Deep Energy Reductions in Existing Homes: Strategies for Implementation

Linda Wigington, Affordable Comfort, Inc. (ACI)

ABSTRACT

The residential sector accounts for 21% of both the U.S. energy use and carbon emissions (EIA 2006). Given recent increases in energy costs and the urgent need to reduce greenhouse gas (GHG) emissions, it is time to re-examine our assumptions about the level of energy reductions that are achievable in existing homes. This paper addresses the importance of developing a foundation to cut energy use in existing North American homes by 70%–90%. Properly implemented, the deep energy reduction paradigm offers the potential for reduced energy vulnerability and environmental impact over the life of a dwelling, while enhancing comfort, indoor air quality, and durability. However the deep energy paradigm requires a "beyond technology alone" strategy and must encompass behavioral choices and community-based strategies. While some experience gained from housing, energy, and utility programs supports implementation of the deep energy reduction paradigm, other residential energy efficiency traditions make it more difficult to obtain deep energy reductions.

This paper builds on the ACI Summit held in July, 2007 in San Francisco, "Moving Existing Homes toward Carbon Neutrality," and the resulting white paper. It explores the insights, challenges, and recommendations that emerged from that gathering of 100 North American housing, building science, and energy efficiency experts.

Transforming the physical and institutional infrastructure is a daunting task. The issue is, not whether deep energy reductions are necessary, but rather how to define and support this vision.

Housing & Energy: Opportunity & Challenge

The recent confluence of political, social, environmental, economic, and technical awareness of global climate change makes a compelling case to re-examine our assumptions regarding the degree to which energy use can be reduced in existing homes (Environmental Building News 2007; Pillen & Doerrie 2008; Steinmüller 2008a). Transforming the physical and institutional infrastructure to support rather than threaten global, regional, community, and household sustainability is a daunting task. The issue is not whether deep energy reductions are necessary, but how to define and support this vision.

There are 124 million dwellings in the U.S. and 13 million dwellings in Canada. These homes simultaneously represent a tremendous investment of resources and a commitment to maintenance and operating costs for years to come (Community Solutions 2007). It is estimated that 60% of the homes present in 2050 are in existence today (NREL 2006). In 2006, $228 billion was invested in U.S. home improvements; in 2005, $38 billion was invested in siding, windows, roofing, insulation, and HVAC systems alone (JCHS 2007a). The residential sector accounts for 21% of both the U.S. energy use and carbon emissions (DOE 2006).

A Crisis of Obsolescence

The assumptions that are woven into how we design, construct, finance, maintain, operate, and renovate our homes have become dangerously outmoded.

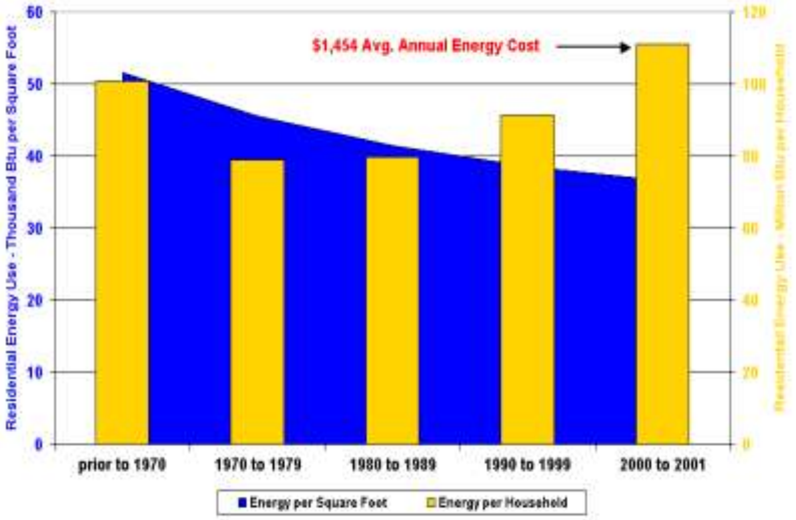
The first flawed assumption is that both the supply of and the costs for energy and water are predictable. That is not the case for energy. In many regions of the U.S., potable water supplies are becoming less certain and more costly[1].

The second flawed assumption is that climate and weather events are stable. There have been many unusually disruptive weather events—severe rain, wind, ice storms, and droughts—and these patterns are predicted to worsen in the future (Hansen 2007; IPCC 2007). Even without sea level rise, these weather events negatively impact housing, notably by wind damage, basement flooding, heat waves, and power outages.

The third flawed assumption is that our energy use is value neutral, that energy is just a “commodity,“ and our patterns of use and energy sources have no ethical or environmental consequences. The costs of geopolitical conflict, greenhouse gases (GHGs), and the environmental impact of extraction, generation, and consumption are not reflected in the price we pay for energy. “Present knowledge does not permit accurate specification of the dangerous level of human-made GHGs. However, it is much lower than has commonly been assumed.” (Hansen *et al.* 2007, 26). Annual per capita U.S. carbon emissions are 19 tons of CO_2. To reduce U.S. emissions by an order of magnitude or more will require a significant transformation of our energy-using infrastructure.

The fourth flawed assumption is that new construction will save the day. Intuitively, most would assume that a new home, particularly a new home built to exceed energy codes would be environmentally superior to an existing structure. However, as you can see in Figure 1, the average energy consumption per household in new housing is greater than the average energy use of existing homes (DOE 2006; NREL 2006).

