Ohio Valley Household Energy Surveys 2001-2012

Review, Analysis & Summary

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By

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Design, Analysis, Consulting & Education since 1983
to Improve Energy & Ecological Performance

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Preface

During and after a couple super-cold winters, an Arab-led oil embargo against the United States, huge natural gas price increases and some rationing of oil and natural gas in the middle and late 1970s, President Carter told Americans in a nationally televised speech that they were not energy efficient, that they wasted too much energy. Since then there have been many rounds of rising home energy costs, also many varieties of home energy programs and subsidies aimed at encouraging and helping residential energy consumers and home energy professionals to lower conventional home energy use and bills. Despite all this, many if not most households are still quite inefficient, still using and wasting very large amounts of energy.

But there are actually many homeowners who have achieved very low energy usage. Some books and magazine articles have been written about low-energy-using homes and homeowners. A common shared distinction among low-energy-using homes and households, regardless of what strategies, designs and/or technologies they implemented, is they seem almost always motivated and intentional about achieving their low-energy use.

In other words, most of the history of very low energy use describes homeowners, designers and/or builders who intentionally aimed and worked toward achieving and maintaining low energy use. Often the low-energy-use goals are determined in advance, used as targets during design and construction or when considering a home to purchase or remodel. After occupancy, a home's occupants strive to achieve or maintain such low usage. Many homeowners who learn how to cut their energy usage gain more confidence and continue cutting to achieve even lower usage. The most important fact about all this is that very low usage is almost never accidental.

The main reasons why the overwhelming majority of homeowners in new and existing houses tend to use so much energy may simply be that:

- most homes are not designed, built, selected or operated intentionally to use less
- most homeowners, designers and builders are not motivated or taught to reduce or limit their home energy use

Another factor may be that there is so little discussion, even among energy educators and professionals, about what low energy use means. Too much energy education and most energy programs are not even written or presented in language describing what energy volumes qualify as low usage. Most popular energy programs focus on particular strategies, designs, products and technologies, while never defining low energy use goals. Consumers focus mostly on energy prices and energy bills. But since energy prices and bills vary so wildly, those often offer little insight into the actual energy usage. Most residential energy users who know their energy prices and costs seem not to know or understand the volumes of their energy usage.

Many home energy users who achieve very low energy usage pay more attention to their energy use, tracking the volumes of the various energies they use month by month and year by year. This author began tracking his own home energy use in the late 1970s after buying his first home, which was uninsulated, airleaky and inefficient in many respects. As the home's energy features were improved, tracking the energy usage year to year made it easy to quantify the energy performance results in terms of saved energy and money. When this author began his energy consulting and design business in 1983, he also began a routine practice of evaluating his customers' energy performance and energy reduction progress by tracking their energy use.

Introduction

It is useful to understand energy performance before selecting or operating household devices, appliances, equipment or structures, whether they are small like portable electronics or large like homes. But there are few widespread education opportunities especially for consumers and non-energy professionals to learn about and compare actual home energy performance.

Most energy ratings on homes and their typical energy-using equipment do not state how much energy will be needed short-term (like peak watts or BTUs/hr) or long-term (like annual kWhs or BTUs). Popular home energy certifications do not usually describe performance after a home is built, not even how it will compare to best existing homes or homes rated by other programs. Most home ratings are based on energy estimations done during design and/or construction. Few home energy ratings and programs focus on and measure actual energy use to verify better performance.

When discussing home energy, most consumers and professionals compare energy bills. It seems most common to seek to lower energy bills when they are higher than desired, expected or affordable. When asked to describe a home's energy performance, most homeowners and their associated professionals usually cite upgraded energy features like R-values, airtightness, windows, heating and cooling equipment, lightbulbs and solar panels. But these are not descriptions or ratings of actual energy use or performance. They do not answer questions like

How much are the annual energy usage, cost & emissions per floor area (sf)?

How much are the annual energy usage, cost & emissions per person?

How do usage, cost & emissions in one household compare to other households?

How do usage, cost & emissions compare year-to-year?

What is local best performance & what upgrades & efforts were used to achieve it?

Which home energy tax incentives, Ohio Valley utility rebates and energy programs address these questions? Most just reward for buying or using certain energy-related products and processes. Energy use reductions likely do result from these incentives and programs, but achieved better energy performance is usually not measured or reported. Sometimes progress is only reported by how many audits, work implementations, designs and certifications are accomplished. Indeed, some home energy programs are actually designed in large part to encourage, improve or expand certain local energy-related trades, professions and technologies.

One Ohio Valley city offers a multi-year property tax abatement, often of far greater value than the achieved energy savings, for new or remodelled homes certified during design and construction by a certain energy program. But actually achieving ongoing lower energy use or better performance after occupancy is not even a requirement for receiving the tax abatements in future years.

Ohio Valley electric utilities allow homeowners with net-metered PVs to sell solar electricity surpluses to the utility when onsite solar generation per month exceeds onsite monthly usage. Consumers often perceive this as storing their surplus solar kWhs, but no Ohio Valley electric utilities store electricity, not even from one hour to the next. So participating consumers use dollars from their solar kWh sales in sunny months to buy conventional energy during future cloudy months. But this practice is marketed by many solar electric retailers and some Ohio Valley politicans as renewable energy storage which offsets or negates future conventional energy use and emissions.

Ohio is an “open electricity market” where consumers can choose from several certified electricity suppliers. One SW Ohio city “aggragated” to buy all its citizens’ electricity from a NE Ohio supplier claiming “100% renewable energy”. But that supplier does not have access to sufficient transmission capacity to move that much power from its location to SW Ohio. So despite the advertising and political claims, that city’s consumers are not actually receiving the renewable energy.

Many electric utilities in Ohio and Indiana also promote efficiency and renewable energy while offering lower energy prices for higher monthly usage. And in recent years many Ohio Valley home consumers have seen much lower energy bills because electricity and natural gas prices declined. Higher energy prices and bills often motivate consumers to reduce energy use, but lower prices and bills lessen such motivation. This table shows the recent history of electricity and natural gas prices in Cincinnati. Notice how electricity price fell after 2012, how natural gas price fell after 2006 and again after 2008. Notice also the 30% price discount for higher electricity use from October to May.

Cincinnati Residential Electricity & Natural Gas Prices 2006-2012

		kWhs per month				**ccf per month**	
			over 1000		Snapshot		
Year	Qtr	**1-1000**	**Oct-May**	**Jun-Sep**	Month	**1-1000**	**over 1000**
2006	1	$0.101	$0.068	$0.115	January	$1.394	$1.374
	2						
	3						
	4						
2007	1	$0.096	$0.063	$0.110	January		
					February	$1.193	$1.185
	2						
	3						
	4	$0.102	$0.069	$0.116	October		
2008	1					**New Usage Breakdown**	
	2					**Begun For Ngas**	
	3	$0.107	$0.071	$0.122	August	**1-400**	**over 400**
	4				October	$1.198	$1.266
2009	1						
	2						
	3	$0.119	$0.082	$0.135	July	$0.656	$0.724
	4	$0.124	$0.087	$0.140	October	$0.662	$0.729
					November	$0.796	$0.864
2010	1	$0.130	$0.090	$0.147	March		
	2						
	3	$0.128	$0.088	$0.145	August	$0.789	$0.857
	4						
2011	1	$0.121	$0.081	$0.138	January	$0.731	$0.798
	2	$0.115	$0.075	$0.132	April	$0.602	$0.670
	3						
	4	$0.124	$0.084	$0.141	October	$0.688	$0.756
2012	1	$0.101	$0.068	$0.115	February	$0.598	$0.666
	2						
	3	$0.102	$0.069	$0.117	July	$0.481	$0.549
	4	$0.102	$0.068	$0.116	Oct/Nov	$0.601	$0.669

Sums all per-usage costs including riders & taxes, excluding fixed customer charges.
kWh = kilowatthours ccf = centum cubic feet or hundred cubic feet

Much of the energy pricing, programs, incentives and marketing aimed at Ohio Valley households has not been well designed to incentivize and achieve improved actual energy performance or reduce conventional energy use. And some of the energy pricing seems designed to encourage or forgive worse energy performance and increased conventional energy use.

All this has left many Ohio Valley consumers and professionals confused, unfocused, more often self-motivated or self-taught in their energy awareness, use and cost expectations. It has also resulted in very wide ranges of actual energy use, expense and sensitivity to the real environmental consequences of their energy. Some consumers and households target and achieve low energy use while others experience very high use yet seem unmotivated to change that situation.

This report describes household energy surveys conducted 2001-2012 in and around the Ohio Valley (mostly Southwest Ohio, Southeast Indiana and Northern Kentucky) by energy consultant and home designer John F Robbins, CEM / CSDP. As of July 2013, 94 households have supplied 252 energy data samples for the years 2001 to 2012. Some households participated in multiple years, others in just one or two. Robbins also participated in all 12 years. Only a few households participated in all 12 years.

Originally for tracking actual energy performance of households living in Robbins' new and remodelled homes, the surveys expanded to include mostly non-Robbins customers. With Robbins' reputation for designing and consulting on projects with more aggressive energy performance goals, one might expect Robbins' customers to be more focused and driven than average consumers to achieve better energy performance. But it became noticible that many survey participants even when not Robbins' customers also seemed more interested than average householders in achieving or being confirmed as achieving better energy performance or lower conventional energy use. It may be that households already interested in or already achieving superior performance have more tendency to seek and participate in energy surveys like Robbins'. So while some survey participants have shown average or worse-than-average energy use, this survey probably better represents average and better-than-average performers than households with high to very high energy use.

Survey participation has been voluntary. Respondents were not recruited or selected scientifically. Only a few participants live in homes designed or influenced by Robbins. Robbins sends email invitations to customers, contacts and students, past survey participants and other Ohio Valley design and energy professionals. Participation is also encouraged at Robbins website (www.johnfrobbins.com) and the website of the Association of Energy Engineers SW Ohio Chapter (www.aeecincy.org). Being a member of Sierra Club and the SW Ohio Alternate Energy Association, Robbins has also encouraged participation from these groups. But the websites and 2 groups have produced relatively few participants, especially in recent years.

Robbins surveys never gained widespread interest. There has been a wane in participation in recent years even among better-performing households already participating. Factors like the substantial recent price reductions in non-petroleum energies in much of the Ohio Valley, the economic recession beginning in 2007-8 and the 20% milder-than-average Ohio Valley winter of 2011-12 have almost certainly caused lessening consumer interest and concern about home energy.

A second goal of this report is to improve awareness especially among consumers and non-energy professionals about how to discuss and present household energy performance data, especially how to compare such data to normal ranges and demonstrated bests in a region and the nation. By explaining how to understand, calculate and compare energy data, Robbins hopes to generate more interest about longer-term household energy performance. Robbins believes householders benefit by seeing how their performance compares with other local households. Those achieving better performance can track and verify continuing performance. Poorer performers can become motivated to use less when seeing how much they lag behind others. Planners and administrators of energy programs can gain insight to improve their program targeting and ratings.

Getting The Energy Data

Robbins' survey asks participants to provide information about all amounts, types and costs of conventional energy acquired for their home over a calendar year, including energy acquired for free, like firewood. Starting in 2005, water acquisition data was also requested by the survey.

Since utility billing cycles and fuel acquisitions usually do not cleanly start and end with a calendar year, participants are asked to sum all energy acquired or paid for during a calendar year, not how much is actually used during a calendar year. This can create minor inaccuracy for participants in just one survey, especially with large irregular acquisitions. But participants over multiple years tend to lose the inaccuracy since each year usually contains similarly repeating error.

Participants are asked to estimate the conditioned space of their home in floor square feet (sf). They are asked to state the total number of home occupants. They are asked about the the county and state where their home is located. They are also asked to select from a list all the energy efficiency and renewable energy features inherent in the home or used by the household.

