What We Learned Getting to 2 Million ENERGY STAR® Certified Homes that is Positioning Zero Energy Ready Homes for Exponential Growth

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ABSTRACT

The Environmental Protection Agency's (EPA) ENERGY STAR® Certified Homes program has just crossed the 1.8 million certified home threshold and is well on its way to two million (ESCH, *Locate Builders, Raters, and Incentives in Your Area*). It could be argued that the success of ENERGY STAR Certified Homes substantially contributed to an impressive 30% growth in rigor of the International Energy Conservation Codes from 2006 to 2012 (EECC 2012). Meanwhile, the U.S. Department of Energy (DOE) launched the Zero Energy Ready Home (ZERH) program in 2012 as a meaningful step up from ENERGY STAR. Five years later, this program has just crossed the 2,000-home threshold. Yes, this is a slow start. However, the program now has over ten thousand homes in the pipeline committed to ZERH certification based on internal tracking data. This paper draws extensively from the author's experience leading the ENERGY STAR Certified Homes program for 17 years from conception in 1995 to over 1.2 million certified homes in 2011. It examines why DOE made the decision to launch its own voluntary high-performance zero energy home labeling program; key lessons from ENERGY STAR Certified Homes applied to help ensure success; five barriers that made market adoption a significantly greater challenge for ZERH compared to ENERGY STAR Certified Homes; and how lessons-learned can be applied to other programs targeting zero energy performance. Effectively conceiving and implementing one of the most successful voluntary high-performance new home programs in the history of the federal government was a great accomplishment for ENERGY STAR. Not leveraging the lessons-learned would be a tragedy.

Introduction

There is a growing zero energy home movement across the United States (U.S.). This is evidenced by an increased interest in zero energy codes (e.g., California, Oregon, District of Columbia, and others); exponential growth in the number of zero energy homes constructed including more than double the rate of growth from 2016 to 2017 *(NZEC 2018)*; studies showing a significant increase in builders committed to zero energy construction *(DD&A 2017)*; and the disruptive innovation in progress related to the cost and performance of solar electric systems *(DOE 2012)* and battery storage *(Seba 2017)*. More importantly, the zero movement is too important not to succeed. First, critical environmental metrics are approaching planetary boundary conditions with increasing risk. This includes unprecedented increases in the magnitude and velocity of change for global temperatures and atmospheric carbon dioxide (CO_2) driving extreme climate events and sea level rise due to melting polar ice caps; ocean acidification creating vast dead zones unable to support breeding of marine life; and species extinctions reducing biosphere integrity (SRC). In addition, as global population growth

explodes past 11 billion people by the end of this century, every aspect of planetary sustainability will be severely challenged (Vyawahare 2015).

Many scientists and policy experts are suggesting it's prudent and effective to ensure against these risks with draconian CO_2 emissions reductions. And electricity generation is the largest contributor to CO_2 emissions. Which leads to 'why zero?' Any meaningful reduction in CO_2 emissions requires a transformative change to how we use energy in buildings because they consume over 40% of all electric power generation and nearly 75% of electricity (EIA 2012). Furthermore, residential buildings represent more than half of the energy consumption in buildings (EIA 2012). Zero energy ready buildings are an imperative for any strategy designed to manage planetary risk.

What is equally important to the rationale for zero energy buildings is the compelling business case. Consider that DOE analysis shows that Zero Energy Ready Homes provide optimized energy savings while also including comprehensive measures ensuring comfort, durability, health, and safety *(BASC)*. Commercial buildings studies also show impressive energy savings along with evidence of higher worker productivity, reduced absenteeism, and greater worker retention which dramatically improves bottom line business performance (Knox 2014). Finally, from a societal perspective, zero energy buildings result in substantial job growth, improved national security, and over trillion dollars of reduced operating cost that can support economic growth.[1]

That all said, the purpose of this paper is not to justify zero energy buildings as good policy. Instead, if we accept the merits of a ZERHs risk management strategy, this paper examines how to leverage the impressive success of the building science movement to help ensure an equally successful zero energy ready buildings movement. In particular, this paper will review the historic success of the ENERGY STAR Certified Home program as a basis for developing and implementing the DOE ZERH program and then make recommendations for other zero related programs.

