REFERENCE DESIGN GUIDE

Final Report

REFERENCE DESIGN GUIDE FOR HIGHLY ENERGY EFFICIENT RESIDENTIAL CONSTRUCTION

Prepared for

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Section 1:
ABSTRACT

The project objective was to determine the least cost path, using conventional approaches, toward achieving a Home Energy Rating System (HERS) score of 90 or better[1] in New York State homes using RESNET accredited rating software[2] to determine the score. Our approach involved a review of energy modeling files of more than 2,000 homes built to the ENERGY STAR standard. Field data from those involved in the home design and construction industry in New York State and surrounding area were also obtained and analyzed. Energy efficiency measures were evaluated and prioritized based on their incremental costs and associated projected savings. Findings show primary savings from the following efficiency measures prioritized by their respective benefit/cost ratio:

1. Reduced duct losses through placement of all ducts within the thermal envelope
2. ENERGY STAR lights and appliances
3. Reduced infiltration levels from .5 to .15 air changes per hour with mechanical ventilation
4. Windows with a U-value of .3 or less
5. Heating system efficiency improvements
6. Water heating efficiency improvements
7. Improved thermal performance of walls and ceilings

Methodologies for implementing these approaches, as well as cost and savings data, and various insights from the field are described in this report.

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[1] The HERS Score defined the reference home as a score of 80 and then calculated the score as a one point adjustment for each 5% difference in projected energy usage. Homes projected to use 50% less energy than the reference home would get a score of 90 (50% savings divided by 5% per point = 10 points better than 80). A HERS score of 84 or higher qualifies a home to be ENERGY STAR .

[2] This report used REM/RATE/rate as the NY ENERGY STAR Labeled Homes program uses this software esclusively. See www.resnet.us/programs/software/directory.htm for a complete list of accredited software.

Section 2:

ACKNOWLEDGEMENTS

The NYSERDA study team consisted of many individuals and organizations, all selected for their specialized expertise in residential energy efficiency technologies and markets. The chart below lists the affiliation and responsibility of each member of the study team.

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Section 3:
SUMMARY

PURPOSE

The purpose of this study is to determine and to explain the least cost path to achieving high levels of energy efficiency in single family detached residential new construction. This study is focused on conventional design and construction methods, materials, and mechanical systems that lead to reduction in energy use as projected, using the Home Energy Rating System (HERS.) It should be noted that there are other approaches to achieving large reductions in energy consumption associated with homes: People can choose to live in smaller houses, live closer to where they work, integrate renewable energy systems into their homes or make behavioral changes that result in significant energy savings. These approaches are numerous, valid and reasonable, but not the subject of this report.

DESCRIPTION OF STUDY

Energy efficiency measures were evaluated in several ways and prioritized based on their incremental costs and associated savings. This report describes a least cost path, using conventional approaches, to achieving a HERS score of 90 or better using REM/*Rate* software version 12 to determine HERS score. The following methodology was used:

1. Review data obtained and establish baseline reference home
2. Analyze REM/*Rate* files on 1,971 NYS ENERGY STAR homes to determine most common efficiency measures used to achieve a HERS score or 90 or better
3. Interview those involved in the design and construction of 90+ homes to learn their preferred approaches
4. Review current literature on cost effective efficiency measures
5. Interviews with builders and key trade allies to gather additional cost data
6. Assess multiple combinations of efficiency measures in REM/*Rate* to determine least cost package
7. Conduct billing analysis of ENERGY STAR homes to assess accuracy of REM/*Rate* consumption estimations

RESULTS

There are numerous technologies, methods and materials currently available and in use to achieve high levels of energy efficiency in residential new construction. There are also multiple information resources on how to integrate these approaches into design and construction practices. Many builders are familiar with energy efficient construction techniques, however they often feel they can't convince their clients that

energy efficiency is worth the extra investment. Virtually all production and custom home builders seem entirely satisfied building to meet minimum code standards. Few have implemented ENERGY STAR certification as a standard or as an optional feature. Many builders have been in the business for generations, and believe that the homes they build are "good enough." Builder education is only one of many barriers to wider spread implementation of high performance building. The primary challenge facing NYSERDA and others in the business of facilitating market transformation is in getting people to understand it, value it, demand it and implement it. The problem is sociological not technological.

Table 1 shows the efficiency measures found to be most cost effective and attainable by conventional builders, sorted in order of cost effectiveness as measured by the ratio of the present value of projected savings to the present value of loan payments, or benefit cost ratio (B/C):

Table 1. Efficiency Measures Ranked in order of Cost Effectiveness

Ranked by Benefit Cost Ratio (Homeowner perspective)						
Measure	**Incremental Cost**	**Annual Savings**	**Change in Monthly Cash Flow in Year 1**	**B/C**	**Change in HERS score**	**$/Point**
Ducts w/in thermal env	$0	$344	-$28.67	∞	2	$0.00
Window Orientation	$0	$131	-$10.83	∞	0.6	$0.00
OVE framing, FG grade 1	$0	$100	-$8.33	∞	0.6	$0.00
Programmable T stat	$20	$25	-$1.95	18.83	0.2	$100.00
Lights and Appliance	$425	$240	-$17.15	8.83	0.6	$708.33
Infiltration-.5 to .15 EOV	$298	$153	-$10.75	8.02	1.2	$248.67
U.3 Windows	$325	$151	-$9.83	4.95	0.8	$406.25
Furnace 78 to 94	$1,785	$471	-$27.26	4.12	2.8	$637.50
On Demand WH	$500	$75	-$2.89	2.34	1.2	$416.67
R-60 Attic	$860	$107	-$3.14	1.94	0.6	$1,433.67
Drainwater heat recovery	$800	$27	$3.12	0.67	0.6	$1,333.33
AC SEER 13 to 15	$500	$8	$2.69	0.25	0.8	$625.00
Totals	$5,514	$1,630	-$98.81	4.62	10	

Our analysis leads to several additional conclusions:

- Getting to a HERS score of 90 is much more difficult now, under REM/*Rate* version 12, than it was under REM/*Rate* version 11, as a result of changes to the reference (baseline) home resulting from codes and standards revisions such as increasing air conditioning SEER rating requirements from 10 to 13, higher water heating standards, and a tighter infiltration rate
- The average HERS rating for participants in the New York State ENERGY STAR Homes Program is well above the 84 point minimum
- REM/*Rate* overestimated average gas heating usage by about 10% when compared to actual consumption. Heating load estimates for walls, attics, windows, and infiltration were all related to measured gas usage, but projected loads from measured duct leakage and from foundations were not found to be related to measured gas usage.
- Usage analysis implies that HERS scores in the 86 to 90 range do not correspond to actual efficiency improvements

RECOMMENDATIONS

1. There is a publication, available on the NYS codes Website, entitled "Field Guide, Residential New Construction; Energy Efficient Construction, ENERGY STAR® Homes, New York Energy Code." This guide outlines many of the approaches discussed in this report. The guide was prepared in 2005 by Conservation Services Group, but was never printed. The guide could be updated and supplemented with findings from this report at a modest cost. We recommend NYSERDA consider updating and printing this guide and making it available as widely as possible.

2. Many homes are not meeting code. Education for building officials, home designers and builders in energy efficiency practices and methods for verification of compliance is recommended

3. Two by four construction is still widely prevalent with wall cavity insulation levels in the R-11 to R-13 range. We recommend educating builders in the merits of rigid foam continuous exterior insulation. This approach can be used with conventional two by four construction. We did not find significant variation in construction practice that was closely correlated to geographic region.

4. As a result of the Thermal Bypass Inspection Checklist, inspectors are finding that fiberglass insulation is most commonly installed at a Grade III level in vertical wall cavities (*Grade III:* Lowest Quality with substantial gaps and voids amounting to 2-5% of the area, open on one side to a vented cavity or not in contact with one surface.). This level of installation leads to significant decreases in the effective R-value of the fiberglass batts. i.e. A rated R-11 fiberglass batt has an effective R-value of 3 with gaps over 5% of the insulated area.

5. Hot water, and electrical loads become a much more significant percentage of total energy use in a house with an efficient thermal shell. Emphasis in efficiency program needs to be placed on these areas concurrently with shell improvement programs.

Additional study may be warranted to dealve more deeply into statewide baseline construction practices, issues with rater input and the descrepancy between actual and modeled energy usage.

Section 4:

DETERMINING CURRENT BUILDING PERFORMANCE LEVEL IN THE HOME CONSTRUCTION MARKET

In order to establish a baseline to determine savings of various efficiency measures, the team surveyed the New York State home construction market to determine typical residential single family detached new construction practices. The builder survey was conducted in cooperation with the New York State Builders Association, on current methods, materials and mechanical systems. (See Appendix 4 for complete survey.) The survey was given at several NYSBA meetings around the state. We also collected approximately 400 REScheck residential code compliance software reports from around the state.

While we were successful in obtaining specific information on over 500 completed homes throughout the state, the summary data regarding methods, materials and mechanical systems was inadequate, inconclusive and misleading. The results of the baseline research are summarized in Table 2 below:

Table 2. Baseline Survey and REScheck Findings

Typical Composite Home	Zone 4	Zone 5	Zone 6
Sample Size	63	394	126
Sq Ft	2,696	1,736	1,873
Volume	23,264	n/a	n/a
Bedrooms	4	n/a	n/a
Living Units	1	n/a	n/a
Foundation	Unconditioned Basement	Walk out	Walk out
Ceiling	R-27.5	R-34	R-38
AG Walls	R-13	R-13	R-19
Foundation Walls	uninsulated	insulated	insulated
Foundation Walls: Inside or Outside	n/a	Interior	Interior
Foundation Walls: Insulation Type	n/a	Fiberglass	Fiberglass
Foundation Walls: Insulation R-Value	n/a	R-13	R-16
Floors Over Basement	R-18	R-24	R-29
Floors Over Garage	R-21	n/a	n/a
Windows	U-47, SHGC-.55	U-38	U-33
Skylights	U-44, SHGC-.42	n/a	n/a
Doors	R-3.17	n/a	n/a
Slab	R-.45	R-10	R-10
Average Infilatration (cfm - 50)	3,098.77	n/a	n/a
Average Infilatration ACH	0.53	0.50	0.50
Joists	R-14	n/a	n/a
Whole hours leakage to outside	382.60	n/a	n/a
Mechanical Ventilation	0.18	n/a	n/a
Number of CAC Units	1	n/a	n/a
SEER - Unadjusted (EER for MF)	10.26	13	14
SEER - Adjusted (charge, airflow, size)	7	n/a	n/a
Number of Heating Units	1	n/a	n/a
Heat Fuel Type	Natural Gas	NG, LP	NG, LP
Heating Distribution System	Ducted	Ducted	Ducted
Duct Insulation	R-4.25	n/a	n/a
Duct Leakage (cfm - 25)	382.60	n/a	n/a
Heating System Efficiency (AFUE)	83.40	90	94
DHW Type	Conventional Tank	Conventional Tank	Conventional Tank
DHW Energy Factor	0.56	0.94	0.80
Average Tank Size (gallons)	33.55	n/a	n/a
Number of DHW Units	1	n/a	n/a
DHW Tank Location	garage	n/a	n/a

After reviewing our findings with the NYSERDA project manager, we decided to use the Energy Conservation Construction Code of New York State as our baseline for comparison. We created a REM/*Rate* energy model of this code compliant house and found that a house that conforms with the code essentially also qualifies as a New York State ENERGY STAR home. As a result of the team's extensive field experience we knew that this was not also indicative of actual construction practices commonly in use in New York State. Our resulting baseline is a combination of code minimum, field based inquiries and review of various regional construction practice studies to create a composite home that aims to represent

average construction practice throughout the state. The features of this composite home are summarized in Table 3 below.

Table 3. Summary of Typical Construction Practices Used to Create Baseline Home

Typical Single Family Detached Home	
Sq ft	2,300
Volume	19,780
Bedrooms	3
Foundation	Conventional concrete Insulated with 2X4 frame wall interior
Rim and band joist	16 o.c. framing, R-19 fiberglass batts friction fit into bays
Ceilings flat	R-35
Ceilings sloped	R-30
AG Walls	2X6 16" o.c. R-19 FG batts Grade III installation
Windows	U - .47 SHGC - .4
Doors	R-4
Average Infiltration ACH	0.5
Air condition SEER rating	13
Heating Fuel	Natural Gas
AFUE	78%
Distribution system	Forced Air
Duct Leakage (cfm-25)	325, total leakage to outside
Hot Water	NG, EF 56%, 40 gal
Location of mechanical systems	Unconditioned (or semi conditioned) basement

Section 5:

NEW YORK STATE ENERGY STAR HOME COMPLETED BUILDING DATA ACQUISITION AND ANALYSIS

Team member Conservation Services Group (CSG) is the ENERGY STAR™ Labeled Homes program administrator for New York State. CSG maintains a database with detailed information about each of the ENERGY STAR™ homes built in New York since 2004. We analyzed this database to identify the characteristics associated with homes receiving various HERS scores. These scores were broken into two categories; those receiving a score of 90 points or more, and those receiving a score of less than 90. Energy ratings for the ENERGY STAR™ Labeled Homes program in New York are done using the REM/*Rate* software. REM/*Rate* stores all of the data inputs and outputs from each rating in a database that contains more than 800 data fields across more than 50 tables. During 2006, the program switched from using REM/*Rate* version 11 to version 12, which involved a modified database format, among other changes. The two databases (versions 11 and 12) provided by program administrator CSG contained data on 2,117 Energy Star Homes built from 2004 through late 2006. The focus of this project is on single family detached homes, so we removed 146 units from the analysis (nearly all town homes) leaving 1,971 homes in the analysis.

A Note on Home Energy Rating Methodology Changes in 2006

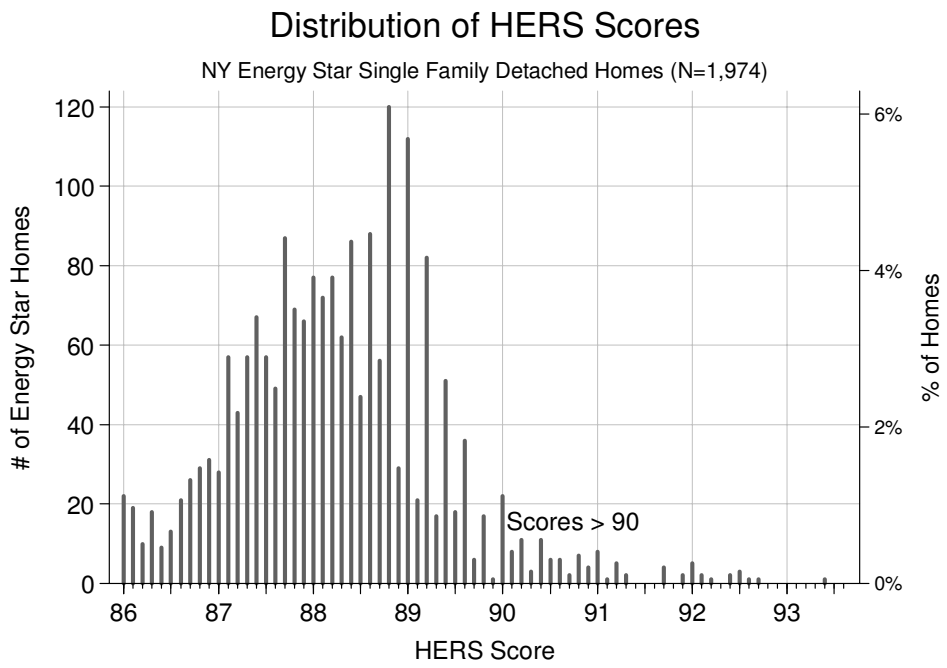
The national standards for home energy ratings were revised in 2006, leading to the release of a new version of the REM/*Rate* software (v.12). These changes created some difficulties in pooling information across homes rated under different versions of the rating system. There were changes in some technical aspects of the ratings (e.g., the new system includes quality ratings for insulation installations), there was also a change in the definition of the reference home, and a change from a HERS Score to a HERS Index. The HERS Score defined the reference home as a score of 80 and then calculated the score as a one point adjustment for each 5% difference in projected energy usage. Homes projected to use 50% less energy than the reference home would get a score of 90 (50% savings divided by 5% per point = 10 points better than 80). The HERS Index is defined as the percentage of the reference homes' energy usage, so a lower score is better and a score of 50 would correspond to 50% savings from the reference home. The technical changes in the ratings standards and reference home complicate any direct translation between the old HERS Score and the new HERS Index. RESNET recommends a conversion formula of:
HERS score = 80 + (100 – HERS Index)/5 for converting version 12 HERS Index to a HERS score. We were, however, trying to compare version 12 HERS Indexes with version 11 HERS scores in 422 of our 1,971 REM/*Rate* files. As a result of the change in baseline to a more stringent baseline home, we employed the following formula to convert the version 12 Index results to the version 11 Scores:
HERS Score = 82 + (100 – HERS Index) / 5

The two point difference is the estimated impact of the upgrade in the baseline. For example, version 12 baseline is SEER 13 AC, while version 11 baseline is SEER 10.

Distribution of Rating Scores

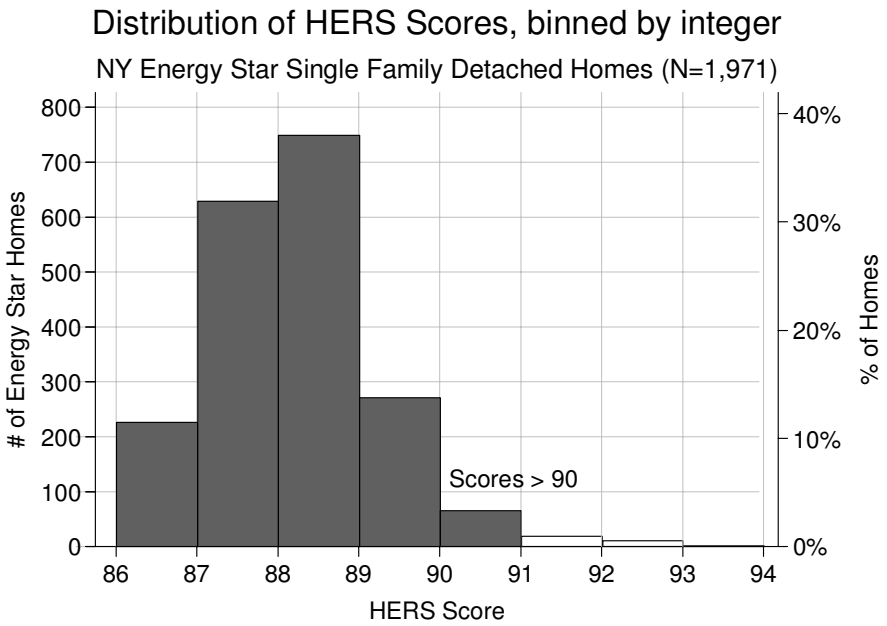
Figure 1 shows the distribution of the rating scores for the 1,974 homes in the database. Just 96 homes had scores greater than 90, but many scored above 89. Interestingly, the figure shows a preference for scores ending in even digits -- 88.8 is the mode, but 88.6, 89.0, 89.2, and 89.4 are all more common than "odd" scores of 88.9, 89.1, and 89.3.