Robbins seldom questions submitted data unless there are obvious errors or omissions. If such are noticed, a participant is alerted to recheck and resubmit. Only a few submittals have been rejected over 12 years, almost always because there was no response to a recheck request.

The list below shows efficiency and alternate energy features participants could select for their responses in the 2012 survey. The list contained only 10 features when surveys began in 2001, but it grew to 18 by 2006. In the table are columns noting the first survey year for each feature, how many times each feature was selected and the percentage of the 252 annual household samples which selected it. In each survey, participants were asked to list all features which apply, using their own judgement, and only seldom did Robbins modify or seek clarification. The surveys asked no questions about energy labels or certifications, so participants were able to claim having efficient appliances or windows, for example, whether or not they were officially rated as such.

	Feature Description	**In Survey Since**	**Feature Tally**	**Of The 252 Datasets**
A	Active Solar (heating water and/or air)	2001	28	11%
B	Bermed Living Spaces	2001	91	36%
C	No clothes dryer and/or frequent use of a clothesline	2004	29	12%
D	No dishwasher and/or very infrequent use	2004	30	12%
E	Efficient Appliances	2001	138	55%
F	Mostly Daylighting + Fluorescent & LED lamps	2001	171	68%
G	Superior Windows (>/= R-3, < 0.10 cfm/sf air leakage)	2006	49	19%
H	Efficient HVAC System	2001	153	61%
I	Income-produced at/from home	2005	57	23%
L	Landscape (shade, food, windbreak, waste processing, storage, etc)	2005	72	29%
Na	No air conditioner	2001	10	4%
Nf	No furnace	2001	5	2%
P	Passive Solar (substantial daylighting, winter heating, summer cooling)	2001	80	32%
S	Superinsulation (150% of code level or higher)	2001	97	38%
T	Airtightened	2005	64	25%
U	Underground Roof & Walls	2001	4	2%
V	PVs (solar electricity)	2001	13	5%
W	Home Water Supply, like a well or roof-fed cistern	2005	14	6%

Figures 1 and 2 compare annual household energy use per-person and per-sf 2006-2012 (after EE/RE features count stabilized) to how many conservation, efficiency and renewable energy features were reported. Both show fewer occurrences of higher energy use as more efficiency and renewable energy features are implemented. Neither show that more than 6 or 7 features results in even lower usage. Maybe this means there are diminishing returns. Or maybe most households implement their more significant energy improvements first, less significant improvements last.

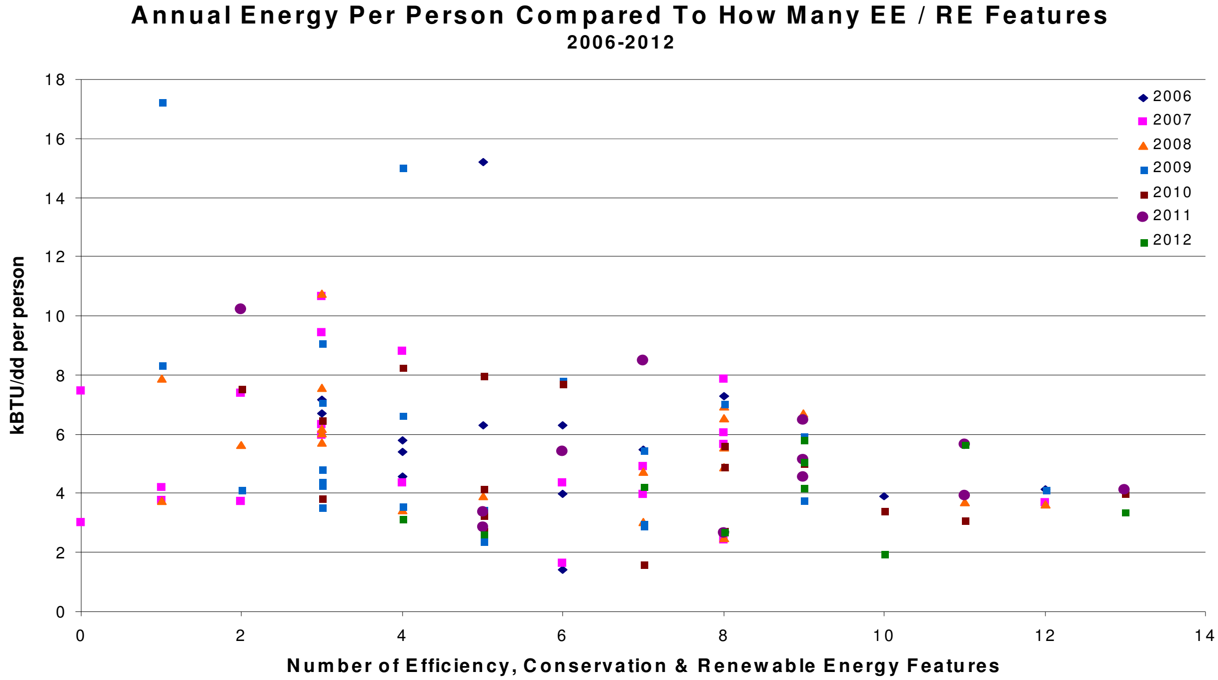

Figure 1: Energy Per Person

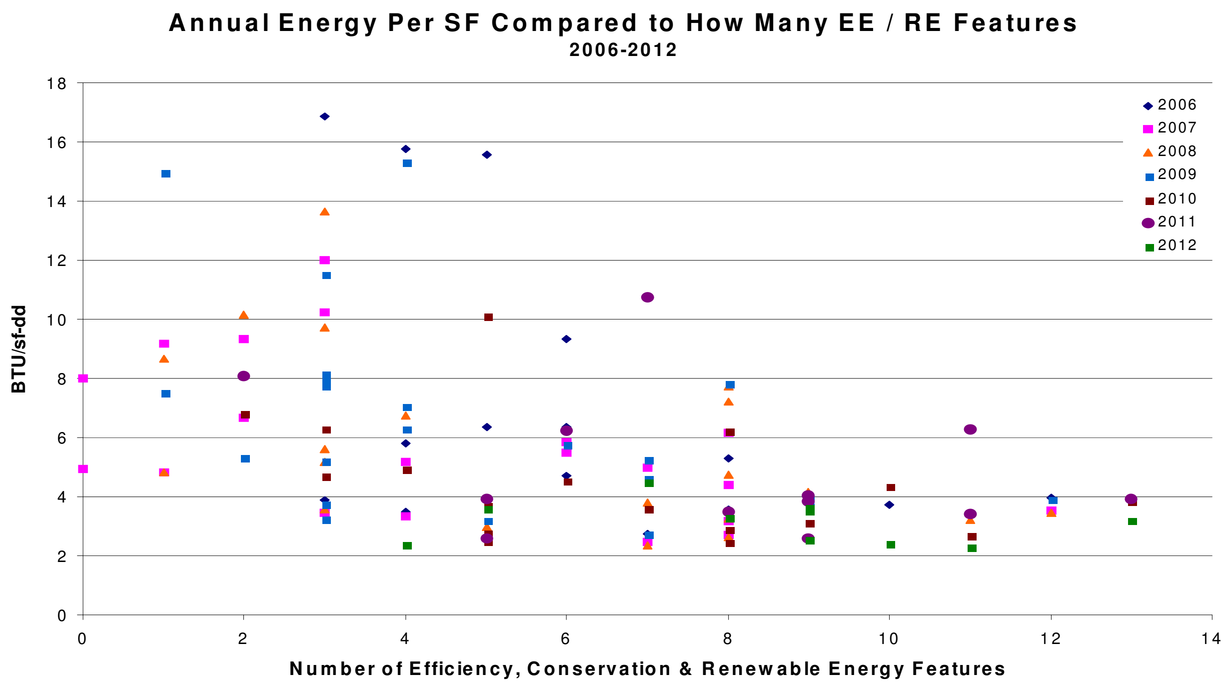

Figure 2: Energy Per Square Foot of Floor Area

Describing Energy Performance

Counting efficiency and renewable energy features is not a good way to describe or compare energy performance. So Robbins compares and describes energy performance in more useful ways.

First, all reported on-site purchased or otherwise acquired conventional energy is converted to equivalent BTUs according to the following uniformly applied conversion rates. This is to allow better assessment and comparability between energy sources of different energy content.

Energy Type	BTU Content
Electricity	3413 per kilowatt-hour aka “kWh”
Heating Oil	139,000 per gallon
Kerosene	137,000 per gallon
Liquid Propane (LP)	91,600 per gallon
Natural Gas	102,900 per hundred cubic feet aka “ccf”
Pellets	8000 per pound
Wood	25,000,000 per full cord
	18,750,000 per mini-cord (also called “MC”, 3/4 of a full cord)

Some energy analysis methods try to assess “embodied energy” to account for all the additional energy required to extract, transport, refine or generate and transmit energy from its original form and location to its final form and location where used. For example, it is widely accepted that electricity generated by burning coal and delivered via average electric grids contains as little as one-third of the energy content in the original coal when it reaches a consumer. But this does not include energy to mine and transport coal to the generator. Similarly, embodied energy for electricity generated by burning natural gas does not include energy required to extract and transport gas to the generator. Modern horizontal fracking is more energy intensive than older extraction methods, so it is expected that embodied energy in modern natural gas is higher than in the past.

Electricity generation in the Ohio Valley is also not based on just one fuel. So accurately assessing embodied energy per kWh requires assessing the “fuel mix” behind kWhs supplied in a local electric grid. When Robbins surveys began, coal-fired generation far exceeded natural gas-fired generation in the Ohio Valley. But the percent of coal-fired electricity generation has been dropping while natural gas-fired generation has been rising. The historic recent increase in new natural gas supplies found in Midwest USA and the accompanying drop in wholesale natural gas prices have changed the average fuel mix behind conventional kWhs in the Ohio Valley.

Even when an electricity consumer has a large enough quantity of onsite grid-connected renewable energy that annual solar generation equals annual onsite electricity usage (called “net-zero”), it is still difficult to assess accurately the average embodied energy content per kWh. That consumer still needs to acquire conventionally generated electricity at night and on cloudy days. And most conventionally generated kWhs in the Ohio Valley come from burning coal and natural gas.

Robbins’ survey assesses only the onsite energy value of household energy because there is too much difficulty and uncertainty in accurately estimating embodied energy content.

After summing total annual BTUs per household, they are divided by each home's conditioned floor area to produce the "energy usage index" (EUI) or annual BTUs per sf of conditioned floor area. EUI is usually expressed in thousands of BTUs, so kBTU/sf is the actual index (thousands of BTUs per sf per year). According to the United States Energy Information Agency (EIA), average household EUI in USA in 2001 was 46.7 kBTU/sf.

Figure 3 tracks Robbins' survey EUI by year, noting the highs, averages and lows 2001-2009. (Surveys 2010-2012 are not included in many of the following figures because those surveys are still in-progress.) It is easy to see that average EUI in early years of Robbins' surveys tracks close to EIA's national average for 2001. Robbins suspects that EUI average becomes lower in later years because fewer average and high energy users seem to be participating in the survey.