Figure 1 Residential Energy Use by Year of Construction (site energy[2])



---

[1] The link between water and energy has been overlooked. In the U.S., one half gallon of water is used to produce each kWh of electricity; 20% of the annual stationary energy consumption is needed to pump, treat, and process potable water and waste water. “Saving energy saves water. Saving water saves energy” (Klein 2008).

[2] Site energy is the energy used at the building. Source energy provides a truer picture of environmental impact, as it reflects the energy lost in extraction, conversion, and transmission.

(NREL 2006)

If we only view energy use on a per square foot basis, it appears that significant progress is being made. However, the trends in increased house size, fewer people per household, and increased use of electricity rather than direct use of fuels are neutralizing the significant efficiency gains that have resulted from better codes, appliance standards, and increased use of CFLs (compact fluorescent lights) (Waide et al. 2006). To get a more accurate understanding of energy use and environmental impact it is important to use a cluster of indicators that reflect energy use per person and per household (Harris et al. 2006). Buildings represent 85% of the U.S. fixed capital assets with a life expectancy of 50 to 100 years. They have the slowest turnover of any major kind of infrastructure (Lovins 2007). While it is critical to minimize lost opportunities in new construction; existing homes represent a huge resource and potential for reduced energy use, both in percentage and absolute terms.

To begin to address the faulty assumptions outlined above, we need a comprehensive strategy for deep reductions that includes a blend of technical improvements and behavioral changes that will begin to mobilize citizens, communities, institutions, and government to transform our existing housing stock.

The challenges and barriers represented by this sector also reveal unique opportunities. To succeed, a critical perceptual change is needed. People as citizens have far greater capacity than in their limited role as consumers. We need a strategy that taps our capacity to think, act, create, and implement solutions. We need a strategy that empowers, informs, and provides transparent feedback processes that make it easy to measure progress against a goal, as well as to ensure accountability of those engaged, and most importantly, to measure actual use. We need a strategy that provides for viral information dissemination (Gladwell 2002), and recognizes the power of community-based local and regional solutions.

ACI Summit Addresses Existing Homes

In July 2007, Affordable Comfort, Inc., (ACI) convened the Summit, “Moving Existing Homes toward Carbon Neutrality” in San Francisco. The goal of the Summit was to create and clarify the vision of deep energy savings (70%–90% reduction in total energy use) in existing single-family and multifamily dwellings through a combination of technical interventions and behavioral choices. “We have the opportunities and knowledge to make extremely deep cuts in the energy consumption of existing housing, in some cases to zero net energy levels. Actual reductions will vary from house to house and different retrofit strategies are needed to address the variability in climate, housing types, and lifestyles. While many homes may not be candidates for deep energy reductions in the near future, we propose that the deep energy reduction paradigm can and should provide the framework for viewing energy and carbon reductions at a household, programmatic, and policy level. The technology for these ambitious cuts largely exists, but the essential knowledge is fragmented” (Wigington 2007, 1).

The 100 persons from the United States, Canada, and Europe in attendance represented nonprofit organizations, utility companies, ESCOs, consultants, designers, contractors, national research laboratories, foundations, product manufacturers, publishers, research institutions, and local, state, and federal governments. Key questions included: What paths will take us to deep reductions and how are they different from business as usual? What are the strategies that can help to bring this vision to reality? A revelation to many was that some near term efficiency efforts could make it more difficult and expensive to achieve deep reductions in the future. Lost opportunities are created when below optimal energy efficiency measures and systems are implemented. Our policies, technologies, and markets still have flawed assumptions embedded resulting in a significant lag in both what is achieved and also defined as possible. For example, many recommendations and codes that impact renovation do not reflect our current knowledge regarding the societal cost of climate change or the price of oil.

Four foundational strategies emerged:

- Assume net zero energy and carbon neutrality is achievable within existing homes;
- Optimize the investment in behavior, efficiency, renewables, and community solutions;
- Accurately assess, value, and communicate the energy and non-energy benefits; and
- Reduce the costs of, and obstacles to, accessing a deep energy reduction package (Wigington 2007).

Assume Net Zero Energy[3] and Carbon Neutrality is Achievable within Existing Homes

Early efforts to demonstrate significant reductions in heating loads through superinsulation were pioneered in the U.S. and Canada in the 1980's (Orr & Dumont 1987). Recently, Building Science Corporation completed the comprehensive renovation of a 100 year old home that resulted in a 60% energy savings while increasing the living space by 80%[4] (Pettit 2008).

Strategies will vary by household, climate, region, and housing type. With more than 10,000 buildings constructed or modernized in Germany and Austria to the Passive House standards, the Passive House Institute has demonstrated synergies in performance and cost reductions that can result when the peak heating loads are reduced significantly (10 watt/meter^2) (Steinmüller 2008a). For example, a deep reduction approach with comprehensive insulation and air sealing can make a conventional furnace and its distribution system unnecessary, thus creating the opportunity for simpler technical solutions to combustion safety, distribution systems, durability, and indoor air quality problems. In North America, a deep energy retrofit work scope might call for the elimination of the conventional chimney, furnace, and attic ductwork and the installation of a mechanical ventilation system to address indoor air quality and moisture control. As a result, the need to diagnose and address the existing systems is minimized. Rating a house prior to retrofit may be an unnecessary expense. The work scope may have more in common with new construction than with a retrofit.

Demonstration projects focusing on existing housing are underway in Europe through the German government "dena" (Deutsche Energie Agentur) Efficient Homes project and IEA's Task 37. Since its inception in 2003, 140 buildings have incorporated enhanced efficiency measures during their modernization in the German Efficient Homes project. Before retrofitting, the average source energy use for heat and hot water was 336 kWh/meter^2 (106,512 Btu/ft^2). Based on modeling, the post retrofit use for heating and hot water was 44 kWh/meter^2

---

[3] A net zero energy is a building that produces as much energy as it consumes in a year; renewables are not the focus of this paper, but when a deep energy reduction strategy incorporates renewable, net zero energy is achievable.