Figure 1. Distribution of REM/Rate HERS Scores



The general pattern of the distribution of scores may be better summarized by binning the scores by integer as shown in Figure 2. The majority of homes had scores between 87 and 89, with more than a third scoring between 88 and 89 and nearly 30% scoring between 87 and 88. Very few homes had scores greater than 90.

Figure 2. Distribution of REM//Rate HERS Scores, Binned by Integer



Geography

Each rated home is assigned to the nearest weather station for REM/*Rate* analysis. These weather stations were then assigned to one of the three DOE climate zones of New York shown in Figure 3.

Figure 3. Climate Zone Map for New York State

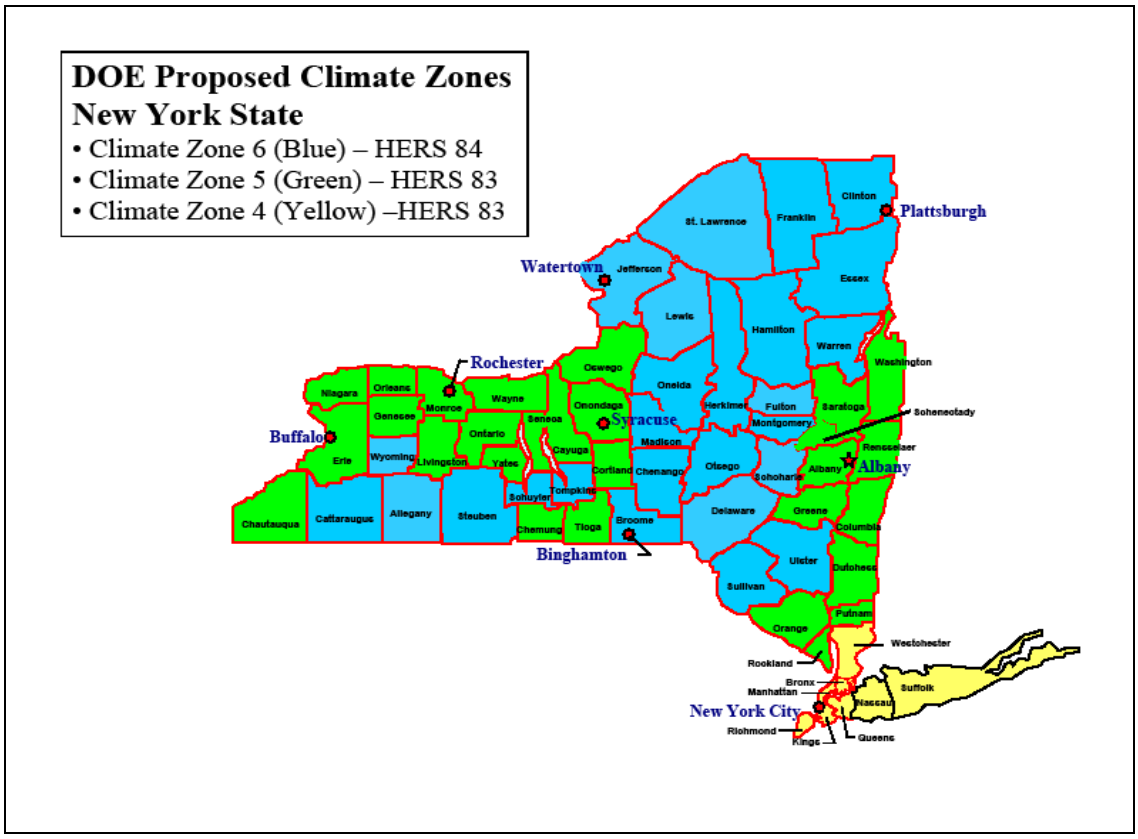


Table 4 below shows the distribution of weather station and climate zone assignments for the Energy Star homes and for the 96 homes scoring greater than 90.

Table 4. Location of homes: weather stations and climate zones

		All Homes		Homes >90		Housing Starts *	
Weather Station	**Climate Zone**	**#**	**%**	**#**	**%**	**#**	**County Name**
Albany	5	238	12%	13	14%	493	Albany
Binghamton	6	13	1%	5	5%	194	Broome
Buffalo	5	495	25%	21	22%	1,304	Erie
Jamesville	5	5	0%	0	0%	1,007	Onondaga
Massena	6	2	0%	1	1%	233	St Lawrence
New York	4	11	1%	6	6%	3	New York City
Newburgh	5	58	3%	17	18%	1,244	Orange
Riverhead	4	2	0%	1	1%	4,241	Suffolk
Rochester	5	918	47%	24	25%	1,395	Monroe
Syracuse	5	227	12%	7	7%	1,007	Onondaga
Watertown	6	2	0%	1	1%	369	Jefferson
Total		**1,971**	**100%**	**96**	**100%**		

* Data for county-wide housing starts

Nearly half of the homes were built in the Rochester area and one quarter were built in the Buffalo area. Very few were built in the New York City metropolitan area. In some areas the NY ENERGY STAR Labeled Homes program was not yet in place at the time of this study. Climate zone 5 contains 98% of the ENERGY STAR homes. Just 13 homes were in climate zone 4, and 17 were in climate zone 6. Curiously, about 15% of the homes scoring above 90 were in these two climate zones (7 of the 13 homes in zone 4 and 7 of the 10 homes in zone 6). However, due to such small sample sizes, the following analysis did not attempt to identify climate-specific approaches to reaching scores greater than 90.

House Size Issues

An initial analysis found that homes scoring greater than 90 (referred to as the 90+ homes) were somewhat larger than those with lower scores (Sub 90 homes). Table 5 summarizes average building size information for the 96 90+ homes and the 1,875 Sub 90 homes.

Table 5. House Size Characteristics

Characteristic	90+ Homes	Sub 90 Homes
Conditioned Floor Area (ft^2)	4,012	3,687
Ceiling Height (ft)	9.5	8.5
Volume (ft^3)	36,553	31,578
Shell Area (ft^2)	8,162	7,300
Shell Area per unit floor area	2.20	2.04
2+ stories	70%	81%
# Bedrooms	3.17	3.50

The 90+ homes averaged 8.8% greater conditioned floor area and one foot higher ceilings, yet had fewer bedrooms and were more likely to have just one story compared to Sub 90 homes. These differences mostly point towards the 90+ homes being more luxurious than the Sub 90 homes.

The difference in size between the 90+ and Sub 90 homes needs to be accounted for when comparing projected loads. A common approach for dealing with differences in the size of houses is to normalize the energy usage on a Btu/ft^2 of conditioned floor area basis. This seemingly intuitive approach can actually introduce its own bias because heat loss tends to occur in proportion to the area of the building shell which will vary not just with floor area, but also with floor plan aspect ratio, number of stories, and ceiling height. For a given ceiling height and number of stories, shell area tends to grow more slowly than floor area, so Btus/ft^2 tend to decline as floor area grows. In this group of homes, that tendency is offset by the greater ceiling height and greater frequency of one story construction for the 90+ homes. Overall, the 90+ homes have 8.8% greater floor area and 11.8% greater shell area than the Sub 90 homes.

Based on these considerations, when comparing heating and cooling loads, between the 90+ and Sub 90 homes, we adjusted for house size by adjusting the 90+ homes' loads using the ratio of shell areas (7,300/8,162= 0.89) as a multiplier.

Heating, Cooling, and Water Heating Fuels

Heating and water heating fuels, and the presence of central air conditioning, are factors that can complicate comparisons between homes. Table 6 shows the distribution of fuel types and the penetration of central air conditioning for the ENERGY STAR Homes.

Table 6. Distribution of Heating, Cooling and Water Heating Fuels

Characteristic	90+	Sub 90
Heating		
Gas	59%	96%
Propane	30%	3%
Oil	2%	1%
Electric	6%	0%
Wood	2%	0%
Water Heating		
Gas	66%	96%
Propane	29%	3%
Oil	2%	1%
Electric	2%	0%
Wood	1%	0%
Central Air Conditioning	**51%**	**35%**

Nearly all of the Sub 90 homes have gas heat while just 59% of the 90+ homes heat with gas. Propane is used in the majority of the non-gas homes and is typically selected due to lack of access to natural gas, not for any efficiency reasons. Virtually all gas and propane heating systems in 90+ and Sub 90 homes were condensing units with efficiencies above 90%. Three of the six electrically-heated 90+ homes had ground source heat pumps. Water heating fuels show a similar pattern. The table also shows that the 90+ homes are more likely to have central air conditioning, although it is still only present in about half the homes.

Projected Annual Loads

Table 7 summarizes the projected annual loads for heating, cooling, and water heating. The heating and cooling loads for the 90+ homes have been multiplied by 0.89 to adjust for the house size differences.

Table 7. Projected Loads

	Projected Usage (MMBtu/yr)		"Savings"	
Load	90+	Sub 90	MMBtu	%
Total Loads (Ht/Cl/HW)	**84.8**	**105.3**	20.5	19%
Reference Load	171.7	179.0	7.3	4%
Savings (vs. Reference)	86.9	73.7	13.2	18%
% Savings (vs. Reference)	51%	41%		
Heating Load	**57.9**	**76.3**	18.4	24%
Reference Heating Load	134.6	143.3	8.7	6%
Savings vs. Reference	76.7	67.0	9.7	14%
% Savings	57%	47%		
Heating Components:				
Walls	17.4	25.0	7.6	30%
Foundation	14.5	17.8	3.3	19%
Roof / Attic	7.2	7.5	0.3	4%
Windows	10.4	11.8	1.4	12%
Infiltration	13.4	15.2	1.8	12%
Fans	3.8	4.5	0.8	18%
Ducts	2.1	8.2	6.0	73%
Internal Gains	-13.8	-16.9	-3.1	-18%
Other	2.9	3.2	0.3	9%
Cooling Load (All Homes)	6.9	**3.7**	-3.2	-86%
Reference Cooling Load	9.3	7.3	-2.0	-27%
Savings vs. Reference	2.5	3.7	-1.2	-32%
% Savings	26%	50%		
Major Cooling Components:				
Windows	7.2	3.6	-3.6	-102%
Infiltration	-0.7	-0.4	0.3	-74%
Roof / Attic	0.3	0.2	-0.2	-101%
Water Heating Load	20.0	**25.3**	5.3	21%
Reference DHW Load	27.8	28.3	0.5	2%
Savings vs. Reference	7.8	3.0	4.8	160%
% Savings	28%	11%		

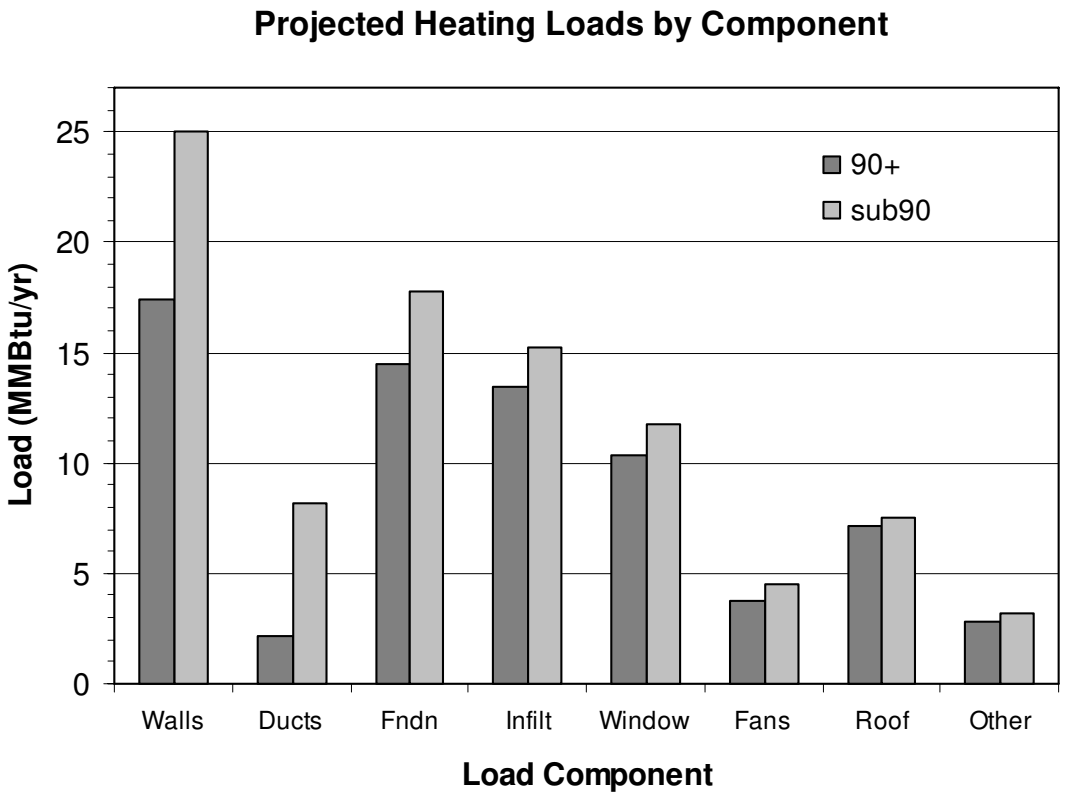
The projected total annual loads for heating, cooling and water heating averaged 85 MMBtu for the 90+ homes (after house size adjustment) and 105 MMBtu for the sub 90 homes. The 90+ homes had 19% smaller projected loads than the sub90 homes. The difference in heating loads was 24%, the difference in water heating loads was 29% and the difference in cooling loads was negative 86% due in part to differences in central air conditioning penetration.

The reference home loads for calculating the energy rating were about 4% smaller for the 90+ homes after adjusting for house size. The projected loads averaged 51% smaller than the reference home for the 90+ homes and 41% smaller than the reference home for the sub90 homes.

The majority of the building loads are associated with heating. Projected heating savings compared to the reference home averaged 57% for 90+ homes and 47% for Sub 90 homes.

Figure 4 shows the average projected heating loads for each building component for the 90+ and Sub 90 homes, except for the internal gain estimates, which are negative. The components are ordered by the size of the load difference between the two groups of homes.

Figure 4. Average Projected Heating Loads by Building Component: 90+ vs. Sub 90 Homes



Walls and ducts are projected to provide the majority of the heating savings relative to the sub90 homes while foundation and infiltration losses also contributed to the difference.

Walls

Walls comprise the largest component of heating loads, responsible for about 30% of the overall projected heating load. The 90+ homes have 30% smaller projected wall loads than the sub90 homes. Table 8 outlines wall construction approaches used in ENERGY STAR homes.

Table 8. Key Wall Construction Features

Characteristic	90+ Homes	Sub 90 Homes
R-Value (average overall)	17.4	12.9
Framing: 2x6	73%	39%
Framing: 24 o.c.	8%	5%
Foam insulation	16%	2%

The 90+ homes have significantly higher average wall R-values due to a combination of more frequent 2x6 wall construction and more frequent use of rigid foam insulation on the outside of walls. Wall construction appears to be a key method used by builders to achieve rating score greater than 90.

Ducts

Duct losses are the second largest contributor to the difference in projected loads between 90+ and Sub 90 homes. Projected duct losses were dramatically lower (by 73%) for the 90+ homes. Table 9 summarizes some duct characteristics of the homes.

Table 9. Duct Characteristics

Characteristic	90+ Homes	Sub 90 Homes
Hydronic	18%	1%
Ducts: Leakage Measured	64%	40%
Ducts: Default Losses	18%	59%
Ducts Inside or Heated Bsmt (% of FWA homes)	76%	95%
Duct Leakage to outside at CFM25*	89	151

* Note: Duct leakage CFM25 was measured in 60 90+ homes and 645 Sub 90 homes and may not represent typical leakage rates

The major reason for the dramatic reduction in projected duct losses for the 90+ homes is that very few of these homes had default duct losses but instead had their duct leakage measured for the rating or had hydronic heat. When duct leakage is measured, especially when ducts are essentially in the conditioned space (or a heated basement), the calculated duct losses are usually quite modest. The "savings" from ducts in 90+ homes may not be real savings, but merely the result of a very pessimistic default duct loss rate, which can be dramatically reduced just by measuring duct leakage. The duct loss default is a penalty built into HERS to encourage duct testing, which will soon be required. Although the 90+ home ducts that were measured were tighter than the Sub 90 homes, it is not clear that there is any significant difference in the real world efficiency of these homes due to duct losses, especially given that the 90+ homes were more likely to have ducts outside the conditioned space.

The default duct losses in the ratings system have caused considerable controversy in Northern climates where the defaults are considered too punitive by many, forcing a significant increase in the cost of providing a rating due to the high cost of duct testing. Most of the research pointing out potential energy

savings from sealing ducts has occurred in cooling climates with ducts located in attics, crawlspaces, and garages. The REM/*Rate* default duct loss is not nearly as punitive in cooling climates.

Foundations

Foundation heat loss was calculated as the sum of the projected loads for foundation walls, crawlspaces, slabs, and foundation floors from the REM/*Rate* output. It is the third largest contributor to the difference in projected heating loads between the 90+ and Sub 90 homes and is responsible for about one sixth of the overall difference. The foundation heat loss of 90+ homes is estimated to be 19% smaller than the losses for the Sub 90 homes. Table 10 shows the frequency of different foundation types and the average R-values of basement walls.

Table 10. Foundation Types & R-Values

Foundation	90+ Homes	Sub 90 Homes
Conditioned Basement	71%	89%
Unconditioned Basement	10%	9%
Conditioned Crawlspace	11%	1%
Closed Crawlspace	0%	0.3%
Slab	7%	0.1%
Multiple Types	0%	0.7%
R-wall Conditioned Basement	20.4	16.5
R-Wall Unconditioned Basement	8.7	13.8

The 90+ homes had more crawlspaces and slab foundations than the sub90 homes, which were virtually all built on basements. Slabs had the lowest average projected heat loss of all foundation types. The 90+ homes also had higher average R-values for walls of conditioned basements. It is not clear if all conditioned basements are always properly assigned since REM/*Rate* indicates that a basement is only conditioned if it has direct heat supply while many practitioners consider a basement conditioned if it has exterior wall insulation.

Infiltration

Projected infiltration loads were 12% smaller in 90+ homes compared to sub90 homes. This difference represents about one tenth of the overall heating load differences between the homes. Table 11 summarizes some key measures of infiltration.

Table 11. Infiltration

Infiltration Measure	90+ Homes	Sub 90 Homes
CFM50	1,762	1,835
CFM50 / ft² floor	0.50	0.51
CFM50 / ft² shell	0.22	0.25
ACH50	3.14	3.57
ACH – natural heating	0.159	0.182

The 90+ homes are 4% tighter than the Sub 90 homes in absolute CFM50 leakage. Adjusting for house size, the 90+ homes are 11% tighter when normalized for shell area and 12% tighter in terms of the more common measure of ACH50 (Air Changes per Hour at 50pa).