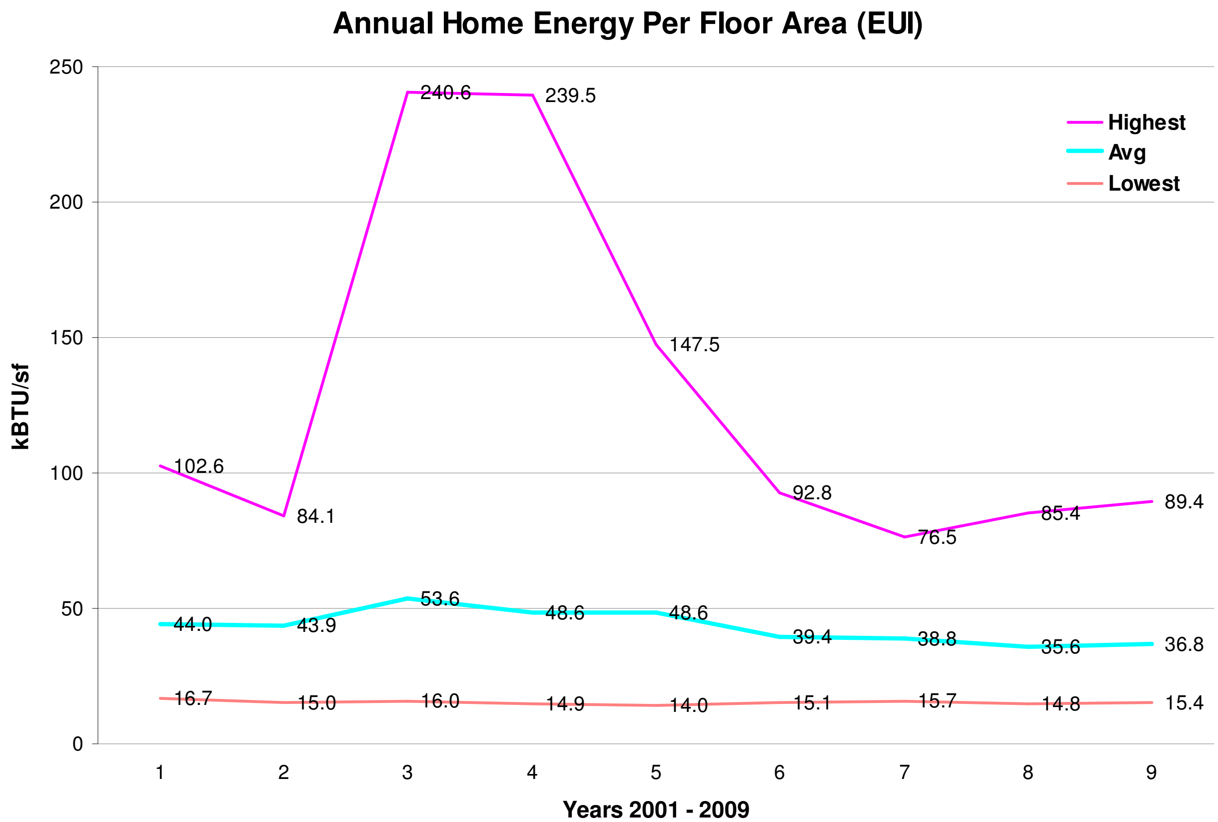

Figure 3: Energy Per SF By Year

EUI tends to decrease as house size increases. This is because there often is less "thermal envelope area" per floor area in larger homes. Simplest explanation for this is that conducted heat losses and gains, which get reduced by increasing R-values, also are directly proportional to how much area in ceilings, walls, windows, doors, floors, etc., which separate a home's conditioned spaces from the lower or higher outside temperatures. So thermal conduction increases with lower R *and* higher surface areas. Thermal conduction decreases with higher R *and* lessor surface areas. Geometrically, larger homes tend to have less exterior surface areas per floor area than smaller homes. The tendency of EUI to drop as floor area increases is obvious in Figure 4 which shows all 252 EUIs over 12 years compared to each EUI's conditioned floor area. Easy to see why EUI is not especially useful when comparing homes of substantially different size.

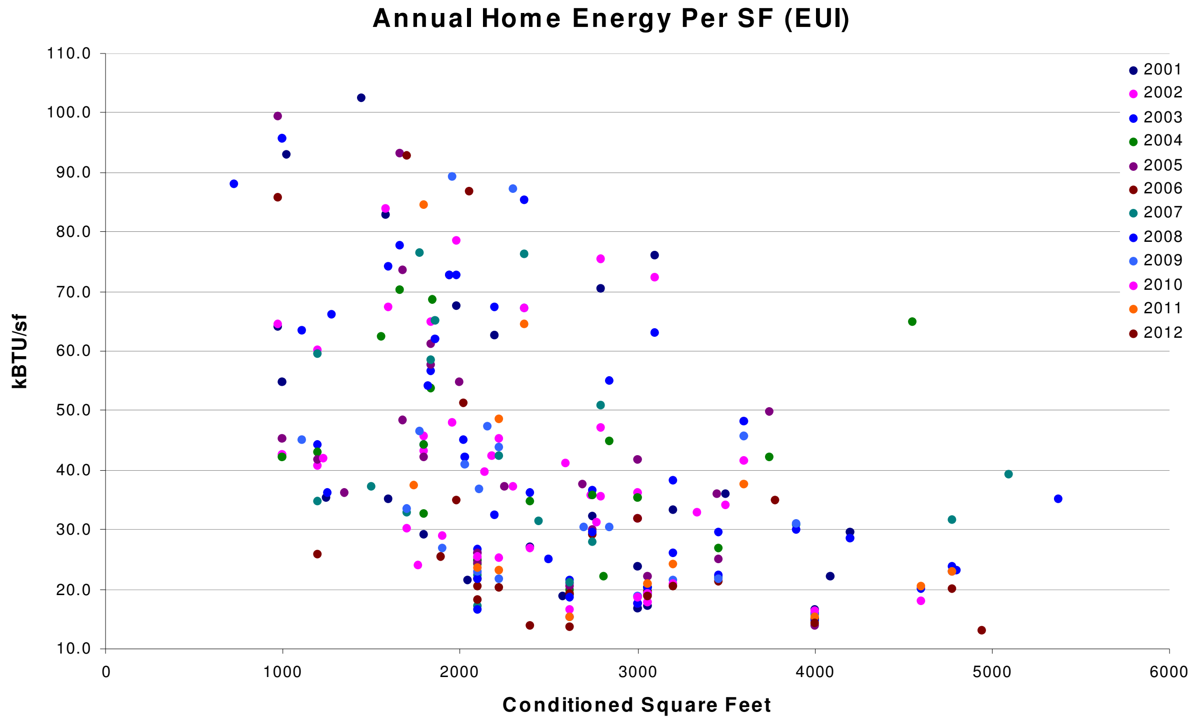

Figure 4: Home Energy Use Compared to Home Size

EUI also varies significantly with the changing year-to-year outdoor climate. Ohio Valley homes typically use a large amount of their annual energy for heating and cooling. There are relatively cold heating seasons and hot humid cooling seasons. Cincinnati averaged 4907 “heating degree-days” (HDD) per year 2001-2010, varying from 4400 in 2006 (-10.3%) to 5184 in 2003 (+5.6%). Cincinnati also averaged 1180 “cooling degree-days” (CDD) per year 2001-2010, varying from 848 in 2003 (-22.1%) to 1637 in 2007 (+38.7%).

Heating and cooling degree-days measure accummulated differences between average daily outdoor temperatures and typical indoor temperature. This measurement assumes no heating energy is needed if outdoor temperature is at least 65F, no cooling energy is needed if outdoor temperature is not over 65F. Heating and cooling degree days are sometimes written as HDD(65) and CDD(65), but “65" refers to outdoor temperature, not indoor temperature. If a day’s average temperature is 30, that day has 35 HDDs. If average temperature is 80, there are 15 CDDs.

Degree-days are tracked and published daily, monthly, seasonally and yearly by weather and energy professionals to allow better understanding and comparability of weather and energy trends. Heating energy usage rises with higher HDDs. Cooling energy usage rises with higher CDDs.

To allow better comparability of energy performance by conditioned structures in different years, locations and climates, energy professionals divide EUI by HDDs and/or CDDs to produce a climate-sensitive version of EUI.

In Robbins’ surveys, each home’s EUI is divided by the sum of each year’s heating AND cooling degree-days, using published values for Cincinnati or Columbus OH, Louisville or Lexington KY, based on the home’s location. The resulting value is BTU/sf-dd, or BTUs per square foot per (heating + cooling) degree-day. Figure 5 shows high, average and low BTU/sf-dd for 2001-2009.

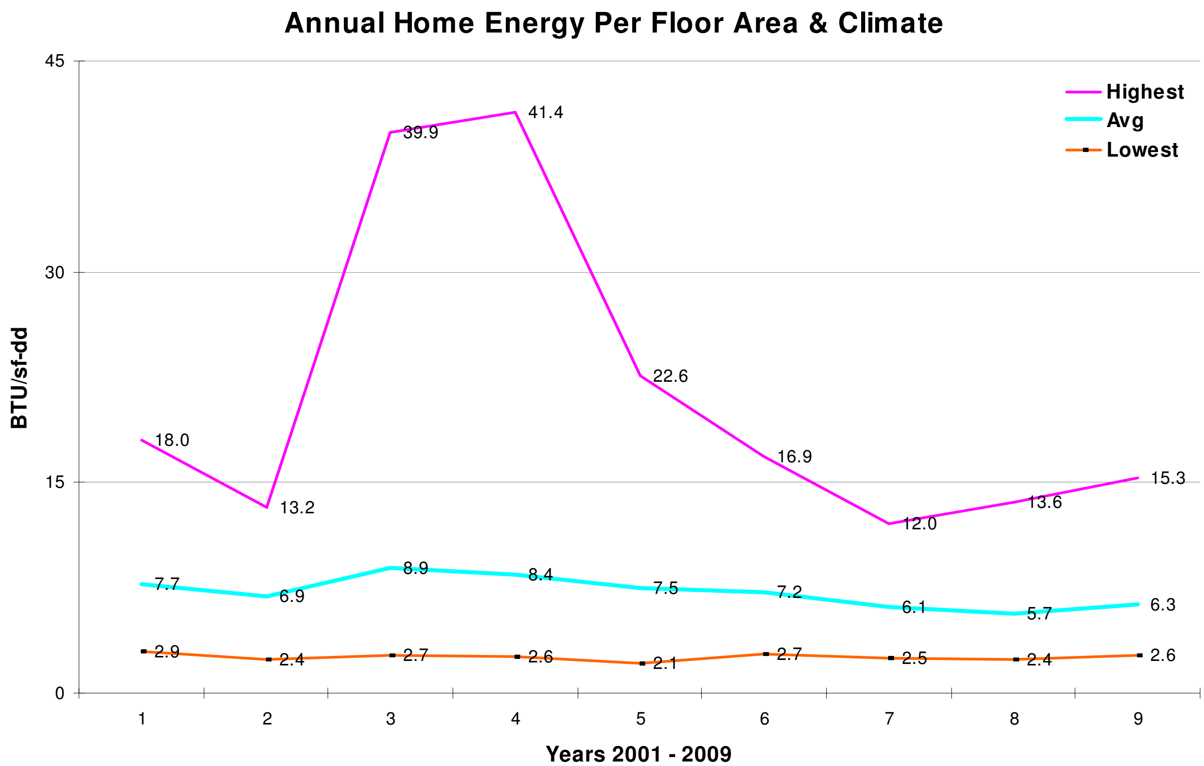

Figure 5: Annual EUI Per Degree-Days

Robbins created a “Ratings Gauge” (Figure 6) to show usual best-to-worst ranges for home energy performance in the Ohio Valley, based on his home energy evaluation and design experiences since 1983. His early research had uncovered one study describing average for Midwest USA as 10 BTU/sf-dd. Heating-only average was cited as 9 in a New England study. Top line in Figure 4 shows the usual best-to-worst ranges for BTU/sf-dd. Average is shown as 8 to 12.

