Maine New Homes: How a Baseline Study Can Set You Straight

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ABSTRACT

Maine is the only state in the Northeast without an ENERGY STAR Homes program. That will change in 2008 when Efficiency Maine rolls out a residential new construction program. As part of program development, the planning team conducted a 78 home baseline study of newly constructed homes in late 2007 / early 2008 to gauge their level of energy efficiency. Full HERS ratings, detailed lighting information, rater rankings of energy issues in each home, and homeowner interviews provide a complete picture of the state of new home construction practices in the Pine Tree State.

Without a new homes program, how does the market naturally assimilate energy efficiency? How do homes in Maine compare to other Northeast states that have long-standing ENERGY STAR Homes programs? Is the new housing stock appreciably more energy efficient in states with ENERGY STAR Homes programs? Without a program, do builders still strive to improve home energy efficiency? Where does the average new home stand relative to code? What are areas of focus identified for a new homes program to address? These and other questions are addressed in this paper.

Introduction

Maine has never had an all-fuels residential new construction program. The electric-only Good Cents Home program is a distant memory from the 1990's, and really didn't have any lasting impact. More recently, Efficiency Maine, a program of the Maine Public Utilities Commission, has had a successful record of residential and business efficiency programs, primarily focused on residential products. Due to an initial focus on more cost-effective programs and a desire to prove success before expanding offerings, a residential new construction (RNC) program has taken a number of years to move out of the gate. In 2007, as part of rebidding for the delivery of Efficiency Maine programs, an RNC program was specified. A team led by Energy & Resource Solutions was selected and proposed conducting a baseline study prior to designing a new homes program. The baseline study was conducted to:

- Provide a baseline of typical new home technical characteristics to aid in future program evaluation.
- Enhance Efficiency Maine's understanding of the residential new construction market to help inform program design, including setting standards and incentive levels.
- Determine the need for builder outreach and training and what training should focus on to address problems identified in the new home inspections.
- Develop a reference building model against which to compare future participating homes in order to assess participant and program savings.

Methodology

Owners of 80 new homes were recruited from geographically-targeted locations throughout Maine. Random calls were made to lists of new homes compiled from town clerks, city halls, building suppliers, and electric utilities. A cluster-sampling technique based on building activity in different regions in the State was used to develop a representative sample. Recruited homeowners were paid $100 for opening up their homes to our team of four certified Home Energy Rating System (HERS) Energy Raters for a half-day.

The Energy Raters performed energy ratings to the standards of the Northeast HERS Alliance and RESNET[1]. In addition, a comprehensive survey of supplemental energy, customer, and building performance information was collected on each house and entered in an Access database. Due to attrition and data quality issues, 76 homes from the Access database and 78 from REM/Rate HERS energy ratings were ultimately used.

The project team conducted the following analyses on the collected data in order to better understand the implications of our findings while using it to inform energy policy and program design:

- Calculated HERS indices;
- Compared HERS results to other Northeastern states with ENERGY STAR Homes programs;
- Conducted a least-cost analysis to determine the upgrade cost of the optimal package of energy efficiency improvements to bring the average baseline home to code (performance and prescriptive approaches), ENERGY STAR, Federal Tax Credit levels, and micro-load homes (without and with a renewable energy system);
- Conducted a cash-flow analysis (energy savings less increased mortgage cost) for bringing the average baseline home to the same efficiency levels as in the least-cost analysis; and
- Assessed Maine Energy Code compliance (for energy efficiency and mechanical ventilation).

Anticipated Findings

The project team had some expectations going into the baseline study. Having worked extensively in both Maine and other Northeastern states long before ENERGY STAR Homes programs were prevalent, we had some expectations about what we might find, including:

- Homes sized around 2,200 square feet on unconditioned basements;
- Generally good construction with recommended insulation levels (a mix of 2x4 (R-11 or 13) and 2x6 (R-19)walls and R-30-38 ceilings);
- Some low-E windows;
- Leaky construction;
- Very little basement insulation;

