

Perceived Value of Energy Efficiency Investments in Residential Construction

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This paper presents a ranking of energy efficiency investments for residential construction based on the knowledge of residential builders and preferences of homeowners. Altogether, the systems and appliances in our homes consume a substantial amount of energy to create a comfortable and controlled indoor environment. This research investigated the viewpoint of homeowners and residential builders regarding the value of energy efficiency investments in homes. Data was collected via online surveys and telephonic interviews of residential builders and homeowners in North Texas. The top ranked collective measures for improving energy efficiency were found to be: increasing the quality and amount of ceiling and walls insulation, installing high efficiency windows, sealing the building envelope; installing Energy Star© appliances, and use of energy efficient lighting.

Keywords: Energy efficiency, Energy conservation, Residential construction, High performance homes, Mixed-methods research

Introduction and Background

A great challenge facing modern civilization is high rate of population growth, increasing energy needs, and strong reliance on finite carbon-based fuel sources (Tverberg, 2013). Over the last 50 years, per capita energy use has increased worldwide as electrical service areas have expanded and technological devices have become widely available and affordable. Today, most Americans say that they cannot live without many things that were previously viewed as luxury items, such as computers, microwave ovens, dishwashers, and air conditioners (Taylor et al., 2006), which when combined, have resulted in increased demand of energy per household.

Residential structures, their systems, and appliances represent a great opportunity for energy consumption reduction, with the potential for individual homeowners to achieve considerable energy cost savings in the long term. Residential buildings consume 22% of the United States total energy (Kolahdoozan and Leite, 2012). Manufacturers, builders, and homeowners control production, construction, and operation of these structures and their appliances (Stern, 1992). Energy efficiency is achieved by using the least amount of energy to maintain the condition, utilities, and appliances users expect in a comfortable home. While opportunities exist in the residential segment to reduce energy consumption, the challenge is how to realize this potential through widespread adoption of more efficient technologies, especially considering that homeowners face a trade-off between high initial capital costs and future energy cost savings (Wada et al., 2012).

According to the US Energy Information Administration, residential energy consumption is projected to increase over the next 25 years (EIA, 2015). Over the course of the last 50 years, there have been significant changes in the end uses of residential energy consumption. Space heating and cooling previously accounted for more than half of all residential energy consumption. However, with the availability of highly efficient heating and air conditioning equipment, windows, insulation, and programmable temperature control devices, the energy use for space heating and cooling has declined. However, it continues to remains a large percentage of the total residential energy bill (See Figure 1). There has been significant research into many aspects of residential energy efficiency measures from social science influences to complex engineering solutions. Successful reduction in energy consumption requires a comprehensive approach and an understanding of the relationships between the building structure, systems, and appliances, as well as the values, preferences, and behaviors of occupants.

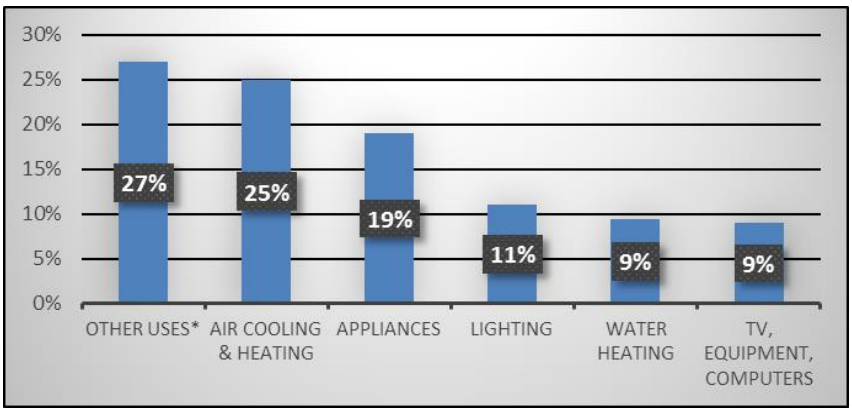

Figure 1: Distribution of average American residential energy consumption (adapted from EIA, 2015)
**Other Uses: Includes small electric devices, heating elements, and motors (i.e. pool pumps, vacuum cleaners) not included in other categories.*

