Zero Net Energy: Available and Scalable

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ABSTRACT

The perception of zero energy home (ZEH) buyers has historically been associated with those of high economic status, or radical environmental advocates. In recent years however, a paradigm shift has begun, and zero energy homes have become a more viable option for the average consumer. This shift has been accelerated by an understanding of proper tools and knowledge of key stakeholders, coupled with a motivation by state entities to create road maps for zero energy homes, designed to make zero energy homes increasingly more scalable and accessible. As the price of energy continues to rise, the need for zero energy homes grows increasingly more important. This paper will review utility best practices and business perspectives on how zero energy homes are being achieved in the Eversource residential sector in Connecticut, and how various stakeholders have played a critical role in achieving zero energy homes. While energy costs and economic status continue to remain predominant themes to the adoption of zero energy homes, they are no longer the only driving forces behind this movement. Creating market awareness for zero energy homes using existing industry resources is crucial to the acceleration of zero energy home construction. Likewise, it is pivotal that the industry begin to understand the next generation of homebuyers, and the preferences that these individuals are striving for. While the cost of constructing zero energy homes appears to be on a downward trend in the State of Connecticut, market awareness and a comprehensive understanding of the key market demographics, have been the most significant barriers to the adoption of zero energy home construction.

Introduction

Residential households, on average, account for 39% of U.S. electricity consumption, and approximately 22% of U.S. primary energy consumption (D&R International, LTD. 2012). As population continues to increase, the growing demand for energy generation has led federal regulators to impose reductions in the amount of greenhouse gas emissions from new energy production. Much work has been done by the Department of Energy, as well as, statewide energy efficiency programs, to create a market transformation towards zero energy home construction. The overall goal of this effort is to make zero energy homes commercially viable by 2020.

Since the implementation of residential energy conservation codes, newly constructed houses have sought to reduce their overall impact on the electric grid, and likewise on the environment. Over this same time frame, many housing characteristics and dynamics have changed the way that we look at the residential new construction marketplace. This dynamic can largely be explained in the same way that we look at new ideas and technologies throughout a range of different industries throughout the world. *Diffusion of Innovations* describes the theory first developed in 1962 by Everett Rogers which explains how new ideas are spread through special types of communications, and at what rate these new ideas are spread throughout certain cultures. These new ideas have a certain element of uncertainty, and thus require a certain element of social change, that can be explained through the lens of key social figures, namely Innovators, Early Adopters, Early Majority, Late Majority, and Laggards (Rogers 2003).

In our instance, the small majority of those constructing these zero energy homes can be included within the "innovator" segment. This segment paves the way for each additional segment of adopters. The focus for most states with aggressive energy efficiency standards has been to create a market shift towards zero energy homes, and in doing so, rapidly accelerate the adoption of these construction practices by the Early Majority of new home builders.

Even those builders who refuse to utilize zero energy construction practices (i.e. the Late Majority or Laggards), will not be able to avoid future code adoptions. New buildings typically have very long lifespans, and thus the energy efficiency of these buildings will directly influence the buildings energy consumption for years to come. Residential energy conservation codes offer the opportunity to influence design and construction practices in order to achieve these levels of energy efficiency. In the United States, we live in an era where residential building energy codes have become increasingly more stringent in regards to energy use and energy consumption (*Figure 1*).This continued shift towards more aggressive energy efficiency targets, directly impacts design and construction considerations amongst builders, and tightens the gap between code-compliant and zero energy.