Attics

Projected attic loads were just 4% smaller in 90+ homes compared to Sub 90 homes, contributing very little to the overall difference in loads. Ceiling R-values averaged 40.1 in 90+ homes compared to 34.4 in Sub 90 homes, but the overall ceiling loads are so low (about 10% of heating) and the incremental value of higher R-value so small that this difference contributes little to the overall building efficiency.

Windows

Projected window heating loads averaged about 12% smaller in 90+ homes compared to Sub 90 homes contributing a small amount to the overall load differences. Windows are projected to be responsible for 15%-18% of the average heating loads. The 90+ homes had an average window U-value of 0.327 compared to 0.347 for the Sub 90 homes. There was no difference in window SHGC (Solar Heat Gain Coefficient). The 90+ homes had a greater window to floor area ratio: 11.1% compared to 9.7% for the Sub 90 homes (note: floor areas include conditioned basement areas). This difference occurs primarily in homes with cathedral ceilings.

Water Heating

The raw projected water heating loads were about 21% smaller for 90+ homes than Sub 90 homes. On a per bedroom basis, which drives much of the water heating load estimate, the difference is just 11%. Differences in equipment efficiency drove this difference in loads. Table 12 shows the types of water heaters in the homes and average Energy Factor ratings.

Table 12. Water Heating

	90+ Homes	Sub 90 Homes
Conventional	49%	96%
Instantaneous	32%	2%
Integrated	16%	1%
Ground Source Heat Pump	2%	0%
Energy Factor	.74	.61

Nearly all of the Sub 90 homes used conventional water heaters while half of the 90+ homes used alternatives such as instantaneous water heaters, integrated water heater / boilers, and ground source heat pumps. These differences led to an average 74% EF for the 90+ homes compared to 61% for Sub 90 homes.

Cooling

As mentioned previously, central air conditioning was more common in 90+ homes than Sub 90 homes (51% vs. 35%). Because of this difference, 90+ homes had much larger projected cooling loads than Sub 90 homes. Still, **cooling loads are only about one tenth as large as heating loads** and so the overall penalty on the rating score is relatively modest.

Infiltration appears as a negative cooling load, implying that tighter homes would have higher cooling loads than leakier homes. This is an attempt to account for people opening the windows when the temperature is below the thermostat set point.

Summary of Features Associated with 90+ Ratings

In addition to the analysis of each component of the projected loads, we also tabulated the frequency of certain efficiency "features" in the 90+ and Sub 90 homes to identify common combinations that contributed to 90+ scores. Table 13 shows the number of 90+ and Sub 90 homes that have each combination of five energy features:

- Wall: wall R-value greater than 16;
- Duct: non-default duct losses (either hydronic or leakage tested);
- DHW: non-conventional water heater
- Win: window R-value greater than 3; and,
- GSHP: ground source heat pump

The rows of the table are sorted by the proportion of homes with the specified features that have rating scores greater than 90.

Table 13. Frequency of Energy Features

Energy Features	# 90+ Homes	# Sub 90 Homes	% 90+
Wall GSHP (1 w/Win)	3	0	100%
Wall DHW Duct Win	13	7	65%
Wall DHW Duct	4	3	57%
Wall Duct Win	20	32	39%
Wall	4	7	36%
DHW Duct	6	11	35%
Wall DHW Win	1	2	33%
DHW Duct Win	13	27	33%
DHW Win	2	8	20%
DHW	1	7	13%
Wall Win	3	28	10%
Wall Duct	4	47	8%
Duct	11	397	3%
Duct Win	7	253	3%
Win	2	303	1%
No Features	2	743	0%

The table shows that all three homes with ground source heat pumps (GSHP) had ratings greater than 90 and these homes also had higher wall R-value (and 1 had higher window R). The majority of homes with wall, water heating, and duct features also qualified for 90+ ratings. About one third of the homes with water heating and duct features qualified as 90+. Almost none of the homes qualified as 90+ if they had none of these features or if they just had window and duct features. It almost always required water heating and/or wall features combined with other features to meet the 90+ threshold.

Section 6:

COST AND SAVINGS OF EFFICIENCY MEASURES

Costs vary widely in New York as everywhere. This study includes results from interviews with builders, suppliers, estimators and other experts in the state in an attempt to develop reasonable estimates of average incremental costs for a variety of efficiency measures. The summary of costs and savings of these measures is presented in this section of the report. The presentation is organized by measure with a discussion of the role each measure can play in reducing energy use. Additionally this section will provide pictures and/or graphs on how it can be applied; and present a summary table that includes the estimated cost, annual energy bill savings, HERS score improvement, and benefit-cost ratio (annual energy bill savings to annual mortgage payment, assuming 30 year mortgage and 7% interest rate). Note that our cost estimates do not take into consideration either the $2,000 federal tax credit available for homes built to the standard we are analyzing, or the tax deductions for the interest portion of mortgage payments.

Estimating incremental costs accurately is very difficult. For example, how much various wall configurations cost is dependent on perceptions of various builders as much as actual time and materials expenses. It is difficult to identify definitive costs for various systems, materials and methods as it depends on level of experience as well as market conditions, which are perpetually moving targets. In addition, it is very difficult to persuade builders, vendors and/or others to provide precise costs, both because they are reluctant to provide confidential data so key to their business, and because they are reluctant to spend the time necessary to extract actual costs or compute incremental costs when they cannot be easily extracted. Finally, changes to one element of construction often affect another in ways not often considered by builders during standard surveys. Thus, estimates of costs should be viewed as best approximations at the time of writing of this report.

COST AND SAVINGS METHODOLOGY

- Cost and savings for various efficiency improvements in new construction are typically financed through the homeowner's mortgage. Therefore costs were amortized over the life of a 30 year loan at 7% interest. These amortized costs, expressed in terms of monthly payments, were then compared to the monthly energy savings, based on retail prices, to determine net impact in terms of monthly cash flow to the home owner.
- In addition to impacts on monthly cash flow, Net Present Value (NPV) and Benefit to Cost (B/C) ratio of these investments was calculated. NPV is the present value of future net cash flows over the term of the loan using a real discount rate of 5%. The B/C is the ratio of the present value of the savings divided by the present value of the costs (loan payments). Measures that have a NPV of greater than 0 and a B/C of >1 are cost effective measures.

- The assumptions for these calculations are a nominal discount rate of 7.73%, and an inflation rate of 2.6% yielding a real discount rate of 5%. (This approximates the average real discount rate as used in energy efficiency measure savings analysis in NY, VT, and MA. This analysis also includes energy price escalation (beyond inflation) of 2%.

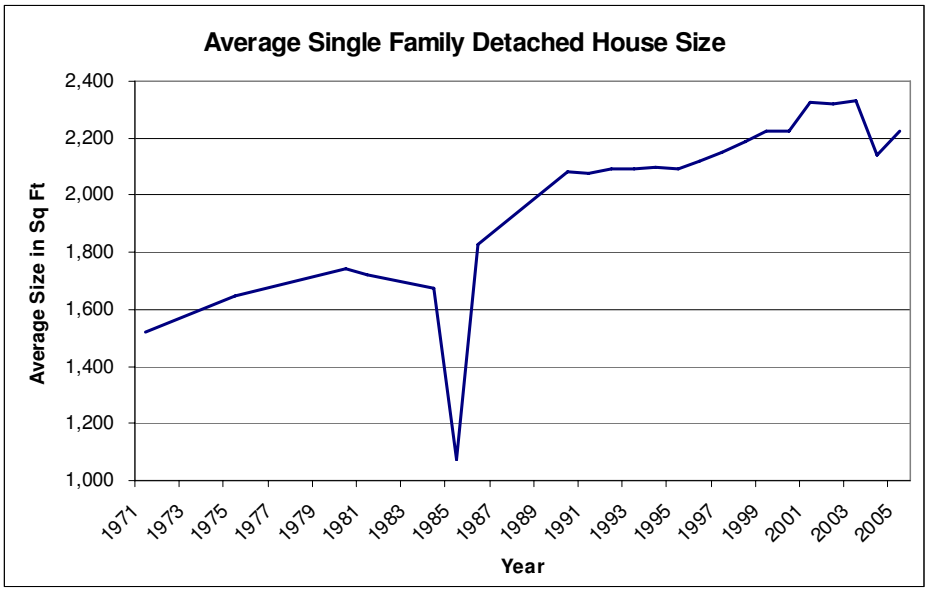
SUMMARY OF EFFICIENCY MEASURES

No Cost – Low Cost Energy Saving Measures

The following items are efficiency measures that can be integrated into new homes at zero or negative incremental costs. Consultation with energy efficiency and building science experts at the beginning of the design process can result in significant impacts on the home's comfort, durability and resource consumption throughout the life of the building.

- **Build Smaller**
  Eliminating excess square footage, removal of formal dining, removal of formal entry, use of multi-purpose rooms, reduced storage, use of dimensional framing for attic rafters as opposed to trusses or insulated ceilings, insulating slopes as opposed to knee walls to capture more conditioned storage space, and finished basements are all excellent approaches to achieving architectural program objectives in a smaller space. Figure 5 summarizes the trend in average house size.

Figure 5. Average House Size (U.S. DOE 2006 Building Energy Data Book)



- **Simplified Building Shape**

  Keeping the shape of the building simple improves performance at negative cost, since it's also cheaper to build. Avoid cantilevers and complicated roof lines, in particular, avoid creating North facing roof valleys. Be sure to create a continuous thermal envelope.

- **Orientation**

  Site the house on the lot where it has access to southern light and is sheltered from prevailing winds. Ideally the long axis of the home should be oriented East and West. Minimize North glazing, locate more windows on the south wall, size overhangs to reduce summer overheating, use higher SHGC (>.4) on South windows and integrate mass to capture winter sun. Place rooms of most occupancy on the South side with stairs, bathrooms and storage areas on the North.

  - Resources; "Builder's Guide to Cold Climates" section 1; Design

- **Tune Glazing**

  Higher SHGC on South wall, lower on West walls to reduce cooling loads.

- **Summer Gains Strategies**

  Strategic use of overhangs and deciduous trees can also significantly reduce summer heat gain while allowing the winter sun through.

- **Simplified HVAC**

  With a tight, well insulated house so there is no longer a necessity for heat supply on outside walls. This allows for the potential to greatly simplify distribution systems to a central trunk with fewer and shorter branches. This, combined with a smaller furnace to meet reduced demand for heat, can save thousands of dollars in mechanical costs.

- **Integrated Design**

  Coordinate layout of mechanical and distribution systems as well as plumbing vent stacks before the building is built.

- **Advanced Framing**

  Optimum Value Engineered framing saves on materials used and may save on labor as a result of fewer pieces being handled.

- **Right Sized HVAC**

  Standard practice is often to oversize to reduce call backs. An oversized system will cycle more frequently, which is less efficient than running a smaller system for longer periods. Research shows that installation issues, such as proper refrigerant charge levels and air flow over cooling coils for CAC systems, can sometimes result in greater savings than increased SEER rating.

Subsystem	Subsystem Incremental Cost	Annual Savings	Improvement in HERS Score	Benefit Cost Ratio
Orientation, tuned glazing,	$0	$131	.6	∞
OVE Framing, FG insulation G1	$0	$100	.6	∞

Infiltration:

The importance of good air sealing at the time of construction (pre-drywall) can not be overemphasized. The best time to inspect for and repair potential leaks is just before insulation is installed to enable identification of the leak source. While homeowners can and will change most things in a house, it is difficult and expensive to make changes to the thermal shell after initial construction. Meticulous attention to sealing, caulking and foaming all shell penetrations and verifying performance with a blower door to achieve .18 ACH is commonly being achieved by ENERGY STAR home builders in NYS. In order to achieve these levels, the insulation specification should be written explicitly to state air sealing goals, and the use, and timing of use, of a blower door. The EPA ENERGY STAR Homes Thermal Bypass Checklist is a great resource to help builders unfamiliar with air sealing techniques.

Advanced air sealing must go hand in hand with mechanical ventilation, or by solving one problem you may be creating several more. Mechanical ventilation is typically achieved through one of three means. The most efficient approach is energy recovery ventilation, followed by heat recovery ventilation. The least expensive approach is exhaust only ventilation, achieved by putting upgraded household fans, such as bath fans, on timers to ensure a specified amount of air exchange is occurring. Avoid using the furnace fan for ventilation as this fan typically moves more air than is necessary. Efficiency gains are enhanced by specifying an HRV system that uses an electrically commutated motor, ECM. An HRV unit with an ECM such as the RecoupAerator® by UltimateAir™ will move roughly twice the volume of air, per watt, of a conventional motor.

The average infiltration value for the 90+ homes in our REM/*Rate* analysis was .16. In fact the average infiltration value for all the ENERGY STAR homes in the REM/*Rate* analysis was .18. This indicates that significant improvements over code minimum air leakage requirements are regularly being achieved[3].

[3] NYS code does not give credit for air change levels below .35. ENERGY STAR requires ventilation for air tightness levels below .35. It should be noted that when tightening a house below .35 ACH and adding heat recovery ventilation, overall energy use goes up as you are exhausting some heated air and using electricy to run the ventilation fan. Building tight and vetilating provides for optimal comfort, health and safety as well as energy efficiency.

Figure 6. Continuous Exterior Insulation and Strapping Detail

Figure 7. Leaks at Top and Bottom of Building Take Highest Priority (Stack Effect)

Figure 8. Blower Door Air Tightness Testing

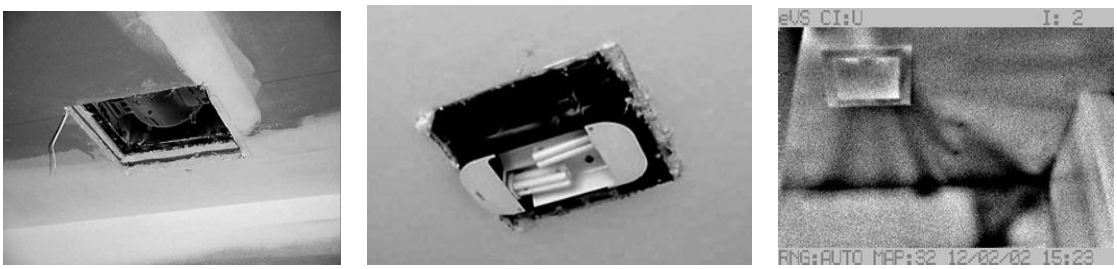
Concentrate on big openings first, then move on to smaller details. A blower door can be used at several points during the construction process to help locate leaks.

- Omit polyethylene vapor barrier. A polyethylene vapor barrier on the inside is a problematic approach to reduce air infiltration, and can capture water in the wall cavity under certain circumstances.

(2 coats of latex paint are an effective vapor barrier in an air managed wall assembly)

- Use insulating materials that serve as good air barriers
    - Foam- spray on, and board
    - Dense packed cellulose
    - Spray applied cellulose

Figure 9. Fan Housings Should be Sealed to Sheetrock



If drywall is air barrier, seal it to windows, doors, sub floor, ceiling fans, lighting cans…

A chase is a messy air sealing detail, and a great place for 2-part foam.

Figure 10. Plumbing and Electrical Penetrations and Chases, Use Two Part Foam

Figure 11. Sealing Window and Door Openings and Rim and Band Joists With Spray Applied Foam is the Best Way to Seal and Insulate This Difficult Area

Figure 12. Switch and Outlet Boxes

Figure 13. Ducts to Sheetrock

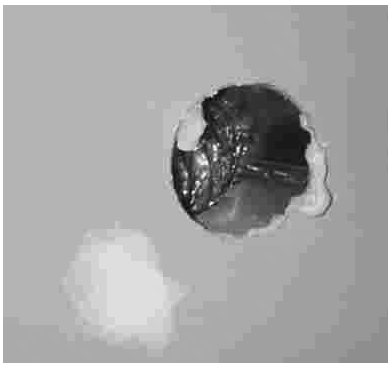


Figure 14. With a Tight Shell, You Must Provide Fresh Air; Heat Recovery Ventilation Provides Fresh Air Without Losing all the Energy in the Heated Air

Subsystem	Subsystem Incremental Cost	Annual Savings	Improvement in HERS Score	Benefit Cost Ratio
Advanced air sealing package, from .5 ACH natural to .15	$273.4	$182	1	10.4

<u>Lights and Appliances</u>

Electricity savings for lights and appliances can be significant. The current version of REM/*Rate* takes in to account L&A usage and gives credit for efficient choices. L&A upgrades for the 90+ home in this

analysis includes 75% fluorescent lighting, clothes dryer and oven/range switched to natural gas and a refrigerator upgraded from 675 to 400 kWh/year usage.

Subsystem	Subsystem Incremental Cost	Annual Savings	Improvement in HERS Score	Benefit Cost Ratio
Lights and Appliances	$425	$240	.6	8.83

Optimize HVAC Equipment & Distribution

Heating, Ventilating and Air Conditioning (HVAC) equipment should be designed appropriately for tthe specific building. When a building's shell is air tight and well insulated, the heating and cooling loads are considerably reduced. This allows for use of smaller, cheaper HVAC equipment.

- Size HVAC equipment according to the calculated heat loss of your building, not the installer's recommendation
- Use only the distribution that you need
- Locate ducts (and preferably all mechanical systems) within the thermal envelope
- Simplify layout of distributed systems. A central trunk with few branches can save thousands of dollars on unneeded equipment
- With an airtight, well-insulated building, the drywall side of exterior walls will remain within 2.2°F during the entire heating season. This eliminates the need for heat on outside walls and allows for simplified centralized duct runs.