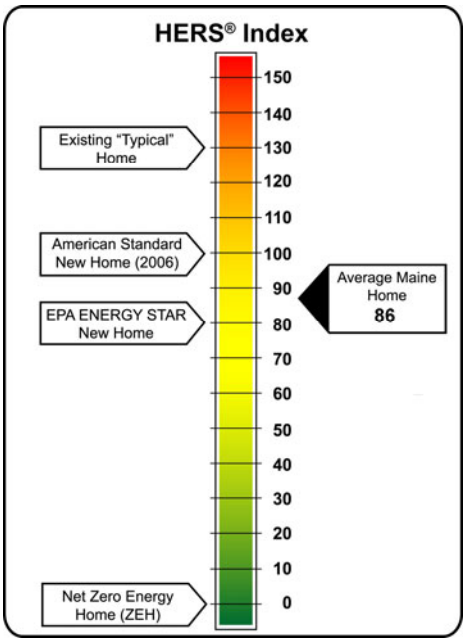
[1] RESNET: Residential Energy Services Network.

- Minimally-efficient oil boilers with inefficient tankless coil water heating systems;
- 10-20% of homes with central air conditioning systems;
- Many ENERGY STAR appliances and some CFLs from Maine's products programs;
- Average HERS ratings in the 90 Index range, with a range of scores for all homes;
- Most homes compliant with the energy requirements of the Maine Energy Code (IECC 2003) but generally not with mechanical ventilation (ASHRAE 62.2-2003) requirements;
- Total annual energy costs of about $4,000 (at today's higher energy rates); and
- Costs to upgrade from baseline to ENERGY STAR of about $2,000, as is generally the case in other surrounding states.

While some of our expectations were confirmed, we were way off the mark with others. In fact, with respect to code findings, the results were so dramatic that the Maine legislature took the findings and used them to pass an energy code for the first time in the State.

Findings

Figure 1. RESNET HERS Index Example



All homes in the Maine study were run through the REM/Rate HERS software. This uniform measure of a homes' efficiency enables comparisons across homes and with other states that also use the HERS Index as the basis for residential new construction programs. The HERS Index is shown graphically in Figure 1. It was created by RESNET and sets "the American Standard New Home" (a new home built to national energy code) at 100 points, awards one point for each percent energy saved relative to the 100-point reference home, establishes 80 points as the "ENERGY STAR Homes" level for northern-tier states like Maine, and sets 0 points for a home that requires no purchased energy, or a "Zero Energy Home". The lower the score, the more efficient the home.

Figure 2 shows the distribution of HERS scores over all 78 homes. The average, median, minimum, and maximum HERS scores are also noted. Maine homes' HERS indices averaged 86, which is a little better than we expected, and about six points above (worse than) ENERGY STAR. The home with the maximum score (183) uses almost twice the energy it would if it had been built to the average Maine home characteristics. The minimum score (58) is below the level that would make it eligible for the $2,000 federal tax credit—approximately 60-65. Thirty-six (36) percent of the homes have HERS indices of 80 or less. However, a handful of very poor performing homes with very high HERS indices pulled the mean up to 86.