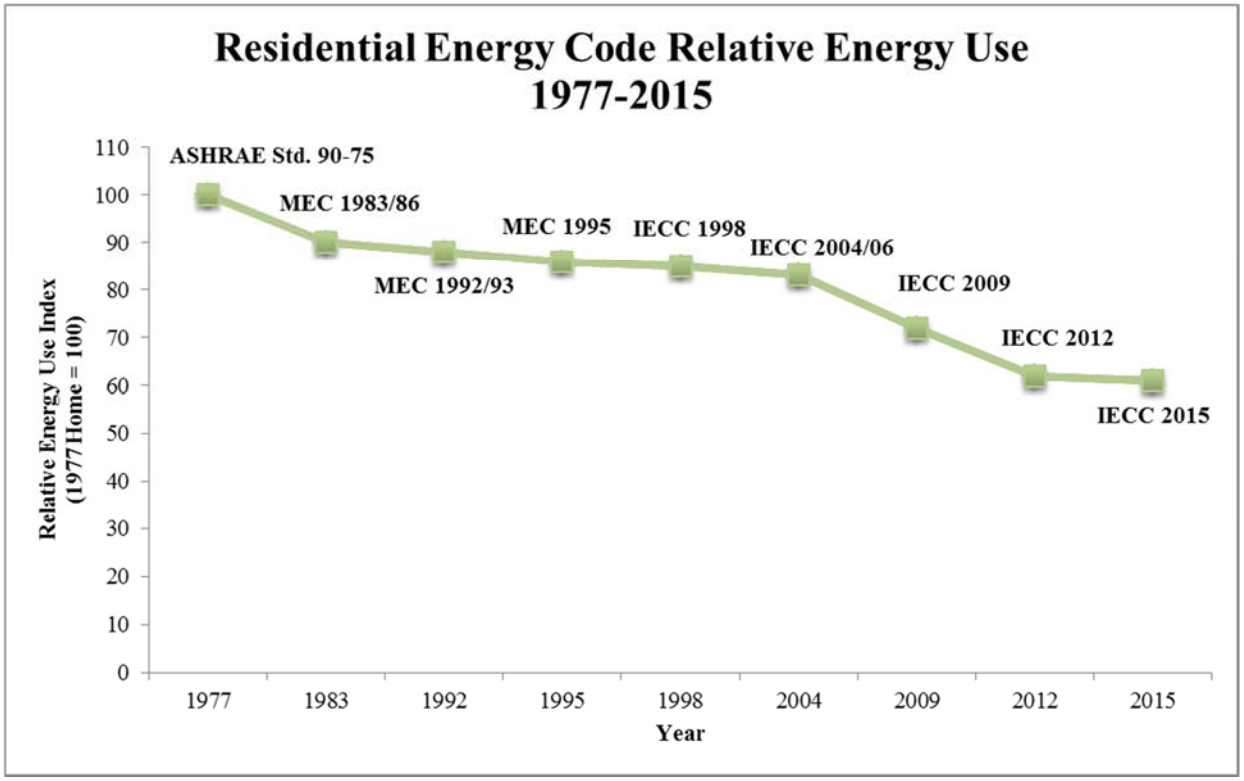

Figure 1. Relative energy use index under various residential building energy codes for new construction. Energy use index correlates to efficiency gains by comparing a home built under the respective building energy code guidelines to a similar home built using the ASHRAE Std. 90-75 building code standards. *Source:* (Amann, 2014) using data from U.S. DOE Building Codes Program

There is much confusion within the building industry as to what constitutes a zero energy home, and as a result, interpretations can vary rather substantially. For the purpose of providing some clarity, this paper will utilize the Department of Energy's *Common Definition of a Zero Energy Building*, applied, in this case, to define residential zero energy homes. A zero energy home is "a [home] where, on a source energy basis, the actual delivered energy is less than or

equal to the on-site renewable exported energy" (DOE 2015). In this instance, source energy is used as the variable for defining a zero energy home, because quantifying the impact of extraction, processing and transportation of primary fuels, better illustrates the overall impact of energy consumption for a given household. It should also be noted that zero net energy (ZNE) and zero energy, are often used interchangeably, but in this instance imply the same meaning. This paper will use the term "zero energy home," for both clarity, and consistency, as it has been found that the term "net" is often unnecessary in describing the same concept as a zero energy home (DOE 2015).

In looking at the current state of residential new construction activity in Connecticut, we can illustrate the barriers and opportunities for market transformation for zero energy homes. Most of the information hereafter will come from a detailed review of current literature around the residential new construction industry as a whole, as well as, current efforts in the state of Connecticut to shift the market towards zero energy home construction.

Market Transformation at the State Level

A 2013 study conducted by the United States Energy Information Administration found that residential energy consumption accounted for the largest portion of end-use consumption in the state of Connecticut, followed closely by transportation (*Figure 2*).

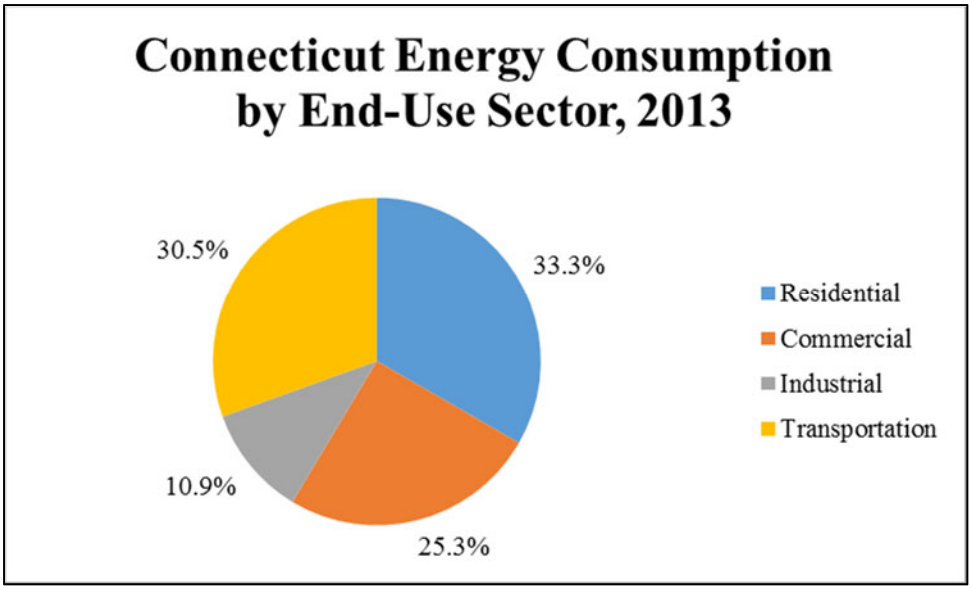

Figure 2. Primary energy consumption by end-use sector in Connecticut (percentage, FY 2013). *Source:* EIA 2013

Reducing consumption is only half of the equation however. In Connecticut, cheaper, more affordable energy sources are vitally important, due in large part to the relatively high electric prices within the state. Connecticut has the third highest prices for electricity in the nation behind only Hawaii and Alaska. Using data from the EIA, the 5 year average for years 2010-2014 for average residential retail electric price is $0.184/kWh (EIA 2015). High costs for electricity, coupled with relatively high consumption in the residential sector, have prompted state regulators to adopt innovative strategies for conservation and energy efficiency in the

variety of sectors. As previously discussed, newly constructed homes have a relatively long lifecycle. Throughout the years electric costs have continued to trend upward in the state of Connecticut. Thus builders, and buyers alike, have begun to consider true lifecycle costs of home ownership. In order to keep energy prices down, energy efficiency has become a strong motivator to new construction, and has helped to accelerate the interest in zero energy homes in the state. This sector offers the potential to incorporate high performance building design, in association with energy efficiency technologies, without the added cost of substantial redevelopment. The incremental premium costs for high performance can often be diminished, if not entirely offset, by utility incentives, as well as, federal tax credits. This market shift has created a growing niche in the United States for zero energy new construction. In addition to the reduction in cost, this transformation has been driven by new net metering legislation, efficiency increases and reduction in the cost of PV technologies, better glazing characteristics, an increase in the efficiency and a reduction in the cost of mini-split heat pump technologies (Rosenbaum 2016), and a desire of builders to differentiate themselves from competitors.