Outside Air	Inside Air	Wall Surface
50°F	68	67.4
20	68	66.3
-10	68	65.2[4]

[4] Interior wall surface temp = Interior air temperature (deg. F) – ((0.68(interior air temp – exterior air temp)) / R-value of the wall assembly)

Figure 15. Saving on HVAC Distribution

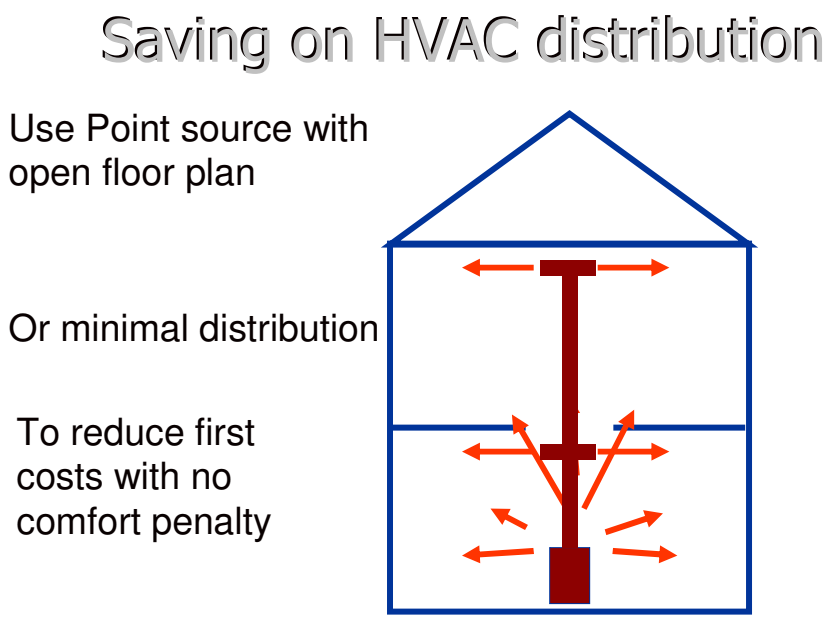


Figure 16. Drainwater Heat Recovery

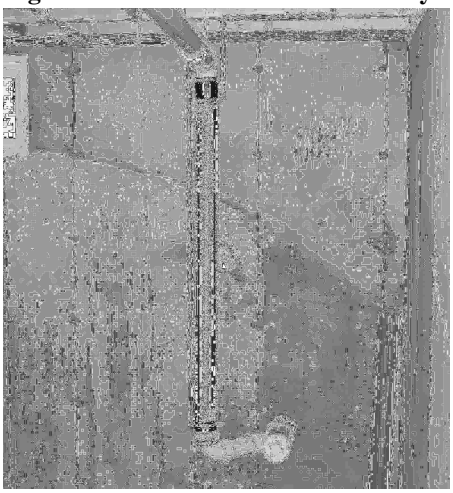


Figure 17. High Efficiency Boiler with Side Arm DHW Storage Tank

Subsystem	Subsystem Incremental Cost	Annual Savings	Change in monthly payment	Improvement in HERS Score	Benefit Cost Ratio
Furnace upgrade, 78 to 94 AFUE	$1,785	$471	$-27.26	2.8	4.12
Programmable Thermostat	$20	$25	$-2	.2	17.39
Ducts inside	$0	$344	$-28.67	2	∞
On Demand DHW	$500	$75	$-2.89	2	2.34
Drainwater Heat Recovery	$800	$27	$3.12	.6	.67

Thermal Shell:

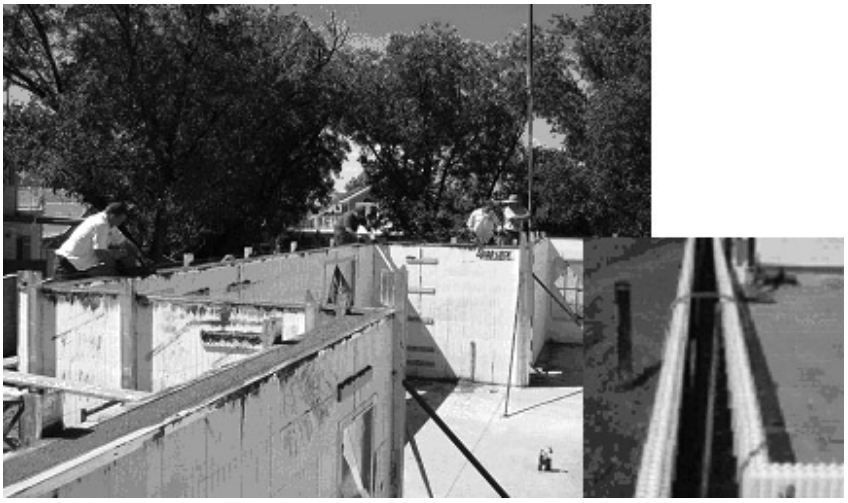
In the climate of New York State, the priority for decreasing residential energy consumption is to maximize reduction in heating load through thermal performance improvements in the building shell (including foundation). Done properly, this can account for a 50 % decrease in heating energy usage in an average home with minimal and cost effective improvements in conventional practices. When these thermal shell improvements are combined with passive strategies, efficient mechanical and distribution equipment, energy efficient lighting and appliance choices, and adequate home owner education in the proper use and maintenance of these technologies, high levels of energy efficiency can be obtained today with minimal additional investment.

Foundation:

NYS code, and the IECC require basement walls to be insulated. Insulated Concrete Forms - ICFs - were chosen as the recommended efficiency measure for foundation walls because they are the least cost path to achieve an R-22.5 insulation value if finishing the basement in the future, which often occurs.

As with many of these measures, incremental costs are widely variable. Many homes with full basements eventually finish all or part of the space. ICFs, have integral fastening systems for easy application of wall finish. With ICFs, openings are already framed out with nailing surfaces for doors and windows. This is not the case with a conventional poured wall. Some ICFs require less cement, saving on material costs. Among those surveyed, the consensus was that there is a slight premium for ICFs, but that many builders felt the benefits were worth the costs.

Figure 18. Insulated Concrete Forms (ICFs)



Subsystem	Subsystem Incremental Cost	Annual Savings	Improvement in HERS Score	Benefit Cost Ratio
Conventional to ICF Foundation	$3,000	$129	.8	.51

Walls:

Several wall systems were analyzed for insulating value, ease of air tightening and cost. The most cost-effective approach to achieving an energy efficient wall structure, using relatively conventional approaches, is to apply 2" of rigid foam continuous exterior insulation, regardless of framing method or cavity insulation type. Advanced framing, or optimum value engineering (OVE) framing, as it is also known, involves the reduction of framing members by going from 16" to 24" o.c. spacing, as well as other techniques, and uses approximately 30% fewer pieces. This should lessen labor costs and framing time as well as allowing for higher levels of insulation and reduced thermal bridging. Two-by-four 24"o.c. framing is possible in a two story home if trusses are stacked above wall studs. Using this method can have a negative incremental cost resulting from the reduction of materials used. There is a learning curve associated with switching to advanced framing techniques. While learning a new system, it will take more time to build insulated headers, use drywall clips, build ladder blocking, etc. Framers are not yet recognizing a labor saving for OVE framing. The saving in materials is approximately $450 for a 3,000 square feet house.

Using rigid foam in lieu of plywood sheathing with let in bracing, or shear panels, provides a highly energy-efficient wall system at a cost comparable to conventional approaches. (*"Guide to Insulating Sheathing" Building Science Corp.)* This would probably be the most cost effective approach, and there are several builders currently using this technique. Insulated sheathing is not analyzed in this report, however, because it is perceived as unconventional.

Costs associated with the various wall systems shown in Table 14 are widely variable. While SIPs (Structural Insulated Panels) score well in terms of insulating value and quite well on air tightness as well,

their costs are generally considered to be on the order of 5% to 10% higher than other wall systems, lowering their benefit cost ratio.

Table 14. Wall Systems and Associated R Values

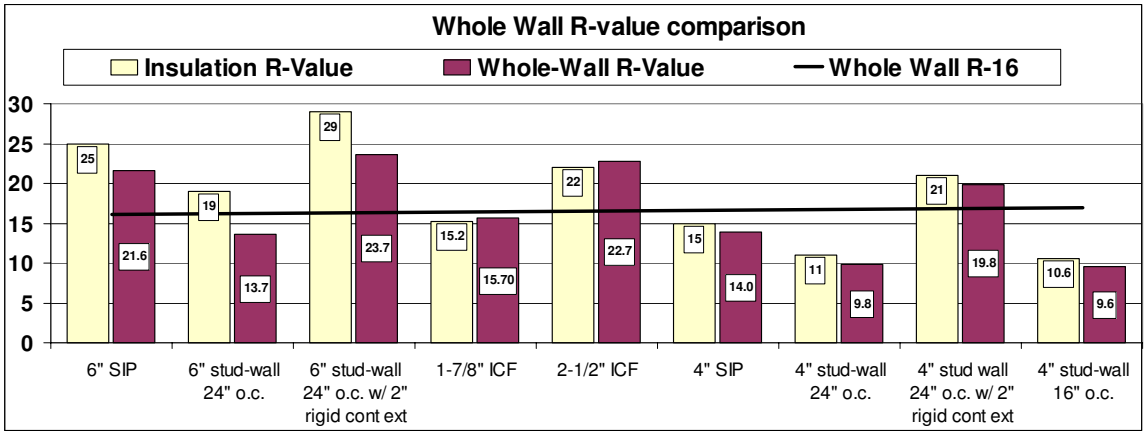


Figure 19. Good Cellulose Insulation

Subsystem	Subsystem Incremental Cost	Annual Savings	Improvement in HERS Score	Benefit Cost Ratio
2X6 24oc, FG w/ 2" rigid continuous exterior	$2,636	$301	1.6	1.78
OVE framing, FG grade 1	$0	$100	.6	∞

Windows:

Windows are the building's weakest link in its thermal shell, as well as being one of the most expensive building components. Glazings should be used wisely to frame for views and to harvest passive gains. While code requires a U-value of .35, U-values of as high as .5 are regularly being installed. A recent study of 76 homes built in Long Island showed an average U-value of .47. The incremental cost of going from .47 to .3 is relatively small. This efficiency improvement is usually obtained by adding low-E coating and filling the space between the panes with an insulating gas such as argon. To get below about U-.25

generally requires going to triple glazing. Triple glazed argon-filled windows with two low-e coatings are available with a whole-window U-factor as low as 0.17. This adds considerable cost for a relatively modest improvement in performance over double paned low-e argon filled glazings. Most window brands and sellers these days have common units in stock in the range of U.29 to U.33. The cost differential for window types varies considerably based on method of construction. Cost does not generally vary directly with U-value. In other words, a U-value of .3 can be specified at no incremental cost. A U-value .3 window can be purchased for the same price as a U-value .45 window, or even less. In buying the same window type, from the same manufacturer, there is an incremental cost of between 5% and 10% to add Low-e coating and argon gas, which generally brings the window down to a U-value of .3 or less.

Subsystem	Subsystem Incremental Cost	Annual Savings	Improvement in HERS Score	Benefit Cost Ratio
Window U.47 to .3	$325	$151	.8	4.95

Ideally Solar Heat Gain Coefficient should be specified for windows of different orientations. The Solar Heat Gain Coefficient, also called a shading coefficient, is a measure of how well a window absorbs or reflects heat from the sun. The lower the coefficient, the better the window is at blocking the sun's heat. Windows should be specified with low (<.4) SHGC on west facing orientations in particular, and higher SHGC should be specified on south facing windows. Resources: http://www.efficientwindows.org. "Residential Windows: A guide to new technologies and energy performance book," third edition, Carmody/Selkowitz/Arasteh/Heschong.

Ceiling insulation:

The baseline home in this report has 962 square feet of R-35 insulation blown in over trussues with a 2X6 bottom chord for R-19 in the cavities and R-16 continuous over the top. The baseline also has 50 square feet of vaulted area with 2X10 16" oc with R-30 batts installed to grade III. Improving this to R-60 in the flats and R-38 in vaults going to 2X12 16" oc. provides measurable savings at modest incremental costs.

Subsystem	Subsystem Incremental Cost	Annual Savings	Improvement in HERS Score	Benefit Cost Ratio
R-60 Ceiling	$860	$30	.2	1.94

Figure 20. R-60 Cellulose Attic Insulation

Water Heating:

Water heating represents between thirteen and seventeen percent of national residential energy consumption, making it the second largest energy end use in homes. As homes become more energy efficient, the percentage of energy used for water heating and for lighting and appliances steadily increases. Of the 9.8 million water heater shipments in the U.S. in 2006, 4.8 million were conventional electric-resistance and 4.7 million were conventional gas storage. Advanced water heating technologies constitute a very small portion of the market. Using the DOE test procedure for calculations, a whole-home gas tankless water heater with a 0.80 Energy Factor would consume 187 therms per year. This is a saving of nearly 30%, or 74 therms, in comparison to the typical gas storage water heater. The annual energy savings equal $102, using the national average gas rate. (from the *California Energy Commission, 2005 Integrated Energy Policy Report.)*

The analysis in this study, using REM/*Rate,* is consistent with the above findings, going from a standard 40 gallon natural gas water heater, with a federal minimum energy factor of 56%, to a tankless on-demand water heater with an EF of 81%, saves 44% of water heating energy use. However much of the heat lost in an inefficient water heater offsets space heating demand, so the net impact for the efficiency improvement is $75 per year savings. Savings may be even greater as national test proceedures may overstate water consumption due to lag time in recognizing implementation of water saving technologies. The effect of more efficient water use in a conventional gas water heater is that standby losses are an even higher percentage of of total water heating energy consumption. Using a high efficiency boiler to heat a hot water storage tank for domestic water heating is also a sound approach.

Subsystem	Subsystem Incremental Cost	Annual Savings	Improvement in HERS Score	Benefit Cost Ratio
Water heating, EF .56 to .81 tankless	$500	$75	2	2.34
Drainwater Heat Recovery	$800	$27	.6	.67

Solar water heating is a cost effective measure and it improves the HERS score by 1.6. NYSERDA directed that solar water heating be excluded from this analysis, as the focus is on shell improvements.

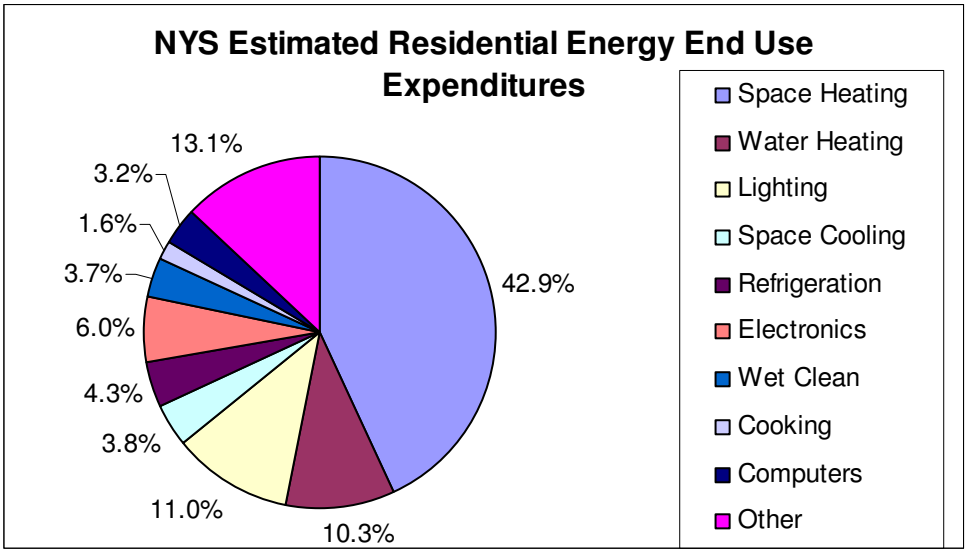
Table 15, below, is the list of all efficiency measures analyzed. The first twelve items represent the least cost package of measures to get to a HERS score of 90. The change in HERS scores is not additive because of interactive effects of measures. The measures are listed in order of benefit/cost ratio, but can be re-ordered depending on the desired perspective. For example a home owner might want them prioritized by their change to monthly cash flow, or a builder might order the measures in terms of $/point, or a developer might rank them by first cost.

Table 15. Efficiency Measure Cost and Savings Summary

LIST OF ALL MEASURES						
Measure	Incremental Cost	Annual Savings	Change in Monthly Cash Flow in Year 1	B/C	Change in HERS score	$/point
Ducts w/in thermal env	$0	$344	-$28.67	∞	2	$0.00
Window Orientation	$0	$131	-$10.83	∞	0.6	$0.00
OVE framing, FG grade 1	$0	$100	-$8.33	∞	0.6	$0.00
Programmable T stat	$20	$25	-$1.95	18.83	0.2	$100.00
Lights and Appliance	$425	$240	-$17.15	8.83	0.6	$708.33
Infiltration-.5 to .15 EOV	$298	$153	-$10.75	8.02	1.2	$248.67
U.3 Windows	$325	$151	-$9.83	4.95	0.8	$406.25
Furnace 78 to 94	$1,785	$471	-$27.26	4.12	2.8	$637.50
On Demand WH	$500	$75	-$2.89	2.34	1.2	$416.67
R-60 Attic	$860	$107	-$3.14	1.94	0.6	$1,433.67
Drainwater heat recovery	$800	$27	$3.12	0.67	0.6	$1,333.33
AC SEER 13 to 15	$500	$8	$2.69	0.25	0.8	$625.00
MEASURES ABOVE ARE LEAST COST PATH TO HERS 90						
.5 to .35 ACH	$273	$182	-$13.33	10.4	1	$273.40
.5 to .15 HRV	$2,773	$103	$10.04	0.58	1.2	$2,311.17
ICF foundation walls	$3,000	$129	$9.40	0.67	0.8	$3,750.00
Above grade wall 2" foam	$2,525	$301	-$8.13	1.86	1.6	$1,578.13
Window U-value to .2	$6,240	$245	$21.49	0.61	1.4	$4,457.14
Solar water heating	$7,000	$205	$29.93	0.46	1.6	$4,375.00

Figure 21, below, shows the approximate breakdown of energy use by end use for single family detached homes in New York State. As the thermal shell becomes more efficient, hot water and electric loads become a larger percentage of total energy use.

Figure 21. Energy Use by End Use in NYS



Section 7:

CONCEPTUAL DESIGN FOR HIGH PERFORMANCE BUILDING

There are numerous paths to achieving highly energy efficient houses. Likewise there are numerous experts advocating a variety of methods and materials to obtain energy efficient construction. The approach in this report was to find the least cost path to energy efficiency using commonly available materials and relatively conventional approaches to building. A HERS score of 90 can be achieved with a conventionally framed house if air sealing is implemented as outlined in the ENERGY STAR thermal bypass checklist; mechanical ventilation is included to enable the savings to be claimed from reduced air leakage; readily available U.3 windows are used; attics are insulated toR-60 and high efficiency mechanical equipment is specified, such as readily available 94% efficient furnace, (with all ducts inside the thermal envelope); and an on demand water heater with an EF of 81% or better is used. (A high efficiency boiler with a storage tank for domestic hot water is also a great approach. Additionally, ductless mini split systems which concentrate the cooling where needed are a great alternative to central air conditioning.) As REM/*Rate* version 12 or higher calculates the whole house energy use in assigning a HERS score, our conceptual house uses readily available cost competitive ENERGY STAR appliances and a majority of fluorescent lighting.

Taking results from our REM/*Rate* analysis, builder surveys and interviews, expert interviews and field visits, a conceptual house was designed in REM/*Rate* that incorporates the most cost effective efficiency measures to get to a HERS score of 90. The primary elements that lead to advanced levels of energy efficiency are summarized in Table 16.

Table 16. 90+ Concept House Summary of Design Elements

Thermal Shell		
Foundation	2” of rigid foam on the exterior, Or ICFs or equivalent	
Walls	2 X 6 24” o.c. framing with fill insulation and 2” continuous rigid foam exterior	
Windows	U-.3 or better	
Doors	Pre-hung insulated	
Ceilings	R-60	
Infiltration Measures	Achieve infiltration of .15 ACH natural	Add mechanical ventilation
Mechanical Systems		
Furnace	AFUE 90 or better	
Ducts	Located within the thermal envelope	Sealed. Insulation not necessary
Boiler	AFUE 90 or better	Include indirect water heater
Water Heating	EF of 81 or better	Consider indirect or instantaneous
Drainwater heat recovery		
Lights and Appliances		
ENERGY STAR™ Appliances	Fluorescent bulbs and fixtures in 50% of	

	locations.	