Ratings Gauge

	Best	Super	Better	Average	Poor	Worst
BTU/sf-degree-day	<= 2	2.01 - 4	4.01 - 8	8.01 - 12	12.01 - 16	16.01 =>
kBTU/person-deg-day	<= 2	2.01 - 3	3.01 - 6	6.01 - 9	9.01 - 12	12.01 =>

Figure 6: How Robbins Rates Home Energy Performance

Using this gauge and Figure 5, it is easy to see that best per-sf performances each year, ranging from 2.1 to 2.9, were in the better half of the “super” category. No households achieved 2.0 or lower, what Robbins presumes to be “best” only from reading about home performance. Averages in Figure 5 ranged from 5.7 to 8.9, rated by the gauge as “better” to “average”. The wide range in highest values, 12 to 41.4, translates as “poor” to “worst” according to the gauge.

Truly superior household energy performance should demonstrate superior values per-sf *and* per-person. Since it appears normal for heating and cooling energy per sf to drop as house size increases, and since it is also normal for per-person energy to increase as floor area per person increases, it is important to assess both per-sf and per-person indices to determine overall performance. Otherwise, it is possible for energy use per sf to drop while use per person rises.

Indeed, it has not been uncommon in Robbins' surveys for households in thermally efficient larger homes with greater floor area per person to score substantially better in energy per sf than energy per person. For example, of the lowest BTU per-sf per degree-day scores in each of the 12 survey years, 11 were for households with 2000 or more sf/person, achieving per sf scores from 2.1 to 2.9 (super) but BTUs per person per degree-day scores from 4.3 to 5.8. (More about this below.)

To measure conventional energy per-person, Robbins initially divides each household's total annual BTUs by the number of home occupants. The answer is in the millions, so the index is mmBTU/person or millions of BTUs per person per year. According to US EIA, average household energy usage in USA in 2001 was 36.0 mmBTU per person. Figure 7 describes high, average and low per-person energy in Robbins' surveys 2001-2009.

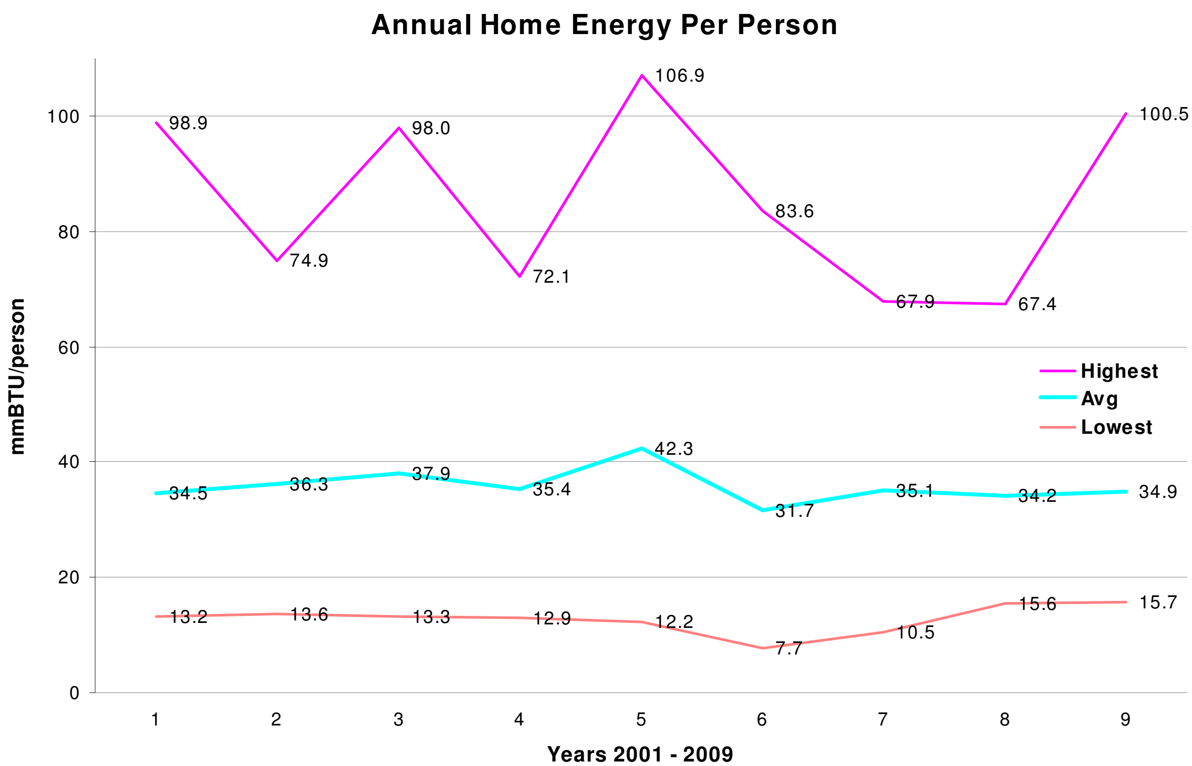

Figure 7: Energy Per Person

It is easy to see in Figure 7 how average per-person energy tracked close to EIA's published 2001 value, varying from 31.7 in 2006 (-12%) to 42.3 in 2005 (+17.5%). Lowest per-person usage varied from 7.7 in 2006 (-79%) to 15.7 in 2009 (-56.4%). Highest usage per person ranged from 67.4 in 2008 (+87%) to 106.9 in 2005 (+197%).

Per-person home energy usage can be broken into 2 main components: (1) each occupant's share of the whole house heating, cooling, ventilation, lighting and refrigeration energy and (2) each occupant's own energy use, like personal hot water, lighting and power for small electronics. As floor area per person increases, each occupant "shares" a greater portion of the whole house energy.

According to EIA, average floor area per person in USA in 2001 was 760 sf. Figure 8 clearly shows the tendency of per-person energy usage to increase as floor area per person increases past 760 sf. This explains why some households in thermally efficient homes but with greater floor area per person score sometimes substantially worse in energy per person than energy per sf.

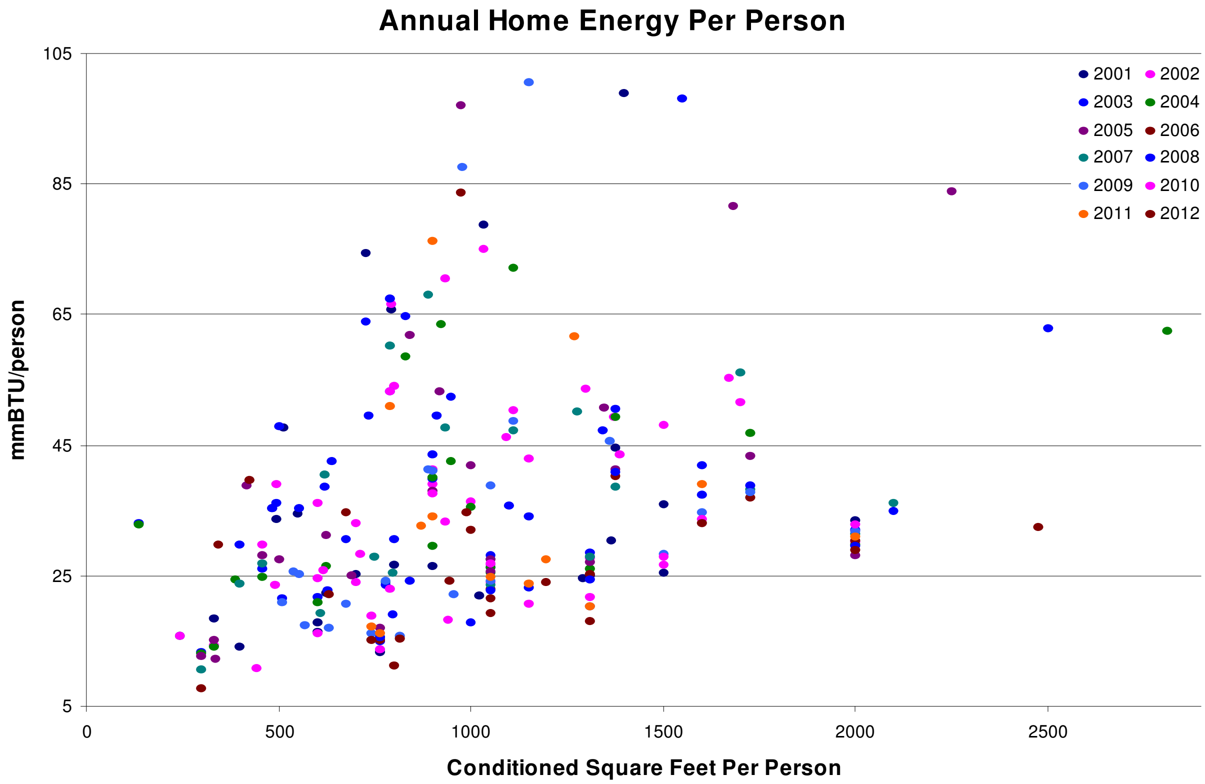

Figure 8: Energy Per Person Compared To House Size

Figure 8 shows that lowest per-person energy usage has occurred in Robbins' surveys only when floor area per person is average (760 sf) or lower-than-average. Lowest energy use per person doubles as conditioned space increases from 500 - 750 sf/person to 1500 - 2000 sf per person.

Most thermally efficient homes are represented along the bottom of the scatter diagram, including several households in Robbins' home designs. Robbins homes all have similarly high component R-values, better-than-average airtightness and more efficient heating and cooling systems. One Robbins' design is a vertical line-up of data points around 15 MMBTU/person slightly greater than 750 sf per person. Robbins' own home, a retrofit, is the vertical line-up of data points between 30 and 15 MMBTU/person at slightly more than 1000 sf person. Another household in a Robbins design is the almost-solid vertical line-up of data points around 30 MMBTU/person at 2000 sf per person. These clearly show how similarly efficient homes produce substantial differences in energy usage per person based almost solely on how much floor area per person.

As with per-sf evaluation, each year's per-person energy use also fluctuates according to severity of each's year's outdoor climate. To improve comparability of per-person energy between different years and/or locations, per-person energy is divided by the sum of each year's heating + cooling degree-days to produce a climate-referenced per-person energy index, similar to what was done with energy per sf. As in the climate-sensitive per-sf evaluation, published degree-day values for Cincinnati or Columbus OH, Lexington or Louisville KY were used for this calculation, depending on which location was closer to the home. This climate-sensitive per-person energy answer is in the thousands, so the actual index is kBTU/person-dd, or thousands of BTUs per person per degree-day.

Figure 9 shows the high, average and low per-person energy per degree-day 2001-2009.

