Roll with the Changes: The Evolution of a Residential New Home Construction Program in Wisconsin

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ABSTRACT

Wisconsin ENERGY STAR® Homes is a voluntary program promoting building practices that address combustion safety, durability and a long building life, occupant comfort, and energy efficiency. In addition to meeting the national ENERGY STAR Homes program requirements, the Wisconsin program has added requirements including construction site visits, shell air tightness, and equipment standards to better ensure combustion safety, and mechanical ventilation.

This paper describes program changes based on lessons learned from the first three years of operation. Changes were required to ensure that new Wisconsin homes continue to be built to greater levels of performance and efficiency, and so that the state building community welcomes and supports this voluntary effort. The goal of the paper is to communicate these lessons, which the authors believe are transferable to other new home construction programs.

The paper addresses three broad program changes regarding: 1) construction standards prompted by the results of an energy savings and ventilation effectiveness study of program homes, 2) program delivery to ensure a high quality, valued service, and 3) how to differentiate program homes, and communicate to homebuyers and other market players about the benefits of high performance, energy efficient homes; specifically addressing problems relying on a home energy rating score (HERS) to communicate these benefits.

Introduction: Why the Change?

After three years working directly with the Wisconsin building community to certify over 1,050 new homes, the Wisconsin ENERGY STAR Home program team identified changes required to improve this voluntary service.[1] The goal is to work on a voluntary basis with the building community to produce increasingly energy efficient homes, and address the variety of issues that can result from "tighter" new home construction.[2] The challenge is to make changes and balance the desires of program funders for greater energy savings, with

[1] A more detailed description of the Wisconsin ENERGY STAR Homes program is included with the ACEEE 2000 Summer Study Proceedings (Meunier 2000). The program team includes staff from the Wisconsin Department of Administration, Wisconsin Energy Conservation Corporation, Home Building Technology Services, Energy Center of Wisconsin, Advanced Energy of Wisconsin, Conservation Services Group, Dick Stone Consulting, and Hofmann Energy Consultants.
[2] For example, the increased risk of back drafting from combustion appliances, moisture related problems, and poor indoor air quality.

the willingness of the building community to produce these homes, and homebuyers to potentially spend more money to buy them.

The team identified changes in three areas including: 1) construction standards to improve gas and electric savings and to better ensure effective mechanical ventilation, 2) how to select and monitor work completed by the people advising builders and homebuyers, and 3) how to communicate the benefits of high performance homes to homebuyers and others in the new home market. These changes were driven by a combination of program staff's experience implementing the program on a daily basis, program evaluation, and market research. The paper details some of the rational behind these changes, and how the program team made changes to improve the service offering.

Changes to Construction Standards Based on Evaluation Results

The program was initiated in February 1999 by the Wisconsin Department of Administration's Energy Bureau as an experiment to gauge builder support for a home energy rating-based service to gradually improve new home efficiency. The program met some initial success securing builder interest, and expanded from a pilot to serve as service for builders and homebuyers located in Wisconsin Public Service, Alliant Energy and Wisconsin Electric Power Company's service territories. After the program's first full year of operation, the team started to evaluate impacts in terms of energy savings and the effectiveness of mechanical ventilation standards. While large energy savings per home was not the priority during the outset of the program, the team realized that increasing energy savings would become important to program funders over time, and to ensure cost-effectiveness. Similarly, the team wanted to learn if ventilation standards were working to provide for air quality and control moisture in program homes, or if improvements to the standards were needed.

Energy Savings

In 2001 the team initiated a billing study comparing the actual energy use of 100 program homes to 170 non-program homes (Pigg 2001). The study found the average Wisconsin ENERGY STAR Home to use about 10 percent less natural gas and 4 percent less electricity, though the latter is not statistically significant (Table 1).

