.

Most Michigan affiliates stay in close contact with the SSO and consider it to be a trusted source of information. An email from HFHM to affiliates describing our project served as a warm introduction that alleviated most of the challenges we anticipated around making initial contact. That said, some communication was not as fluid as we would have liked. However, problems were limited to a small subset of affiliates, and we attribute this disconnect to a lack of resources and to employee turnover. In most cases a phone call or additional email was all that was necessary to resolve issues.

Challenges communicating with partner families were largely driven by the sheer number of households we attempted to sample. With additional time and resources it would have been ideal to reach out to partner families individually, which possibly would have allowed us to frame questions more appropriately and increase our response rate with a more personal interaction. For affiliates who chose to keep family contact information confidential, non-personalized surveys were sent out on our behalf. This prevented the team from sending follow-up letters, resulting in lower response rates and longer survey return times.

Data Procurement Challenges

From the standpoint of data procurement, we faced challenges, both internal and external to Habitat for Humanity, primarily driven by incomplete information and internal policies.

Because HFHM does not keep a centralized database of all projects, our team worked with individual affiliates to procure data. Since the number of projects completed per year varied drastically, reaching out to affiliates and consolidating data was very time consuming and could have introduced errors stemming from data retrieval and entry.

While affiliates provided most of the necessary information, some data (square footage, HERS, etc.) were unavailable. These homes were excluded from the statistical analysis, which further limited our sample size. Another challenge associated with sampling and data collection involved the variability in project type. In recent years there has been an overwhelming increase in the number of retrofit projects versus new builds, and these projects have different economics and construction profiles.

We also experienced challenges procuring data from DTE Energy, as previously discussed in the *Energy Consumption Data* section. Serious project delays resulted from working with DTE Energy, the largest energy utility in the state of Michigan. The company not only took an exorbitant amount of time to approve our legal waivers but also placed very strict requirements on our data transfer and storage protocols. Together, the waiver approval and data management process for DTE Energy delayed our project by three months.

Results

Affiliate Interviews

Within the "Construction" section of the affiliate interviews, we found that the number of projects completed annually across all interviewed affiliates ranged from 1 to 20 with an average of 5.7 projects. The cost of these projects varied from $65,000 to $160,000 with an average cost of $96,000. Project timelines varied greatly, but for new builds the average project took 26 weeks, with some affiliates completing projects in as few as 12 weeks or as many as 52. The extent to which these projects were new builds versus rehabilitations depended largely on specific funding opportunities (HUD Funding for Kalamazoo) and blight levels (Macomb and Huron Valley). In total, about 40% of projects were rehabs.

The majority of properties were acquired from private donors and state/local land banks. Very few affiliates relied entirely on open-market purchases. Thus, most affiliates did not have a specific neighborhood or region where they concentrated projects. Despite this opportunistic approach, 43% of affiliates reported that many home sales did not cover the cost of construction, often due to official appraisals that undervalued the home. Several affiliates pointed to a lack of Energy Star 3.0 raters, which meant homes were not being valued based on the advanced building science that was incorporated into them.

When asked about the energy-efficient techniques that were currently being employed, most affiliates focused on insulation, HVAC systems, and water heaters. Insulation levels are specified by R-Value, a measure of insulation's ability to resist heat traveling through it. A higher the R-Value indicates better the thermal performance. On average, R-values of 11, 22, 28 and 51 were estimated for below slab, below grade, above grade, and attics, respectively.

Several affiliates have completed projects using insulated concrete forms (ICF). With this type of construction, interlocking, modular units of rigid, thermal insulation are dry stacked and filled with concrete. The individual blocks are stacked somewhat like "Lego" blocks, creating the structural walls and floors. Although this type of construction is extremely efficient, it is also quite costly so implementations were largely driven by product donations and other incentives.

In order to determine the efficiency of Habitat homes, all projects are evaluated based on the Home Energy Rating System (HERS). This is an industry standard and a nationally recognized system for determining a home's energy performance. To calculate the HERS score, a certified rater completes an evaluation of the home and compares the data to a modeled reference home. The resulting score is relative to the size, shape, and type of building being evaluated. Some of the variables included in the energy rating are exterior walls (above and below grade), floors, ceilings, windows and doors, as well as HVAC systems, water heating systems, and thermostats. A standard new home has a HERS score of 100, with a score of 70 being 30% more efficient than this baseline. On average, affiliates reported HERS scores of 57 with the lowest being 45 and highest being 100. Most affiliates had a goal of further reducing these scores by 10-20% in the coming years. When asked about energy-efficient approaches they would like to explore in the future, affiliates tended to focus on renewable energy integration and advanced heating systems.

The "Systems" portion of the interviews focused on specific appliances and systems included in the homes. Although CFLs are the dominant form of lighting, almost half of affiliates have used LEDs in some capacity. Refrigerators and stoves are always installed through gift-in-kind donations from Whirlpool. A washer, dryer, and dishwasher are often installed with costs rolled into the mortgage. In the majority of cases, appliances are Energy Star rated.

In the "Communication" portion of the interview, we were primarily interested in how affiliates interacted with partner families before and after they moved into the home. Prior to move in, affiliates interacted with partner families during sweat equity hours, financial and maintenance training, and walkthroughs. After move in, it is common for some affiliates to have a family support partner who remains in contact with the family for one year following move in. Some affiliates also send out regular newsletters. Most affiliates identified this "post-move-in stage" as an area that could be significantly improved upon. In the *Recommendations* section below, our team explores opportunities to expand on the level of communication so as to improve energy efficiency.

The final component of the interview consisted of general questions that did not fall into any of the above categories. The first of these questions addressed key information channels. According to interviews, affiliates relied on various sources for information pertaining to energy efficient construction practices including magazines, webinars, conferences, and other affiliates. Despite this diversity, most pointed to the SSO and, specifically, Thom Phillips as a key channel. When asked to identify particularly progressive affiliates in energy efficiency and sustainable building, an overwhelming number of responses included Kalamazoo Valley, Kent County, and Grand Traverse Region.

The final question in the survey asked affiliates to identify other financial or social concerns. From a financial standpoint, affiliates focused on uncertainty around the sources of project funding and low home appraisals. Some affiliates were even exploring the prospect of charging interest in loans in order to fund operations. Social concerns tended to gravitate towards whether or not affiliates were successfully accomplishing their mission and preparing partner families for long-term success in their homes.

Partner Family Survey

Response Rate

We sent out 490 surveys and received 115 completed surveys back. Additionally, 8 respondents returned their completed customer authorization forms, but did not return a completed survey booklet. This yielded a 25.1% response rate. In general, response rates were higher from families for whom the survey materials were personalized.

Respondent Demographics

Based on the demographics of survey respondents, we feel that the respondents roughly represented the general HFH partner family population across the state of Michigan. Of respondents, 64% of families listed a woman as the head of household, 10% were Hispanic or Latino, and 13% spoke languages other than English. Returned surveys represented a diverse racial distribution, and families had lived in their homes for a significant range of time. Results for respondent demographics can be found in Appendix D, Figures 11-14.

Qualitative Results

Along with quantitative questions, the survey included four open-ended questions to which respondents could write sentences to give us deeper understanding of their home experiences and energy behaviors. The excerpts highlighted below are representative of responses we received overall.

1. WHAT DO YOU LIKE MOST ABOUT YOUR HOME?

Habitat families loved talking about how much they liked their home. Some standout language used included “mine, affordable, everything.” When considered together, these answers suggest that people feel a sense of ownership of their home and that it is a satisfactory home in a good place to live. Some quotes from the survey include:

- *Knowing it is mine and I also helped build it. I feel secure and very proud in my home. I love making it look good and in my own taste.*
- *I have more space than before and my house is an energy efficient and affordable home.*
- *Everything! It is safe, nice, beautiful gardens, I like my home so much. It is so comfortable!*

2. WHAT DO YOU DISLIKE MOST ABOUT YOUR HOME?

Overall, people gave much more varied responses than in the previous question. However, many homeowners expressed concerns about space, especially as related to “basement, garage, and small.” Quotes from the survey reveal:

- *No storage, no basement for kids to play.*
- *With 5 people and only one bathroom, the only thing I would change is having another bathroom installed.*

Amenities also seemed to be something people mentioned, with several responses along the lines of:

- *I would like central air. Other than that there is nothing I dislike.*

It is important to note how often “nothing” was used in response to this question, signaling that many families thought there was nothing they dislike about their home. One person did a nice job summarizing this feeling by saying:

- *There is nothing!!! My family loves our home.*

3. WHAT DIFFICULTIES OR PROBLEMS DID YOU OR YOUR HOUSEHOLD HAVE REDUCING ENERGY USAGE?

Problems with windows, doors, and family buy-in to energy saving practices were frequently mentioned issues. People said:

- *I try to do things but my family does not seem to follow my lead on saving energy.*
- *Kids leaving lights on and doors open and having too many electronics*

plugged in.

- *No difficulties saving energy now that kids are gone.*

These responses are significant because they signal a pathway for future energy reduction that is driven by education and setting goals, versus infrastructure or building practices.

4. DOES ANYONE IN YOUR HOUSEHOLD TAKE STEPS TO REDUCE ENERGY USAGE? IF SO, WHAT ARE THEY?

Many people are reducing energy usage through turning off lights, turning down the thermostat, and turning off the water whenever possible. Families mentioned:

- *Use ceiling fans rather than A/C; Close drapes to keep out heat/cold; run furnace @ lowest temp for comfort; turn down thermostat when gone 8 hrs or more*
- *Turn off lights; use rain barrels; wrap water heater and pipes; use cf light bulbs*

Many people already understand the basics of saving energy, which signals that some families might be ready, willing, and able to take on additional environmental behaviors. Certainly some already are, for example:

- *Lower the thermostat. Limit TV. Turn off lights when not in use. Compost.* (Composting takes more knowledge and skill than simply flipping a switch, but it can considerably reduce the amount of waste coming from a home.)

Quantitative survey results

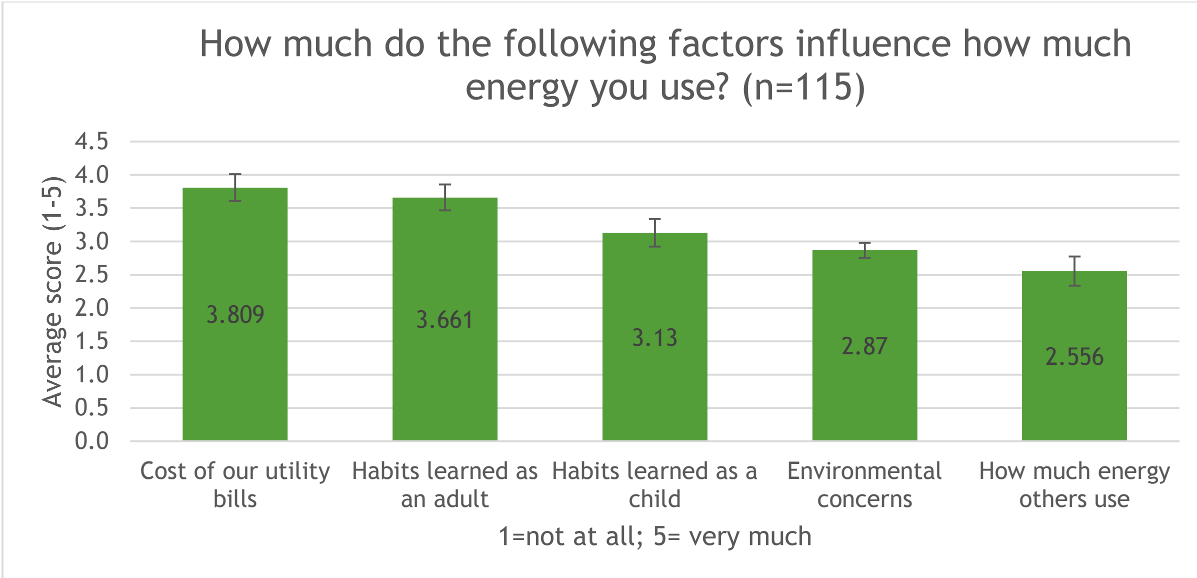
Capturing data from homes built before affiliates were actively aiming for energy efficiency can show how effective improvements targeted specifically at energy efficiency have been. Furthermore, energy efficiency in homes decreases over time due to depreciation of the homes' infrastructure and equipment. If two identical homes were built five years apart, it is highly likely that the older home will be less efficient today solely due to the wear and tear on the home itself. Therefore, capturing homes with a somewhat wide range of ages can indicate how well energy efficiency improvements installed by Habitat affiliates hold up over time.

Additionally, one valuable component of this project was the social research around

Habitat families' technological competency, behavioral patterns, and understanding of sustainability. This information provided measures for key independent variables that we hypothesized would have an effect on household energy consumption. With information about technological capabilities, green behaviors, environmental knowledge and attitudes, and specific knowledge about energy-efficient features of their home, educational materials and messaging can be strategically directed to have meaningful and durable results. Given this information, it is possible to employ pamphlets, smart phone applications, action interventions, and many other educational strategies. We recommend that Habitat consider working with future SNRE Masters Project teams to further develop some of these solutions.

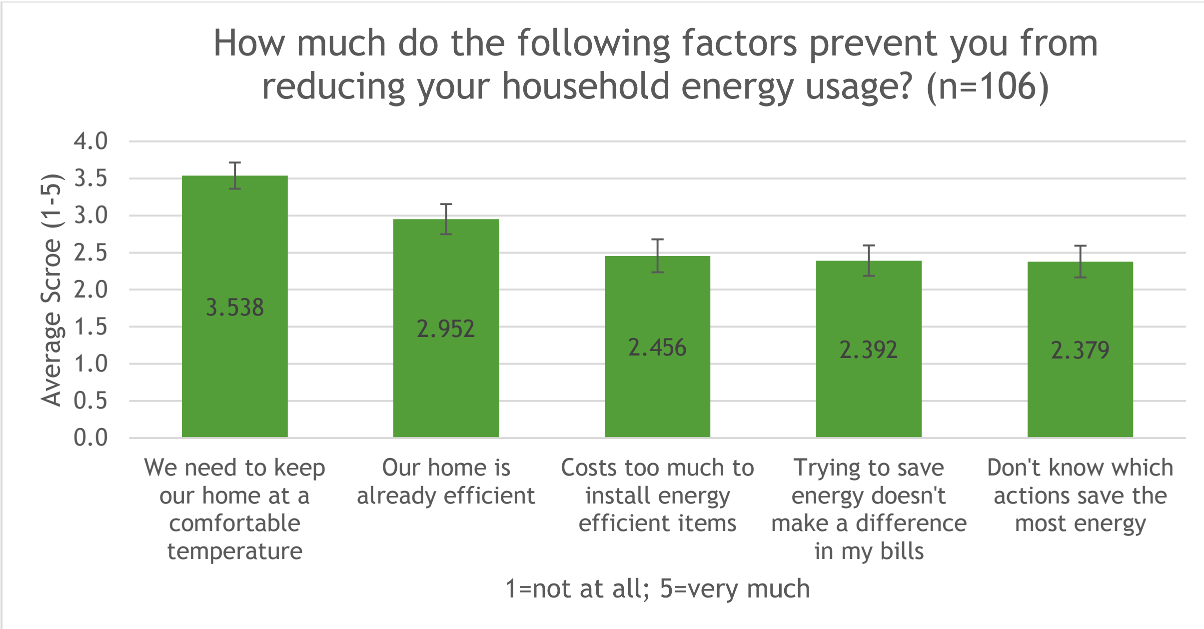
In trying to illustrate typical attitudes of HFH partner families, we calculated the "average" responses for a number of survey questions. These responses uniformly followed the 5-point Likert scale, with a score of 1 indicating a low level of agreement or importance, and a score of 5 indicating a high level of agreement or importance. One survey question, "What are the most important factors in conserving energy?" allowed respondents to self-report what factors influence whether or not they make an effort to conserve energy. Respondents reported that the "Cost" (mean: 3.8) and "Habits learned as an adult" (mean: 3.7) were the two most important factors in whether families tried to conserve energy, while "Amount [of energy] others use" (mean: 2.6) was self-reported as being the least important. These results are represented graphically in Figure 2 below. However, a meta-analysis of experimental studies on this type of behavior suggest that social modeling ("How much energy others use") has a greater impact than cost on whether individuals try to conserve energy – when individuals feel they are being compared to others, they will try to improve their behavior (Osbaldiston, 2011). This suggests that families' conception of their own behaviors may not be truly representative of their actual behavior.