Figure 2. HERS Index Distribution

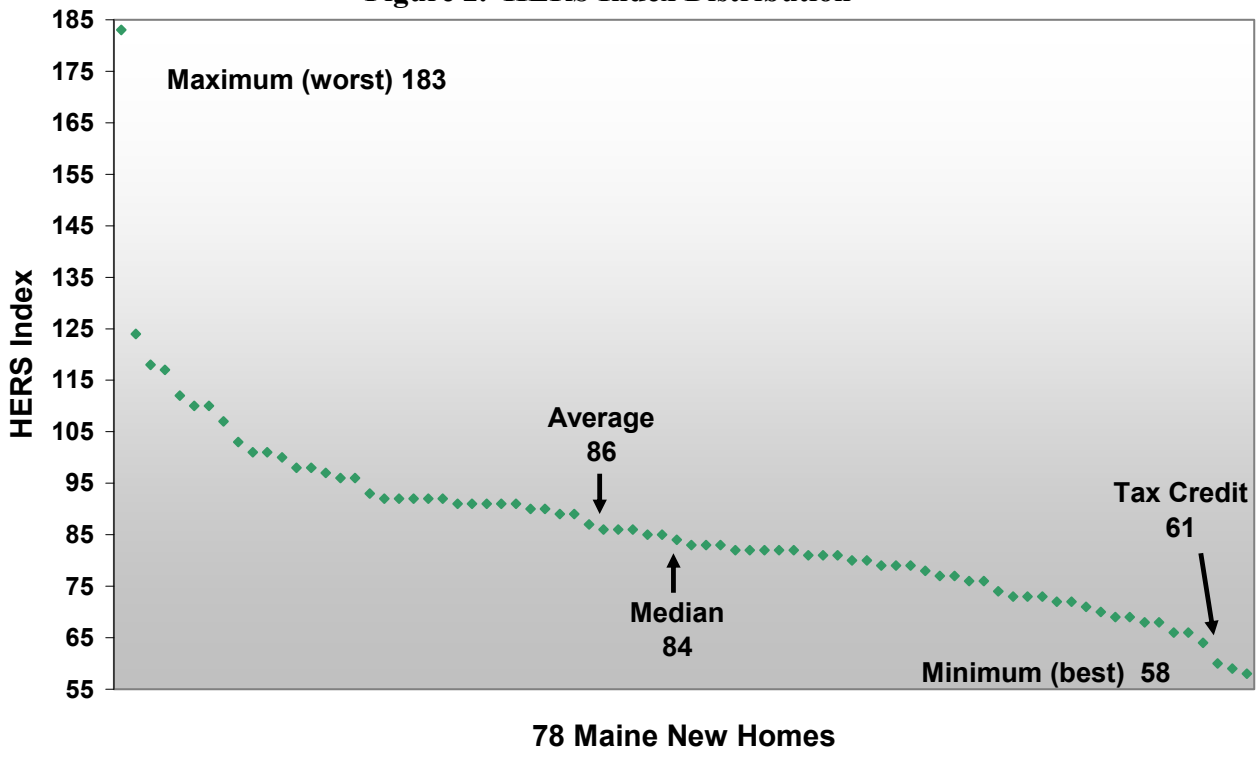


Table 1 shows the average characteristics of a new Maine Home. In general, homes were found to be smaller than in most other Northeastern states (2,057 square feet, compared to Vermont's 2,400, Long Island's 2,696 and Massachusetts' 2,672). Most homes had 2x6 walls, no basement insulation, were heated with oil boilers, and 12% had central air conditioners. These results are generally in line with expectations except for the high heating system efficiencies.

However, some results surprised us (see Table 2). In addition to more efficient heating systems than we expected to find without any ENERGY STAR or new homes program, most windows were low-E, and the majority of water heating systems were the more expensive, and more efficient, indirect-fired storage tank set up as a zone off the boiler. Given that the incremental cost can be upwards of $1,000 for such a system, the industry seems to have moved by itself in the direction of both efficiency and convenience (almost endless hot water as opposed to tankless coils' limited production). Additionally, house air leakage, without any formal builder education, was reasonably tight, in the range of the ENERGY STAR Homes standard of 5 ACH50. The high boiler efficiencies and low-E windows suggest that the building industry and homebuyers are aware of the benefits of and value of these more expensive, more efficient products. However most homes (82%) did not have ventilation systems and, therefore, did not meet Maine ventilation code. Our conclusion regarding house air tightness is that the combination of predominantly geometrically simple-shaped homes, sheet-goods building materials that naturally seal-up homes, and an increasing emphasis on building tightness in builder publications all combined to deliver tighter homes than expected.

Table 1. Average New Maine Home Building Shell and HVAC Characteristics

Average New Maine Home Building Shell and HVAC Characteristics	
Conditioned Area	2,057 ft^2
Building Shell Insulation Levels	
Flat Ceiling	R-30.8
Vaulted Ceiling	R-30.1
Above Grade Wall	R-17.5
Exposed Floor	R-15.3
Framing—Percent of Homes	
2 x 4 Framing	14%
2 x 6 Framing	83%
Insulated Concrete Forms	2%
Foundation Wall Insulation	
No Insulation (% of homes)	66%
Average R-value of Insulated Foundation Walls	R-3.4
Slab on Grade—% of homes with insulation under the slab or on the perimeter	57%
Heating and Cooling Systems	
Type of Heating System	**% of Homes**
Ducted	14%
Hydronic	81%
Other (baseboard/unit heaters)	5%
Heating System Efficiency	**Average AFUE**
Furnaces	87.7
Boilers	85.3
Heating Fuel	**% of Homes**
Natural Gas	4%
Propane	15%
Fuel Oil	75%
Electric	5%
Type of Cooling System	**% of Homes**
Central Air Conditioning	12%
Room Air Conditioner	34%
Cooling System Efficiency	**Average**
Central Air Conditioning	12.85 SEER
Room Air Conditioner	10.42 EER