Figure 22. Energy Efficient Shell Measures

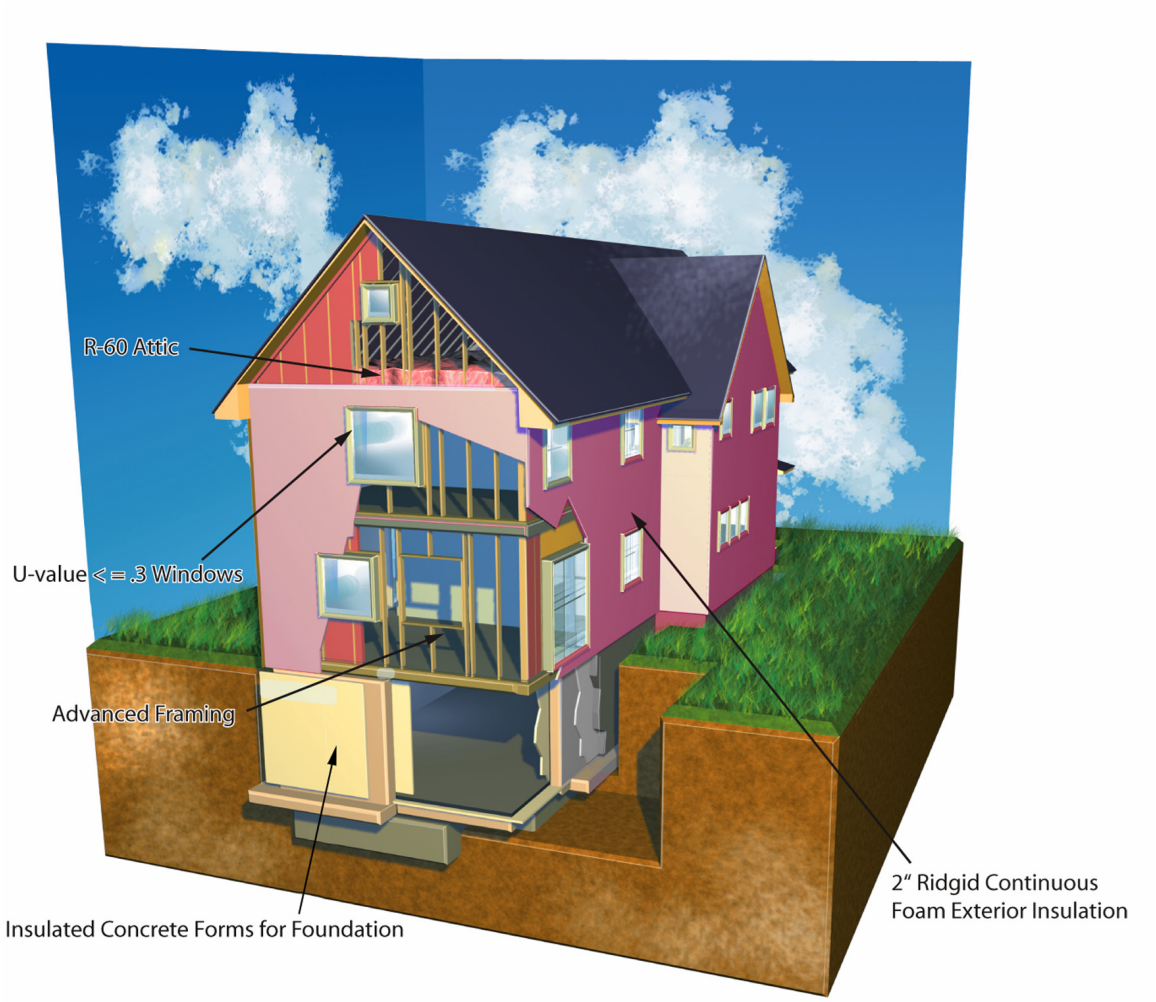


Figure 23. Energy Efficient Mechanical Measures

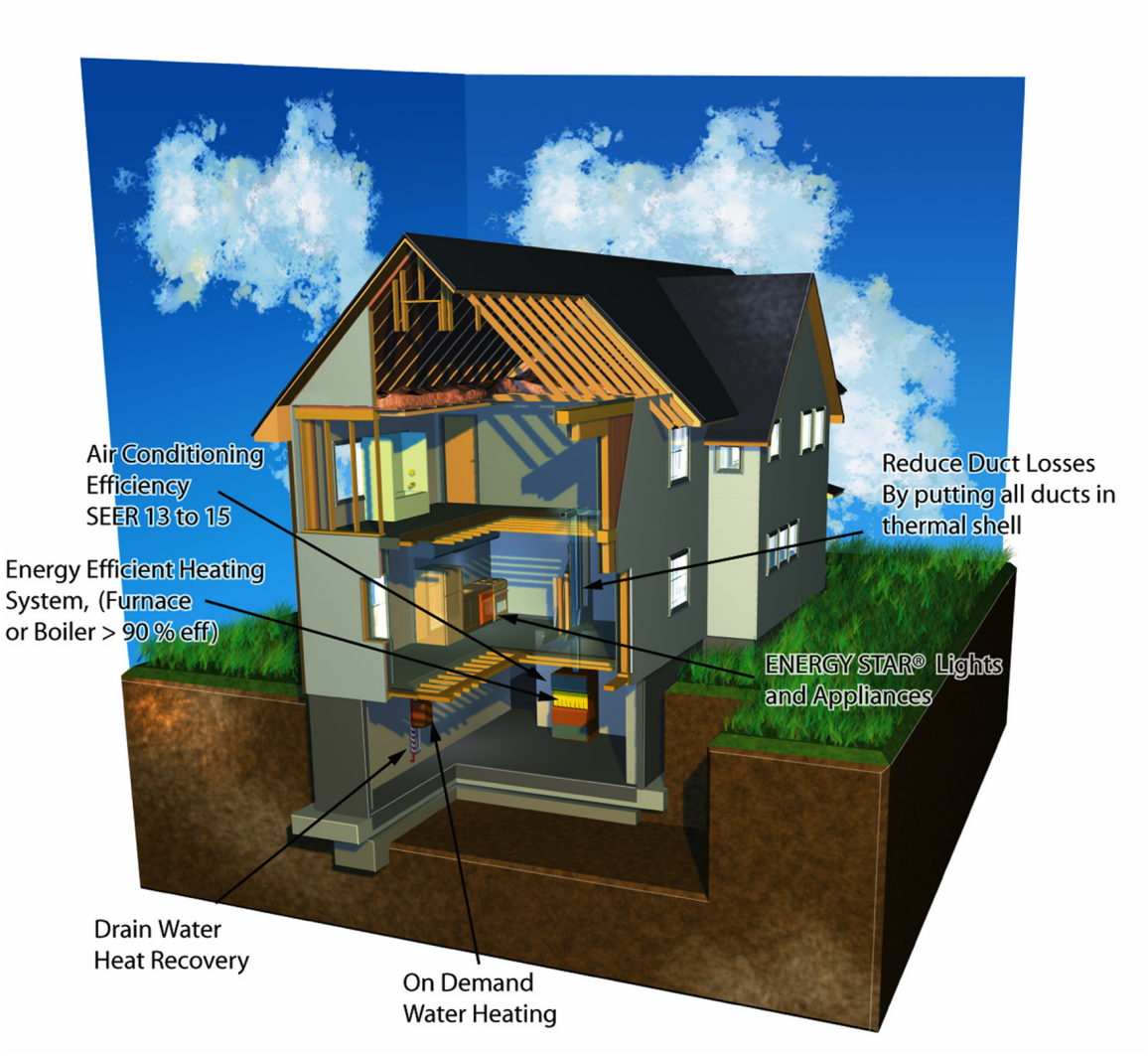


Figure 24. Orient the Building to Maximize Passive Gains

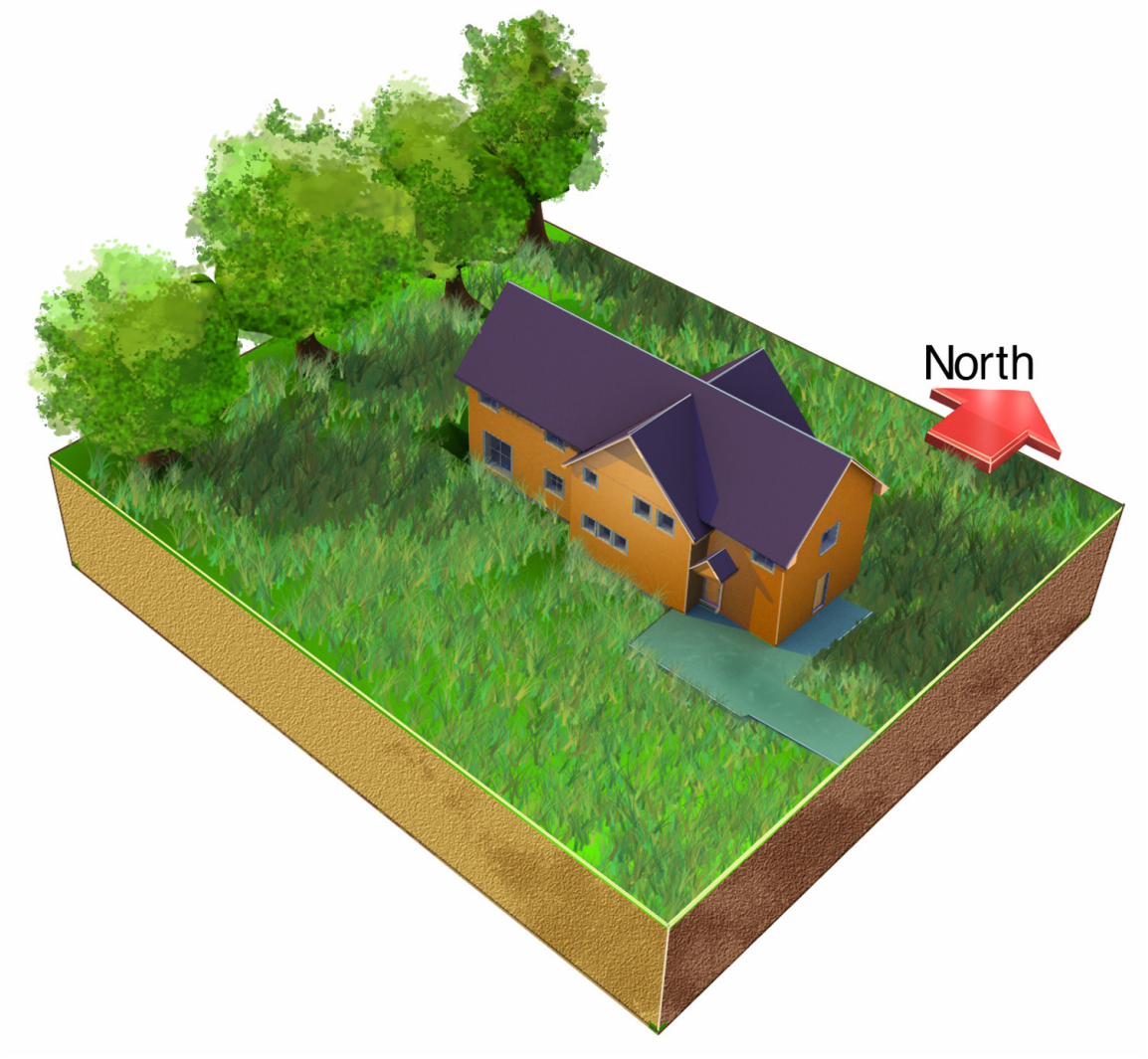
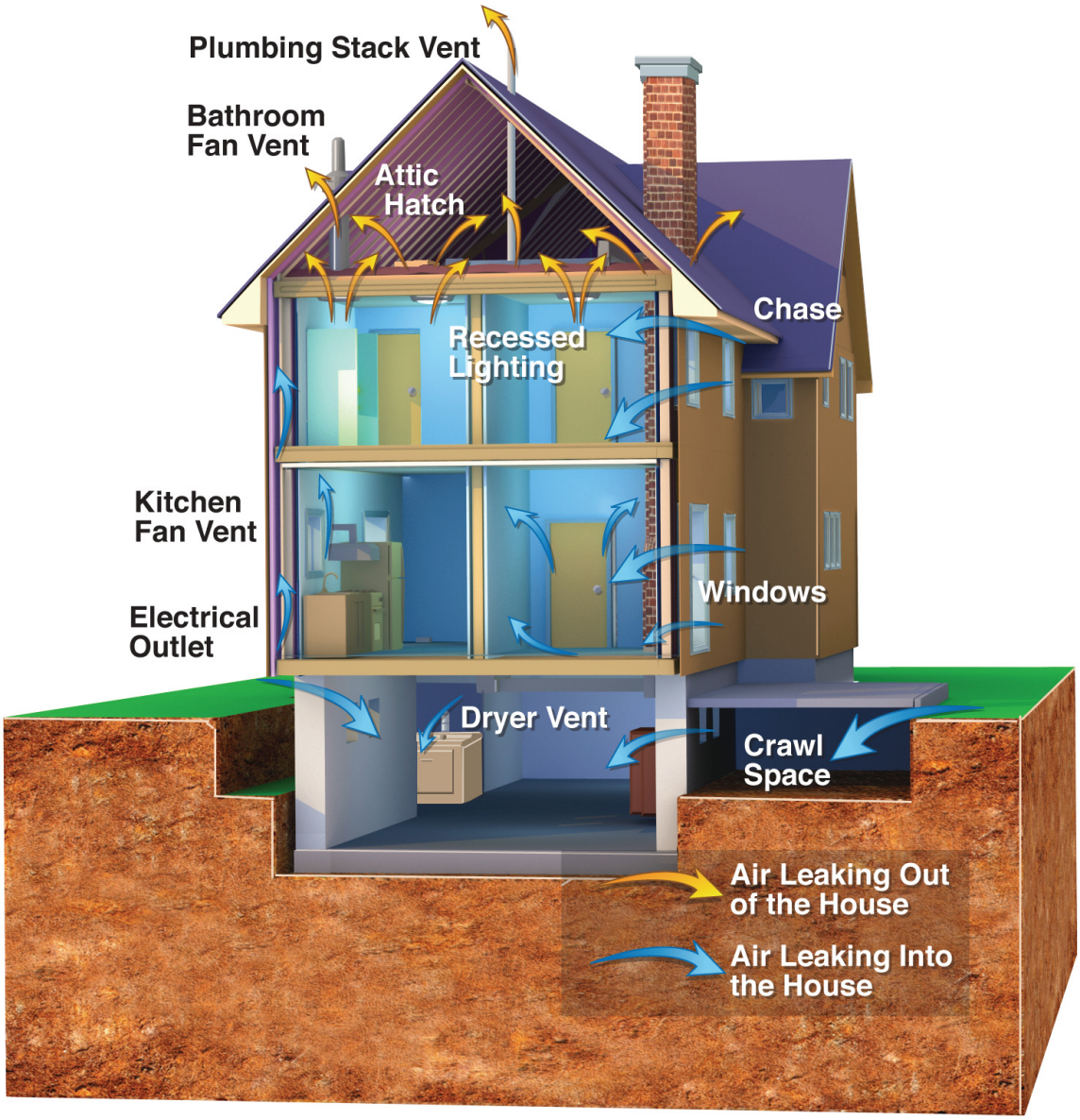


Figure 25. Common Air Leakage Paths



Section 8:
FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

If followed, the Energy Conservation Construction Code of New York State will produce very energy efficient houses. In fact, depending on the compliance approach taken, often an ECCC of NYS code compliant house complies with the NYS ENERGY STAR Labeled Homes program requirements. However many homes are not being built this way in New York State. This is a complex issue involving numerous influences from code interpretation and enforcement, to builder and consumer attitude, and understanding of strategies for achieve energy efficiency. While this study outlines cost effective strategies to achieving high levels of energy efficiency, the larger challenge is getting conventional builders to understand and implement them, and getting consumers to understand and value them.

Analysis of 1,971 ENERGY STAR homes built in New York State shows the typical path leading to a HERS score of 90 or better involves the use of more efficient wall systems, more efficient distribution systems, such as hydronic, or placing all ducts within the thermal envelope, and use of high efficiency water heating equipment. Other items that also can contribute significantly to higher HERS scores are infiltration levels and window U values and orientation.

Surveys and RES-Check files of numerous New York State builders, as well as existing studies on current construction practice, lead to the following conclusions and recommendations:

1. Many homes are not meeting code. Education in energy efficiency practices and methods for verification of compliance is recommended for building officials, home designers and builders.
2. Two-by-four construction is still widely prevalent with wall cavity insulation levels in the R-11 to R-13 range. Educating builders in the merits of rigid foam continuous exterior insulation is recommended. This approach can be used with conventional 2X4 construction.
3. We did not find significant variation in construction practice that was closely correlated to geographic region.
4. There is no penalty for house size in ENERGY STAR. The average size of the 1,971 ENERGY STAR homes in our analysis was 3,702 sq ft. That is about 60% larger than an averagesized house. Building larger homes more energy efficiently does not lead to a reduction in energy use. Another example of this is refrigerator efficiency, which has increased 75% since the mid 1970s. However at the same time, the increase in refrigerator ownership, the percent of homes having two or more refrigerators, and the average size of refrigerators have resulted in no net reduction in residential refrigerator electrical consumption: 1974, 125.9 billion kWh, 2006, 124.9 billion kWh. *(Putting Energy Efficiency in a Sustainability Context; The Cold Facts About Refrigerators. Jack N. Barkenbus, October, 2006.)*
5. Code minimums for mechanical system efficiencies are outdated
6. NY ENERGY STAR Labeled Homes window U-value requirements could be more stringent

7. Ducts placed in the attic waste substantial amounts of energy. This can be avoided with thoughtful design.
8. Air leakage; research indicates that while homes are meeting code on this issue, ENERGY STAR builders are producing houses with 1/3 the air leakage, with minimal additional expense.
9. The use of central air conditioning is growing. Emphasis should be placed on sizing CAC correctly, charging it correctly with refrigerant and ensuring that air flow over the cooling coils is as designed
10. Fluorescent lighting is not the norm. Perceptions of poor lighting quality from fluorescents persist.

Comparison of actual energy use to REM/*Rate* - predicted energy use showed the REM/*Rate*-predicted usage averaged about 10% greater than the actual usage. The analysis further showed that increasing the HERS score from 86 to 90 does not directly correlate to less energy use. There are too many variables including the algorithyms in the software, the raters diligence in gathering data, the data itself, the small sample size, etc. to draw definitive conclusions from this; however it is a disturbing finding. (See Appendix 1 for more information.)

OTHER FINDINGS OF NOTE

Effects of Education on Behavioral Changes to Achieve Energy Efficiency

Occupant behavior has significant quantifiable impacts on energy use. There are considerations of which the designer and builder of homes should be aware in order to develop dwellings that support energy conserving awareness and behavior. Occupants need to be educated on how to properly operate an energy efficient dwelling (or an inefficient dwelling) to realize the energy savings potential as fully as possible.