FIGURE 2: MOTIVATIONS FOR SAVING ENERGY



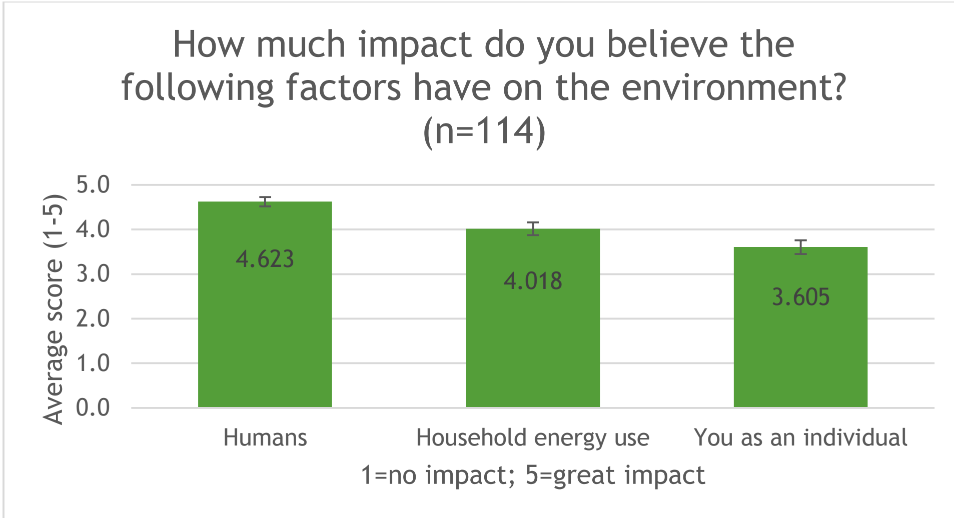
Our survey also examined common barriers to saving energy. Respondents indicated that, on average, needing to keep their homes at a comfortable temperature was the largest barrier (mean: 3.5). Respondents also reported that the fact that their homes were already energy efficient made it difficult for them to save more energy (mean: 3.0). However, factors related to the cost of energy efficient items, convenience, or knowledge were not rated highly. These results are represented graphically in Figure 3 below. These results, combined with the energy consumption analysis results below, indicate that partner families recognize that home heating and cooling contribute to their energy usage. They also indicate that while HFH affiliates should communicate the energy efficiency of their homes to partner families, they should also make it clear that these energy efficient features should not stop partner families from changing their behavior to save more energy.

Figure 3: Barriers to saving energy



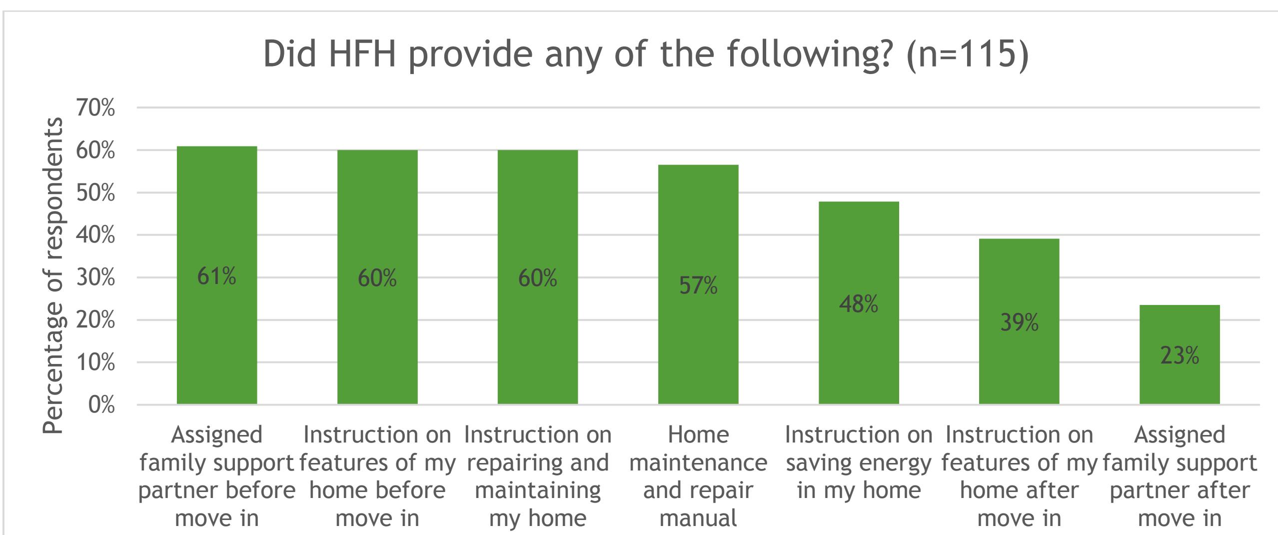
Ultimately, our survey returned a number of interesting results related to environmental concerns. While the majority of respondents acknowledged human impact on the environment (mean: 4.6), respondents tended to place less emphasis and responsibility on their household (mean: 4.0) and themselves (mean: 3.6) when it came to environmental impact. These results reflect the idea that individuals, in general, tend to place less weight on their personal environmental impact. However, it was valuable to note that the majority of respondents did agree with the assertion that "caring for the environment is a moral and ethical duty" (mean: 4.1). These results are represented graphically in Figure 4 below.

FIGURE 4: PERCEPTIONS OF ENVIRONMENTAL IMPACT



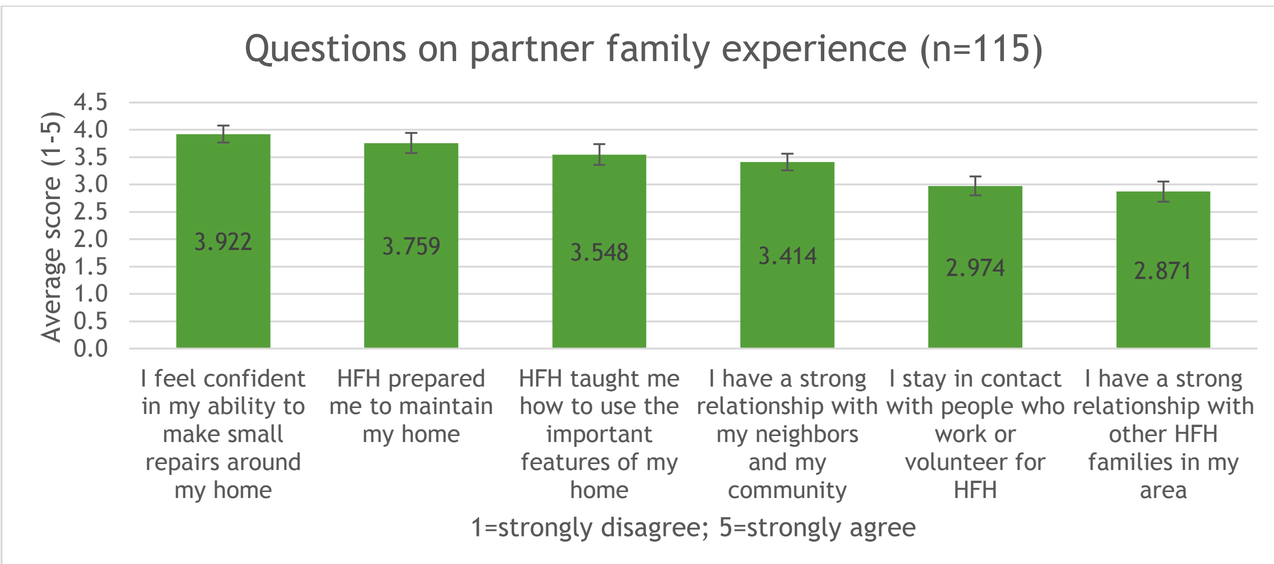
A common thread found in affiliate interviews was the desire to maintain contact with partner families to ensure they properly cared for their homes. In general, affiliates admitted that contact with families after move-in was an area they sought to improve. These facts were reflected in our survey data: while 60% of survey respondents stated that HFH provided instructions before moving into their new homes, only 39% noted that HFH provided instructions after move-in occurred. Furthermore, only 48% of respondents stated that the received instructions on how to save energy from HFH. These results are represented graphically in Figure 5 below.

FIGURE 5: HFH EDUCATIONAL INTERVENTIONS



Habitat partner families generally responded positively when asked about their homeowner training experience with their affiliate. Partner families tended to agree that they felt confident in their ability to make small repairs around their home (mean: 3.9) and that HFH prepared them to maintain their homes (mean: 3.8). However, Habitat families tended to agree less that they remained in contact with a representative from their Habitat affiliate, indicating a potential lack of communication after partner families move into their homes. This reflects a common sentiment that we heard during our affiliate interviews, in which many affiliates wished they could improve their post-move-in communications with partner families. These results are represented graphically in Figure 6 below.

FIGURE 6: PARTNER FAMILY EXPERIENCE



Our statistical analysis of the survey results included an examination of the covariance among key variables. Variables with notably high covariance included responses to "our home is already efficient" and "our energy bills are cheap" (0.87), "habits that I learned as an adult" and "habits I learned as a child" as motivators for saving energy (0.84), "our home is already efficient" and "my energy bills are affordable" (0.8), and "people in my household do not care about saving energy" and "how much energy others use" as challenges to saving energy (0.72).

These results reveal a few noteworthy points. First, people who tend to believe that their homes are already energy efficient are more likely to believe that their energy bills are cheap or affordable. This implies a link between the perception of energy efficiency and tangible financial savings. However, results also show that some people who have difficulty affording their energy bills are the same people who do not find their homes efficient; this presents a potential area of intervention for HFH in terms of both improving the efficiency of technologies in homes and energy saving techniques used in home construction, and in educating families about how best to maintain and use their home features to save energy and, subsequently, money.

A second takeaway from these covariance results is the importance of personal habits given the high covariance between habits learned as a child and as an adult as reasons for saving energy. The behavioral component of energy saving cannot be ignored, but is clearly more difficult to implement than technological upgrades. However, these results suggest that HFH should focus on educating the entire family in energy saving techniques, as a significant number of respondents qualitatively reported children or teenagers using excessive amounts of energy as a reason their household has difficulty saving energy.

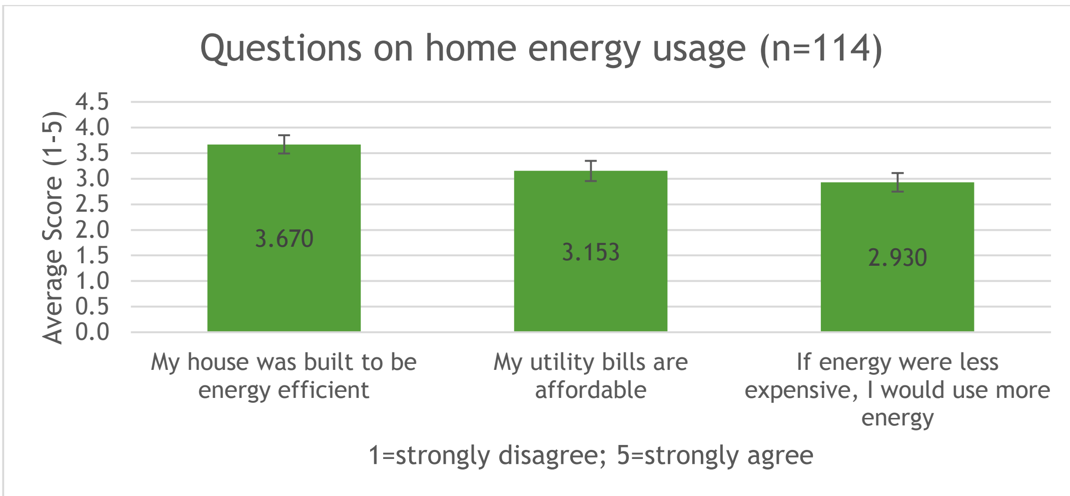
Our results also revealed one significant negative covariance between "it costs too much to install energy efficient items" and "my utility bills are affordable" (-0.85). This is a highly interesting result, as it reveals that people who believe that their utility bills are *affordable* also believe that energy efficient item installations are *not* too expensive, and vice versa. HFH's next steps might help allay the misgivings of those families who believe that energy efficient items cost too much to install and that their utility bills are not affordable; HFH can take the lead by installing energy efficient items that will save families money, and by informing families that their appliances are efficient.

Another key result from these data is that environmental considerations alone are not enough of a motivator for saving energy. HFHM must be cognizant of educational opportunities within the family in order to encourage energy saving habits. Namely, these results indicate that social proof and cost are more effective motivators.

We also found several interesting covariances when comparing certain variables with responses to the statement "My utility bills are affordable" (mean: 3.1). "Costs too much to install energy efficient items" (-0.87) and cost of energy as a motivator for saving energy (-0.80) had strongly negative covariances with perceived affordability of utility bills, indicating that those respondents who were the most concerned with cost were also concerned with the affordability of their utility bills. This further supports emphasizing costs in educational outreach as a potential motivator to save energy.

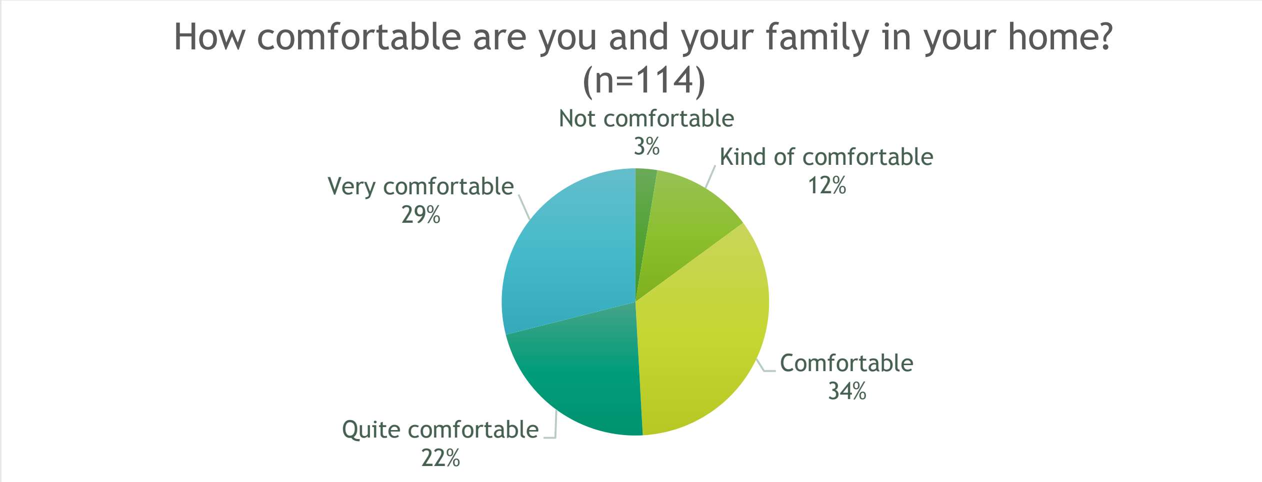
Other variables had strongly positive covariances with perceived utility bill affordability. The covariances for "My house is already energy efficient" (0.81) and "My house was built to be energy efficient" (0.78) indicate that Habitat households who agreed more strongly that their homes were energy efficient were also more likely to perceive their utility bills as being affordable, indicating that Habitat households, in general, see a direct link between the energy efficiency of their home and financial savings. A graphical representation of responses related to home energy usage can be found in Figure 7 below.

FIGURE 7: PARTNER FAMILY ATTITUDES ON HOME ENERGY USAGE



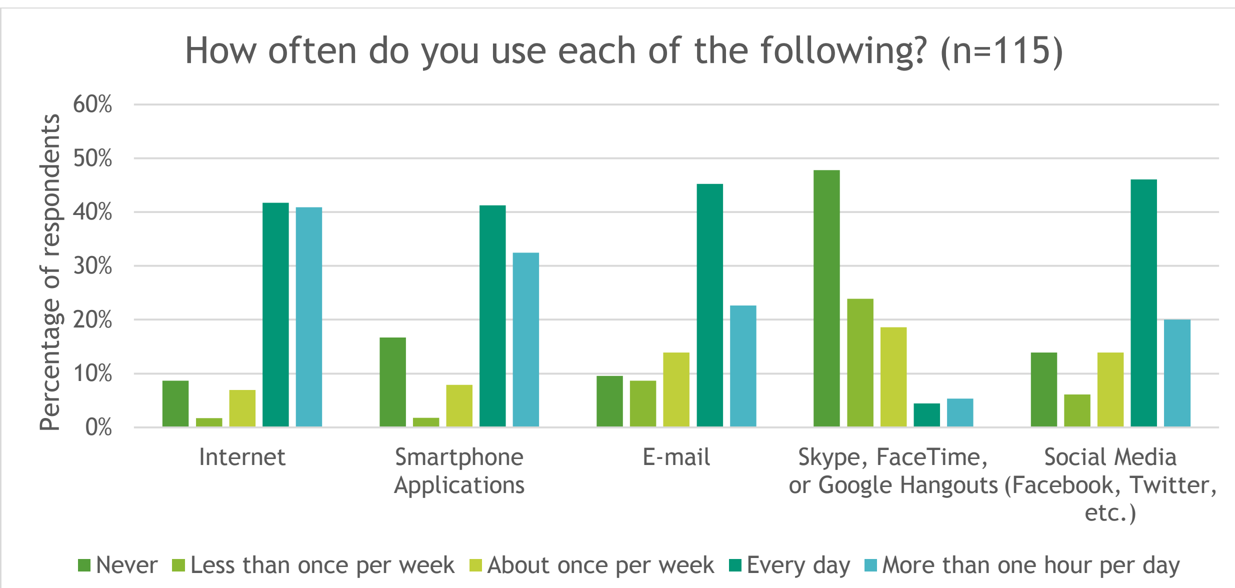
When asked whether they found their home comfortable (mean: 3.6), our study found several significant covariances. "My utility bills are affordable" (0.58), "My house was built to be energy efficient" (0.54), "HFH taught me how to use the important features of my home" (0.39), the respondent about important features of the home (0.39), and "Our home is already efficient" (0.38) have a positive covariance, indicating that utility bill affordability, perceived home efficiency, and homeownership preparation contribute positively to perceptions of home comfort. The key takeaway here is that Habitat partner families, in general, see a positive link between home efficiency and utility bill affordability, as well as a direct link between home comfort and home efficiency, utility bill affordability, and adequate homeowner training. A graphical representation of home comfort scores can be found in Figure 8 below.