Table 2. Windows, Leakage, Ventilation, and Water Heating Characteristics

Windows	
Average Window U-value	.37
Leakage	**Average**
Air Changes per Hour at 50 Pascals (ACH50)	5.4
Natural Air Changes per Hour (ACH-Natural)	0.3
Duct Leakage—CFM25 per 100 ft^2 of Conditioned Space	10.0
Ventilation	
Percentage of Homes with No Ventilation System	82%
Domestic Hot Water Type	**% of Homes**
Integrated—Indirect-fired storage tank	63%
Tankless Coil	17%
Conventional	13%
Instantaneous	6%
Combination Tank	3%

On the negative side, we were surprised to find that insulation installation was particularly poor. Haphazardly installed batts, very low-density blown-in fiberglass, many

uninsulated hatches, and even completely uninsulated surface areas were the common picture in most homes. We weren't surprised to find two-thirds of basements uninsulated, but it seemed to reinforce the lack of attention to insulation issues in new homes. Despite the fact that homes were relatively tight, there were still numerous opportunities for better air sealing, especially addressing attic by-passes and at the marriage walls in the double-wide manufactured homes.

Regarding major appliances for which we were able to verify the efficiency, more than 60% were ENERGY STAR—a testament to Efficiency Maine's product programs[2] (see Table 3).

Table 3. Appliances

Appliance	ENERGY STAR
Refrigerator	65%
Dishwasher	68%
Clothes Washer	60%
Clothes Dryer Fuel Type	91% Electric

For the first time that the authors are aware of for projects of a similar nature, the study team counted all of the available lighting sockets. The average of 70 sockets (a mix of hard-wired and plug-based) represents a tremendous lighting opportunity for savings beyond the 20% of sockets (15% of fixtures) that are already fluorescent (see Table 4).

Table 4. Lighting

Lighting	
Average Total Sockets per Home	70
Percent Fluorescents in Sockets	20%
Percent Fluorescents in Fixtures	15%
Percent Incandescents in Fixtures	85%

Energy Consumption and Cost

From the HERS energy ratings conducted on each home, we averaged projected energy consumption (in terms of millions of Btus) and costs based on current electricity and fuel prices. The average home will expend approximately $5,000 at today's rates[3] for annual energy costs. This is about $1,000 more than we expected, due primarily to the lower efficiency of homes than we had expected.

[2] Average Energy Star Appliance Penetration - Maine State, Northeast, and US. D&R International (2006)

[3] Heating costs are estimated using REM/Rate software to provide consumption data and average current utility rates for Maine: Electric ($0.16/kWh); Natural Gas ($1.34/therm); Propane ($3.05/gal); Fuel Oil ($3.45/gal); Wood ($170/cord)

Table 5. Estimated Annual Energy Use and Cost for Average New Maine Home

End Use	MMBtu	Cost
Heating	108.0	$ 2,741.51
Cooling	3.8	$ 257.35
Hot Water	17.5	$ 466.29
Lights & Appliances	32.4	$ 1,501.36
Service Charge		$ 92.17
Total	**161.8**	**$ 5,058.68**

Note that the cooling cost represents the average annual cost for only those homes that have central air conditioning.

We also looked at energy consumption by house size. As would be expected, larger homes have a proportional increase in average annual energy consumption, with one exception in the 3,500 – 3,999 square foot range.

Additional Analyses

We further analyzed study findings to better understand how Maine homes compare to homes in other states; what it might cost to improve the average new home in Maine to different efficiency levels, and how those costs compare to the savings when financed in a mortgage; and where the inspected homes are in relation to Maine's Energy Code.