The Building Science Movement Precursor to ENERGY STAR

Before discussing how the building science movement grew, it is important to establish what it is. Most simply, it is a discipline that applies basic laws of physics to ensure complete control layers for managing air flow, thermal flow, and moisture flow (both bulk and vapor) in energy-efficient buildings.

The basis for this movement began when buildings started to be insulated in earnest on the heels of the two oil embargos in the 1970s followed by state and national energy codes in the late 1970s and early 1980s. This led to an unintended consequence of increasing moisture-related risks in construction assemblies that now had colder surface temperatures and reduced drying potential attributed to the greater levels of insulation and air tightness. These risks spurred the launch of the building science movement which has been attributed to the emergence of the Super Insulated Home by a group of Canadian building science leaders in the mid-1980s *(Holladay 2010)*. Building science further took hold in Canada with the R-2000 energy-efficient home labeling program. However, the program's aggressive air leakage targets proved too difficult for mainstream builders and resulted in very limited traction *(NRC 2006)*. Nonetheless, there was a growing building science community that spread into the U.S. with the Energy

[1] Internal spreadsheet analysis at U.S. DOE for Zero Energy Ready Home program

Efficient Building Association (EEBA, now the Energy and Environmental Building Alliance). EEBA had its greatest impact from the late 1980s through the 1990s driven by publication of climate-specific 'Builder Guides' written by Dr. Joe Lstiburek and annual conferences that served as a mecca for the building science community to share knowledge and lessons-learned. The EEBA Builder Guides were widely embraced by all housing stakeholders because they were written in a format that was both entertaining, graphically appealing, and understandable.

What We Learned From Success of ENERGY STAR Certified Homes

The ENERGY STAR program was introduced in 1992 by the EPA as a voluntary label for helping consumers easily identify and make an energy-efficient product choice by looking for a 'trusted brand' from an independent 'voice-of-authority'. Starting with computers, the program quickly grew to a wide range of product categories. The timing could not have been more perfect. Appliance and product manufacturers were very concerned about the proliferation of different state standards following California's leading efforts in this area. This would create havoc because it would be costly, if not impossible, to adjust their manufacturing infrastructure to a broad range of specifications for different markets. Yes, the private sector embraced ENERGY STAR as 'great government' because it introduced one national voluntary guideline for each product category and substantially involved them in the threshold development process.

The ENERGY STAR Certified Home program was introduced in 1996 and today is rapidly approaching two million labeled homes. The truly historic growth is shown in Figure 1 with ENERGY STAR Certified Homes accounting for nearly 25% market penetration during the housing industry down-turn between 2007 and 2011[2] and settling nicely into nearly 10% of single-family housing starts *(ESCH, 2016 ENERGY STAR Certified New Homes Market Share)*.