Energy use in the home may be reduced by 20% through changes in behavior. Consumer education can produce significant and measurable energy savings. *(Energy and Environmental Security, Swedish Defense Research Agency)* In recognition of this, there is the first ever "Behavior, Energy, and Climate Change Conference" being held November 7 - 9, 2007 in Sacramento, California.

RECOMMENDED SOURCES OF INFORMATION

Energy efficiency is a priority for the State of New York. New York State Energy Research and Development Authority (NYSERDA) is the agency that facilitates the State's energy efficiency efforts. NYSERDA is a public benefit corporation created in 1965 by the New York State Legislature to help solve New York's most difficult energy and environmental issues. In the residential sector, there are considerable resources to assist in achieving energy efficiency:

The New York Energy $mart Program - a partnership between NYSERDA and the Public Service Commission (PSC) – is the ENERGY STAR® Program provider in New York State.
The New York Energy $mart Find-A-RESOURCE MAP (http://www.getenergysmart.org/resource.asp) for: ENERGY STAR Homebuilders, Products Retailers & Home Performance Contractors near you.

Home Performance with ENERGY STAR, a national program from the U.S. EPA and U.S. DOE, offers a comprehensive, whole-house approach to improving energy efficiency and comfort at home, while helping to protect the environment.
New York State ENERGY STAR Labeled Homes Program provides builders with technical assistance and targeted financial incentives to encourage the adoption of energy-efficient design features and the selection and installation of more energy-efficient equipment.
ENERGY STAR Products Program, is designed to save energy by increasing the market share of ENERGY STAR and energy-efficient products in homes throughout New York State. The program accomplishes this by addressing both the supply and demand for these products, including appliances, lighting, and home electronics.
Energy Smart Students program, empowers K-12 teachers by providing them with teacher-developed, classroom-tested materials on the science of energy, sources of energy, electricity, energy efficiency and conservation, alternative fuels, and Hydrogen.
The New York Energy $martSM Communities Program creates networks of organizations and agencies that contribute to energy-focused community projects.
EmPower New York Program provides low income weatherization services.
New York State, Department of State, Division of Code Enforcement and Administration has numerous resources including the "Field Guide to Residential New Construction," a great resource.
http://www.dos.state.ny.us/code/energycode/residential.htm
Energy and Environmental Building Association, EEBA building guides, www.eeba.org
Building Science Corporation, Authors of the Builders Guide to Cold Climates, the definitive resource for home designers and builders on building science and energy efficient construction approaches.
www.buildingscience.com
Residential Energy, Cost Savings and Comfort for Existing Buildings, Krigger, Dorsi. While this volume is aimed at existing buildings, there is much great info regarding home energy use to inform a designer or builder of a new home.

Section 9:

APPENDICES

APPENDIX 1: ENERGY USE DATA ANALYSIS

We analyzed gas and electric energy consumption data of a sample of Energy Star homes as part of this project to help assess whether differences in HERS scores are related to differences in actual energy usage, and to explore for potential patterns in any discrepancies that may be related to building characteristics. This consumption analysis was a relatively small part of the overall project and should not be considered in any way a comprehensive evaluation of the effectiveness of NYESH. No data was collected on non-Energy Star new homes for comparison.

Data Collection

A mailing was sent to 887 NYESH homes completed during 2005, asking for homeowners to sign fuel record release forms so we could access utility usage data. A total of 240 signed release forms were returned, a 27% response rate.

Usage data were requested from five utility companies: National Grid, National Fuel Gas, New York State Electric & Gas, Rochester Gas & Electric, and Central Hudson Gas & Electric. We were able to obtain matching utility gas usage histories for 142 homes and electric usage histories for 167 homes. RG&E served about half of the homes with matching data.

Analysis Approach

The raw usage data from the utility were "cleaned" to deal with estimated meter readings and to eliminate meter readings that may represent unoccupied periods. All usage prior to 2006 was excluded to avoid potential pre-occupancy usage. Periods were also excluded if they spanned fewer than 20 days or more than 40 days, indicating an off-cycle reading or correction. Initial months with less than 5 therms of gas consumption or 200 kWh of electric consumption were also dropped as potentially pre-occupancy. Electric usage periods were also dropped if the usage was less than 150 kWh or was less than 200 kWh for a home where median monthly usage was more than 400 kWh.

The energy usage data for each home was weather-normalized, using weather data from the REM/*Rate*-assigned local weather station (Albany, Binghamton, Buffalo, Rochester, and Syracuse were the stations used).

For gas usage, we employed a variable-base heating degree day regression model. The model fit a heating degree day reference temperature for each home, which maximized the regression R-squared, similar to the PRISM™ model. However, we employed a slightly modified version of the algorithm that penalizes unusual reference temperatures. There were 130 homes with gas usage data for the analysis. The weather normalization results were screened to eliminate homes with potentially unreliable results, defined as having an R-squared less than 0.7, or a standard error of normalized usage greater than 10%, or negative

baseload or heating estimates, or standard errors of greater than 100% for heating or baseload. Eighteen homes were eliminated by this screening, leaving 112 homes with gas usage results.

For electric usage, we employed a fixed heating and cooling degree day adjustment procedure using reference temperatures of 70°F for cooling and 60°F for heating. There were 158 homes with usage data for analysis. We eliminated cases as unreliable if the usage data did not span at least 270 days, include at least 40% of a typical year's heating and cooling degree days, and include at least one month of true baseload. This screening eliminated 29 homes from the analysis, leaving 129 homes with electric usage results.

Gas Usage Results

Table 17 summarizes the gas usage analysis results including summaries of overall gas use and REM/*Rate*-predicted gas use as well as break-outs of heating and baseload, and usage normalized for floor area and building shell area.

Table 17. Gas Usage Summary

			Percentiles of Distribution				
Characteristic	**Mean**	**±90% c.i.**	**10th**	**25th**	**Median**	**75th**	**90th**
Total Gas Use (MMBtu/yr)							
Actual Gas Use	106.9	±3.9	76.3	89.0	104.8	125.1	141.4
Predicted Gas Use	119.0	±3.8	90.4	103.1	117.4	131.4	146.3
Actual as % of Predicted	91%	±3%	70%	81%	91%	102%	113%
Heating Use	80.4	±3.3	53.1	65.9	77.2	93.7	110.6
Predicted Heating Use	88.1	±3.7	60.5	73.2	85.3	101.2	115
Reference Heating Use	145.5	±5.9	98	118.7	143	170.8	189.1
Actual as % of Predicted	93%	±3%	68%	78%	93%	105%	118%
Baseload Use	26.5	±1.7	13.3	18.0	25.5	32.8	39.8
Predicted Baseload Use	30.9	±0.8	24.9	27.8	29.2	34.0	39.3
KBtu/ft² Floor Area							
Total Use	31.0	±1.3	22.6	26.0	29.7	35.0	43.3
Predicted Use	34.5	±1.2	26.9	29.3	32.8	38.6	48.6
Heating Use	23.2	±1.0	16.3	19.2	22.5	26.7	31.2
Predicted Heating Use	25.1	±0.9	19.5	21.9	24.3	27.8	30.8
Heating Use: Btu/ft²/HDD65	3.42	±0.14	2.43	2.83	3.35	3.97	4.58

KBtu/ft² Shell Area							
Total Use	14.9	±0.5	11.2	12.8	14.5	16.9	19.1
Predicted Use	16.5	±0.4	13.5	14.7	16.4	18.3	19.2
Heating Use	11.1	±0.4	7.9	9.4	10.8	12.5	14.4
Predicted Heating Use	12.0	±0.3	9.6	10.9	12.1	13.1	14.3
House Information							
HERS Score	87.9	±0.1	86.9	87.4	87.9	88.4	89.0
Conditioned Floor Area (ft²)	3,609	±159	2,472	2,903	3,684	4,193	4,657
Shell Area (ft²)	7,336	±254	5,367	6,109	7,202	8,383	9,470
Volume (ft³)	31,325	±1,444	20,908	25,145	31,204	36,570	43,860
2+ Stories	81%	±6%					
# Bedrooms	3.54	±0.10	3	3	4	4	4

Annual gas usage averaged 106.9 MMBtu (1,069 therms) in the 112 homes with results. The weather normalization algorithm estimated heating usage at 80.4 MMBtu and baseload usage at 26.5 MMBtu, which includes water heating and may also include cooking, clothes dryers, and gas fireplaces.

The analysis group includes no homes with HERS scores greater than 90, includes just two homes with instantaneous water heaters, two homes not built on basements, and all have gas forced air heating systems.

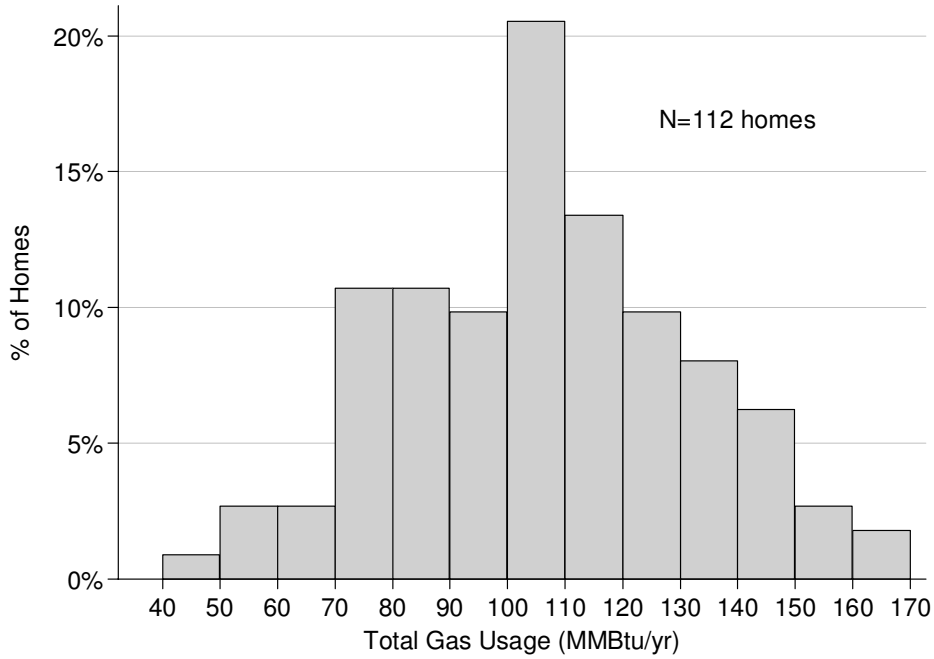
The Energy Star homes in the analysis have average gas use comparable to the average home in upstate New York, and this usage costs approximately $1,800 per year at recent gas rates of about $1.70/therm. However, the ES homes were quite large – averaging 3,609 ft² of conditioned floor space. It appears that the efficiency of ES new construction was able to compensate for the larger size of the homes to produce approximately average usage.

For comparison, an analysis of Energy Star homes in Wisconsin[6] found 13% lower average gas usage of 92.8 MMBtu for similar sized homes (3,570 ft²) in a colder climate. The heating energy intensity in those Wisconsin homes averaged 2.51 Btu/ft²/HDD65 compared to 3.42 for these New York State homes.

Figure 26 shows the distribution of annual gas usage. The usage ranged from 48 MMBtu to 170 MMBtu. Usage was less than 100 MMBtu for 37% of the homes, 21% used between 100 and 110 MMBtu/yr, and 42% used more than 110 MMBtu/yr.

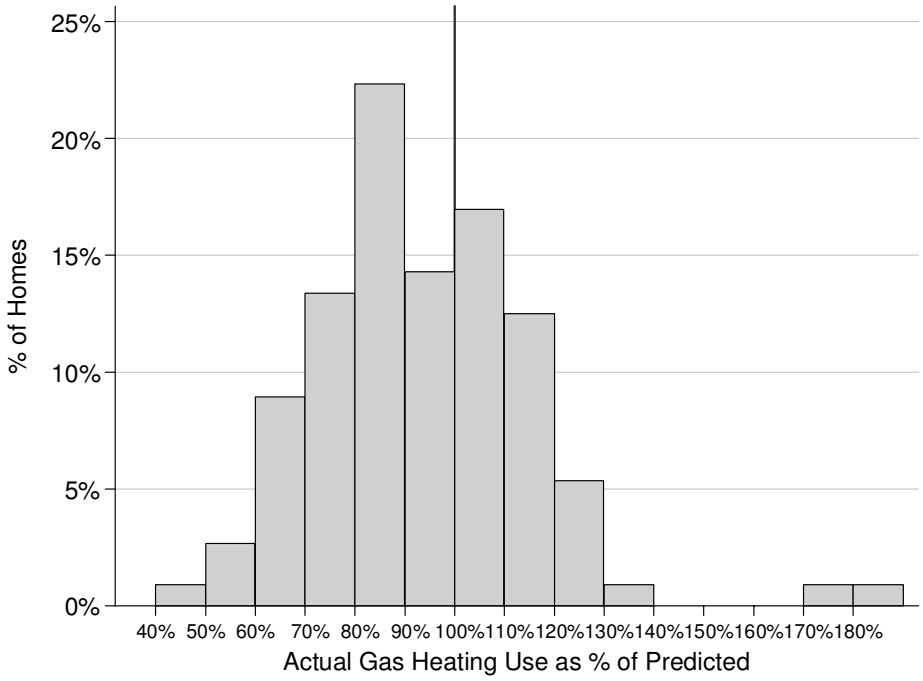
[6] See "Energy Savings from the Wisconsin Energy Star Homes Program", Scott Pigg, Energy Center of Wisconsin Report 211-1, October 2002.

Figure 26. Distribution of Annual Gas Usage



The REM/*Rate*-predicted usage averaged about 10% greater than the actual usage. Figure 7 shows the distribution of the ratio of actual to predicted heating usage. About two thirds of the homes had heating usage between 70% and 110% of the REM/*Rate* prediction. This range appears reasonable, given that rated usage is based on assumed thermostat settings. In terms of heating prediction errors, the average absolute error was 21% and the median absolute error was 17%. Predictions were within 25% of the actual heating usage for 71% of all homes and errors were larger than 50% in just 7% of homes.

Figure 27. Actual Gas Heating Usage as Percent of REM/Rate Predicted Usage

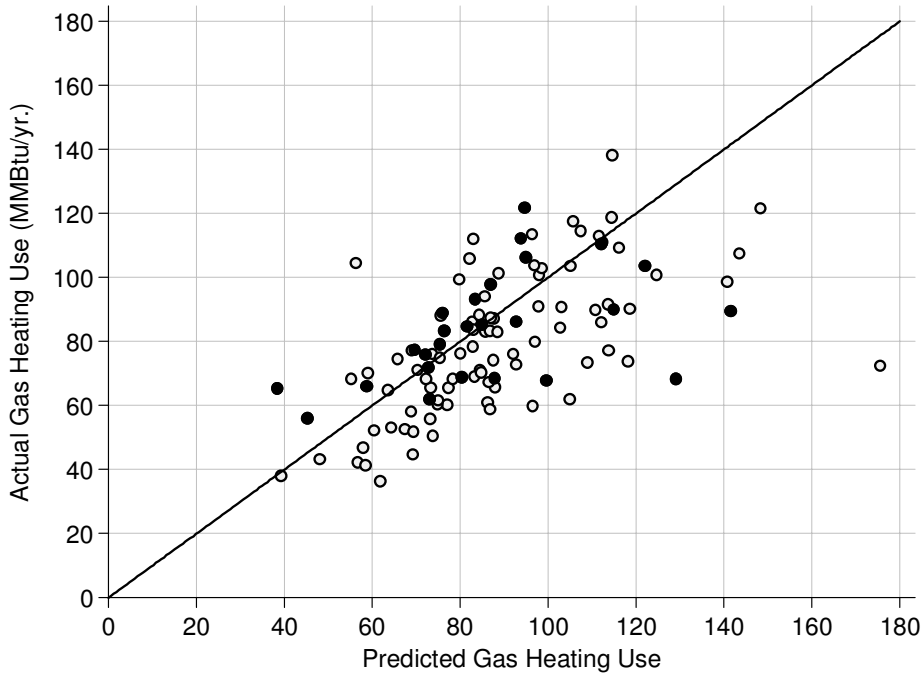


The average heating overprediction of about 10% could be due to many factors, such as bias in the assumed thermostat settings or in other assumptions or algorithms. The Wisconsin study found a similar over-prediction, which they attributed to the default duct leakage penalty in the HERS regulations.

Predicting Gas Heating Usage

Figure 28 shows a plot of actual vs. predicted gas heating use. The darker circles indicate homes with higher HERS scores (the 26 homes with scores >88.5). The figure shows an identifiable relationship between predicted and actual heating use, but with a fair amount of scatter. Of course, a fairly strong pattern should be expected due to variations in house size alone.

Figure 28. Actual vs. Predicted Gas Heating Usage



A regression of actual heating usage as a function of REM/*Rate*-predicted heating use has an r-squared of 0.34. If the outlier on the right side of the graph (with predicted heating use of nearly 180 MMBtu) is removed, the r-squared increases to 0.41. We explored a variety of regression models of actual gas heating usage (with and without the outlier) and found that:

- A model based on just wall and window areas provided a slightly better fit to actual heating usage than the REM/*Rate*-predicted heating usage did, even though the REM/*Rate* estimate is based on all of the detailed building inputs including areas, R-values, leakage rates, etc.
- Measured air leakage and ceiling area also provided some explanatory power to the heating usage model, although the ceiling area impact was small, as should be expected, given the high R-value of this component.
- Foundation wall area had a statistically weak relationship to heating usage, and only if the single outlier was excluded from the analysis.
- REM/*Rate*-predicted heating loads associated with walls, windows, air leakage, and roofs had slightly better predictive power than just using areas and CFM50 values (i.e., information about R-value, etc. had value). The r-squared increased from 0.479 to 0.494 when changing from areas and CFM50 to predicted component loads.

- REM/*Rate*-estimated heating loads associated with foundations were not related to actual heating usage – the relationship was actually negative unless the outlier is removed, but even then is not statistically or practically significant.
- REM/*Rate*-estimated heating loads associated with duct losses were not statistically significant when duct leakage was measured, and could not be properly estimated when not measured due to the automatic 15% load penalty (which makes it collinear with other loads in the model).
- REM/*Rate*-estimated heating loads associated with exposed floors, mechanical ventilation, internal gains, and other miscellaneous loads, were not statistically significant.

Overall, it appears that the REM/*Rate* predictions of heating loads associated with walls, windows, air leakage and roofs are all fairly good predictors of actual heating usage – better than simply using component areas and CFM50 values. However, the other components of the heating load prediction do not appear to add to the model's predictive capability, but instead add noise. For smaller building components or predicted loads based solely on assumptions (e.g., internal gains), this lack of a relationship is not unexpected. The lack of a relationship with measured duct leakage is also to be expected given that the true duct losses are very hard to model and are probably very small in homes like these where ducts are located within the conditioned space and/or in a basement with insulated walls. The findings related to foundation heat loss are of greater concern because foundations are estimated to be the second largest component of heat loss (after walls) and account for about 20% of total predicted heat loss in these homes. Foundation heat transfer is difficult to model due to variations in ground conductance, the presence of appliance and duct waste heat in basements, and the greater variability of basement temperatures in homes. In the usage analysis sample, 93 homes are listed as having conditioned basements, 17 have unconditioned basements, 1 has "multiple" foundation types, and 1 has a conditioned crawlspace.

