BARRIERS AND IMPEDIMENTS TO A HOLISTIC APPROACH TO PROMOTING SUPER-ENERGY-EFFICIENT (SEE) HOMES

Qian Chen,[1] Gary Kinzel,[2] Allen Zimmerman,[3] Scott Potter,[4] and Michael Lichtensteiger[5]

ABSTRACT

Reducing energy consumption and environmental impacts of homes remains a critical task for researchers and practitioners. Although numerous energy efficient (EE) home strategies have been developed, their adoption across the entire industry has still been limited. Nationwide, only a small number of EE homes have been built under several well-known EE home programs. Therefore, the research question of, "what prevents EE homes from being widely accepted and built?" needs to be addressed and investigated thoroughly. This paper presents the findings—a comprehensive set of barriers and impediments to the wide spread adoption of EE homes—from an on-going effort made by an alliance of researchers, educators, builders, suppliers, appraisers, real estate agents, and other parties associated with the home construction industry. These findings are being used to develop and implement a holistic action plan to advance the cause of EE homes through research, education, and outreach. The provided insights will also help other researchers, educators, practitioners and government agencies re-evaluate the strategies used in promoting EE homes and improve the effectiveness of on-going and future programs.

KEYWORDS

energy efficiency, energy conservation, home, residential building, systems integration, strategies, barriers, impediments

INTRODUCTION

Being a vital part of the building sector, U.S. homes alone account for about 22% of national energy use and 21% of carbon dioxide emissions (Energy Information Administration [EIA] 2009a). Also, a 0.7% annual growth in residential delivered energy consumption through 2030 was predicted in EIA's Annual Energy Outlook 2008 (EIA 2008). In recent years, homeowners have experienced increasing energy costs. The EIA's Monthly Energy Review showed that the retail price of electricity in the residential sector increased by a factor of 1.4 for the period 2000 – 2008 (from 8.24 cents/kWh to 11.36 cents/kWh in nominal dollars). During the same period, the price of natural gas delivered to residential consumers increased by a factor of 1.8 (from $7.76 per thousand cubic feet to $13.68 per thousand cubic feet) (EIA 2009b). Although energy costs in some categories, e.g., natural gas, have dropped recently due to the economic crisis, big increases in electricity retail prices to cover increasing fuel costs, infrastructure investments and environmental fees were reported across the country (Brier 2006; Davidson 2008; Winters 2008). Therefore, minimizing energy consumption in homes is very important in terms of both environmental impacts and energy costs.

Energy-efficient (EE) homes are not a novelty in the U.S. A number of EE building strategies and technologies have been known for several decades. Significant efforts to promote EE homes have occurred periodically in the home construction industry during so called energy crises. However, neither the principles nor practices associated with EE homes have been widely acknowledged and accepted by industry and the public as standard practices and must-have features. According to the 2007 annual report of the ENERGY STAR program (EPA 2008), only 12% of new homes built nationwide have earned the government's ENERGY STAR for superior energy efficiency. Only a very small portion (840,000 units) of the more than 120 million existing U.S. homes, are considered

[1]Assistant Professor, Department of Food, Agricultural, and Biological Engineering, The Ohio State University, chen.1399@osu.edu.
[2]Professor, Department of Mechanical Engineering, The Ohio State University, Kinzel.1@osu.edu.
[3]Professor, Agricultural Technical Institute, The Ohio State University, Zimmerman.7@osu.edu.
[4]Senior Energy Advisor, Institute for Energy and the Environment, The Ohio State University, potter.138@osu.edu.
[5]Lecturer, Department of Food, Agricultural, and Biological Engineering, The Ohio State University, lichtensteiger.2@osu.edu.

energy efficient (EPA 2008; U.S. Census Bureau 2008). There is a critical need to identify and understand the barriers and impediments that prevent EE homes from being widely accepted and built.

This paper presents findings from an on-going effort on the part of researchers at The Ohio State University (Ohio State) who are collaborating with a wide variety of stakeholders in the housing industries, including home builders, component manufacturers, utility providers, real estate agents, mortgage companies, trade groups, and government agencies. This collaboration differs from other research-focused or practice-oriented approaches in that its major goals are 1) to identify and investigate the barriers and impediments that prevent the widespread adoption of EE home principles and practices, and 2) to develop a viable action plan to overcome those barriers and impediments and make affordable super-energy-efficient (SEE) homes (50% or more energy efficient than required by the 2009 International Energy Conservation Code [IECC]) the best choice for builders and homeowners. Specifically, this paper presents a comprehensive assessment of the barriers and impediments to the adoption of EE homes that were identified during several workshops. The provided insights will help researchers, educators, practitioners, and government agencies re-evaluate the strategies used in promoting EE homes and improve the effectiveness of current and future programs.

ENERGY EFFICIENT HOME PRINCIPLES AND PRACTICES

During the past 30 years, the basic principles and practices for building SEE homes have been indentified and developed. These include advanced construction techniques (e.g., well insulated and tight building envelopes), better quality components (e.g., high-performance windows), and improvements in design features (e.g., optimizing passive solar gain in respect to both heating and cooling climates). Researchers and practitioners have evaluated and quantified the resulting energy savings. For example, a study of 70 passive solar homes documented an average reduction of auxiliary space heating of 70% (Solar Energy Research Institute 1984). The Energy Source Builder (1994) reported that homes using structural foam core panels were 40% more energy efficient than stick-built houses. According to Lee et al. (1994), by limiting solar gains, which contribute 24–31% of the electricity consumption, high-performance windows could greatly reduce energy use and peak demand in residences in cooling-dominated climates. Yost and Lstiburek (2002) found that applying R-5 insulation to the upper half or full height of a basement wall could reduce basement heat loss by 50 and 70%, respectively.

Although the above-mentioned EE technologies could achieve considerable energy savings, it has been well documented that the concept that is essential to achieving the desired level of energy efficiency in homes on a consistent basis is systems integration—treating the whole house as a single system—in the design, construction, testing phases, and follow-up measurement and performance assessments (Dorgan 1977; Nisson and Dutt 1985; Owens Corning 1996; Mayo and Sinha 1997; Florides et al. 2002; PATH 2002; DOE 2004). The term "superinsulated" was coined by some early researchers and practitioners to denote homes that integrate a well-insulated and sealed thermal envelope with controlled ventilation and passive solar features (Nisson and Dutt 1985). As reported by Shurcliff (1986), superinsulated homes can reduce fuel consumption by 75–95% relative to conventional houses with only 0–10% increase in construction costs. Formal programs that followed include "Building America" and "ENERGY STAR" sponsored by government agencies and "Owen Corning's System Thinking" from the private sector (Owens Corning 1996). The U.S. Department of Housing and Urban Development (HUD) also launched the Partnership for Advancing Technology in Housing (PATH) program to support research in whole-house design and construction, focusing on synergies and positive interactions in home design and construction (PATH 2002).