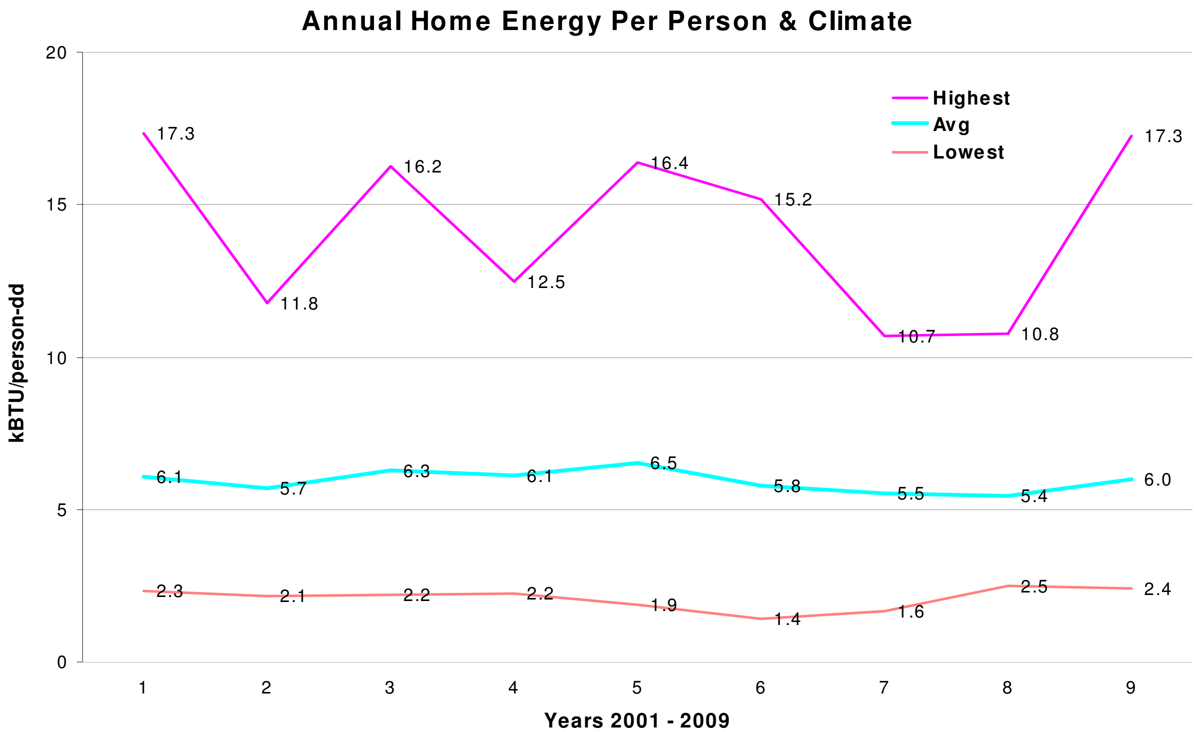

Figure 9: Energy Per Person Per Degree-Day

Robbins' Ratings Gauge (Figure 6 on page 11) shows expected ranges for BTU/person-dd in the Ohio Valley, based on Robbins' home energy evaluation and design experiences since 1983. Lowest household energy usage per person ranged from 1.4 BTU/person-dd in 2006 to 2.5 in 2008. These are "best" and "super", respectively, according to the gauge. The 2006 household scoring best per person scored only "better" per sf per degree-day. The 2008 household achieving 2.8 per person ("super") also achieved "super" per sf per degree-day. Average usage ranged from 5.4 BTU/person-dd in 2008 to 6.5 in 2005, which is "better" to "average" according to the gauge. High per-person usage ranged rather wildly from 10.7 to 28.5, which is "average" to "worst" by the gauge.

Referring again to the Ratings Gauge (Figure 6 on page 11), Robbins considers '***super overall***' those households which use not more than 2 - 4 BTUs/sf-dd *and* 2 - 3 MMBTUs/person-dd. Of the 252 annual household energy samples in Robbins surveys 2001-2012, this dual distinction was achieved only 20 times by only 6 households. Only 2 households achieved it more than once.

One SW Ohio household of 4, living in a relatively new 3058 sf home designed by Robbins, achieved the dual distinction 12 times, having participated in all 12 years of the survey. This is the same 2008 household, mentioned above, which achieved "super" per person AND per sf. This household not only cited many efficiency and renewable energy features (8 of 18) including superior insulation values, airtightness and windows, passive solar design, bermed living spaces (a finished insulated basement), efficient HVAC system, lights and appliances, but also only 765 sf of floor area per person, very close to the national average floor area (760 sf) per occupant cited in 2001 by EIA.

A household of 3 in a 2220 sf house in central Kentucky achieved the dual distinction 4 times, participating in the survey only 4 times. This household cited many energy features (5 of 18) including superior airtightness, bermed living space, efficient HVAC, efficient lights and appliances. It had only 740 sf of floor area per person, very close to the national average cited in 2001 by EIA.

Of the top-20 households achieving Robbins' dual distinction, the average number of reported efficiency and renewable energy features was 7. Highest number cited was 10. 19 households cited bermed living spaces, meaning at least some conditioned living space below outside grades, like a finished basement. 19 top-20 households cited efficient lights and appliances. 18 cited efficient HVAC systems. 17 cited superior airtightness. 14 cited superior insulation levels. 13 cited passive solar. 11 cited superior windows. Only 1 household reported only 1 feature: efficient lighting. Only 1 household reported active solar heating. No dual distinction households cited solar electricity.

Describing Energy Cost

Each household's reported annual home energy expenses were also totalled and examined. Since survey participation spanned 12 years and came from diverse urban and rural locations with sometimes very different energies and unit prices, average energy cost per BTU varied so widely that it was less useful for comparing or rating households.

Total household annual energy cost in Robbins' surveys 2001-2012 varied over 12:1, shown in Figure 10. The low was $537 in 2002. The high was $6625 in 2010. Each survey year had huge differences. Among the top-20 '*super-overall*' households, the SW Ohio household for 12 years paid $899 for energy in 2001, $1773 in 2012; the central Kentucky household for 4 years paid $1082 in 2009, $1241 in 2012. Neither household had lowest energy cost in any survey year.

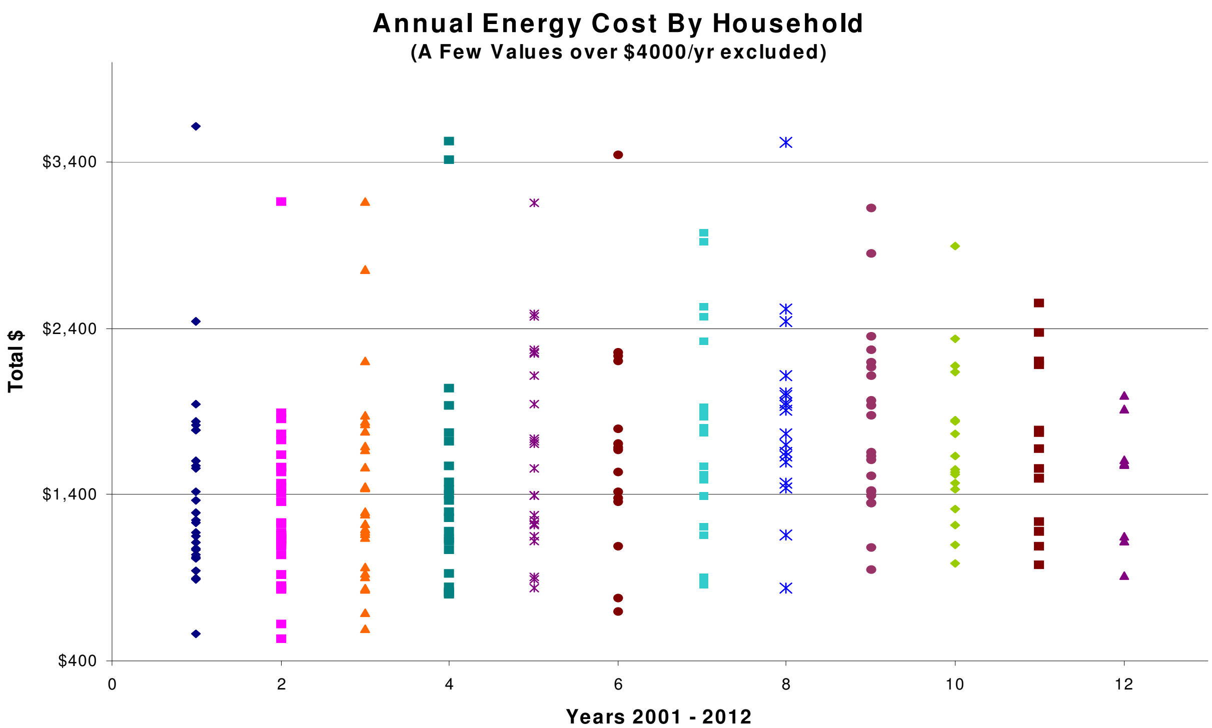

Figure 10: Large Variations in Annual Household Energy Cost

Houses are many sizes from small to large, so annual energy cost was also compared per sf of floor area. There was over 13:1 ratio in energy cost per sf, shown in Figure 11, from a low of $0.28/sf in 2002 to a high of $3.69/sf in 2004. Among the top-20 '*super-overall*' households, the SW Ohio household achieved the low in 2002, rose to $0.58/sf in 2010 and 2011, then dropped to $0.52/sf in 2012. The central Kentucky top-20 household achieved $0.49/sf in 2009, rose to $0.59/sf in 2010, then dropped to \$0.50/sf by 2012. 2002 was the only survey year when any of the top-20 '*super-overall*' households also achieved lowest energy cost per sf.

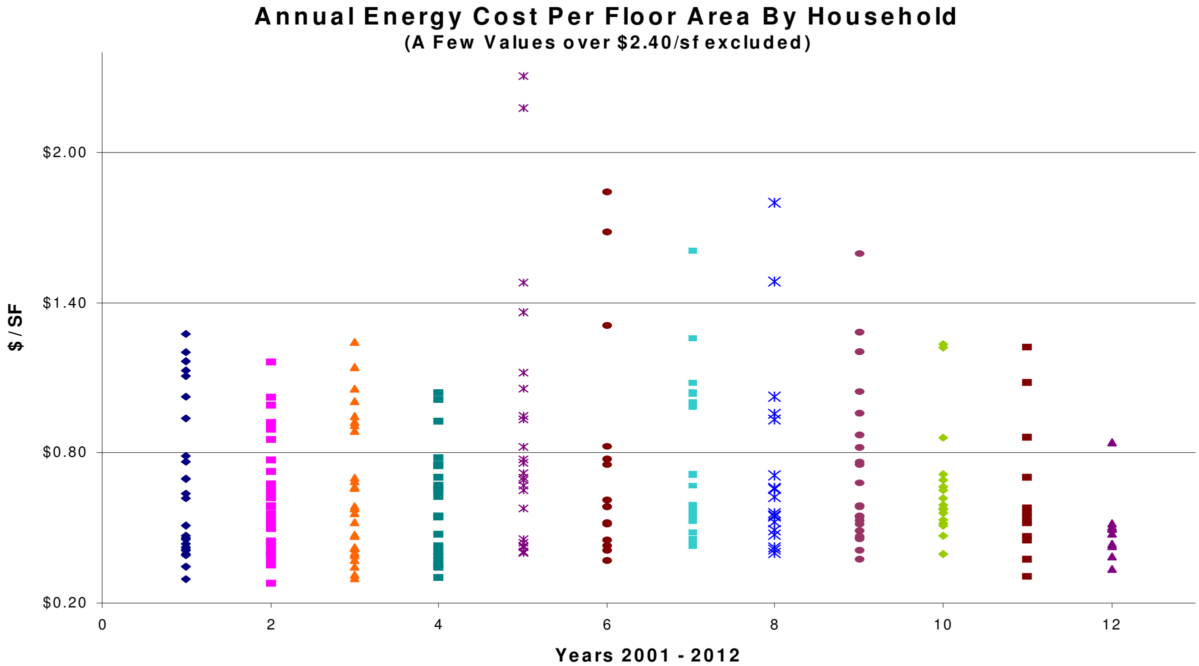

Figure 11: Large Variations in Energy Cost Per SF

Annual energy costs per person, shown in Figure 12, varied over 19:1, from a high of \$3312 in 2010 to a low of \$173 in 2003. Among the top-20 '*super-overall*' households, the SW Ohio household achieved \$225/person in 2001, \$422/person in 2012. The central Kentucky household achieved \$361/person in 2009, \$372/person in 2012. Neither household had lowest energy cost per person in any survey year.