Evaluation, Measurement, and Verification of Energy Efficiency Measures in Texas

The state of Texas is the sixth largest consumer of energy per capita when compared to other states' usage rates (EIA, 2013). In an annual ranking of energy efficiency policies and programs among the United States, Texas has been slipping faster than any other state (dropped 11 places from 23rd to 34th from 2009 to 2014) (Galbraith, 2010; EIA, 2013). However, in 2015, Texas moved up eight places and now ranks 26th (Malewitz, 2015). Statewide adoption of the energy codes for residential and commercial buildings is a huge improvement that will result in reductions in energy waste and cost over the lifetime of the building (estimated to reduce 1 million megawatt-hours per year in energy consumption by 2030) (Malewitz, 2015). In addition, the Texas State Legislature enacted *SB 1125*, which required the Public Utility Commission of Texas to develop an evaluation, measurement, and verification framework (EUMMOT, 2015). Implementation of SB 1125 has resulted in creation of a third party team, which developed a program tracking system to review utility programs, customer and market surveys, and on-site measurement and verification for samples of projects. Their energy efficiency program evaluations have a 90% precision rate for evaluated savings estimates and assumptions. The program offers financial incentives for purchase and installation of specific energy efficiency measures in order to reduce system peak demand, energy consumption, and energy costs.

In Texas, it is especially important to reduce residential summer time peak energy demand. The program encourages participation in the Energy Star® New Homes Construction program, which requires new homes to be constructed 15 percent more energy efficient than the locally adopted International Energy Conservation Code (Frontier Associates, 2014). To achieve this, the Public Utility Commission of Texas program provides training for residential home builders and subcontractors (EUMMOT, 2015). Estimates of savings are based on investments in energy efficiency measures compared to an established baseline for each category. Implementation of the program has resulted in greater savings (243% achievement over the goal) in energy consumption than was expected. In 2013, the program produced 548 gigawatt hours (GWh) of energy savings and 414 megawatts (MW) of peak demand reduction (Frontier Associates, 2014). The energy efficiency measures implemented in 2013 will result in a total of 56 megawatt hours of savings throughout the estimated lifecycle of the particular investments.

Research Aim, Key Questions, and Scope

The aim of this research is to explore current energy efficiency technologies and systems within the home construction industry, study their relative benefits and risks, and the perceptions of homeowners and builders on the perceived value of different implemented measures. The answers of following key research questions are explored through this research: (1) What energy efficiency improvement efforts offer the greatest return on investment?; (2) What are homeowners perceptions of value related to various residential energy efficiency measures?; (3) Are the perceptions of residential builders regarding various residential energy efficiency measures in alignment with homeowners?; and (4) Are builders constructing homes with energy efficiency features that are highly valued by homeowners? The research scope is limited to residential construction in North Texas. Energy efficiency measures are identified by category of performance or function and the unit of cost measurement is based on cost per square foot or average cost for items like cost of appliances.

Research Design and Methodology

This research study employed a mixed-methods approach and used online surveys of both homeowners and builders as well as personal interviews with the residential builders. The collected data provided insights about builders and homeowners' divergent perceptions of value and their likelihood to construct with selected energy efficiency improvement measures. The online survey asked participants to rate their perception of value for different energy efficiency measures as follows (see Table 1).

Table 1

Survey rating criteria for homeowners and builders.

Ranking Options	Value for Homeowners	Value for Home Builders
Low	I would never do this at my house	I would never recommend building a home with these features
Moderate	I would like to do this at my house	I often recommend this feature to homeowners
High	I have already done it at my house, or I have plans to do it	I always build homes with this feature

Note: The rating points of all the survey participants were averaged based on the different weights of the ratings (low = 1, moderate = 2, high = 3, I don't know = 0, and Not Applicable = 0).

Results and Discussion

Homeowners' Perspective

The homeowners' survey was created online and links were sent to recent homeowners through various listservs and social media groups. Seventy-seven (77) homeowners completed the online survey from Oct 7-21, 2015. The homeowners' survey results (shown in Table 2) indicated preference for items that they understand well and would highly recommend in all homes. The highest rated energy efficiency measures selected by homeowners were: (1) CFL/LED light bulbs; (2) Energy star appliances; (3) High ceiling insulation; (4) Central air conditioner; and (5) Energy Star windows. Homeowners indicated the least value for the following measures: (1) Replace window air conditioner; (2) Ground source heat pump; (3) Heat-pump water heater; (4) Floor insulation; and (5) Solar water heater. Respondents to the home owner survey frequently selected the "I don't know" option because they were not knowledgeable about certain items (though a glossary of terms was provided to them). Homeowners demonstrated the least knowledge about the following energy efficiency measures: (1) Install ground source heat pump; (2) Install heat pump water heater; (3) Install central heat pump; (4) Reduce air infiltration; and (5) Install faucet aerators.