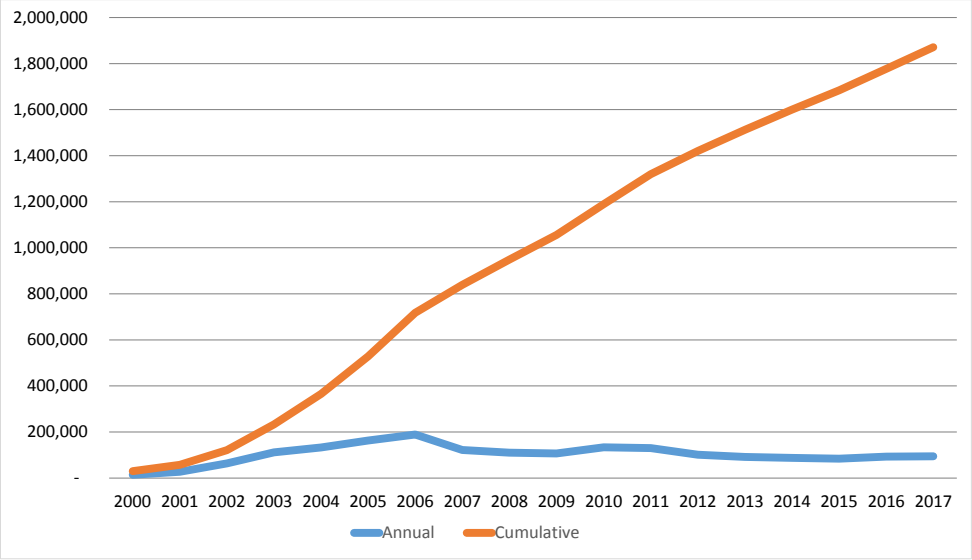

Figure 1: ENERGY STAR Certified Homes Growth. *Source: Internal Data from EPA*

[2] Based on author's comparisons of actual tracking data for ENERGY STAR Certified Homes to industry reported housing starts while serving as National Director for ENERGY STAR Certified Homes from inception in 1995 to 2011.

This growth of ENERGY STAR Certified Homes is strongly correlated with substantial increase in rigor of the nation's residential energy code including nearly 40% improvement between the 2006 and 2012 International Energy Conservation Code (IECC) (see Figure 2).

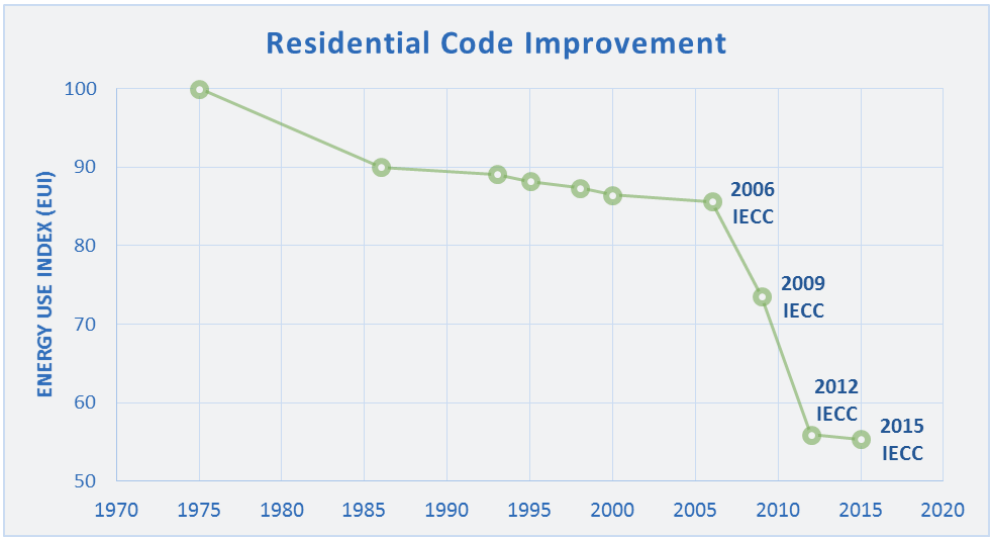

Figure 2: Increasing Rigor in U.S. Residential Energy Code. *Source: Greenfield 2016.*

Of course, there are many important factors that contributed to the success of the ENERGY STAR Certified Home program, but the following five were critical and are described in more detail below.

- Specify energy efficiency plus performance
- Build an effective supply chain
- Strategically sequence the program to targeted goals
- Ensure market-ready specifications
- Employ effective marketing

Specify Energy Efficiency plus Performance

Maybe the most important core principle underlying the ENERGY STAR label is ensuring meaningful energy efficiency while also meeting or exceeding consumer performance expectations. This core principle corrected prior market transformation failures where performance was ignored. For example, billions of dollars were invested by the utility sector in the mid-to-late 1980s with large cash rebates and free products promoting compact fluorescent lamps (CFL). These first generation CFLs were up to 70% more energy-efficient than standard incandescent bulbs, but they failed prematurely, provided poor color, had annoying hum and flicker, and wouldn't work in cold weather conditions (*Sandahl 2006).* In other words, the utility sector invested billions of dollars to convince the American public this was a technology they didn't want to touch with a ten-foot pole because of performance issues. Not only does ignoring performance stop market transformation dead in its tracks, it makes it much more difficult where the technology does improve performance to regain consumer trust. That's why the ENERGY STAR implementation is obsessively disciplined enforcing this core principle.

