USING AN OCCUPANT ENERGY INDEX FOR ACHIEVING ZERO ENERGY HOMES

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ABSTRACT

Standard procedures for estimating energy consumption of a building involve conducting hourly simulations using a particular architectural design, energy related features and operating assumptions. The use of a single set of operating assumptions is adequate when the goal is to estimate savings relative to a "reference" home.

However, in the case of zero energy homes it is absolute consumption, rather than relative savings, that is of interest. In such cases, a single set of operating assumptions will not suffice because a home that was designed to consume zero energy based on standard operating assumptions will not likely meet this expectation. To more accurately assess the odds that a zero energy home will truly consume zero energy, this paper introduces the concept of the Occupant Energy Index.

The Occupant Energy Index, a scale of 0 to 100, defines the full spectrum of influence that occupant behavior can have on the energy consumption of a home. A home designed to consume zero energy using an Occupant Energy Index of 100 will achieve this goal with occupants that have decisions and behavior similar to the reference occupant used in the analysis. This paper defines a methodology for establishing points on the index and illustrates various levels on the Occupant Energy Index.

The Occupant Energy Index can be used by zero energy home program designers to establish the rigor of their program requirements, control consumer expectations about the efficiency of their homes, and perhaps most importantly to educate consumers about the role they play in making a highly-efficient home a truly zero energy home.

INTRODUCTION

Consider a home built to the requirements of the weakest energy code in the country. Now, remove all of the occupants from the house, turn off all of the HVAC systems, flip off the lights and unplug all the appliances. Is the result a zero energy home? Most would think not, because once the occupants return the odds are good that consumption will dramatically increase. This scenario may emphasize the obvious - that occupants play a large role in determining the energy consumption of a home. However, consider a home at the other end of the spectrum – one that not only exceeds every energy code in the country, but also produces power onsite. How much might energy consumption increase when occupants return to this home?

Past research has demonstrated that occupant behavior can have dramatic impacts on energy consumption. Maintained interior temperatures of similar homes located in the same geographic location have been found to vary by 10 degrees Fahrenheit, resulting in cooling energy variations of approximately 5:1 (Parker et. al., 1996).

The purpose of this paper was to assess the impact of occupants on the energy consumption of a home and begin to define a uniform process for quantifying these impacts. The uniform process serves to define the Occupant Energy Index (OEI), which allows occupant behavior to be indexed.

For the purpose of this paper, occupant impacts were defined as any energy consumption in a building that is primarily attributable to the behavior of a specific occupant. The following were considered to fall under the domain of occupant impacts: schedules for opening and closing windows and shades; thermostat setpoints; water consumption; and lighting and appliance quantity, efficiency, and schedule.

Conversely, energy consumption that is not primarily attributable to a specific occupant, such as consumption driven by equipment efficiency, component insulation levels, and architectural characteristics, did not fall under this definition.

The energy performance of a home, excluding most occupant impacts, can already be evaluated using the Home Energy Rating System (HERS). The Home Energy Rating System is a uniform methodology for assessing the performance of a proposed home relative to a standard reference home design. It's value is not in predicting actual utility bills, but rather in the uniformity of its rating process. It evaluates the impact of equipment efficiencies, component insulation levels, and architectural characteristics and allows the home to be benchmarked on the HERS index. The reference home has an index of 100, by definition. A zero energy home scores zero on the index and a home that consumes more energy than the reference home scores above 100. HERS contains some basic adjustments for occupant impacts so that annual consumption can be simulated. These include: modifying water usage based on the quantity of bedrooms, making limited modifications to thermostat setpoints based on thermostat type, modifying internal gains based on the use of efficient lighting, ceiling fans, dishwashers, and refrigerators. HERS does not contain adjustments for other occupant behaviors, such as varied scheduling and energy consumption of other appliances.

HERS serves as one model for defining the OEI. The OEI defines a Reference Occupant, with a self-defined index of 100, that comprises a specific occupant profile. The occupant profile defines relevant lighting and appliance quantities and efficiencies, as well as all occupant schedules. An occupant with a more energy-intensive profile would score greater than 100 and an occupant with the least energy-intensive profile would score zero.

METHODOLOGY

This analysis was conducted using the DOE2.1E energy modeling program along with a proprietary front-end. Homes were modeled using the HERS methodology coupled with customized occupant profiles. This analysis was limited to three cities:

1) A hot and humid climate (Houston, TX – 2004 IECC Climate Zone 2),
2) A mixed climate (Baltimore, MD – 2004 IECC Climate Zone 4), and
3) A cold climate (Minneapolis, MN – 2004 IECC Climate Zone 6).

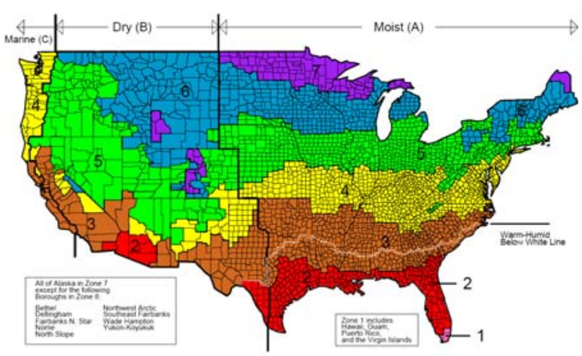

Figure 1. 2006 IECC Climate Zone Map

These cities were selected so that the impact of occupant behavior could be compared across diverse climates.

This analysis was divided into four steps:

1. Define a baseline housing construction and occupant profile for each city.
2. Identify and analyze individual changes to the baseline occupant profile to estimate its impact on total annual energy consumption.
3. Assess the synergistic impact of multiple changes to the baseline occupant profile in two bundles – all changes to the profile that decrease energy consumption and all changes to the profile that increase energy consumption. These bundles serve to illustrate how varying occupant profiles would create variation on the OEI.
4. Complete a tangential exercise to determine the impact of the OEI on the HERS Index. This exercise serves to illustrate that differences in occupant profiles can greatly impact the performance of a home on the HERS Index.

The methodology and results of each of these steps is discussed in more detail below.

CONCEPT DISCUSSION

How do you define an occupant energy index? In this section, the authors examine the various options that can be used along with their potential uses.

Statistical Confidence Scale

A statistical confidence version of an Occupant Energy Index is simply stated as a scale from 0 to 100, where 0 represents the most energy-intensive occupant for a given house. A 50 on the scale would represent an occupant of average energy intensity, where 50% of occupants would likely result in decreased energy consumption in the same home, while 50% of occupants would likely result in increased energy consumption.

Statistical Confidence Occupant Energy Index Scale:

- OEI 0 – 0% confidence compared to similar home
- OEI 50 – 50% confidence compared to similar home
- OEI 100 – 100% confidence compared to similar home

The statistical confidence scale is the simplest way to relate energy use across various home type, sizes, and locations. This approach is similar to the ENERGY STAR ratings system used for benchmarking commercial buildings. While this approach is superior in ease of use when relating an occupant to industry average, it is not used in the results section of this paper due to the effort required to set up baseline data that relates across each of the climates.

Percent Energy Impact Scale
A percent energy impact version of an Occupant Energy Index is intended to mirror the HERS Index, where 0 means the home and occupant will create a Zero Energy Home and 100 means that the home and occupant would perform the same as the reference occupant. Also, similar to the HERS Index, this scale would go higher than 100 for any situation where the occupant would use more energy than the reference occupant.

Percent Energy Impact Occupant Energy Index Scale:

- OEI 0 – zero energy using occupant
- OEI 100 – reference energy using occupant
- OEI 200 – double energy using occupant

The "Percent Energy Impact Scale" is the simpler of the two scales to define and determine for the purposes of this paper, and is used in the results section to illustrate the magnitude change in energy use based on occupant behavior.

The Occupant Energy Index for the purpose of this paper is the Percent Energy Impact Scale, but the authors recommend utilizing the statistical confidence scale for simpler industry comparisons.