In spite of the long history of, and numerous programs devoted to EE homes, their adoption remains very limited. Large numbers of homebuilders, appraisers, and mortgage financiers are not aware of the value of EE homes. Many homebuilders are not knowledgeable about EE construction principles and techniques. Stick building using traditional framing materials and methods dating to the early 1900's is still the prevailing homebuilding method. As one example, panelized systems represented only 0.2% of new housing in 1999 (PATH 2002). This situation persists even though the International Residential Code (IRC) is constantly being updated to include new materials and methods based on innovations in building science. For example, provisions for unvented attic and roof assemblies have recently been added to the IRC (Zimmerman 2009a).

REPRESENTATIVE ENERGY-EFFICIENT HOME PROGRAMS

Several programs funded by government agencies have had positive impacts on the development of EE homes. Building America is an industry-driven research program sponsored by the U.S. Department of Energy (DOE) with the goal of improving the quality, function, and energy efficiency of homes. This program adopts a systems engineering approach to model homes holistically and seeks to unite scattered segments of the building industry. As an example, structural insulated panels (SIPs) and other innovative wall systems are integrated with EE windows, optimally sized mechanical systems, and ductwork improvements. Since 1995, approximately 41,600 EE homes have been built under this program (DOE 2009a).

ENERGY STAR is a joint program of the U.S. Environmental Protection Agency (EPA) and DOE to help consumers save money and protect the environment via EE products and practices. The program's goals include 1) cutting

the environmental impact and energy use of new housing by 50% or more when compared to market houses built on average minimum energy codes and 2) reducing energy use in at least 15 million existing homes by 30% or more. Since its inception in 1992, the program has had considerable success in increasing the use of EE products and practices and building a broad partnership among various industry sectors. However, as mentioned earlier, homes built to the ENERGY STAR standard account for only a very small portion of the U.S. housing stock. In addition, most ENERGY STAR homes built were only 15% more energy efficient (EPA 2007).

DOE has recently supported the concept of "net-zero energy" homes which combine energy efficient building systems and appliances with renewable energy sources, such as wind turbines and solar panels, to achieve net zero energy consumption. Research conducted at the Florida Solar Energy Center involving its "Very Low Energy Home" found that a 92% decrease in energy from offsite sources could be achieved when compared to a conventional home with an identical floor plan and constructed by the same builder. EE construction techniques and the photovoltaic (PV) system were credited with 69% and 23% of the reduction, respectively (Parker 2009). There were significant additional initial costs for building near net-zero energy homes. These costs were associated with the added efficiency improvements ($3,400 to $26,000), PV ($40,000), and solar water heating ($7,000) (Anonymous 2002; Norton et al. 2005; Norton and Christiansen 2006). In part because of the additional costs, only a limited number of net-zero energy prototype houses have been built nationwide (Anonymous 2002; Norton et al. 2005; Norton and Christiansen 2006; Alter 2007; Kamin 2009).

CUSTOMER AWARENESS AND ADOPTION OF EE HOME PRODUCTS AND SERVICES

There is a rich literature on the customers' willingness and behaviors to buy green, eco-friendly merchandise (Prothero 1990; Wasik 1992; Rice et al. 1996; Kirchhoff 2000; Cason and Gangadharan 2001; Tsen et al. 2006). It was found that average consumers would be willing to pay more for environmentally safe products (Prothero 1990; Wasik 1992; Cason and Gangadharan 2001). A growing body of similar research has been reported in the course of promoting EE homes. The main research focus is to understand the gap between home buyers' awareness and adoption and identify "tipping points" to get consumers to invest in EE home products and services.

In order to promote EE homes, especially those with Northwest ENERGY STAR labels, the Northwest Energy Efficiency Alliance (NEEA) ordered qualitative research to be performed among recent and potential home buyers. The purpose was to study their perceptions, attitudes and acceptance of EE homes (NEEA 2009). In this study, 48 participating consumers formed six focus groups to provide feedback. Most important research findings include:

- Energy-efficiency and environmental consideration were seldom at the forefront of participants' minds in selecting a new home. However, when reminded of energy efficiency, they were more likely to consider investing money on common EE features related to windows, insulation, and heating and cooling systems.
- Customers' most wanted EE benefits were saving money on utility bills, increased resale value, and year-round comfort.
- Awareness of existing brands/labels of green or EE home programs was very low and there were misinterpretations about "green" and a lack of understanding of the Energy Performance Score.

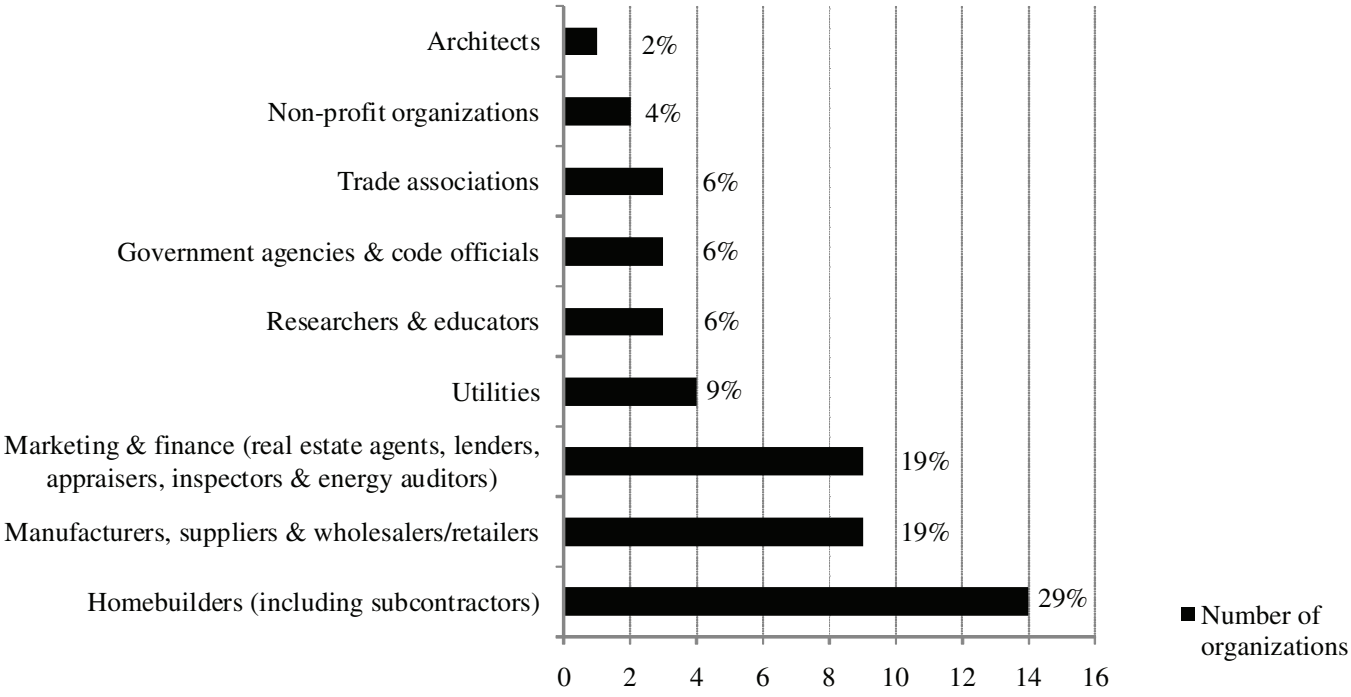
In addition, the Home Energy Efficiency Survey program tailored for Southern California Edison's hard-to-reach customers disclosed that consumers often lacked information and knowledge about, and faced difficulty assessing the value of, EE opportunities. There was a measurable increase in customer awareness and adoption of the recommended EE products after the survey was completed. One contributing factor to this success was providing "no cost" and "low cost" energy-saving recommendations (SCE 2006).