In the case of ENERGY STAR Certified Homes program, the specification was designed to ensure significantly increased energy efficiency above minimum code while also integrating building science measures that deliver performance improvements related to comfort, health, durability, and safety.

Build an Effective Supply Chain

It was critical to figure out a supply chain that would leverage concomitant interests to promote the program due to a very limited budget for a national housing program. Ultimately, this is what led to the initial decision to hitch ENERGY STAR Certified Homes to a Home Energy Rating System (HERS) verification, that was at that time 'nascent' with a smattering of HERS raters in generally smaller markets (e.g., Indiana, Mississippi, Utah, and one starting in Florida). However, if the program could effectively stimulate the growth of the HERS rating industry, it would have professionals whose livelihood was directly tied to engaging builders in ENERGY STAR. That is because the primary impetus behind setting up HERS programs – retrofit projects – did not work out. The subject of how ENERGY STAR Certified Homes initial funding and support led to the impressive HERS infrastructure that now exists is the subject for another paper. What is most important is that the gamble paid off and provided EPA with an impressive sales force for engaging the nation's home builders. Utility programs proved to be an effective distribution network by reaching out directly to homeowners and builders, helping develop the HERS infrastructure, and in some cases, providing incentives to jump start interest in certified homes.

Strategically Sequence the Program to Targeted Goals

The initial Version 1 program specifications for ENERGY STAR Certified Homes introduced in 1995 required energy efficiency to be 30% above the latest national code at that time – the 1993 Model Energy Code (MEC). This threshold is almost laughable relative to current codes (see Figure 2 above), and in fact there was criticism from some experts communicated directly to the author that it was not strong enough. However, getting the right strategic sequence to a larger goal is critical with any new program. Ask for too much, and you wind up with the painfully slow growth experienced by the R-2000 program. Make it too easy, and the program does not provide a meaningful contribution to market transformation. With this in mind, ENERGY STAR Certified Homes Version 1 targeted five key innovations:

- More air-tight construction;
- More air-tight heating and cooling duct distribution;
- Low-emissivity (low-e) windows in all climates;
- High-efficiency heating and cooling equipment; and
- HERS verification, including blower door testing to verify air-tightness and duct blaster testing to verify duct leakage.

These initial program requirements provided a very effective platform for establishing the label. However, continued program growth would require more rigorous technical underpinnings that were serendipitously provided by the DOE Building America program. It was launched in 1994 while ENERGY STAR Certified Homes was under initial development. In addition to important research with national laboratories, DOE contracted with world-class research teams

working directly with home builder partners to develop and validate building science best practices.

Results from this program provided an invaluable technical basis for ramping up the ENERGY STAR Certified Home specifications. This includes adding comprehensive air barriers via the thermal bypass checklist and insulation alignment with those air barriers in the 2006 Version 2 specification; and insulation quality installation, HVAC quality installation, and comprehensive bulk water management in the 2011 Version 3 specification *(ESCH, History of the ENERGY STAR Guidelines for New Homes)*. These technical specifications significantly contributed to the growth in rigor of the national energy codes discussed earlier, evidenced by how closely they were adopted in 2009, 2012, and 2015 IECC codes.

Ensure Reasonable Specifications

ENERGY STAR is a voluntary program working in partnership with private sector businesses. This reality led to the following four requirements for all technical specifications:

1. They had to be based on sound science and empirical research findings. It is not acceptable to ask partners to make business investments based on technical assumptions.
2. All requirements had to be cost-effective. Sometimes this cost-effectiveness was achieved after applying lessons-learned, but solid data had to demonstrate it was possible.
3. All technologies and practices specified had to be fully compatible with mainstream builder construction practices. It would be a poison-pill to mandate wholesale changes to established housing industry materials and techniques.
4. There had to be a readily available supply infrastructure for all specified technologies and practices. Builders could not be forced to drop preferred suppliers and assume liabilities to manage any issues that came up with new technologies or unknown suppliers.

Any time a builder or HERS rater would raise concerns and validate any of these four requirements were not met, the program policy would be to provide accommodations at the speed-of-business. Without trust, voluntary programs cannot succeed.