Home Builders' Perspective

The home builders' survey link was sent to all resisted residential builders in North Texas. Twenty-seven (27) home builders completed the online survey from Oct 7-21, 2015. In the survey, builders identified major building components as the key factors for reducing energy consumption. Builders demonstrated their awareness that air conditioning is highest energy cost item in the residential home and that measures to reduce loss of conditioned air will produce the greatest savings. They also understand the interrelationships between the different building components and were well aware that implementing one measure without addressing all of the related measures will not produce any significant savings. The highest rated measures by residential builders were: (1) Central Air Conditioner; (2) Seal building envelope; (3) Install Energy Star Windows; (4) Increase ceiling and walls insulation; (5) Energy-star appliances; and (6) CFL/LED bulbs. Residential builders showed the least value for the following measures: (1) Ground source

heat pump; (2) Solar water heater; (3) Replace window air conditioner; (4) Solar screens; and (5) Heat pump water heater. The residential home builders selected "I don't know" for few measures in the survey.

Table 2

Ranking of home owner perceptions of value for energy efficiency measures.

No.	Energy Efficiency Measures	Low Value (%)	Moderate Value (%)	High Value (%)	I Don't Know (%)	N.A. (%)	Mean Rating
1	Install CFL/LED Light Bulbs	3%	27%	69%	1%	0%	2.64
2	Install Energy Star Refrigerator	6%	21%	70%	1%	1%	2.58
3	Install Energy Star Clothes Washer	5%	25%	68%	3%	0%	2.57
4	Increase Ceiling Insulation	1%	43%	55%	0%	1%	2.51
5	Install Energy Star Dish Washer	5%	21%	68%	3%	4%	2.49
6	Install Central Air Conditioner	3%	5%	73%	0%	19%	2.31
7	Install Energy Star Ceiling Fans	10%	32%	52%	3%	3%	2.31
8	Install Energy Star Windows	6%	38%	49%	3%	4%	2.30
9	Increase Wall Insulation	16%	35%	38%	5%	6%	1.99
10	Install Low-Flow Showerhead	32%	21%	42%	5%	0%	1.99
11	Reduce Air Infiltration	5%	43%	35%	14%	3%	1.96
12	Install Water Heater Tank Insulation	23%	34%	35%	5%	3%	1.96
13	Install Faucet Aerators	21%	25%	38%	14%	3%	1.83
14	Install Solar Screens	27%	45%	21%	5%	1%	1.81
15	Install Hot Water Pipe Insulation	21%	34%	30%	9%	6%	1.78
16	Install High Efficiency Ducts	12%	36%	29%	13%	10%	1.70
17	Install Tankless Water Heater	36%	30%	23%	6%	4%	1.66
18	Install Central Heat Pump	23%	12%	36%	18%	10%	1.56
19	Install Solar Water Heater	48%	29%	8%	12%	4%	1.29
20	Increase Floor Insulation	35%	23%	14%	10%	17%	1.25
21	Install Heat Pump Water Heater	47%	14%	8%	22%	9%	0.99
22	Install Ground Source Heat Pump	42%	16%	4%	32%	6%	0.84
23	Replace Window Air Conditioner	10%	1%	18%	4%	66%	0.68

Table 3

Ranking of home builders perceptions of value for energy efficiency measures.