RESEARCH METHODS AND PROCEDURES

The investigation of the history of SEE homes and the ongoing programs to promote them has revealed that due to various causes, there remains very limited market penetration of SEE homes. Based on our analysis of the situation, it is apparent that existing programs, whether research-based or government and/or industry-driven, have not resulted in large numbers of SEE homes being added to the production housing stock industry wide. Therefore, we advocate a more holistic approach which involves partnering with various sectors of the home construction industry to bring about a revolutionary change in energy efficient home construction. This will be accomplished through a coordinated and far reaching program of research, education, training, outreach, and demonstrations with SEE living learning lab homes and retail owner-occupied SEE homes.

To date, a series of three workshops were conducted in 2008 and 2009 to 1) explore the major issues and challenges related to the wide spread adoption of SEE home principles and practices; 2) solicit recommendations and ideas for promoting SEE homes; and 3) establish a collaboration of industry leaders with the goal of significantly increasing the number of SEE homes. Attendees at the workshops represented nearly 50 companies/organizations including academic researchers, homebuilders, suppliers/manufacturers, trade associations, utilities, inspectors/auditors, real estate agents, representatives from state energy agencies, etc. These companies/organizations were recruited based on a brainstormed list of major players in the Ohio housing construction industry. Figure 1 shows the demographic distribution of workshop participants. The diversity of participants serves as the basis

FIGURE 1. Demographic distribution of workshop participants.



for creating and implementing a holistic approach to promoting SEE homes.

The first workshop held at Ohio State was preliminary in nature. Of 25 attendees, most of them were academic researchers, educators and home builders. This group initiated a discussion of the potential barriers and impediments to building SEE homes and also established the necessity of involving other sectors that comprise the home construction industry.

The second workshop consisted of 56 participants from a much broader range of stakeholders who collectively identified and acknowledged key barriers and impediments to SEE homes as well as coping strategies. In order to actively involve workshop attendees and reach a broad consensus, workshop participants were divided into four break-out groups led by non-Ohio State coordinators. Individuals from the same organizations were assigned to different groups. The group discussion and feedback was summarized and major items were sorted by their level of importance. The coordinators then brought five of the most important barriers/impediments and coping strategies identified by their groups to the final discussion session involving all workshop participants. The findings which were repeatedly mentioned and agreeable to most attendees were recorded.

The third workshop included six Ohio State researchers and a select group of 15 industry leaders, most of whom had attended the second workshop. The purpose was to further develop and refine the results of the first two workshops and to solicit comments and buy-in for a holistic approach to increasing the number of SEE homes being built. Workshop participants also identified technical research needs in the SEE home area.

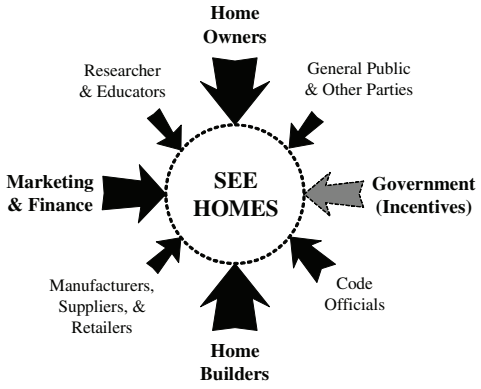
To verify and supplement workshop findings, the second round of literature study was performed. All the results are summarized and presented below.

WORKSHOP RESULTS AND DISCUSSIONS

Above all, the workshop participants stressed the importance of identifying and including the entire spectrum of interests associated with home building. The direct involvement of these stakeholders is essential for the broad success of a revolutionary SEE home building program. Based on the insights gained from the workshops, a diagram (see Figure 2) was developed to illustrate the major parties that should be involved in successful SEE home programs. In this diagram, the weighted power of influence of these stakeholders is represented by the thickness of individual arrows. This conceptual model provides a guide for selecting the players invited to partner for the purpose of developing holistic programs and action plans to address the issue of SEE homes. It is worth mentioning that the incentives from the government become optional at the stage when bankers and other financial institutions realize the value of SEE homes when determining mortgage rates.

Another significant result of the workshops was the identification of barriers and impediments to SEE homes from the perspective of the various players. Summarized findings as well as further reviews and discussions are organized according to each stakeholder group.

FIGURE 2. Parties critical to successful EE home programs.



Homeowners

Homeowners are obviously one of the most important stakeholder groups. However, their involvement in formulating SEE home programs was often overlooked. Although at the current stage, homebuyers were not included in the series of workshops, what buyers thought and behaved were obtained through the feedback from builders, retailers, real estate agents, and other parties who constantly interacted with the homebuyer group. A broad consensus formed in our workshops is that the lack of demand for, or interest in, SEE homes on the part of homeowners is a major impediment to market penetration of SEE homes. If homeowners are fond of EE alternatives, the increased demand alone could lead to a change in market direction. All of the market suppliers including builders, manufacturers, suppliers, etc. will fall in line.