[4] Upgrades included: roof, R-60; walls, R-40; basement walls, R-20; basement floor, R-10; new ENERGY STAR® windows and mechanical systems with distributed mechanical ventilation as well as baseload measures.

(13,948/Btu/ft^2)[5] (Steinmüller 2008b), less than half of the minimum requirement for new German housing. Actual consumption will be tracked for a two year period after each project's completion. The Efficient Homes Project focused on all types of existing residential buildings in order to generate best practice case studies. To inspire innovation, neither methods nor products are specified. The sole exception is that every home is required to have a mechanical ventilation system. The program is scaling up. By mid 2007, 1300 owners applied to participate (Pillen & Doerrie 2008). Both the experience and product innovation gained from the Passive House[6] experience contributed to the Efficient Homes Project's success.

Reducing the heating and hot water loads alone will not achieve a 70%–90% reduction. These loads account for less than half of the average primary residential energy use. We lack case studies that have brought all of the elements of deep reductions together in sample North American homes, but there is evidence that behavior, good management, and the appropriate technical systems can also achieve deep reductions in mechanical cooling and electric baseloads.

The study, *Approaching Net Zero Energy in Existing Housing*, recently commissioned by the Canadian Mortgage Housing Corporation (CMHC) concluded that climate, housing stock, energy loads, solar gain, and occupant behavior all contribute to the feasibility of reaching net zero energy use in existing homes. There is no Canadian government incentive in place for PV (photovoltaics). As a result, it is not cost effective to achieve net zero energy in most Canadian housing. However, with the assumptions used, it is technically possible and in some cases economically viable to achieve reductions on the order of 70%–90% (Henderson & Mattock 2008). The technical assumptions modeled were less aggressive than those used to meet Passive House standards. Significant barriers also pose opportunities. Solving problems with wet basements, radon, outdated mechanical equipment, and inadequate indoor air quality can help justify energy efficiency decisions.

The reduction of heating loads was viewed by many ACI Summit participants as a relatively easy accomplishment. The greater challenge was achieving deep reductions in baseloads and cooling loads, which are more responsive to occupant behavior and lifestyle. Motivated occupants are essential. Though typically new construction, off grid homes demonstrate the potential for greatly reduced electricity use that is equally applicable to existing homes. As a result of monitoring the energy use patterns of 12 off-grid homes, it was clear that it is possible to greatly reduce electricity use without compromising modern conveniences. One family maintained an average electricity budget of 5 kWh per day demonstrating that with a combination of efficient equipment, smart system design (both AC & DC circuits), and good management facilitates a normal lifestyle using 80% less electricity than the average Canadian family (Henderson 1999).

Follow-up evaluation of the consumer response to the 2000-2001 California energy crisis concluded that most of the 15% reduction in electrical energy use was primarily a result of occupant behavior[7], not technology. The evaluation credited the actions of a small number of supersavers and modest efforts by many Californians as the explanation for the reduction (Lutzenhiser et al. 2003).

---

[5] For comparison, the U.S. average residential source energy use for space and water heating is 36,590 Btu/ft^2 (DOE 2007, Table 1.2.3).

[6] www.PassiveHouse.de

[7] At least 1/3 of the conserver households…chose not to use AC. Few of these consumers experienced significant discomfort and negative lifestyle impacts, suggesting that comfort itself is probably more elastic than imagined.

A retrofit case study of a 9 year old home in Sacramento originally built to utility program standards illustrates an approach that substantially reduced energy use in a home that already had energy efficient features such as low-e windows. Natural gas use was reduced by 42% and electric loads by 59% including a reduction of cooling loads by 72%[8]. Building enclosure improvements focused on reducing air infiltration and upgrading and improving the performance of insulation. Heating and cooling systems were replaced, duct leakage addressed; products and controls further reduced electrical and cooling loads. The amortized monthly cost of these improvements is $8.00 (Ceniceros 2008). While less than a 90% savings from this homes' baseline, it provides a revealing example of the potential to retrofit a relatively new home to achieve improved air quality, comfort, and energy performance.

Optimize the Investment in Behavior, Efficiency, Renewables, and Community Solutions

The more willing a homeowner or community is to question assumptions about how they currently live and meet their needs, the more options emerge. Possible strategies may include the use of a community-based renewable energy supply or choices regarding the use of space and number of people in a home. Technically feasible, but perhaps more challenging socially, would be the creation of a co-housing community within an existing neighborhood, with very efficient shared cooking, water heating, clothes washing, and entertainment services. While improbable by today's standards, remember that thirty years ago few would have predicted the rise of condos and urban living in North American cities.

The range of possibilities is as varied as our housing stock and communities. A capital intensive strategy combines technologies that embrace both improved product and system efficiency and renewables. Creative solutions involving behavioral choices, community solutions, and lower cost technical fixes have the potential to achieve the same or greater reductions with less capital. The combination of behavioral choices, community solutions, and technical strategies has the potential to optimize the capital and embodied energy invested.

One failure of a simple payback analysis is that measure life is not reflected. The decisions made regarding a homes' structure usually last longer than mechanical systems, appliances, or renewables. Marc Rosenbaum suggests a simple maxim, "Invest as much as you can afford to reduce the load, even if it means completing a project in phases" (Rosenbaum 2008). A trigger event that makes it possible to achieve optimum results appears as major systems (e.g. siding, roofing) are replaced or renovations made. We need to capture opportunities as they emerge.