Employ Effective Marketing

The success of the ENERGY STAR Certified Home program was also driven by marketing solutions that effectively differentiated builders. This begins with a very successful national brand. In 2016, more than 90 percent of U.S. households recognize the ENERGY STAR, and nearly 700 utilities serving roughly 85 percent of American households leveraged ENERGY STAR in their efficiency programs *(EPA 2017)*. The ENERGY STAR Certified Homes team started with this brand awareness platform and then augmented it with powerful consumer messages of ‘better’ performance. The current marketing tag line is “Better is Better.”

Why DOE Launched Zero Energy Ready Home

DOE to-date has over a $250 million investment in the Building America research portfolio *(IE 2018)*. Although this represents a substantial amount of resources, it is incredibly small relative to need. This is because our nation's home builders and high-performance product manufacturers only invest a little over one percent of revenue in research compared to nearly four percent for corporate America as a whole *(NSF 2008)*. Thus, Building America serves as a vital hub of innovation for the residential sector. However, a pipeline for validating the proven innovations is critical to link them to the housing industry. ZERH was designed to serve this role.

Applying ENERGY STAR Certified Homes Lessons-Learned to ZERH

The paragraphs below show how the same five key success factors for ENERGY STAR Certified Home were applied to ZERH with variations as needed based on unique program requirements.

Specify Energy Efficiency plus Performance

The ZERH energy efficiency target was set at a minimum 30% above the 2009 IECC. This threshold was derived from extensive Building America modeling simulations by the National Renewable Energy Laboratory. The software used was BEopt, which is a residential energy modeling tool that has a built-in cost-optimization algorithm *(Christensen 2006)*. The energy efficiency threshold was achieved along with targeted performance improvements by mandating 2012 IECC as a minimum enclosure along with additional building science and technology innovations from the Building America program *(DOE 2017)*. The key innovations above ENERGY STAR Certified Home include:

- At least 30% greater energy efficiency then 2009 IECC;
- Optimized duct location inside conditioned space or buried below the attic insulation;
- Dehumidification in hot-humid climates with either high latent load capacity equipment or whole-house dehumidification;
- Comprehensive indoor air quality measures based on EPA Indoor airPLUS program;
- Efficient hot water distribution that ensures no more than a half-gallon of water wasted waiting for hot water flow from a fixture;
- Comprehensive package of energy-efficient lighting, appliances, equipment, and fans based on research documenting components and miscellaneous electric loads represent more than half the energy consumption in a high-performance home; and
- Solar ready construction in regions with significant solar insolation using no- and low-cost details and practices that enable future solar electric system installation with no- or minimal cost penalty or disruption.

DOE believes these additional innovations are essential with high-performance enclosures to optimize energy efficiency while managing greater risks associated with comfort in low-load homes and accumulation of contaminants with more air-tight construction. Additionally, efficient hot water distribution offers a unique opportunity available during construction to save both energy and wasted water.

Build an Effective Supply Chain

Like ENERGY STAR Certified Homes, ZERH from the beginning focused on building an effective supply chain which is shown below in Figure 3.