Comparison to Other Northeastern States

We compared the average HERS rating of the sample of Maine homes (HERS Index of 86) to other northern New England states, all of which have had ENERGY STAR Homes programs and the associated builder training and support for years. The average Maine home is actually not too far out of line from some of them, and even did better than some.

Baseline HERS Comparisons

While there is no single consistent and reliable source to obtain comparable HERS Energy Ratings across states, we compiled data from recent baseline studies to derive composite average ratings. These comparisons are by no means definitive and must be taken "with a grain of salt". Baseline studies conducted two or more years ago may understate the current level of energy efficiency and some studies included ENERGY STAR homes in their sampling while others did not. The purpose of the Massachusetts study was to update the baseline home used in estimating savings, and the study results for custom and spec homes were weighted to reflect the mix of custom and spec homes in the Massachusetts ENERGY STAR Homes Program—93% spec homes. Accepting these study differences, the Maine HERS Index of 86 appears to compare favorably with other New England scores. However, compared to Vermont, which has had a new homes program for more than a decade, it appears that Maine has a way to go to move the energy efficiency of new homes up to the Vermont level, which is approximately comparable to the ENERGY STAR Homes standard. In all states except for Massachusetts, the baseline represents the average of all new homes, including ENERGY STAR and not. However, in Massachusetts, only non-ENERGY STAR Homes were included in their baseline study. Also,

note that the ENERGY STAR threshold begins at HERS Index 85 in Massachusetts and downstate New York[4], but is at 80 for the rest of the northern tier states of New Hampshire, Maine, and Vermont.

Table 6. Selected Northeast States Baseline New Homes HERS Scores[5]

State	HERS Rating Index
Vermont Baseline	80
Maine Baseline	86
New Hampshire Baseline	90
Massachusetts Baseline	92
New York Baseline	99

ENERGY STAR Homes program comparisons. We also looked at the 2007 HERS indices from selected Northeast states that use ENERGY STAR as the central focus of their programs. While the threshold for ENERGY STAR designation is 85 points up through Climate Zone 5 (approximately at the northern border of Massachusetts) and 80 for states farther north, we found that the average HERS index for program participants was significantly lower than the ENERGY STAR threshold in all states where the HERS information was available. Table 7 shows that the average scores, in all those states are at least 10 points below the ENERGY STAR threshold, with average scores ranging from 74 to 64.

Table 7. Selected Northeast States ENERGY STAR Program Homes HERS Scores[6] in 2007

State	HERS Rating Index
New Hampshire	64
Vermont	64
Connecticut Light & Power	68
Massachusetts	68
Rhode Island	74
Connecticut – United Illuminating	74

Least-Cost Analysis

The purpose of the least-cost improvement analysis was to determine those combinations of measure upgrades that would most cost-effectively improve the average home in the study so that it would meet the energy-efficiency requirements of different program tiers. The results of this analysis will assist planners as they design programs and set incentive levels that reflect the

[4] New York still uses the "old" HERS score and has determined that old-84 is the statewide threshold for ENERGY STAR Homes.

[5] HERS index values are estimates calculated by VEIC based on information from recent baseline studies, other reports and professional judgment.

[6] Sources: NH, MA and RI: Bill Blake, National Grid; CL&P: Joe Swift; UI: Chris Ehlert, VT: Pat Haller, Efficiency Vermont.

improvement costs. In addition, the analysis demonstrates which measures are generally more cost-effective and yield greater energy savings.

The methodology used to conduct this least-cost analysis consists of several key parts. First, a baseline "reference home" was created in REM/Rate to serve as a proxy for the typical average single-family detached home in Maine. Energy consumption and costs from the 78 modeled homes in the baseline study were averaged and compared with this reference home and found to have greater than 98% correlation in terms of energy consumption. Next, potential efficiency measures such as improved building shell, better mechanical equipment, etc. were added to the baseline model. Through an iterative process, the most cost-effective (i.e. most HERS points per improvement cost) combination of efficiency measures needed to reach each improvement tier was determined. The incremental costs for the efficiency measures were based on existing information collected from an extensive survey of builders[7] and product distributors in New York[8], New Jersey, and Vermont.