RESULTS

Step 1: Define a Baseline Housing Construction and Occupant Profile
The baseline housing construction for each city was defined using the HERS Reference home, which is similar to the 2006 IECC standard design. The specifications for these homes are listed in figure 2.

Energy consumption associated with an occupant profile was accounted for in two ways. First, annual lighting and appliance consumption was calculated based on the quantity, efficiency, and annual hours of use. Second, for each occupant profile the authors defined a custom daily internal gains distribution curve and peak internal gains value. These were then modeled in conjunction with the housing construction to determine how they impacted the heating, cooling, and water heating consumption. The customized internal gains distribution curve used for the baseline occupant profile is presented in figure 3.

House Characteristic		Base Case
House Characteristics	Area per Floor (ft^2)	2000
	Number of Stories	single
	Foundation Type	slab-on-grade, vented crawlspace, unconditioned bsmt
	Aspect Ratio	2:1
	Window Distribution	25% on each side
Shell	Framing	2x4, 16" O.C.
	Window Area	18%
	Window U-value	[0.75, 0.40, 0.35]*
	Window SHGC	[0.40, 0.55, 0.55]*
	Attic Insulation	[R-30, R-38, R-49]*
	Wall Insulation	[R-13, R-13, R-19]*
	Wall Sheathing	[None]*
	Slab Insulation	[R-0, N/A,N/A]*
	Roof Absorptivity	0.75
	Air Infiltration	[0.00048 SLA]*
HVAC + DHW	Air Conditioner	[13 SEER]*
	Gas Furnace	[78 AFUE]*
	Heat Pump	[7.7 HSPF]*
	Duct Leakage	[80 DSE]*
	Duct Insulation	
	Hot Water	[0.59 EF gas]*
Architect-ural Design	Exterior Shading	[None]*
	Building Orientation:	North
Lighting & Appliances	Lighting	Standard
	Appliances	Standard
Behavior Modification	Thermostat	Manual Heating 68/ Cooling 78
	Hot Water Utilization	Standard Hot Water Use

* Specifications within brackets are base home characteristics for hot, moderate and cold climates, respectively, as required by the 2006 IECC Residential Energy Efficiency Code.

Figure 2. House Characteristics of the Base Cases

The baseline energy use, including heating, cooling, water heating, lighting, appliances and plug loads end-uses are presented in figures 4-6 for each of the three cities analyzed in this study. These pie charts illustrate the relative magnitude of each of the end-uses for the baseline scenario in each location.

It is important to note that these values are not intended to represent the energy consumption of an average home. Instead, they reflect the energy consumption of a baseline home configured to meet the specifications of the HERS reference home.

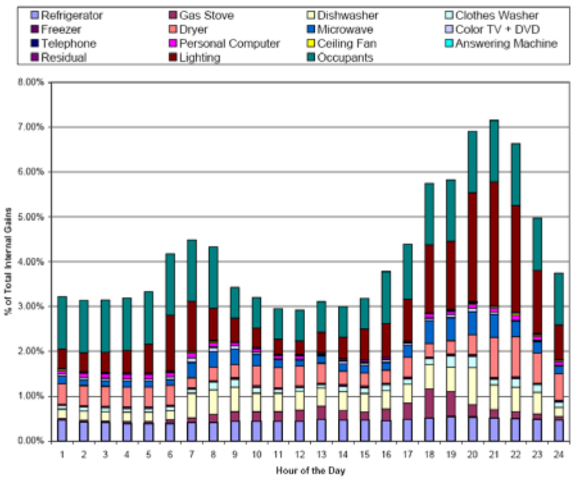

Figure 3. Baseline Internal Gains Distribution

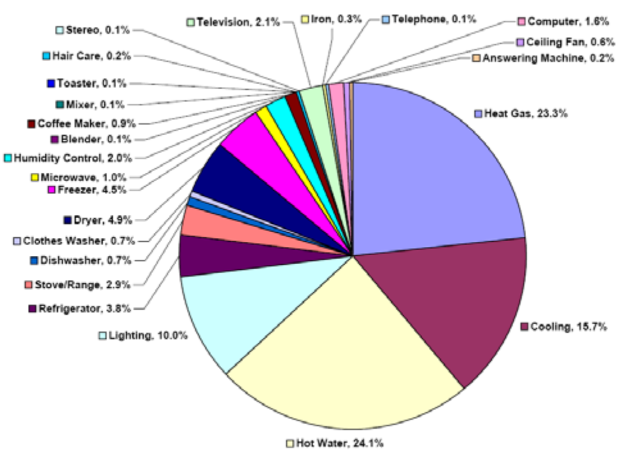

Figure 4. Houston Pie Chart of Baseline Home Energy Use

For Houston, a hot and humid climate, energy use for heating, cooling and hot water accounts for 63% of the annual energy use of the home. Prior to the development of the 2006 HERS Guidelines, the remaining 37% of the home's energy use was not capable of being addressed through the HERS methodology. In addition, all end-uses presented in the table can influenced by occupant behavior and decisions.

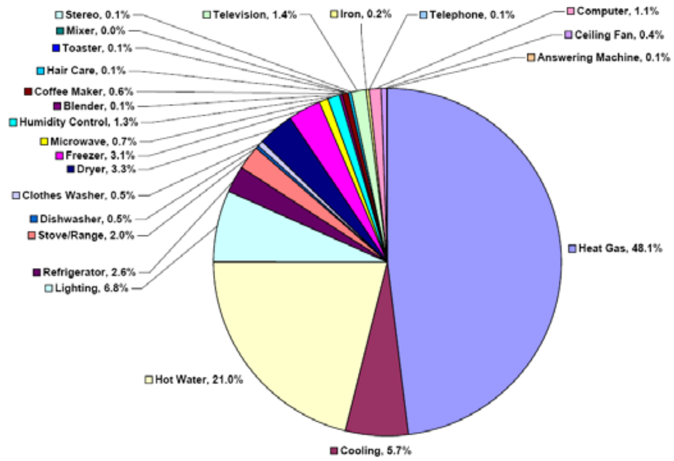

Figure 5. Baltimore Pie Chart of Baseline Home Energy Use

For Baltimore, a mixed climate, the energy use for heating, cooling and hot water accounts for approximately 75% of the annual energy use of the home. In comparison to Houston, these end-uses comprise over 10% more of total energy use, suggesting that the same occupant behavior in different climates can produce variable impacts.

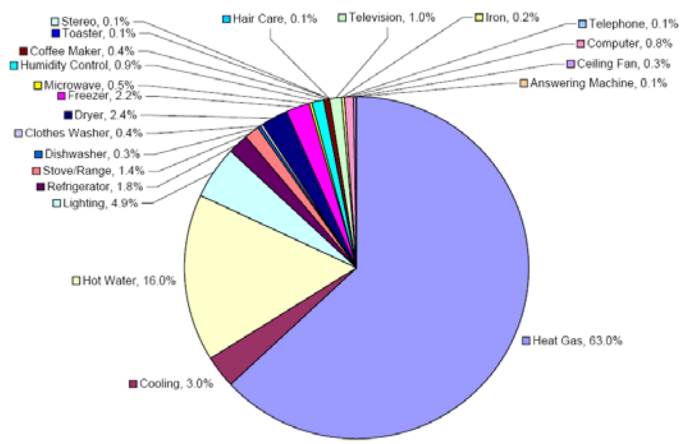

Figure 6. Minneapolis Pie Chart of Baseline Home Energy Use

For Minneapolis, a cold climate, the energy use for heating, cooling and hot water accounts for approximately 82% of the annual energy use of the home. With 63% of total energy consumption accounted for by space heating, one might infer that an occupant profile will impact end-uses in Minneapolis significantly different than end-uses in Houston.

Step 2: Identify and Analyze Individual Changes to the Baseline Occupant Profile

A series of mini-studies were conducted to determine the impact of individual changes to the baseline occupant profile. The impact is measured as a change in each of the home's end use categories, as follows:

- Heating, including fans
- Cooling, including fans
- Water Heating
- Lighting
- Plug loads/Appliances

Occupant Impacts via Thermostat.

