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White Paper inspired by the July 2007 ACI Summit:

One Year Later: Moving Existing Homes Toward Carbon Neutrality

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ABSTRACT

This white paper addresses the potential of reducing energy use in existing homes by 70–90%. It discusses how the emerging ‘deep energy reduction’ paradigm contrasts with conventional efforts to reduce residential energy use. It explores the opportunities, challenges, and recommendations that are the result of the ACI (Affordable Comfort, Inc.) Summit “Moving Existing Homes Toward Carbon Neutrality,” July 11 - 13, 2007 and discussions stimulated by that event. The following key points have emerged: (1) Deep energy reductions (70–90%) are achievable now, but full scale implementation will benefit from technical innovations and institutional partnerships; (2) Achieving deep energy reductions requires re-evaluating current assumptions about the potential for reducing energy use in existing homes. 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; (3) Occupant behavior and lifestyle change can either help to make deep energy reductions possible or unachievable; and (4) 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.

EXECUTIVE SUMMARY

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% to 90% reduction in total energy use—in existing single-family and multifamily dwellings. These levels of reductions are achievable now through a combination of technical interventions and behavioral choices. While not all homes will be good candidates for deep energy reductions, we propose that the deep energy reduction paradigm can and should provide the framework for viewing energy and carbon reductions at a household, program, and policy level. Indeed, the increased awareness of climate change's likely impacts makes it compelling to adopt deep energy reductions as the new anchor by which we develop policy and invest resources. Properly implemented, the deep energy reduction paradigm offers the potential for reduced energy vulnerability and environmental impact both at a national level and at the level of an individual dwelling, while enhancing a building's comfort, indoor air quality, and durability.

The technology for achieving ambitious reductions largely exists, but the essential knowledge is fragmented. Different retrofit strategies will be needed to address the variability in climate, housing types, and lifestyles. Technical innovations and institutional partnerships are necessary for full-scale implementation of these retrofits. Transforming the physical and institutional infrastructure to support rather than to threaten global, community, and household sustainability is a challenging and urgent task.

Residential Sector: Huge Infrastructure, Large Opportunity

The residential sector accounts for 21% of U.S. energy use and carbon emissions. There are 124 million households in the U.S. and 13 million in Canada. Existing homes simultaneously represent a tremendous investment of resources and a commitment to maintenance and operating costs for years to come. The median age of U.S. housing is 34 years, and roughly 60% of these homes will still be occupied in 2050. The majority of these homes are wasting energy. In 2006, $228 billion were invested in U.S. home improvements—improvements that often could have included deep energy reductions. This level of investment indicates that both the resources and the opportunities exist for achieving deep energy reductions. However, significant improvements in residential building codes, code enforcement, commissioning, education, and incentives are needed before the majority of remodeled, and even new homes will no longer be immediate candidates for additional energy improvements.

Deep energy reductions are achieved by a combination of energy efficiency, energy conservation—which depends on occupants' behavioral choices and lifestyle, community solutions, and renewables. While there are major efforts to stimulate renewable energy technology, there have not been comparable efforts in North America to address deep reductions through efficiency improvements in existing homes. Yet, efficiency investments often have a lower cost per kWh saved than the same investment in photovoltaics. We recommend a substantial immediate effort to develop comprehensive strategies that:

- Start by assuming that zero net energy and carbon neutrality is achievable in existing homes;

- Optimize the investment in conservation, efficiency, community solutions, and renewable energy sources;
- Accurately value the energy and non-energy benefits of deep energy reductions; and
- Identify opportunities to reduce the costs of a deep energy reduction package.

New Paradigm

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. For example, rather than addressing the many problems of forced air distribution systems, a better option may be to eliminate the need for a conventional central heating or cooling system. In many climates, the best technical strategy for low-energy homes is the combination of a very well insulated and tight building enclosure, a small, integrated space-and-water-heating systems, and heat-recovery ventilation.

Energy reductions are limited when you address the efficiency of each end use independently and fail to ask the fundamental question "*What do we really need to live well?*" We need to go back to the principles of creating comfortable living spaces and find ways to satisfy these requirements as simply and effectively as possible, with the ultimate goal of achieving net zero energy and carbon neutrality.

Costs and Non-Energy Benefits

Achieving deep energy reductions in existing homes is more challenging and often more expensive than in new construction. To make deep energy reductions more practical and less costly, it is critical to, as Amory Lovins suggests, "tunnel through" the cost barrier. He cites two key ways to do this: an integrative design approach that produces multiple benefits from single expenditures, and coordination with retrofits being done anyway.

While this approach will bring down the costs for individual homeowners, the multiple benefits that result from investments in efficiency retrofits need to be viewed from a broader perspective than just energy reductions for the occupant. These investments also benefit the utility, the community, and the larger society. Because the cost 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 lower utility costs and greenhouse gas emissions, deep energy reductions provide the following benefits:

1. Buffer and protect occupants from outdoor temperature extremes that occur during power outages and/or severe weather events and from potential future spikes in energy prices.
2. Maintain and build on embodied energy and resources already invested in homes.
3. Improve housing quality by increasing building durability, improving indoor air quality, increasing comfort, correcting health and safety problems, and reducing noise and pests.
4. Increase the impact of investment in renewables by making it easier to satisfy a home's remaining reduced energy demands.
5. Shift investment and / or spending to products and services with greater local economic benefit.

6. Reinforce voluntary lifestyle choices through the aggregation of benefits and occupant feedback.
7. Reduce the cost of home ownership and increase home affordability.
8. Stimulate product development and deployment that can benefit the remainder of the residential and small commercial sectors.
9. Enable occupants to enhance their reliance and reduce their personal energy use and carbon footprint through both household and community solutions.
10. Ease strain on energy supplies and distribution networks and help to make the U.S. and Canada more energy-independent with reduced energy-related pressures.

Current Actions

- The pilot phase of the Thousand Home Challenge has been launched to demonstrate the feasibility and methods of achieving deep energy reductions in existing homes in diverse North American climates and housing stock.
- A consensus process is underway to establish indicators of performance for defining deep energy reductions in existing homes based on actual energy use.
- A guidance document for deep energy reduction in North America is being developed to support the Thousand Home Challenge.

Recommended Next Steps

Recommendations to lay the foundation and accelerate implementation of deep energy reductions include:

- Convene follow-up events to stimulate information exchange on deep energy reductions in existing homes.
- Support research and monitoring to assess the field performance of technologies, systems, and projects, as well as to increase our ability to model deep energy reductions in existing homes.
- Support contractors, remodelers, designers, and homeowners by developing regional guides and protocols for deep energy reductions.
- Create a green collar workforce development initiative.
- Stimulate and support the research, development, and deployment of products and systems that are an integral part of deep energy reductions.
- Support efforts to convey the potential for occupant behavior lifestyle choices to impact residential energy use and environmental impact with comprehensive campaigns, as well as local efforts that provide positive and concrete messages, initiatives, feedback systems, and case studies.
- Develop tools that make it possible to quantify the benefits of deep energy reductions from a societal, community, and household level.
- Support the development of new organizational systems needed to deliver, package, aggregate, and track the performance of deep energy reductions.
- Influence energy efficiency, green, and carbon emission reduction initiatives and policies so that they support rather than conflict with the deep energy reduction paradigm.

Our nations have met great challenges before, marshalling the courage, commitment, and creativity needed to meet and exceed seemingly impossible goals. We now need to confront the challenge of achieving deep energy reductions in our existing homes. 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.

We have the means; we must summon the will.

CRISIS OF OBSOLESENCE

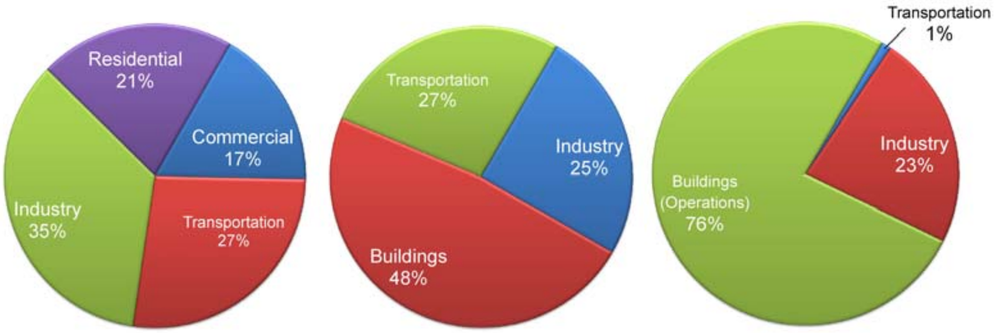
Housing and Energy: Opportunity and Challenge

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 (CPUC 2008; Wilson & Wendt; DENA 2008; Steinmüller 2008a). Transforming the physical and institutional infrastructure to support rather than threaten global, regional, community, and household sustainability is a daunting task. Deep energy reductions in existing buildings that could approach the factor of 10 are possible through a combination of system-level efficiency improvements and behavioral choices. The issue is not whether deep energy reductions are necessary, but how to define and support this vision.

There are 124 million households 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 that will be present in 2050 are in existence today (BEDB 2007). 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 (BEDB 2007).

The amount of energy used and greenhouse gases emitted by the U.S. and Canada is badly out of proportion to our population and not sustainable in absolute quantity or rate of growth. The U.S. accounts for 5% of the world's population but consumes 25% of fossil fuels produced each year (Bartlett 2006). The residential sector represents 21% of U.S. energy consumption and an equal percentage of greenhouse gas production. By comparison, U.S. automobiles contribute 20% of the green house gas emissions. Existing homes have a large impact on energy use and our carbon footprint; 21.1 quads of energy and 1254 million metric tons of CO_2 (BEDB 2007). Seventy percent of the CO_2 emissions from the residential sector are from electricity; thirty percent are from the direct use of fossil fuels. Of the worldwide CO_2 emissions that result from building operation, the contribution from U.S. buildings (with only 5% of the world's population) is 42% (BEDB 2007).

Figure 1, 2, and 3. U.S. Energy Consumption (left, middle) and Electricity Consumption (right)[1]



Even if we achieved a twenty, thirty, or fifty percent reduction in residential energy usage in North America most households would still be using drastically more energy per capita than the world average, and generating more greenhouse gas (GHG) emissions than the earth's carrying capacity. To achieve reductions in GHG emissions called for by cities, states, and regions by 2015, 2020, and 2030[2] (CPUC 2008: City of Chicago 2008) we must exceed 30 to 50% reductions in many homes. By doing so we can compensate for homes where barriers to reduction are significant, population growth, and the increase in number of households.