We also analyzed usage patterns in terms of usage per square foot of shell area so that the impact of overall house size variations was virtually removed from the analysis[7]. The model of heating usage per square foot of shell area based on component heat losses for walls, windows, air leakage, and roofs had more than twice the explanatory power as one based on REM/*Rate*-predicted usage – the R-squared was just 0.11 based on REM/*Rate*-predicted heating usage but jumped to 0.28 when based on component heat loss rates (all normalized by shell area).

Usage Variations, Scores, and Construction Features

We examined how the relationship between actual and predicted usage varied based on differences in HERS scores and specific energy features that were associated with higher scoring homes. The sample did not contain enough homes to estimate the impacts of some house characteristics. Specifically, just two homes had instantaneous water heaters, five homes had foam insulation on the outside of walls, and two

[7] There was a strong inverse relationship between floor area and heating usage per square foot of floor area – larger homes use less heating energy per square foot of floor area. This makes sense, given that heat loss occurs primarily through the shell area, which tends to grow more slowly than floor area. Therefore, we normalized usage by shell area, which did not exhibit this strong relationship.

homes were not built on basements. A much larger sample would be needed to adequately represent some of these less common construction features.

We focused on comparisons of heating usage normalized by shell area and used a ratio estimator to assess whether the ratio of actual-to-predicted usage varied significantly between groups of homes. Key findings from this analysis are summarized in Table 18 for factors where the ratio differed by more than five percentage points and the difference was statistically significant (at least at the 10% probability level, with the exception of 11% level for 2x6 walls).

Table 18. Heating Usage Comparisons: KBtu/yr/ft² shell area

Characteristic	# Homes	Actual	Predicted	Ratio
HERS Score				
86.0-86.9	13	11.47	13.37	86%
87.0-87.9	50	10.99	12.30	89%
88.0-88.9	37	11.02	11.63	95%
>=89.0	12	11.74	10.61	111%
Duct Testing				
Duct Leakage Measured	43	11.51	11.82	97%
Default Ducts	69	10.90	12.15	90%
Wall Framing 2x6				
2x6 walls	45	10.98	11.32	97%
Not 2x6 walls	67	11.24	12.49	90%
Windows				
Windows R value >= 3	38	10.60	12.35	86%
Window R value < 3	74	11.41	11.85	96%
Basement				
Conditioned Basement	93	10.73	11.88	90%
Unconditioned Basement	17	12.90	12.92	100%

Although it may not be completely clear from Figure 8, we found that homes with higher scores tended to have higher usage relative to REM/*Rate* predictions than homes with lower scores. The effect is fairly dramatic as the ratio of actual to predicted heating usage (KBtu/yr/ft² shell) increased from 86% for homes scoring 86-86.9 to 111% for homes scoring 89 or higher. The normalized heating usage was predicted to decline by about 20% from the lowest scoring bin to the highest scoring bin, but the actual normalized

heating usage appears to fluctuate without a pattern and the highest scoring homes actually have greater heating usage intensity than the lowest scoring homes. Although the sample size is relatively small, this finding is somewhat disturbing since it implies that the HERS scores do not correspond to any real world improvement in efficiency – at least within the range of scores among these Energy Star homes.

The results in the table also indicate that:

- Testing ducts does not correspond to increased performance. Homes with tested ducts were predicted to have lower heating usage than those with default ducts, but they actually had higher usage.
- Homes with 2x6 walls averaged 97% of predicted usage compared to 90% of predicted usage for homes without 2x6 wall framing, implying that 2x6 walls may not perform as well as predicted. Usage was predicted to be 9% lower in the 2x6 wall homes but was just 2% lower.
- Homes with R-3+ windows performed better than expected. Heating usage was 86% of predicted for high R window homes compared to 96% for homes with lower R windows. This difference is somewhat surprising, given that the R-values did not differ dramatically, averaging 2.86 and 3.09 for the two groups. This finding may illustrate potential problems with the small sample size, observational dataset, and univariate nature of these tests. Houses that had higher R windows may have differed in other characteristics that affected performance.
- Homes with conditioned basements appear to perform better than homes with unconditioned basements – averaging 90% of predicted usage compared to 100% for unconditioned basements. This finding may be related to the previous duct testing and foundation heat loss findings – duct and foundation losses are both projected to be larger in homes with conditioned basements than those with unconditioned basements (although the increase in included shell area makes the normalized heating usage look lower). It appears that the energy penalty of a conditioned basement may not be as large as predicted by REM/*Rate*.

Overall, the gas analysis indicates that differences in HERS scores between Energy Star homes may not translate into any tangible differences in real world performance, especially when the scores differ due to testing of ducts (vs. default duct losses), using 2x6 wall framing, or classifying basements as conditioned vs. unconditioned.

Electric Usage Results

The results of the electric usage analysis are summarized in Table 19.

Table 19. Electric Usage Summary (kWh/yr)

			Percentiles of Distribution				
Characteristic	**Mean**	**±90% c.i.**	**10th**	**25th**	**Median**	**75th**	**90th**
Total Electric Use	11,040	±892	5,537	7,078	9,744	13,003	17,760
Baseload Use	9,333	±837	3,291	5,862	8,029	11,734	15,646
Winter/Heating Use	829	±211	0	0	0	1,155	2,561
Summer/Cooling Use	878	±208	0	0	543	1,101	2,329
Summer/Cooling Use							
Homes w/Central A/C (n=47)	990	±479	0	0	467	1,261	2,330
Predicted Cooling Use	896	±90	534	607	830	1,177	1,539
Actual as % of Predicted	108%	±53%	0%	0%	45%	119%	284%
Homes no CAC (n=82)	814	±186	0	0	602	1,016	1,962
House Information							
HERS Score	87.9	±0.13	86.8	87.4	87.9	88.4	89.0
Conditioned Floor Area (ft²)	3,631	±162	2,393	2,915	3,562	4,178	4,906
2+ Stories	78%	±6%					
# Bedrooms	3.50	±0.10	3	3	4	4	4

Annual electric usage averaged 11,040 kWh/yr for these homes – higher than the statewide average usage although perhaps typical for such large homes. At an average rate of about $0.15/kWh, this usage costs about $1,650 – nearly as large as the $1,800 gas usage.

Nearly all of the electric usage was "baseload" (i.e., non-seasonal) with only about 8% of usage appearing as winter seasonal loads and 8% appearing as summer seasonal loads. These homes were all completed in 2005, prior to REM/*Rate* including a prediction of all baseload electric end uses, so comparisons to predictions are limited. In addition, the billing analysis cannot differentiate between actual heating or cooling loads compared to seasonal end uses such as dehumidifiers or swimming pool pumps or even the seasonality of year-round end-uses such as lighting (that peaks in the winter) or refrigeration (that peaks in the summer). For that reason, one can't expect a very close match between these seasonal usage patterns and predicted cooling (or heating) loads.

With this caveat in mind, the table does compare the summer seasonal load and the predicted cooling load for the 47 homes with central air conditioning. The average usage compares well. Actual summer loads average 8% larger than predicted cooling loads, but there is tremendous scatter in the data, as evidenced by the ±53% confidence interval and the wide variation in the ratio of actual to predicted. Many homes had no

detectable cooling load at all.I In fact, 43% of the homes with central air conditioning showed no summer/cooling usage, compared to just 27% of the homes without central air conditioning. The average summer loads were fairly similar regardless of the presence of central air conditioning.

Overall Energy Usage

The total energy usage for these Energy Star homes averaged 106.9 MMBtu of gas usage and 11,040 kWh of electric usage. The overall gas and electric usage is estimated to cost about $3,500 per year in these homes with nearly half coming from the electric bill, even though all of the homes had gas heating and water heating.

The absolute level of energy usage in these homes is actually somewhat higher than the typical residential customer in upstate New York, especially for electric usage. The large size of the homes explains how this occurred. The natural gas savings that may accrue from the more efficient new construction are offset by the larger size of the homes. Electric baseload efficiency was not very well addressed by Energy Star when these homes were completed in 2005, and the potential for gains is limited to some extent by the proportion of the electric use that is associated with homeowner-purchased appliances and other end uses not installed by the builder.

APPENDIX 2: REM/*RATE* NEW YORK BASELINE DEFINED

Location: Syracuse, NY (Climate Zone 5A)

6789 HDD base 65F, and 3516 CDH base 74F

Design Heating Temp: 68F / Design Cooling Temp: 78F

$0.16/ kWh

$1.42/CCF (At time of study)

We have chosen for our baseline a mix of code minimum values and methods and materials that are most prevalent in New York and the Northeast based on our interviews, energy modeling review of 2,000 NYS ENERGY STAR homes, and our extensive field experience. Some of these individual methods and measures may not meet with code minimum values. Below is an explanation, measure by measure, of what constitutes our baseline home, and how we chose each measure in it. It is a conservative estimate of typical construction practice in New York State.

Foundation Wall: Conventional concrete poured wall with 2X4 24 o.c. framed wall held 1" off foundation wall with grade III (based on RESNET…) R-11 fiberglass batts installed. This was chosen based on field experience of the most common foundation wall assembly in today's residential new construction.

Framed Floor: Uninsulated between conditioned space and unconditioned (but insulated) basement.

Rim and Band Joists: 16 o.c. framing with R-11 fiberglass batts friction-fit into bays. Batt is not enclosed on all six sides, poorly installed and not in an air tight cavity. As a result, the effective R-value given to this assembly in REM/*Rate* is R-2.5 (0.7 per inch.) (ASHRAE document "Heat Transmission Coefficients for Walls, Roofs, Ceilings and Floors" 1996). There is much room for improvement here, specifically to spray foam rim and band joists, but this is what we have found is common practice.

Above Grade Wall: 2x6 16 o.c. with grade III R-19 fiberglass batts. This was chosen based on field experience and interviews of the most common wall assembly in today's residential new construction.

Windows: U-value of 0.47 and Solar Heat Gain Coefficient (SHGC) of 0.40. Average U-value and SHGC from the analysis of REM/*Rate* files from ENERGY STAR Homes was 0.34 and 0.35 respectively. Baseline in New York State would be less. Average U-value of double pane window without low-E coating and argon gas is 0.45-0.50. Glazing percentage is based on the study of 1,971 NY ENERGY STAR Homes that showed an average of 10.6% window to floor area. Average window U-value from LI RNC Baseline study was .47.

Doors: Assumed two 3' x 7' steel insulated doors at R-4.0.

Ceiling: We used the ratio of flat attic to vaulted ceiling from the ENERGY STAR analysis. Average flat attic assumed to be 10" of loose-fill cellulose (R-35) within 24 o.c. truss system with 2 x 6 bottom cord. Vaulted ceiling assumed to be 2 x 12 16 o.c. with grade III R-38 fiberglass batts installed. Most assemblies use proper vents for ventilation and fit a 10" batt into an 8" cavity. That, combined with other poor installation practices, results in a grade III installation.

Mechanicals: Natural Gas Furnace (78%) and stand alone water heater (EF 56%) that both meet code and federal minimum requirements. Air Conditioner is 13 SEER and meets code and federal minimum requirements. No programmable thermostats installed. All mechanicals installed in unconditioned basement. (Unconditioned basement is defined here as insulated, but without dedicated HVAC supply.)

Duct System: Used REM/*Rate* default supply and return duct area based on six return ducts. Sixty six percent of ductwork is located in conditioned space and 34 percent in the unconditioned basement. Two hundred and fifty cfm of duct leakage assumed to the outside through band joists, interior wall cavities and ceiling.

Infiltration: 0.50 ACH natural. Information on the actual air exchange rates of the residential housing stock is sketchy at best, but estimates of air leakage based on blower-door measurements suggest that the existing single family housing stock has, on average, 1.0 air changes per hour (Sherman 1996). Because of code changes and other mandates for more energy-efficient construction, new housing is considerably tighter than existing residences, with air exchange rates reported to be averaging 0.5 ACH for new construction. (AN OVERVIEW OF THE U.S. BUILDING STOCK, Richard C. Diamond, LBNL-43640, January 2001.) (Sherman & Dickerhoff August 3, 1998 AIR-TIGHTNESS OF U.S. DWELLINGS) Our own LI RNC baseline study shows .56 natural ACH for new homes in 2004, avg. size 2,696.

Ventilation: None. Most homes assumed to have non-ENERGY STAR exhaust fans on toggle switches and non-programmable timers.

Lights and Appliances: Entries are based on average usage data compiled by Efficiency Vermont.

This produced a home with a HERS score of 80.6 and an estimated average annual usage of 129 MMBtu, or an approximate annual energy cost of $2,624.

APPENDIX 3: DESCRIPTION OF EFFICIENCY MEASURES

Order of Upgrades within Interactive Model

1) **Baseline:** NYbase.blg
2) **Reduced Air Leakage:**
    a. Reduced ACH: *NYbase_35ACH* Reduction from .5 to .35 ACH.
    b. Reduced ACH w/ HRV: *NYbase _15ACH_HRV.blg* . 0.159 ACHnat was achieved as the average air infiltration with the ninety-six - 90+ ENERGY STAR Homes from the REM/*Rate* analysis of 1971 ENERGY STAR homes. Balanced ventilation was incorporated into this energy model to ensure both 0.35ACHnat and credit under REM/*Rat*e. REM/*Rate* does not reward homes tighter than 0.35ACHnat without balanced ventilation.
    c. Reduced ACH w/ EOV: *NYbase _15ACH_EOV.blg* (Exhaust Only Ventilation)

    This option not used in final 90 home
3) **Mechanical Upgrade (from 78% furnace/13SEER AC/56% DHW):**
    a. ENERGY STAR Furnace: *NYbase _Furnace.blg* (78% to 94% and a programmable thermostat)
    b. Programable Thermostat: Was also analyzed as a separate measure. *NYbase _Therm.blg*
    c. Duct losses: *NYbase_Ducts.blg*. Eliminated the duct leakage to outside (from 325,) and increased the % of supply and return ducts in conditioned space to 66% (from 33%) eliminating the ducts in the attic, and essentially putting all ducts in conditioned or semi conditioned space.
    d. Instantaneous: *NYbase _On_Demand.blg* (.56EF to .81EF)
    e. ENERGY STAR AC: *NYbase _AC* (13 to 15 SEER)
4) **Envelope Upgrade:**
    a. Foundation: Insulated Concrete Forms: *NYbase _ICF.blg* (R-11 to R-22) ICF's were chosen because they are the least cost path to achieve an R-22.5 insulation value if finishing the basement in the future, which often occurs.
    b. Walls: Continuous Rigid Foam Sheathing: *NYbase _CE10.blg* (CDX to 2" EPS)
    c. Ceiling: Ceiling Insulation Upgrade: *NYbase _Ceiling.blg* (R-34 to R-60 flat / Vaulted from R-30 Grade III to R-38 Grade I installation) This upgrade included an increase in rafter size (2x10 to 2x12) to accommodate the larger batt.
5) **Window Upgrade:**
    a. U-value 0.4 to 0.3 Upgrade: *Window_U3.blg* While Code requires U-0.28 windows, these are not readily available off the shelf. Windows with a U-value of 0.3 or greater are far more common. An effort was made to not require triple-glazed windows to achieve a HERS score of 90+.
    b. U-value 0.4 to 0.2 Upgrade: *Window_U2.blg*

    This option not used in final 90 home

6) **GFX Upgrade:** *NYbase _GFX.blg* (6' wastewater heat recovery system on the whole house waste pipe. The cold water inlet that feeds the domestic hot water tank is preheated by the house's wastewater.)

7) Lights and Appliances: *NYbase_L&A.blg* 75% fluorescent lighting, clothes dryer and oven/range switched to natural gas, refrigerator upgraded from 675 to 400 kWh/year usage

8) **Solar DHW Upgrade:** *NYbase _solar_dhw.blg* (2-4x8 panels and 80g. storage)

   This option not used in final 90 home

9) **Solar DHW and GFX Upgrade:** *NYbase _solar_dhw_GFX.blg*

   This option not used in final 90 home

APPENDIX 4: BUILDERS SURVEY

BUILDER'S SURVEY

Builder/Company name (Optional): _____ _____ ❑ SF ❑ MF ❑ Affordable

Number of homes/units built annually: _____ Number of ENERGY STAR Homes built annually: _____

Scope of operation: ❑ Local ❑ Regional ❑ Multi-Regional ❑ National

Percent of homes built that are custom vs. production/spec: _____

Breakdown of homes built by type: ____ Starter ____Move-up_____Vacation/Second_____Other_____

Average selling price of new home built: _____ Average finished area of new home built: _____

High performance features in a home: ❑ Standard ❑ Optional ❑ Never installed

What high performance components or approaches do you typically incorporate?
_____

_____

Why do you offer high performance components? _____

_____

_____

How much more (rough %) can a house with a high performance package sell for? _____

_____

What are the high performance approaches or components that cost more but do not add value to a home? _____
_____

What are the high performance approaches or components that DON'T cost more but DO add value to a home?
_____

_____

AVERAGE BUILDING SHELL	**Insulation Material** (check choice)	**Insulation Thickness** (inches)	**Total R-Value of Insulation**	**Framing and spacing**
FOUNDATION WALLS Average height above grade: ft Average depth below grade: ft	Insulation is: ❑ interior ❑ exterior ❑ none Insulation material is: ❑ Rigid Foam ❑ Fiberglass ❑ Cellulose ❑ Other: _____			(if interior) **2 x** _____ ❑ 16" O.C. ❑ 24" O.C.
SLAB ON GRADE Types of slabs ❑ Full slab on grade ❑ Part of house on slab ❑ Walk-out basement ❑ Other:	Full insulation under slab? ❑ Y ❑ N Edge insulation? ❑ Y ❑ N Insulation material is: ❑ Rigid Foam ❑ Other: _____			

AVERAGE BUILDING SHELL	Insulation Material (check choice)	Insulation Thickness (inches)	Total R-Value of Insulation	Framing and spacing
EXPOSED FLOORS ❑ Cantilevered floor ❑ Tuck-under garage ❑ Bay area ❑ Other:	Insulation material is: ❑ Rigid Foam ❑ Fiberglass ❑ Cellulose ❑ Other: _____			**2 x** _____ ❑ 16" O.C. ❑ 24" O.C.
EXTERIOR WALLS ❑ Typical wood frame ❑ Structural insulated panels ❑ Log, thickness: " ❑ Other:	Insulation material is: ❑ Rigid Foam ❑ Fiberglass ❑ Cellulose ❑ Other: _____			**2 x** _____ ❑ 16" O.C. ❑ 24" O.C.
CEILING FLAT ❑ Common truss ❑ Engineered or raised heel ❑ Scissors truss ❑ Other: (show ceiling heights on plans)	Insulation material is: ❑ Rigid Foam ❑ Fiberglass ❑ Cellulose ❑ Other: _____			**2 x** _____ ❑ 16" O.C. ❑ 24" O.C.
CEILING SLOPE ❑ None ❑ Cape ❑ Cathedral/vaulted (show ceiling heights on plans)	Insulation material is: ❑ Rigid Foam ❑ Fiberglass ❑ Cellulose ❑ Other: _____ *If cape, kneewall insulation placement*: ❑ Diagonally along collar ties to eaves ❑ Vertically down kneewall, and horizontally to eaves			**2 x** _____ ❑ 16" O.C. ❑ 24" O.C.