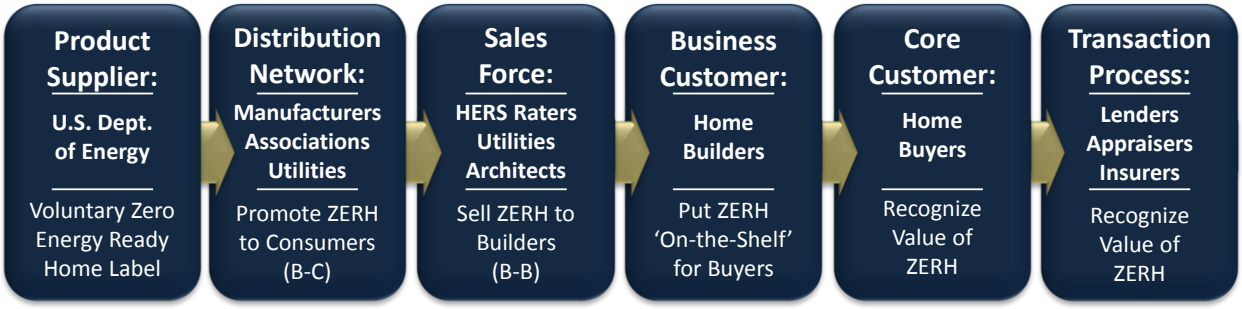

Figure 3. Zero Energy Ready Home Supply Chain. *Source: Author*

The ***Product*** is the ZERH voluntary label that recognizes high-performance homes so energy-efficient, they can offset all or most annual energy consumption with on-site renewable energy. Manufacturers and associations related to high-performance home products and utilities serve as the ***Distribution Network*** helping DOE engage the ***Core Customer*** (e.g., homebuyers) on the value of ZERH. HERS raters serve as the ***Sales Force*** engaging builders to participate in the program and certifying homes. Finally, the Builder Partners represent the ***Business Customer***, essential to putting the product (e.g., ZERH labeled homes) ***'on the shelf'*** for the core customer, the U.S. homebuyer. Of course, with housing there is also a ***Transaction Process*** where the challenge is to ensure the key players (e.g., lenders, appraisers, and insurers) recognize the added value of ZERH and appropriately integrate that value into their services. However, this last part of the supply chain is the most difficult to influence change and would consume too much limited bandwidth, so more limited efforts are invested in this area.

Strategically Sequence the Program to Targeted Goals

As with the ENERGY STAR Certified Home program, ZERH leverages developments from the Building America program to inform future progression of its specifications towards a larger energy efficiency target of 50% above the 2009 IECC, along with improved performance. Specific innovations under consideration by the program team for future specifications include:

- Fully thermally broken walls (e.g., less than eight percent framing factor)
- R-5 and R-7 windows in cold climates
- Heat/enthalpy recovery whole-house ventilation except in hot dry climates
- HVAC with fault detection and diagnostics
- SMART Home and grid integration technology
- Whole-house water use efficiency
- Disaster resistant/resilient construction

Ensure Reasonable Specifications

The ZERH national program requirements have the exact same strategy for reasonableness as ENERGY STAR Certified Homes. This includes an extensive vetting process; active listening to partners; and accommodating requests against the same reasonableness criteria: sound science, cost-effectiveness, compatibility with mainstream builders' construction practices, and readily available infrastructure.

An additional requirement for ZERH is that the new specifications should be completely aligned with ENERGY STAR Certified Homes. It would be unreasonable to ask HERS raters and builders to learn and implement a completely different specification format and verification process. As a result, the ZERH specification framework was set up identical to ENERGY STAR Certified Homes including the same three-part structure with mandatory requirements; Reference Home specifications for the HERS software analysis (called Target Home for ZERH); and size adjustment factor table. Thereafter, the HERS rating process was also set up to be identical with the same two field visits. Finally, ENERGY STAR Certified Home was made mandatory to form a natural step up from one program to the next.

Employ Effective Marketing

The ZERH marketing message by necessity had to be very different from ENERGY STAR Certified Home to effectively make the business case for stepping up from this widely established label. This is because code builders and buyers are typically not the audience since ZERH is generally too big a lift for them. The key marketing message developed for the ZERH program conveys how each certified home lives, works, and lasts better based on the following consumer experiences:

- ***$10,000's of utility bill savings*** over a 30-year mortgage, and often over $100,000;
- ***Advanced thermal protection*** that blocks the hottest and coldest weather;
- ***Total comfort*** at a whole new level with advanced heating and cooling;
- ***Healthy living*** by keeping contaminants out of the air you breathe every day;
- ***Peace-of-mind*** from moisture problems with a complete water protection system;
- ***Enhanced future value*** with construction that meets and exceeds future codes; and
- ***Certified performance*** with a home that has been independently tested and inspected to the federal government's highest performance guidelines.