Table 1 suggests a universe of strategies to be selectively mixed and matched to achieve deep energy reductions related to thermal comfort--the dominant load in most homes[9].

---

[8] Based on 4 year pre treatment consumption and 1 year post data. The home also changed occupancy. Post consumption was not weather normalized. There was an estimated 10% – 20% cooling performance penalty though participation in a peak load control "precooling program." The installed cooling demand was reduced from 3.48 kW to 1.6 kW.

[9] On a household level, loads vary tremendously, thermal comfort is estimated to be 25% to 80% of the site energy use. In 2005 the national average of U.S. residential energy use for space heating and cooling was 55.4% of the direct (site) and 43% of the source energy use (DOE 2007, Table 1.2.3).

Table 1. Many Paths To Thermal Comfort[10]

	Community Solutions	**Behavioral Choices**	**Technical Fix – higher cost**	**Technical Fix – lower cost**	**On-Site Renewables**
Range - % Reduction[11]	**20% – 70%**	**10% – 90%**	**30% – 85%**	**5% – 80%**	**10% – 70%**
Thermal comfort accounts for 25% to 80% of the residential energy use / household Options to reduce the energy use per person needed to achieve affordable, sustainable thermal comfort	Comfort centers Cogen or micro-cogen Community thermal storage Community-based renewable energy supply Use of waste heat from industrial processes GHG reduction campaigns Feedback, benchmarking, aggregation Competitions / Challenges within and between communities Technical, financial, & regulatory support	24/7 set point adjustment or setback Apply comfort zone Change use of space; new thermal boundaries Adaptive comfort (clothing, surface temp, air movement) Increase occupancy Reduce internal gains (behavioral – cooling loads) Decrease occupancy: (short-term or long-term) relocate or demolish	Climate specific superinsulation: (walls, ceiling, floor, foundation R 25 – R 80) Efficient windows (climate specific SHG, + U 0.1 to 0.3) Super air tightening (to 0.2 CFM/ft^2 floor space) High efficiency mechanical ventilation Ultra high efficiency HVAC system Automatic movable window insulation Highly insulated doors	Fill cavities with insulation Air sealing (to 1 CFM50/ft^2) Do-it-yourself superinsulation Seal / insulate attic ducts; better yet eliminate ducts Point heat or cooling source High performance storm windows Manually controlled movable window insulation Reduce internal gains technical fix (cooling loads) Control systems to optimize comfort, IAQ, & humidity control	Increase solar gain through windows Sunspace or solar buffer to reduce heat loss Active solar thermal Solar PV Wood heat (EPA approved) Trees, vegetation, or other shading to reduce cooling loads

Accurately Assess, Value, and Communicate Energy and Non-energy Benefits

Efforts to achieve deep energy reductions should be viewed within the constellation of benefits at the ecological, societal, community, and household levels so the greater investment required is understood and justified. Because the perception of the price of deep energy reductions is a major barrier to implementation, we need new mechanisms to quantify site and societal costs and benefits. In addition to dramatically smaller utility costs and greenhouse gas emissions, deep energy reductions provide the following benefits.

---

[10] The items in each column are not listed in order of importance. Achieving deep reductions requires a combination of options shown both within and between the columns, optimized in response to the site, occupants, resources, and the community.

[11] This percentage relates just to the reduction of the thermal comfort load. While the highest percentage reductions may be more possible in cooling-dominated or moderate climates than cold climates, larger absolute savings result when preconsumption is highest.

1. Investing in existing homes maintains and builds on the embodied energy and resources already invested in homes.
2. Comprehensive retrofits have the potential to increase building durability, improve indoor air quality, increase comfort, correct health and safety problems, and reduce noise and pests.
3. Reduced residential energy use eases strain on energy supplies and distribution networks.
4. Lower loads make it easier to meet a home's energy demands with renewable sources.
5. Lower utility and maintenance costs mean more money is available to the household for investment or spending on products and services more beneficial to the local economy.
6. Lower utility costs reduce the cost of home ownership and can increase home affordability.
7. Low load homes buffer and protect occupants from outdoor temperature extremes that occur during power outages and/or severe weather events and from spikes in energy prices.
8. Through aggregation of benefits, benchmarking, and feedback, occupants can see the impact of their actions, providing a mechanism to reinforce voluntary lifestyle choices.
9. Deep energy reductions in existing homes can stimulate product development and deployment that can benefit the remainder of the residential and small commercial sectors.
10. Deep energy reductions enable occupants to reduce their personal energy use and carbon footprint.
11. Deep energy savings can make the U.S. more energy independent and reduce accompanying energy-related pressures.

Occupants and professionals alike lack a common language that accurately and simply conveys the energy performance of existing homes. We have better indicators of performance for cars and computers than we have for our homes. In addition to energy use per square foot, other indicators may include energy use per household, per occupant, peak load per household or energy cost per household. The range of consumption is huge, so in come cases percentage reduction from the home's previous consumption is appropriate, while in homes that already use less than average, an absolute target rather than percentage reduction more fairly allots the environmental responsibility.

Indices of energy performance are needed to provide transparent, inexpensive ways for a homeowner, community, or program to benchmark the performance of a home based on actual consumption. Options include plugging energy bills into an online service or doing a back-of-the-envelope calculation to estimate improvement from one year to the next or attainment with a predetermined target. Tools that allow people to compare their energy use and to see the effect of aggregating their savings with others have the potential to reinforce and support behavior change.