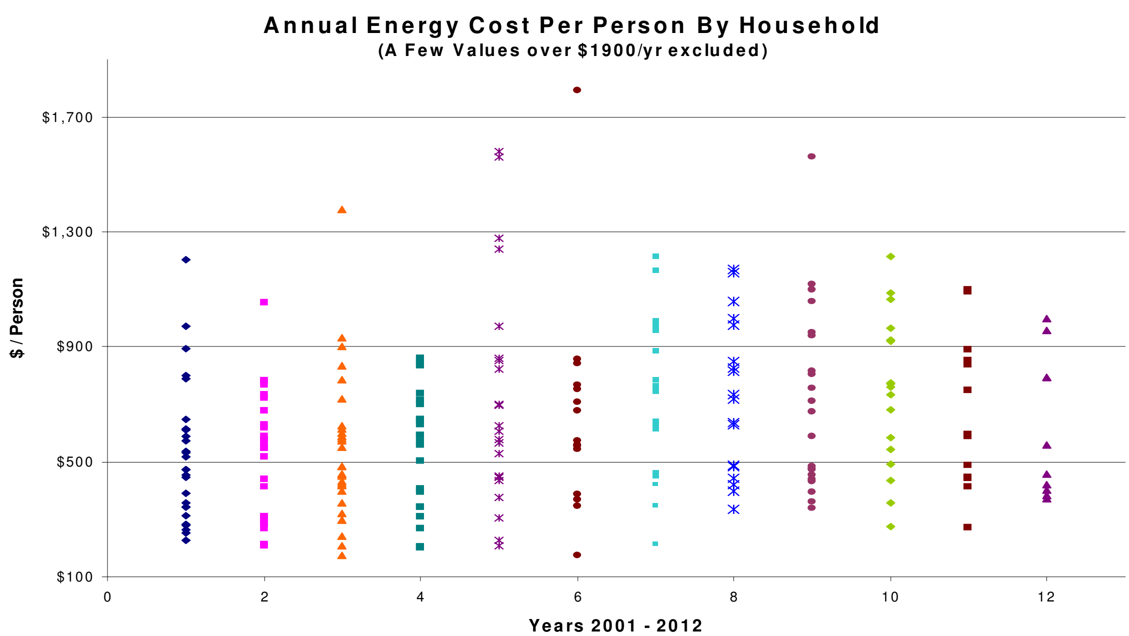

Figure 12: Large Variations in Energy Cost Per Person

Figure 13 presents the 2001-2009 annual averages for home energy costs per-sf and per-person. Average home floor area and average floor area per person are included in this graph since growth in both may account for part of the growth in total and per-person energy cost indices 2001-2009. Indeed, the floor area per-person line almost exactly parallels the energy cost per person line.

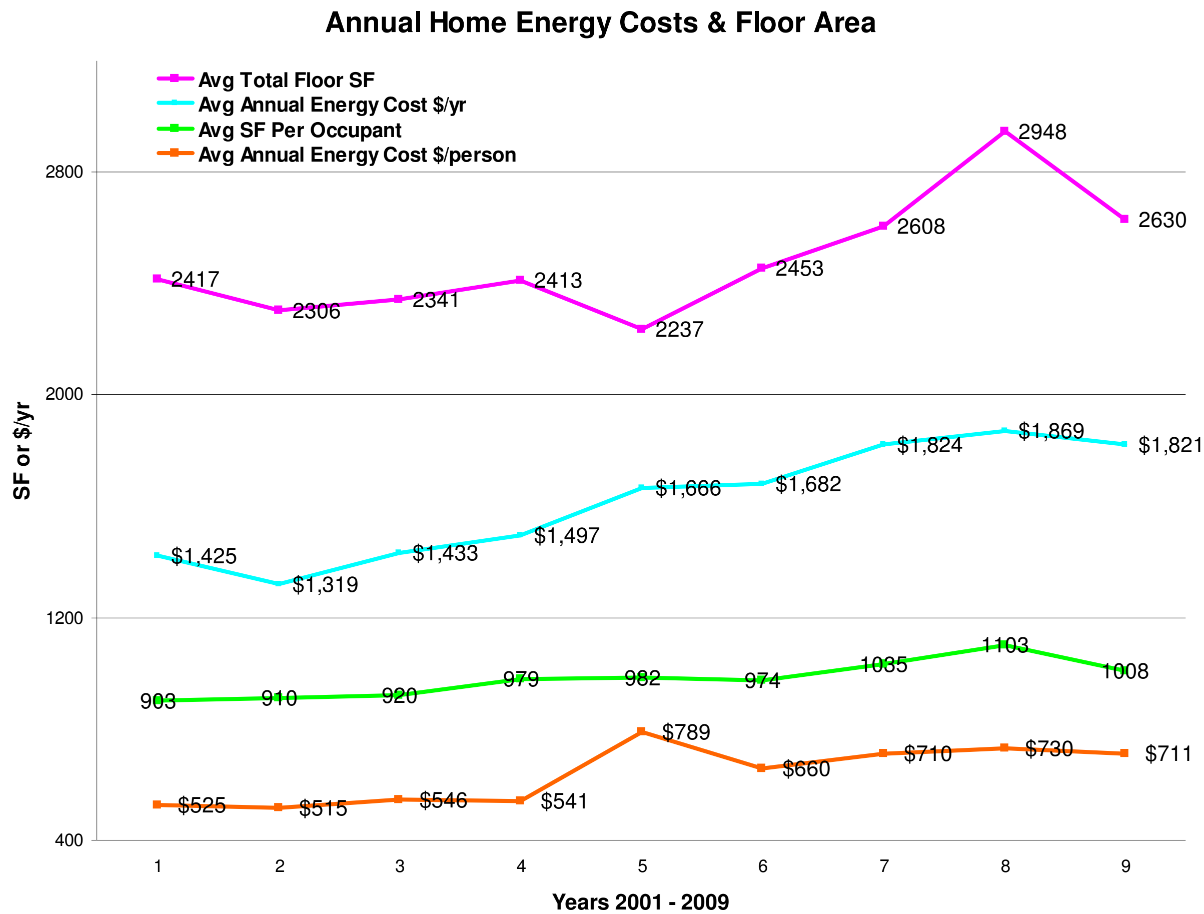

Figure 13: Home Energy & Per-Person Energy Compared to Home Size

There are two other reasons explaining why overall, per-sf and per-person energy costs rose. The first is that most energy sources got steadily more expensive in the Ohio Valley. It is easier to understand this if purchased energy is compared according to how much energy content per dollar. There was well over 4:1 ratio in the average annual kBTUs of energy content per dollar spent by households in Robbins surveys 2001-2012, from a high of 124 to a low of 28. Both extremes ironically occurred in 2011.

Part of this large ratio was due to some households acquiring some or all firewood for free. Indeed, the 124 kBTU/dollar household in 2011 reported no cost for its 4 cords of firewood. The 28 kBTU/dollar household in 2011 also reported no cost for its firewood but acquired only 1/16 cord, using low kBTU/dollar electricity for all the rest of its annual energy. Neither of the two top-20 '*super-overall*' households used firewood, instead buying all energy from 2 different utility companies which increased prices. The SW Ohio household's annual kBTU per dollar index dropped 39% from 59 in 2001 to 36 in 2012. In 2012 it was getting only 61% as much energy per dollar as in 2001. The central Kentucky household's annual kBTU per dollar index dropped 11% from 45 in 2009 to 40 in 2012. In 2012 it was getting only 89% as much energy per dollar as in 2009.

Figure 14 tracks the annual survey averages for residential kBTUs (thousands of BTUs) per dollar for major Ohio Valley household energy sources. Firewood was excluded because so many households got firewood for free and the average energy value per dollar for purchased firewood was so much higher than more traditional conventional energies. It is easy to see that all these household energy sources lost value 2001-2012, even natural gas which improved its value 2008 - 2011 after major devaluation 2002 - 2006.

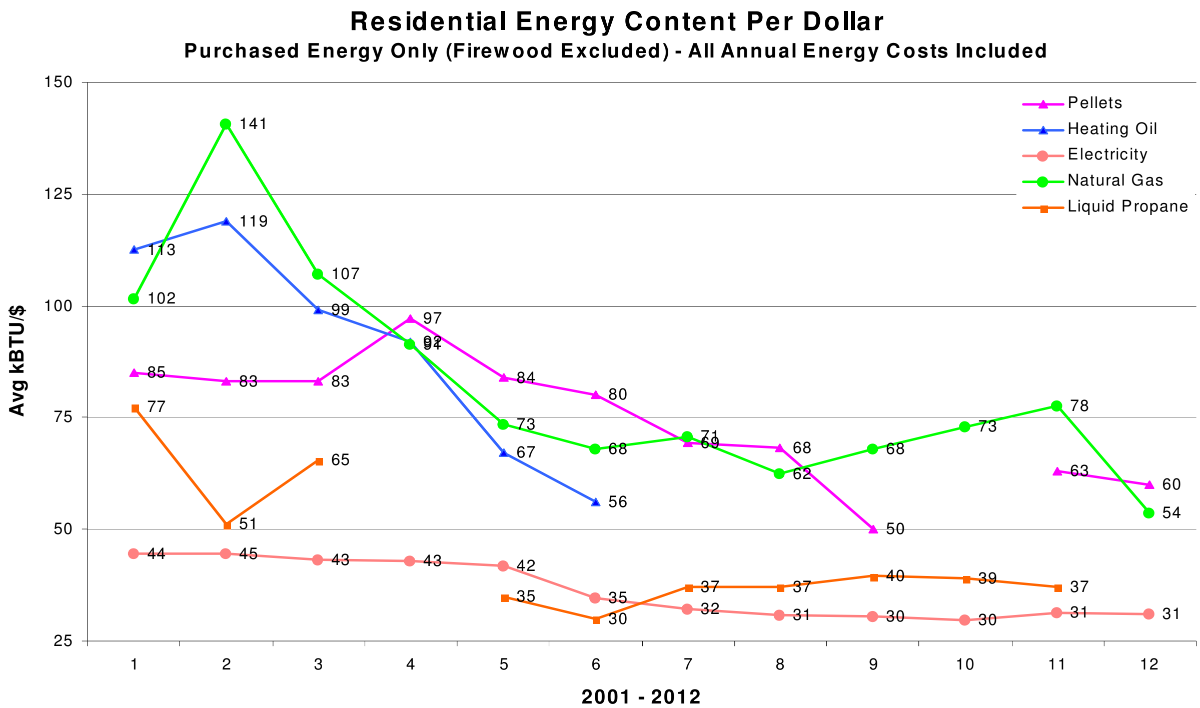

Figure 14: Ohio Valley Energy Values 2001-2012

What looks like a sharp drop in average natural gas value per dollar in 2012 was not because the average unit price of residential natural gas suddenly rose substantially. It was because the only 3 households in the 2012 survey (survey still in progress at the time of this writing) which used natural gas for heating are living in very thermally efficient homes and buying gas from the same supplier which has very high fixed monthly charges unaffected by gas usage. These 3 natural gas-using households buy such small volumes of natural gas that less than 1/3 of their annual gas bills relate to their gas usage. As more participants in less efficient homes and in other supplier territories report for 2012, average energy value for natural gas in this graphic will lose the apparent decline in 2012 since Ohio Valley gas prices were low and average to high monthly gas usage will generate enough usage-related costs to make fixed charges a much smaller portion of the overall bills.

Robbins' surveys have attracted a high percentage of households achieving less energy usage, so it should not be surprising that this analysis shows the especially negative energy cost impact on low users from energy pricing designs with high fixed monthly charges. High fixed monthly charges also occur among some "rural electric cooperative" (REC) utilities supplying survey households in Ohio, Indiana and Kentucky. And some major Ohio and Indiana electricity suppliers have low fixed monthly charges but offer lower rates per kWh when more kWhs per month are used. Both these pricing designs result in lower average cost per energy unit as monthly purchase volume increases, or higher average cost per energy unit as purchase volume goes down. This is called "regressive pricing." Figure 15 shows the regressivity of electricity pricing among survey participants.