To assess thermostats, the heating and cooling setpoints of the baseline occupant profile were modified. Changes to thermostat setpoints are presented first because they were found to have the largest impact on the overall energy use of the home among all individual changes to the baseline occupant profile.

In this analysis the "Base Case" had temperature settings consistent with the HERS reference home – 68 degrees F for the heating setpoint and 78 degrees F for the cooling setopint. To approximate an energy-intensive occupant attempting to maintain consistent mean radiant temperature year-round, the heating setpoint was increased to 74 degrees F and the cooling setpoint was reduced to 72 degrees. To approximate an energy-conservative occupant attempting to minimize utility costs, the heating setpoint was reduced to 62 degrees F and the cooling setpoint was increased to 84 degrees F.

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	16.3	11.0	16.8	7.0	18.8
Thermostat set at (74, 72)	29.9	18.4	16.8	7.0	18.8
Thermostat set at (62, 84)	7.0	5.6	16.8	7.0	18.8

Figure 7. Houston Thermostat Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
Thermostat set at (74, 72)	141	-30.0%	-26.9%
Thermostat set at (62, 84)	71	20.9%	18.9%

Figure 8. Houston Thermostat Energy Savings

In Houston, the revised thermostat setpoints impacted the purchased energy use by as much as 46% between the least and most energy intensive occupant, actual site energy by more than 50%, and as much as 70 points on the HERS Index between the energy-intensive and energy-conservative occupant.

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	49.5	5.9	21.6	7.0	18.8
Thermostat set at (74, 72)	71.0	10.8	21.6	7.0	18.8
Thermostat set at (62, 84)	31.5	3.1	21.6	7.0	18.8

Figure 9. Baltimore Thermostat Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
Thermostat set at (74, 72)	134	-25.7%	-23.5%
Thermostat set at (62, 84)	77	20.2%	17.7%

Figure 10. Baltimore Thermostat Energy Savings

In Baltimore, the revised thermostat setpoints impacted the purchased energy use of the baseline home by as much as 41% between the energy-intensive and energy-conservative occupant.

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	90.6	4.3	23.1	7.0	18.8
Thermostat set at (74, 72)	117.4	10.6	23.1	7.0	18.8
Thermostat set at (62, 84)	68.4	1.3	23.1	7.0	18.8

Figure 11. Minneapolis Thermostat Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	102	0.0%	0.0%
Thermostat set at (74, 72)	139	-23.0%	-22.8%
Thermostat set at (62, 84)	79	17.6%	16.4%

Figure 12. Minneapolis Thermostat Energy Savings

In Minneapolis, the revised thermostat setpoints impacted the purchased energy use of the baseline home by as much as 39% between the energy-intensive and energy-conservative occupant.

Occupant Impacts via Lighting.

To assess lighting, the quantity of fixtures and the percentage of fluorescent lighting was modified.

In this analysis the "Base Case" had a lighting intensity consistent with the HERS reference home, which assumes 10% fluorescent lighting. To approximate an energy intensive occupant, the lighting intensity was doubled. To approximate an energy-conservative occupant, the lighting intensity was decreased and the percentage of fluorescent lighting was increased. These modifications impacted the heating, cooling and lighting energy consumption of the baseline home.

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	16.3	11.0	16.8	7.0	18.8
100% Fluorescent	16.9	10.6	16.8	4.3	18.8
0 Lights On	17.9	10.0	16.8	0.0	18.8
Double Lighting Energy	14.6	12.0	16.8	14.0	18.8

Figure 13. Houston Lighting Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
100% Fluorescent	96	3.5%	5.1%
0 Lights On	88	9.1%	13.1%
Double Lighting Energy	112	-9.1%	-13.1%

Figure 14. Houston Lighting Energy Use Savings

In Houston, the revised lighting intensity and percentage of fluorescent lighting had a significant impact on the energy use of the home. As lighting intensity increased, so did the cooling load. As will be seen, this impact diminishes as in colder climates.

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	49.5	5.9	21.6	7.0	18.8
100% Fluorescent	51.0	5.6	21.6	4.3	18.8
0 Lights On	53.3	5.3	21.6	0.0	18.8
Double Lighting Energy	46.0	6.5	21.6	14.0	18.8

Figure 15. Baltimore Lighting Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
100% Fluorescent	97	1.4%	3.1%
0 Lights On	92	3.8%	8.1%
Double Lighting Energy	108	-4.0%	-8.3%

Figure 16. Baltimore Lighting Energy Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	90.6	4.3	23.1	7.0	18.8
100% Fluorescent	93.0	4.0	23.1	4.3	18.8
0 Lights On	96.8	3.8	23.1	0.0	18.8
Double Lighting Energy	84.9	4.8	23.1	14.0	18.8

Figure 17. Minneapolis Lighting Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	102	0.0%	0.0%
100% Fluorescent	100	0.4%	1.9%
0 Lights On	97	1.0%	4.7%
Double Lighting Energy	107	-1.2%	-4.9%

Figure 18. Minneapolis Lighting Energy Savings

Occupant Impacts via Refrigerators.

To assess refrigerators, equipment efficiency and quantity were modified.

The “Base Case” scenario assumed an equipment efficiency consistent with the HERS Reference Home. To approximate an energy-intensive occupant, two refrigerators were modeled. To approximate energy-conservative occupants, an ENERGY STAR refrigerator and a best-available efficiency refrigerator were modeled, as well as no refrigerator at all.

These modifications impacted the appliances, heating and cooling energy consumption of the baseline home. The minimum and maximum energy use studied, “No Refrigerator” and “Two Refrigerators” vary by as much as 4.9% less energy use to as much as 4.8% increase in energy use from the baseline, as shown in Figures 19-25. Refrigerators have a larger impact on energy savings in the hottest climates.

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	16.3	11.0	16.8	7.0	18.8
ENERGY STAR	16.3	10.9	16.8	7.0	18.4
Highest Efficiency	16.4	10.9	16.8	7.0	17.9
No Refrigerator	16.9	10.6	16.8	7.0	16.2
Two Refrigerators	15.5	11.4	16.8	7.0	21.5

Figure 19. Houston Refrigerator Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
ENERGY STAR	99	0.8%	1.0%
Highest Efficiency	99	1.3%	1.7%
No Refrigerator	96	3.4%	4.9%
Two Refrigerators	105	-3.2%	-4.8%

Figure 20. Houston Refrigerator Energy Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	49.5	5.9	21.6	7.0	18.8
ENERGY STAR	49.8	5.9	21.6	7.0	18.4
Highest Efficiency	50.0	5.8	21.6	7.0	17.9
No Refrigerator	51.1	5.6	21.6	7.0	16.2
Two Refrigerators	48.0	6.1	21.6	7.0	21.5

Figure 21. Baltimore Refrigerator Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
ENERGY STAR	100	0.2%	0.4%
Highest Efficiency	99	0.5%	1.1%
No Refrigerator	97	1.2%	2.9%
Two Refrigerators	103	-1.4%	-3.0%

Figure 22. Baltimore Refrigerator Energy Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	90.6	4.3	23.1	7.0	18.8
ENERGY STAR	91.0	4.1	23.1	7.0	18.4
Highest Efficiency	91.5	4.1	23.1	7.0	17.9
No Refrigerator	93.1	4.0	23.1	7.0	16.2
Two Refrigerators	88.3	4.4	23.1	7.0	21.5

Figure 23. Minneapolis Refrigerator Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	102	0.0%	0.0%
ENERGY STAR	101	0.1%	0.4%
Highest Efficiency	101	0.1%	0.6%
No Refrigerator	100	0.3%	1.7%
Two Refrigerators	103	-0.3%	-1.7%

Figure 24. Minneapolis Refrigerator Energy Savings

Among the individual modifications analyzed, the top three occupant impacts were due to thermostat setpoints, lighting intensity, and refrigerator efficiency and quantity. The next seven most significant impacts are shown below for Houston. Additional data are available in the appendix.

Occupant Impacts via Cooking Range.
To assess cooking ranges, the efficiency of the burners (through the pilot and variability of low to high flame) and annual hours of use were modified.