Deep energy reductions in existing buildings that could approach the factor of 10 are possible through a combination of system-level efficiency improvements and behavioral choices.

Four Flawed Assumptions

The assumptions that are woven into how we design, construct, finance, maintain, operate, insure, 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 (Bartlett 2003; Heinberg 2007; Hunt 2008). In many regions of the U.S., potable water supplies are becoming less certain and more costly[3]. Our energy using buildings, habits, equipment, and systems reflect our long-standing perception of the apparently infinite abundance of low cost energy.

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 et al. 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

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[1] Source: www.architecture2030.org/current_situation/building_sector.html

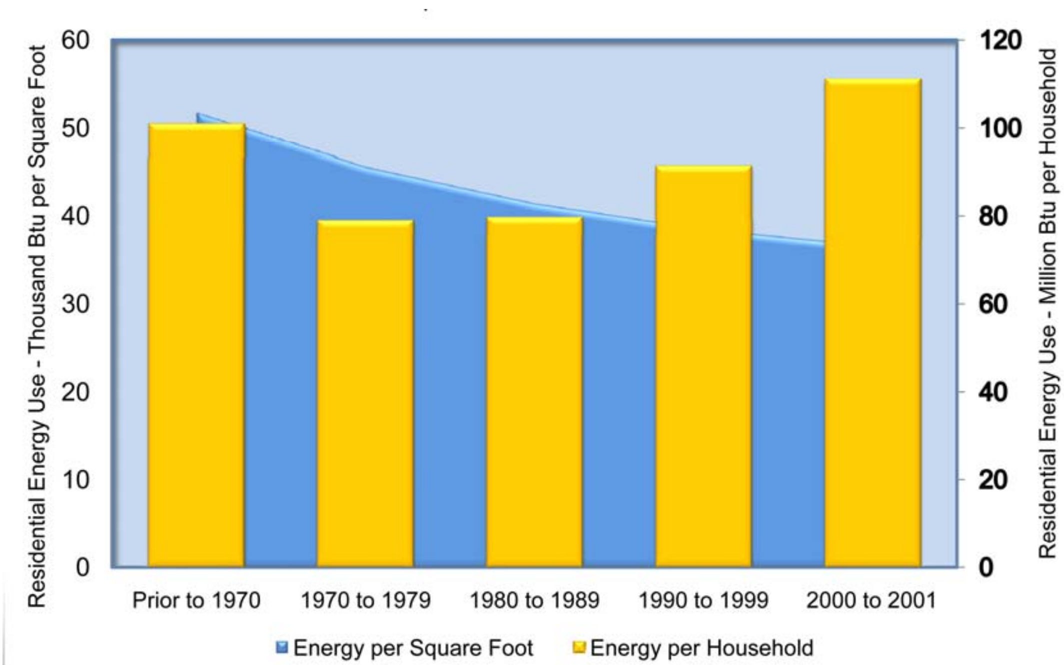
[2] For example, The California CPUC's goal for the existing residential sector is 20% by 2015 and 40% by 2020 (CPUC 2008). The City of Chicago released its plan September 18, 2008 calling for a 25% reduction from their baseline of 1990f (City of Chicago 2008).

[3] The link between water and energy has often 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).

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.

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 4, the average energy consumption per household in new housing is greater than the average energy use of existing homes (BEDB 2007; NREL 2006).

Figure 4. Residential Site Energy[4] By Vintage - Per Square Foot and Per Household[5]



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 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.

[4] 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. Site energy is also referred to a delivered energy. Source energy is also referred to as primary energy.
[5] Source: BEDB, 2007 Building Energy Data Book 1.2.5.

To begin to address the faulty assumptions outlined above, we need a comprehensive strategy that transforms rather than just making incremental improvements to our housing stock. This transformation needs to embrace a blend of technical improvements and behavioral changes that will begin to mobilize citizens, communities, institutions, and government.

The challenges and barriers represented by the residential 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 EMERGING PARADIGM

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.

One hundred persons in attendance from the United States, Canada, and Europe represented nonprofit organizations, utility companies, ESCOs, consultants, designers, contractors, national research laboratories, foundations, product manufacturers, publishers, research institutions, and local, state, and federal governments.

The Summit focused on reducing housing energy consumption regardless of its source. Though greenhouse gas emissions can be best reduced by reducing the use of fossil fuels, reducing any utility-provided energy (including hydro, geothermal, nuclear, and renewables) has the potential to offset the consumption of carbon-based fuels elsewhere. The Summit process, objectives, participants, and summary of Summit work groups are summarized in Appendix A, B, and C.

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[6] and Carbon Neutrality is Achievable within Existing Homes

Early efforts to demonstrate significant reductions in heating loads of existing homes through superinsulation were pioneered in the U.S. and Canada in the 1980's (Marshall & Argue 1981; 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%[7] (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 the pre-existing systems is minimized and an energy rating of the home prior to retrofit may be an unnecessary expense. The energy-related work scope may have more in common with new construction than with a traditional energy efficiency 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 (13,948/Btu/ft^2)[8] (Steinmüller 2008b), less than half of the code 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. By mid 2007, 1300 owners had applied to participate (DENA 2008). Both the experience and product innovation gained from the Passive House[9] experience contributed to the Efficient Homes Project's success.

Reducing the heating and hot water loads alone will not achieve a 70–90% reduction. In the United States, these loads account for less than half of the average primary residential energy

[6] A net zero energy home 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 renewables, net zero energy is achievable.
[7] 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.
[8] For comparison, the U.S. average residential source energy use for space and water heating is 36,590 Btu/ft^2 (BEDB 2007 1.2.3).
[9] www.PassiveHouse.de

use. We lack case studies that have brought all of the elements of deep reductions together in homes across North America, 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 released by the Canadian Mortgage Housing Corporation (Henderson & Mattock 2008) 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%. 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. Typically newly constructed, 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 citizen 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[10], 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).

A retrofit case study of a nine 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%[11]. 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 70% 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.

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

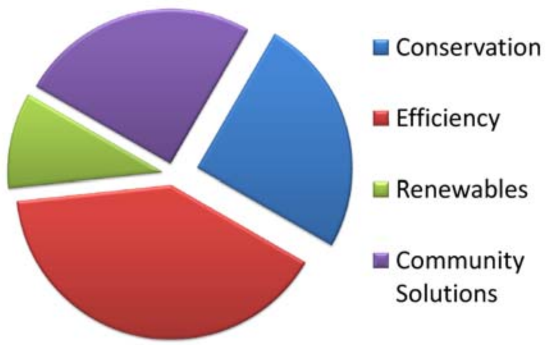
[11] Based on 4 year pre treatment consumption and 1 year post data. The home also changed occupancy. Post consumption was not weather normalized. There was an estimated 10–20% cooling performance penalty though participation in a peak load control "precooling program." The installed cooling demand was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

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.

Figure 5 Optimize Investment[12]



One failure of a simple payback analysis is that the life of efficiency measures 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.

As an example, 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[13].

[12] Wigington 2008b

[13] On a household level, loads vary tremendously, thermal comfort is estimated to be 25-80% 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 (BEDB 2007, Table 1.2.3).

Table 1. Many Paths To Thermal Comfort[14]

	Community Solutions	Behavioral Choices	Technical Fix – higher cost	Technical Fix – lower cost	On-Site Renewables
Range -% Reduction[15]	**20–70%**	**10–90%**	**30–85%**	**5–80%**	**10–110%**
Thermal comfort accounts for 25-80% of the residential energy use per household Options to reduce the energy use per person 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, and 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, and 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 Use of biofuel generated through sustainable processes

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

Achieving deep energy reductions in existing homes is more challenging than in new construction. Efforts to achieve deep energy reductions should be viewed within the constellation of benefits at the societal, community, and household levels so greater investment is justified. Because the cost 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 lower utility costs and greenhouse gas emissions, deep energy reductions provide the following benefits:

[14] 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.
[15] This percentage relates just to the reduction of the thermal comfort load. While the largest percentage reductions may be more possible in cooling-dominated or moderate climates than cold climates, larger absolute savings result when preconsumption is highest.

1. Buffer and protect occupants from outdoor temperature extremes that occur during power outages and/or severe weather events and from potential future spikes in energy prices.
2. Maintain and build on embodied energy and resources already invested in homes.
3. Improve housing quality by increasing building durability, improving indoor air quality, increasing comfort, correcting health and safety problems, and reducing noise and pests.
4. Increase the impact of investment in renewables by making it easier to satisfy a home's remaining reduced energy demands.
5. Shift investment and / or spending to products and services with greater local economic benefit.
6. Reinforce voluntary lifestyle choices through the aggregation of benefits and occupant feedback.
7. Reduce the cost of home ownership and increase home affordability.
8. Stimulate product development and deployment that can benefit the remainder of the residential and small commercial sectors.
9. Enable occupants to enhance their reliance and reduce their personal energy use and carbon footprint.
10. Ease strain on energy supplies and distribution networks and help to make the U.S. and Canada more energy-independent with reduced energy-related pressures.

In existing homes there is an added complexity due to the fragmentation of our thought process, technical systems, institutions, and policy in response to energy, housing, and the environment. In many instances you cannot make a case for the investment needed to achieve deep energy reductions based on the occupants' known reductions in energy expenditures. From a conventional economic standpoint the optimal investment may be shallower. It is only when the recognition of our flawed assumptions and the need for a transformation of energy use is combined with the non energy benefits on the household, community, regional, federal, and world levels that the case and imperative is clear. Ironically, with a more substantial investment, it is possible to leap over the barriers, rather than confront challenges on a customized piece meal approach. A deeper investment has the potential to simplify the technical processes and result in integrated systems capable of rapid deployment.

New approaches and initiatives are needed to demonstrate the synergies and benefits and catalyze the investment from stakeholders involved with the following issues:

- Water reuse and conservation
- Economic and community development
- Green collar job creation
- Improved indoor air quality (IAQ), reduced allergens
- Fire, earthquake, and storm resistance; increased adaptability
- Passive survivability
- Housing affordability and household financial security
- Home automation, home security
- Reduced household pests / critters (source of disease, toxin exposure and allergens)
- Sound insulation (airports – highways)
- Reduced pollution and green house gas emissions
- Improved economic security through decreased reliance on imported energy

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 (Lovins, 2007).

Without a guiding vision for deep reductions, both comprehensive projects and incremental improvements will fall short of their potential. As a result it will be more difficult and expensive to achieve deep energy reductions in the future. 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.

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.