Table 1. Natural Gas and Electricity Use, by Group, and Difference Between Groups

	Participant Homes	Non-Participant Homes	Difference	Percent Difference
Natural Gas				
Total use[a] (therms/year)	928	1024	-96 ± 68[b]	-9.4% ± 5.7
Heating Energy Intensity[c] (BTU/ft^2/HDD)	2.51	2.83	-0.32 ± 0.20	-11.3% ± 5.4
Electricity (kWh/year)[d]				
unadjusted	9,495	10,068	-573 ± 813	-5.7% ± 7.6
adjusted for difference in household size[e]			-396 ± 680	-3.9% ± 6.8

Results weighted for geographic representativeness
[a] excludes homes with supplementary fuel use and poorly determined gas consumption; part. n=87, non-part. n=157
[b] 90% confidence interval
[c] also excludes homes with a single or inconsistent estimate(s) of square footage; part. n=47, non-part. n=98
[d] excludes homes with supplementary electric heat, electric water heat, or poorly determined annual electricity use; part. n=86, non-part. n=148
[e] based on regression model of annual electricity use as a function of square footage, number of people in household, and indicator variable for participation in the program (r^2 = 0.356)

These relatively low energy savings did not surprise the team, given that Wisconsin has a relative stringent energy code, a high market share for high efficiency furnaces, and the initial set of program construction standards primarily addressed combustion safety and mechanical ventilation versus an emphasis on energy efficiency.[3] In fact, the only standards which have a direct impact on efficiency include 1) a home built to achieve a HERS score of at least 86, and 2) an air tightness rate of .25 CFM@50 per square foot of shell area, or less.[4] Overwhelmingly, the score did not force homebuilders to increase insulation levels or the efficiency of mechanical equipment, however the program had significant impact on how airtight homes are: program homes have a median air leakage of about 2.4 air changes per hour at 50 Pascals, compared to 3.9 for a random sample of 43 new, non-program Wisconsin homes tested in 1999 (Pigg and Nevius, 2000).

The program started with the proposition that a fledgling effort needs to first address the immediate needs of the building community, and only then look to raise the bar with regards to both space heating savings, and electrical savings. The program team needed to address the building community's concern that increasing a home's air tightness and addressing mechanical ventilation would work to reduce moisture related problems, not increase the incidence of these problems. Indeed, in-depth interviews with 100 Wisconsin building and remodeling contractors in 1995 revealed a relatively widespread concern that homes are being built too tight (ECW, 1996).

[3] For context, Wisconsin's Code slightly exceeds the Model Energy Code of 1995
[4] Measured upon completion of every program home by blower door testing.

Space heating savings. The study concluded that there is a statistically significant correlation between measured air leakage and heating energy intensity. Simply put, the tighter the home, the lower the energy use per square foot, which the team could use to provide feedback to the building community.

Table 2. Billing Study Summary

Percentile of Program Homes by Heating Intensity	Average Heating Intensity (Btu/Ft2/DD)	Average Shell Airtightness (CFM@50 Pa / Ft2 of Shell Area)	Air Changes @ 50 Pascals	Average HERS Score
1- 25%	1.9	0.14	1.95	88.0
26 – 75%	2.5	0.17	2.39	87.8
76% - 100%	3.3	0.21	3.18	87.2

Results of the space heating savings analysis did not initiate significant changes in the construction standards in the program, however, it did prompt the team to consider using space heating intensity as a better indicator of a home's performance versus the HERS score, since all homes nearly averaged an 88 score. This is discussed further in the final section of the paper.

The study also provided insight to set a premier level of building performance in the state; for example, the team used characteristics of homes performing in the top space heating intensity quartile to establish a premier level for shell air tightness. The team relied on what is achievable and what makes sense locally, rather than simply setting a standard from other new home programs, which may not make sense for the Wisconsin building community. Using information from Wisconsin program homes, the program arrived at a standard, which is achievable and meaningful in terms of bottom line results and benefits for homebuyers in the Wisconsin market.

Electrical savings. To increase electrical savings per home, the team targeted end uses that could yield the greatest energy and peak demand savings. Given that forced air furnaces provide central heating for the overwhelming majority of homes in Wisconsin (Pigg and Nevius, 2000), the team targeted furnaces equipped with an electronically commutated motor (ECM) as a key efficiency measure[5]. In addition to the efficiency benefits, the team agreed that ECMs would be a good technology to promote since many builder participants encouraged homebuyers to run fans more continuously for "air exchange" or "turnover."