Although at the current stage a thorough and broad survey of homeowners' interest and acceptance in EE technologies as well as the rationale behind their decisions has not been performed, common views among workshop participants were able to be formed. The workshop participants agreed that current energy prices remain relatively low. Therefore, typical homeowners are less interested in investing in EE features than in those features that support their desires and preferred lifestyles, for example, bigger houses, larger windows, and upgraded amenities. However, indications are that homeowners will become increasingly focused on energy costs and feel forced to make EE improvements when their utility, especially electricity, bills increase significantly (going up more than 70% or an average of $129 per month) according to the 2009, fifth annual Energy Pulse survey conducted by Shelton Group (Anonymous 2009).

This scenario might become true in the near future due to a couple of reasons: the increasing energy demand, rising fuel costs, significant increase in infrastructure investment costs, the fear of diminishing fossil fuel supplies, and pressures to reduce fossil fuel greenhouse gas emissions. There is already a national trend in increasing utility costs and raising retail rates (Brier 2006; Davidson 2008). In addition, electricity rates could significantly increase if some of the proposals for monetizing CO_2 emissions are enacted (Davidson 2008; Winters 2008). These upward pressures on utility rates have the potential to significantly enhance homeowners' interest in SEE homes.

The builders stressed that initial cost is typically the major factor in homebuyers' considerations. Today, energy efficiency is often seen almost as a finish option to a new home. Builders and buyers choose between R-value options when selecting insulation, performance ratings when selecting windows, and energy efficiency ratings when selecting individual appliances. In each case, the higher energy-efficiency options carry higher component price tags. Consequently, a home labeled as energy efficient in today's typical market carries forward the incrementally higher prices of each component, resulting in a home with a higher cost to build. This higher cost to build the basic structure and mechanical systems competes with the buyers desires for more apparent amenities and visual upgrades. Therefore, the added costs associated with energy efficiency are a major barrier to promoting SEE homes to buyers.

In addition, even when a homeowner is presented energy efficiency information, there is often a significant amount of uncertainty and variation (e.g., site limitations, choices and mistakes; rent vs. own decisions, politics, etc.) with regard to the projected energy cost savings of a home. Homes do not typically come with an energy efficiency performance guarantee. This uncertainty makes it difficult for a homeowner to make reasonable cost-benefit decisions. Today, a homeowner wanting to build an "EE" home will typically be faced with a significant premium for that desired energy efficiency. While we do not believe the higher added costs are always necessary, the current cost premium does highlight the problems with payback calculations. It was widely perceived that homeowners will make decisions about investments in visual amenities and upgrades often based on the notion that these basic cost items will add to the market resale value of the home. However, investment decisions for EE measures are not so simple. Homeowners lack evidence that added EE features will decrease the true cost or increase the resale value of their homes. Also, mortgages and resale prices do not generally value the EE performance of a home. This is evident in the data cards used by real estate agents to describe the features of a home. These cards rarely contain information on utility costs. Homebuyers, therefore, find it difficult to calculate payback periods and the value of energy efficient investments.

There is a lack of widely accepted, practical tools that can be used to evaluate the energy efficiency of new and existing homes on the market and determine corresponding operational costs of the home. There are 118 energy simulation program tools listed on the DOE Building Technologies Program website (DOE 2008), 31 of which can be used by homeowners and 15 of which are free. Most of these computer programs differ in terms of their modeling approach, level of sophistication, and adequacy. Even if they have the requisite technical expertise and are aware of the programs, it is hard for buyers to determine which programs they should use and it is also hard for them to overcome the steep learning curves. Therefore, although programs such as Degree

Day Forecasts/Reports, Energy Usage Forecasts, and Home Energy Efficient Design (HEED) are readily available, only a limited number of homeowners use them according to the DOE's tracking records on total user count for each of the individual programs (DOE 2008).

There are several home rating systems currently in use, but none of them are well understood or even recognized by average homeowners. In addition, each of these rating systems has its pros and cons. The Home Heating Index (HHI), developed by the Iowa State University Extension Service (Hodges 1984, p. 172), was the first consistent indicator of energy-efficiency that was not encumbered by the problems associated with other indices in use at the time, such as Normalized Annual Consumption, Thermal Integrity Factor, California Point System, etc. (Huebner 1983). However, the HHI is more appropriate for homes in heating climates. The Home Energy Rating System Index (HERS) developed by the Residential Energy Services Network (RESNET) adopts a systematic whole-house energy simulation approach and is used for the ENERGY STAR and some other major labeling and certification programs, e.g., Building America, federal tax credit, etc. Theoretically, the lower the score, the more energy efficient the homes should be. However, there is no guarantee that homes with a better score will actually use less energy than homes that scored worse (Stein 1997).

LEED (Leadership in Energy and Environmental Design) for Homes initiated by U.S. Green Building Council (USGBC) and National Green Building Standard (ANSI) proposed by National Association of Home Builders (NAHB) target more comprehensive, but also more complex, assessments of home performance including energy efficiency, water use, indoor environmental quality, etc. (NAHB 2009; USGBC 2008). Unlike HHI, which can be calculated with the aid of computer programs, obtaining ENERGY STAR, LEED, and Green certifications requires significant costs. For example, non-refundable registration and certification fees in the amount of $375 for USGBC members or $525 for non-members need to be paid to pursue LEED certification for a single-family home. Since completion of on-site inspections is required prior to certification, additional provider and green rater verification costs apply and are determined based on market prices (USGBC 2008). Actually, such added costs may or may not lead to energy efficiency. A study on measured energy usage data from 100 LEED-certified buildings disclosed that 28-35% of LEED buildings actually used more energy than their conventional counterparts (Newsham et al. 2009).

Our workshop participants stated the need for a simple, accurate, inexpensive, and easily-understood home energy rating system analogous to the "MPG" (miles-per-gallon) rating for cars. Candidates for such a system could include the HHI, Home Energy Index (HEI), and/or Home Electrical Energy Index (HEEI), which are simple and straightforward (Zimmerman 2009b).

Homeowners and many homebuilders typically do not understand the basic principles of building science associated with SEE homes and the resulting benefits. This may lead them to a misconception that SEE homes are of poorer quality and will lower living comfort. For example, advanced framing and SIPs are sometimes viewed as flimsy due to the reduction in lumber use, and tight houses are considered unhealthy because of the fear of stagnant air. Homebuyers and builders are both victims and spreaders of myths and criticisms of SEE home building techniques and measures. There is another common misconception that tight houses cannot "breathe." Yet, the reality is that EE or SEE homes, if properly designed and built, are actually more comfortable, durable, and healthy than conventionally constructed homes (DOE 2000). These benefits are not widely known and accepted by homebuyers.