ENERGY REDUCTIONS IN EXISTING HOMES

We need immediate action to demonstrate the practicality of significant reductions in energy use, to evaluate and refine the systems, to accelerate product development, and to build the human capacity to make the improvements. Some energy using products, such as appliances and home electronics, are relatively simple to replace with more efficient models. On the other hand, homes operate as complex systems and comprehensive solutions are needed. Well-intentioned singular efforts, such as replacing the heating system without properly sizing and delivering conditioned air to the living space, ignore house interactions that can negatively impact durability, combustion safety, and/or indoor air quality. Isolated improvements also miss the opportunity to achieve positive synergy. When replacing a central air conditioner, a smaller one can be installed if the insulation and air tightness is improved and solar gain through windows addressed. It may be possible to eliminate a conventional central system altogether.

Since short-term improvements can make it more difficult or expensive to achieve long-lasting deep reductions in energy use, it becomes critical that programs and policies include metrics and methodology sufficient to express the true cost (by true cost we mean the total societal cost of producing, transporting, and consuming energy resources).

Energy reduction renovations can be variously expensive and also variously effective in reducing electrical and heating use. Danny Parker's ACI Summit address (Parker 2007) included the following example:

Retrofit Type	Cost per home	Savings kWh/yr	Savings Therms/yr
Low-hanging fruit	$ 1,500	1,000	100
Extensive Retrofit	$10,000	4,000	400
Deep Retrofit	$50,000	7,000	600
Deep Retrofit + 3 kW PV	$75,000	7,000 + 4,300	600

The question, "Can we afford to invest in measures that could be obsolete in one or five years…or that are already obsolete depending on one's assumptions?" surfaced as a key challenge.

Existing homes represent a challenging sector but have a simultaneously huge potential for energy efficiency. The traditional approach to energy savings opportunities has been viewed from a short-term economic perspective. Given finite resources to invest, logically a home owner or program would examine the opportunities, assess their cost and energy savings, and select those with either the best payback or the highest return on investment. With this traditional paradigm, the higher the investment, the lower the returns, with a decreasing cost-effectiveness. To make a case for deep energy reductions it is critical to break through the cost barrier. To do this the synergy between actions must be considered. 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.

Efficiency efforts focus on meeting household loads with more efficient building materials (e.g., insulation), components (e.g., windows), and equipment (e.g., appliances). Conservation efforts focus on reducing loads, or the amount of energy needed to live in the house, and depend largely on occupant behavior, preferences, and lifestyle choices. However, any and all energy reduction strategies are directly tied to human behavior in that any self-driven reduction in energy use is dependent upon occupant action -- be it a one-time decision to replace an inefficient appliance or a decision to consistently change daily behaviors. Nothing short of a worldview would lead to the 70–90% levels of deep reduction being proposed.

The potential for drastically reducing energy use of existing homes is huge, but so are the challenges. Reducing total energy consumption by an order of magnitude requires nothing short of a paradigm shift in our commitment to and understanding of what reductions are achievable and how they can be achieved.

A critical first step is to recognize that to be successful, efforts to reduce energy use must incorporate a systems approach. This approach is based on the understanding that changes that affect energy use have the potential to positively or negatively impact moisture, building durability, combustion safety, and indoor air quality.

The Systems Approach To Deep Energy Reductions

In housing we have discovered that moisture and mold problems, combustion spillage, and indoor air pollution can only be addressed by the systems approach, whereas the component by component approach of old did not work. With all of these problems, the interactions between components of the house were very important, but were not always obvious when we looked at one component or area at a time. For example, while the moisture problem may have seemed worse in the bedroom of a sick child, it often started either outside or in the basement/crawl space. Combustion spillage problems in the utility room were sometimes caused by the powerful new kitchen range hood. Changing a natural draft furnace to a high-efficiency one, without introducing controlled, low-rate ventilation, often resulted in the build-up of pollution indoors that was worse than the occasional spillage problem from that furnace. All these were system problems and they were much more easily identified when the systems approach was used.

To produce deep energy reductions we have to do what Hunter and Amory Lovins did when they built their first ultra-low energy use building in Snowmass, Colorado. They took the mental leap to a view of a building that would use very little energy, by processes that they had not yet determined, and then went from that visualized endpoint to determining what individual components would have to be like and how they would have to perform. This produced a whole new paradigm to address the problem, one that would never have occurred if only incremental changes were envisioned. There would be no huge heating or cooling system; it would not be needed. Therefore, of course, there could not be large heat losses through the envelope nor heat gains through windows. With a little effort, they found that those performance goals could be achieved. Air could not be permitted to leak readily through the envelope, so airtightness was mandatory. They found ways to make walls and ceilings airtight. Ventilation was needed, but passive approaches were developed that could do the job (Since then we have developed low-energy-use mechanical systems that can also do the job, although passive ventilation works well in some climates and buildings. We can even do better, if we learn more about small-motor system performance issues.). Interactions between components were important to the successful operation of the building as a whole; they were found and addressed. They ended up with a successful building that used very little energy but was a joy to live and work in; quite an accomplishment.

To dramatically reduce the energy use in our existing housing we must make a similar leap of imagination, make similar evaluations of whole building performance, and then do the renovation to suit the building in question. This will be challenging at first, but will produce great rewards in both energy use reduction and in building performance and occupant satisfaction. The important point here is that the approach to the energy use reductions improves the overall house performance; it does not degrade it as incremental changes have done in the past.

The renovated, deep energy reduction house will have to meet all real needs of the occupants, and address all interactions between components, environments and processes. The renovation must ensure that heat losses and air leakage are low, but that moisture that gets into the structure can quickly get out again before damage is done. When heat flows are large we can sometimes move lots of moisture with little damage; that is not possible in low-energy-use buildings. Techniques that do not meet these requirements will not be used, even if they have been used before and met historical code and standard requirements. The heating and cooling systems will be small, if not miniscule. These systems will be efficient and they will not significantly pollute the indoor or outdoor air. In damp regions or local areas, moisture in outdoor air will be addressed before it can cause structural damage or indoor air comfort and quality problems. If soils are prone to wetness, waterproofing will be used, not just damp-proofing. Surface water will be dealt with properly, not ignored. The existing construction, climate, use and other factors will make significant demands on what can and should be done in any renovation.

Obviously some of the above actions are not practiced in conventional housing, not even in some of our present low-energy-use new housing, but the systems approach defines what must be done for a renovated housing unit to meet all needs, and then defines ways that those needs can be met.

If the systems approach is properly developed for deep energy use reductions, it can succeed. An important task will be to determine which existing or evolving techniques and products can be used and which cannot, if the renovation is to be successful. Renovated houses that fail to meet real needs could give the whole movement a black eye.

Note that it will likely be necessary to measure how well we have performed new and critical tasks; perhaps even tried and true ones. Some techniques for inspection and performance determination already exist. Others may be needed. Proper inspection should never be a major cost of building or renovating, but, nevertheless, will be necessary. A few percent of the value of the renovation, spent as insurance of proper performance, is well worth spending.

Challenges Posed by the Existing Housing Sector

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 impacts 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[16] 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.

Four Paradigms

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 and 4) the emerging deep energy reduction paradigm.

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 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

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 5–35%. 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.

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

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 Emerging 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.

HOW DO WE GET FROM HERE TO THERE?

Three Implementation Paths

Efforts to achieve deep energy reductions fall into three very different implementation paths. The first one, "All at Once" involves a one shot comprehensive project, logically building on a remodel, renovation, or home improvement. The key question for this 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?"

The second path "Phased" is characterized by a deep energy reduction project being deployed in stages over a period of years. Two key questions for this 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?"

The third path, "Creative" is characterized by community and lifestyle solutions in response to major physical or financial barriers to investment in technical improvements at the household level Key questions for this path include "How can we achieve new communities within our existing infrastructure that transform our liabilities into assets? "How can we combine the strength of housing and energy traditions and adaptation to respond to our needs and wants in order to create solutions that are compelling and do not involve perceived sacrifice?" Deep reductions could be achieved with optimized investment in community energy production and use systems combined with a lower investment in individual homes.

Key opportunities for intervention include:

- homeowner seeking to reduce carbon footprint;
- replacement of major components (roofing, siding, mechanical systems);
- renovation (addition or remodel);
- community-based global warming campaigns;
- home sale;
- homeowner seeking to resolve problems (comfort / IAQ);
- actions taken to address non-energy activities such as lead / noise abatement, radon mitigation;

- annual maintenance;
- energy efficiency, environmental, or green program intervention.

A cornerstone of the whole-house systems approach is that optimizing thermal characteristics of the enclosure (the home's outside walls, doors, attic or roof, floor and foundation) allows significant downsizing of space conditioning equipment. It is often more cost-effective to make substantial improvements at the time of replacement or home renovation. However, these major components, such as roofing, siding, and windows, have longer lifetimes and are not replaced as often as HVAC equipment and appliances. The challenge in existing homes is to maximize improvements as opportunities present themselves, while maintaining a focus on long-term enhancements, so the potential for deep energy reductions is not compromised by short-term incremental improvements.

Our understanding of systems needed to achieve deep energy reductions is not static. A strong emphasis on rapid feedback and verification can accelerate the learning curve, fine tune the climate-specific applications, and verify that the intended results are being achieved and maintained. As new innovations and technical systems are developed the potential for broader applications at lower costs emerge. It is also likely that new strategies for achieving deep energy reductions will occur as we further develop our understanding.

Guiding Principles to Deep Energy Reductions

While many strategies can be used to achieve deep energy reductions, universal principles are emerging. To summarize, they are:

1. A systems approach is necessary to optimize site and off-site benefits and interactions;
2. Good indoor air quality and building durability are integral elements;
3. Performance must be verified with a combination of diagnostic equipment and actual measurement (both energy use and other benefits);
4. Occupant behavior and lifestyle are an integral part of a deep reduction strategy;
5. Even if the investment of resources is made at a single point in time ("All at Once"), deep energy reductions should be viewed as an ongoing process, as building systems need to be properly maintained and operated; and,
6. In some cases, the trigger event that makes it possible to achieve optimum results may only appear every 20 or 50 years as major systems are replaced or renovations made. Processes need to be in place that enable us to intervene and optimize energy reduction and cost savings during these opportunities.

The systems approach considers and optimizes the interactions between home energy use, combustion safety, physical durability, indoor air quality, and occupant safety and health. It also emphasizes the importance of quality installation of building materials and systems, and performance measurement and verification. The systems approach is necessary to prevent adverse side effects, such as creating combustion safety hazards or other indoor air quality problems as a result of air sealing, while capturing multiple benefits, such as solving existing problems related to infiltration, moisture, lead, or radon.