Figure 8: Partner family home comfort



Interestingly, many more HFH families reported regularly using the Internet, e-mail, and social media than initially expected. For example, 83% of HFH families reported using the Internet at least once per day. More detailed results for Internet and social media usage can be found in Figure 9 below.

Figure 9: Internet and social media usage



Energy Consumption Analysis

Partner Family Perception of Home Efficiency

On average, our respondents' perception of the energy efficiency of their homes compared to other homes was relatively accurate. A Welch two-sample t-test using an alpha level of 0.1 showed that those respondents who thought they used less energy than their neighbors did in fact use between 0.02 and 0.16 hundred cubic feet (CCF) less natural gas per square foot than other Habitat respondents. However, the difference in means between those who thought they used more energy and those who did not was not statistically significant. For the 27% of respondents who reported that they did not know how much energy they used in comparison with their neighbors, they used roughly the same amount of natural gas on average as the average of all other Habitat respondents.

These results were similar for electricity usage. Those respondents who thought that they used less energy than their neighbors used between 161 and 2,645 kWh less electricity on average than other Habitat households. Those who reported using more did tend to use between 289 and 5,745 kWh more, on average, than other Habitat households. Those who reported that "they did not know" used about the same amount of electricity, on average, as those who reported that they used about the same amount of energy as their neighbors. This indicates that respondents tended to consider both their natural gas and electricity usage when comparing their energy consumption with their neighbors.

We also compared perceptions of energy efficiency with actual energy usage. Based on a varimax rotation analysis to determine which Likert scale responses tended to correlate strongly with one another, we created a composite score to represent each respondent's general perception of the energy efficiency of their home. We took the average of the responses to the following prompts:

- Our home is already efficient
- My house was built to be energy efficient

The correlation between a composite score for how efficient each respondent thought their home was with natural gas usage was -0.28, indicating that as homeowners' perception of their home's energy efficiency increased, natural gas usage tended to decrease. However, the low strength of this correlation indicates that perhaps homeowners' perception of their home's efficiency was not always an accurate indicator of actual natural gas usage.

Additionally, the correlation between the composite energy efficiency perception score and actual electricity usage was -0.05, which indicates a very weak relationship. This suggests that while respondents tended to consider their electricity usage when comparing themselves with their neighbors, they did not tend to consider electricity usage when rating the overall energy efficiency of their home.

Environmental Views

Based on a varimax rotation analysis to determine which Likert scale responses tended to correlate strongly with one another, we created a composite score to represent each respondent's general environmental sentiment by taking an average of their responses for the following prompts:

- How much do the following factors influence the amount of energy you use – Environmental concerns
- I go out of my way to protect the environment
- My actions affect the environment
- Caring for the environment is a moral and ethical duty
- I feel connected to the environment

The correlation between this composite score and actual natural gas usage was -0.13, indicating that as respondents' environmental sentiment increased, natural gas consumption tended to slightly decrease. However, this variable was not significant in the natural gas consumption model. Additionally, this correlation was much weaker when considering electricity consumption (-0.08). These correlations and the lack of significance in the energy consumption models indicate a relatively weak association between self-reported environmental views and actual energy consumption.

Interaction with Habitat for Humanity

Households who stated that they received instructions on saving energy did tend to use less natural gas per square foot than those who did not. We are 90% confident that Habitat homes who reported receiving instructions on saving energy used between 0.01 and 0.15 CCF less natural gas per square foot on average than those who did not. However, this variable was not significant when included in the natural gas consumption model. Similarly, we are 90% confident that households who reported receiving instructions on saving energy consumed between 213 and 2791 kWh less electricity than households who did not. However, as with the natural gas model, this variable was not significant in the electricity consumption model. This indicates that homes who received instructions on saving energy tended use less energy. However, it is not necessarily clear whether this relates to the effectiveness of the educational intervention, or whether affiliates who specifically incorporate education on saving energy are also more likely to install more energy efficient features in the homes they build.

Other educational interventions did not indicate as strong of a difference in natural gas or electricity consumption. The difference in means for both natural gas consumption per square foot and electricity consumption was not statistically significant between homes that stated that they received instructions before or after move-in and those who did not. Similarly, the difference in means for energy consumption was not significant for those who stated that they interacted with a family support partner before or after move-in and those that did not. This indicates that of all the educational interventions we queried, procedural instructions specifically on saving energy were the most likely to be associated with actual energy savings in Habitat homes.

Linear Regression Model Results

To determine which factors household characteristics and behaviors had the greatest effect on energy consumption and isolate key areas for intervention to reduce energy usage, we produced a series of multiple linear regression models. For reference, results for HFH partner family home heating, cooling, and appliance usage behavior can be found in Appendix D.

First, we used data specifically for Habitat homes to model natural gas and electricity consumption separately. Then, we combined the Habitat dataset with data on select homes from the 2009 Residential Energy Consumption Survey (RECS) to create separate natural gas and electricity consumption models that allowed us to compare energy consumption in Habitat homes versus similar non-Habitat homes.

For each multiple linear regression model, we followed the same series of steps to validate the model. First, we examined the F-statistic to determine whether at least one independent variable included in the model had a statistically significant effect on the energy consumption dependent variable. Using an alpha level of 0.1, we found that the F-statistic for each model was significant.

Second, because each model included more than one independent variable, we examined the Adjusted R Square to analyze how well the model explained overall variation in the energy consumption dependent variable. Overall, some models did a better job at explaining variation in the dependent variable than others. The meaning of the Adjusted R Square for each model is discussed separately below.

Third, for each model, we examined the model residuals against each independent variable to search for any signs that the model violated regression model assumptions. Namely, we sought to verify that errors in each model were roughly normally distributed with a mean of zero, that errors had a constant standard deviation for all levels of the independent variables, and that the errors in the model were not correlated. Therefore, we examined residual plots to ensure that the spread of the residuals was roughly the same for all values of the independent variables and to verify that there were not obvious signs of heteroskedasticity (where the variability of the dependent variable is unequal across values of the independent variable) or autocorrelation (where variability in the dependent variable follows a non-random pattern). For each model described below, we did not find any obvious violations of regression assumptions.

Finally, we examined the t-statistic for each independent variable included in the models to determine whether each variable had a significant effect on the dependent energy consumption variable. We used an alpha level of 0.1 to determine statistical significance. We also build a 90% confidence interval around each coefficient to estimate the possible effect size of each independent variable on the dependent variable.

Habitat-Only Energy Consumption Models

We developed separate multiple linear regression models to explain natural gas and electricity consumption in Habitat homes. For each model, we isolated energy usage by season in order to determine key drivers of consumption during the highest usage periods: winter for natural gas and summer for electricity. It also allowed us to compare consumption across the rough age of construction among Habitat homes only to see if energy consumption in older Habitat homes was different than that of new Habitat homes.

Natural Gas

For the natural gas model, we used as the dependent variable natural gas consumption in hundred cubic feet (CCF) for the months of December 2013, January 2014, and February 2014. Unlike the RECS comparison models, we did not perform a natural logarithmic transformation of the dependent variable. We found that the natural gas consumption data were relatively normally distributed, and performing the natural log transformation actually negatively skewed the distribution, which reduced the significance of the model. The results of the natural gas model are displayed in Appendix E, Table 6.

In this model, the adjusted R square (0.3709) indicates a decent fit, where approximately 37% of the variation in wintertime natural gas consumption is explained by the independent variables in the model. However, this level of explanation is still somewhat low, largely because there are many factors that affect natural gas consumption, like the HERS score and insulation R-values, that were not captured in our survey.

To interpret the effect size of each independent variable, we first clarify that each independent variable coefficient represents the change in wintertime natural gas consumption (in CCF) attributable to a one unit increase in the independent variable, all else constant. We also build a 90% confidence interval around each independent variable coefficient. Therefore, the effect size for each independent variable is as follows:

TABLE 1: HFH SURVEY NATURAL GAS CONSUMPTION MODEL EFFECT SIZES

Variable	Lower 90% Conf. Limit	Upper 90% Conf. Limit
Square Footage	0.08376 CCF	0.25658 CCF
Years in Home	7.29288 CCF	16.19388 CCF
Winter Night Temp	0.65614 CCF	8.02596 CCF
Electric Space Heater	22.86613 CCF	129.17620 CCF

As expected, the Square Footage coefficient is positive, indicating that as the square footage of the home increases, natural gas consumption also marginally increases. However, heating degree days did not exhibit statistical significance in the model. This could be the result of the relatively small range of heating degree days among the

Habitat homes included in our sample, or because our Habitat-only sample was relatively small. We also did not find evidence that the number of household members or having a basement or crawlspace had a significant effect on natural gas consumption. This does not mean that we can conclude that the number of household members or the inclusion of a basement or crawlspace does not have an effect on natural gas consumption; it simply means that these variables were not found to be significant when compared with other variables using a relatively small sample. However, it would make sense that the number of household members would not have much of an effect on natural gas consumption, since most gas usage is for space heating, which depends much more on the size of the home than on the number of household members.

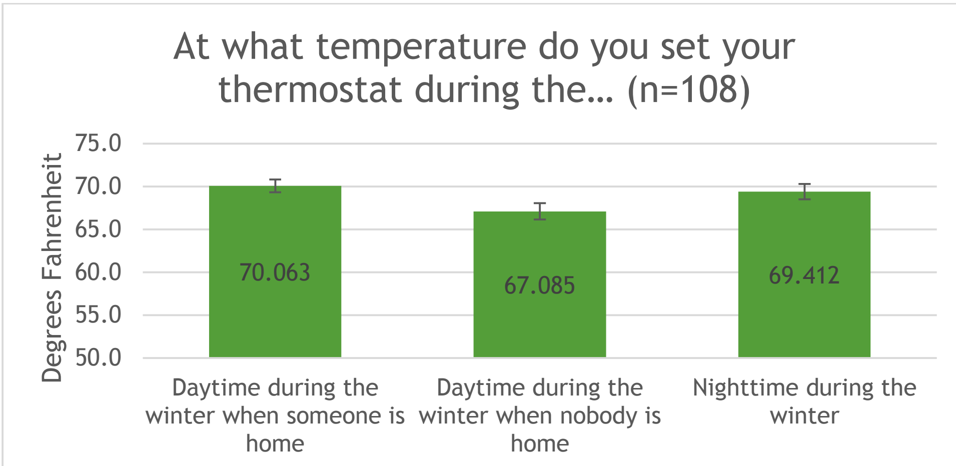
One interesting finding was that natural gas consumption tended to increase as the number of years that the family had lived in the home increased. This indicates that homes that were more recently completed by Habitat affiliates tended to consume less natural gas, all else constant, than older Habitat homes. Unfortunately, it is not possible to determine whether this effect is attributable to Habitat affiliates' improvements over time in making homes more energy efficient or simple deterioration in the energy efficiency of homes over time. However, we can confidently say that there is not evidence that Habitat affiliates' experimentation with energy efficiency interventions over time is hurting energy efficiency.

Actionable Findings

Our first actionable finding was that the winter nighttime thermostat setting had a significant effect on natural gas consumption, more so than the daytime thermostat setting. However, while we can confidently say that natural gas usage increases significantly as the winter nighttime temperature setting increases, the effect size is not terribly clear given the wide range in the confidence interval around the coefficient. This effect size becomes clearer when leveraging observations from RECS alongside the Habitat observations.

Thermostat settings are an especially critical recommendation given Habitat partner families' knowledge of the thermostats in their home. About 29% of survey respondents either reported that their home did not have a programmable thermostat or that they did not know whether their thermostat was programmable. Based on our affiliate interviews in which nearly every affiliate self-reported that they installed programmable thermostats in the homes that they build, we assume that many of the respondents who stated that they did not have a programmable thermostat actually do have a programmable thermostat, but perhaps do not know how to use the programmable settings. Either way, these households are likely not taking full advantage of the option to set their thermostats at lower temperatures when they are away or sleeping. Average thermostat settings among HFH partner families are represented graphically in Figure 10 below.

FIGURE 10: WINTER THERMOSTAT SETTINGS



Perhaps the most unexpected finding in the model was the effect of using an electric space heater. We hypothesized that a potentially efficient use of an electric space heater would be to keep the overall home at a slightly cooler temperature than desired while using a space heater to only heat occupied rooms, thus offsetting natural gas consumption with usage of a space heater. In this case, we would expect the coefficient for the electric space heater variable to be negative. However, in the Habitat-only model, we found that homes that used an electric space heater were actually likely to use *more* natural gas, all else constant, than homes that did not. This indicates that these homes are not using electric space heaters efficiently to offset natural gas usage, and provides a point of intervention for Habitat affiliates. We found that about 22% of the Habitat homes in the sample reported that they used electric space heaters and that there was no evidence of a strong relationship between how long a family had lived in their home and the likelihood of using an electric space heater.

Electricity

For the electricity consumption model for Habitat-only homes, we used electricity consumption (in kilowatt hours, or kWh) during the months of June 2013 through August 2013. We did not perform a natural logarithmic transformation of the dependent variable because the electricity consumption data were roughly normally distributed. Therefore, we interpret each independent variable coefficient as the change in actual electricity consumption (in kWh) attributable to a one unit change in the independent variable, all else constant. The results of this model are shown in Appendix E, Table 7.

The adjusted R square indicates a decent level of fit for the model, where approximately 44% of the variation in the dependent variable is explained by the model parameters. To determine the effect size for each independent variable, we built 90% confidence intervals around each independent variable coefficients. These effect sizes are as follows:

TABLE 2: HFH ELECTRICITY CONSUMPTION MODEL EFFECT SIZES

Variable	Lower 90% Conf. Limit	Upper 90% Conf. Limit
Time in Home	18.91036 kWh	120.212 kWh
TVs	183.7186 kWh	450.3546 kWh
CDD * Central AC	0.97041 kWh	2.41379 kWh
CDD * Window AC	0.945834 kWh	2.50176 kWh
Aquarium	490.3046 kWh	1556.209 kWh

Similar to the natural gas model, we found that as the number of years in the home increased, electricity consumption also increased. Again, because we cannot isolate how much of the increase in electricity consumption as the home ages is attributable to improved energy efficiency interventions, like more efficient lighting and appliances, versus simple deterioration of energy efficiency over time, we can only claim that Habitat affiliates' attempts to improve electricity conservation in homes are not having a negative impact.

Many independent variables that we would expect to have had a significant effect on electricity consumption did not exhibit significance in the Habitat-only model. This includes the number of household members, the square footage of the home, and presence of separate freezers, gaming systems, and dishwashers. This is likely explained by three main factors. First, the sample size of the Habitat-only model is quite small, which provides little power to isolate the effects of more than a few independent variables. Second, the interquartile range for square footage and number of household members is relatively narrow, providing little variation against which we could examine differences in electricity consumption. Third, the Habitat-only model considers summertime electricity usage as opposed to electricity consumption over an entire year. This may amplify the effect of certain variables, like air conditioning, and crowd out others, like separate freezers, since air conditioning is only likely to be used significantly during summer months.

Surprisingly, we found that homes that had an aquarium were likely to consume much more electricity than similar homes that did not. This may indicate a special characteristic among Habitat homeowners, perhaps that those who are likely to own an aquarium may be likely to own more than one, or are more likely to also perform electricity-intensive activities like growing plants indoors. While it may be possible to communicate the electricity costs associated with owning one or more aquariums to Habitat partner families, we view this is a less promising area for intervention because it would require Habitat partner families to significantly change behavior and give up an important hobby rather than implementing a more convenient solution that required a less drastic lifestyle change.

Actionable Findings

Unsurprisingly, we found that the number of TVs used in the home had a strong positive effect on electricity consumption, although the effect size is somewhat unclear given the wide range of the confidence interval around the coefficient. While it would be difficult to convince Habitat households to stop using TVs altogether, it may be possible to help households turn off their TVs more often when not in use. The average number of TVs in Habitat homes was between 2.6 and 3.1.

To examine the effect of climate, we assumed that climate should only have a significant effect on electricity consumption if air conditioning were installed in the home, since fans use relatively little electricity. Therefore, we created an interaction variable to only account for cooling degree days when either central or window air conditioning was present in the home. Interestingly, the presence of both central and window air conditioning were found to have a significant effect on electricity consumption. To interpret these effect sizes, we use the example of a home in Lansing, Michigan. A home near the Capital City Airport weather station experienced roughly 569 cooling degree days from June through August 2013. Therefore, we would expect a home with central air conditioning to have consumed between 552 and 1,373 kWh more than a similar home that did not have air conditioning. A home with window air conditioning would have consumed between 538 and 1,424 kWh more than a home without air conditioning.

Because of the wide range of the confidence intervals around the coefficients for central and window air conditioning, we could not determine whether there was a difference in summertime electricity consumption between homes with central air conditioning or homes with window air conditioning. However, this may indicate that instead of installing expensive central air conditioning, it may be more cost-effective to consider installing targeted window air conditioning units, particularly newer models that are more energy efficient than older or less efficient models that Habitat households may install on their own. We found that about 41% of the Habitat homes in the sample had central air conditioning, while 26% of homes had window air conditioning. For the homes that did not have central air conditioning, we found a positive correlation (0.32) between the number of people in the home and the presence of window air conditioning – that is, as the number of people in the home increased, the likelihood of having window air conditioning tended to increase. A two-sample t test indicated that we are 90% confident that the mean number of people was between 0.4 and 2.0 higher in homes with window air conditioning than in homes with no air conditioning.