Homebuilders (Including Subcontractors)

Participants at the workshops agreed that in general the home construction industry lacks both the awareness of, and training on, SEE homes. Many energy efficient materials and methods are not widely known and understood by homebuilders and subcontractors even though relevant information has been available for many years. Therefore, most builders and subcontractors continue to use traditional materials and techniques that date from periods in history when energy efficiency was not an important consideration.

As stated previously, SEE homes should be designed and built as a "system." This is difficult to accomplish under the current practice of having numerous subcontractors work independently during construction and equipment installation. Therefore, problems such as poorly installed insulation, random holes in the thermal envelope, and over-sized HVAC systems are very common, but are typically overlooked or accepted in conventional homes. For SEE homes, different and more sophisticated management and oversight are required. Another important problem is that a fragmented approach to making a home more energy efficient can lead to unnecessary added costs. When SEE homes are designed and built as a system, cost increases in some areas can be partly or completely offset by cost reductions in others including HVAC downsizing, less lumber use, etc.

Homebuilders also commented on the lack of economic incentives, market acceptance, and robust energy codes that are available. The financial incentives that are available from federal and/or state sources to builders who adopt energy efficient principles and practices are very limited. Third-party warranty programs that would insure the structural integrity and energy performance of SEE homes do not exist. Energy efficient builders are thus placed at a disadvantage due to increased project costs and the marketing ploys of competitors who build standard homes.

Energy codes requirements are relatively easily met and often not enforced. Currently, there are even some states that have no requirements for home energy conservation or may have an energy code as recommended practice only (OCEAN 2010). Therefore, EE homebuilders operate at a disadvantage

in that competitors can build and market lower cost homes as code approved. Many conventional builders aggressively lobby against using building codes to improve energy efficiency. Their argument is that the added cost of SEE homes will make them uncompetitive with older homes. Therefore, prospective new home buyers will elect to renovate an older home rather than purchase a new energy efficient one.

Manufacturers, Suppliers and Retailers

Manufacturers, suppliers and retailers for EE materials and products play supporting roles in the SEE home movement. Workshop participants noted that market demand determines the willingness and ability of these stakeholders to provide EE materials and products. So lack of demand was their major impediment to manufacturing or supplying EE products. However, manufacturers, suppliers, and retailers, who have experience in producing and selling SEE home materials and products, have the capability to react quickly to any increased demand on the part of their customers (builders, subcontractors, and homeowners) for EE materials and products. These stakeholders also have some existing customer education programs in place and are willing to participate in additional training and educational efforts.

Marketing and Finance: Real Estate Agents, Lenders, Appraisers and Inspectors

Real estate agents, lenders, appraisers and inspectors play integral and essential roles in the buying and selling of homes and thus the marketing of SEE homes. However, the workshop participants agreed that few in these professions fully understand the principles and methods of EE construction or the extra value associated with SEE homes. In addition, individuals in these fields are generally not well trained for selling, financing, appraising, or inspecting SEE homes.

Most real estate agents fail to recognize and market the extra value of SEE homes. Few training opportunities concerning SEE homes specifically oriented to these agents exist, even though their role in promoting SEE homes has been recognized. As an example, in a fact sheet titled "Working with ENERGY STAR as a Real Estate Agent," the values the real estate agents can bring to their customers by working with ENERGY STAR are explained and potential resources for interested agents are suggested. However, these resources are mainly fact sheets, presentations, and brochures, not including actual training opportunities and incentives for them to do that. Another problem is that real estate listings do not commonly include a list of EE features or annual utility costs, which affects the resale market for SEE homes. Therefore, SEE homes are often marketed the same as conventional homes, and the added value is not reflected in the selling price.

Financing the higher initial costs that may be associated with SEE homes can become a major problem for homeowners if lenders do not take the reduced monthly energy costs into account. In addition, few lenders know about, or choose to participate in, Energy Efficient Mortgage (EEM) and Energy Improvement Mortgage (EIM) programs that are provided by the Federal Housing Administration (FHA), Veteran's Administration (VA), and the secondary mortgage market such as Fannie Mae and Freddie Mac. As an example, currently in Ohio only four lenders are listed on the ENERGY STAR website as partners in providing EEMs.

The purpose of these mortgage programs is to enhance the affordability of SEE homes or homes having EE measures. These programs cover new construction such as ENERGY STAR qualified homes. They are also used to purchase existing homes that will be upgraded via EE measures. There are some problems associated with EE related mortgages. The lending processes are different from traditional mortgages and usually more complicated from both the borrowers' and lenders' perspectives. There are also added costs to such loans, such as the requirement of a home energy rating. In addition, the maximum allowable additional amounts for EEMs offered by FHA (not exceeding $4,000 or 5% of the appraised value with a cap of $8,000) and VA (no greater than $3,000 without verification or $6,000 with verified and documented energy improvements) are much lower than the EE costs in most real-world cases. However, some states, such as Alaska, Virginia, and Vermont, offer additional, small financial incentives (e.g., a $2,000 recognition award for lenders and a quarter-point mortgage interest rate reduction for borrowers), and/or diverse services (e.g., appraiser training, code compliance documentation, etc.), to increase the number of EEMs completed (Plympton 2008).

In general, these incentives are probably too small to influence a buyer's decision on what house to purchase unless the buyer was already predisposed to considering an SEE home. In particular, a typical buyer would probably be more influenced by the amenities in conventional homes than the small financial incentives being offered to buy an SEE home. The workshop participants strongly endorsed the need for new and innovative mortgage programs which provide significant financial incentives to homeowners who purchase SEE homes. Important criteria identified include reduced interest rates, simplified paperwork and third party verification of the energy performance of the home.

An appraisal, which costs $200-$500 on average, is required for the buyer to secure a loan. Selected by the lender, a professional appraiser visits the property to be sold and evaluates the size, room layout, condition, quality, function, etc. of the home as well as its neighborhood and general location. Often, the value of the home is determined based on comparisons to the sale prices of similar homes in the area. Unfortunately, few appraisers are knowledgeable about EE features and typically do not include them in standard evaluations of home value. Many lenders also require a home inspection. Unfortunately the situation is similar to that for appraisers and appraisals. Few home inspectors are knowledgeable about EE features and typically do not include an in depth discussion of them in standard home inspection reports.