Another cornerstone of a systems approach to home performance is the use of diagnostic tools and techniques, which include measuring building enclosure leakage area, duct leakage and delivered fan flows. In existing homes, diagnostic testing is used not only to verify post-retrofit conditions and performance, but may also help to identify existing problems that need to be fixed during the retrofit.

However, it may be easier to eliminate (rather than fix) many problems typically found in existing homes by specifying several fundamental building changes that are consistent with high performance homes. For example, replacing open combustion with a combination of sealed combustion appliances and balanced heat recovery mechanical ventilation, or moving ductwork into the conditioned space, eliminate many of the potential problems that are addressed, and can complicate a traditional home performance job. Whole house deep efficiency strategies have the potential to simplify and remove the uncertainty from the retrofit process.

Site Assessment Process - Nine Steps To Deep Reductions

The following steps, listed in order of priority—but not necessarily in order of sequence—provide a framework for assessing and implementing a deep energy reduction for a specific dwelling. This process can be used to help define priorities or clarify whether interim measures support the achievement of deep reductions or make it more difficult.

Step 1 - Assess Needs, Site, Goals, and Use of Space

This step is centered on the occupants, their use of space, and the house. What are the occupants' goals, needs, and priorities? These could include affordability, allergen reduction, sustainability, carbon neutrality, security, adaptability, passive survivability, safety, comfort, and more. What challenges and opportunities do the house and community provide? Does the dwelling have solar access or other renewable options? Are radon, asbestos, vermiculite, or lead based paint risks that need to be considered? Are there opportunities to incorporate water reuse, rainwater capture, and to minimize the impact of basement flooding in the event of a deluge? Step 1 provides an opportunity to clarify energy benefits beyond site boundaries. Air pollution, energy supply, utility rate structures, electrical capacity, supply, incentives and rates may influence decisions at the local level. Two homes in similar climates may have different technical solutions as a result of differing regional and local priorities.

Step 2 - Optimize Enclosure to Reduce Heating and Cooling Loads

The goal of Step 2 is to reduce the heating and cooling loads through a combination of air-sealing, insulation, shading, and window treatments. The higher the R-value of insulation, the more critical it is to address thermal bridging[17]. Minimizing summertime solar heat gain can limit electrical peak loads driven by air conditioning. If windows are being replaced, there is an opportunity to change window areas to maximize passive heating, minimize summertime solar gain, and optimize natural ventilation. Keeping thermal distribution systems within the thermal boundaries is important to achieve house tightness, minimize air handler-induced house pressure differences, and to optimize distribution efficiency.

[17] Thermal bridging refers to the heat loss from a thermal short circuit through the structure or framing of windows and doors, etc. In a wood frame building the heat loss through the studs (framing) can contribute as much to heat loss as the rest of the insulated wall area. In addition to heat loss, thermal bridging contributes to cold interior surfaces in the wintertime that may be sources of condensatio

Step 3 - Minimize Internal Loads (Lighting, Appliances, Electronics)

Although these improvements usually have shorter life expectancies than the building enclosure or mechanical equipment, they have a significant effect on the peak electric demand and heating and cooling loads and can add up to a large annual energy component. Load reduction is achieved by new technology, careful operation and occupant understanding and feedback. Shifts in patterns of consumption represent an unknown that is largely driven by occupant knowledge, preference and behavior. Energy use is a function of the device's size and efficiency, the manner in which it is operated, and how long it is used.

Step 4 - Provide Fresh Air

Even in mild climates, an intentional, distributed, efficient supply of outdoor air for ventilation is essential because there will be times when occupants do not open windows or ventilation rates are poor, even when windows are open. Ventilation strategies vary depending on the climate. Control of indoor moisture, IAQ pollutants, and the exclusion of soil gasses or pollutants from an attached garage, basement, or crawlspace should be considered during the ventilation system design. Control of indoor moisture and exclusion of soil gasses should be considered during ventilation system design.

Step 5 - Control Humidity

Summertime humidity is often a source of discomfort. High humidity also contributes to allergens, mold, poor indoor air quality, and structural deterioration. Tightening the home and using a mechanical ventilation system is one way to minimize indoor humidity during the summer. It is also important to control indoor sources of moisture. Controlling summertime humidity may eliminate the need for a conventional air conditioning system. Development of more efficient and effective dehumidification strategies is a priority and a short-term possibility.

Step 6 - Determine Cooling Needs

Greatly reduced cooling loads provide the opportunity for non-conventional cooling strategies, and in many climates mechanical cooling can be eliminated. Humidity control can eliminate or minimize the need for cooling. Providing cooling with minimal impact on peak loads increases a home's adaptability over time. Ironically, with a very efficient building enclosure, the effect of internal gains from lighting, appliances, and plug loads is sometimes significantly greater than gains from outdoor sources. The determination of the need for mechanical cooling can impact the decision regarding the optimum heating system.

Step 7 - Determine Heating Needs

With greatly reduced heating loads, and distributed ventilation air, it is possible to eliminate a central heating system in many climates. Heating loads may be met with internal loads, a point source of heat, such as a ductless heat pump, supplemented with a solar thermal system. The lower the load, the harder it is to justify a $10,000 - $20,000 investment in an extremely efficient heating system. Though electric resistance heat is the most flexible, it has low source efficiency (33%), unless it is from an on-site source, and is often associated with a high carbon generation source.

Step 8 - Integrate Hot Water with Other Loads

In energy efficient homes, water heating may be the dominant load. In many cases, the same equipment can provide both space heating and water heating. By combining two small loads it is possible to justify a higher investment and obtain higher efficiency. Consider heat pump technology, combined hydronic, solar, and heat recovery from other processes. Hot water loads can be minimized by addressing distribution losses and more efficient end uses. Significant energy use is embodied in the entire water supply and treatment cycle, so reducing water use also reduces energy used to treat and pump water.

Step 9 - Incorporate Verification, Feedback, and Evaluation

Careful design, best intentions, and good modeling results do not alleviate global climate change; real-world reductions in use do so, however. Deep home energy reductions must be verified through monitoring and utility bill analysis in order to verify that expected savings result. Monitoring systems can provide feedback to all involved, regarding temperature, humidity, and indoor air quality as well as energy use so that the building systems and their operation can be optimized. Measurement and verification are also a crucial aspect of learning from experiences, modifying our assumptions, and improving systems for achieving deep reductions.

From Demonstration to Mass Market

Deep energy reductions will only support the transformation needed if it is scalable and can address tens of thousands of homes within 10 years. We propose that it is. On the technical side, the development of compressive systems are needed – systems that function as packages, as widgets, in a sense that can be tested, verified, financed, and deployed. This simplifies the array of decisions needed addressing products, techniques and system integration. The task then is to select the package that fits the context, the needs and opportunities and house. Rather than blazing a new trail with a custom approach for every home seeking energy reductions we are creating roads that make it much easier for a home owner or contractor to reach the destination. These packages provide greater opportunity to achieve and aggregate both the energy and non-energy benefits.

What is needed related to behavior and lifestyle change is much different than whole house technical packages. Many folks are already following well defined paths to energy use that are driven by custom, social norms, and marketing of products. The examples provided by the 2001 California energy crisis, the Ontario ice storm that led to extensive power outages, and the recent experience in Juneau, Alaska demonstrate that we have tremendous opportunity to meet our needs in less energy consumptive ways. But how do we achieve the opportunity posed by reexamining our lifestyle assumptions without an urgent crises of cost or supply? How do we support and stimulate the process of self examination? We propose that clear indicators of performance that include actual total household energy use have the potential to support behavior change and lifestyle choices. Case studies that demonstrate both the enormous potential for technical improvements and lifestyle choices can illustrate the opportunity to drastically reduce energy use, energy cost, and environmental impact. For behavior change and investment to take place, we need that change in perception of what is possible. The Thousand Home Challenge will test this assumption.

THE THOUSAND HOME CHALLENGE

Given its unique role within the building science and home performance communities, Affordable Comfort, Inc. (ACI) is positioned to serve as a convener for a collaborative effort to achieve deep energy reductions (DER) in one thousand homes across the U.S. and Canada. Many North Americans are willing to act to slow global climate change and respond to rising energy prices, but we cannot reduce our collective carbon footprint to sustainable levels unless we boldly address the energy use of existing homes, which accounts for 21% of U.S. greenhouse gas emissions.

The Thousand Home Challenge (THC) is designed to:

- **Reduce** the total energy consumption of one thousand North American homes – specifically existing single-family and low-rise multifamily buildings – by 70–90%.
- **Develop** indicators of home energy performance that are measurable, easy to understand and use, and accommodate a wide range of climates, housing types, and fuels.
- **Exemplify** a performance-based 'systems' approach to improving the thermal comfort, health and safety, indoor air quality, energy efficiency, and affordability of existing homes.
- **Assemble** private, non profit, community, citizen, trade and professional associations, and government involvement into regional coalitions.
- **Demonstrate** that it is possible and potentially practical to achieve deep energy reductions through a combination of technical innovations, community-based solutions, behavioral choices, and renewable energy sources.
- **Stimulate** communication, collaboration, creative problem-solving, and innovative products and approaches to transforming our existing North American housing stock.

Thousand Home Challenge Timeline

UNDERWAY NOW
- Strategic Planning
- Confirmation of Sponsors and Stakeholders
- Development of Guidance Document (Review Draft – 9/30/08)
- Recruit Participants for Pilot (Fall 2008 – Spring 2009)

FULL LAUNCH (Summer 2009 – 2012)
- One thousand homes across North America
- Ongoing feedback, monitoring of results, and information dissemination

BEYOND THC - TARGETED COMMUNITIES / REGIONS (2011 on)
- Local and regional Thousand Home Challenges to demonstrate rapid deployment initially focusing where the greatest need, benefits, and resources exist

Thousand Home Challenge Process

In terms of product innovation and system integration, the THC has more in common with emerging efforts to achieve net zero energy in new construction than less aggressive residential energy efficiency efforts. Integrated design presents a huge opportunity for enhancing performance, reducing cost, and minimizing lost opportunities. Community and regionally-based mobilization offer a way to bring deep energy reductions to millions of North American homes.

Deep energy reductions will not overcome the cost, complexity, and implementation challenges if each house is addressed as a unique customized project. Much as with the BOPs (Builder Option Package) approach to new construction, a variety of verified packages are needed that demonstrate the optimization of systems to address energy, indoor air quality (IAQ), and durability issues. The THC offers the potential for many comprehensive house packages to be developed, refined, and tested in response to the specific challenges and opportunities. Deep energy reduction packages offer a way to bring integrated design to existing homes.