In hot and humid climates, where cooling is a primary concern, the amount of cooking and location of cooking can have a significant impact on the heating and cooling load of the home. Often indoor/outdoor kitchens can provide significant energy savings year-round in hot climates, where kitchens are enclosed during the heating season and open during the cooling season. An occupant that often entertains by cooking for other people will be a high energy user.

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	16.3	11.0	16.8	7.0	18.8
Efficient Range	16.3	10.9	16.8	7.0	18.4
Highest Efficiency	16.4	10.9	16.8	7.0	18.1
Double Cooking	15.6	11.3	16.8	7.0	20.9
No Cooking	16.8	10.6	16.8	7.0	16.8

Figure 25. Houston Cooking Range Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
Efficient Range	99	0.8%	1.0%
Highest Efficiency	99	1.1%	1.5%
Double Cooking	104	-2.4%	-3.6%
No Cooking	97	2.8%	4.0%

Figure 26. Houston Cooking Range Energy Savings

Occupant Impacts via Dishwasher.
To assess dishwashers, the equipment efficiency and annual wash cycles were modified.

These modifications primarily impacted the appliance and hot water energy consumption of the baseline home. Similar to cooking, an occupant that entertains guests will tend to have an increased number of annual wash cycles.

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	16.3	11.0	16.8	7.0	18.8
ENERGY STAR	16.3	11.0	16.4	7.0	18.7
Highest Efficiency	16.3	11.0	16.3	7.0	18.7
No Dishwashing	16.4	10.9	14.0	7.0	18.3
Double Dishwashing	16.1	11.0	19.6	7.0	19.3

Figure 27. Houston Dishwasher Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
ENERGY STAR	100	0.7%	0.6%
Highest Efficiency	100	1.0%	0.8%
No Dishwashing	98	4.7%	3.7%
Double Dishwashing	103	-4.5%	-3.5%

Figure 28. Houston Dishwasher Energy Savings

Occupant Impacts via Clothes Washer.
To assess clothes washers, the equipment efficiency and annual wash cycles were modified.

Similar to the dishwasher, the clothes washer primarily impacted the appliance and hot water energy consumption of the baseline home. An occupant that has a profession which requires significant cleaning of often soiled clothes will be a high energy user.

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	16.3	11.0	16.8	7.0	18.8
ENERGY STAR	16.3	11.0	16.4	7.0	18.7
Highest Efficiency	16.3	11.0	16.2	7.0	18.6
No Clothes Washing	16.4	10.9	15.4	7.0	18.3
Double Clothes Washing	16.1	11.0	18.3	7.0	19.3

Figure 29. Houston Clothes Washer Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
ENERGY STAR	100	0.8%	0.7%
Highest Efficiency	100	1.1%	0.9%
No Clothes Washing	98	2.8%	2.5%
Double Clothes Washing	102	-2.6%	-2.2%

Figure 30. Houston Clothes Washer Energy Savings

Occupant Impacts via Freezer.
To assess freezers, equipment efficiency and quantity were modified.

Often a home will not have a separate stand-alone freezer, which in itself is the primary decision that impacts the amount of energy use. A high energy user will tend to be an occupant that buys food in bulk.

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	16.3	11.0	16.8	7.0	18.8
ENERGY STAR	16.3	10.9	16.8	7.0	18.4
Highest Efficiency	16.4	10.9	16.8	7.0	18.1
No Freezer	17.0	10.5	16.8	7.0	15.6
Two Freezers	15.4	11.5	16.8	7.0	22.0

Figure 31. Houston Freezer Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
ENERGY STAR	99	0.7%	0.9%
Highest Efficiency	99	1.0%	1.4%
No Freezer	95	4.2%	6.0%
Two Freezers	106	-4.0%	-5.9%

Figure 32. Houston Freezer Energy Savings

Occupant Impacts via Microwave.
To assess microwaves, the capacity and quantity of microwaves were modified.

The microwave has a large electric demand, but does not have long term use like other appliances. As a result, promoting increased adoption can decrease energy consumption relative to a range, while deterring increased adoption can reduce demand. In this study the authors have focused on its impact on energy consumption.

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	16.3	11.0	16.8	7.0	18.8
ENERGY STAR	16.3	11.0	16.8	7.0	18.7
Highest Efficiency	16.3	10.9	16.8	7.0	18.6
No Microwave	16.4	10.9	16.8	7.0	18.1
Double Microwave Use	16.0	11.1	16.8	7.0	19.5

Figure 33. Houston Microwave Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
ENERGY STAR	100	0.2%	0.3%
Highest Efficiency	100	0.5%	0.7%
No Microwave	99	1.0%	1.4%
Double Microwave Use	102	-0.8%	-1.2%

Figure 34. Houston Microwave Energy Savings

Occupant Impacts via TV/DVD.
To assess televisions and DVD players, equipment efficiency and annual hours of use were modified.

A home's entertainment center, starting with the TV and DVD player, has become a more prominent energy using segment of a home, with larger TVs, increased TV use and increased video gaming. Both the increase in number of TV's and the increase in number of hours of TV use increases the energy use of the appliances and heat gain in the home. In Houston, with a baseline of only 2.1% of the home energy use coming from TV's, increasing the usage of television will increased the purchased energy by 2.8%.

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	16.3	11.0	16.8	7.0	18.8
ENERGY STAR	16.3	11.0	16.8	7.0	18.7
Highest Efficiency	16.3	10.9	16.8	7.0	18.5
No TV or DVD	16.6	10.8	16.8	7.0	17.3
Double TV and DVD usag	15.9	11.3	16.8	7.0	20.3

Figure 35. Houston TV/DVD Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
ENERGY STAR	100	0.2%	0.3%
Highest Efficiency	99	0.6%	0.8%
No TV or DVD	98	1.9%	2.8%
Double TV and DVD use	103	-1.9%	-2.8%

Figure 36. Houston TV/DVD Energy Savings

Occupant Impacts via Computers.
To assess computers, the equipment efficiency and hours of annual hours of use were modified.

Similar to televisions, computers have become more prominent. Additionally, there is a large variance in both the number of computers in a home and the amount of time when computers in use.

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	16.3	11.0	16.8	7.0	18.8
ENERGY STAR	16.3	11.0	16.8	7.0	18.7
Highest Efficiency	16.3	10.9	16.8	7.0	18.6
No Computer	16.5	10.8	16.8	7.0	17.7
Double the Computers	15.9	11.1	16.8	7.0	19.9

Figure 37. Houston Computers Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
ENERGY STAR	100	0.2%	0.2%
Highest Efficiency	100	0.5%	0.6%
No Computer	98	1.6%	2.2%
Double the Computers	102	-1.2%	-1.9%

Figure 38. Houston Computers Energy Savings

Occupant Impacts via Ceiling Fans.
To assess ceiling fans, equipment efficiency and quantity were modified.

Ceiling fans offer an interesting situation for occupant energy use. On one hand, ceiling fans use energy, create heat gain that needs to be cooled, but they also increase comfort in higher space temperatures. In the analysis that was conducted for this mini-study, the authors looked at only the impact of fan usage without regard to potential thermostat savings from increased comfort.

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	16.3	11.0	16.8	7.0	18.8
ENERGY STAR	16.3	11.0	16.8	7.0	18.8
Highest Efficiency	16.3	11.0	16.8	7.0	18.7
No Fans	16.3	10.9	16.8	7.0	18.4
Double Ceiling Fan Use	16.1	11.0	16.8	7.0	19.2

Figure 39. Houston Ceiling Fan Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
ENERGY STAR	100	0.1%	0.1%
Highest Efficiency	100	0.1%	0.2%
No Fans	99	0.8%	1.0%
Double Ceiling Fan Use	101	-0.4%	-0.7%

Figure 40. Houston Ceiling Fan Energy Savings

Step 3: Low & High Energy Using Occupant

In combining each of the lowest and highest energy using occupant behaviors, this study was able to determine the maximum energy savings impact from the variations in occupant decisions and behavior that were analyzed in the mini-studies.