Government Agencies and Code Officials

Governmental agencies such as DOE, EPA, and HUD have played a leading role in promoting SEE homes. These federal agencies have sponsored various programs that have made considerable progress in research, manufacturing, and implementation of SEE home principles, products and techniques. Offering government incentives to EE builders and homeowners for home efficiency improvements is one of their common strategies. However, according to the workshop participants, the effectiveness of these incentives has been limited. The workshop participants indentified the problem that these programs do not require follow up performance testing and evaluation. There was also no well-known mechanism to measure the impact of government incentives on consumer adoption of EE improvements.

Table 1 summarizes the latest incentives for home builders and owners for energy efficiency as listed on the ENERGY STAR website. Of particular note concerning builders, the incentives are not large, require energy audits, and building ENERGY STAR qualified homes does not guarantee a tax credit. So they are not attractive from the builder's perspective. For homeowners, incentives up to $1,500 are provided for basic EE improvements in existing homes including upgrading insulation, replacement of windows and doors, installation of high efficiency water heaters, etc. Greater emphasis is, however, placed on renewable energy systems such as geothermal heat pumps, solar panels, solar water heaters, and small wind energy systems for which consumer rebates could be 30% of cost with no upper limit. As aforementioned, certain renewable systems (e.g., PV) were actually far less cost effective in cutting down home energy consumption than EE construction techniques (Parker 2009). Also, no incentive is provided for homeowners who are interested in purchasing new EE homes that are not dependent on renewable energy systems. The tax credits for the first-time and long-resident home buyers (up to $8,000 and $6,500, respectively) do not include any home energy efficiency requirements.

There are also energy programs sponsored by state agencies. These programs offer practical guidelines and trainings to builders and Energy Raters, educate buyers about SEE homes, as well as provide some financial assistance to low and moderate income families. For example, the New York ENERGY STAR program covers up to 50% of the costs associated with the energy efficiency improvements, up to a maximum of $5,000 per household or $10,000 for a 2–4 family building.

In terms of code requirements, the consensus of workshop participants was that current residential building codes and regulations are not stringent enough in energy conservation,

TABLE 1. Federal tax credits for energy efficiency for home builders and owners.

Applicants		Tax Credit	Requirements
Home builders	Building EE homes	$2,000/each home	50% energy savings for heating and cooling over the 2004 International Energy Conservation Code and supplements; 15% must come from building envelope improvements; Cannot be directly linked to Energy Star qualified homes.
	Building EE manufactured homes	$1,000/each home	30% energy savings for heating and cooling over the 2004 International Energy Conservation Code and supplements; 1/3 must come from building envelope improvements; Can be directly linked to Energy Star qualified manufactured homes.
Home owners	Existing home owners	30% of cost, up to $1,500 for all products	For insulation, windows and doors, roofing, HVAC, water heaters, biomass stove; Must be taxpayer's principal residence; Must have a Manufacturer Certification Statement.
		30% of cost, no upper limit	For geothermal heat pumps, solar water heaters, solar panels, and small wind energy systems (second homes also qualify).
	Building your own home	30% of cost, no upper limit	Only applies to geothermal heat pumps, solar panels, solar water heaters, small wind energy systems (second homes also qualify) and fuel cells (principal residence; up to $500 per .5 kW of power capacity); Windows, doors, insulation, roofs, HVAC, or non-solar water heaters are not qualified.
	First-time home buyers	Up to $8,000	No requirements for energy efficiency of homes to be purchased.
	Long-time resident home buyers	Up to $6,500	No requirements for energy efficiency of homes to be purchased.

and therefore, do not support SEE homes. The most important energy codes in the residential housing area are presented below, sorted in descending order of the number of states adopting these codes (VanGeem 1998):

- Model Energy Code (MEC), now the International Energy Conservation Code (IECC) published and maintained by International Code Council (ICC);
- The International Residential Code (IRC) from ICC; and
- ASHRAE Standards 90.2 Energy Efficient Design of Low-Rise Residential Buildings.

These codes are updated every three years. For ASHRAE 90.2, the current version is 2007 and for the other two codes the latest versions are 2009. The IECC addresses energy efficiency only and includes both commercial and residential buildings. The IRC is a stand-alone code for one-two family dwellings and townhouses and often refers to the IECC for energy efficiency. Therefore, the energy efficiency requirements in these two codes are almost identical (DOE 2009b).

Some energy efficient home programs, e.g., ENERGY STAR, require homes to have overall energy efficiency up to 50% above current versions of IECC/IRC. In other words, homes built to code are not considered energy efficient. Furthermore, although it is assumed that newer codes should result in higher energy efficiency, there is evidence that this is not always true. For example, a study on the differences between 2003 and 2006 IRC/IECC found that in some cases homes built according to the newer code consumed more energy than homes using the older code. This is because the newer code uses uniform insulation requirements for larger climate zones and also allows lower insulation requirements under certain circumstances (Musser 2006).

A challenge to code officials will be to enhance buildings' energy performance in various climate zones by using cost effective and more standardized approaches for easier application. Also the enforcement of code modifications is complicated by the resistance from the home building industry. At state level, the challenge lies in maintaining and upgrading state energy codes in response to updates every three years in the international codes. The lag time in some states is one or more code cycles (OCEAN 2010).

Researchers and Educators

Some workshop participants had the opinion that most of the technical issues in terms of designing and building SEE homes are known and not much additional research is needed. Such a viewpoint is not uncommon in both academia and industry. However, some areas for which further research would be required were discussed. These include:

- The whole-house systems approach for best energy performance including standardized SEE home designs, long-term and large scale data collection, and the subsequent analysis of actual energy performance;
- Sensor, metering and home energy management systems for control and monitoring of the performance of major home subsystems;
- Innovative construction methods and project management systems to enhance quality while minimizing project costs; and
- The capacity, efficiency and economics of combining energy efficiency with onsite renewable energy generation.

The workshop participants stated that there is not enough education and training available on EE home principles, materials and techniques for audiences including homeowners, builders, subcontractors, marketing professionals, government officials, and the general public. The unique needs of these various stakeholder groups must be considered when educational, training, and outreach programs are developed and implemented. As an example, there is a lack of understanding in homeowners and the general public concerning terms and labels/certificates such as "energy-efficient," "ENERGY STAR," "LEED," and "green" even though they are hot topics. Properly designed and delivered educational materials and programs can help resolve this situation.

The workshop participants also stressed the need for an academic and/or governmental based "third-party" group with expertise in building science to act as a reference and coordinator for initiatives to advance SEE homes. The general public is skeptical of claims and promotions made by home builders because the perception is that the home builders are simply marketing their products. Therefore, an unbiased third party which promoted SEE homes would have considerable credibility. In addition, the participation of this group in an SEE home warranty program is essential.