The levels examined in this analysis include the following:

- "IECC Code": Maine Model Building Energy Code (IECC 2003);
- "Maine Rx Code": Maine Model Building Energy Code Appendix A;
- "ENERGY STAR": EPA ENERGY STAR Homes program standards applicable to Maine;
- "EPACT": Federal Energy Policy Act of 2005 levels (50% savings for heating and cooling);
- "Micro": Highly energy efficient home with HERS Index of 54; and
- "Micro RE": Highly energy efficient home with 3.5 kW photovoltaic system and solar how water system, HERS index of 39.

In general, the most cost-effective measures, not including the required components (i.e. code and required kWh savings levels for each program tier) were the following:

- Air sealing to <.5 CFM50/square foot of floor area (or <1,026 CFM50) (with mechanical ventilation);
- Sealing ductwork (where it exists);
- Adding foundation wall insulation; and
- Improving insulation installation quality.

With limited incentive dollars, focusing on air-sealing (both shell and ducts) and quality installation of thermal and mechanical components appears to be the most cost-effective route toward ENERGY STAR levels after all code requirements are met. As Table 8 below indicates, the incremental costs to reach the various improvement tiers increase with the desired score level.

[7] NJ ENERGY STAR Homes Program Incentives and Smart Growth Analysis, March 2003, VEIC
[8] NYSERDA Reference Design Guide for Highly Efficient Construction, July 2007, VEIC

Cash-Flow Analysis

Using the projected costs to upgrade homes to various energy efficiency levels, we examined the costs and savings assuming a home buyer were to finance each improvement package as part of a 30 year mortgage. The cash flow (energy savings less incremental mortgage costs) results indicate that while all packages--except the Maine Rx Code and micro-load home with renewables--generate greater energy savings in the first year than the incremental mortgage cost, achieving higher ENERGY STAR and EPACT levels are more cost-effective than building to code. In fact, achieving the EPACT level of efficiency will generate $976 per year cash-flow. Adding renewables on a highly-efficient home will cost the homeowners about $660 more per year than the savings it will generate. Note that this analysis assumes energy savings at today's prices. As energy prices increase, mortgage costs stay fixed and the cash flow to the homeowners will increase, making all of these packages look more favorable.

Table 8. Cash Flow Analysis Results for Improvement Packages

Maine RNC Improvement Financing Scenarios							
	Baseline	IECC code	Maine Rx code	ENERGY STAR	EPACT	Micro	Micro RE
Improvement Costs	$ -	$ 3,692	$ 3,366	$ 4,144	$ 4,661	$ 18,723	$ 47,763
Mortgage Interest Rate	6%	6%	6%	6%	6%	6%	6%
Loan Term (Years)	30	30	30	30	30	30	30
Annual Incremental Mortgage Payment	$ -	$ 268	$ 245	$ 301	$ 339	$ 1,360	$ 3,470
Annual Energy Costs, 2008	$ 4,917	$ 4,605	$ 4,676	$ 4,184	$ 3,602	$ 3,030	$ 2,108
Annnual Energy Savings from Baseline	$ -	$ 312	$ 241	$ 733	$ 1,315	$ 1,887	$ 2,809
Annual Cash Flow	**$ -**	**$ 44**	**$ (4)**	**$ 432**	**$ 976**	**$ 526**	**$ (661)**

Code Analysis

The residential energy components of Maine's "Model Building Energy Code" are based on the International Energy Conservation Code (IECC) 2003 version (including Chapter 11 of the International Residential Code (IRC), 2003). The residential ventilation components of the Maine Code are based on standard ASHRAE 62.2-2003. We were able to use the HERS Energy Rating software to generate a code compliance report for each home in the sample in order to determine typical code compliance rates for new Maine Homes.

A full 83% of homes in the study do not pass the "IECC 2003 Consumption Compliance" analysis and 95% do not pass the alternative compliance route, the "IECC 2003 Overall Uo Compliance" analysis. Maine has a long way to go to move new homes to compliance with the Energy Code; much of this could be achieved by insulating basements.