In addition to the ECM, ENERGY STAR central air conditioners, ENERGY STAR clothes washers, gas clothes dryers, and lighting for high use areas were selected to assist in increasing electric and peak demand savings from program homes. The team initially leaned toward including many of these components as standards of the program, however it relied

[5] A detailed discussion of ECM technology can be found in ASHRAE Transactions 1998 V. 104 Pt 1 "Impact of Blower Performance on Residential Forced Air Heating System Performance." The author of this paper puts energy savings from ECMs into perspective: in a typical furnace blower application at high speed a ½ hp ECM draws 400 to 600 watts compared to 500 to 800 watts for a standard ½ hp permanent split capacitor (PSC) motor. Furnaces equipped with ECMs are widely available in Wisconsin, usually at an incremental cost of $500 - $750. This incremental cost estimate is simply based on program staff's informal conversations with trade contractors and builders participating in the program.

on input from a Program Advisory Group before making this decision[6]. The Advisory Group cautioned these requirements might limit voluntary participation and not allow the program to achieve its goal of certifying a minimum of 10% of all new homes in Wisconsin by mid 2004. The Group advised that making these items an option, and then offering targeted incentives, would better allow growth of the program. There also was the notion that the option of these components would "force" the building community and consultants to make the case for these options, assisted by some limited financial incentives.

Ventilation Impacts

When the program started in 1999, the team adopted a mechanical ventilation standard promoted by the Energy Efficient Building Association at that time (EEBA 1998). The objective was to initially establish an achievable ventilation standard, without inducing high incremental costs on the builder or homebuyer, and over time evaluate how well that standard worked to control moisture and provide for acceptable air quality in program homes. The team looked to the Wisconsin Uniform Dwelling Code – where exhaust capacity is required in each bathroom – as the basis for what could be used to meet these standard.

To summarize, the program ventilation standard is:

- Program homes must be equipped with at least one exhaust fan capable of delivering a continuous airflow equal to 20 cubic feet per minute (CFM) for the master bedroom, and 10 CFM for each additional bedroom. Note, the fan does not have to operate continuously, but simply have the ability to run continuously if the homeowner desired. Exhaust flows are tested upon completion of each home. Low sone fans (e.g. 1.5 sones or less) and automatic controls are optional.
- Spot ventilation is required in the kitchen and all bathrooms. Tested exhaust flows in these areas must meet a minimum of 20 CFM. Gas ranges must have a dedicated hood or downdraft to meet the standard.

In practice about half of program homes employ a heat recovery ventilator (HRV) or central exhaust system, and half rely on spot exhaust fans alone for mechanical ventilation.

The team realized that the ventilation standards were a bare bones approach, and that greater levels of ventilation *may* be required depending on homeowner lifestyle. As the program evolved, the team considered adopting the draft standard put forth by the ASHRAE 62.2P committee (ASHRAE 2002). However, the team was cautious about requiring upgrades, without any *local* verification of how well current ventilation strategies were working. As a result, the team initiated a 2001 field ventilation study in 18 program homes as well as 6 non-program new homes (Pigg et al. 2002).

[6] The Advisory Group is comprised of participating Wisconsin ENERGY STAR Home builders, contractors, product suppliers, and utility staff.

What Did We Learn?

The study—which used passive tracer gas tests and carbon dioxide monitoring, as well as monitoring of ventilation equipment use—showed overall ventilation rates that ranged from about 7.5 CFM per occupant to more than 60 CFM per occupant, with most homes falling in the range of 15 to 30 CFM per occupant. Understand that these ventilation rates result from overall activity in the home including opening and closing doors, clothes dryers, and the operation of the home's ventilation equipment.

Though all of the homes in the study met the program standards for ventilation *capacity*, actual use of the ventilation equipment varied widely. Spot bathroom exhaust fans provided less than 2 CFM per occupant for most program homes on average, while balanced HRV systems and central exhaust fans provided flows in a range from 3.5 to 60 CFM per occupant. Only one (non-program) home in the study appears to have met the overall requirements of ASHRAE 62.2P; this home employed two HRVs running continuously. Nonetheless, humidity levels were reasonable in the homes, and the homeowners did not perceive a need for additional ventilation for the most part.