The benefit to these homes are far ranging and widely acknowledged throughout the state of Connecticut, which has seen increasing success in the zero energy home industry over the last five years. In a recent study from the Net Zero Coalition, Connecticut has ranked fifth nationally in the construction of zero energy homes (Net Zero Energy Coalition, 2015). The catalyst for change has been accomplished in large part by the work of a statewide initiative known as Energize Connecticut^{SM}. Energize Connecticut is an initiative dedicated to empowering Connecticut to make smart energy choices, both now and in the future. The initiative is funded through the Connecticut Energy Efficiency Fund ("Fund"). The Fund is supported by electric and natural gas ratepayers through a combined public benefits charge for electric customers, and a conservation charge for natural gas customers. The Fund is administered by Eversource and United Illuminating, the state's two primary electric and natural gas utility companies. In 2015, the work of the fund helped Connecticut achieve $968 million in lifetime energy savings for consumers in a variety of segments (EnergizeCT 2016).

Residential New Construction Trends in Connecticut

One of those segments is the residential new construction marketplace where a variety of trends have been fairly prominent over the last 15 years. Perhaps the most notable trend has been the volatility of residential housing permits in the state of Connecticut. In 2005, new home permits in CT peaked at 11,885 (CT DECD 2014). Over the next six consecutive years to follow, new home permits declined exponentially, until finally reaching an all-time low in 2011 *Figure 3*.

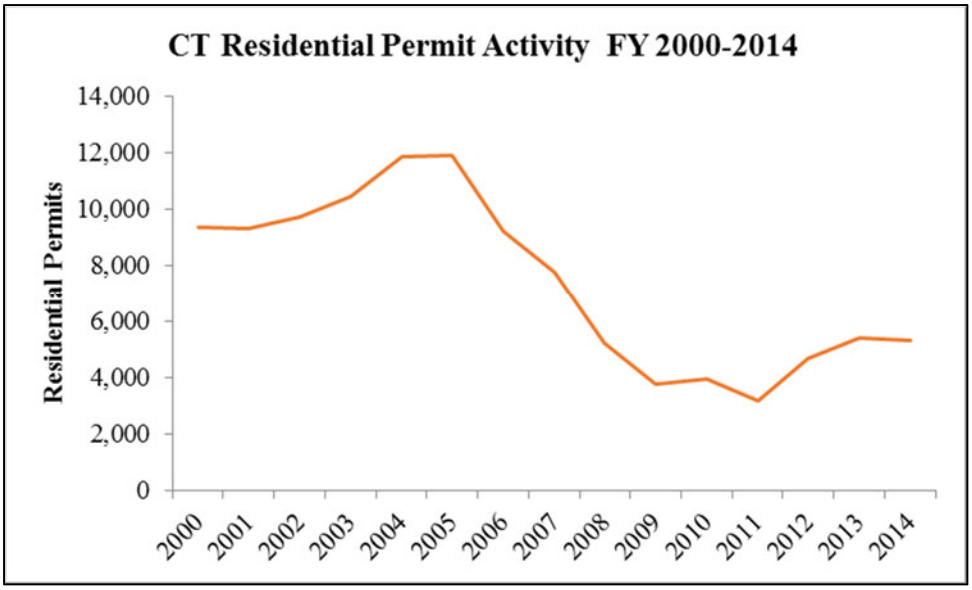

Figure 3. Connecticut residential permit activity, 2000-2014 (number of new permits).
Source: CT DECD 2014

It's no doubt evident that the recession greatly attributed to the decrease in permit activity and demand for newly constructed homes. However, as the economy has begun to recover, we have begun to see a steady uptake in the new construction marketplace. From 2011-2015, the housing market has continued to recover at a relatively slow pace due primarily to improvements in the overall economy, low mortgage rates, and strong consumer confidence in the housing market (Sun 2015). However, while permit activity has continued to show some signs of promise, it is evident that the housing market has changed radically in Connecticut favoring multi-unit developments over traditional single family homes. According to the latest statistics from *Fitch Ratings*, over the last decade, the state has seen a gradual decline in single-family permit activity, from about 77% in 2006 down to 52% in 2014. Over this same period of time, the demand for multi-unit permits (5 units or more) has steadily increased from 19% in 2006 to 43% in 2012 (Offerman 2016).

This shift has been accelerated predominately by density dynamics, and a changing demographic of new home buyers in Connecticut. According to Douglas Offerman, a senior director for *Fitch Ratings*, many areas near job markets are already saturated with single-family homes, and are thus taking the remaining space available and using it to increase the number of individuals that can live on it (Offerman 2016). The individuals moving into these locations have been, by-and-large a younger generation, attracted to the benefits of more dense areas. A survey conducted by the National Association of REALTORS® showed that in 2014, individuals between the ages of 18-34 (otherwise known as 'millenials') comprised 32% of the housing market (NAR 2015). Over this same time frame, many individuals reaching retirement age (otherwise known as 'baby boomers'), are seeking to downsize both the size of their home, as well as, the economic burden of owning a home, while at the same time, enjoying more simple conveniences of everyday living.