While custom projects are not discouraged, efforts will focus on stimulating projects with the highest potential for replication, by addressing common 'vintage" house styles such as the four square, post-war bungalow, ranch and split level homes, townhouses, and masonry row homes.

Throughout the THC, events will serve as catalysts to demonstrate the potential for deep reductions and to simultaneously develop broader consensus on strategies and system integration. During their renovation, projects can tap opportunities to expand the pool of leaders and train others in techniques specific to deep energy reductions. These events can also stimulate improvements in techniques and innovation.

The THC seeks to empower and stimulate regional centers of excellence. These coalitions will develop and customize solutions in response to their unique environmental and housing needs, micro climates, policies, and initiatives. They will support local projects and assist in building the professional, human, and organizational capacity needed.

In heating dominated climates, superinsulation is an integral part of achieving deep energy reductions. There are instances where physical, economic, and historic barriers to changing the thickness of walls are significant. The optimization of the existing structure, integration of mechanical systems, reduction of baseload, community solutions, behavioral choices, and incorporation of renewables can provide either transitional or permanent deep energy reductions.

The THC provides a way to incorporate behavioral choices within a larger framework that embraces energy efficiency, renewables, and community solutions. With unlimited financial resources, zero net energy is within reach of every North American dwelling. While that may be an option for some, a far greater opportunity is to achieve deep reductions by combining technical and community solutions with lifestyle choices that have the potential to reduce the cost substantially.

There will be a need to critically evaluate, learn from, and fine tune initial assumptions of the pilot phase while maintaining and building momentum. Risks include dilution or confusion about key principles. These could threaten a whole house approach that is based on the recognition that indoor air quality (IAQ) or durability problems can result as unintended side effects of energy-use-only reduction strategies. They could also include confusion with efforts that achieve significantly fewer benefits and / or that make false claims.

While the Thousand Home Challenge's scope is North America, it creates the model for Thousand Home Challenge spin-offs within cities and regions. With replicable house retrofit packages, centers of excellence, and strategies that incorporate training, feedback, and verification, the potential for accelerated deployment is achievable. While workforce development is a potential constraint, some aspects of DER projects are conducive to deploying a trained and supervised volunteer and do-it-yourself work force working in tandem with qualified contractors.

Thousand Home Challenge Key Elements

A) The Thousand Home Challenge Guidance Document

The purpose of the Thousand Home Challenge Guidance Document is to lay the foundation for participating in the pilot phase. The Guidance Document will support participation by clarifying the THC purpose, and defining what we mean by deep energy reductions and how attainment is measured. A representative stakeholder group will help ensure that the pilot and Thousand Home Challenge respond to diverse needs and interests as effectively as possible.

B) Training Trainers

Much of the knowledge and skills needed to achieve deep energy reductions in existing North American homes exists; however efforts have been limited to a handful of highly motivated homeowners or energy and housing professionals. There is a critical need to develop a cadre of trainers who can demonstrate and share information with others, building on techniques that have already been developed and overcoming implementation challenges. Train the Trainer activities are not intended to replicate current efforts to develop home performance professionals but rather focus strategically on innovative techniques and integration of systems.

C) Organize Regional Coalitions for the Pilot Phase

The pilot phase of the Thousand Home Challenge will begin in the fall of 2008 and transition into the full launch of the Thousand Home Challenge during the summer of 2009. Stakeholders will be encouraged to participate in the pilot by joining regional coalitions that facilitate the development of local or regional centers of excellence. The Centers could address climate and housing stock issues, thus stimulating local solutions. They could also provide training, access to resources, technical, and monitoring support. Of critical importance is the integration of deep energy reduction with efforts addressing energy efficiency, peak load reduction, and climate change.

Keeping Score and Defining Deep Energy Reductions

The most challenging and important task needed to support the Thousand Home Challenge is defining the criteria for projects based initially on the design intent and ultimately on actual energy use.

Developing metrics for use in the Thousand Home Challenge (THC) involves two major tasks. The first is to define the units of measurement that will be used to evaluate and compare home energy performance. The second is to determine the values of those units that constitute the THC's criteria. A process in underway to develop consensus. The guiding principle is to have thresholds for participation in the THC that are equally challenging across a variety of housing types, households, and climates, while not favoring any specific group. An absolute number, such as KBtu per square foot applied equally to all prospective participants would be biased towards large homes with few occupants in mild climates. Tens of thousands of homes could qualify with minimal effort while many households in very cold climates would not be able to meet the threshold without heroic effort and investment.

Metrics

The THC's fundamental metric, which will be required of all participating homes, is total annual household site energy consumption. Additional indicators of performance fall into two groups: those that are direct (i.e., measured) and those that are indirect (i.e., estimated).

In addition to total annual energy consumption, THC participants will also report the energy costs, finished floor area, and occupancy corresponding to the billing period.

The direct metrics are:

- total annual energy costs,
- total annual energy use per finished floor area (FFA),
- total annual energy use per resident, and
- peak summer and winter electric demand (if available from a demand meter or feedback device).

The indirect metrics are:

- total annual source energy consumption
- total annual energy use per heating and cooling degree day (HCDD, per FFA)
- total annual greenhouse gas emissions
- peak heating and cooling load (if estimated from load calculations or equipment ratings), and
- Home Energy Ratings or simulated performance estimates.

At this stage it is anticipated that only direct metrics will be used to determine minimum criteria for the Thousand Home Challenge.

Energy Performance Criteria for Participation

At least during its pilot phase, the THC will offer two different options for participation, each with a different performance goal, or criteria. Option A requires that a post-retrofit home's total annual site energy consumption be at least 75% less than it's pre-retrofit total annual site energy consumption (based on actual use, not modeled use). Using Option B, participants must meet a customized threshold for total annual site energy consumption based on home size, number of residents, and climate. This is the maximum allowable energy use, including wood, and excluding on site solar electric generation.

Having two options enables more homes to participate. Option A encourages larger, higher-consuming households to dramatically reduce their energy use, even if they cannot meet Option B's challenging performance criteria. Option B is appropriate for (a) homes without pre-retrofit consumption data, (b) participants committed to reducing energy use as much as possible, and (c) existing homes that are already very low energy users, which can serve as examples or case studies.

Participants are expected to indicate their design intent for a project in order to gain provisional acceptance. Official acceptance of a Thousand Home Challenge project will be given at the point when a minimum of one year of energy use verifies that the home meets the threshold for that particular household.

RECOMMENDATIONS and NEXT STEPS

ACI recommends the following actions to lay the foundation for and accelerate the implementation of deep energy reductions:

- Convene follow-up events to stimulate information exchange on deep energy reductions in existing homes.
- Support research and monitoring to assess the field performance of technologies, systems, and projects, as well as to increase our ability to model deep energy reductions in existing homes.
- Support contractors, remodelers, designers, and homeowners by developing regional guides and protocols for deep energy reductions.
- Create a green collar workforce development initiative and post secondary competition modeled after the Solar Decathlon but focused on existing homes.
- Stimulate and support the research, development, and deployment of products and systems that are an integral part of deep energy reductions.
- Support efforts to convey the potential for occupant behavior lifestyle choices to impact residential energy use and environmental impact with comprehensive campaigns, as well as local efforts that provide positive and concrete messages, initiatives, feedback systems, and case studies.
- Develop tools that make it possible to quantify the benefits of deep energy reductions from a societal, community, and household level.
- Support the development of new organizational systems needed to deliver, package, aggregate, and track the performance of deep energy reductions.
- Influence energy efficiency, green, and carbon emission reduction initiatives and policies so that they support rather than conflict with the deep energy reduction paradigm.

Specific recommendations for federal government, private sector and foundations, energy efficiency stakeholders, and local government are summarized in Appendix F.

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 to respond collaboratively to the challenges upon us.

APPENDIX A: THE ACI SUMMIT PROCESS

The ACI Summit focused on developing strategies for achieving deep energy reductions in existing single and multifamily homes throughout the U.S. and Canada. The term “deep energy reduction” was initially defined as reducing the energy consumption of a home by 70–90% from its current consumption.

The Summit focused on reducing energy consumption regardless of its source. Though greenhouse gas emissions can be best reduced by reducing the use of fossil fuels, reducing any utility-provided energy (including hydro, geothermal, nuclear, and renewables) has the potential to offset the consumption of carbon-based fuels elsewhere.

Summit objectives were to:

- Explore the opportunities, challenges, barriers, costs, and benefits of achieving deep energy savings in selected house types and diverse climatic regions of the United States and Canada by employing a combination of technical interventions and behavioral choices.
- Propose simple, transparent energy performance metrics that help to define and communicate residential energy use and its impact on the environment.
- Begin to identify the technical systems (products, applications, etc.) that can accelerate deployment and lower the cost of deep energy savings.
- Explore strategies for achieving deep energy reductions by incorporating both custom approaches and mass-produced systems.
- Explore the potential for alignment of current programs, initiatives, incentives, markets, and policies with the longer-term goal of deep energy reduction.
- Identify and catalyze the key steps needed to move forward individually and collaboratively.

The Summit specifically avoided discussion of these important and related issues in order to focus on reducing the energy loads attributable to the building and occupant activity within the building:

- carbon offsets and trading,
- onsite power generation (renewable energy),
- transportation energy used in commuting and delivering goods and services to homes,
- energy used in water supply and wastewater treatment systems,
- energy embodied in building materials,
- energy used in solid waste management,
- energy used in food production.

The Summit agenda consisted of whole group sessions, Working Group sessions, and informal networking sessions that included food and poster presentations. Whole group sessions provided a consistent context for all participants. John Krigger of Saturn Resources Management, Inc. and Danny Parker of the Florida Solar Energy Center made presentations during the opening session. After being recognized for their pioneering contribution to deep home energy reductions, Harold Orr, retired from Canada’s NRC, and Amory Lovins of Rocky Mountain Institute provided brief remarks.

The primary work of the Summit was conducted through Working Groups, which consisted of twenty Issue Groups and nine Scenario Groups. Issue Groups focused on specific topics (listed below and summarized in Appendix C) and Scenario Groups focused on how to achieve deep energy reductions in a specific house type in a given geographic location. Poster

Sessions were designed to give participants an opportunity to informally share deep home energy reduction case studies, key concepts, and strategic initiatives.