THE NEED FOR AN SEE HOME PROGRAM AND ITS POTENTIAL IMPACTS

Based on the results of the workshops, some of which were discussed above, several focus areas are necessary to promote Super Energy Efficient Homes:

- Intensive and extensive public education tailored individually to the diverse groups involved in SEE homes;
- Technical training oriented to the needs of the various professions involved in the home construction industry;
- Enhancement and enforcement of energy codes;
- Significant and well publicized financial incentives to attract new home buyers and offset the risks to builders;
- Research on standardized designs with a systems approach, a unified rating system, and monitoring and smart metering; and
- Adequate demonstration and showcase of SEE homes through model homes and through realistic multi-media presentations.

The workshop participants believed that there is a need for a large, multifaceted program on the state and national level to promote SEE homes which use less than 50% of the energy of homes built to current codes. Because of the size of the effort required, both state and federal funding would almost certainly be required. Government funding is also justified because the benefits of energy efficiency are enjoyed over a

long period, and the benefits are spread over the nation as a whole due to the reduction on energy dependency and greenhouse gas emissions. To be successful, such a program would have to involve the participation of representatives from all of the stakeholders in the home building industry including homeowners. Before proposing a multibillion dollar program at the national level, it would be reasonable to conduct a pilot program at the state level. There would be a huge impact on Midwestern states such as Ohio. For Ohio, some of the benefits are discussed below.

Ohio remains one of the nation's largest energy consumers, particularly of coal, which is used to generate 86% of its electricity according to The Public Utilities Commission of Ohio (PUCO 2009). In order to protect the environment, Ohio is actively seeking ways to raise efficiency standards and lower greenhouse gas emissions. In a letter to the Secretary of Energy dated March 23, 2009, Ted Strickland, the Governor of Ohio, emphasized three focal areas for the State regulatory authority and the State or the applicable units of local government: 1) To seek to implement a general policy that provides utility financial incentives to help their customers use energy more efficiently; 2) To adopt more energy efficient codes for both residential and commercial buildings and achieve 90 percent compliance within eight years; and 3) To prioritize the grants toward funding energy efficiency and renewable energy programs (Strickland 2009).

According to Ohio Department of Development (2009), approximately 50,600 houses were built on average per year from 2001 to 2004, prior to the recent economic downturn. The yearly energy consumption for heating, cooling, and water heating in these homes is approximately 3542 billion BTUs. If half of the new homes built in Ohio used 50 percent less energy for heating, cooling, and water heating than their conventional counterparts, the energy savings for the state can be estimated as 885.5 billion BTUs. Being converted into electricity, the savings would be equivalent to the yearly output of a 30 megawatt power plant. The reduction in electricity generation would also decrease annual carbon dioxide emissions by approximately 158,908 metric tons. For Ohio homeowners and renters, savings on their electricity bills could be up to $27.8 million annually. If the program were to be implemented successfully nationally, the potential benefits can be scaled up easily.

Successful implementation of the program described will also result in a change of culture in the home construction industry, increase the affordability of housing to homeowners and renters, and lower the Ohio's energy subsidy costs. In addition, the promotion of SEE homes will help revive the homebuilding industry in the state and create new jobs.

CONCLUSIONS

Although it is to the nation's benefit to base all new homes built in the future on SEE home principles and practices centered on treating each new home as an integrated system, the current approach of offering small financial incentives to adopt EE principles is not likely to produce a major cultural change in the near future. Therefore, while some SEE homes will continue to be built, the vast majority of new homes will be built using conventional techniques that meet minimum code standards. The results of three workshops hosted by the Ohio State researchers identified many of the barriers and impediments to SEE homes from the perspective of various home construction industry stakeholder groups. The results of these workshops also revealed that it is necessary to not only build each new home as an integrated system, but also think of the home building industry as a system where all of the stakeholders need to be involved in the process to change the home building culture. There is a need for researchers, practitioners and government agencies to reevaluate the strategies for implementing a culture change that will improve the effectiveness of SEE home programs across the nation.

REFERENCES

Alter, L. (2007). Zero-energy condo wins equilibrium competition. http://www.treehugger.com/files/2007/02/zeroenergy_cond.php (Aug. 20, 2009).

Anonymous. (1994). Panel house demonstrates building innovations, *Energy Source Builder,* 35.

Anonymous. (2002). First zero energy home goes up in California, *the Air Conditioning, Heating and Refrigeration News*.

Anonymous. (2009). Consumers would rather make their homes prettier than energy-efficient, according to Energy Pulse survey, RISMedia. http://rismedia.com/2009-11-03/consumers-would-rather-make-their-homes-prettier-than-energy-efficient-according-to-energy-pulse-survey/#ixzz0Vtl012V7 (Dec. 21, 2009).

Brier, M. W. (2006). Rising electricity prices: A challenge to consumers, regulators, and utilities, NASUCA 2006 Mid-Year Meeting, Memphis, TN.

Davidson, P. (2008). Price jolt: Electricity bills going up, up, up, USA Today, Jun. 15.

DOE. (2000). *Elements of an energy efficient house*, DOE/GO-10200-1070, FS-207, U.S. Department of Energy (DOE), Washington, D.C.

DOE. (2004). *Whole-house approach benefits builders, buyers, and the environment*, Building America Program, U.S. DOE, Washington, D.C.

DOE. (2008). Building energy software tool directory: Whole building analysis, Building Technologies Program, U.S. DOE, Washington, D.C.

DOE. (2009a). Building technologies program: Building America, U.S. DOE, Washington, D.C.

DOE. (2009b). *Residential requirements of the 2009 IECC*. U.S. DOE. http://www.energycodes.gov/training/pdfs/2009_iecc_residential_transcript.pdf (Sept. 6, 2009).

Dorgan, C. E. (1977). Residential energy design, *Proc. of the Annual UMR-DNR (Univ of Mo-Rolla/Mo Dep of Nat Resour) Conference on Energy*, Rolla, MO, 393–401.

EIA. (2008). *Annual energy outlook 2008 with projections to 2030*, DOE/EIA-0383[2008], U.S. DOE, Washington, D.C.

EIA. (2009a). *Annual energy review 2008,* DOE/EIA-0384[2008], U.S. DOE, Washington, D.C.

EIA. (2009b). *Month energy review: Energy prices*, U.S. DOE, Washington, D.C. http://www.eia.doe.gov/mer/prices.html (Nov. 25, 2009).

EPA. (2007). Energy Star homes account for more than 12 percent of new housing construction in 15 States—energy efficient homes continue to produce savings, U.S. Environmental Protection Agency (EPA), Washington, D.C.