This trend in demographic age groups moving to more highly populated areas can be seen throughout many of Connecticut's most dense cities. In looking at ten most densely populated cities in Connecticut, we find two prevailing trends. One trend is that each of these cities has

shown a gradual increase in population from 2000-2010. In fact, on average these municipalities have shown a general increase of 5.62% population increase over the last ten years, as indicated in *Table 1*. Likewise, the average median age amongst the ten densest cities in the state, is far lower than the state median age of 40. On average, the ten densest cities in the state have an average median age of 34.6, more than 5 years difference from the state median. Likewise, in looking at the 10 least dense cities in the state of Connecticut, we find that the exact opposite holds true. In fact, of the 10 least dense cities, 5 has shown drastic decreases in population size over the least 10 years, and as such show an average median age of 49.3, more than 9 years difference from the state median age of 40.

Table 1. Comparison of Demographics between 10 Most Dense vs. 10 Least Dense Municipalities in Connecticut. Data from *Source:* CT Economic Resource Center and CT DECD 2000-2010

		Population		Density	% Increase in Population	
Town	**Land Area (Sq. Miles)**	**2000**	**2010**	**2010**		**Median Age**
Bridgeport	16	139,797	147,612	9,226	5.59%	32
Hartford	17.3	124,380	124,705	7,208	0.26%	30
New Haven	18.9	123,768	130,282	6,893	5.26%	31
New London	5.5	25,692	30,685	5,579	19.43%	31
New Britain	13.3	71,653	72,878	5,480	1.71%	33
West Haven	10.8	52,418	54,905	5,084	4.74%	36
Norwalk	22.8	83,145	88,145	3,866	6.01%	41
Waterbury	28.6	107,413	109,307	3,822	1.76%	35
Stamford	37.7	117,334	128,278	3,403	9.33%	36
Ansonia	6	18,572	18,959	3,160	2.08%	41
				Average	5.62%	34.6

		Population		Density	% Increase in Population	
Town	**Land Area (Sq. Miles)**	**2000**	**2010**	**2010**		**Median Age**
Salisbury	57.3	3,974	3,665	64	-7.78%	51
Eastford	28.9	1,617	1,734	60	7.24%	46
Kent	48.5	2,856	2,910	60	1.89%	46
Warren	26.3	1,258	1,427	54	13.43%	50
Sharon	58.7	2,969	2,725	46	-8.22%	59
Colebrook	31.5	1,469	1,445	46	-1.63%	48
Norfolk	45.3	1,657	1,655	37	-0.12%	49
Canaan	33	1,077	1,195	36	10.96%	51
Cornwall	46	1,437	1,398	30	-2.71%	51
Union	28.7	694	846	29	21.90%	42
				Average	3.50%	49.3

This demographic shift is important for a variety of reasons, perhaps the most important being a shift in technological comprehension and environmental awareness, and a difference in the amount of accrued debt. In regards to technology, this shift represents a gap between those with basic understanding of new technologies, to a generation of tech-savvy individuals who heavily incorporate new devices and networked connectivity into everyday life. However, it is not only technology which attracts younger generations of home buyers, but also their commitment to sustainability is unsurpassed by any other generation. In a recent survey conducted by The Glass Packaging Institute, it was found millenials are not only more concerned about the environment, but many of them (77.2% to be exact), are more willing to look for changes to make their homes/lifestyles greener as compared to older age groups of individuals, where eco-sensitivity begins to drop off (GPI 2014). A similar study conducted by Nielsen found that 72% millennials are willing to pay more for products and services that come from companies who are committed to the environmental and social well-being of the Earth's people (Nielson 2015).

While, access to, and understanding of, new technology and a generalized awareness of good environmental stewardship, can certainly be an advantage for a growing population of individuals, it does not substitute for the growing problem that this group faces. A recent survey conducted by Fannie Mae, shows that over 80% of millenials prefer owning to renting (Fannie Mae 2014), particularly due to an increase in accrued debt, which, for the average undergraduate with a bachelor's degree, can be approximately $30,000 in student loans alone (Miller 2014). It is thus evident why many millennials are hesitant in purchasing new homes, and why renting is preferred for these individuals.

These three primary rationale expressed in the aforementioned accurately depict the nature of the housing market in Connecticut, and the changing demographic of new home owners. It is important to mention this, because as more millenials are able to pay down student loans, the vision of purchasing a new home becomes more promising; and once this vision becomes a reality, it can be certain that many of these individuals will be looking to fulfill their desire for technological innovation and a greener, more sustainable living environment.

The Connecticut Zero Energy Challenge

In 2010, the Connecticut Energy Efficiency Fund initiated what has become known as The Connecticut Zero Energy Challenge. The Zero Energy Challenge (hereinafter "Challenge") is an annual design and build competition for single and multi-family homes built in Connecticut. The Challenge is an initiative through the Residential New Construction program, and is designed to create a market shift towards zero energy homes, and in doing so, rapidly accelerate the adoption of these construction practices by the Early Majority of builders and new home buyers. As part of the Challenge, participants compete for cash prizes, while gaining exposure to media and various forms of technical assistance provided by the Challenge sponsors and partners. Completed homes are assigned a performance score based on the presence of energy-efficient features that reduce overall energy use. Specifically, the Challenge uses RESNET Rating Standards to determine each completed home's Home Energy Rating Score (HERS) Index. The home's HERS Index, coupled with factors including the cost-effectiveness of project construction, and the home's total estimated energy use, are utilized to determine the winners. Winners are selected based on four different categories, and are recognized each year as part of an annual awards ceremony.