Whole group sessions and additional interviews were videotaped by Dave Robinson. John Krigger's and Danny Parker's presentations and some poster sessions are available at: http://www.affordablecomfort.org/event/aci_summit_moving_existing_homes_toward_carbon_neutrality

Below is a list of the Working Groups (both Issue and Scenario Groups) formed during the Summit:

Issue Group	Facilitator
Affordable Housing	Elizabeth Chant
Alignment with Current Initiatives, Programs, Markets	Charles Segerstrom
Audits & Related Consumer Information	Charles Segerstrom
Carbon	Rick Diamond
Consumer Behavior	Kindle Perry
Financing & Incentives	Elizabeth Chant
House Size per Person	Jane Thompson
HVAC & Water Heating	Keith Aldridge
Implementation & Infrastructure	Dennis Creech
Lighting, Appliances, & Plug Loads	Rana Belshe
Mechanical Ventilation & House Tightness	Courtney Moriarta
Metrics & Semantics	Keith Aldridge
Multifamily Issues	Kindle Perry
Passive Survivability	Rana Belshe
Product & Technical System Innovations	John Brooks Smith
Regulatory Issues, Insurance, & Codes	David Weitz
Verification, Monitoring, & Feedback Systems	Danny Parker
Wall & Roof Systems	Chris Dorsi
Windows, Doors, & Daylighting	Bill Burke
Workforce Development	Dennis Creech
Foundations: Basements, Crawl Spaces, & Slabs	Pat Heulman

Scenario Group	Facilitator
1980 Ranch on slab, Atlanta GA	Dennis Creech
1980 Ranch on slab, Phoenix AZ	Keith Aldridge
1980 Townhouse, Denver CO	John Krigger
1970 Ranch with crawlspace, Portland OR	Ann Edminster
1970 Ranch with basement, Minneapolis MN	Rana Belshe
1970 Ranch with garage, Albany NY	Charles Segerstrom
1950 One and a half story, Pittsburgh PA	Chris Dorsi
1920 Two story foursquare, Burlington VT	Kindle Perry
1900 Multifamily, New York City NY	Elizabeth Chant

APPENDIX B: ACI SUMMIT PARTICIPANTS, SPONSORS, and PARTNERS

Ninety-nine people from the United States, Canada and Germany participated in the ACI Summit. They represented various local, regional, and national nonprofit organizations; municipal, state, and federal governments; national laboratories; utility companies; residential architects, contractors and remodelers; building scientists, consultants, and educators; and product inventors, manufacturers, and distributors.

Linda Wigington of ACI initiated the Summit, served as whole group leader, and led the planning effort. Rick Diamond of Lawrence Berkeley National Laboratory (LBNL) facilitated all whole group sessions. Working groups were led by a team of facilitators who also provided input to the agenda and working group activities. Summit sponsors, partners, group facilitators and participants are listed below.

Sponsor organizations contributed financial and in-kind support to the Summit. Pacific Gas & Electric (PG&E) provided financial support as well as the Pacific Energy Center, where the Summit was held.

Partner organizations expressed commitment to the goal and objectives of the Summit and supported it though their attendance, contribution to planning efforts, and feedback to the white paper.

Sponsors

Name	**Organization**	**Representation**
Dave Hepinstall	Association for Energy Affordability	Implementation - Programs
Mary James	Home Energy Magazine	Print, online media
John Krigger	Saturn Resource Management Inc	Print, online media
David Lee*	U.S. Environmental Protection Agency	Federal Government
Li-Ling Young	Vermont Energy Investment Corp	Implementation - Programs
Richard Morgan	Austin Energy	Utility and Local Government
Charles Segerstrom	Pacific Gas & Electric	Utility
Brian Simmons	Fluid Market Strategies Inc	Implementation - Programs
Bradley Steele	Energy Federation Inc	Distributor
Dan Taddei	Natl Assoc. of the Remodeling Industry	Trade Organization - Remodelers
David Weitz	Conservation Services Group	Implementation - Programs

*Not in attendance

Partners

Name	**Organization**	**Representation**
Keith Aldridge	Advanced Energy	Implementation
Katherine Austin	AIA Housing & Residential Knowledge	Trade Organization - AIA
Steve Baden	Residential Energy Services Network	Trade Organization - HERS providers
Rana Belshe	Conservation Connection Consulting	Implementation
Cal Broomhead	San Francisco Dept of the Environment	Local Government
Rich Brown	Efficient Window Collaborative	Deployment
Dennis Creech	Southface Energy Institute	Implementation - Programs
Laverne Dalgleish	Building Performance Institute	Trade Group
Rick Diamond	Lawrence Berkeley National Laboratory	Energy Research
Ann Edminster	Design AVEnues	Implementation - Design
Katrin Klingenberg	Ecological Construction Laboratory	Implementation – Design
Paul Knight	City of Chicago, Dept of Environment	Local Government
Michael Little	City of Portland – Sustainability	Local Government
Courtney Moriarta	Steven Winter Associates	Research / Implementation
Eugene (Pat) Murphy	Community Solutions	Advocacy

Greg Nahn	Wisconsin Energy Conservation Corp	Implementation - Program
Danny Parker	Florida Solar Energy Center	Building Research
Bill Parlapiano	BP Consulting	Implementation - Consultant
Sean Penrith	Earth Advantage	Implementation - Programs
Patricia Plympton	DOE / Natl Renewable Energy Lab	Building Research / Deployment
Bill Rose	Building Research Council, Univ of IL	Building Research
Chris Scruton	California Energy Commission	State Government
Bill Semple	Canada Mortgage and Housing Corp	Federal Government - Research
John Brooks Smith	Johns Manville	Manufacturer
Marko Spiegel	Conservation Technology International	Implementation - Design
Aaron Townsend	Building Science Corporation	Building Research
Alecia Ward	Midwest Energy Efficiency Alliance	Advocacy
	Partners not in attendance:	
Terry Brennan	Camroden Associates	Building Research
Nils Petermann	Alliance to Save Energy	Research and Advocacy

Attendees (in addition to those listed above)

Name	Organization	State / Province
Dave Backen	Ecos Consulting	Oregon
Chris Benedict	Chris Benedict, R.A.	New York
Bill Burke	Pacific Gas & Electric	California
Dave Canny	Pacific Gas & Electric	California
Peter Chandler	Living Space	Colorado
Elizabeth Chant	CVOEO Weatherization	Vermont
Rick Cherry	Community Environmental Center	New York
Glenn Chinery	U.S. Environmental Protection Agency	Washington, DC
Rick Chitwood	Chitwood Energy Management	California
Larry Crowson	Bay Systems North America	Oregon
Chris Donatelli	Donatelli Castillo Builders	California
Chris Dorsi	Saturn Resource Management Inc	Montana
Eric Doub	Ecofutures Building	Colorado
Fred Ellis	Pacific Gas & Electric	California
Yael Gichon	City of Boulder – Office of Environment	Colorado
Henry Gifford	Architecture and Energy Affordability	New York
Charlie Gohman	Arizona Energy Office	Arizona
Matt Golden	Sustainable Spaces	California
Jeffrey Gordon	Building Research Council	Illinois
William Haas	Illinois Dept of Commerce	Illinois
Sharon Hanrahan	Energy Center of Wisconsin	Wisconsin
Bob Hendron,	NREL / Building America	Colorado
Nancy Hoeffer	Community Energy Services Corp	California
Robert Housh	Metropolitan Energy Center	Missouri
Pat Huelman	Cold Climate Housing, U. Minnesota	Minnesota
Peter Hurley	Portland Office of Sustainable Development	Oregon
Steve Kaloustian	Masco Corporation	Michigan
Michael Kamon	City of Aurora	Illinois
Rick Karg	RJ Karg Associates	Maine
Mike Kernagis	Ecological Construction Laboratory	Illinois
Larry Kinney	Synetech Systems	Colorado
Robert Knight	Bevilacqua-Knight Inc	California
Paul Knight	Domus PLUS	Illinois
Steve Kromer	Efficiency Evaluation Organization	California
Jim Larsen	Cardinal Glass Industries	Minnesota
James Lambach	Bayer Material Science	Pennsylvania
Mike LeBeau	Conservation Technologies	Minnesota
Keith Levenson	Vermont Energy Investment Corp	Vermont

Michael Little	Seattle City Light	Washington
Erin McCollum	(ACI) Affordable Comfort Inc	Pennsylvania
Joel Morrison	Penn State U. West Penn Power Sust Fund	Pennsylvania
David Murphy	The Community Solution	California
Harold Orr	Retired	Saskatchewan
Helen Perrine	(ACI) Affordable Comfort Inc	Pennsylvania
Kindle Perry	Energy Education Consultant	New York
Paul Raymer	Heyoka Systems	Massachusetts
Mike Rogers	GreenHomes	Vermont
Judy Roberson	Building Wise	California
Dave Robinson	Renaissance Total Comfort Systems	California
Carl Seville	Seville Consulting	Georgia
Richard Smith-Overman	Housing Finance Agency	North Carolina
Bernd Steinmueller	Sustainability Management Consulting	Germany
Don Stevens	Panasonic Home & Environment Co	Washington
Greg Thomas	Performance Systems Development	New York
Jane Thompson	Jane Thompson Architect	Ontario
Michael Thompson	Sierra Center for Sustainable Living	California
Dan Varvais	BaySystems North America	California
Larry Weingarten	Water heater expert	California
Linda Wigington	ACI (Affordable Comfort, Inc.)	Pennsylvania
David Wooley	Energy Foundation	California
Peter Yost	Building Green Inc	Vermont

Guest [Opening Session]

Name	**Organization**	**State / Province**
Amory Lovins	Rocky Mountain Institute	Colorado

APPENDIX C: 2007 ACI SUMMIT WORKING GROUP DISCUSSION and INSIGHTS

Throughout the Summit some consistent messages developed and some differences of opinion, approach and concern also occurred. To better explain why this White Paper recommends what it does, and to allow development of an understanding of the scope of work to be done, the following subsections present summaries of those discussions.

Feedback, Monitoring, and Verification

Feedback does not exist at a sufficient level for occupants, building owners, contractors, program implementers, designers, and policy makers. Evaluation efforts have tended to focus on counting installed units rather than measuring impact. There is a lack of data on installed performance of individual measures or technologies, as well as systems. Greater use of utility bill data is an important first step. Bill disaggregation can help determine patterns of use and be used to target households or buildings with the highest opportunity for reductions. Websites that use utility data and other basic household information as inputs have the potential to provide more useful feedback to occupants regarding their energy use.