Four scenarios are summarized below for each of the three analyzed cities: the base case scenario using the HERS reference home; a scenario with zero lighting and appliance usage; a scenario with all high-efficiency appliances and lighting; and a scenario with double the quantity of reference home appliances and increased lighting energy use.

Houston

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	16.3	11.0	16.8	7.0	18.8
Zero Lighting/Appliances	10.5	3.1	12.6	0.0	0.0
All Efficient Appliances	18.9	9.5	15.7	2.9	12.6
Double All Appliances	11.6	14.1	16.8	7.5	37.6

Figure 41. Houston Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
Zero Lighting/Appliances	27	62.5%	71.6%
All Efficient Appliances	82	14.7%	20.2%
Double All Appliances	135	-25.4%	-36.6%

Figure 42. Houston Energy Savings

With purchased energy savings of 71.6% in the zero lighting and appliances scenario, an occupant that was able to live in that minimalist situation would achieve an Occupant Energy Index of 28.4 (100 – 71.6). Another occupant, who simply lived the same as the reference occupant, but made the decision to purchase the highest efficiency appliances would achieve a 79.2 OEI without compromising comfort or convenience.

Baltimore

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	49.5	5.9	21.6	7.0	18.8
Zero Lighting/Appliances	44.0	2.3	15.6	0.0	0.0
All Efficient Appliances	55.4	5.0	20.0	2.9	12.6
Double All Appliances	39.3	7.8	21.6	7.5	37.6

Figure 43. Baltimore Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
Zero Lighting/Appliances	45	39.9%	51.1%
All Efficient Appliances	87	6.7%	12.8%
Double All Appliances	123	-10.6%	-22.5%

Figure 44. Baltimore Energy Savings

Minneapolis

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	90.6	4.3	23.1	7.0	18.8
Zero Lighting/Appliances	90.3	2.4	16.5	0.0	0.0
All Efficient Appliances	100.3	3.5	21.3	2.9	12.6
Double All Appliances	73.8	5.9	23.1	7.5	37.6

Figure 45. Minneapolis Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	102	0.0%	0.0%
Zero Lighting/Appliances	60	24.1%	34.6%
All Efficient Appliances	94	2.2%	7.6%
Double All Appliances	115	-2.8%	-13.1%

Figure 46. Minneapolis Energy Savings

Step 4: HERS Index Study

Each of the simulations conducted included results that show a theoretical impact on the HERS Index from occupant behavior. These results show that there is significant potential for energy savings through guided occupant decisions. The HERS Index, the standard scale used in rating energy efficient homes, has the opportunity to index occupant energy use along side the energy efficient characteristics of the home.

The HERS Reference home (HERS Index 100) does not necessarily have an appropriate average occupant setup or one that should be used as a reference for the Occupant Energy Index. This is a topic that should be further explored, but is not the main emphasis of this concept paper.

NEXT STEPS

This paper illustrates the significant impact that occupants can have on the energy consumption of a home and introduces the concept of the Occupant Energy Index. To further illustrate the benefits of the Occupant Energy Index, the following areas of research should be considered:

1. Fully defining the Reference Occupant
2. Fully defining a home's energy use equation to represent, understand and benchmark home energy use: Energy Use Equation = Building Enclosure + HVAC + Occupant + Weather
3. Fully exploring the annual 8760 hour occupant schedule and determine occupant impact on the Occupant Energy Index
4. Considering impact of occupant behavior on electric demand

CONCLUSIONS

While there are opportunities to analyze the efficiency of homes through the Home Energy Rating System, industry has not made progress on the ability to predict, rate and educate home owners about their own impact on the energy use of their home. The Occupant Energy Index, a concept introduced in this paper, can be utilized by the home industry to help consumers understand the impact of their decision and behavior on the overall energy use of the home.

While there are multiple versions of the Occupant Energy Index that can be utilized, this paper introduces the Statistical Confidence Scale and the Percent Energy Impact Scale as options that can be utilized. The critical component of each of these scales that needs to be further explored is the definition of the actual reference or baseline occupant.

This paper illustrates that there is the potential for significant energy savings or increased energy usage based on occupant decisions and behavior. With a static home, occupants can shift the energy use of the home by 50% or more in hot and humid climates, with selecting more or less efficient appliances and by using the appliances more or less than a typical occupant.

This energy use that is currently not capable of being analyzed or tracked can have significant impact on the actual performance of a utility or government energy efficiency program. The use of the Occupant Energy Index will allow for professionals in the home building industry to educate consumers, provide bill guarantees to builders, and determine actual potential for energy and demand savings for utility and government energy efficiency programs.

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APPENDIX

This includes all the scenarios that are not included in the main body of the paper.

Occupant Impacts via Refrigerators

Occupant's impact on home energy use via refrigerators comes primarily in two means, first by selecting the efficiency of the refrigerator and second by the quantity or size of the refrigerator.

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	16.3	11.0	16.8	7.0	18.8
ENERGY STAR	16.3	10.9	16.8	7.0	18.4
Highest Efficiency	16.4	10.9	16.8	7.0	17.9
No Refrigerator	16.9	10.6	16.8	7.0	16.2
Two Refrigerators	15.5	11.4	16.8	7.0	21.5

Figure A1. Houston Refrigerator Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
ENERGY STAR	99	0.8%	1.0%
Highest Efficiency	99	1.3%	1.7%
No Refrigerator	96	3.4%	4.9%
Two Refrigerators	105	-3.2%	-4.8%

Figure A2. Houston Refrigerator Energy Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	49.5	5.9	21.6	7.0	18.8
ENERGY STAR	49.8	5.9	21.6	7.0	18.4
Highest Efficiency	50.0	5.8	21.6	7.0	17.9
No Refrigerator	51.1	5.6	21.6	7.0	16.2
Two Refrigerators	48.0	6.1	21.6	7.0	21.5

Figure A3. Baltimore Refrigerator Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
ENERGY STAR	100	0.2%	0.4%
Highest Efficiency	99	0.5%	1.1%
No Refrigerator	97	1.2%	2.9%
Two Refrigerators	103	-1.4%	-3.0%

Figure A4. Baltimore Refrigerator Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	90.6	4.3	23.1	7.0	18.8
ENERGY STAR	91.0	4.1	23.1	7.0	18.4
Highest Efficiency	91.5	4.1	23.1	7.0	17.9
No Refrigerator	93.1	4.0	23.1	7.0	16.2
Two Refrigerators	88.3	4.4	23.1	7.0	21.5

Figure A5. Minneapolis Refrigerator Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	102	0.0%	0.0%
ENERGY STAR	101	0.1%	0.4%
Highest Efficiency	101	0.1%	0.6%
No Refrigerator	100	0.3%	1.7%
Two Refrigerators	103	-0.3%	-1.7%

Figure A6. Minneapolis Refrigerator Savings

Occupant Impacts via Cooking Range

Occupant's impact on home energy use via cooking range comes primarily in two means, first by selecting efficiency of the burners (through the pilot and variability of low to high flame) and second by the quantity of time the burners are in use.

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	16.3	11.0	16.8	7.0	18.8
Efficient Range	16.3	10.9	16.8	7.0	18.4
Highest Efficiency	16.4	10.9	16.8	7.0	18.1
Double Cooking	15.6	11.3	16.8	7.0	20.9
No Cooking	16.8	10.6	16.8	7.0	16.8

Figure A7. Houston Cooking Range Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
Efficient Range	99	0.8%	1.0%
Highest Efficiency	99	1.1%	1.5%
Double Cooking	104	-2.4%	-3.6%
No Cooking	97	2.8%	4.0%

Figure A8. Houston Cooking Range Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	49.5	5.9	21.6	7.0	18.8
Efficient Range	49.8	5.9	21.6	7.0	18.4
Highest Efficiency	50.0	5.8	21.6	7.0	18.1
Double Cooking	48.4	6.0	21.6	7.0	20.9
No Cooking	50.8	5.6	21.6	7.0	16.8

Figure A9. Baltimore Cooking Range Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
Efficient Range	100	0.2%	0.4%
Highest Efficiency	99	0.4%	0.9%
Double Cooking	102	-1.0%	-2.3%
No Cooking	98	1.0%	2.3%

Figure A10. Baltimore Cooking Range Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	90.6	4.3	23.1	7.0	18.8
Efficient Range	91.0	4.1	23.1	7.0	18.4
Highest Efficiency	91.4	4.1	23.1	7.0	18.1
Double Cooking	88.8	4.4	23.1	7.0	20.9
No Cooking	92.6	4.0	23.1	7.0	16.8

Figure A11. Minneapolis Cooking Range Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	102	0.0%	0.0%
Efficient Range	101	0.1%	0.4%
Highest Efficiency	101	0.1%	0.5%
Double Cooking	103	-0.2%	-1.3%
No Cooking	100	0.2%	1.4%

Figure A12. Minneapolis Cooking Range Savings

Occupant Impacts via Dishwasher

Occupant's impact on home energy use via dish washers comes primarily in two means, first by selecting the efficiency of the dishwasher and second by the number of runs cycles used.