What Were the Changes in Program Standards?

Since half of all program homes rely on bathroom exhaust fans as the ventilation strategy, the results of this study were important. The team now has more detailed information to provide to builders and homebuyers who want to rely on bath fans as a ventilation strategy; bath fans alone are not used enough to meet target ventilation rates. The study lent some credence to the team's notion that promoting quiet fans with some type of automatic controls, for example a timer or dehumidistat, can help builders provide a more reliable means of meeting the target ventilation rate for each home.

Understanding the reality that many program builders and homebuyers want to rely on spot fans, and to facilitate the adoption of this lower cost ventilation strategy, the team decided to provide a financial incentive on quieter, higher quality bathroom exhaust fans combined with some simple controls. The team believes these components can provide a more reliable means of delivering a higher average ventilation rate when compared to the current program requirement, but admit this will need to be measured and evaluated. Finally, the team agreed to invest in ongoing surveys to understand what is acceptable to homebuyers with regards to air quality. The team plans to follow up with program homebuyers to gauge their satisfaction with their home's ventilation equipment and their ability to control air quality.

Changes in How Construction Advisors are Selected and Monitored

Over the course of the program's development two main issues arose which required immediate attention if the program was to continue providing valuable, unbiased consulting services to the building community. The program works with independent consultant who work directly with the building community and homebuyers to review a home based on plans and identify improvements and challenges in terms of insulation or air sealing, complete construction site visits to verify performance details and installation quality, and finally to test homes upon completion for air tightness and ventilation flow rates. The first issue involved developing an infrastructure of private companies qualified to advise on high performance construction, and who would be viewed as valuable resource to the building community. The second issue was how to maintain this infrastructure given that early program activities were inadequate at times to attract and sustain high quality, full time individuals.

The following details how the team addressed these issues and developed a dependable, highly qualified, core of consultants of which more then 50 percent are now delivering program services as a full-time occupation.

Program funders wanted this effort to produce local expertise that can continue to provide services to the building community after/if the program expired. The team was directed to screen and train local businesses to ensure services were available statewide. This is a dramatically different approach compared to a centralized utility, or single company approach where one entity is responsible for all program design and delivery.

The team was given the task of keeping a group of 30 individual business people, all with their own background, motivations and agenda, on the same page to deliver Wisconsin ENERGY STAR Homes consulting services. While this is a more difficult task compared to one company delivering services, the team agrees that this effort can yield more lasting results for Wisconsin builders and homebuyers. For example, a private home inspector located in Eau Claire, Wisconsin trained in building science and who served as a consultant can continue to provide services and be called on by that local building community to consult on energy and related performance issues in homes long after any program is gone.

To meet this goal, the team initially recruited candidates for the delivery of program services from an existing pool of home energy raters, many of whom served the existing home market. Individuals were selected based on experience performing field ratings and use of home energy rating software. The team quickly realized that performing ratings for homeowners as opposed to consulting on the construction of new homes with seasoned builders presented new challenges and required some new skills. To address this issue and build program credibility in the eyes of the building community, the team moved quickly to provide building science training for all consultants. These advanced building science seminars are now an on going requirement for participation in delivering consulting services.

Beyond establishing an initial core group of qualified consultants the team recognized the need to sustain and expand this group if the program were to grow, meeting rising demand and target goals. Thus, to make the consultant position viable and to retain and to attract motivated individuals on a full time basis, the team developed consultant contracts for both experienced and new consultants. These contracts were designed to supplement the direct program funding for consultants and allowed them to bill for supplemental program support services, defined in a scope of work, that increased their market value, education, and/or business exposure. Further, low cost training opportunities, partial scholarships to building science seminars and conferences, and an equipment purchase plan were all developed to support the effort in cultivating the consultant position into a viable, educated, highly trained, and valued actor in the new construction market.