Reduce Costs and Barriers of a Deep Energy Reduction Package

To make a case for deep energy reductions, it is critical to break through the perceived cost barrier. Our methods for analyzing cost effectiveness for energy efficient improvements are too limited (Knight et al. 2006). The synergy between actions must be considered. As mentioned above, the solutions and benefits need to be viewed from a broader perspective rather than the limited context of direct and immediate energy reductions for the occupant or utility. Amory Lovins cites two ways to tunnel through the cost barrier: 1) an integrative design approach that produces multiple benefits from single expenditures; and 2) coordination with retrofits being done anyway.

Two of the primary approaches to completing a deep energy reduction retrofit are: 1) “all at once”; and 2) “phased” process over several years with the end point defined. The key question for the “all at once” path is: “How do we develop the systems and infrastructure to achieve and encourage deep efficiency as the opportunities present themselves through a major renovation or remodeling project?” Questions for the “phased” path are: “How do we develop the methods to engage and support homeowners and occupants in a process that can lead to deep energy reductions and to make it possible to achieve those reductions over a period of time through a series of investments?” and, “How do energy, housing, and environmental programs and initiatives align themselves with, rather than challenge or ignore, the vision of deep energy reductions?” Without a guiding vision, incremental improvements can make it more difficult and expensive to achieve deep energy reductions. Sealing ductwork in unconditioned spaces, upgrading a central HVAC system, and installing new windows are measures that may have to be redone or eliminated to achieve deep energy reductions. The vision for deep energy reductions is needed early in any renovation project to fully optimize investment.

As new innovations and technical systems are developed, the potential for broader applications at lower costs emerge. The process for both the “all at once” and “phased” approaches need a strong emphasis on rapid feedback and verification in order to accelerate the learning curve, fine tune the climate-specific applications, and to verify that the intended results are being achieved and maintained.

Many of the low load systems appropriate for net zero energy new construction are applicable to the existing home market as well. Cooperation and participation from manufacturers is essential. Both transitional and final-stage products are needed. Financing, bulk purchasing, and credible websites featuring innovative products could stimulate adoption of new products. A unique government role to stimulate product deployment could offer a “bleeding edge” insurance policy to make sure early adopters and innovative companies are not saddled with replacement costs when there are premature failures. Citizens who are willing to be climate champions could volunteer to field test new products. With a utility or efficiency program facilitating the performance testing of emerging products, risk and cost to manufacturers could be reduced and lead time for products reaching markets shortened.

Challenges of Existing Housing

Our traditional strategies to reduce residential energy use face a number of challenges. While the residential market represents a huge infrastructure, it is diverse and fragmented with 124 million households and even more decision makers. These decision makers are influencing the way energy is used on a daily basis as well as making decisions to upgrade, repair, maintain, or defer maintenance that impact energy use for years to come. Housing reflects a diversity of vintages and styles, and covers an array of climates that shift the opportunity and priorities for reducing energy use.

Many homes have moisture, combustion safety, or indoor air quality problems. It is estimated that 40% of basements in Canada are damp. For children, the health effect of living in damp environments is equal to exposure to secondhand smoke (Fugler 2007). One in 15 homes in the U.S. has elevated radon; 64 million homes have lead-based paint somewhere in the building. Over 20 million Americans have asthma; in 1990 asthma was the cause of 4500 deaths annually (EPA 2004). Many asthma triggers are found in indoor environments.

Energy improvements have the potential both to exacerbate or create new problems as well as to fix existing ones. Anticipating the array of potential problems and their interactions is complicated; we lack a trained work force to do so.

Information and misinformation abounds and is often contradictory: “A vapor barrier is essential;” “Vapor barriers are the problem.” Whether you are a professional or homeowner, the contradictory information from the press, product manufacturers, professionals, and building codes can be overwhelming.

In many cases the opportunity for efficiency improvement is not a function of the presence of a product, but rather its appropriateness and correct installation. Significant efforts are underway by industry and government to address this through certification and quality assurance programs offered by organizations such as NATE, BPI and ACCA[12] as well as the EPA Home Performance with ENERGY STAR® program. The lack of a trained work force is a tremendous barrier to improving energy efficiency in buildings. Whether a homeowner spends $1,000 on insulating an attic or $100,000 on a major remodel, how can they be sure that the energy-related work is delivering the expected performance?

These challenges collectively make the case for a new, more comprehensive, and deep energy reduction paradigm.

How Do We Get There from Here?

To understand the deep energy reduction paradigm, one needs first to consider the characteristics, status, and limitations of the three paradigms that influence residential energy efficiency efforts—1) the widget, 2) whole house or home performance, and 3) the sustainable paradigms.

Widget Paradigm

The widget paradigm focuses on an isolated product or technology, and defines efficiency by the presence of key products. Examples include rebates for ENERGY STAR® appliances, CFLs, and high performance air conditioners. This approach can lower product costs down and increase saturation and adoption. Programs can ramp up quickly, are easy to deploy, and fairly easy to evaluate, since evaluation is usually based on number of units multiplied by adjusted energy reduction. While widget-based programs are characterized by relatively low savings per unit, the high number of units and low per-unit transaction cost can yield significant and cost-effective energy reductions, particularly if the market is truly transformed after the removal of the incentive.

One drawback of this approach is that it does not address site-specific application, installation, measure interaction, or side effects. Measure-specific programs designed to reduce heating and cooling loads can lead to lost opportunities and have the potential to create negative side effects. For example, rebates offered for high efficiency air conditioning systems may result in systems that do not perform as expected due to incorrect charge, improper air flow, and duct leakage.