Habitat and Non-Habitat Comparison Models

In addition to analyzing energy consumption in Habitat homes, we also compared consumption among Habitat homes to that of similar non-Habitat homes. As discussed in the Methodology section above, we used microdata from the US EIA 2009 Residential Energy Consumption Survey (RECS) to perform this comparison.

When the RECS data was combined with the Habitat data, we found that the data for both natural gas and electricity consumption were positively skewed, so we used a natural logarithmic transformation of each dependent variable to achieve a more normal distribution. The natural logarithmic transformation of the dependent variable also assisted with interpretability by making a one unit increase in the independent variable equal to a (100 * independent variable coefficient) percentage change in the dependent variable, as opposed to a one unit increase in the independent variable representing an absolute change in the dependent variable.

Natural Gas

The combined natural gas model compares a year's worth of natural gas usage (in CCF) in Habitat homes (from year 2013) with that of similar RECS homes (from year 2009). While it is not ideal to compare energy consumption from different time periods, we feel confident in the model results given that we were able to control for climatic differences between these two years by using heating degree days. The results are given in Appendix E, Table 8.

In this case, an Adjusted R Square value of 0.1412 does not indicate a high level of explanation for the overall model. This makes sense conceptually because there are many other factors that affect natural gas consumption that were not captured in our data collection process. For instance, the type, amount, or quality of insulation, air sealing, windows, doors, and insolation would all likely have a significant effect on the amount of heating required in a home, but these variables were not captured through our data collection or in RECS. We would also expect a lower adjusted R square than in the Habitat-only model because the range of natural gas usage in the combined dataset is much larger (2,081 CCF) than the range among Habitat homes (1,103 CCF).

To determine the effect size associated with each independent variable, we built a 90% confidence intervals around each coefficient:

TABLE 3: RECS NATURAL GAS COMPARISON MODEL EFFECT SIZES

Variable	Lower 90% Conf. Limit	Upper 90% Conf. Limit
HDD	4.5076E-06	8.87E-05
Square Feet	4.1478E-05	2.67E-04
Winter Night Temp	0.0154	0.0307
Electric Space Heater	-0.1717	-0.0144
Habitat	-0.3555	-0.1617

To interpret these effect sizes, we multiply the coefficient by 100 to determine the percentage change in the dependent variable attributable to a one unit increase in each independent variable. These results are as follows:

TABLE 4: RECS NATURAL GAS COMPARISON MODEL EFFECT SIZES IN PERCENTAGE TERMS

Variable	Lower 90% Conf. Limit	Upper 90% Conf. Limit
HDD	0.00045%	0.00887%
Square Feet	0.00415%	0.0267%
Winter Night Temp	1.54%	3.07%
Electric Space Heater	-17.17%	-1.44%
Habitat	-35.55%	-16.17%

As expected, natural gas consumption increases marginally for each incremental increase in the square footage of the home and the number of heating degree days in the year. We would expect heating degree days to be significant in this model, but not necessarily the Habitat-only model, because the range of heating degree days in the combined data set (4,970 heating degree days) was much larger than the range among only Habitat homes (2,921 heating degree days).

Unlike the Habitat-only model, this model shows that, as expected, the use of an electric space heater tended to have a negative effect on natural gas usage. That is, when a household used an electric space heater, they were likely to use less natural gas overall, indicating that these households offset natural gas usage by using space heaters. This difference is likely due to the presence of more observations from RECS data in the combined dataset than Habitat data.

Furthermore, as we found in the Habitat-only model, the presence of a basement or crawlspace in the home was not a significant independent variable in the model. It is certainly possible that our sample size was not large enough to glean the actual effect of having a basement or crawlspace, but based on our model results, we cannot validate a recommendation to avoid including basements or crawlspaces in homes in order to reduce natural gas consumption. We also found that the number of household members was not a significant variable in the model, at least when explaining natural gas usage.

ACTIONABLE FINDINGS:

Most importantly, we sought to identify the effect that being a Habitat home has on natural gas consumption, controlling for climate and the size of the home. This model shows that, holding all other variables constant, we are 90% confident that Habitat homes, on average, consume between 16.17% and 35.55% less natural gas than similar non-Habitat homes. This provides evidence that Habitat homes are significantly more energy efficient in terms of natural gas consumption compared to non-Habitat homes, and that the various energy efficiency interventions employed by affiliates around the state are having a significant effect. However, it is important to keep in mind that Habitat homes are significantly newer than non-Habitat homes. The median year built for the RECS homes in the sample was 1955, while most of the Habitat homes in the sample were built within the past 15 years. Including the year that the home was built as an independent variable in the model in place of the Habitat dummy variable yields similar results. It is thus possible that Habitat homes have simply experienced less deterioration over time than the non-Habitat homes in the sample, and were not actually constructed to be more energy efficient. While it would have been helpful to compare natural gas usage in Habitat homes to that of other similar, newer homes, these data were not available. However, given the results of our affiliate interviews, we are reasonably confident that at least some of the energy efficiency improvements in Habitat homes are directly leading to decreased natural gas consumption.

We also find that the winter nighttime thermostat setting has a strong effect on natural gas consumption. Daytime winter thermostat settings were initially included in the model, but did not have a significant effect. For each degree Fahrenheit increase in the winter nighttime thermostat setting, we are 90% confident in a 1.54-3.07% increase in natural gas consumption, all else constant. Additionally, we found through a two-sample Welch's comparison of means test that Habitat households, on average, set their thermostats to higher temperatures at night during the winter than similar non-Habitat homes. The mean winter nighttime thermostat setting for Habitat homes was 69.4 degree Fahrenheit, while the mean for non-Habitat homes was 67.0 degrees Fahrenheit. We are 90% confident that Habitat homes' winter nighttime thermostat settings are between 1.4 degrees Fahrenheit and 3.4 degrees Fahrenheit higher than non-Habitat homes.

Electricity

For the electricity model, we used as the dependent variable the natural logarithm of a year's worth of electricity consumption (in kWh) for Habitat homes (from year 2013) and similar RECS homes (from year 2009). The results of this model can be found in Appendix E, Table 9.

The adjusted R square indicates a decent level of fit where 47.61% of the variation in the dependent variable is explained by the model. This adjusted R square is much higher than that of the natural gas model. This is most likely the result of our data including far more variables that would be likely to have an effect on electricity consumption than natural gas consumption.

We also found that this model was far more robust than the electricity model we built using only Habitat observations, in that a larger sample size allowed us to isolate the effects of a larger number of independent variables. To determine the effect size of each independent variable, we multiply the 90% confidence interval around each coefficient by 100 to determine the percentage change in the dependent variable attributable to a one unit change in each independent variable. These effect sizes are as follows:

TABLE 5: RECS ELECTRICITY COMPARISON MODEL EFFECT SIZES IN PERCENTAGE TERMS

Variable	Lower 90% Conf. Limit	Upper 90% Conf. Limit
Square Feet	0.0115%	0.0361%
Household Members	8.04%	8.63%
TVs	8.05%	14.45%
Separate Freezers	11.73%	26.67%
Printers	8.00%	24.06%
Gaming System	4.25%	21.47%
Dishwasher	2.75%	18.01%
Electric Space Heater	3.14%	20.73%
CDD * Central AC	0.0039%	0.0239%
Habitat	-26.54%	-5.35%

In this model, unlike the Habitat-only model, an increase in the number of household members did increase electricity usage, all else constant. Conceptually, this makes sense, since the presence of more people is most likely associated with increased appliance, electronics, and lighting usage. Electricity usage also increases marginally with an increase in the square footage of the home. This is most likely due to increased lighting needs as the size of the home increases.

ACTIONABLE FINDINGS

Even after controlling for household characteristics and the presence of certain high-consumption appliances, we found that Habitat homes, on average, used significantly less electricity than non-Habitat homes, all other variables held constant. We are 90% confident that being a Habitat home reduces electricity consumption by between 5.35% and 26.54%. Based on our affiliate interviews, we found that Habitat affiliates tend to have less control over the characteristics of the home that would affect electricity consumption than those that would affect gas consumption. This is indicated by the Habitat dummy variable having a smaller effect size for electricity consumption than natural gas consumption. However, the electricity model provides evidence that the few areas where Habitat can influence electricity consumption are leading to energy savings. This includes installing energy efficient lighting, including a new refrigerator in the home, and for some affiliates, including other energy efficient appliances like washers, dryers, and dishwashers.

Interestingly, while we found no statistically significant effect of having window air conditioning on electricity consumption, we did find a significant effect for central air conditioning. The reason for this discrepancy between the Habitat model and the comparison model is unclear. It is possible that examining only summertime electricity usage in the Habitat model increases the importance of window air conditioning relative to other variables more so than examining electricity usage over the entire year. It is also possible that Habitat homeowners tend to have older, less energy efficient window air conditioners than their non-Habitat counterparts.

To give an example of an interpretation of the CDD * Central AC interaction variable, consider a home near the Capital Region Airport in Lansing, Michigan. The weather station at Capital City Airport recorded 811 cooling degree days total during the year 2013. Multiplying 811 cooling degree days by the confidence interval around the coefficient, we would be 90% confident that a home near Capital City Airport that has central air conditioning would consume between 3.16% and 19.38% more electricity during the year than the same home without central air conditioning.

When comparing air conditioning in Habitat homes with that in similar RECS homes, we find that Habitat homes are much less likely than non-Habitat homes to have central air conditioning. About 41% of Habitat homes in the sample had central air conditioning, while 61% of the non-Habitat homes had central air conditioning. We are 90% confident that between 10.30% and 30.00% fewer Habitat homes have central air conditioning than non-Habitat homes. Interestingly, we found that the proportion of Habitat homes with window air conditioning was very similar to the proportion of non-

Habitat homes with window air conditioning. About 26% of homes in each sample had window air conditioning.

We also found statistically significant effects on electricity consumption for several common household appliances and electronics. Those with the most verifiable effect sizes are the number of separate freezers and the number of TVs used in the home. Those with significant, but less precise effect sizes are whether or not a printer, gaming system, dishwasher, or electric space heater are used in the home.

When comparing Habitat homes with similar RECS homes, we find that a similar proportion of Habitat homes have one or more separate freezers as similar RECS homes. The mean number of separate freezers among Habitat homes is 0.43, while the mean among non-Habitat homes is 0.34. Using an alpha level of 0.1, this difference in means is not statistically significant. Not surprisingly, the likelihood of owning at least one extra freezer is positively correlated with the number of people in the home (0.42) – that is, as the number of people increases, the likelihood of owning a separate freezer increases.

The presence of at least one gaming system could be significant for several reasons. First, gaming systems are likely to be left on even when not in use, consuming significant “vampire” power. Second, when gaming systems are used, they are used in combination with one or more televisions in the home, amplifying electricity consumption. Third, the presence of a gaming system in the home is strongly correlated with the presence of at least one child in the home. Among Habitat homes, about 68% of respondents with children reported owning a gaming system, while only 26% of those without children owned a gaming system. Based on qualitative survey responses, many Habitat homeowners report having difficulty saving energy because their children are not as careful in turning off lights and appliances. Whatever the reason, Habitat homes were more likely to have at least one gaming system than non-Habitat households, which makes sense given that Habitat homes are more likely to house children than similar non-Habitat homes. About 54.95% of Habitat homes in the sample had at least one gaming system, while about 34.69% of non-Habitat homes had at least one gaming system. We are 90% confident that Habitat homes are between 10.4% and 30.2% more likely than non-Habitat homes to use at least one gaming system.

Similarly, the number of printers used in the home could be significant for several reasons. First, printers are likely to be left on all the time in standby mode, even when not in use, which can consume significant vampire power. Second, a household owning and using a printer in the first place may indicate a higher likelihood of working from a home office than a household without a printer. In this case, someone may be home and consuming electricity in other ways more often than a household where nobody works from home. We found that Habitat homes are slightly less likely than non-Habitat homes to use at least one printer. About 53.1% of Habitat homes in the sample had at least one printer, while about 63.3% of non-Habitat homes had at least one printer. We are 90% confident that Habitat homes are between 0.3% and 20.1% less likely than non-Habitat homes to use at least one printer.

As for electric space heaters, a similar percentage of Habitat homes reported using electric space heaters as non-habitat homes. About 22.1% of Habitat homes reported using at least one electric space heater, while 24.5% of non-Habitat homes reported doing so. The difference in these proportions was not statistically significant.

Discussion and Recommendations

Key Recommendations

Partner Family Survey

One of the key interests expressed by affiliates at the HOMES Green Building Summit in January 2015 was the opportunity to access the survey online for distribution to other current and future Habitat families. To this end, the SNRE partner family survey will be prepared for online distribution to Habitat families and the complete survey questionnaire will be available for Habitat affiliates to print and distribute as needed.

Internet Access and Connectivity

One surprising discovery from the partner family survey was the number of Habitat families that report using the internet and social media at home. We recommend that HFH affiliates leverage social media and email as a way to keep in touch with partner families and create an online HFH community through which to share information about activities, events, and home maintenance. A HFHM YouTube channel would be one way that Habitat affiliates around the state could work together to create and share basic home maintenance tutorial videos that could be passed on to partner families. Videos such as, "How to change your air filters" or "How to install weather stripping" could help families prepare for winter, complete basic maintenance, and otherwise stay comfortable in their home. We believe that visual tutorials would be more successful in helping families care for their home than a book-style manual that might be misplaced or difficult to interpret.

Additionally, one method HFHM and affiliates could use to improve overall energy efficiency of future projects would be to help new families set up an online bill-pay account with their electric and gas utilities upon moving into the home. Instead of trying to collect energy consumption information directly from utilities, which can be a time- and resource-consuming process, families could opt to sign a waiver to share their online utility accounts with their affiliate, giving the affiliate access to monitor and compare historical energy consumption between homes. Keeping a waiver of this type on file withaAffiliates would also serve to simplify future energy efficiency studies.

Thermostat Settings at Move-in

We have identified two ways that Habitat Affiliates can help families improve energy consumption by taking small actions when the family moves into the home. Based on the energy consumption analysis, one primary indicator of natural gas consumption was the family's nighttime winter heat setting. While most homes are equipped with a programmable thermostat, we suspect that many families are unsure of how to program the thermostat, or when they initially program it, the nighttime temperature setting is unnecessarily high. We found evidence that Habitat families set their nighttime temperature settings significantly higher, on average, than non-Habitat families.

Reducing thermostat settings through behavioral modifications will no doubt be difficult for partner families to adopt across the board. Instead, we recommend that, during the initial home walkthrough when families move into their homes, the HFHM affiliate representative use a double strategy of "social proof" (Allcott, 2011; Cialdini, 2001) and anchoring (Hammond, *et al*, 2006) for thermostat settings. Social proof has been leveraged by companies like OPOWER to show utility ratepayers how much electricity they use compared with other similar homes in their neighborhood, and has led to measurable reductions in electricity usage. Similarly, anchoring has also proven to be a common psychological heuristic, where initial impressions or estimates, however trivial, tend to anchor subsequent judgments. For instance, in countries that have an "opt-out" organ donation policy, where citizens must specifically request to be removed from the organ donation program, participation rates are orders of magnitude higher than in countries where organ donation participation is "opt-in" (Johnson and Goldstein, 2003).

Specifically, after the representative provides instructions for the thermostat, he or she should tell the partner family at what temperature the "average family" sets their thermostat, and then set the thermostat for them at that moment. This will provide social proof that other similar households set their thermostat at a lower temperature, while also creating a default setting against which partner families will anchor their judgments on reasonable temperature settings. Finally, in future communications to partner families, affiliates can continue messaging to partner families what the "average" temperature settings are in similar homes.

We also recommend that when teaching families about energy savings, Habitat Affiliates frame energy savings in terms of loss rather than gain (money lost due to energy efficiency compared to money saved with energy efficiency). Based on our research, environmental messaging is less effective in driving behavior change than money or societal pressures, and when considering money, framing equal financial risk in terms of losses rather than gains has a greater effect on human behavior (Kahneman and Tversky, 1984). When considering thermostat settings, it is therefore more effective to frame an increase in thermostat settings as a loss or cost rather than framing a reduction in thermostat settings as a gain or savings

Individual Actions

There are a number of actions that individual families could take that would likely help lower energy consumption within the home. Some of these might require some education on the part of Habitat Affiliates. One primary suggestion is to help families find ways to reduce hot water usage through behavior modifications (suggesting shorter showers, washing clothes in cold water, etc.).

When implementing energy efficiency, it is important to be cognizant of the Jevons Paradox, also known as the Rebound Effect. This term refers to total energy usage increasing after energy efficiency techniques are implemented, as individuals perceive the extra efficiency as allowing for more consumption (Alcott, 2007). It is for this reason that technological innovations alone are insufficient to decrease energy consumption, and behavioral interventions are required as a necessary cornerstone.

Whole Family Inclusion on Energy Saving Education

Reducing energy usage can only be achieved if Habitat affiliates involve the partner families themselves in the conversation around energy savings. Along with talking about the purpose and methods of energy reduction, we suggest that affiliates provide training on home maintenance and energy saving for their partner families. Outreach was an area many affiliates admitted they could improve, and this is one area especially we see as a potential for tangible gains via interaction between the affiliate and partner families. Furthermore, the qualitative responses in our survey suggested that many partner families have difficulty saving energy because their children or teenagers do not turn off lights or electronics. Including the whole family in energy conservation training may help mitigate this problem.