The effort to expand the number of qualified program consultants to meet expected demand for program services built upon experiences with the initial group. An improved consultant candidate screening, training, and evaluation process was developed which targeted areas of expected high demand and defined specific skills for training and evaluation. The screening included building science pre-tests, background history information, and several job type interviews to determine a candidate's motivation, aptitude and availability to perform program services. Only the "best match" candidates were then selected for training. The training and evaluation process included, beyond advanced building science, computer, building diagnostics, and communication/presentation skills as well as a mentoring program and probationary period for new consultants, and on-going evaluation or accredited

Changes in How the Best Homes Are Recognized

Since the start of the program, the team struggled with a means to accurately differentiate program homes in terms of performance and greater levels of energy efficiency. Similar to the work in most other states employing the ENERGY STAR label, Wisconsin ENERGY STAR Homes relied on the numerical HERS score to provide that differentiation.

However, by the end of the first program year, there was dissatisfaction by a growing number of homebuyers and builder participants in how homes were differentiated. The Wisconsin effort focused a great deal of attention on the HERS score because 1) a financial incentive was tied to the final score on the home; the higher the score, the higher the reward amount for the homebuyer, and 2) the team learned that consumers and builders like numbers; they want a number which is easy to understand and can provide the ability to compare across homes.

While the score seemed to provide what builders and buyers desired, the team decided to completely drop the use of the HERS score to differentiate homes for the following reasons:

- The score compares one home to its own potential. The score does not provide the ability to compare one home to another, as most homebuyers and builders believe.
- The score can help some in differentiating, but is still a component-based approach that does not adequately capture performance differences. The score does not adequately take into account critical real world performance indicators of a home, namely 1) combustion safety, 2) air-tightness, 3) ventilation, and 4) details, which affect a home's durability (e.g. exterior drainage plane detailing).
- The score currently does not take into account the electrical efficiency of Wisconsin homes: furnace blower motors, plug loads, lighting, and appliances. Increasing the efficiency of central air conditioners will not necessarily be reflected in a higher score. This is critical since these electric devices add the most to Wisconsin's electrical peak loads requiring new generation or transmission facilities.
- The score can be deceptive, and lead customers / builders to make improvements that are not economic or in the best interest of efficiency – e.g. sealing ductwork located within the conditioned area of a home, *adding* central air conditioning versus building shell tightening. Using the score as the criteria to make construction or specification choices might not provide the buyer / builder with the most cost effective means of improving performance or energy efficiency.

The team conducted homebuyer focus groups, which revealed the HERS score was commonly misunderstood, and that many program homebuyers, who were otherwise thrilled with their Wisconsin ENERGY STAR Home, were disappointed when they learned their home only rated an 86 or 87, rather than a 95 or better. Buyers liked the fact the score provided a benchmark, but were dissatisfied that the score was not comparative. Participants wanted to compare there home's performance to typical construction around the state (Monalco 2002).

Two common concerns among participating builders included: 1) the score seemed to arbitrarily "jump around" from home to home[7], and 2) extremely airtight homes which employed some of the best ventilation strategies and flows, and where the builder paid a great deal of attention to electrical efficiency did not necessarily rate higher. As one builder on the program advisory group phrased it "the limitations of the HERS score throws all builders, regardless of quality or extra attention to detail, into the same barrel."

Using this input, the team decided to simply focus on the Wisconsin ENERGY STAR Home brand. For those homebuyers interested in a number to compare across homes, a space-heating intensity is calculated for the home, including some context as to how that home compare to all new homes built in the state. For example, a home at 2.0 btu/ft2/dd performs in the top 25% of all new homes built in the state.

Based on builder input, the team placed emphasis on differentiating program builders rather than homes. Table 3 lists the criteria the program team is currently considering to recognize top-level builders in the program. The team envisions this "Gold" level recognition for those builders who build the overwhelming majority of their homes annually in the program, and these homes consistently meet these criteria. The purpose is to recognize this group of builders as leaders, make homebuyers aware of this quality, and hopefully over time motivate other builders to step up to these building practices.