Home Performance Paradigm

---

[12] NATE – North American Technician Excellence, Inc; ACCA – Air Conditioning Contractors of America; BPI – Building Performance Institute, Inc.

The whole house or home performance paradigm focuses on building system performance with energy reduction as one part of the greater whole. To date, whole house approaches have mostly been delivered through low-income programs and, more recently, by for-profit companies. Typical costs range from $3,000 to $35,000 per house; energy reductions range from 5% to 35%. A savings of 50% is rare but obtainable in a high-use home or with a comprehensive project addressing air sealing, insulation, HVAC system replacements, and appliance change outs. A home performance job may include work and cost that is directed to solving problems, such as correcting a wet basement or crawl space, which may not generate energy savings.

Home performance programs offer an excellent opportunity to incorporate durability, healthy housing, comfort, renewables, and sustainability and provide a constellation of benefits not limited to energy reductions. Since providing these services requires significant investments in training and education, it requires a longer lead time to develop contractor capacity than widget-based programs.

With this approach, the transaction cost per house is high. The larger the job, the easier it is to justify the investment in site-specific (visual, diagnostic, and energy-use) analysis, occupant interviews, financing, and work scope development. In homes with average or below-average energy use for heating and cooling, the complexity and cost of ensuring "doing no harm" can swamp the benefit, if energy reduction is the only goal, and the menu is limited to traditional energy efficiency measures such as CFLs, wall cavity and attic insulation, air and duct sealing, and heating system replacement.

Sustainable Paradigm

The sustainable paradigm brings a much broader scope than the product or site-specific focus of the first two paradigms. The current and long-term impact on the community and larger environment are considered by assessing the life cycle of building components and products consumed in house operation. Land use, water use, and site environmental impact, as well as a building's durability and energy use are examined. A significant variation in emphasis may be placed on different components of sustainability. There is a rapid growth of interest and investment in green building from both professionals and the general public. Green building is perceived as energy efficient, although it doesn't necessarily incorporate a whole building performance-based approach to energy efficiency. Within green programs that address both new and existing homes, there has been the tendency to focus on products or modeling results, and to assume that energy performance is automatic. The interest in USGBC and ASID's green guideline for existing homes, REGREEN, released in 2008 has exceeded the expectation of the developers (Yost 2008).

The New Deep Energy Reduction Paradigm

The deep energy reduction paradigm builds on the strengths and experience of each of the previous paradigms. The productivity and simplicity of the widget paradigm has the potential to be applied to deep energy retrofit packages that can be deployed in large numbers to common housing stock rather than the craftsman, "each house is unique," home performance model. In addition as demonstrated with European Passive House experience, the development of new systems-based widgets can make it easier and less expensive to achieve deep reductions

(Shultze-Darup 2003). The home performance paradigm brings the comprehensiveness of the systems approach and the potential to reduce lost opportunities while capturing non-energy benefits. Verification of performance is essential. The deep energy paradigm fits well within a sustainable paradigm that incorporates a design centered approach, and the inclusion of impacts beyond the site.

Key elements of this paradigm are transparent indicators of performance, redesigning systems for a much greater level of energy reductions, and embracing behavior and community solutions in addition to site specific technical strategies. While many strategies can be used to achieve deep energy reductions, universal principles are emerging. To summarize, they are:

- A systems approach is necessary to optimize on-site and off-site benefits and interactions;
- Good indoor air quality and building durability are integral elements;
- Performance must be verified with a combination of diagnostic equipment and actual measurement (both energy use and other benefits);
- Occupant behavior and community solutions are an integral part of a deep reduction strategy;
- Even if the investment of resources is made at a single point in time, deep energy reductions should be viewed as an ongoing process, as building systems need to be properly maintained and operated; and,
- A trigger event that makes it possible to achieve optimum results may appear every 20 or 30 years as major systems (e.g. siding, roofing, HVAC systems) are replaced or renovations made. We need to capture opportunities as they emerge.

Two Challenges to Stimulate and Document Case Studies

We need trail blazers to help redraw the map for our efficiency and conservation efforts. ACI is proposing, and asking for participation in two exciting existing home initiatives, the **1,000 Home Challenge** and the **Starting From Home Challenge (SFHC).**

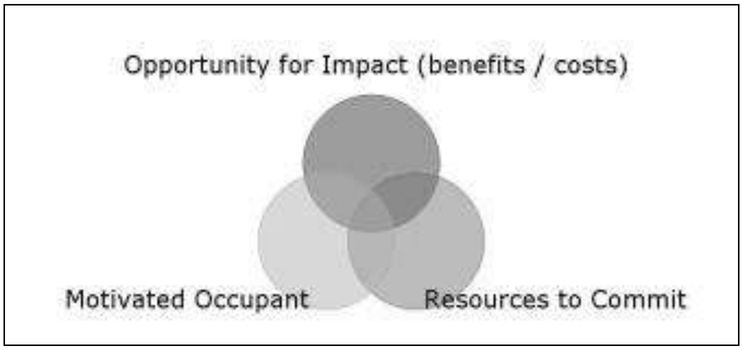
A central goal of the **1000 Home Challenge** is to stimulate successful deep energy reduction case studies throughout North America. We are working to define the parameters of this challenge and to identify the resources and opportunities that will make this challenge a reality. We welcome your collaboration on this project and seek partners who are interested in developing centers of excellence to lead deep energy reduction efforts within their region. Involvement from the private sector and manufacturers is critical to foster innovations in products and deployment.