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	16.3	11.0	16.8	7.0	18.8
ENERGY STAR	16.3	11.0	16.4	7.0	18.7
Highest Efficiency	16.3	11.0	16.3	7.0	18.7
No Dishwashing	16.4	10.9	14.0	7.0	18.3
Double Dishwashing	16.1	11.0	19.6	7.0	19.3

Figure A13. Houston Dishwasher Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
ENERGY STAR	100	0.7%	0.6%
Highest Efficiency	100	1.0%	0.8%
No Dishwashing	98	4.7%	3.7%
Double Dishwashing	103	-4.5%	-3.5%

Figure A14. Houston Dishwasher Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	49.5	5.9	21.6	7.0	18.8
ENERGY STAR	49.6	5.9	21.0	7.0	18.7
Highest Efficiency	49.6	5.9	20.8	7.0	18.7
No Dishwashing	49.9	5.9	17.6	7.0	18.3
Double Dishwashing	49.3	5.9	25.6	7.0	19.3

Figure A15. Baltimore Dishwasher Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
ENERGY STAR	100	0.5%	0.5%
Highest Efficiency	99	0.8%	0.7%
No Dishwashing	97	4.0%	3.5%
Double Dishwashing	103	-4.1%	-3.6%

Figure A16. Baltimore Dishwasher Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	90.6	4.3	23.1	7.0	18.8
ENERGY STAR	90.8	4.3	22.4	7.0	18.7
Highest Efficiency	90.8	4.3	22.2	7.0	18.7
No Dishwashing	91.1	4.1	18.7	7.0	18.3
Double Dishwashing	90.1	4.3	27.4	7.0	19.3

Figure A17. Minneapolis Dishwasher Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	102	0.0%	0.0%
ENERGY STAR	101	0.4%	0.4%
Highest Efficiency	101	0.6%	0.6%
No Dishwashing	99	3.1%	2.9%
Double Dishwashing	104	-3.0%	-2.8%

Figure A18. Minneapolis Dishwasher Savings

Occupant Impacts via Clothes Washer

Occupant's impact on home energy use via clothes washers comes primarily in two means, first by selecting the efficiency of the clothes washer and second by the number of runs cycles used.

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	16.3	11.0	16.8	7.0	18.8
ENERGY STAR	16.3	11.0	16.4	7.0	18.7
Highest Efficiency	16.3	11.0	16.2	7.0	18.6
No Clothes Washing	16.4	10.9	15.4	7.0	18.3
Double Clothes Washing	16.1	11.0	18.3	7.0	19.3

Figure A19. Houston Clothes Washer Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
ENERGY STAR	100	0.8%	0.7%
Highest Efficiency	100	1.1%	0.9%
No Clothes Washing	98	2.8%	2.5%
Double Clothes Washing	102	-2.6%	-2.2%

Figure A20. Houston Clothes Washer Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	49.5	5.9	21.6	7.0	18.8
ENERGY STAR	49.6	5.9	21.0	7.0	18.7
Highest Efficiency	49.6	5.9	20.8	7.0	18.6
No Clothes Washing	49.9	5.9	19.5	7.0	18.3
Double Clothes Washing	49.3	5.9	23.7	7.0	19.3

Figure A21. Baltimore Clothes Washer Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
ENERGY STAR	100	0.6%	0.6%
Highest Efficiency	99	0.9%	0.8%
No Clothes Washing	98	2.2%	2.0%
Double Clothes Washing	102	-2.3%	-2.1%

Figure A22 Baltimore Clothes Washer Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	90.6	4.3	23.1	7.0	18.8
ENERGY STAR	90.8	4.3	22.4	7.0	18.7
Highest Efficiency	90.8	4.3	22.1	7.0	18.6
No Clothes Washing	91.1	4.1	20.8	7.0	18.3
Double Clothes Washing	90.1	4.3	25.3	7.0	19.3

Figure A23. Minneapolis Clothes Washer Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	102	0.0%	0.0%
ENERGY STAR	101	0.4%	0.5%
Highest Efficiency	101	0.7%	0.6%
No Clothes Washing	100	1.7%	1.7%
Double Clothes Washing	103	-1.6%	-1.6%

Figure A24. Minneapolis Clothes Washer Savings

Occupant Impacts via Freezer

Occupant's impact on home energy use via freezer comes primarily in two means, first by selecting the efficiency of the freezer and second by the quantity and size freezer.

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	16.3	11.0	16.8	7.0	18.8
ENERGY STAR	16.3	10.9	16.8	7.0	18.4
Highest Efficiency	16.4	10.9	16.8	7.0	18.1
No Freezer	17.0	10.5	16.8	7.0	15.6
Two Freezers	15.4	11.5	16.8	7.0	22.0

Figure A25. Houston Freezer Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
ENERGY STAR	99	0.7%	0.9%
Highest Efficiency	99	1.0%	1.4%
No Freezer	95	4.2%	6.0%
Two Freezers	106	-4.0%	-5.9%

Figure A26. Houston Freezer Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	49.5	5.9	21.6	7.0	18.8
ENERGY STAR	49.8	5.9	21.6	7.0	18.4
Highest Efficiency	50.0	5.8	21.6	7.0	18.1
No Freezer	51.4	5.6	21.6	7.0	15.6
Two Freezers	47.8	6.1	21.6	7.0	22.0

Figure A27. Baltimore Freezer Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
ENERGY STAR	100	0.1%	0.3%
Highest Efficiency	99	0.3%	0.8%
No Freezer	97	1.5%	3.5%
Two Freezers	104	-1.6%	-3.6%

Figure A28. Baltimore Freezer Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	90.6	4.3	23.1	7.0	18.8
ENERGY STAR	91.0	4.1	23.1	7.0	18.4
Highest Efficiency	91.4	4.1	23.1	7.0	18.1
No Freezer	93.6	4.0	23.1	7.0	15.6
Two Freezers	87.8	4.5	23.1	7.0	22.0

Figure A29. Minneapolis Freezer Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	102	0.0%	0.0%
ENERGY STAR	101	0.1%	0.3%
Highest Efficiency	101	0.1%	0.5%
No Freezer	100	0.3%	2.0%
Two Freezers	104	-0.4%	-2.1%

Figure A30. Minneapolis Freezer Savings

Occupant Impacts via Microwave

Occupant's impact on home energy use via microwave comes primarily in two means, first by selecting the size of the microwave and second by the quantity of microwave use.