Basements

Though it is currently HFHM's policy to advise affiliates not to install basements, our study results found no statistically significant evidence that basements lead to more energy usage. This does not mean that we can conclusively state that basements have no effect on energy usage. Rather, based on our limited sample, the inclusion of a basement did not have a large enough effect size to be considered statistically significant when compared with other household characteristics. Furthermore, the qualitative responses on our survey revealed that families who currently have basements love them, and families who do not have basements often complain about lacking space for children to play and for storage. Therefore, given the general sentiment among Habitat families that basements are a desired characteristic of their homes, and the lack of evidence that excluding basements yields significant energy savings, we suggest that HFHM reconsider their policy of recommending that affiliates avoid including basements if the primary reason for avoiding basements was to improve energy conservation.

Rehabbed Homes

Interestingly, we also found no significant difference in natural gas or electricity consumption between rehabbed homes and new builds. A difference was not apparent in either a comparison of means test or any of the linear regression models. Therefore, we cannot recommend one strategy over another in terms of energy consumption. Because rehabs may involve using less building material in total than new builds, there is potentially an argument to be made that the carbon intensity of the construction is smaller with rehabs than new builds, suggesting that affiliates should try to rehab homes whenever possible. However, this decision depends on the specific characteristics of the housing market in each affiliates' service area. Those territories that have many recently foreclosed homes that are otherwise in decent condition are most suitable for rehabs, while territories without as much existing quality housing stock may still want to focus on new builds.

Windows and Doors

Doors and windows present key places where heat loss can occur within a home. Furthermore, qualitative evidence from our survey suggests that many Habitat families think their windows and doors are drafty and leaky. Therefore, we suggest that Habitat affiliates ensure the installation of durable, high-quality windows and doors, and that the construction manager of each affiliate closely oversee the installation of windows and doors in order to ensure proper technique and reduce risk of heat escaping.

Air Conditioning

HFHM has a long-term Climate Change Adaptation Strategy known as the Disaster Risk Reduction framework. With that in mind, HFHM should recognize that average temperatures in Michigan are likely to rise in the coming years, leading more partner families to install air conditioning units. Though it is not HFHM's policy to install window unit AC, we found that 44% of partner families who did not have central AC installed window units themselves. In order to avoid partner families buying and installing cheaper and less efficient window AC units, we suggest that either HFHM look into the feasibility of changing their central air conditioning policy, or explore the possibility of lobbying HFHI to extend gift-in-kind partnerships for window units to Michigan and other temperate areas, as such policies are already in place in the southern US. Installing the best available technology will not only reduce energy costs, but also reduce the likelihood that partner families will need to install a new unit on a regular basis in case of equipment failure.

Improved Efficiency over Time

Perhaps unsurprisingly, our quantitative analysis found that newer homes are more energy efficient. This is most likely the result of HFH affiliates' improved building practices, including better insulation, use of CFL and LED lighting, and use of insulated concrete forms. While it is likely that some of this observed difference over time is the result of the deterioration of energy efficiency as homes age, our affiliate interviews revealed that HFH affiliates are using some of the best building practices for both new builds and retrofits, and continually work to learn new strategies and improve their current methodology. Our findings indicate that his experimentation is paying off in terms of average energy consumption.

Space Heaters

The statistical analysis revealed that space heaters possess a positive coefficient for both electric and natural gas usage, indicating that Habitat partner families, on average, are not using space heaters efficiently to selectively heat one room while keeping the rest of the house cooler. Therefore, a greater preponderance of space heaters implies a higher level of total energy usage in partner family homes. Overall, it is more energy efficient to simply raise the temperature of central heating, particularly in the small homes that Habitat affiliates build. Leveraging loss aversion, we recommend that HFH affiliates frame this consequence in terms of losses, rather than savings, when educating partner families about this result. Effectively, HFH affiliates should state using space heaters leads to financial losses and energy waste.

Stand-alone Freezers

In general, separate freezers correlated to much higher energy usage. For families of four or more, it is not recommended that HFH affiliates try to motivate them not to buy this extra freezer, as a larger family likely values the extra space and convenience and the extra energy usage is mild on a per capita basis. Instead, HFHM should focus on telling smaller families that they will lose money by buying a separate freezer.

Smart Power Strips

Smart Power Strips offer an appealing alternative for partner families to reduce energy usage. One of our study's key findings was that houses with gaming systems tended to display significantly higher energy usage. We postulate that part of this result may derive from individuals not turning off gaming systems and other television accessories, or leaving them in standby mode, which still drains power via "vampire loads" (NREL, 2013).

To address this problem, we suggest that HFH affiliates either supply or encourage partner families to purchase Smart Power Strips. These devices are utilized to reduce energy usage by automatically turning off multiple appliances plugged into them when certain criterion is fulfilled. In particular, we recommend HFHM pursue Master-Controlled Power strips, which function by having a "master plug" into which the main appliance, usually the television, is plugged in. When the device plugged into the "master plug" is turned off, all the other appliances connected to the Smart Power Strip, like gaming systems, cable boxes, and stereos, are immediately turned off (NREL, 2013). This way, simply by a family member turning off the television, other devices will be turned off, offering a simple, yet effective, way of saving energy without requiring significant behavior change. Fortunately, these devices are relatively inexpensive, usually costing around $30.

HFHM and HFHI could also work with companies like Schneider Electric and Belkin to secure master-controlled Smart Power Strips as gift-in-kind, and supply them to homeowners when they move into the house. This would help mitigate energy waste, especially in households with children, which were more likely to have gaming systems and, consequently, higher electricity usage.

Partner Families as First-Time Homeowners

During our affiliate interviews, most HFHM affiliates reported that the majority of their partner families are "first time homeowners." HFHM should consider providing training on home maintenance and repairs that a landlord would have performed in rental housing.

For example, some affiliates mentioned that several of their partner families had never used a lawnmower before. This speaks to the necessity of proper instructions for partner families so that they can best maintain their home. As a result, affiliate outreach and education programs are of paramount importance.

Small Affiliate Concerns

During the affiliate interview phase of our project, smaller affiliates often expressed concerns regarding the implementation of recommendations, both from our project and HFHM in general. Barry County, in particular, expressed concerns about the ability to implement recommendations.

However, the strategies recommended in this report are relatively low-cost, and most interventions rely on education rather than advanced and expensive building techniques. This suggests that these strategies can be used by affiliates of all sizes, not just those who have building science experts in-house or benefit from strong budgets and high appraisal values. One of our project goals was to draft a scalable plan, and we believe our suggestions can and will be successfully implemented by HFH affiliates regardless of size.

Affiliate Mentoring

Building off the aforementioned concerns of smaller affiliates, partnerships and mentoring between affiliates is recommended. Under this schema, larger affiliates with more resources can work with smaller affiliates to share strategies, expertise, and perhaps even manpower for both new construction and rehabilitation projects. Knowledge sharing is already a key attribute within HFHM, as evidenced by events such as the annual HOMES Conference. Thus, mentoring provides the next step in the framework and will allow for best practices to be taught and utilized more extensively across HFHM.

Future SNRE Masters Projects

After our excellent experience working with HFHM and Michigan affiliates, our team confidently recommends that SNRE continue the partnership for future masters projects. We have identified a number of areas for further exploration.

Long-term Effect of Habitat Homes Entering a Community

Little research has been conducted on the long-term effect of Habitat homes entering a neighborhood. Anecdotal evidence from some of our affiliate interviews pointed to neighborhoods improving in social and economic outlooks after their arrival, as these newly constructed or renovated houses inspired those already living there to upgrade or take better care of their own homes. GIS analysis could form a key piece of this investigation, as it would all for geospatial analysis and comparisons of neighborhood change over time.

Solar Photovoltaics (PV)

During our affiliate interviews, a number of affiliates expressed interest in implementing solar PV. Regrettably, we did not have enough time to investigate this possibility during our study. However, future investigations could certainly research solar PV and determine whether it makes sense for HFHM.

Solar PV prices have dropped significantly in recent years, and federal tax credits, such as the Investment Tax Credit, can aid in the affordability of these systems. However, while solar systems are low-maintenance, monitoring and regular maintenance is key to ensure their proper functioning. Additionally, the Investment Tax Credit is set to expire at the end of 2016, which may significantly hurt the economics of installing solar PV.

Community-owned solar PV systems is one area of potential interest. In this schema, residents in a community each buy into a locally sited solar farm, and each receive a portion of the power generated. This option may be more appealing than rooftop solar PV installed on individual homes because larger solar installations benefit from economies of scale and reduced installation costs on a per-watt basis. This may be an option worth investigating.

Improved Energy Consumption Data Collection

Though our study did collect a significant amount of energy consumption data, there is certainly room for improvement. Collecting more granular energy usage data, and comparing said data to similar non-Habitat homes, would lead to a more detailed and comprehensive analysis. Using a building energy analysis platform, such as the CleaRESULT platform, may form a useful cornerstone of this analysis.

Financial Case for Partner Families

Determining an ideal financial mix for families presents another area meriting investigation and study. Balancing both energy efficiency investments with mortgage and other bills would form useful result to help HFH affiliates identify the most cost-effective energy efficient building techniques and improve the financial stability of partner families. Additionally, a project team could examine creative financing approaches that affiliates could utilize to increase upfront investment in energy efficiency in the homes they build and renovate.

Conclusion

Although this project is primarily focused on HFHM, the findings could also be valuable for affiliates throughout HFHI. As the largest of the 25 SSOs, HFHM is well positioned to have a powerful bottom-up effect on HFHI. In general, SSOs tend to be much more nimble, moving quickly and exploring new opportunities ranging from novel sources of capital to advanced building technologies. The HOMES Green Building Summit in January 2015 served as an opportunity to discuss preliminary findings of the study and work with HFH affiliates on a broad level; this experience made it clear that HFHM possesses the infrastructure, skill sets, desire, and drive to pursue energy efficiency strategies comprising both technological and behavioral modifications.

Additionally, HFH is the sixth largest homebuilder in the United States. Actions Habitat takes to improve the sustainability and energy efficiency of the homes it builds and renovates will likely reverberate throughout the affordable housing community. Therefore, while our deliverables are aimed specifically at affiliates and the SSO in Michigan, we hope that our research will serve to enlighten other efforts to improve sustainability in affordable housing outside of Habitat.

We also hope that these results can influence for-profit construction outside of HFH. Generally speaking, for-profit builders tend to be less concerned about the efficiency of their projects and more focused on the income they generate and the satisfaction of the future homeowner. Considering this fact, it is not surprising that these individuals are hesitant to implement new energy efficient technologies, particularly if the value of those technologies is not adequately reflected in home appraisals. Not only can these alternatives be more expensive but, since their reliability is often unknown, they are considered an unnecessary risk yielding no benefit to the builder. HFH provides a unique arena where these new technologies can be proven so builders feel more confident using them and homeowners are more likely to specifically request them.

Ultimately, we hope that the results of our research inform practices that are implemented to improve the sustainability and energy efficiency of affordable housing in a cost-effective manner. While we hope to fulfill the needs of our direct client, we hope that Habitat affiliates around Michigan, as well as other organizations that provide affordable housing, can use the strategies we recommend to improve the quality of life of the families they serve as well as limit negative environmental externalities associated with fossil fuel combustion.

Finally, we hope that our research can help identify other potential areas for improvement in terms of sustainability in affordable housing. Energy efficiency is but one piece of the puzzle, and Habitat affiliates could likely benefit from research on strategies to improve indoor air quality and health, ensure the sustainability of Habitat building materials and supplies, and improve the efficiency of Habitat operations, to name a few other key areas of potential improvement.

APPENDIX A: HFH Affiliate Interview Questions

Currently, there is limited knowledge of actual energy performance among Habitat-constructed households and limited direction in further improving energy efficiency and conservation among these homes. Our team sought to answer a number of relevant questions related to the efficacy of sustainable building practices and influencing energy consumption behavior through interviews with the following 21 HFH affiliates:

Organizational:

1. Do Habitat affiliates see sustainability and energy conservation fitting into their mission and values?
    a. If so, how?
2. How does each affiliate approach building or renovating each home to ensure energy efficiency?
3. What level of interaction do affiliates have with their partner families before and after move-in?
4. Do affiliates encourage interaction and community-building among partner families after move-in?
5. Where do affiliates learn about construction, operations, and community-building best practices?
6. How interested are Habitat affiliates in further improving energy efficiency and conservation in the homes they build?
    a. What priority is energy efficiency given compared to other issues?

Habitat Households:

1. How does actual household energy consumption among Habitat homes compare to:
    a. Modeled or expected consumption based on household features?
    b. Average consumption among homes with similar design features, demographic characteristics, and within similar climate zones?
2. Is there a statistically significant decrease in actual household energy consumption attributable to various energy efficiency measures installed in Habitat households?
3. Does actual household energy consumption change over time once energy efficiency measures are installed in the household?
4. How do Habitat partner families view themselves in relation to energy consumption and the environment?

5. How do individual and family consumption behaviors affect the actual energy consumption of Habitat households?
    a. Which behaviors have the highest impact?
    b. Which educational and behavior-change interventions can be combined in a context-appropriate way to achieve maximum energy consumption reductions?
6. What is the observed average cost-effectiveness of existing energy-efficiency measures in Habitat households?
7. What non-construction practices performed by Habitat affiliates, including homeowner trainings and volunteer support, have a statistically significant impact on household energy consumption?
8. Do Habitat partner families feel closely connected to their affiliates, their neighbors, and other Habitat partner families?
9. Can social modeling, including utilizing descriptive and injunctive norms related to energy consumption, be an effective strategy for encouraging energy conservation among Habitat households?

<u>Best Practices and Strategy:</u>

1. Can new energy efficiency and renewable energy technology interventions further reduce consumption in Habitat households in a cost-effective manner?
    a. If so, which technologies are most appropriate?
2. Can strategies aimed at encouraging energy conservation, as opposed to installing energy efficiency equipment, be pursued in a way that respects the independence and autonomy of Habitat partner families?
3. What are the most effective educational and behavioral interventions for reducing residential energy consumption?
4. Can strategies to improve energy efficiency and conservation also improve home comfort and health?
5. Are there available funding sources for energy efficiency improvements that are not currently being utilized by Habitat affiliates?
6. What kinds of administrative resources would be necessary to further improve energy efficiency and conservation among Habitat households?

APPENDIX B:
HFH Partner Family Survey Questions

Q1 Compared to similar homes in your neighborhood, do you think that your home energy bills, including natural gas and electricity, are:

Less (1)
About the same (2)
More (3)
Do not know (4)

Q2 How much do the following factors influence how much energy you use? (1 = not at all, 5 = very much)

______ Cost of our utility bills (1)
______ Environmental Concerns (2)
______ Habits I learned as a child (3)
______ Habits I learned as an adult (4)
______ How much energy others use (5)

Q3 Does anyone in your household take steps to reduce energy usage?

Yes (1)
No (2)

Q4 What are these steps?

Q5 What difficulties or problems did you or your household have reducing energy usage?

Q6 How much do the following factors prevent you from reducing your household energy usage?(1 = not at all, 5 = very much)

______ It is not convenient for us (1)
______ We need to keep our home at a comfortable temp (2)
______ Other things are always more important (3)
______ Not enough time in the day (4)
______ Our energy bills are cheap (5)
______ We don't know how to reduce energy usage (6)
______ Our home is already efficient (7)
______ Don't know which actions save the most energy (8)
______ People in my household do not care about saving energy (9)
______ Trying to save energy doesn't make a difference in my bills (10)

______ Cost too much to install energy-efficient items (e.g. lightbulbs) (11)
______ Our energy use doesn't affect anyone but us (12)

Q7 How much impact do you believe humans have on the environment?
______ 1-low impact, 5-heavy impact (1)

Q8 How much impact do you believe household energy use has on the environment?
______ 1-low impact, 5-heavy impact (1)

Q9 How much impact do you believe you (as an individual) have on the environment?
______ 1-low impact, 5-heavy impact (1)

Q10 For each of the following statements, how strongly do you agree: (1-not at all, 5-very strongly agree):
______ I go out of my way to protect the environment (1)
______ My actions affect the environment (2)
______ Caring for the environment is a moral and ethical duty (3)
______ I feel connected to the environment (4)
______ Other people hurt the environment more than I do (5)
______ When solving a problem, I like to work with others (6)
______ I feel confident in my ability to understand scientific concepts (7)
______ I am open to new ideas and new experiences (8)
______ If energy were less expensive, I would use more energy (9)
______ My house was built to be energy efficient (10)
______ My utility bills are affordable (11)

Q11 How comfortable are you and your family in your home?
______ 1-not comfortable at all, 5-very comfortable (1)

Q12 Is anything about your home uncomfortable?
Yes (1)
No (2)

Q13 What about your home is uncomfortable?

Q14 Has the health of your family gotten worse, stayed the same, or gotten better since you moved in to your home?
Better (1)
About the Same (2)
Worse (3)

Do not know (4)

Q15 What do you like most about your home?

Q16 What do you dislike most about your home?