The **Starting From Home Challenge** is an annual, post secondary school competition in which student teams compete to produce deep energy reductions on real homes in real neighborhoods with real occupants. Modeled after the biannual, federally funded Solar Decathlon competition, the SFHC was created by Heyoka Solutions, LLC and Affordable Comfort, Inc. Results will be debuted at the annual ACI conference (Raymer 2008).

Identify Opportunities

To seed implementation of the deep energy reduction paradigm, we must identify and target communities or situations that offer the combination of lowest costs and / or greatest benefits, access to resources, and motivated occupants.

Figure 2 – **Necessary Circumstances for Deep Reductions**



From a standpoint of cost effectiveness and reducing lost opportunities, the most obvious situations to target are homes undergoing a major remodel. As with dena's Efficient Homes project, the potential for deep reductions can be as practical as during new construction. Other opportunities include communities that are rebuilding from disaster or are confronting supply or environmental constraints, such as energy capacity or air quality problems. Communities or households highly motivated to reduce their carbon footprint could develop a do-it-yourself (DIY) or volunteer workforce supervised by home performance professionals.

Widgetize Home Performance

Ironically, in common and relatively simple house types— ranch, bungalow, four square, town house—packages customized to address the deep energy reduction strategy could be simpler and faster to deploy than the current whole house approach. Given a vision of what is achievable, many strategies will emerge.

Counter-intuitively, delivering a comprehensive deep energy reduction package could be less complicated to deploy than a customized home performance job, which involves fixing, rather than replacing systems. A variety of approaches can be designed and tested. Non-energy benefits and energy performance can be verified and packages of systems sold as a single product. Exterior superinsulated wall systems could be "manufactured" locally as an integral part of re-siding homes. Financing and code approval for such packaged systems would streamline the process for contractors. Demonstrations focusing on common house types can help to stimulate proven packages that could be broadly deployed.

Develop Models for a Phased Process

Households in which an "all at once" retrofit is not practical can still plan for a deep energy retrofit in a phased, 5 or 10 year, process. However, a phased approach to deep energy retrofits is probably the most challenging deployment scenario due to sequencing and indoor air quality, durability, and combustion safety issues Models must be developed to assist homeowners in this process. The steps that can be taken independently over time without compromising the end result—to avoid having to redo or undo measures—need to be identified. For example, one such transitional strategy may be leasing a major appliance and replacing it as better technology comes along, with the original appliance being reused in an appropriate setting.

A point source of heat (e.g., ductless heat pump, or efficient direct vented gas fireplace) could be installed in tandem with an older heating system, until the building's loads are reduced to the point that the central system is not needed. Automatic exterior movable window insulation could reduce heat loss and gain through windows delaying or eliminating the need and cost of window replacement[13]. Behavioral choices may also be appropriate as a transitional strategy.

The same measure can be on the path to deep reductions in one house and an impediment to deep reductions in another home. A ground source heat pump (GSHP) may not be justified in a home that is a good candidate for wall thickening resulting in significant load reductions. However, a GSHP may be appropriate in an historic home with restrictions that limit load reduction.

As efforts to reduce energy use are accelerated, it is possible to create even more lost opportunities. It is far easier and more cost effective to superinsulate and airseal an uninsulated attic, than one that has 12 inches of loose-fill insulation. Examples of lost opportunities that are being created include re-siding without reducing thermal bridging, installing central AC systems prior to reducing the load, purchasing good products (windows, appliances) instead of best available, sealing attic ducts instead of eliminating them, and converting a basement to living space without addressing durability, moisture, soil gas, and energy performance.

CONCLUSION

Our nations have met great challenges before, marshalling the courage, commitment, and creativity needed to meet and exceed seemingly impossible goals. Our patterns of energy use have developed during a period of climate stability, low energy prices, and the perception of abundant sources. We now need to confront the challenge of achieving deep energy reductions in our existing homes. If our vision is limited to component substitution or correcting building flaws we will be creating lost opportunities. It is possible that field verified, regionally specific deep reduction packages can achieve an economy of scale and be deployed more easily than custom house-specific incremental approaches. Properly implemented, the deep energy reduction paradigm offers the potential for reduced energy vulnerability and environmental impact over the life of a dwelling, while enhancing an occupant's comfort, indoor air quality, and financial health. By engaging occupants and communities to re-examine how we meet our needs, and more critically, to differentiate needs from wants, the potential exists to change the use of energy in housing by a factor of ten.

We have the means; we must summon the will.

REFERENCES

Cisneros, Bruce (SMUD). 2008. Personal communication. May 27.

Community Solutions. 2007. The Energy Impact of Our Buildings. *New Solutions*, 11: 1 – 12. January 2007. http://www.communitysolution.org/nsreports.html. Yellow Springs, OH.

Darup-Schultze, Burkhard. 2003. *"Energy Efficient Restoration of Residential Buildings with "Factor 10"*. Dissertation FB Architecture of the University of Hannover. Hanover, Germany.

---

[13] This product also has the potential to increase storm protection.

[DOE] U.S. Dept. of Energy. 2005. *Buildings Energy Data Book.* http://buildingsdatabook.eren.doe.gov. Washington, D.C.

[DOE] U.S. Dept. of Energy. 2006. *Buildings Energy Data Book.* http://buildingsdatabook.eren.doe.gov. Washington, D.C.

[DOE] U.S. Dept. of Energy. 2007. *Buildings Energy Data Book.* http://buildingsdatabook.eren.doe.gov. Washington, D.C.