Stakeholder collaboration is needed to overcome barriers including privacy concerns and the use of common indices of performance. This is important in multifamily buildings (tenants, maintenance staff, building owners). Access to consumption information can help measure impact on a community or aggregate basis. If manufacturers are going to install sensors or communication devices, there should be standards that address interface issues.

A variety of “dashboard” systems for occupants are emerging. These provide occupants with energy feedback and benchmarking. Criteria include: 1) They must be simple; 2) They are not for everyone; 3) Levels of complexity can vary as required by occupant; 4) Real time results are best; 5) Mass production and good marketing are needed to get costs down; 6) They should include all metered energy; 7) Occupant education is necessary; 8) Monitor ventilation, CO, furnace filter condition, humidity, water use, and the desirability of opening windows for ventilation; 9) Could be wireless; 10) Break out heating, cooling, water heat, and base loads separately. Devices that provide feedback to occupants can also inform professionals and programs.

Metrics

The lack of clear, quantifiable targets or performance indicators is a critical barrier to deep energy reductions and repeatedly surfaced as an issue throughout the Summit. The easier our metrics are to understand and use, the more effective our efforts will be. Metrics serve different purposes; the purpose helps to define the approach. Energy ratings have been developed to evaluate the performance of a building, independent of its occupants. The goal has been to develop instruments that qualify homes for the purpose of financing, incentives, tax credits, or labeling. This current tool is in the process of revision and is designed to include new and existing homes. The Metrics Issue Group recommended that deficiencies in the current tools be addressed. The rating number is the easiest understood metric across a large number of users. Software used to create numbers needs to be improved; the primary shortcomings identified were lack of accuracy and the bias toward larger homes.

In addition to a rating tool, there is a benefit to having performance indicators that provide the opportunity to benchmark a dwelling to compare it to others, compare it to itself over time, or to measure field performance against a goal such as zero energy. It was agreed that no single metric is complete and that several, in combination provide a more accurate understanding of past, current, and potential performance. The combination of energy use per square foot, energy use per house, energy use per occupant, carbon footprint and cost provide a more complete picture of performance than any one of them on their own. Both site energy (reflected by utility bills) and source energy (primary energy consumed at the power plant) were viewed as useful. The indices should be useful to any occupant who is interested in evaluating his or her household's performance. There is the possibility of integrating these indices with EPA's web-based "Energy Yardstick."

The challenge of identifying targets for what would qualify a home to achieve the status of deep reductions is elusive. The weakness of percent reduction or Factor 10 is that the quantity is relative to the starting point. A very efficient home may achieve a 50% reduction and end up at a much lower absolute energy use (per square foot, per person or per building) than a home that is an energy hog and reduces its energy use reduced by 90%.

There was disagreement on the value and use of carbon footprint as a metric. An area of surprising consensus was that kWh is preferable over BTUs as a measure of energy use.

We recommend the development of a universal one-page base report for dwellings that incorporates both performance-based and rated information. This report needs to be recognized in the marketplace and could be incorporated into the home sales and improvement process. The city of Portland, Oregon is starting this reporting with an Energy Performance Certificate and information from this report is included in the multi-list service.

Alignment and Synergies

Alignment refers to consistency between programs, policies, and initiatives to the long-term goals of deep energy reductions. For example, a program that promotes insulating attics before they are air sealed is not in alignment, because it makes it harder to achieve a tight building enclosure (something that may also be very important in that building). Also, rebating medium performance windows in a northern climate is not in alignment because it precludes higher performance windows that can be justified in many ways other than just energy use reduction.

Some important questions here are: a) How can the existing programs and efforts that have a single measure focus, i.e., compact fluorescent light (CFL) bulbs, sealing ducts, or replacing HVAC equipment, across a broad population be leveraged?; b) How can we build on the comprehensive focus and infrastructure development provided by Home Performance with ENERGY STAR and the Weatherization Assistance Program and entice these programs to go further and deeper?

Alignment is potentially the most politically-challenging issue of the deep energy reduction paradigm. Programs and policies call for immediate reductions in energy use and carbon emissions. Some have annual time tables; others have intermediate goals that are relatively short-term. As of June 2007, over 600 U.S. municipalities have signed onto meeting the Kyoto Accord which calls for reductions by 2012. The tendency has been to accelerate efforts to capture cost-effective energy savings through single-measure programs that are relatively easy to ramp up and evaluate. How do you integrate additional choices and options in a program without making it more costly, more complicated, and more confusing?

We need creative approaches that provide greater citizen, contractor, and program incentives for deep reductions without compromising immediate goals. For example, sealing ducts that are located in unconditioned attics is a key opportunity for energy savings. However, as part of a long-term strategy for deep energy reductions there are other options. Either move the ducts inside of the conditioned space (by moving the boundary from the attic floor to the roof or by moving them to the inside of the house) or eliminate the need for the forced air system altogether. Both of the latter approaches offer five advantages: 1) decreased heat loss through the ceiling; 2) increased air tightness of the home; 3) increased distribution efficiency; 4) reduced potential for pressure effects caused by duct leakage; and 5) elimination of the need to seal and test the attic ductwork. If the goal is to achieve the greatest reductions of energy use and energy load, efficiency programs need to drive the decisions to the optimum solutions. For a homeowner, sealing the ducts becomes a deterrent to making the other changes in the future.

Realistically, not sealing the ducts could mean that the immediate opportunity for reductions in energy use and load is missed because the homeowner never gets around to implementing the more comprehensive solution.

Increased efficiency incentives are needed for technologies that offer to transform the market that are on par with the incentives for renewables. Once field research clearly documents their performance, incentives could be offered to the most highly efficient technological systems to stimulate manufacture, distribution, and customer adoption. This model is not new; the Golden Carrot Refrigerator Initiative was a collaborative effort. Comprehensive programs can increase adoption of new technologies by building on incentives. Ideally, the collaboration of spurring efficiency would be done at both the national and international levels; there are examples in place already. A clear signal to manufacturers, that is independent of any single country's political process, could provide for sustained investment in research, development, and deployment with a greater emphasis placed on the latter. We have many great technologies that never get out of R&D because they are cost prohibitive (as perceived in isolation) or there are infrastructure issues with proper installation and maintenance. These need increased focus to achieve deep energy reductions.

There is a need to change the utility evaluation mechanism (broaden the criteria for energy program selection) for determining cost effectiveness. Cost effectiveness tests developed to protect rate payer investments by providing accountability are a barrier to comprehensive programs that leverage significant home owner investments and embrace measures that offer non-energy benefits. The Total Resources Cost (TRC) Test was cited as a significant impediment to the deployment of whole house programs (Knight 2006). The utility cost-recovery equation needs to exclude the cost of non-energy benefits so more deep energy savings in the residential sector can be realized, quantified, and be deemed cost-recoverable.

Financing and Incentives

Financing sources and mechanisms that could be used to support deep energy strategies are within reach. They include things like white tags and green tags, mortgage financing, green initiatives backed by banks, and legal settlements.

These financing mechanisms are not without substantial challenges. While the energy reductions obtainable in the residential market are huge, they are also scattered among 100 million dwellings and even more decision makers. The high transaction cost is a huge impediment. A deep energy reduction strategy offers the potential of increasing the comprehensiveness of energy savings in a house and a lower transaction cost per dollar invested.

Aggregation of savings is needed in order to qualify for some of the financing opportunities. The development and deployment of comprehensive deep energy reduction packages could overcome many challenges by minimizing transaction costs, alignment with aggregators, reducing risk, and incorporating feedback systems to monitor and maintain performance.

Affordable housing is a sector whose occupants are more vulnerable to rising costs of energy and who have less access to financing for improvements. Comprehensive cost and value analysis is needed to incorporate the societal cost of inaction and to justify private and government investment. Accurate assessment of non-energy benefits is essential to justify the expenditure needed. Priority for investment should be placed on areas of greatest vulnerability and highest energy intensity.

Limiting investment in affordable housing to an engineering-only cost analysis is risky. How is the death of an elderly person due to excessive heat valued? We need decision-making strategies that reflect a value of life as well.

Strategic Alliances and Initiatives

The group reached three fundamental conclusions:

- When high-percent energy improvements are the goal, the distinctions between remodeling or renovation projects vs. new homebuilding become less of an issue. Some of the same basic strategies, design measures, etc., are in play, including renewables. We can look to high-performing new custom homes for models that might be adapted for use in existing homes.
- To be able to "tunnel through" (i.e., bypass the incremental, cost-additive approach to energy improvements), we need model projects that have done just that. These model projects would form the basis for a massive outreach/education effort. In order to get model projects, however, we need to seed a process, for example, a very engaging international competition. The group felt this could be a very high-profile initiative and could engage the vast and varying array of players.
- We need measures for a phased approach. Many of the traditional incremental measures may not work because they don't lead to tunneling through and therefore aren't economical enough to achieve the improvement needed.

Occupant Behavior

Occupant behavior is a rich opportunity precisely because of its inherent challenges. It was simultaneously viewed as the biggest opportunity to reduce energy use and also the biggest obstacle to achieving deep energy reductions. Huge reductions in energy use are possible with a combination of the following:

- Recognition of the need or opportunity on the part of the household;
- Recognition that their actions can make an impact;
- Accurate, consistent information on which to base decisions and avoid unexpected negative consequences;
- Resources to make investments (including time, personal energy, as well as financial resources);
- Feedback on the effectiveness of their actions (should be almost real-time);
- Incentives (not limited to financial) that reinforce progress;

- A way to measure progress against a goal; and,
- Access to technical expertise.

Californians' response to the ENRON debacle provides an excellent case study of the potential for occupants to act en masse with a peak load reduction of over 10% (Lutzenhiser et al. 2003).

Traditional vs. emerging deep energy reduction paradigm implications for occupant behavior include:

- From "we use energy" to "we buy energy";
- From "consumptive" to "sustainable";
- From "unaware" to "aware" at the moment of choice;
- From "everyone else's actions matter" (not mine), to "personal responsibility" (my actions do matter);
- From "disconnect" to "feedback at the point of purchase and use";
- From "behavior" to "lifestyle"; and,
- From "reactive" (when it breaks I will fix), to "proactive" (I maintain it so it will last).

The linkage is not at all clear between energy *use* and energy *behaviors* in occupants' minds.

- Using energy is not clearly perceived as making a purchasing decision.
- The *true costs* of energy are largely unknown by North American occupants, and are often intentionally obfuscated at a societal level.
- Occupants often feel they are at the mercy of energy providers, energy systems, and energy-consuming devices, versus being *in control* of their energy use.