Q17 For each of the following statements, check how strongly you agree (1-not at all, 5-very strongly agree):

______ Habitat for Humanity prepared me to maintain my home (1)
______ HFH taught me how to use the important features of my home (2)
______ I feel confident in my ability to make small repairs around my home (3)
______ I have a strong relationship with my neighbors and my community (4)
______ I have a strong relationship with other HFH families in my area (5)
______ I stay in contact with people who work or volunteer for HFH (6)

Q18 Did Habitat for Humanity provide any of the the following? (Check all that apply)

Instruction on the features of my home before move in (1)
Instruction on the features of my home after move in (2)
Instruction on repairing and maintaining my home (3)
Instruction on saving energy in my home (4)
Home maintenance and repair manual (5)
Assigned family support partner BEFORE move in (6)
Assigned family support partner AFTER move in (7)

Q19 How often do you use each of the following (never, less than once per week, at least once per week, every day, more than one hour a day):

	Never (1)	Less than Once a Week (2)	About Once A Week (3)	Every day (4)	More than one hour a day (5)
Internet (1)					
Smart Phone Applications "Apps" (2)					
Email (3)					
Skype, FaceTime, etc. (4)					
Social Media like Facebook, Twitter, etc. (5)					

Q20 Is the thermostat in your home programmable?

Yes (1)
No (2)
Do not know (3)

Q21 At what temperature does your household set your thermostat during the...

	Answer in Degrees Fahrenheit (1)
Daytime during the winter when someone is home (1)	
Daytime during the winter when nobody is home (2)	
Nighttime during the winter (3)	

Q22 Does your home have air-conditioning?

Yes (1)
No (2)

Q23 What kind of air-conditioning?

Central (1)
Window Units (2)

Q24 At what temperature does your household set your thermostat during the...

	Answer in Degrees Fahrenheit (1)
Daytime during the summer when someone is home (1)	
Daytime during the summer when nobody is home (2)	
Nighttime during the summer (3)	

Q44 How many window AC units do you use?

Q25 How many of each of the following types of refrigerators do you use in your home? If none, please enter “0”.

	Number of Refridgerators (1)
Half-size/compact/mini (1)	
Full Size (2)	
Stand-alone upright freezer (3)	
Stand-alone chest freezer (4)	

Q26 How many televisions does your household use? If none, please enter “0”.

Q27 How many times per week does your household use each of the following appliances? If you don’t own or never use the appliance listed, please enter “0”.

	Number of Uses per Week (1)
Stove/Oven (1)	
Microwave/toaster (2)	
Clothes Washer (3)	
Clothes Dryer (4)	
Dishwasher (12)	
Coffee Maker (5)	
Power Tools (6)	
Portable Space Heater (7)	
Window Air-Conditioning Unit (8)	
Dehumidifier (9)	
Sun Lamp (10)	
Gaming Systems (11)	

Q29 Does your household use any of the following items?

Cable Box (1)
DVR (2)
Stereo and speakers (3)
Computer (4)
Printer (5)
Internet Modem/router (6)
Electric space heater (7)

Aquarium with lamp (8)
Other major appliance (9)

Q45 How many computers?

Q46 What other major appliance?

Q30 How often do you unplug appliances and chargers after use?
Never (1)
Rarely (2)
Sometimes (3)
Often (4)
Very Often (5)

Q31 How often are the lights left on in unoccupied rooms?
Never (1)
Rarely (2)
Sometimes (3)
Often (4)
Very Often (5)

Q32 Does your household own a clothes washer?
Yes (1)
No (2)

Q33 How often is the hot water setting used?
Never (1)
Rarely (2)
Sometimes (3)
Often (4)
Very Often (5)

Q34 Does your household own a dishwasher?
Yes (1)
No (2)

Q35 How often do you use the “dry” setting?
Never (1)
Rarely (2)
Sometimes (3)

Often (4)
Very Often (5)

Q36 Demographic Info:

	Answer (1)
How many people live in your household (including yourself)? (1)	
How old were you on your last birthday? (2)	
What is the age of the oldest resident living in your household? (3)	
What is the age of the youngest resident living in your household? (4)	
How long have you lived in your current house? (5)	

Q39 What is the gender of your head of household?
Female (1)
Male (2)

Q40 What is the race of your head of household?
American Indian or Alaskan Native (1)
Asian or Pacific Islander (2)
Black (3)
White (4)
Other (5)

Q47 Other (please specify):

Q41 Is your head of household Hispanic or Latino/Latina?
Yes (1)
No (2)

Q42 Does your household speak a language other than English at home?
Yes (1)
No (2)

Q43 What language(s)?

APPENDIX C:
Example Utility Customer Authorization Form

Consumers Energy
Customer Authorization Form

Customer Authorization, Release and Disclaimer Form

Date*				
Service Customer Name*	Service Address*	Service City*	State*	Zip Code*
Primary Phone*	Account Number			

*Fields with an asterisk (*) are required.

The University of Michigan – School of Natural Resources & Environment or its affiliated researchers ("UM-SNRE") will be performing an energy consumption survey of homes owned by Habitat for Humanity partner families ("Survey") in order to assess the home energy performance of Habitat for Humanity affiliates. In order to maximize the effectiveness of the Survey, Consumers Energy will provide to UM-SNRE a limited amount of your historic energy consumption data ("Energy Consumption Data"). As consideration for the Survey, you shall sign this form agreeing to all the terms and conditions listed below:

I certify that I am the owner or occupant (or the owner's or occupant's authorized representative) of the above property, and I am authorized to approve the Survey. By my signature below, I provide Consumers Energy with permission to share my Energy Consumption Data with UM-SNRE for purposes of the Survey.

DISCLAIMER AND LIMIT OF LIABILITY: I UNDERSTAND AND AGREE THAT CONSUMERS ENERGY DOES NOT WARRANT IN ANY WAY THE SERVICES PROVIDED IN CONNECTION WITH THE SURVEY AND THAT ALL SUCH SERVICES SHALL BE ACCEPTED "AS IS" WITH RESPECT TO CONSUMERS ENERGY. IN NO EVENT WILL CONSUMERS ENERGY BE LIABLE, WHETHER IN CONTRACT, TORT (INCLUDING NEGLIGENCE), STRICT LIABILITY, WARRANTY OR OTHERWISE FOR ANY DAMAGES WHATSOEVER, INCLUDING BUT NOT LIMITED TO, DIRECT, SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES, CONNECTED WITH OR RESULTING FROM THE SURVEY.

I further acknowledge and understand that it is necessary for Consumers Energy to share my Energy Consumption Data with UM-SNRE to facilitate the optimization of data collection in the Survey. Therefore, I agree with the following:

_______ (Mark "X") I hereby give Consumers Energy permission to share my Energy Consumption Data with UM-SNRE for purposes of the Survey.

Accordingly, I hereby release, hold harmless and discharge Consumers Energy, its agents, officers, directors, shareholders, employees, contractors, affiliates, successors in interest and assigns from and against any and all claims of whatever nature arising in connection with or associated with the Survey or with the sharing of my Energy Consumption Data.