[EIA] Energy Information Administration. 2006. *Emissions of Greenhouse Gases in the United States 2005.* www.eia.doe.gov/oiaf/1605/ggrpt/carbon.html. Washington, D.C.

Environmental Building News. 2007. *The Challenge of Existing Homes: Retrofitting for Dramatic Energy Savings* 16 (7). July. www.buildinggreen.com.

[EPA] U.S. Environmental Protection Agency. 2004. *Buildings and the Environment: A Statistical Summary*. Compiled by: U.S. Environmental Protection Agency Green Building Workgroup *December 20, 2004.* http://www.epa.gov/greenbuilding/. Washington, D.C.

Fugler, Don (Canadian Mortgage Housing Corporation). 2007. Personal communication. October 23.

Gladwell, M. 2002. "*The Tipping Point*." New York, N.Y.: Time Warner Book Group. www.twbkmark.com.

Hansen, J., M. Sato, P. Kharecha, G. Russell, D. W. Lea, and M. Siddall. (2007). "Climate Change and Trace Gases." *Phil. Trans. Roy. Soc. A* **365**: 1925 - 1954.

Harris, J., R. Diamond, M. Iyer, C. Payne, and C. Blumstein. 2006. "Don't Supersize Me! Toward a Policy of Consumption-Based Energy Efficiency." In *Proceedings of the ACEEE Summer Study on Energy Efficiency in Buildings*, 7:100-114. Washington, D.C.: American Council for an Energy-Efficient Economy.

Henderson, Shawna. 1999. *Research Highlight: Energy Use Patterns in Off-Grid Houses*, Technical Series 01-103, Canadian Mortgage Housing Corporation. Ottawa, Ontario.

Henderson, Shawna and Chris Mattock. 2008. *Approaching Net Zero Energy in Existing Housing* (*Draft*), Canadian Mortgage Housing Corporation. Ottawa, Ontario.

[IEA] International Energy Agency Task 37. 2008. http://www.iea-shc.org/task37/objectives.htm.

[IPCC] International Panel on Climate Change. 2007. Summary for Policymakers. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 7-22.

[JCHS] Joint Center for Housing Studies. 2007a. *Foundations for Future Growth in the Remodeling Industry, Improving America's Housing 2007.* Harvard University. www.jchs.harvard.edu/. Cambridge, MA.

[JCHS] Joint Center for Housing Studies. 2007. *The State of the Nation's Housing.* Harvard University. www.jchs.harvard.edu/. Cambridge, MA.

Knight, R., L. Lutzenhiser, and S. Lutzenhiser. 2006. "Why Comprehensive Residential Energy Efficiency Retrofits are Undervalued." Proceedings of the *ACEEE Summer Study on Energy Efficiency in Buildings*;7:141-150. Washington D.C.: American Council for an Energy-Efficient Economy.

Lovins, Amory. 2007. *Public Lectures in Advanced Energy Efficiency: 1 Buildings.* Stanford University. March 26. www.rmi.org/sitepages/pid231.php. Snowmass, CO.

Lutzenhiser, L., R. Kunkle, J. Woods, and S. Lutzenhiser. September 30, 2003. *Conservation Behavior by Residential Consumers during and After the 2000 2001 California Energy Crises*, 192. CA CEC, Sacramento, CA.

[NREL] National Renewable Energy Laboratory. 2006. *The Potential Impact of Zero Energy Homes.* Golden, CO.: by NAHB Research Center, Upper Marlboro MD. www.toolbase.org/PDF/CaseStudies/ZEHPotentialImpact.pdf.

Orr, Harold and Rob Dumont. 1987. *A Major Conservation Retrofit of a Bungalow*. Ottawa, Ontario.: National Research Council Canada, http://irc.nrc-cnrc.gc.ca/pubs/ir/ir540.

Passive House Institute. http://www.passiv.de/. Darmstadt, Germany.

Pettit, Betsy. 2008. *Toward Zero Energy Homes (New & Existing)*. Presentation http://www.buildingsciencecorp.com/resources/presentations/default.htm. Westford, MA.

Pillen, Nicole and Nana Doerrie. 2008. *"*Germany's Efficient Homes." *Home Energy magazine Climate Solutions*, 30-33.

Raymer, Paul. 2008. Starting From Home Challenge. www.HeyokaSolutionsLLC.com. Falmouth, MA

Rosenbaum, Marc. 2008. "Imagining (and doing) What Needs to be Done." Keynote presented at the ACI Home Performance Conference, Pittsburgh, PA., April 8, 2008. http://www.affordablecomfort.org/event/aci_home_performance_conference_2008/courses_details/1057.

Steinmüller, Bernd. 2008a. *Reducing Energy by a Factor of 10 - Promoting Energy Efficient Sustainable Housing in the Western World*. http://www.bsmc.de/Quellen/quellen.html Sustainability Management Consulting: Paderborn, Germany.

Steinmüller, Bernd (Sustainability Management Consulting). 2008b. Personal communication. May 9..

Waide, P., A. Hinge, and J. Thorne Amann. 2006. "Energy Efficiency in the U.S. Existing Building Stock: What's Worked; What Might Work Better." In *Proceedings of the ACEEE Summer Study on Energy Efficiency in Buildings*, 8:313-325. Washington, D.C.: American Council for an Energy-Efficient Economy.

Wigington, Linda. 2008. ACI *White Paper: Moving Existing Homes Toward Carbon Neutrality.* Waynesburg, PA.: Affordable Comfort, Inc. http://www.affordablecomfort.org/resources_details.php?PageID=23&ArticleID=285 .

Yost, Peter (Environmental Building News). 2008. Personal communication. March 7.