No.	Energy Efficiency Measures	Low Value (%)	Moderate Value (%)	High Value (%)	I Don't Know (%)	N.A. (%)	Mean Rating
1	Install Central Air Conditioner	0%	4%	96%	0%	0%	2.96
2	Reduce Air Infiltration	0%	4%	96%	0%	0%	2.96
3	Install Energy Star Windows	0%	4%	96%	0%	19%	2.96
4	Increase Wall Insulation	4%	4%	96%	0%	12%	2.88
5	Increase Ceiling Insulation	0%	4%	88%	0%	8%	2.73
6	Install Energy Star Dish Washer	4%	27%	69%	4%	0%	2.58
7	Install CFL/LED Light Bulbs	0%	46%	54%	0%	0%	2.54
8	Install Hot Water Pipe Insulation	8%	19%	73%	4%	12%	2.54
9	Install Energy Star Ceiling Fans	12%	31%	62%	0%	0%	2.54
10	Install Central Heat Pump	8%	15%	73%	0%	8%	2.46
11	Install Faucet Aerators	15%	15%	65%	8%	0%	2.38
12	Install High Efficiency Ducts	8%	50%	46%	0%	0%	2.35
13	Install Energy Star Refrigerator	8%	23%	62%	4%	8%	2.31
14	Install Low-Flow Showerhead	27%	31%	46%	0%	0%	2.23
15	Install Tankless Water Heater	27%	35%	42%	0%	12%	2.12
16	Increase Floor Insulation	19%	31%	42%	0%	0%	1.96
17	Install Water Heater Tank Insulation	23%	23%	42%	4%	0%	1.96
18	Install Energy Star Clothes Washer	12%	15%	50%	8%	19%	1.92
19	Install Heat Pump Water Heater	38%	27%	27%	0%	12%	1.62
20	Install Solar Screens	38%	31%	12%	4%	0%	1.31
21	Replace Window Air Conditioner	77%	0%	15%	0%	12%	1.19
22	Install Solar Water Heater	58%	23%	8%	4%	7%	1.15
23	Install Ground Source Heat Pump	54%	12%	12%	8%	19%	1.08

Telephonic interviews were conducted with eight residential home builders. The interviews included prescribed questions, but also included some follow-on questions for collection of additional information and clarifications. Interviews were requested from homebuilders in the North Texas area. The first question asked, "Are builders more likely to install certain energy efficiency measures in new homes, and if so, which measures would be selected and why?" The most frequent responses from builders included the follow measures: (1) More insulation; (2) High efficiency windows, and (3) High efficiency HVAC. Builders also described that blown-in and foam spray insulation are two common energy efficiency measures for residential construction. Several interviewees said that they believe that Energy Star home certification is a good method for selecting energy efficiency measures. Other measures mentioned by builders included: foam board insulation, low flow fixtures, radiant barrier roof decking, and attic ventilation. Figure 2 shows a summary of interviewed home builder's perceptions of the most common energy efficiency measures.

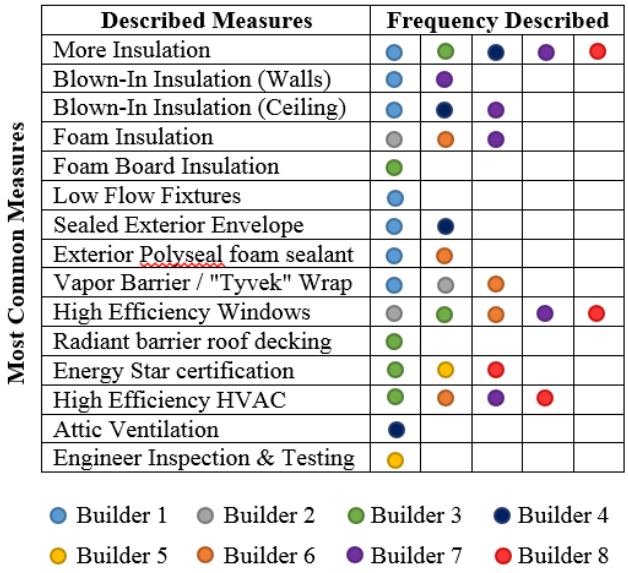

Figure 2: Home builder's perception of the most common energy efficiency measures.

The second question of the interviews asked, "What are the criteria that builders would recommend for building energy efficient homes?" The builders responded with a variety of factors, but the most commonly described factor was the simple payback in utility savings for the home owner. The other primary responses included the cost for both builders and owners. The third question asked, "What energy efficiency measures do homeowners prefer?" Interviewed builders most frequently stated that they believe that owners are seeking lower utility bills, which they feel can be accomplished with quality insulation and high efficiency air conditioning. They said that homeowners do not understand how to achieve an energy efficient residential building. The last question inquired, "What energy efficiency measures are most effective (or provide the greatest return on investment)?" The majority of the answers to this question aligned with the discussion for the prior questions. The most dominant measures described by builders as being highly effective were quality insulation, high efficiency windows, and a sealed building envelope. Every builder included quality insulation as an effective measure for increasing energy efficiency. More than half of the builders said that foam insulation was the most effective insulation; however it requires investment in a high quality and balanced HVAC system.