ADDITIONAL TYPICAL BUILDING INFORMATION

Basement

Is it intentionally heated?

❑ Yes ❑ No

Garage

Do you plan to heat your garage? (If applicable)

❑ Yes ❑ No

Infiltration

Attic by-passes sealed? ❑ Yes No

Foamed rough openings? ❑ Yes No

All joints/gaps sealed? ❑ Yes No

Air-sealing contractor used? Yes No

Blower door tested? ❑ Yes No

Average Blower door results Circle ACH: CFM-50; ACH-50

_____

Windows

Brand: _____

Frame:

❑ Wood
❑ Vinyl
❑ Fiberglass
❑ Other
❑ ENERGY STAR® qualified

❑

Panes (check all that apply):

❑ Double Pane
❑ Low-E coating
❑ Storm windows
❑ Argon filled

Thermal Performance:

NFRC U-value _____
NFRC U-Value not known
Solar Heat Gain Coefficient_____
SHGC not known

Skylights

Brand: _____

Frame:

❑ Wood
❑ Vinyl
❑ Fiberglass
❑ Other
❑ ENERGY STAR® qualified

Panes (check all that apply):

❑ Double Pane
❑ Low-E coating
❑ Storm windows
❑ Argon filled

Thermal Performance:

NFRC U-value _____

❑ NFRC U-Value not known

Solar heat gain coefficient_____

❑ SHGC not known

TYPICAL HEATING SYSTEM

Type

Make: _____

Model number: _____

Btu output: _____

AFUE # (if available) _____

❑ Hydronic Boiler (Water)
❑ Hot Air Furnace
❑ Heat Pump
❑ Vented space heater
❑ Other

Boiler or Furnace ENERGY STAR qualified?❑

Yes ❑ No

Location

❑ Basement
❑ Conditioned space (heated space)
❑ Unconditioned space (attic, crawlspace, outside)

Radiant Heating

Are you installing radiant slab heating?

Yes No

Ducted System Typically Used?

❑ Yes Sealed with mastic?
❑ No Duct insulation?

Fuel

❑ Natural gas
❑ Propane
❑ Oil
❑ Kerosene
❑ Wood
❑ Electric
❑ Solar (Please describe on back of sheet)

Exhaust venting

❑ Through the wall

❑ Chimney N/A

Combustion air supply

Is there a sealed, ducted, combustion air supply directly to the burner?

❑ Yes
❑ No
❑ N/A

Thermostat Controls

Programmable set-back thermostats used?

❑ Yes If yes, how many? _____ ❑ No

CENTRAL AIR CONDITIONING TYPICALLY USED ❑ YES ❑ NO

Make: _____

Model: _____

Efficiency (SEER): _____

❑ ENERGY STAR qualified

❑ Basement

LOCATION

❑ Conditioned space
❑ Unconditioned space (attic, crawlspace, outside)

AUXILIARY HEAT SYSTEM

Check if present
- ❑ Wood stove
- ❑ Fireplace: Wood *or* Gas (circle)

Is there a ducted **combustion** air supply?
❑ Yes ❑ No

Tight-sealing doors for fireplace?
- ❑ Yes
- ❑ No

TYPICAL DOMESTIC HOT WATER SYSTEM

Type

Make: _____
Model: _____
Efficiency or EF: _____
- ❑ Indirect-fired storage tank (tank heated by hydronic boiler)
- ❑ Stand alone tank (tank is self-heating)
- ❑ Tankless coil (no tank and water heated by hydronic boiler)
- ❑ Instantaneous heater
- ❑ Solar (Please briefly describe on back of sheet)
- ❑ ENERGY STAR® qualified

Exhaust venting

- ❑ Through the wall
- ❑ Chimney ❑ N/A

Fuel

- ❑ Natural gas
- ❑ Propane
- ❑ Oil
- ❑ Kerosene
- ❑ Electric
- ❑ Wood
- ❑ Solar (attach description)

Combustion air supply

If the system is stand alone or instantaneous, is there a ducted **combustion** air supply to the burner?
- ❑ Yes
- ❑ No

MECHANICAL VENTILATION

- ❑ Heat recovery ventilator
- ❑ Multi-port fan system
- ❑ Exhaust-only fan system, # of Fans: _____

Make: _____
Model #: _____
CFM: _____

Automatic ventilation controls

- ❑ 24 hour timer
- ❑ Humidistat
- ❑ Other: _____

TYPICAL APPLIANCES

Refrigerator

Size: _____ cu. ft
Make: _____
Model number: _____
- ❑ ENERGY STAR qualified

Cooking Fuel ❑ Gas ❑ Electric

Clothes Dryer Fuel ❑ Gas ❑ Electric

Clothes washer

- ❑ Horizontal axis (front loading)
- ❑ Top Loading
- ❑ ENERGY STAR qualified

Dish washer

- ❑ ENERGY STAR qualified

LIGHTING

- ❑ I typically install _____ qualifying energy efficient, fluorescent light fixtures
- ❑ I typically install _____ qualifying energy efficient, fluorescent light bulbs (screw based CFL)

APPENDIX 5: DETAILED RESULTS OF 1,971 E STAR REM/*RATE* ANALYSIS

NYSERDA Reference Design Project: Analysis of NY Energy Star Home REM/RATE Files M Blasnik revised 12/5/2006

	Single Family Homes				Single Family Gas Heat				**Single Family Gas Heat Warm Air**				Single Family Not Gas Heat				Single Family Gas: Not FWA			
	All	HERS<90	HERS90+	Diff.	All	HERS<90	HERS90+	Diff.	All	HERS<90	HERS90+	Diff.	All	HERS<90	HERS90+	Diff.	All	HERS<90	HERS90+	Diff.
# Homes	1971	1875	**96**		1857	1800	**57**		1829	1784	**45**		114	75	**39**		21	12	**9**	
HERS Score	88.3	88.1	91.0	2.8	88.2	88.1	90.7	2.6	88.2	88.1	90.6	2.5	89.2	88.2	91.3	3.1	89.5	88.1	91.3	3.2
House																				
Area: conditioned	3702	3687	4012	325	3708	3698	4025	327	3708	3703	3910	207	3614	3417	3992	575	3616	3109	4293	1184
Volume	31821	31578	36553	4975	31762	31652	35255	3603	31758	31697	34179	2482	32774	29823	38451	8628	32890	27185	40498	13313
Avg Height	8.6	8.5	9.5	1.0	8.5	8.5	9.0	0.5	8.5	8.5	9.0	0.5	9.2	8.7	10.1	1.4	9.0	8.8	9.4	0.6
Area: shell	7342	7300	8162	862	7336	7311	8140	829	7328	7313	7958	645	7440	7047	8195	1148	7997	7349	8860	1511
Stories	1.80	1.81	1.70	-0.11	1.82	1.82	1.77	-0.05	1.82	1.82	1.76	-0.06	1.60	1.60	1.59	-0.01	1.81	1.67	2.00	0.33
Slab	0.5%	0.1%	**7.3%**	7.2%	0.3%	0.1%	**5.3%**	5.2%	0.1%	0.1%	0.0%	-0.1%	3.5%	0.0%	**10.3%**	10.3%	9.5%	8.3%	11.1%	2.8%
Bedrooms	3.5	3.5	3.2	-0.3	3.5	3.5	3.3	-0.3	3.5	3.5	3.2	-0.3	3.1	3.2	3.0	-0.1	3.4	3.3	3.4	0.1
Fuels																				
Gas heat	94%	96%	**59%**	-37%	100%	100%	100%	0%	100%	100%	100%	0%	0%	0%	0%	0%	100%	100%	100%	0%
Gas HW	94%	96%	**66%**	-30%	99%	99%	97%	-3%	99%	99%	98%	-2%	18%	16%	21%	5%	91%	92%	89%	-3%
Gas Ht & HW	93%	95%	**57%**	-38%	99%	99%	97%	-3%	99%	99%	98%	-2%	0%	0%	0%	0%	91%	92%	89%	-3%
Central A/C	36%	35%	**51%**	16%	35%	34%	**51%**	17%	35%	34%	44%	10%	50%	49%	51%	2%	62%	50%	78%	28%
Solar	2%	2%	1%	-1%	2%	2%	0%	-2%	2%	2%	0%	-2%	1%	0%	3%	3%	0%	0%	0%	0%
Heating System																				
Heater Capacity Kbtu	88.8	88.4	**97.5**	9.1	88.5	88.2	**100.0**	11.8	88.3	88.1	**95.1**	7.0	94.0	94.8	92.3	-2.5	112.7	104.3	123.9	19.6
Heater Efficiency	92.4%	91.5%	108.3%	16.8%	91.6%	91.6%	92.4%	0.8%	91.7%	91.7%	92.8%	1.1%	103.8%	89.4%	**131.6%**	42.2%	89.7%	88.1%	91.7%	3.6%
Heating Use MMBtu																				
Predicted Heat	93	94	**76**	-18	94	94	**80**	-14	94	95	**79**	-16	84	92	**70**	-21	87	89	86	-3
Reference Heat	144	143	**151**	7	144	144	**159**	15	144	144	**156**	12	133	130	**138**	8	146	128	171	44
Savings: Heat	50.3	49.0	**74.4**	25.4	50.3	49.4	**78.7**	29.3	50.2	49.6	**76.6**	27.0	48.7	38.6	**68.0**	29.4	58.7	38.7	85.4	46.7
Water Heating																				
HW efficiency (EF)	62%	61%	**74%**	13%	61%	61%	**73%**	12%	61%	61%	**71%**	10%	73%	71%	**77%**	6%	74%	70%	81%	11%
Predicted HW	25.1	25.3	**20.0**	-5.3	25.3	25.5	20.7	-4.8	25.4	25.5	20.9	-4.6	20.9	21.8	19.0	-2.8	21.7	23.2	19.6	-3.6
Reference HW	28.3	28.3	27.8	-0.5	28.3	28.3	27.4	-0.9	28.2	28.3	26.7	-1.6	29.2	29.6	28.4	-1.2	29.7	30.1	29.2	-0.9
Savings: HW	3.2	3.0	**7.8**	4.8	2.9	2.8	6.7	3.9	2.8	2.8	5.8	3.0	8.4	7.8	9.4	1.6	8.0	6.9	9.6	2.7
Distribution System																				
Not fuel-fired forced air	2%	1%	**26%**	25%	1%	1%	**17%**	16%	0%	0%	0%	0%	23%	14%	44%	31%	100%	100%	100%	0%
Hydronic	2%	1%	**20%**	19%	1%	1%	**17%**	16%	0%	0%	0%	0%	17%	13%	24%	12%	95%	92%	100%	8%
Duct Leakage Measured	42%	41%	**68%**	27%	42%	41%	**77%**	37%	42%	41%	**84%**	44%	44%	39%	54%	15%	19%	8%	33%	25%
No Duct Losses	9%	8%	**42%**	34%	7%	6%	**25%**	19%	5%	5%	4%	-1%	52%	44%	67%	23%	95%	92%	100%	8%
Supply: % fully inside	62%	63%	52%	-11%	63%	63%	54%	-9%	63%	63%	57%	-7%	54%	57%	46%	-10%	4%	6%	0%	-6%
Supply: % In/Htd	94%	95%	**73%**	-22%	95%	95%	**74%**	-22%	95%	96%	**76%**	-20%	82%	85%	73%	-13%	22%	17%	33%	17%
Supply: area	269	266	349	83	265	265	283	18	264	265	256	-9	359	308	**489**	181	498	373	748	375
Return: Area	162	160	198	38	160	160	171	11	160	160	157	-3	194	170	255	85	292	234	408	174
Infiltration																				
CFM50	1832	1835	1762	-73	1833	1832	1863	31	1831	1830	1868	38	1813	1912	1617	-295	2035	2187	1807	-380
ACH-heating	0.18	0.18	0.16	-0.02	0.18	0.18	0.17	-0.01	0.18	0.18	0.18	0.00	0.17	0.19	0.14	-0.05	0.18	0.21	0.15	-0.06
Attic/Roof																				
Area: ceiling	1549	1551	1501	-50	1559	1559	1580	21	1558	1558	1567	9	1379	1376	1385	9	1673	1709	1625	-84
R-ceiling	34.6	34.4	**40.1**	5.7	34.5	34.4	37.5	3.1	34.5	34.4	36.6	2.2	38.3	35.4	45.0	9.6	32.3	26.3	42.5	16.2
Area: cathedral ceil.	80	64	**408**	344	56	52	**189**	137	53	52	77	25	471	337	**728**	391	301	52	633	581
R-cathedral ceil.	28.6	27.6	**38.0**	10.4	27.4	27.1	**37.2**	10.1	27.4	27.2	42.4	15.2	36.7	35.0	38.4	3.4	28.5	19.3	34.7	15.4
Wall																				
Area: walls above grade	2153	2142	2364	222	2161	2151	2482	331	2157	2151	2402	251	2015	1922	2192	270	2501	2317	2747	430
Framing: 2x6	41%	39%	**73%**	34%	39%	38%	**72%**	34%	38%	37%	**69%**	32%	70%	68%	74%	6%	76%	75%	78%	3%
Framing: 24 o.c.	5%	5%	8%	3%	5%	5%	2%	-3%	5%	5%	0%	-5%	10%	5%	18%	13%	10%	8%	11%	3%
Framing: factor	20%	20%	19%	-1%	20%	21%	20%	-1%	21%	21%	20%	-1%	18%	19%	18%	-1%	19%	19%	20%	1%
Foam Insulation	3%	2%	**16%**	13%	2%	2%	**14%**	12%	2%	2%	**11%**	10%	16%	15%	19%	3%	18%	8%	30%	22%
R-wall	13.1	12.9	**17.4**	4.5	12.9	12.8	**16.4**	3.6	12.9	12.8	**15.7**	2.9	16.1	14.7	18.8	4.1	16.1	13.6	19.3	5.7
R-Foundation wall	16.5	16.4	18.5	2.1	16.4	16.4	17.3	0.9	16.4	16.4	16.6	0.2	17.0	15.3	20.7	5.4	17.1	12.0	22.2	10.2
Windows																				
Area: windows	354	352	397	45	350	350	354	4	349	349	335	-14	421	401	459	58	405	384	435	51
Window Area %	9.7%	9.7%	11.1%	1.4%	9.6%	9.6%	9.8%	0.2%	9.5%	9.5%	9.6%	0.1%	12.3%	11.9%	12.9%	1.0%	12.0%	12.6%	11.2%	-1.4%
UA-windows	122	122	131	9	121	121	117	-4	121	121	111	-10	140	134	151	17	134	133	136	3
SHGC	0.34	0.34	0.34	0.00	0.34	0.34	0.33	-0.01	0.34	0.34	0.33	-0.01	0.34	0.34	0.36	0.02	0.33	0.33	0.33	0.00
U-windows	0.35	0.35	0.33	-0.02	0.35	0.35	0.33	-0.02	0.35	0.35	0.33	-0.02	0.33	0.34	0.32	-0.01	0.33	0.35	0.31	-0.03
R-windows	2.9	2.9	3.1	0.2	2.9	2.9	3.0	0.1	2.9	2.9	3.0	0.1	3.1	3.0	3.1	0.1	3.0	2.9	3.2	0.3
Heating Loads MMBtu																				
Total	**75.7**	**76.3**	**64.7**	**-11.6**	**76.1**	**76.5**	**65.2**	**-11.3**	**76.2**	**76.5**	**64.2**	**-12.3**	**69.8**	**72.8**	**64.0**	**-8.8**	**72.2**	**74.4**	**69.3**	**-5.1**
roof	7.5	7.5	8.0	0.5	7.5	7.5	8.5	1.0	7.5	7.5	7.9	0.4	7.5	7.6	7.4	-0.2	9.6	9.9	9.2	-0.7
wall	24.8	25.0	**19.5**	**-5.5**	25.1	25.2	**21.0**	**-4.2**	25.2	25.3	**21.0**	**-4.3**	19.0	19.8	17.3	-2.5	21.9	22.4	21.2	-1.2
windows	11.8	11.8	11.6	-0.2	11.7	11.7	10.9	-0.8	11.7	11.7	10.0	-1.7	13.2	13.6	12.6	-1.0	12.7	11.3	14.6	3.3
infiltration	15.2	15.2	15.0	-0.2	15.2	15.2	15.7	0.5	15.2	15.2	15.3	0.1	14.6	15.0	14.0	-1.0	15.8	15.1	16.9	1.8
Mech Ventilation	4.5	4.5	4.2	-0.3	4.5	4.5	4.2	-0.3	4.5	4.5	3.7	-0.8	4.6	4.8	4.1	-0.7	5.3	4.7	6.2	1.5
Ducts/Distribution	7.9	8.2	**2.4**	**-5.8**	8.1	8.3	**2.5**	**-5.8**	8.2	8.4	**3.2**	**-5.2**	4.4	5.5	2.3	-3.2	1.2	2.0	0.0	-2.0
Joist	2.2	2.2	1.8	-0.4	2.2	2.2	1.9	-0.3	2.2	2.2	1.9	-0.3	1.7	1.6	1.7	0.1	1.8	1.5	2.1	0.6
Foundation Wall	11.6	11.7	10.3	-1.4	11.7	11.7	11.1	-0.6	11.7	11.7	12.1	0.4	10.6	11.4	9.1	-2.3	9.6	10.6	8.1	-2.5
Foundation Floor	0.8	0.8	0.6	-0.2	0.8	0.8	0.6	-0.2	0.8	0.8	0.6	-0.2	0.9	1.0	0.6	-0.4	1.2	1.5	0.7	-0.8
Crawlspace	1.2	1.2	0.9	-0.3	1.1	1.1	0.3	-0.8	1.1	1.1	0.2	-0.9	2.1	2.3	1.8	-0.5	1.6	2.2	0.8	-1.4
Slab	4.1	4.1	4.3	0.2	4.1	4.1	4.1	0.0	4.1	4.1	4.1	0.0	4.2	4.1	4.6	0.5	3.9	4.1	3.5	-0.6
Internal Gains	-16.8	-16.9	-15.4	1.5	-16.9	-16.9	-16.7	0.2	-17.0	-17.0	-16.8	0.2	-14.6	-15.2	-13.4	1.8	-13.7	-12.5	-15.4	-2.9
Other	0.9	1.0	1.5	0.5	1.0	1.1	1.1	0.0	1.0	1.0	1.0	0.0	1.6	1.3	1.9	0.6	1.3	1.6	1.4	-0.2