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	16.3	11.0	16.8	7.0	18.8
ENERGY STAR	16.3	11.0	16.8	7.0	18.7
Highest Efficiency	16.3	10.9	16.8	7.0	18.6
No Microwave	16.4	10.9	16.8	7.0	18.1
Double Microwave Use	16.0	11.1	16.8	7.0	19.5

Figure A31. Houston Microwave Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
ENERGY STAR	100	0.2%	0.3%
Highest Efficiency	100	0.5%	0.7%
No Microwave	99	1.0%	1.4%
Double Microwave Use	102	-0.8%	-1.2%

Figure A32. Houston Microwave Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	49.5	5.9	21.6	7.0	18.8
ENERGY STAR	49.6	5.9	21.6	7.0	18.7
Highest Efficiency	49.6	5.9	21.6	7.0	18.6
No Microwave	49.9	5.8	21.6	7.0	18.1
Double Microwave Use	49.1	5.9	21.6	7.0	19.5

Figure A33. Baltimore Microwave Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
ENERGY STAR	100	0.0%	0.1%
Highest Efficiency	100	0.1%	0.3%
No Microwave	99	0.4%	0.9%
Double Microwave Use	101	-0.3%	-0.7%

Figure A34. Baltimore Microwave Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	90.6	4.3	23.1	7.0	18.8
ENERGY STAR	90.8	4.3	23.1	7.0	18.7
Highest Efficiency	90.9	4.3	23.1	7.0	18.6
No Microwave	91.3	4.1	23.1	7.0	18.1
Double Microwave Use	90.0	4.3	23.1	7.0	19.5

Figure A35. Minneapolis Microwave Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	102	0.0%	0.0%
ENERGY STAR	102	0.0%	0.1%
Highest Efficiency	102	0.0%	0.1%
No Microwave	101	0.1%	0.5%
Double Microwave Use	102	0.0%	-0.4%

Figure A36. Minneapolis Microwave Savings

Occupant Impacts via TV/DVD

Occupant's impact on home energy use via a TV/DVD comes primarily in two means, first by selecting the specifications of the TV and DVD player and second by the amount of use.

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	16.3	11.0	16.8	7.0	18.8
ENERGY STAR	16.3	11.0	16.8	7.0	18.7
Highest Efficiency	16.3	10.9	16.8	7.0	18.5
No TV or DVD	16.6	10.8	16.8	7.0	17.3
Double TV and DVD usage	15.9	11.3	16.8	7.0	20.3

Figure A37. Houston TV/DVD Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
ENERGY STAR	100	0.2%	0.3%
Highest Efficiency	99	0.6%	0.8%
No TV or DVD	98	1.9%	2.8%
Double TV and DVD use	103	-1.9%	-2.8%

Figure A38. Houston TV/DVD Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	49.5	5.9	21.6	7.0	18.8
ENERGY STAR	49.6	5.9	21.6	7.0	18.7
Highest Efficiency	49.8	5.9	21.6	7.0	18.5
No TV or DVD	50.4	5.8	21.6	7.0	17.3
Double TV and DVD usage	48.6	6.0	21.6	7.0	20.3

Figure A39. Baltimore TV/DVD Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
ENERGY STAR	100	0.0%	0.1%
Highest Efficiency	100	0.0%	0.2%
No TV or DVD	98	0.7%	1.6%
Double TV and DVD use	102	-0.7%	-1.6%

Figure A40. Baltimore TV/DVD Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	90.6	4.3	23.1	7.0	18.8
ENERGY STAR	90.8	4.3	23.1	7.0	18.7
Highest Efficiency	90.9	4.1	23.1	7.0	18.5
No TV or DVD	92.0	4.1	23.1	7.0	17.3
Double TV and DVD usage	89.3	4.4	23.1	7.0	20.3

Figure A41. Minneapolis TV/DVD Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	102	0.0%	0.0%
ENERGY STAR	102	0.0%	0.1%
Highest Efficiency	101	0.1%	0.3%
No TV or DVD	101	0.2%	1.0%
Double TV and DVD use	103	-0.2%	-1.0%

Figure A42. Minneapolis TV/DVD Savings

Occupant Impacts via Telephone

Occupant's impact on home energy use via telephone comes primarily in two means, first by selecting the specifications of the telephone and second by the amount of telephone use.

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	16.3	11.0	16.8	7.0	18.8
ENERGY STAR	16.6	10.8	16.8	7.0	17.3
Highest Efficiency	16.3	11.0	16.8	7.0	18.8
No Telephone	16.3	11.0	16.8	7.0	18.7
Double Telephones	16.1	11.0	16.8	7.0	18.9

Figure A43. Houston Telephone Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
ENERGY STAR	98	1.9%	2.8%
Highest Efficiency	100	0.0%	0.0%
No Telephone	100	0.1%	0.2%
Double Telephones	100	0.1%	0.0%

Figure A44. Houston Telephone Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	49.5	5.9	21.6	7.0	18.8
ENERGY STAR	50.4	5.8	21.6	7.0	17.3
Highest Efficiency	49.5	5.9	21.6	7.0	18.8
No Telephone	49.6	5.9	21.6	7.0	18.7
Double Telephones	49.5	5.9	21.6	7.0	18.9

Figure A45. Baltimore Telephone Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
ENERGY STAR	98	0.7%	1.6%
Highest Efficiency	100	0.0%	0.0%
No Telephone	100	0.0%	0.0%
Double Telephones	100	-0.1%	-0.1%

Figure A46. Baltimore Telephone Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	90.6	4.3	23.1	7.0	18.8
ENERGY STAR	92.0	4.1	23.1	7.0	17.3
Highest Efficiency	90.6	4.3	23.1	7.0	18.8
No Telephone	90.8	4.3	23.1	7.0	18.7
Double Telephones	90.6	4.3	23.1	7.0	18.9

Figure A47. Minneapolis Telephone Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	102	0.0%	0.0%
ENERGY STAR	101	0.2%	1.0%
Highest Efficiency	102	0.0%	0.0%
No Telephone	102	0.0%	0.0%
Double Telephones	102	-0.1%	-0.1%

Figure A48. Minneapolis Telephone Savings

Occupant Impacts via Computers

Occupant's impact on home energy use via computer comes primarily in two means, first by selecting the specifications of the computer and second by the amount of computer use.

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	16.3	11.0	16.8	7.0	18.8
ENERGY STAR	16.3	11.0	16.8	7.0	18.7
Highest Efficiency	16.3	10.9	16.8	7.0	18.6
No Computer	16.5	10.8	16.8	7.0	17.7
Double the Computers	15.9	11.1	16.8	7.0	19.9

Figure A49. Houston Computers Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
ENERGY STAR	100	0.2%	0.2%
Highest Efficiency	100	0.5%	0.6%
No Computer	98	1.6%	2.2%
Double the Computers	102	-1.2%	-1.9%

Figure A50. Houston Computers Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	49.5	5.9	21.6	7.0	18.8
ENERGY STAR	49.6	5.9	21.6	7.0	18.7
Highest Efficiency	49.6	5.9	21.6	7.0	18.6
No Computer	50.1	5.8	21.6	7.0	17.7
Double the Computers	48.9	6.0	21.6	7.0	19.9

Figure A51. Baltimore Computers Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
ENERGY STAR	100	0.0%	0.1%
Highest Efficiency	100	0.1%	0.2%
No Computer	99	0.6%	1.3%
Double the Computers	101	-0.6%	-1.3%

Figure A52. Baltimore Computers Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	90.6	4.3	23.1	7.0	18.8
ENERGY STAR	90.8	4.3	23.1	7.0	18.7
Highest Efficiency	90.9	4.3	23.1	7.0	18.6
No Computer	91.6	4.1	23.1	7.0	17.7
Double the Computers	89.6	4.3	23.1	7.0	19.9

Figure A53. Minneapolis Computers Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	102	0.0%	0.0%
ENERGY STAR	102	0.0%	0.0%
Highest Efficiency	102	0.0%	0.1%
No Computer	101	0.1%	0.7%
Double the Computers	102	-0.1%	-0.6%

Figure A54. Minneapolis Computers Savings

Occupant Impacts via Ceiling Fans

Occupant's impact on home energy use via ceiling fans comes primarily in two means, first by selecting the efficiency of the fan and second by the quantity fans being used.