Table 3. Wisconsin ENERGY STAR Homes Gold Level Builder Criteria

Air Flow	Air tightness of .15 CFM@50 per ft2 of shell area
Heat Flow	HERS Score of 86 or better ENERGY STAR Windows
Moisture Flow	Sealed sump pit Continuous drainage plane
Indoor Air Quality	Low sone ventilation w/automatic controls High efficiency filtration
Electrical Efficiency Requirements:	Forced Air Furnace Equipped with ECM 13 SEER 11 EER Central Air Conditioner Manufacturer Best Practices for System Install/Start Up Compact Fluorescent Lights in High Use Areas

Conclusions: If We Had to Do It All Again

If the team were to start this program again, we would follow the same recipe: start small, establish achievable local standards, engage the building community with a service that is beneficial to them as well as the homebuyer, and evaluate program impacts. The energy and ventilation study results put program progress in perspective. Importantly, this evaluation work has lent more credibility to the benefits of airtight construction, and the type of ventilation strategies, which are more reliable to achieve targeted ventilation rates in

[7] As a clarifying example, builders who built nearly the same home model, with similar glass area, and similar orientation would complain that the score from one home to the next might vary as much as two points.

program homes. It also provides some grounding to issues, which the building community is looking for unbiased advice on.[8]

The team believes the model of using independent consultants as construction advisors can provide more lasting impacts in a market. However, there is a price. In addition to some assurance of work for these private businesses, the program team needs to clearly define policies for conducting services and an annual consultant evaluation to ensure professionalism, consistency, and technical competency.

Finally, the team has learned that the goal of recognizing the homes at the top end of the energy efficiency spectrum is not always simple. Homes with the highest rating score may not be the most efficient in practice, the best ventilated, or the best with regards to long-term durability. The HERS score is useful as an efficiency threshold, and to tie a state effort to the national ENERGY STAR Labeled Homes effort. However, criteria for ventilation, electrical efficiency, and durability may likely be needed to provide a more accurate means of recognizing top performing homes – in terms of combustion safety, durability, comfort and energy efficiency -- in a local market or state.

References

[ASHRAE] American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc. BSR/ASHRAE Standard 62.2P "Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings." Third Public Review – April 2002.

[EEBA] Energy Efficient Building Association. "Criteria for Energy and Resource Efficient Buildings" Committee Draft – Version 1.2 February 1998.

[ECW] Energy Center of Wisconsin. 1996. "Tracking the Building Market for Energy Efficiency Services." Energy Center of Wisconsin Report 147-1.

Meunier, Mary G., Edward M. Carroll, and Joseph P. Nagan 2000. "Wisconsin ENERGY STAR Homes Program: Providing Building Trades with Solutions to Cold Climate Building Problems and Recognition for High Performance Homes." In *Proceedings of 2000 ACEEE Summer Study.* Washington, D.C.: American Council for an Energy-Efficient Economy.

Monalco. "Wisconsin ENERGY STAR Home Focus Groups among Participants and Non-Participants in Madison and Appleton, Wisconsin. Final Report" Published by Energy Center of Wisconsin. March 7, 2002.

Pigg, Scott. 2002. "Energy Savings from the Wisconsin ENERGY STAR Homes Program." Energy Center of Wisconsin. Madison, Wisconsin.

Pigg, Scott, Edward Carroll, Gregory Nahn, and Joseph Nagan. 2002. "Ventilation Performance in Wisconsin ENERGY STAR Homes. In *Proceedings of 2002 ACEEE*

[8] A good example of this is documented in a series of articles, which Wisconsin ENERGY STAR Home staff wrote for the Wisconsin building trade magazine, Successful Builder. The publisher of this Wisconsin trade publication is anxious for program input, especially from ventilation field study.

Summer Study on Energy Efficiency in Buildings. Washington, D.C.: American Council for an Energy-Efficient Economy

Pigg, Scott and Monica Nevius. 2000. "Energy and Housing in Wisconsin — A Study of Single-Family Owner-Occupied Homes," Energy Center of Wisconsin, November 2000, www.ecw.org.