Comparison of Home Owner and Builder Perspectives

Figure 3 shows a comparison between the results of the two surveys highlighting the key differences. The weighted average values are used for comparison.

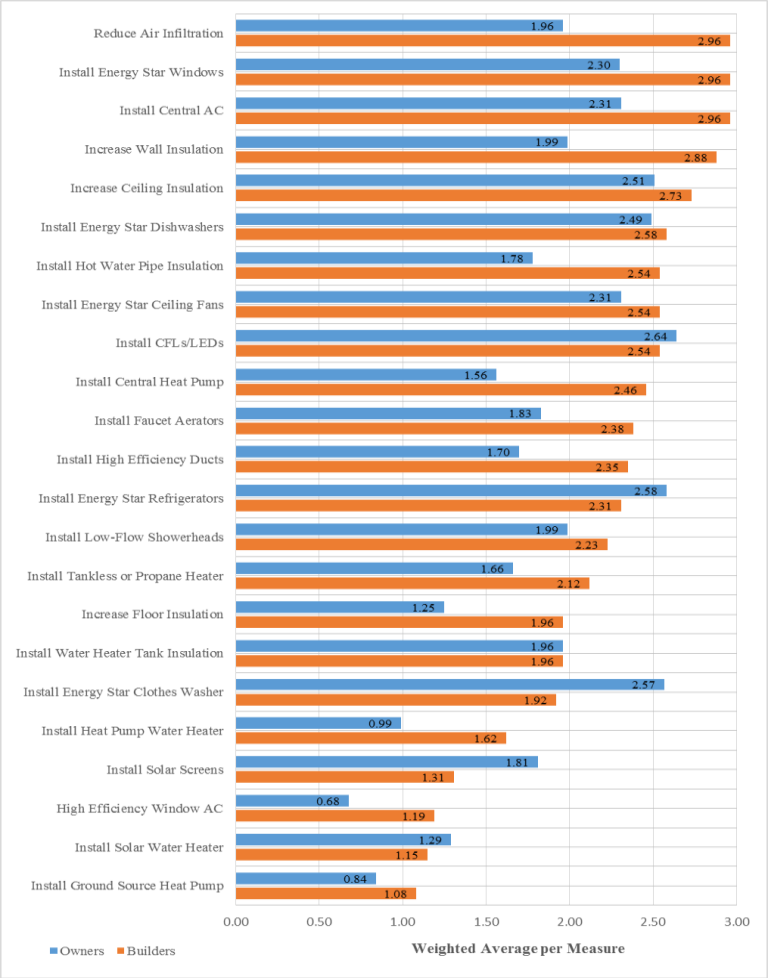

Figure 3: Comparison of calculated perceived values per energy efficiency measure.

The home and builders indicated an almost equal value for the following measures; (1) Increase hot water tank insulation; (2) Install energy star appliances; (3) Install CFLs/LED bulbs; and (4) Use of central air conditioner. The greatest difference in opinion is about reducing air infiltration, followed closely by installation of a central heat pump and increasing wall insulation.

Discussion

Homeowners have the greatest sense of value for items that they interact with on a regular basis, like appliances and lighting. Two of their highest valued measures were found to have the longest payback and lowest return on investment (i.e. Energy Star© Dishwasher and Clothes Washer). However, they do recognize the value of creating a thermal barrier between their conditioned and unconditioned areas (attic); which was included as a high value activity in all research results. The Texas climate creates extremes in outdoor temperatures, and the owners and builders who participated in the study appreciate need to condition indoor spaces and also acknowledge the high cost of creating conditioned air by noting the value of quality insulation. Owners showed only moderate value for reducing air leakage. Perhaps homeowners believe that insulation can eliminate drafts and conditioned air leakage, and therefore rated ceiling

insulation as a higher value. The residential builder's survey and interview results center on their need to produce a comfortable environment inside the home for the owner and occupants. They achieve the desired sense of comfort with the installation of a highly efficient HVAC system and a controlled building envelope to maintain the quality of conditioned air. A high efficiency HVAC system was calculated to provide a simple payback in about 10 years. Quality insulation shows simple payback within one to five years. Advanced technology and high efficiency HVAC systems are more costly than traditional systems, which increases the payback period. Builders seek to provide the greatest comfort for the owner, which they believe is largely accomplished with a fully sealed envelope and balanced, highly efficient HVAC system. During the interviews, builders stated that some homeowners would accept a lesser energy efficient home in exchange for high end appliances and cosmetic finishes like expensive granite countertops. Builders know that people will feel uncomfortable in drafty or humid homes, and regardless of other factors, they will feel dissatisfied with a home that allows uncontrolled air exchange, high utility costs, and/or unpleasant indoor air quality.