Signature of Owner/Occupant/Representative: ____

Printed Name: ___________________________________

APPENDIX D:
HFH Partner Family Household Survey Results

FIGURE 11: RACIAL DISTRIBUTION OF SURVEY RESPONDENTS

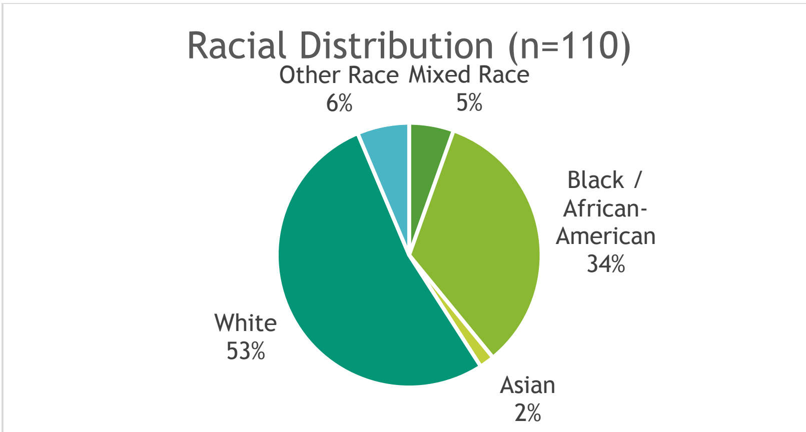


FIGURE 12: NUMBER OF YEARS LIVING IN THE HOME

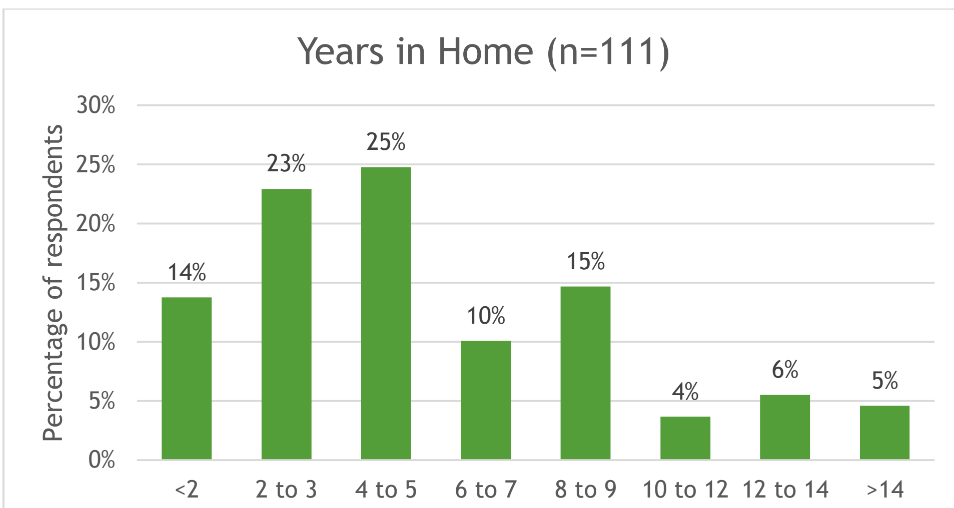


FIGURE 13: AGE OF THE HEAD OF HOUSEHOLD

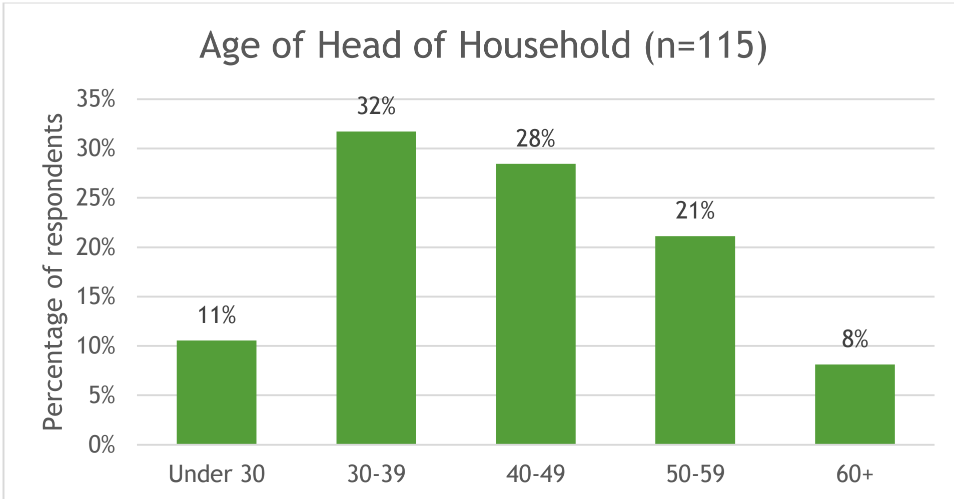


FIGURE 14: NUMBER OF HOUSEHOLD RESIDENTS

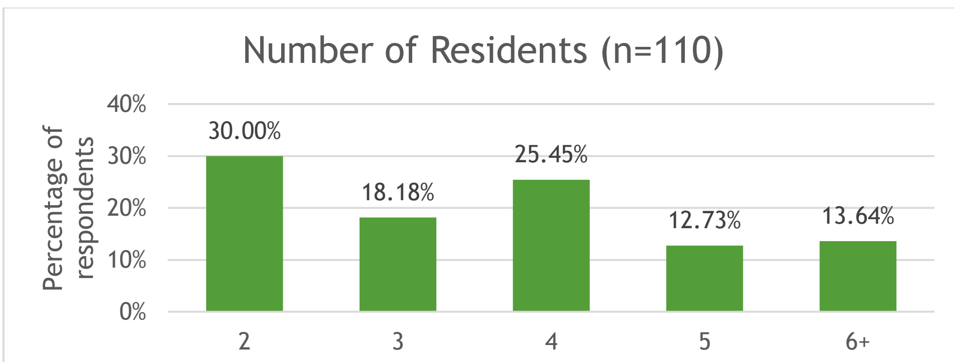


Figure 15: Motivations for saving energy

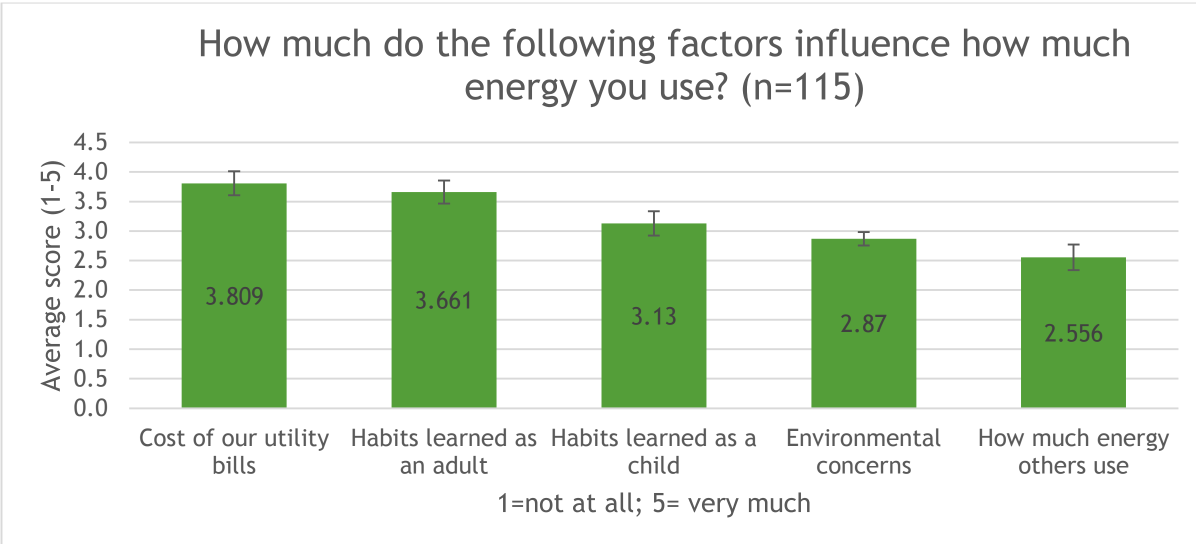


Figure 16: Barriers to saving energy

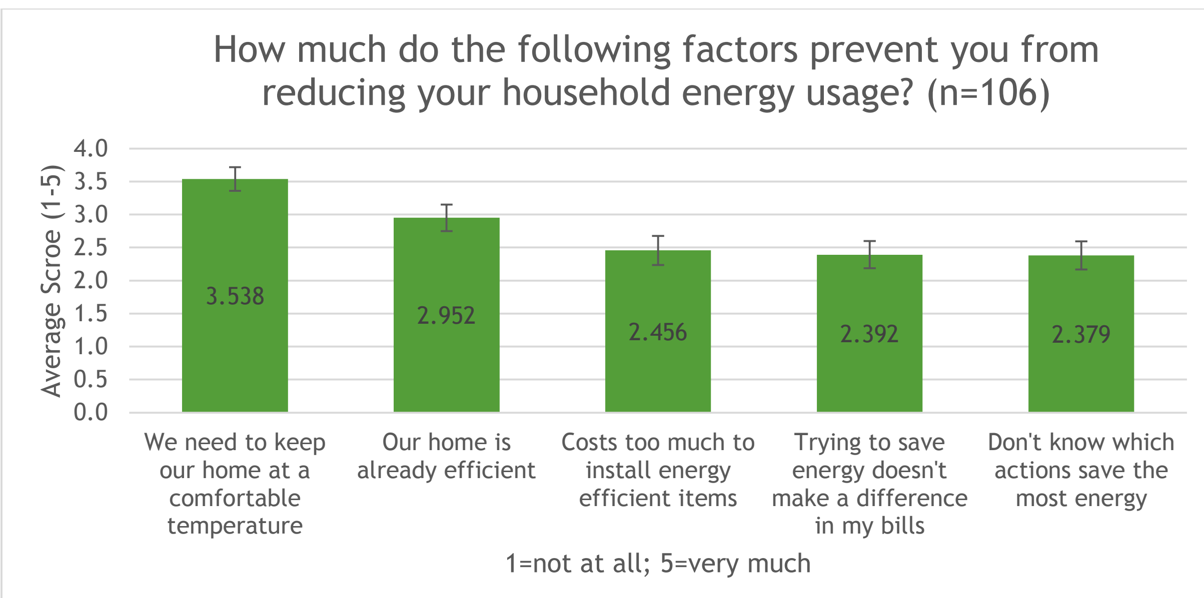


FIGURE 17: PERCEPTIONS OF ENVIRONMENTAL IMPACT

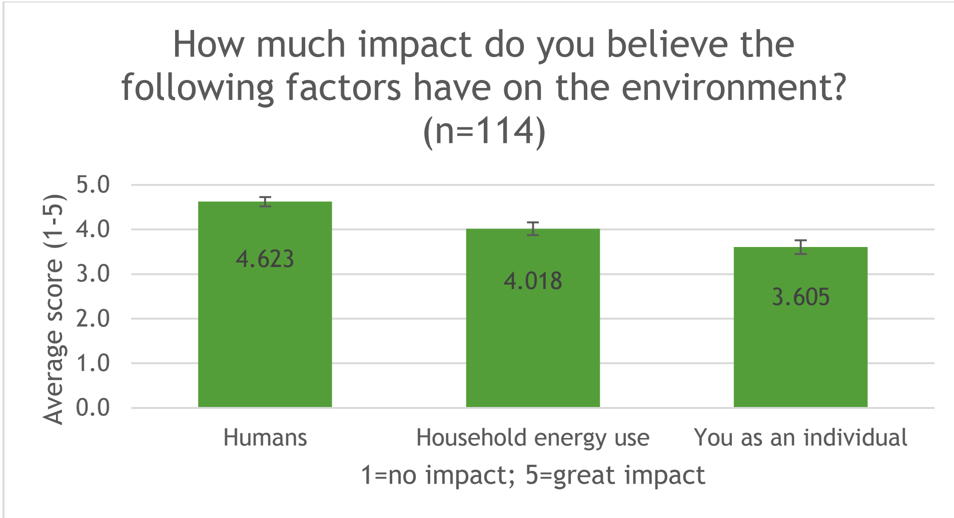


FIGURE 18: ENVIRONMENTAL ATTITUDES

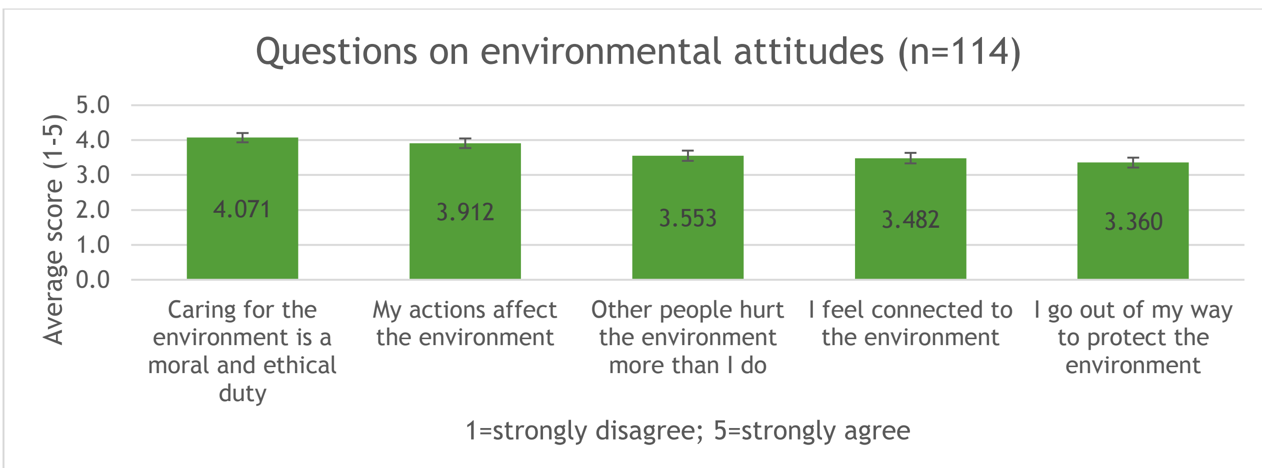


FIGURE 19: HFH EDUCATIONAL INTERVENTIONS

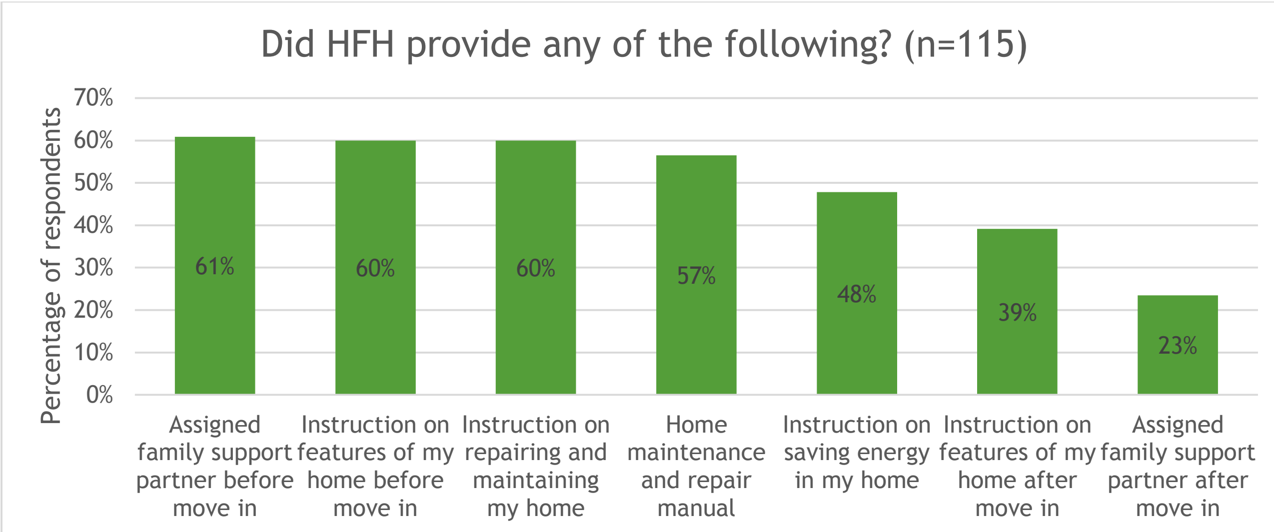


FIGURE 20: PARTNER FAMILY EXPERIENCE

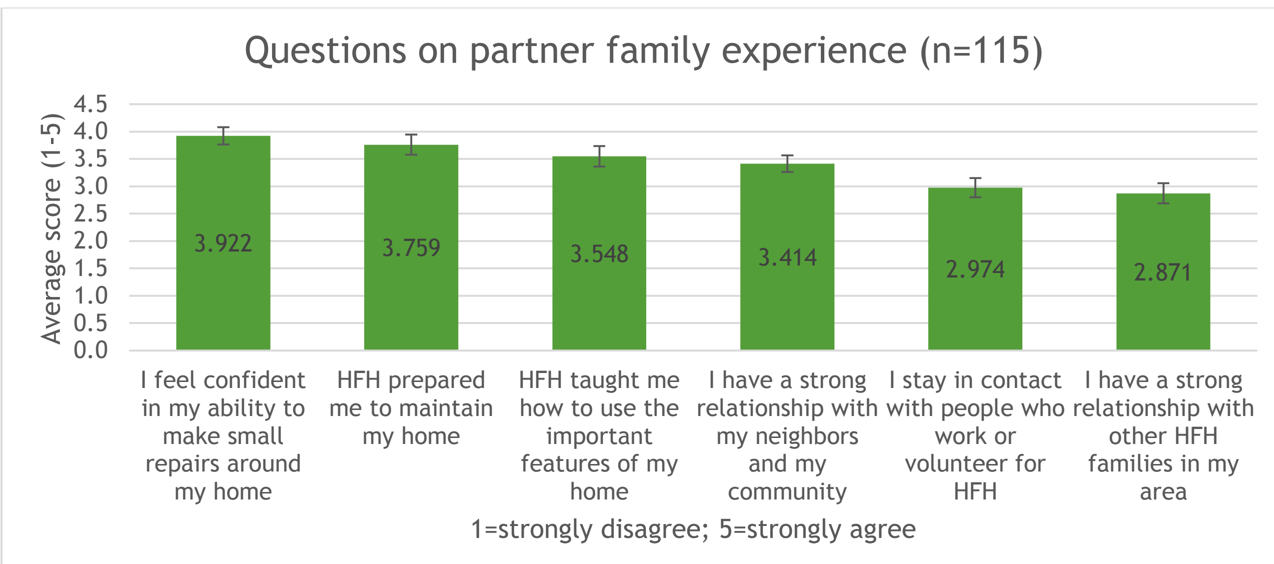


Figure 21: Partner family home comfort

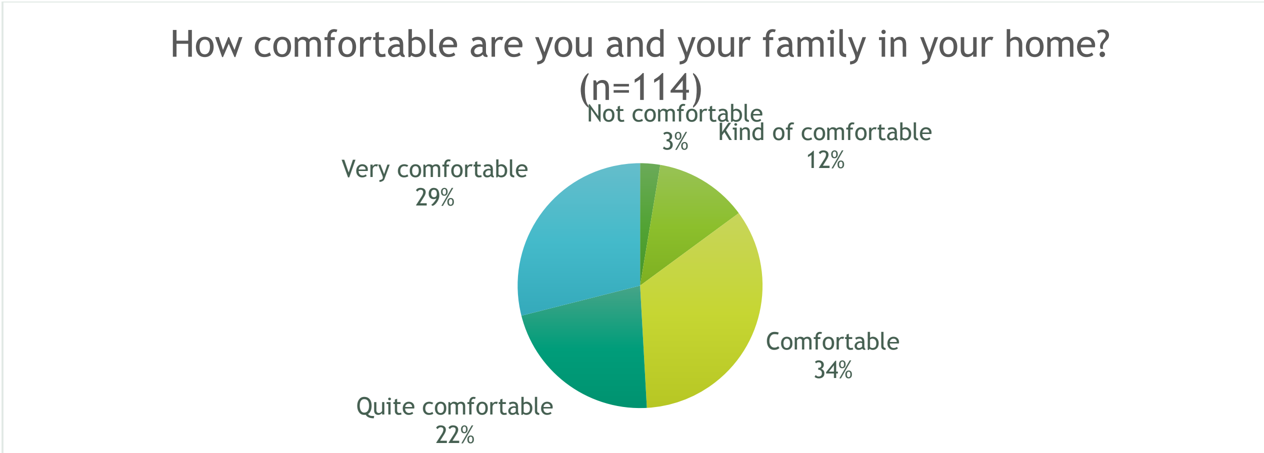


Figure 22: Partner family attitudes on home energy usage

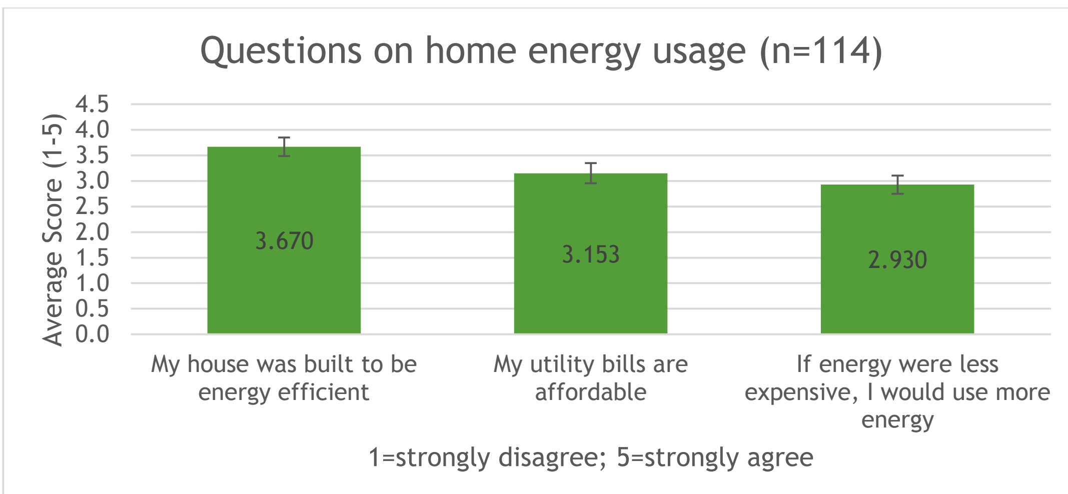


Figure 23: Partner family perception of home energy efficiency

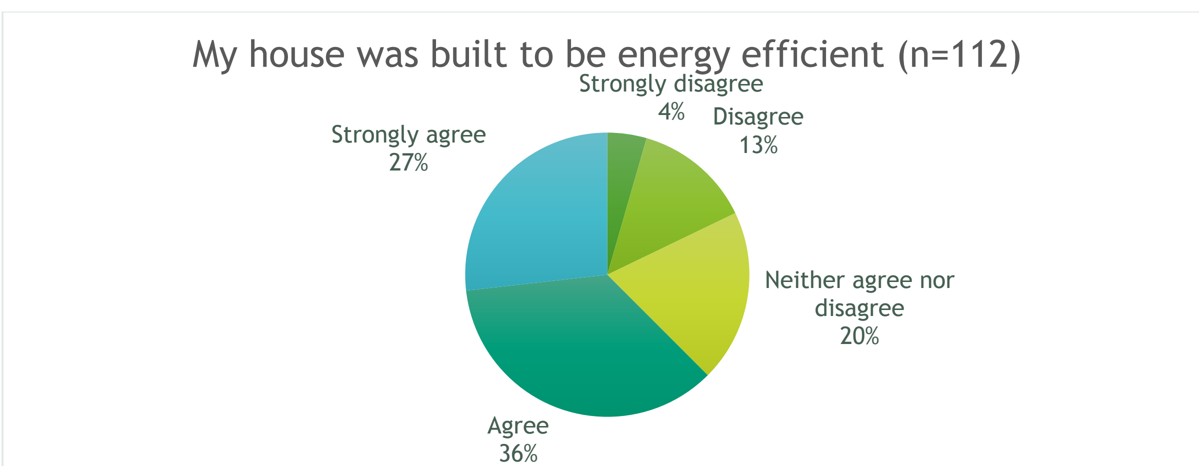


FIGURE 24: PARTNER FAMILY PERCEPTION OF UTILITY BILL AFFORDABILITY

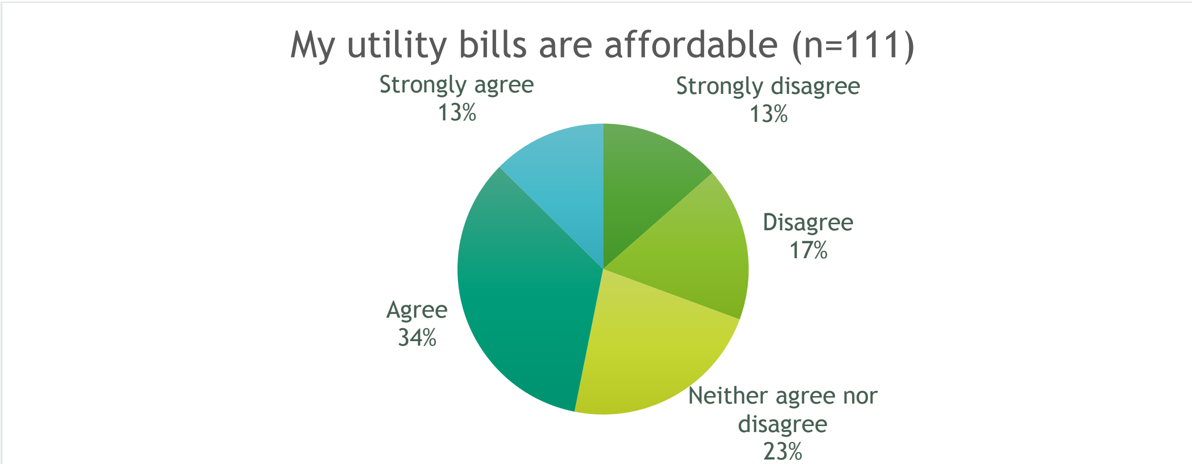


FIGURE 25: INTERNET AND SOCIAL MEDIA USAGE

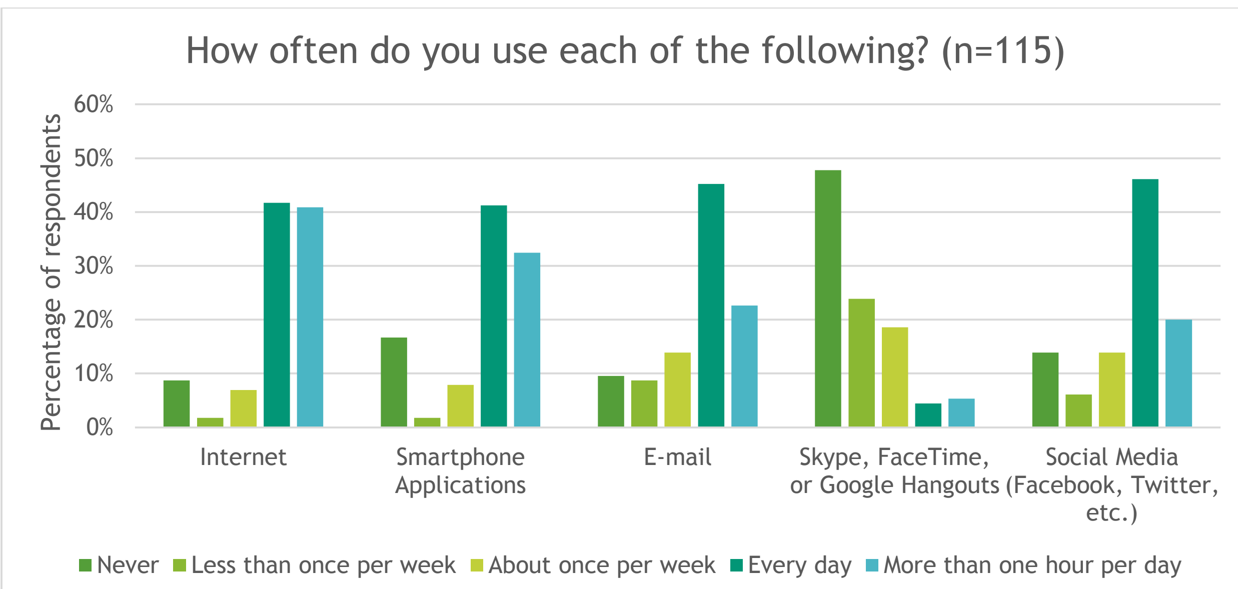


FIGURE 26: WINTER THERMOSTAT SETTINGS

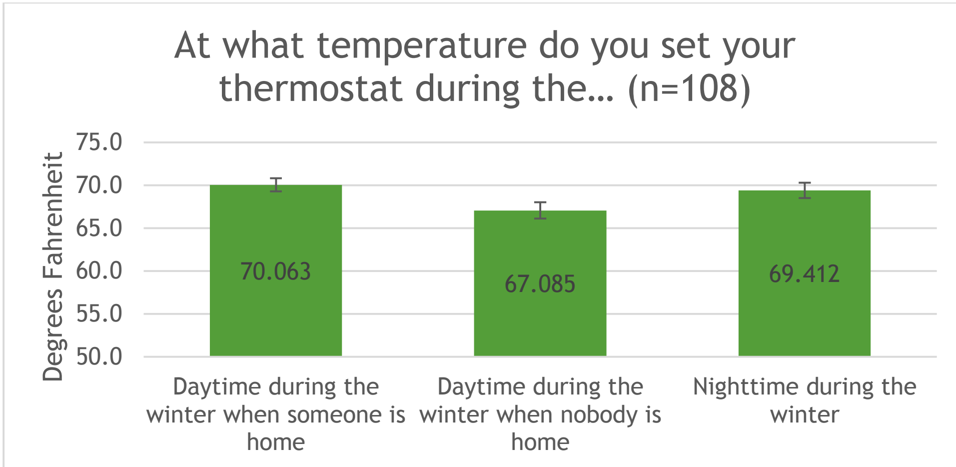


FIGURE 27: PRESENCE OF AIR CONDITIONING

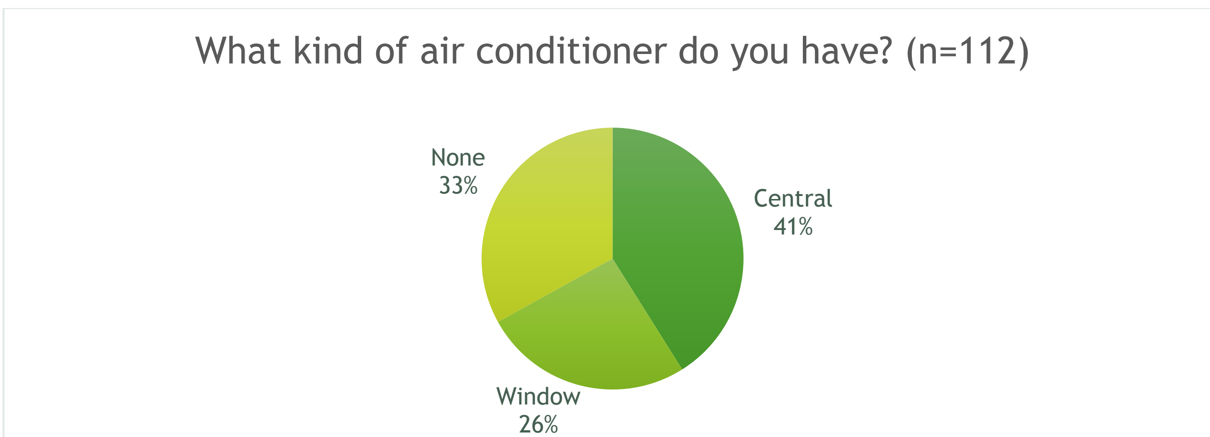


FIGURE 28: REFRIGERATOR AND FREEZER USAGE

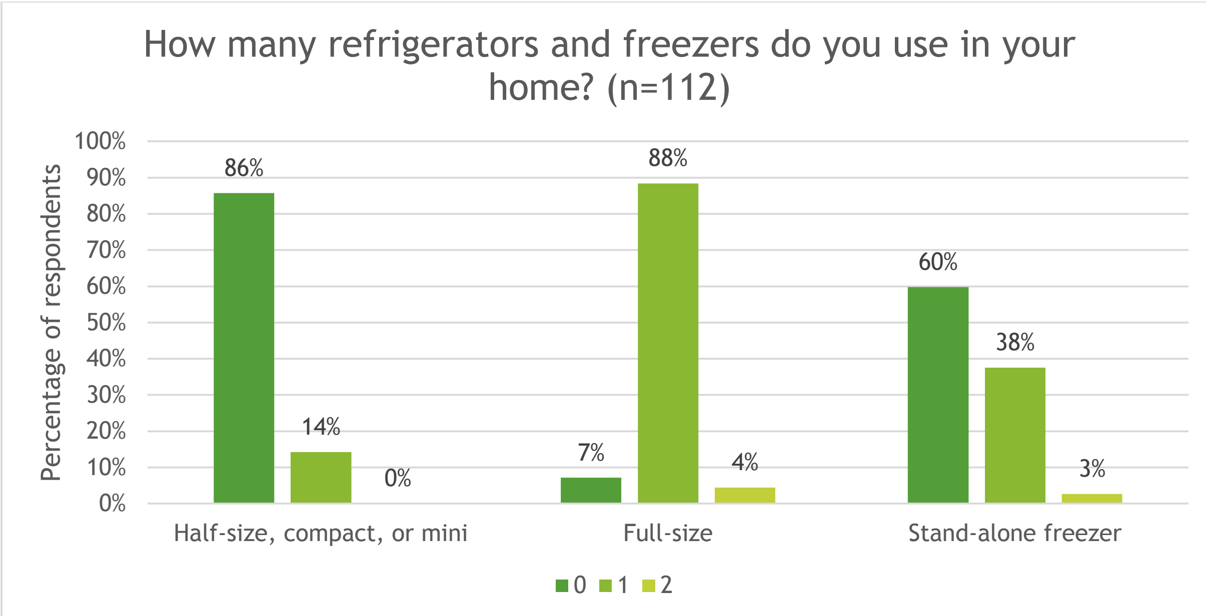


FIGURE 29: TV AND COMPUTER USAGE

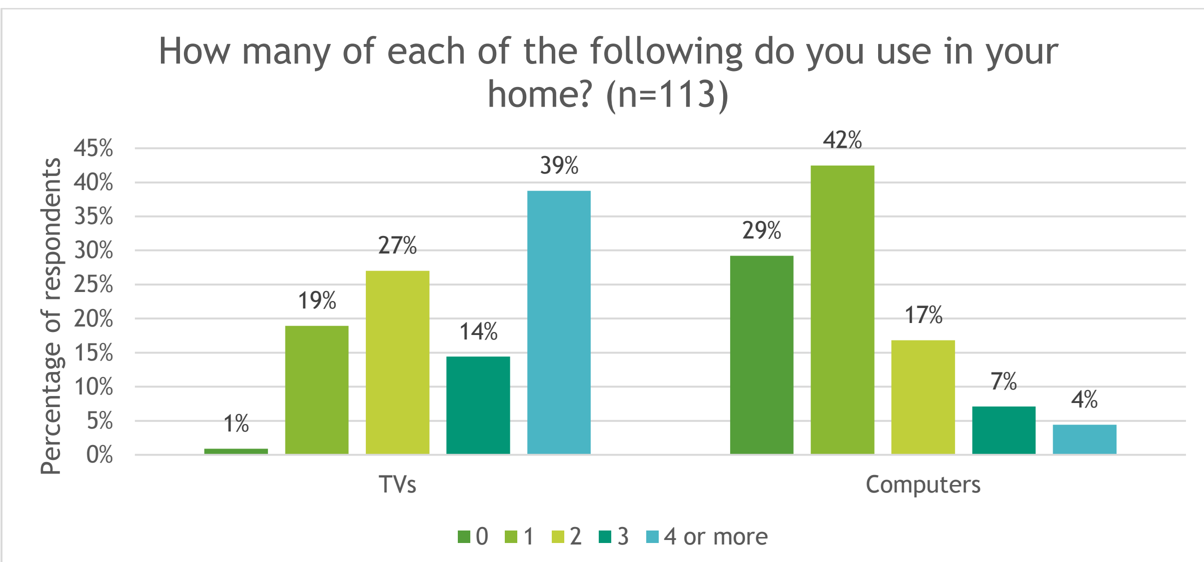
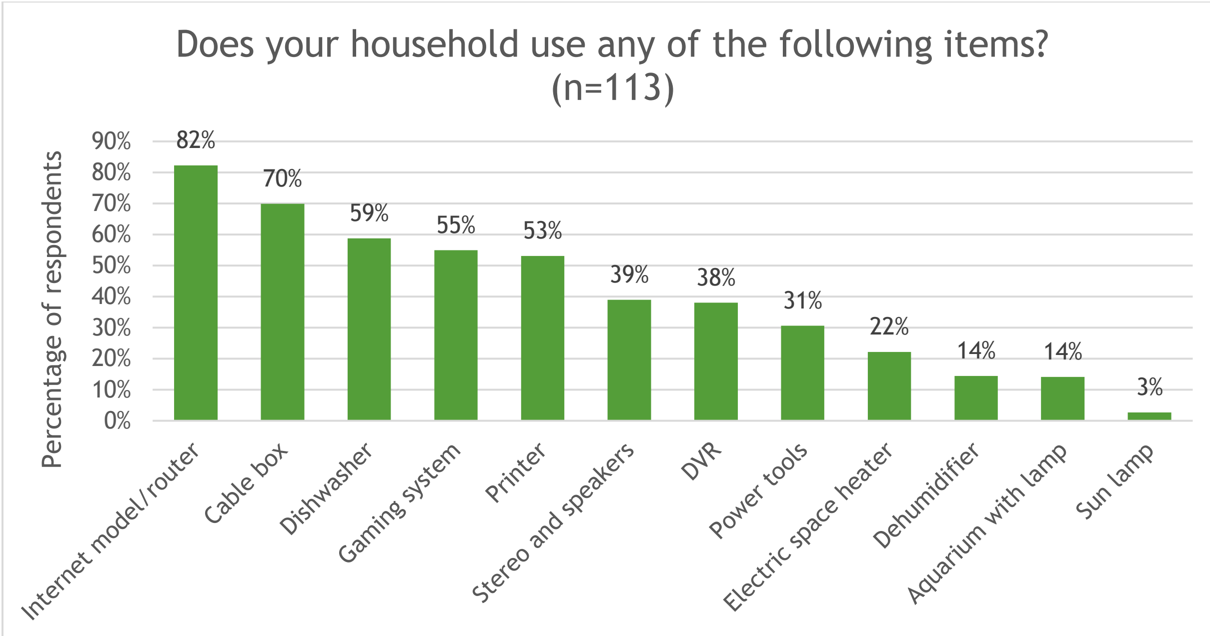


FIGURE 30: OTHER APPLIANCE AND ELECTRONICS USAGE



APPENDIX E: Energy Consumption Model Results

TABLE 6: HFH SURVEY NATURAL GAS CONSUMPTION MODEL

Regression Statistics	
F stat	10.73
P-value	<0.001
R Square	0.409
Adjusted R Square	0.3709
Standard Error	90.06
DF	62

Variable	Coefficient	Std Error	t Stat	P-value
Intercept	-228.08761	159.77704	-1.428	0.15844
Square Footage[1]	0.17017	0.05175	3.289	0.00166
Years in Home[2]	11.74338	2.66528	4.406	<0.001
Winter Night Temp[3]	4.34105	2.20679	1.967	0.05365
Electric Space Heater[4]	76.02116	31.83309	2.388	0.01999

[1] Square Feet = Conditioned square footage of the home.
[2] Years in Home = Self-reported length of time that the Habitat family has lived in their home, which serves as a rough proxy for the length of time since a Habitat for Humanity affiliate constructed or renovated the home.
[3] Winter Night Temp = Self-reported night-time winter thermostat setting, in degrees Fahrenheit.
[4] Electric Space Heater = A dummy variable where a value of 1 indicates that the household self-reported using at least one electric space heater.

Table 7: HFH survey electricity consumption model

Regression Statistics	
F stat	11.46
P-value	<0.001
R Square	0.4803
Adjusted R Square	0.4384
Standard Error	916.5
DF	62

Variable	Coefficients	Std Error	t Stat	P-value
Intercept	-257.1772	362.4972	-0.709	0.480699
Years in Home[5]	69.5612	30.3334	2.293	0.025239
TVs[6]	317.0366	79.8405	3.971	<0.001
CDD[7] * Central AC[8]	1.6921	0.4322	3.915	<0.001
CDD * Window AC[9]	1.7238	0.4659	3.7	<0.001
Aquarium[10]	1023.2567	319.1704	3.206	0.002129

[5] Years in Home = Self-reported length of time that the Habitat family has lived in their home, which serves as a rough proxy for the length of time since a Habitat for Humanity affiliate constructed or renovated the home.
[6] TVs = Self-reported number of televisions used in the home.
[7] CDD: Cooling degree days (using a baseline of 65 degrees Fahrenheit) observed over the course of the energy consumption year (2013 for Habitat homes, 2009 for RECS homes) at the nearest weather station.
[8] Central AC: A dummy variable where a value of 1 indicates the presence of central air conditioning in the home.