Barriers to Zero Energy Ready Home

ZERH only has about 2,000 homes certified after five full years of implementation. This is a very slow rate of growth. However, when all reliable program commitments moving forward are counted, there are over 10,000 homes in the pipeline for certification over the next few years.[3] There is a sense that ZERH is finally tipping. Patience is a virtue, but it is still important to assess why there is relatively slow uptake. To that purpose, the ZERH team has studied the program and come up with five unique challenges:

[3] Department of Energy Internal tracking of Zero Energy Ready Home builder partner projects

- ***Lack of Resources***
  ZERH has about one sixth the resources of the ENERGY STAR Certified Home program. That is just the way it is. There isn't adequate space to describe how this challenge is managed, but suffice to say, there has been an obsessive focus on leveraging concomitant interests and creative partnerships. An example of a win-win partnership would be holding the ZERH Innovation Award event at the EEBA Annual Conference starting in 2015. This provides EEBA with an impressive group of high-performance builder attendees that they covet, while providing DOE at no program cost with an awards ceremony in front of the large conference plenary audience. Virtually every key ZERH initiative relies on this type of partnership.
- ***Rigorous Threshold Competing with More Diverse Labeling Options***
  There were over 220,000 HERS ratings in 2017 with an average HERS Index Score of 62 *(O'Keefe, 2018)*. Statistically, there are thus 10,000s of homes within shooting distance of the ZERH average HERS Index Score from low- to mid-50s. However, there are still some difficult mandatory requirements for many builders when simpler and easier differentiation is available from ENERGY STAR Certified Home and the RESNET EnergySmart Builder program (just a commitment to HERS rated homes).
- ***Launching Program on the Heels of Industry Down-turn***
  ZERH launched right after a housing industry down-turn of historic proportions. Builders continue to remain very cautious and resistant to significant change.
- ***No Dedicated Sales Force (HERS Raters)***
  Where ENERGY STAR Certified Homes took a risk hitching its wagon to HERS verification in 1995, it paid off. For the critical initial growth period, HERS raters' livelihoods depended on ENERGY STAR and they invested tremendous energy and resources to build their business around it. Now, raters have so many more options including RESNET EnergySmart Builders, EPA Indoor airPLUS, a wide variety of green home programs, and very significantly a whole new line of code compliance work. It is much harder to get the sales force's attention to promote ZERH.
- ***Lack of a Common Agenda***
  There are a growing list of programs related to zero energy. These include just getting a HERS Index Score of 10, Living Building Challenge, Zero Net Carbon and state and local energy codes targeting zero energy performance. More are on the way. It is necessary to get all these programs aligned around a common umbrella name, threshold concept, and message for 'zero' to avoid market confusion.

Lessons-Learned Applicable to Other Programs

The author could not imagine taking on the ZERH program without prior experience leading the ENERGY STAR Certified Home program. Virtually every aspect of running this new program benefitted from applying the five key success factors learned in that process: specify energy efficiency plus performance; build an effective supply chain; strategically sequence the program to targeted goals; ensure market-ready specifications; and develop effective marketing. While the ZERH program is just beginning to get traction, it provides other valuable benefits to DOE beyond the numbers. It validates proven innovations from the Building America program which enhances their linkage to the housing industry. It also serves as the basis for DOE's very successful Race to Zero Student Design Competition. This initiative engages

hundreds of architecture, engineering, and construction management professional degree program students to learn building science skills they don't often get in their curriculum; apply these new skills in residential or commercial zero energy ready building projects; learn to effectively communicate their design solutions to leading experts; benchmark their education with a broad range of U.S. and international programs; and be inspired to pursue careers in sustainable buildings *(DOE)*.[4] Additionally, ZERH serves as a basis for a growing number of code initiatives such as the Oregon 2023 zero energy ready home code and Rhode Island stretch code. Even without the velocity of ENERGY STAR Certified Homes, ZERH is proving to be a very special initiative for leveraging DOE investments in high-performance homes.

The key recommendation for other zero energy building programs is that they should apply the five key factors towards program design and implementation while making critical adjustments for their own unique strategic objectives. Effectively conceiving and implementing one of the most successful voluntary high-performance new home programs in the history of the federal government was a great accomplishment for ENERGY STAR. Not leveraging lessons-learned would be a tragedy. And that's what DOE is currently doing with ZERH.

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