Participants throughout the years have provided various insights into some of the key aspects of both construction practices, and stakeholder education, in regards to zero energy homes. Throughout the five years since the program's inception, there have been 64 homes constructed and 38 unique builders involved in the zero energy challenge. The Challenge has spurred the vast majority of zero energy home activity in the state, as is evident by the numerous publications and media advisory which reference the challenge itself, as well as, through the participation of the vast majority of zero energy builders in the surrounding states involved in the challenge. For comparison purposes, this paper will review construction practices of the various homes that have won the challenge in this time frame[1].

In order to gain an understanding of how each of the homes compared throughout the years, we will look at each of the different categories of winners. These categories include *lowest overall HERS index, lowest HERS index without renewables, lowest projected annual net operating cost, affordability (cost per square foot).* Each section below will explore the various findings from each of these categories.

Part One: Lowest HERS Index Before Renewables

The Lowest HERS Index before Renewables category is vitally important to the overall Challenge, as it is, perhaps, the best indicator for quality construction of a home. A HERS index is the industry standard asset scoring tool, used to measure a home's energy efficiency against a home of similar size and shape built to standard building code. The relationship between energy efficiency and a home's HERS index is similar to a golf score, in that the lower the calculated value (HERS index), the more energy efficient the home. A home with a HERS index of 100 is equivalent to a home built to 2006 building energy code standards. Likewise, a home with a HERS index of 60 is 40% more energy efficient compared to a home built to 2006 home building energy standards. This category excludes the energy savings potential of renewable technologies. Although many of the homes in these categories do in fact use renewable technologies once constructed, these renewable technologies are excluded from the calculation of Lowest Overall HERS Index. In order to understand the importance of this category, as well as, the construction characteristics of these homes, a detailed explanation of key building components for each of these homes is included in *Table 2* below.

[1] For a complete list of Zero Energy Challenges Participants, visit https://www.ctzeroenergychallenge.com

Table 2. CT Zero Energy Challenge Lowest HERS Index without Renewables Home Characteristics FY 2010-2015

	Year					
Category	2010	2011	2012	2013	2014	2015
Builder	CES	Appropriate Designs	BPC Green Builders	BPC Green Builders	Glastonbury Housesmith	Lehto Design/Build
HERS Index (Without Renewables)	34	46	41	35	30	33
Conditioned Area (ft^2)	4,539	1,728	3,052	1,607	3,442	3,208
Air Leakage (ACH50)	0.43	2.18	0.45	0.6	0.97	.37
Slab Insulation	R-20	N/A	R-20	R-60	R-20	R-10
Foundation Wall Insulation	R-39	N/A	N/A	N/A	R-20	R-39
Framed Floor Insulation	R-43	R-30	R-33	R-31	N/A	R-26
Above-Grade Wall Insulation	R-42	R-24	R-33	R-38	R-31	R-26
Vaulted Ceiling Insulation	R-62	N/A	N/A	R-78	R-59	N/A
Flat Ceiling Insulation	N/A	R-47	R-72	N/A	N/A	R-62
Window U-Value	0.25	0.28	0.2	0.14	0.26	0.17
Window SHGC	0.38	0.3	0.29	0.49	0.26	0.22
Heating Equipment Cooling Equipment	GSHP	GSHP	ASHP	ASHP	GSHP	GSHP
Heating Efficiency	4.1 COP	4.4 COP	9.2 HSPF	10.5 HSPF	4.4 COP	4.4 COP
Cooling Efficiency	20.6 SEER	22.7 SEER	18.8 SEER	23.0 SEER	29.5 EER	29.5 EER
Ventilation Equipment	ERV	ERV	ERV	ERV	ERV	ERV
DHW Equipment	Solar Thermal	Heat Pump WH	Propane (On-Demand)	Propane (On-Demand)	Heat Pump WH	Electric (On-Demand)
DHW Efficiency	99%	2.35 EF	.83 EF	.91 EF	2.75 EF	.91 EF
Low-Flow Fixtures	Yes	Yes	Yes	Yes	Yes	Yes
ENERGY STAR® LED	90%	100%	100%	100%	100%	100%
ENERGY STAR® Appliances	Yes	Yes	Yes	Yes	Yes	Yes

These different attributes may seem obvious, particularly because we understand how to build high performance homes. However, describing these homes as airtight, and well insulated, is an understatement. With the exception of the 2011 home, the other five homes identified had air leakage rates, less than 1.0 air change per hour when pressurized to 50 Pa. Due to this level of tightness a mechanical ventilation system had to be put into place. This is another trend that has helped high performance homes achieve near net zero energy consumption. Balanced mechanical systems, particularly energy recovery ventilation (ERV) systems, are a major component to high performance homes. When compared to IECC 2009 code requirements, the insulation levels in the various areas of the home far exceed those required by code. Tight, well-insulated thermal

envelopes have been the primary focus of zero energy homes in the state of Connecticut. Another trend is the presence of heat pump technologies. Over the last five years, heat pumps have become commonplace in many high performance homes, and as prices continue to drop, and efficiencies continue to rise, these technologies may be a staple in zero energy homes for years to come.