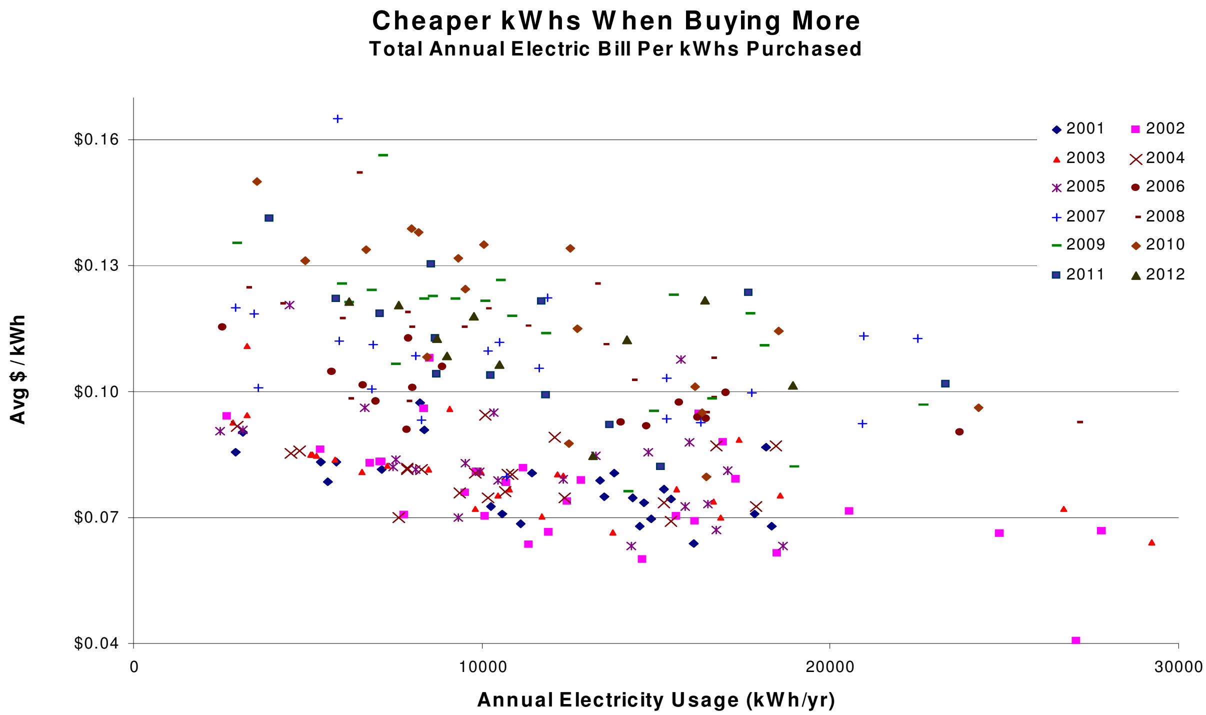

Figure 15: Ohio Valley Avg Electricity Cost per Purchased kWhs 2001-2012

Residential energy cost regressivity is common among most Ohio Valley energy suppliers and most energy sources. Buying less energy usually results in paying more per energy unit. Said another way, a consumer gets less energy per dollar as less is purchased. Figure 16 compares average annual kBTUs per dollar to annual usage for all survey households 2001-2012.

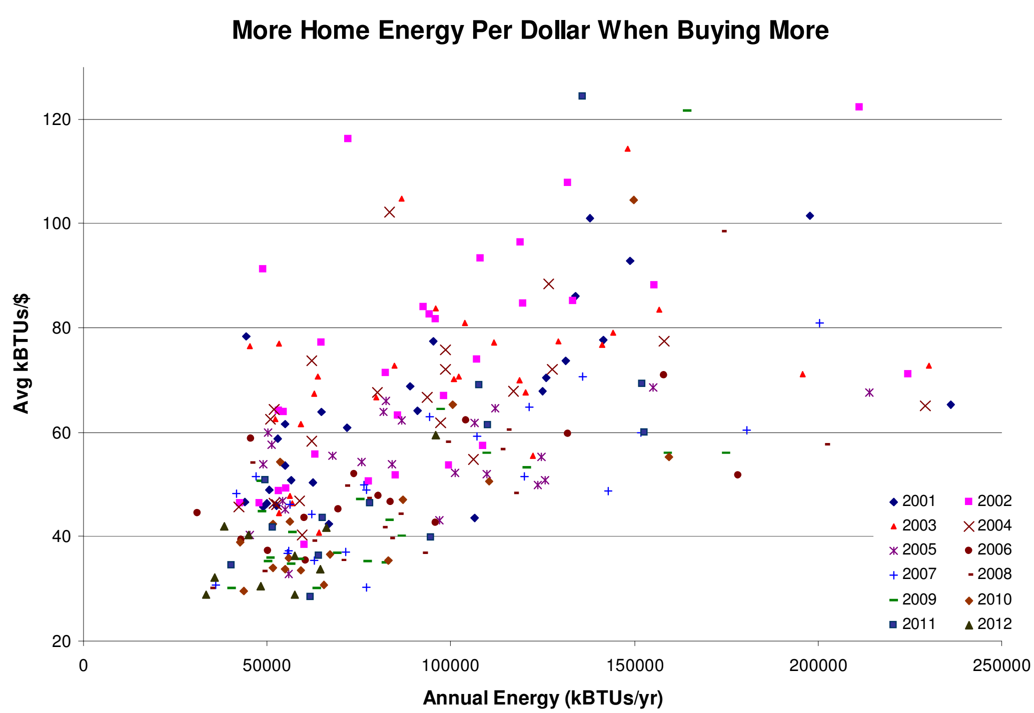

Figure 16: Ohio Valley Avg Energy per Dollar - Depends on Volume

Assessing Emissions From Energy

Annual home energy use in Robbins' surveys was also evaluated to estimate associated CO2 emissions. CO2 emissions per kWh were based on emissions averages reported prior to 2010 by the electric utility most cited by survey participants, Duke Energy. For other fuels, estimates were made using these well-accepted conversion rates for pounds of CO2 emissions per unit of fuel.

Energy Type	CO2 Emissions Rates for Ohio Valley Energies
Electricity	2 pounds per kWh
Gasoline	22 pounds per gallon
Heating Oil	26.4 pounds per gallon
Kerosene	21.5 pounds per gallon
Liquid Propane	12.5 pounds per gallon
Natural Gas	12.1 pounds per CCF
Wood	n/a (deadwood emits similar CO2 when rotting as when burned)

CO2 emissions estimates were divided by floor area and number of home occupants. CO2 emissions per sf varied almost 40:1 (79 lbs/sf per year for a household in 2004, 2 lbs for the only "off-grid" household to participate in Robbins survey in 2002. The off-grid house had no connection to a conventional electric utility). CO2 emissions per person varied more than 43:1 (131 lbs per person per day for a household in 2010, 3 lbs per person per day for the off-grid household in 2002). Figure 17 shows per-person CO2 emissions compared to conditioned floor area per person. It cannot be ignored that greater floor area per person tends to increase CO2 emissions per person.

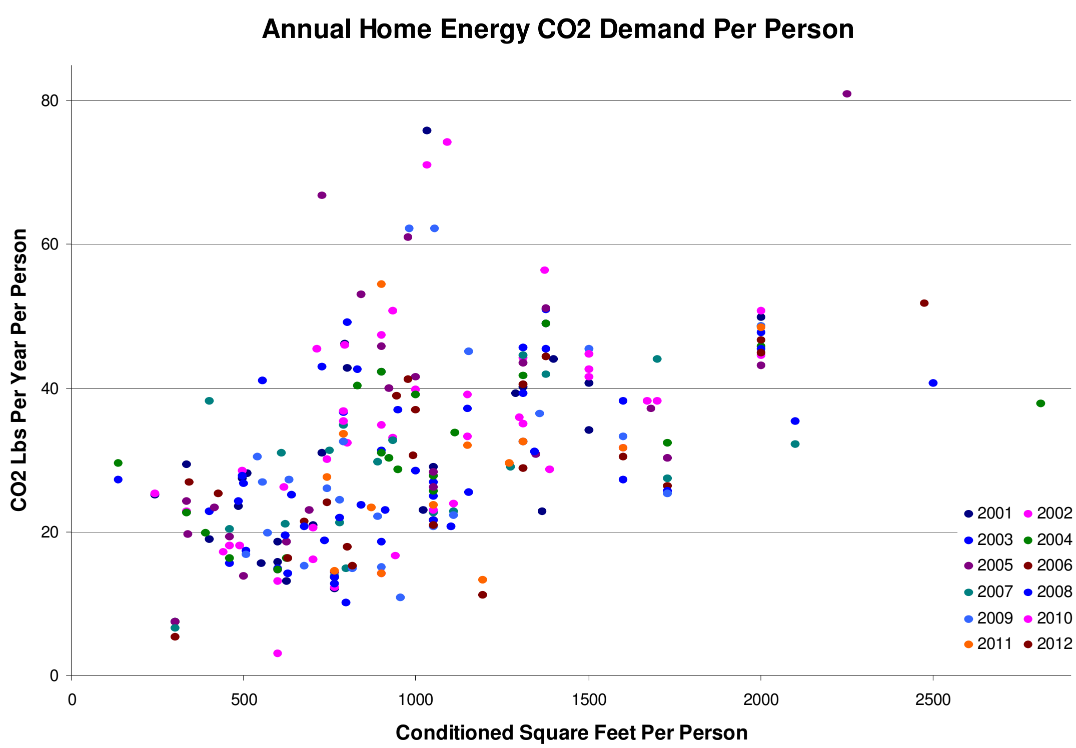

Figure 17: CO2 Emissions Versus How Much Conditioned Space

Since Ohio Valley households use a substantial portion of annual energy for heating, it should not be surprising that lowest CO2 emissions occurred typically in homes using lower CO2/BTU heating energy, especially natural gas and firewood. Highest CO2 per person typically occurred in households living in so-called 'all-electric' homes, because most electricity in the Ohio Valley has historically been generated by burning coal. The wide-spread shift from coal-fired to natural gas-fired electricity generation by 2012 among Ohio Valley electricity suppliers will likely cause a reduction in average CO2 per kWh in future surveys.

Home Water Usage

Beginning in 2005, home water and water cost are also compared per household and person. There have been very wide annual water volume ratios, from as high as 252 gallons per person per day for a household in 2005 to as low as 3 in 2005 and 2010. Highest usage was for a 1-occupant home with a backyard water landscape feature which seemed likely to use a large quantity of water. Very low usage was almost always associated with homes which collect a major portion of their household water from rain, where extra water was purchased only occasionally as during droughts.

Summarizing this Report

The primary purpose of this analysis and report was to discover, document and report the best residential energy performance actually demonstrated in the Ohio Valley. The following table shows the 2001-2009 survey ranges for demonstrated best, average and worst energy performance in 4 key indices related solely to energy usage. Because Robbins survey did not attract many high energy users, the most useful indices for homeowners, designers and others interested in identifying or targeting superior home energy performance in the Ohio Valley should be the ranges for what is best.

Annual EUI (kBTU/sf)	Best:	14.0	-	16.7
	Avg:	35.6	-	53.6
	Worst:	76.5	-	240.6
Climate-Adjusted EUI (BTU/sf-dd)	Best:	2.1	-	2.9
	Avg:	5.7	-	8.9
	Worst:	12.0	-	41.4
Annual PEUI (mmBTU/person)	Best:	7.7	-	15.7
	Avg:	31.7	-	42.3
	Worst:	67.4	-	106.9
Climate-Adjusted PEUI (kBTU/person-dd)	Best:	1.4	-	2.5
	Avg:	5.4	-	6.5
	Worst:	10.7	-	17.3

Below are 4 annual tables further summarizing Robbins' survey data, key index averages and low-high ranges in each year 2001 to 2012. Left-most columns in each annual table show average household energy for the entire USA as published in 2001 by the US Energy Information Agency (EIA). Robbins' surveys 2010, 2011 and 2012 are still in-progress, still accepting new household data, so those annual tables are included but incomplete, likely to be revised substantially in the future. Robbins plans to continue his annual household energy surveys and publish future updates.