The calculations of return on investment (not shown in this paper) support the perspective of the home builders for quality insulation and Energy Star© windows (See Figure 4). Homeowners showed a high sense of value for CFL and LED light bulbs, and the calculated ROI supports the idea that this is a measure that produces cost savings for the home owner. Installation of high quality insulation is the only measure that is included across all perspectives.

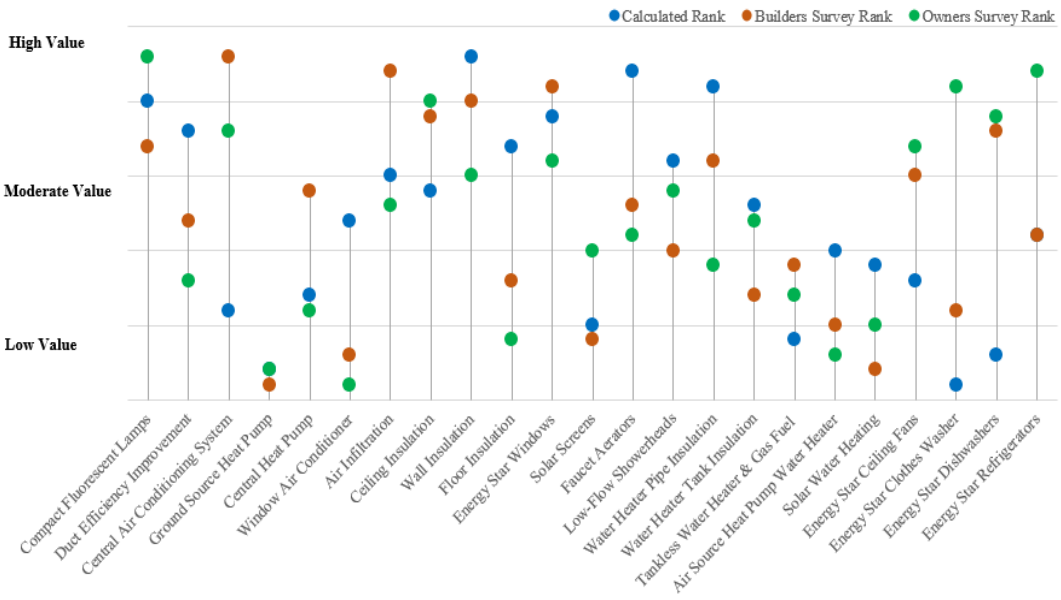

Figure 4: Comparison of ranking results by energy efficiency measures.

Conclusions and Recommendations

This paper presented a ranking of energy efficiency investments for North Texas homeowners that equally considered the knowledge of residential builders, preferences of homeowners, and return on investment and simple payback for the owner. Collectively, the top ranked measures for improving residential energy

efficiency were: replacement of incandescent bulbs with CFL or LED light bulbs, increasing the quality and amount of insulation in walls and ceilings, installing high efficiency windows, and sealing the building envelope to minimize uncontrolled movement of air between the conditioned and outdoor environments. This research considered the return on investment associated with installation of residential energy efficiency measures (the calculations are not in this paper due to space limitations). The perceptions of homeowners and builders were sought through surveys and interviews, in order to quantify the similarities and differences of opinion regarding the value energy efficiency measures. Homeowners showed the greatest value for items that they interact with on a regular basis, including appliances and lighting. They recognize the value of creating a thermal barrier between conditioned and unconditioned areas (attic). The residential builder's survey and interview results focused on installation of highly efficient HVAC systems and creation of a sealed and insulated building. The study considered the inclination of construction professionals and homeowners to install particular energy efficiency methods or appliances based on their perception of value. This study evaluated measures included in the Electric Utility Marketing Managers of Texas Evaluation, Measurement & Verification Technical Reference Manual v2.1 for 2015. As a result, several factors were not included that emerged in through review of literature and builder interviews. The additional measures that could be studied and included in the ranking include: (1) Cool roof and exterior materials, (2) Landscaping and shading from trees, (3) Smart energy monitoring and automated controls systems, (4) Home orientation and passive design features, and (5) Onsite energy generation (solar panels and wind turbines).

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