Part Two: Lowest Overall HERS Index / Lowest Projected Net Annual Operating Cost

Lowest Overall HERS Index indicates exactly how well a house scores compared to code, with renewables included. Lowest projected net annual operating cost is simply an indication of how REM/Rate predicts a home will perform over the course of a particular year. REM/Rate is the industry standard energy simulation software tool used to compute the HERS rating. For the sake of brevity, we will exclude the winners of the *Lowest Projected Net Annual Operating Cost* category, as we have seen that this category is very closely tied to the *Lowest Overall HERS Index,* however the *Lowest Projected Net Annual Operating Cost* for each of the winners in the *Lowest Overall HERS Index* category will be included to provide a better understanding of projected costs for these newly constructed homes. The following section will look at the winners in each of the given years in the category of *Lowest Overall HERS Index.* Lowest Overall HERS Index does include renewable technologies, and thus lower HERS indexes can be obtained compared to those homes without. Below is a description of the homes that have won in the category of Lowest Overall HERS Index *Table 3*. Included in these figures is the size of the renewable system, as well as key HERS index information. In order to show the impact of renewable technologies (predominately PV technology), both the HERS Index with and without renewable technologies is included within these figures.

Table 3. Comparison of CT Zero Energy Challenge Lowest HERS Index FY 2010-2015

Year	Builder	Town	Renewable System Type	Renewable System Size	HERS Index w/o Renewables	Overall HERS Index
2010	George Keithan	Killingworth	Solar PV	13.7 kW	27	-7
2011	Bernard Zahren	Avon	Wind	25.0 kW	61	-9
2012	Wolfworks	Harwinton	Solar PV	10.7 kW	32	-13
2013	CK Architects	Warren	Solar PV	11.5 kW	35	-34
2014	Glastonbury Housesmith	Glastonbury	Solar PV	14.0 kW	30	-22
2015	Skip Kamis	East Haddam	Solar PV	8.4 kW	41	-15

One of the variables that have helped high performance homes achieve high levels of energy performance at cheaper costs has been the declining cost trends, and viability of residential solar PV installations. A recent study by Solar Energy Industries Association has shown that over the last 10 years, as the market continues to adopt solar PV technologies, the price of solar PV has continued to drop substantially (SEIA 2015). This trend has shown in the Zero Energy Challenge throughout previous years, as system sizes continue to grow larger, while the system size range is growing relatively smaller as indicated by *Figure 4.*

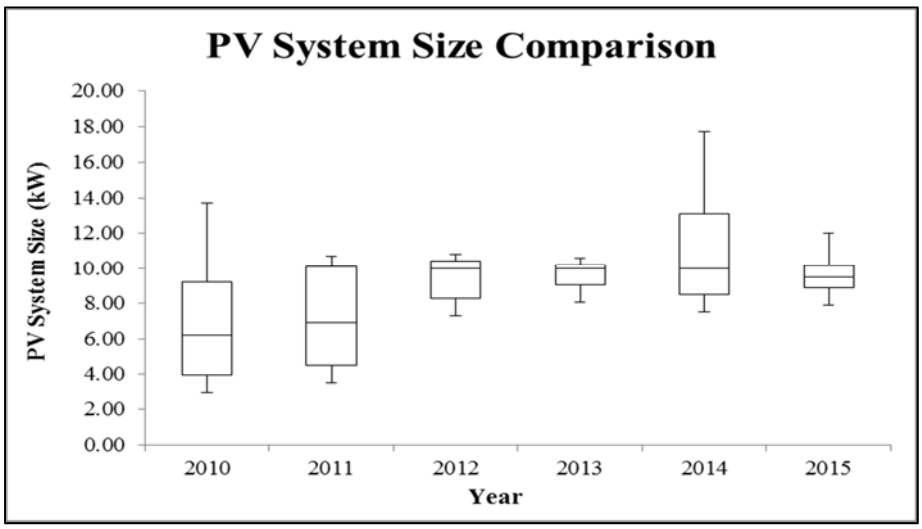

Figure 4. PV system size comparison for 38 Zero Energy Challenge participants FY 2010-2015.

As mentioned earlier, in Connecticut, cheaper energy sources are vitally important, due to high electric prices within the state, averaging around $20.84/kWh in March of 2016 within the residential sector (EIA 2016). In comparison, the average cost from 2012-2015 to install a new solar array for the average Connecticut homeowner, according to data from the Connecticut Green Bank's *Residential Solar Investment Program* is $4.41/Watt. This has shown in the CT Zero Energy Challenge as HERS Index ratings amongst winners has continued to fall well below 0 HERS. This increase in system size however has come second to the

Part Three: Affordability (Cost per Square Foot)

Perhaps the most telling category within the Zero Energy Challenge each year is the *Affordability* category, which shows initial capital cost per square foot for newly constructed homes, with the exclusion of land costs or permitting fees. This category is vitally important, as it shows the scalability of high performance home construction. There are really two main takeaways from this category that have begun to show up fairly predominately throughout recent years. This trend can be summed up rather clearly showing that of the 48 participants since 2011[2], the homes are being built more thermally efficient at a lower cost[3] (*Figure 5*)! This is a key fact, as it shows that these types of homes are absolutely scalable in any community in Connecticut.

[2] The Cost/Sq. Ft. category was not included in the 2010 Zero Energy Challenge, and thus data has been excluded from these figures.
[3] The increase in cost from 2011 to 2012 is attributed primarily to significantly less activity in the 2012 Zero Energy Challenge.