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	16.3	11.0	16.8	7.0	18.8
ENERGY STAR	16.3	11.0	16.8	7.0	18.8
Highest Efficiency	16.3	11.0	16.8	7.0	18.7
No Fans	16.3	10.9	16.8	7.0	18.4
Double Ceiling Fan Use	16.1	11.0	16.8	7.0	19.2

Figure A55. Houston Ceiling Fan Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
ENERGY STAR	100	0.1%	0.1%
Highest Efficiency	100	0.1%	0.2%
No Fans	99	0.8%	1.0%
Double Ceiling Fan Use	101	-0.4%	-0.7%

Figure A56. Houston Ceiling Fan Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	49.5	5.9	21.6	7.0	18.8
ENERGY STAR	49.5	5.9	21.6	7.0	18.8
Highest Efficiency	49.6	5.9	21.6	7.0	18.7
No Fans	49.8	5.9	21.6	7.0	18.4
Double Ceiling Fan Use	49.3	5.9	21.6	7.0	19.2

Figure A57. Baltimore Ceiling Fan Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
ENERGY STAR	100	0.0%	0.1%
Highest Efficiency	100	0.0%	0.0%
No Fans	100	0.2%	0.4%
Double Ceiling Fan Use	100	-0.2%	-0.4%

Figure A58. Baltimore Ceiling Fan Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	90.6	4.3	23.1	7.0	18.8
ENERGY STAR	90.6	4.3	23.1	7.0	18.8
Highest Efficiency	90.8	4.3	23.1	7.0	18.7
No Fans	91.0	4.1	23.1	7.0	18.4
Double Ceiling Fan Use	90.3	4.3	23.1	7.0	19.2

Figure A59. Minneapolis Ceiling Fan Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	102	0.0%	0.0%
ENERGY STAR	102	0.0%	0.0%
Highest Efficiency	102	0.0%	0.0%
No Fans	101	0.1%	0.4%
Double Ceiling Fan Use	102	0.0%	-0.3%

Figure A60. Minneapolis Ceiling Fan Savings

Occupant Impacts via Lighting

Occupant's impact on home energy use via lighting comes primarily in two means, first by selecting the efficiency of the lighting and second by the quantity lighting being installed and used.

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	16.3	11.0	16.8	7.0	18.8
100% Fluorescent	16.9	10.6	16.8	4.3	18.8
0 Lights On	17.9	10.0	16.8	0.0	18.8
Double Lighting Energy	14.6	12.0	16.8	14.0	18.8

Figure A61. Houston Lighting Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
100% Fluorescent	96	3.5%	5.1%
0 Lights On	88	9.1%	13.1%
Double Lighting Energy	112	-9.1%	-13.1%

Figure A62. Houston Lighting Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	49.5	5.9	21.6	7.0	18.8
100% Fluorescent	51.0	5.6	21.6	4.3	18.8
0 Lights On	53.3	5.3	21.6	0.0	18.8
Double Lighting Energy	46.0	6.5	21.6	14.0	18.8

Figure A63. Baltimore Lighting Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
100% Fluorescent	97	1.4%	3.1%
0 Lights On	92	3.8%	8.1%
Double Lighting Energy	108	-4.0%	-8.3%

Figure A64. Baltimore Lighting Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	90.6	4.3	23.1	7.0	18.8
100% Fluorescent	93.0	4.0	23.1	4.3	18.8
0 Lights On	96.8	3.8	23.1	0.0	18.8
Double Lighting Energy	84.9	4.8	23.1	14.0	18.8

Figure A65. Minneapolis Lighting Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	102	0.0%	0.0%
100% Fluorescent	100	0.4%	1.9%
0 Lights On	97	1.0%	4.7%
Double Lighting Energy	107	-1.2%	-4.9%

Figure A66. Minneapolis Lighting Savings

Occupant Impacts via Thermostat

Occupant's impact on home energy use via thermostat comes primarily in two means, first by selecting the programmability of the thermostat and second by the use of the thermostat.

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	16.3	11.0	16.8	7.0	18.8
Thermostat set at (74, 72)	29.9	18.4	16.8	7.0	18.8
Thermostat set at (62, 84)	7.0	5.6	16.8	7.0	18.8

Figure A67. Houston Thermostat Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
Thermostat set at (74, 72)	141	-30.0%	-26.9%
Thermostat set at (62, 84)	71	20.9%	18.9%

Figure A68. Houston Thermostat Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	49.5	5.9	21.6	7.0	18.8
Thermostat set at (74, 72)	71.0	10.8	21.6	7.0	18.8
Thermostat set at (62, 84)	31.5	3.1	21.6	7.0	18.8

Figure A69. Baltimore Thermostat Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
Thermostat set at (74, 72)	134	-25.7%	-23.5%
Thermostat set at (62, 84)	77	20.2%	17.7%

Figure A70. Baltimore Thermostat Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	90.6	4.3	23.1	7.0	18.8
Thermostat set at (74, 72)	117.4	10.6	23.1	7.0	18.8
Thermostat set at (62, 84)	68.4	1.3	23.1	7.0	18.8

Figure A71. Minneapolis Thermostat Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	102	0.0%	0.0%
Thermostat set at (74, 72)	139	-23.0%	-22.8%
Thermostat set at (62, 84)	79	17.6%	16.4%

Figure A72. Minneapolis Thermostat Savings

Occupant Impacts via Window Shades

Occupant's impact on home energy use via window shades comes primarily in two means, first by selecting the type of window shade and second by the use of the window shades to block out solar gain during cooling season and keeping heat in during heating season.

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	16.3	11.0	16.8	7.0	18.8
Window Shades Closed	17.3	10.9	16.8	7.0	18.8
Window Shades Open	16.3	11.9	16.8	7.0	18.8

Figure A73. Houston Window Shades Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
Window Shades Closed	101	-1.3%	-0.7%
Window Shades Open	104	-1.3%	-1.6%

Figure A74. Houston Window Shades Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	49.5	5.9	21.6	7.0	18.8
Window Shades Closed	53.3	5.6	21.6	7.0	18.8
Window Shades Open	49.8	6.6	21.6	7.0	18.8

Figure A75. Baltimore Window Shades Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
Window Shades Closed	102	-3.4%	-2.5%
Window Shades Open	103	-1.0%	-1.3%

Figure A76. Baltimore Window Shades Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	90.6	4.3	23.1	7.0	18.8
Window Shades Closed	98.4	3.9	23.1	7.0	18.8
Window Shades Open	90.6	4.9	23.1	7.0	18.8

Figure A77. Minneapolis Window Shades Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	102	0.0%	0.0%
Window Shades Closed	105	-5.1%	-4.1%
Window Shades Open	104	-0.4%	-0.7%

Figure A78. Minneapolis Window Shades Savings

Occupant Impacts via Natural Ventilation

Occupant's impact on home energy use via natural ventilation comes primarily in two means, first by selecting windows that promote natural air movement and second by using windows for natural ventilation in lieu of mechanical heating or cooling.

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	16.3	11.0	16.8	7.0	18.8
Windows Openable All Yea	14.6	12.1	16.8	7.0	18.4
Windows Closed All Year	18.3	9.0	16.8	7.0	18.4

Figure A79. Houston Natural Ventilation Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
Windows Openable All Yea	99	1.2%	0.2%
Windows Closed All Year	99	0.5%	2.4%

Figure A80. Houston Natural Ventilation Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	49.5	5.9	21.6	7.0	18.8
Windows Openable All Yea	49.0	7.8	21.6	7.0	18.4
Windows Closed All Year	54.5	4.1	21.6	7.0	18.4

Figure A81. Baltimore Natural Ventilation Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	100	0.0%	0.0%
Windows Openable All Yea	100	-1.0%	-1.8%
Windows Closed All Year	100	-2.8%	-0.8%

Figure A82. Baltimore Natural Ventilation Savings

Case	Heat Gas	Cooling	DHW	Lighting	Appliance
Base Case	90.6	4.3	23.1	7.0	18.8
Windows Openable All Yea	90.4	8.1	23.1	7.0	18.4
Windows Closed All Year	97.3	3.4	23.1	7.0	18.4

Figure A83. Minneapolis Natural Ventilation Energy Use Scenarios (MBTU per Year)

Case	Hers Index	Site Energy % Savings	Purchased Energy % Savings
Base Case	102	0.0%	0.0%
Windows Openable All Yea	101	-2.3%	-3.7%
Windows Closed All Year	102	-3.7%	-2.5%

Figure A84. Minneapolis Natural Ventilation Savings