[9] Window AC: A dummy variable where a value of 1 indicates the presence of at least one window air conditioning unit in the home.
[10] Aquarium = A dummy variable where a value of 1 represents a Habitat home that has an aquarium.

TABLE 8: RECS NATURAL GAS* COMPARISON MODEL RESULTS

Regression Statistics	
F stat	11.12
P-value	<0.001
R Square	0.1551
Adjusted R Square	0.1412
Standard Error	0.3502
DF	303

Variable	Coefficients	Standard Error	t Stat	P-value
Intercept	4.701	0.3612	13.015	<0.001
HDD[11]	0.00004658	0.0000255	1.827	0.0687
Square Feet[12]	0.0001541	0.00006826	2.257	0.0247
Winter Night Temp[13]	0.02308	0.004633	4.981	<0.001
Electric Space Heater[14]	-0.09305	0.04768	-1.952	0.0519
Habitat[15]	-0.2586	0.05873	-4.403	<0.001

*Natural gas consumption data were natural logarithm transformed to attain a roughly normal distribution

11 HDD = Heating degree days (using a baseline of 65 degrees Fahrenheit) observed over the course of the energy consumption year (2013 for Habitat homes, 2009 for RECS homes) at the nearest weather station.
12 Square Feet = Conditioned square footage of the home.
13 Winter Night Temp = Self-reported night-time winter thermostat setting, in degrees Fahrenheit.
14 Electric Space Heater = A dummy variable where a value of 1 indicates that the household self-reported using at least one electric space heater.
15 Habitat = A dummy variable where a value of 1 represents a Habitat home and a value of 0 represents a non-Habitat RECS home.

TABLE 9: RECS ELECTRICITY* COMPARISON MODEL RESULTS

Regression Statistics	
F stat	28.44
P-value	<0.001
R Square	0.4934
Adjusted R Square	0.4761
Standard Error	0.3768
DF	292

Variable	Coefficients	Standard Error	t Stat	P-value
Intercept	7.626	0.1223	62.337	<0.001
Square Feet[16]	0.0002377	0.00007446	3.192	0.00156
Household Members[17]	0.08336	0.001792	4.652	<0.001
TVs[18]	0.1125	0.01941	5.797	<0.001
Separate Freezers[19]	0.192	0.0453	4.239	<0.001
Printers[20]	0.1603	0.04864	3.296	0.0011
Gaming System[21]	0.1286	0.05218	2.464	0.0143
Dishwasher[22]	0.1038	0.04625	2.245	0.02554
Electric Space Heater[23]	0.1193	0.0533	2.238	0.02597
CDD[24] * Central AC[25]	0.0001388	0.00006046	2.297	0.02235
Habitat[26]	-0.1594	0.06421	-2.482	0.01364

* Electricity consumption data were natural logarithm transformed to attain a roughly normal distribution

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[16] Square Feet = Conditioned square footage of the home.

[17] Household Members = Self-reported number of household members.

[18] TVs = Self-reported number of televisions used in the home.

[19] Separate Freezers = Self-reported number of stand-alone chest or upright freezers.

[20] Printer = A dummy variable where a value of 1 indicates the presence of at least one printer used in the home.

[21] Gaming System = A dummy variable where a value of 1 indicates the presence of at least one gaming system (e.g. Xbox, Playstation, etc.) that is used in the home.

[22] Dishwasher = A dummy variable where a value of 1 indicates the presence of a dishwasher in the home.

[23] Electric Space Heater = A dummy variable where a value of 1 indicates that the household self-reported using at least one electric space heater.

[24] CDD: Cooling degree days (using a baseline of 65 degrees Fahrenheit) observed over the course of the energy consumption year (2013 for Habitat homes, 2009 for RECS homes) at the nearest weather station.

[25] Central AC: A dummy variable where a value of 1 indicates the presence of central air conditioning in the home.

[26] Habitat = A dummy variable where a value of 1 represents a Habitat home and a value of 0 represents a non-Habitat RECS home.

APPENDIX F: List of Acronyms

HERS: Home Energy Rating System
HFH: Habitat for Humanity
HFHI: Habitat for Humanity International
HFHM: Habitat for Humanity of Michigan
SNRE: University of Michigan School of Natural Resources and Environment
SSO: State Support Organization
EIA: Energy Information Administration
RECS: Residential Energy Consumption Survey

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