Ohio Valley Household Energy Surveys 2001-2012

	2001 USDOE Avg USA	2001				2002				2003			
		Avg	Range			Avg	Range			Avg	Range		
Conditioned Floor Area													
square feet (sf)	**1975**	2417	975	to	4200	2306	975	to	4000	2341	725	to	4800
sf per person	**760**	903	244	to	2000	910	244	to	2000	920	137	to	2500
Occupancy													
# persons	**2.6**	3.0	2	to	7	2.8	2	to	5	3.0	1	to	7
Energy Cost													
total $		$1,425	$566	to	$3,612	$1,319	$537	to	$3,162	$1,433	$593	to	$3,160
kBTU per $		65	42	to	102	73	38	to	122	71	41	to	114
$ per sf		$0.66	$ 0.29	to	$ 1.27	$0.61	$ 0.28	to	$ 1.16	$0.74	$ 0.30	to	$ 3.30
$ per person		$ 525	$ 225	to	$1,204	$ 515	$ 210	to	$1,054	$ 546	$ 173	to	$1,378
Energy Use (conventional energy acquired at homesite)													
Energy Usage Index (EUI): kBTU per sf	**46.7**	44.0	16.7	to	102.6	43.9	15.0	to	84.1	53.6	16.0	to	240.6
Climate-Adjusted EUI: BTU per sf per degree-days (dd)		7.7	2.9	to	18.0	6.9	2.4	to	13.2	8.9	2.7	to	39.9
Personal Energy Usage Index (PEUI): mmBTU per person	**36.0**	34.5	13.2	to	98.9	36.3	13.6	to	74.9	37.9	13.3	to	98.0
Climate-Adjusted PEUI: kBTU per person per dd		6.1	2.3	to	17.3	5.7	2.1	to	11.8	6.3	2.2	to	16.2
CO2 Emissions From Energy													
lbs per kBTU		0.38	0.15	to	0.59	0.36	0.03	to	0.59	0.31	0.14	to	0.59
lbs per sf		15	6	to	38	15	2	to	38	15	6	to	73
lbs per person per day		32	12	to	76	34	3	to	74	31	7	to	96
Purchased Water													
gallons per person per day													

kBTU = 1,000 BTU mmBTU = 1,000,000 BTU dd = heating + cooling degree-days

	2001 USDOE Avg USA	2004				2005				2006			
		Avg	Range			Avg	Range			Avg	Range		
Conditioned Floor Area													
square feet (sf)	**1975**	2413	957	to	4556	2237	975	to	4000	2453	975	to	4000
sf per person	**760**	979	137	to	2812	982	300	to	2250	974	300	to	2000
Occupancy													
# persons	**2.6**	3.1	1	to	7	2.8	1	to	6	3.0	1	to	6
Energy Cost													
total $		$1,497	$804	to	$3,528	$1,666	$839	to	$3,157	$1,682	$697	to	$3,447
kBTU per $		66	40	to	102	55	33	to	68	49	35	to	71
$ per sf		$0.74	$ 0.30	to	$3.69	$0.88	$ 0.40	to	$ 2.30	$0.78	$ 0.37	to	$ 1.84
$ per person		$ 541	$ 201	to	$ 862	$ 789	$ 210	to	$2,245	$ 660	$ 174	to	$1,792
Energy Use (conventional energy acquired at homesite)													
Energy Usage Index (EUI): kBTU per sf	**46.7**	48.6	14.9	to	239.5	48.6	14.0	to	147.5	39.4	15.1	to	92.8
Climate-Adjusted EUI: BTU per sf per degree-days (dd)		8.4	2.6	to	41.4	7.5	2.1	to	22.6	7.2	2.7	to	16.9
Personal Energy Usage Index (PEUI): mmBTU per person	**36.0**	35.4	12.9	to	72.1	42.3	12.2	to	106.9	31.7	7.7	to	83.6
Climate-Adjusted PEUI: kBTU per person per dd		6.1	2.2	to	12.5	6.5	1.9	to	16.4	5.8	1.4	to	15.2
CO2 Emissions From Energy													
lbs per kBTU		0.33	0.17	to	0.59	0.34	0.17	to	0.59	0.34	0.18	to	0.59
lbs per sf		15	5	to	79	15	6	to	34	12	6	to	29
lbs per person per day		29	7	to	49	35	7	to	81	28	5	to	47
Purchased Water													
gallons per person per day						68	3	to	252	54	24	to	99

kBTU = 1,000 BTU mmBTU = 1,000,000 BTU dd = heating + cooling degree-days

Ohio Valley Household Energy Surveys 2001-2012

	2001 USDOE Avg USA	2007 Avg	2007 Range			2008 Avg	2008 Range			2009 Avg	2009 Range		
Conditioned Floor Area													
square feet (sf)	1975	2608	1200	to	5100	2948	1110	to	5376	2630	1110	to	4777
sf per person	760	1035	300	to	2100	1103	508	to	2100	1008	508	to	2000
Occupancy													
# persons	2.6	2.9	1	to	6	3.0	1	to	6	2.9	1	to	5
Energy Cost													
total $		$1,824	$864	to	$2,986	$1,869	$841	to	$3,514	$1,821	$951	to	$3,124
kBTU per $		50	30	to	81	48	30	to	99	47	30	to	122
$ per sf		$0.77	$ 0.43	to	$ 1.61	$0.73	$0.40	to	$ 1.80	$0.74	$0.38	to	$ 1.59
$ per person		$ 710	$ 216	to	$1,217	$ 730	$ 335	to	$1,171	$ 711	$ 338	to	$1,562
Energy Use (conventional energy acquired at homesite)													
Energy Usage Index (EUI): kBTU per sf	46.7	38.8	15.7	to	76.5	35.6	14.8	to	85.4	36.8	15.4	to	89.4
Climate-Adjusted EUI: BTU per sf per degree-days (dd)		6.1	2.5	to	12.0	5.7	2.4	to	13.6	6.3	2.6	to	15.3
Personal Energy Usage Index (PEUI): mmBTU per person	36.0	35.1	10.5	to	67.9	34.2	15.6	to	67.4	34.9	15.7	to	100.5
Climate-Adjusted PEUI: kBTU per person per dd		5.5	1.6	to	10.7	5.4	2.5	to	10.8	6.0	2.4	to	17.3
CO2 Emissions From Energy													
lbs per kBTU		0.33	0.16	to	0.59	0.32	0.16	to	0.59	0.36	0.13	to	0.59
lbs per sf		12	6	to	35	10	5	to	27	12	4	to	23
lbs per person per day		29	7	to	49	28	10	to	46	30	11	to	62
Purchased Water													
gallons per person per day		66	5	to	157	56	32	to	119	49	14	to	141

kBTU = 1,000 BTU mmBTU = 1,000,000 BTU dd = heating + cooling degree-days

	2001 USDOE Avg USA	2010 Avg	2010 Range			2011 Avg	2011 Range			2012 Avg	2012 Range		
Conditioned Floor Area													
square feet (sf)	1975	2648	1230	to	4600	2947	1740	to	4777	3122	1890	to	4948
sf per person	760	1149	442	to	2000	1118	740	to	2000	1293	740	to	2474
Occupancy													
# persons	2.6	2.5	1	to	4	2.8	2	to	4	2.6	2	to	4
Energy Cost													
total $		$1,964	$986	to	$6,625	$1,700	$976	to	$2,555	$1,459	$916	to	$1,999
kBTU per $		46	30	to	105	54	28	to	124	37	29	to	60
$ per sf		$ 0.82	$ 0.40	to	$ 3.38	$ 0.63	$ 0.30	to	$ 1.22	$ 0.49	$ 0.34	to	$ 0.84
$ per person		$ 883	$ 274	to	$3,312	$ 675	$ 273	to	$1,100	$ 614	$ 372	to	$ 999
Energy Use (conventional energy acquired at homesite)													
Energy Usage Index (EUI): kBTU per sf	46.7	38.8	16.4	to	193.7	33.8	15.4	to	84.6	17.9	13.1	to	25.6
Climate-Adjusted EUI: BTU per sf per degree-days (dd)		5.8	2.5	to	29.1	5.6	2.6	to	14.3	3.1	2.3	to	4.5
Personal Energy Usage Index (PEUI): mmBTU per person	36.0	41.1	10.7	to	189.7	35.0	16.1	to	76.1	22.1	11.1	to	33.0
Climate-Adjusted PEUI: kBTU per person per dd		6.2	1.6	to	28.5	5.8	2.7	to	12.8	3.9	2.0	to	5.8
CO2 Emissions From Energy													
lbs per kBTU		0.39	0.14	to	0.59	0.34	0.15	to	0.59	0.48	0.17	to	0.59
lbs per sf		13	6	to	49	10	4	to	22	8	3	to	15
lbs per person per day		36	14	to	131	29	13	to	54	28	11	to	52
Purchased Water													
gallons per person per day		55	3	to	159	50	30	to	86	51	16	to	107

kBTU = 1,000 BTU mmBTU = 1,000,000 BTU dd = heating + cooling degree-days

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John F Robbins is a home designer, professional energy instructor and energy consultant since mid-1980s, working for home and small business owners mostly in Ohio, Indiana and Kentucky to achieve low energy usage, low utility bills and reduced environmental impacts. One of his specialties is designing superinsulated passive solar homes which sometimes also have solar water heating and solar electricity. Robbins also consults on off-grid electricity projects like the PV and batteries electric system powering his own office since November 2001.

Robbins is residential chair for the Association of Energy Engineers (AEE) SW Ohio Chapter. A current member of AEE, John has 2 certifications from AEE, certified energy manager (CEM) since 1990 and certified sustainable development professional (CSDP) since 2007. He has received 6 awards and citations from AEE since 1990 for energy or environmental projects and achievements, including SW Ohio Energy Engineer of the Year in 1994, SW Ohio Environmental Engineer of the Year in 2004 and AEE Region III Renewable Energy Innovator of the Year in 2012.

John was co-recipient of the 1998 Ohio Governor's Award for Excellence in Energy Efficiency in the Education Category. He has written articles on energy which were published in HOMEPOWER and SOLAR TODAY magazines. He develops and teaches technical energy courses in Ohio and Kentucky, providing contractors with CEUs, professional engineers with PDHs and many certified energy professionals with contact hours needed to maintain licenses and certifications.

A renewable energy advocate and user who led SW Ohio Alternate Energy Association from 1995-2005, Robbins is maybe most well known for helping energy consumers to be much more aggressive in how they track, manage and minimize their heating, cooling and non-HVAC energy usage. In his designs and consulting as well as professional and consumer education on a variety of topics from home and office energy to solar and HVAC, John consistently presents and describes reduced conventional energy use as equal to new renewable energy supplies.

Robbins practices what he teaches, designs and specifies. Besides operating an off-grid solar-powered office since 2001 and averaging 40+ mpg with each of his business vehicles since 1992, his home in northern Kentucky has been substantially remodelled for lower energy use, including retrofitted insulation, airtightness, HVAC, efficient appliances and lighting, solar water heating, daylighting and a passive solar addition. His last 2 homes have been on several public tours, including American Solar Energy Society's "National Tour of Solar Homes". Many of John’s customers’ homes have also been featured on such tours.