EPA. (2008). *ENERGY STAR and other climate protection partnerships 2007 annual report*, U.S. EPA, Washington, D.C.

Florides, G. A., Tassou, S. A., Kalogirou, S. A., and Wrobel, L. C. (2002). Measures used to lower building energy consumption and their cost effectiveness, *Applied Energy*, 73(3-4), 299–328.

Hodges, L. (1984). Rating the heating energy efficiency of homes and small buildings, *Proc. of the ACEEE 1984 Summer Study on Energy Efficiency in Buildings*, v. B, Santa Cruz, CA, p. 172.

Huebner, J. D. (1985). *A study of the Home Heating Index and comparison with other energy-efficiency indices*, Ph.D. Thesis, Iowa State University, Ames, IA.

Kamin, B. (2009). Going net zero-for effect; 1st-of-its-kind home in Chicago will produce as much energy as it uses, *Chicago Tribune*, July 22.

Kirchhoff, S. (2000). Green business and blue angels. *Environmental and Resource Economics*, 15, 403–420.

Lee E. S., Hopkins, D., Rubin, M., Arasteh, D., and Selkowitz S. (1994). Spectrally selective glazings for residential retrofits in cooling-dominated climates, *ASHRAE Transactions,* 100 (1), 1097–1114.

Mayo, T., and Sinha, R. (1997). R-2000 and advanced houses: The Canadian experience, *Journal of Thermal Insulation & Building Envelopes*, 21, 91–111.

Musser, A. (2006). Energy impact study of the 2003 IECC, 2006 IECC, and 2006 IRC energy codes for Nebraska, Vandemusser Design, LLC. http://www.neo.ne.gov/neq_online/sept2006/IECC_2006_study.htm#amy (Sept. 3, 2009).

NAHB. (2009). *National green building standard™*, National Association of Home Builders (NAHB), Washington, D.C.

NEEA (Northwest Energy Efficiency Alliance). (2009). *Home buyers focus groups: Market research report*, NEEA/#09-201, prepared by Curtis Research Associates.

Newsham, G. R., Mancini, S., and Birt, B. J. (2009). Do LEED-certified buildings save energy? Yes, but…," *Energy and Buildings*, 41, 897-905.

Nisson, J. D. Ned, and Dutt, G. (1985). *The superinsulated home book*, John Wiley & Sons, New York.

Norton, P., Hancock, E., Barker, G., and Reeves, P. (2005). *The Hathaway "Solar Patriot" house: A case study in efficiency and renewable energy*, NREL/TP-550-37731, U.S. DOE, Washington, D.C.

Norton, P, and Christiansen, C. (2006). *A cold climate case study for affordable zero energy homes*, NREL-CP-550-39678, Boulder, CO.

OCEAN. (2010). Code status: Residential, Online Code Environment & Advocacy Network (OCEAN). http://bcap-ocean.org/code-status-residential (Aug. 6, 2010).

ODOD. (2009). Table 30: Number of private housing units authorized by building permit, 2001-2008, *Ohio County Indicators*, Ohio Department of Development (ODOD). http://www.development.ohio.gov/research/files/s105.pdf (Sept. 6, 2009).

Owens Corning. (1996). Owens Corning's system thinking for the home helps customers increase sales, reduce costs and build value. http://prnwire.com/cgi-bin/stories.pl?ACCT=104&STORY=/www/story/28548&EDATE= (Jul. 28, 2009).

Parker D. S. (2009). Very low energy home in the United States: Perspectives on performance from measured data, *Energy and Buildings*, 41, 512–520.

Plympton, P. C. (2008). *National status report: Home energy rating systems and energy-efficient mortgages*, NREL/TP-550-27635, Prepare for National Renewable Energy Laboratory.

Prothero, A. (1990). Green consumerism and the societal marketing concept: Marketing strategies for the 1990s. *Journal of Marketing Management*, 6, 87–103.

PUCO. (2009). Where does Ohio's electricity come from? The Public Utilities Commission of Ohio (PUCO), Columbus, OH.

Rice, G., Wongtada, N., and Leelakulthanit, O. (1996). An investigation of self-efficacy and environmentally concerned behavior of Thai consumers. *Journal of International Consumer Marketing*, 9(2), 1–19.

SCE (Southern California Edison). (2006). Home energy efficiency survey. http://www.californiaenergyefficiency.com/calenergy_old/sce/2503.pdf (Jul. 28, 2010).

Shurcliff, W. A. (1986). Superinsulated houses, *Annual Review of Energy*, 11, 1–24.

Solar Energy Research Institute (SERI). (1984). *Passive solar performance summary of 1982-1983 class B results*, SERI/SP-271-2362, Golden, CO.

Stein, J. R. (1997). *Accuracy of home energy rating systems*, LBNL Report No. 40394, Lawrence Berkeley National Laboratory, Berkeley, CA.

Strickland, T. (2009). Governor's assurance under ARRA Title IV, Section 410, State of Ohio.

The Partnership for Advancing Technology in Housing (PATH). (2002). *Whole house and building process redesign*, Prepared by National Association of Home Builder Research Center for U.S Department of Housing and Urban Development, Office of Policy Development and Research, Washington, D.C.

Tsen, C., Phang, G., Hasan, H., and Buncha, M. R. (2006). Going green: A study of consumers' willingness to pay for green products in Kota Kinabalu. *International Journal of Business and Society*, 7(2), 40–54.

U.S. Census Bureau. (2008). *Income, poverty, and health insurance coverage in the United States: 2007, current population reports*, U.S. Census Bureau, Washington, D.C.

USGBC. (2008). *LEED for homes reference guide*, U.S. Green Building Council (USGBC), Washington, D.C.

VanGeem, M. G. (1998). *Energy codes and standards*, Whole Building Design Guide, National Institute of Building Sciences.

Wasik J. F. (1992). Green marketing: Market is confusing, but patience will pay off. *Marketing News*, 26, 16–17.

Winters, T. (2008). The rising cost of electricity generation, *The Electricity Journal*, 21(5), 57–63.

Yost, N. and Lstiburek J. (2002). Basement insulation system, Building Science Corporation. http://www.eere.energy.gov/buildings/building_america/pdfs/db/35017.pdf (Aug. 12, 2009).

Zimmerman, A. (2009a). To vent or not to vent, that is the question, *Resource*, April/May, 10–11.

Zimmerman, A. (2009b). MPG for homes: Improving the energy performance of homes and households, *Home Energy*, May/June, 28–30.