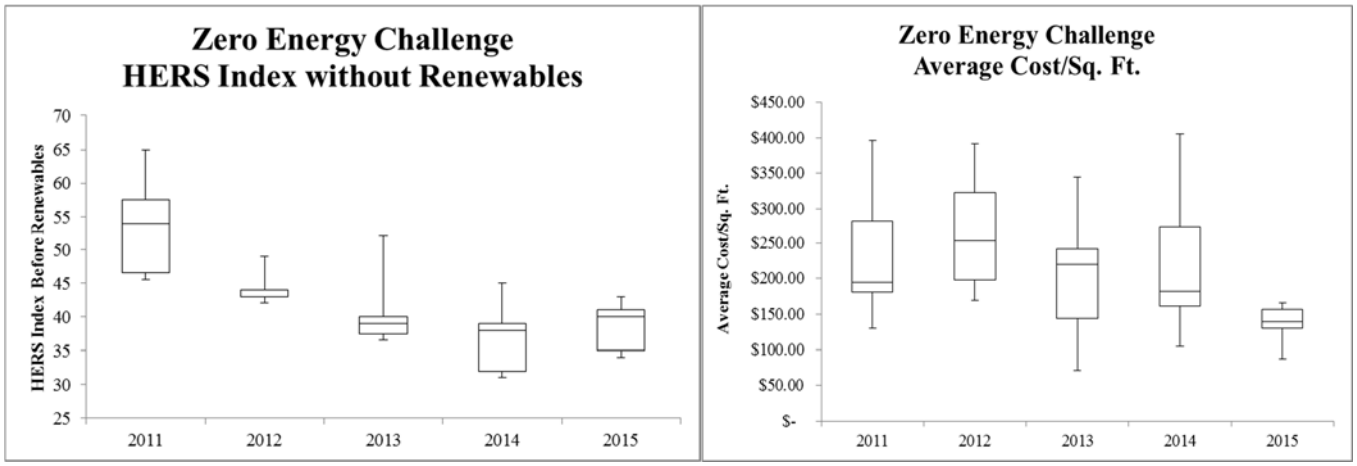

Figure 5. Illustrates the relative HERS index without renewable technologies, which is a direct correlation to thermal efficiency of a newly constructed home, compared to the average cost per square foot of Zero Energy Challenge candidates FY 2011-2015.

County is another important factor to keep in mind with Challenge homes historically in Connecticut. If we compare the percentage of residential permits, by county, in the state of Connecticut over the last 8 years, with the percentage of Challenge homes, by county, we find that there is some discrepancy in where these homes are being built. In order to gauge an understanding into the differences between counties, we can also use a median household income, median home price, population size, and total housing units as factors to include when comparing Residential Permit activity to permit activity within the state of Connecticut, as there is a wide deviation amongst county demographics throughout the state (*Table 4*).

Table 4. County demographics including population size, median household income, median home price, and total housing units for Connecticut counties[5].

County	Population Size (2014)	Median Household Income (2010-2014)	Median Home Price (2010-2014)	Total Housing Units (2010-2014)
Fairfield	934,215	$83,163	$422,400	361,272
Hartford	897,374	$65,499	$238,600	373,809
Litchfield	187,542	$72,068	$259,800	87,338
Middlesex	165,534	$77,931	$288,300	74,832
New Haven	863,148	$61,646	$250,400	361,726
New London	274,071	$66,693	$247,700	120,900
Tolland	152,251	$79,988	$252,400	58,067
Windham	117,918	$59,218	$203,200	49,051

[5]Source data obtained from Connecticut Economic Resource Center

Interestingly enough, there is a fairly even distribution of zero energy homes built in areas of historically low building activity, as compared with areas of relatively high building activity. In fact, about 80% of all residential permit activity from 2005-2013, was attributed to Fairfield, Hartford, and New Haven counties. When looking at the distribution of zero energy home

projects from 2010-2015, what we find is that these same three counties only attributed about 38% of total zero energy home construction, while the three counties with the least permit activity (i.e. Windham, Tolland, and Litchfield counties), have attributed 42% of the total ZEH construction activity. This trend tends to suggest that builders and homeowners alike tend to have a preference towards more rural areas of the state. While occupant behavior has been the subject of much of the research around zero energy homes, we will not cover occupant behavior in this report, but only speculate in saying that homeowners purchasing zero energy homes in the state of Connecticut, choose to build in rural locations where land and development costs are cheapest, and where access to natural gas is limited. This trend is evident in *Figure 6* below.

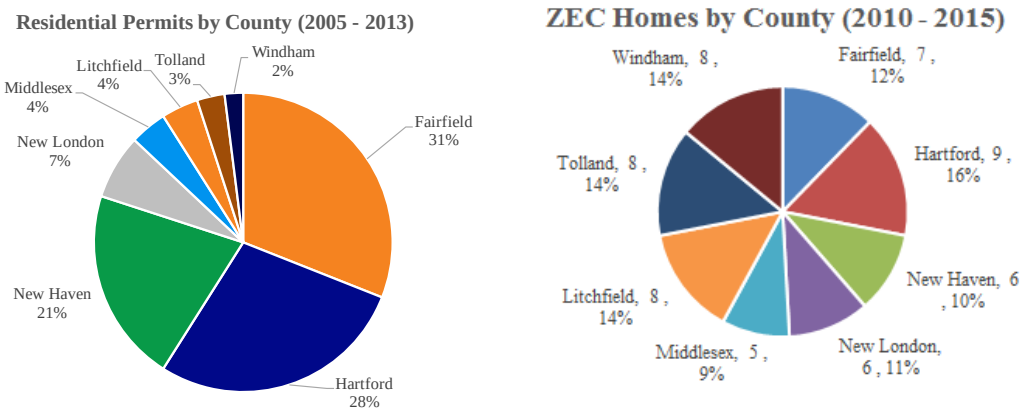

Figure 6. Comparison of residential permit activity in Connecticut (left) FY 2005-2013, against geographic distribution of Zero Energy Challenge home participants (right) FY 2011-2015.