We also examined the mechanical ventilation requirements of the Energy Code (ASHRAE 62.2-2003) and found that only 14 of the 76 homes (19%) had systems that may pass code. Some of the homes with central ventilation systems did not meet all of the seven specific ventilation code requirements (e.g. fan sone ratings, garage isolation, etc.) and so may not have passed code even though they had a controlled ventilation system. Eleven (11) of these systems were heat-recovery or energy-recovery ventilators.

The HERS Index and 2003 IECC Code

A home with a HERS index of 100 is presumed to meet the threshold of the prevailing national energy code. The average Maine home scored 86 on the HERS index, yet failed to meet the compliance or performance requirements or the prescriptive requirements of the IECC 2003 Energy Code.

The baseline study revealed a mix of both efficient and inefficient energy features installed in homes. The average Maine home included mechanical equipment (heating, cooling, and hot water) that exceeded minimum federal code requirements, while insulation levels generally fell short of code requirements.

There are interactive effects that determine whether or not a home meets the code, but these trade-offs are limited to shell features. For example; better than average ceiling insulation might partially offset lower than average wall insulation, but (depending upon compliance methodology), better insulation may not offset a low efficiency heating system. In addition to overall heat loss of the building envelope, there are certain "must-meet" criteria such as mechanical efficiency, duct insulation, and (in the case of Maine's Rx code) ventilation.

When mechanical equipment found in the Maine baseline home was changed (efficiency reduced) in the rating model so that each piece of equipment represented the minimum efficiency requirements of the code, the index rose from 86 to 103, a level that represents 3% greater energy consumption than what might be found in a code compliant home.

Recommendations

Based on study findings any new homes program that Maine institutes should incorporate technical assistance, direct incentives, marketing, and consumer education. Based on the research conducted for this study—field testing and observations, discussions with homeowners, and data analysis—we make the following recommendations:

- *Code Adoption and Enforcement* – Given that more than 83% of new homes do not meet code in Maine, there are real opportunities for raising the energy-efficiency floor to improve the performance of new homes. HERS raters could be used to deliver code compliance services where municipalities do not have code officials.
- *Builder Training* – Maine builders have a lot to learn about building performance and energy-efficient construction.
- *Tiered Approach* – While many of the homes examined do not meet the energy code, some are doing pretty well in terms of energy performance. A "one size fits all" will likely not work because it won't meet the needs of all potential program participants.. Adopting a program with multiple tiers that allows entry at multiple levels and drives participants to higher performance levels would be the most effective approach.
- *Manufactured Homes* – About a quarter of the new homes constructed each year in Maine (including about 25% of survey homes) are built in a factory—quite a few in Maine factories. A concerted focus on improving the energy efficiency of manufactured homes could yield lasting results once processes are established on the assembly line that address building science and energy efficiency.

- *Electricity Focus* –A number of opportunities for electrical savings were identified and should be a focus of the new homes program. These include electric heat, cooling systems, efficient furnace fans, lighting, and appliances.
- *Coordinate Efforts with Oil Dealers and Natural Gas Utilities* – Much of the savings in new homes will be from fossil fuels, which should cover their costs of efficiency.
- *Technical Features* – Homes in the survey had quite a few energy- and building science-related shortcomings. Areas that should be a focus of the new homes program include: building science, insulation, duct sealing, air infiltration, equipment oversizing, and mechanical ventilation.

Conclusions

While some of the results of thoroughly examining 78 new homes in Maine are better than expected, there are still many short-comings. When homes are built in a vacuum without readily available technical assistance, a construction standard, or building science professionals to count on, there are bound to be areas for improvement. Offering a new homes program with builder training, technical assistance, incentives, marketing, and promotion of participating builders will certainly help move the new homes market in the right direction faster and in greater increments than would be the case without a program. However, at least parts of the market seem to be moving along on their own with the help of savvy manufacturers, builders, and consumers who demand and supply greater comfort and efficiency. At any rate, if Maine wishes to ensure compliance with its energy and ventilation codes, and offer a tiered program to push builders up the energy-efficiency ladder faster, it will need a robust and qualified stable of energy professionals ready and available to assist builders and certify homes. Without this foundation and infrastructure, progress will be slower. With enough HERS raters on the ground, they can serve as Maine's delivery vehicle to bring builders to code and beyond in Maine's quest--like most other states these days--to take charge and lead the way to saving energy.

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