As home buyers become more versed in the design and construction practices of zero energy building, they are finding innovative ways to bring down construction costs[4]. 2015 was the most affordable year on record for the zero energy challenge, with an average cost per square foot of approximately $139.00. For reference, average construction costs (Tarducci 2015) were compared from the 2015 Zero Energy Challenge against the county average construction costs; it should be noted however that county-level construction cost information is very difficult to obtain. Please note, there were no candidates in Fairfield, New Haven, or Hartford counties, who participated in the Zero Energy Challenge for 2015. For this reason, we will exclude the average cost per square foot in each of these counties.

[4] In the Zero Energy Challenge, land costs, development costs, and permitting fees are excluded from total construction cost figures.

Table 5. County average construction costs for residential new construction activity compared to the average costs of construction for 2015 Zero Energy Challenge candidates in the state of Connecticut.

2015 Connecticut Residential New Construction Costs by County			
County	County Average[5]	Zero Energy Challenge[3]	% Premium
Litchfield	$102	$135	36%
Middlesex	$135	$164	50%
New London	$135	$165	21%
Tolland	$122	$134	8%
Windham	$100	$130	23%

What these figures show is that the average cost to build a zero energy home in a given county throughout Connecticut, is still moderately high, on average, compared to an estimated county average cost for construction alone. However, in looking at those builders and homeowners who have won in this category, we find that the incremental cost between a conventional home, and a zero energy home, is relatively minimal (*Table 6*).

Table 6. County average construction costs for residential new construction activity compared to the overall winners of the Affordability Category for the 2011-2015 Zero Energy Challenge.

Zero Energy Challenge Winners (Affordability Category) – 2011-2015				
Year	County	County Average	Zero Energy Challenge Winner	% Premium
2011	New London	$135.00	$130.00	3.8%
2012	Litchfield	$102.00	$169.00	65.7%
2013	New Haven	$125.00	$71.00	-43.2%
2014	Windham	$100.00	$104.00	4.0%
2015	Windham	$100.00	$87.00	-13.0%

The homes which have won in the category of affordability have similar attributes in common, primarily a simple design, superior energy performance, replicable construction practices, and a very careful consideration of costs. These homeowners and builders have paid special attention to every cost associated with the project. This would suggest that in order to bring down initial cost, builders will need to have more substantial attention to detail in regards to the cost of construction.

Due to the socio-economic differences, as well as, the difference in the housing market throughout the years, in the state of Connecticut, estimating construction costs figures is a very difficult task, and there is a substantial lack of resources around this topic. Additional research may include the use of location factors for current residential cost data and building construction cost data, as published by R.S. Means, a nationally-recognized company specializing in construction cost indices. Future cost research may hold more promise for accurately showing

[5] County average construction costs from CT Builder Magazine. *Source:* Tarducci 2015

the difference in premium cost for a zero energy home in Connecticut. As well, there is an effort to standardize cost reporting metrics for zero energy homes in Connecticut that participate in the Zero Energy Challenge that will help to eliminate inconsistencies in cost reporting metrics.

Conclusion

Connecticut has become a leader in zero energy home construction in recent years. Initiatives like the Zero Energy Challenge are important to creating consumer awareness around these types of homes, and have given builders and homeowners alike technical and fiscal resources to make zero energy homes commercially viable. The initiative in itself has been successful at encouraging builders and homeowners to push the boundaries of energy efficiency in new construction, however much work still has to be done around understanding trends in the housing market, as well as, creating a greater market awareness around zero energy homes. The technical knowledge, and likewise access to knowledge, in regards to design and construction of these homes has become widely attainable throughout the building industry. The dissemination of this knowledge has not been, as a whole, successful over the years. In order to make zero energy homes the new norm, we need to continue to create a demand for these types of homes, and introduce high performance building practices, and proven technologies, early in the design phase for builders, architects, homeowners, and other key project stakeholders. Each of these individuals contributes to, and is responsible for, the overall success of a zero energy home.

A systematic approach can help improve scalability, and thus availability for zero energy homes. As stated, in order to bring down initial costs, projects need to have a simple design, superior energy performance, replicable construction practices, and a careful consideration of costs. Incorporating proven technologies such as advanced air sealing, heat pump technologies, high R-value thermal assemblies, orientation, and other key zero energy home construction practices has to be first and foremost in this approach. Educating occupants, and setting realistic expectations for all individuals involved, is also a crucial element to the success and longevity of zero energy homes. Favoring total cost of ownership over the life of a home instead of initial cost can more effectively deliver the value proposition for zero energy homes. These are the key themes that have proven successful to the zero energy home industry in the state of Connecticut, and this is the approach that must be taken in order to make zero energy homes available and scalable.

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Commonly Used Acronyms

ZEH – Zero Energy Home

ZNE – Zero Net Energy

ZEC – Zero Energy Challenge

RNC – Residential New Construction

PV – Photovoltaic

HERS – Home Energy Rating System

ERV – Energy Recovery Ventilator

GSHP – Ground Source Heat Pump

ASHP – Air-Source Heat Pump

DHW – Domestic Hot Water