Recommendations include increasing the point-of-use feedback and communicating a sense of urgency, while emphasizing the positive.

From Consumerism to Sufficiency

Lifestyle change has been branded by some as the "Un-American Way." Alternatively, efforts to achieve deep energy reductions could be viewed as contributing to "The New American Way," supporting energy independence, and blazing a vision that demonstrates the strategic combination of choice, efficiency, and renewables. Redefining quality of life and the concept of sufficiency, as opposed to consumption, tend to be seen as political suicide and are therefore relegated to the fringe. Change is therefore more likely to happen at the local and occupant level until the political levels "get it." Strategies for deep energy reduction need to recognize voluntary lifestyle change as one option, and support that option with accurate information regarding the potential impact. This is critical to discouragement of well-intended actions that could contribute to poor health, reduced durability, or to introduction of new indoor air quality problems. The systems approach should help solve even existing indoor air quality problems.

For the past quarter century, the energy efficiency community has worked hard to focus on energy efficiency or productivity (more services per unit of energy) and to sharply distinguish its goals from energy conservation (using less). The latter implied "doing without" the energy services presumed to be essential for modern life. To achieve deep cuts in energy use, we need to look at both energy efficiency and a larger view of energy conservation. Reducing house size, or choosing not to increase house size, is one of the most effective energy conservation strategies available. A small house with only moderate energy performance standards might use substantially less energy for heating and cooling than a large house with very high energy performance standards, once the larger house is filled with goodies. Despite gains in the energy efficiency of building envelopes, lighting, HVAC, and plug loads, total primary energy use has increased more than 30% in U.S. residential buildings since 1978 as a result of ever-increasing house size and the number of appliances within our homes. Smaller homes, which emphasize good design and quality over quantity, reduce both initial construction costs and operating costs thereby freeing up funds for efficiency measures to achieve deep energy cuts.

However, the idea that bigger is better in house size is a leading driver of the real estate industry; the North American "McMansion" has become a status symbol for homeowners. Participants at the house size working group suggested the need for an aggressive marketing campaign to counteract the prevalent occupant perception that bigger is better, to point out the excesses of current housing, and to promote design techniques for optimum use of space. Since our existing older housing is more appropriately sized than typical new construction (living area per family member has increased by a factor of 3 since the 1950's) it is particularly beneficial to maintain and upgrade this stock in a way that incorporates the features important to occupants without creating excess space and to provide flexibility to adapt to changing family structures.

There are few champions for campaigns that have the ability to convey the trend toward increasing house size as being excessive. Our current financial systems do not provide deterrents for excessively large homes, nor do they offer rewards for smaller dwellings with higher occupancy per square foot. LEED for Homes is to be commended for incorporating this item.

National Audit Process

Developing standards for a national audit or rating is a response to the need for accurate homeowner information.. Providing accurate information on energy reduction options is much more challenging than recognized by either occupants or policy makers. Important questions here include: A) What is the context (occupant investment or public investment / incentive)?; B) How accurate is good enough?; C) What is the purpose of the information?; and, D) How is it going to be used? Present energy ratings have the potential to reinforce the perception that energy decisions are independent of health, safety, durability, adaptability, and community development. They also have the potential to convey that deep energy savings are not practical or obtainable "Your energy use is really good for a home this age." The challenge of aligning the proposed rating system to include the paradigm of deep energy use reductions is not to be underestimated. Simultaneously, a protocol for a rating system also has the potential for a more consistent message and the incorporation of this vision in a way that could serve to accelerate the comprehension that deep energy reductions are a possibility. In addition, a coordinated rating system could serve to collect data that would inform program designers and policy makers and to help target deep energy reduction strategies, as well as identify candidates for deep energy reductions.

Workforce Development

This is a severe limitations to implementation of deep energy reductions. We lack the entry-level, skilled, and professional workforce needed to implement residential energy and housing initiatives under the business-as-usual paradigm, let alone a more aggressive strategy. Implementation of deep energy reductions requires a level of teamwork that is not customary for the existing home market. The All at Once approach integrates teamwork or expertise encompassing residential sustainable design, remodeling, contracting, home performance, renewables, healthy house, and energy education.

The lack of appeal of building trades as a vocation for those entering the job market is a major barrier to developing and maintaining a skilled workforce. One solution is to demonstrate an important and exciting career path. Another is to clarify the vision of deep energy reduction so that participation is compelling, and seen as “deep green” and critical to addressing larger energy supply and environmental problems. This builds on the radical, bold nature of a deep energy reduction paradigm and turns it into an asset.

A recommendation by Alex Wilson for a voluntary “Environmental Service Corps” (Environmental Building News, 2007) is an intriguing idea that could serve as a point of entry to the skilled and professional workforce. It could also provide a labor force that could be used in tandem with professionals to catalyze self-help community-based initiatives. Another suggestion made by Bill Parlapiano is to create the Green Collar Workforce Development Initiative (GCWDI). A new service industry will be created that is neither white collar nor blue collar; rather it is “green collar”. At the same time we must continue evolving the existing workforce into new areas of growth and opportunity, to support the green collar economy that is growing rapidly in the country. This is truly the American way in terms of providing opportunity here at home, but there needs to be much more synergy, as too many efforts are presently occurring in a vacuum; they do not compliment one another.

It is difficult for home owners to differentiate conventional contractors from home performance contractors. Remodelers and most insulation, window, siding, HVAC and home performance contractors offer improved comfort and energy savings. Energy savings claims vary widely; every homeowner has been propositioned by window salesmen promising 50% savings. Deep energy savings offers a niche that is uniquely different from business as usual. That difference needs to be marketed, not just to attract customers, but also to attract and retain employees who recognize the vital importance of this new field.

One strategy to maximize impact and lower the labor cost lies in the development of implementation systems that are in sharp contrast to our current house-by-house customized approach. For example, the development and refinement of a package that is appropriate for a common house vintage could have components that are mass produced. Deployment could integrate installation, financing, packaging, and marketing. Key technical details and code issues would be resolved for the package, minimizing potential costs and barriers. Ironically, it is the comprehensiveness of deep energy retrofits that make it possible to simplify the package; systems that can pose challenges and require customized solutions are being replaced or eliminated rather than upgraded. Solutions for indoor air quality, moisture, durability and the provision of mechanical ventilation are essential components. Many communities have housing stock that is the same vintage, same construction, and house type. The package concept could be tied to local manufacturing, or it could be implemented with off the shelf components by a do-it-yourselfer or self-help group with skilled professionals engaged only as needed.

One manufactured option could be the development of a SIPS-type wall panel that minimizes piecework and labor, while addressing vital structural, air leakage and water management issues. Costs would be lowered if multiple homes with nearly vintage and floor plan in the same community were packaged as a single project.

Technical and Market Innovation

Technical and market innovation have the potential to accelerate deep energy reductions. While many products would make it easier to achieve deep reductions in use, it is important to recognize that the majority of Summit participants were confident that we have the technology needed to achieve deep reductions now, assuming a motivated occupant, access to financing, and the expertise needed.

Products and systems are divided into three categories: 1) acceleration needed - already exists in North American market (A); 2) products exist, but not in the North American market (A-NA); and 3) innovation needed (I). In some cases, a product could fall into all three categories. Not all products are appropriate for all climates.

A	A-NA	I	PRODUCT and / or SYSTEM
X	X		Better windows – U.15 with high or low solar gain
X			Window systems with permanent frames and removable sashes
		X	Exterior automatic shutters
		X	Dynamic windows
X			High performance storm windows
	X		Better doors (insulation, durability, tightness)
X	X		Exterior insulation systems for walls and roof
	X	X	Small heating, cooling, ventilation, and dehumidification systems
	X		Prefab exterior wall systems for high R walls – SIPS, LEGOs
	X		Prefab interior wall insulation system – laminated with finished surface
X		X	Home automation systems (to address temperature, humidity, IAQ, plug loads)
		X	Alternatives to conventional dehumidification
		X	Systems to integrate with renewables
		X	Control and monitoring systems for IAQ, mechanical, natural ventilation
	X		Passive ventilation systems
		X	Efficient utility core for retrofit that provides plumbing, refrigeration, dehumidification, cooking, and DHW with heat recovery
X		X	Variety of dashboard systems (energy, water, carbon, and maybe RH, IAQ)
	X		Super-efficient small appliances for motivated occupants
	X		More efficient distributed ventilation systems
X		X	Phase change materials to add thermal mass
X		X	Systems and strategies to enhance material reuse / deconstruction
	X		Super insulated cooking systems to minimize heat input
X		X	Efficient cooking, kitchen options for outdoor living (reduce summer heat gain)
X		X	Appliances and mechanical systems with built-in energy performance tracking

The following activities were identified as mechanisms to accelerate technical systems and product innovation:

1. More funding of research and field testing with recognition of the unique needs of existing homes;
2. Improved metrics, indices of performance, benchmarking, and wireless monitoring systems;

3. Demonstration projects in common house types across climate zones;
4. Thousand home demonstration program / competition;
5. Guidebooks on best practices;
6. Increased funding for deployment efforts including training programs;
7. Better modeling tools designed to address deep reductions and integration with renewables;
8. Government funding of dashboard development;
9. Diagnostic tools for commissioning and monitoring performance;
10. Access to product information and field performance data;
11. Industry challenges such as Golden Carrot Refrigerator (North American and international);
12. Investigate ways to reduce trade / code / product spec barriers for efficient technologies; and,
13. Website or other sources with the most efficient products, appliances, and equipment.

APPENDIX D: RESEARCH NEEDED

While experience from efforts to achieve very high performance new homes offer important lessons for deep reductions in existing homes, it is important to recognize that there are many differences between new and existing homes. Research needs include:

1. Field verification of deep reduction renovation systems (range of climates, lifestyles, and starting points) to develop database and recommendations for optimization;
2. Developing alternatives to conventional residential dehumidification;
3. Investigation and improvement in our ability to model the impact of ground coupling;
4. Verification of comfort and impact of nontraditional HVAC systems;
5. Research into utility peak impacts of deep energy reductions;
6. Investigation of the effectiveness of occupant feedback and benchmarking systems to reinforce and support behavior changes;
7. Research into peak load and energy impact of extreme house tightness (<.2 CFM/per square foot) in different climates, humidity, cooling heating loads and ventilation strategies;
8. Investigation of integrated radon, soil gas, moisture control, and mechanical ventilation strategies;
9. Investigation of interaction of basement wall and floor insulation with moisture flows, humidity, summer cooling, and soil gas entry;
10. Research into the performance of different safe room / comfort zone strategies (energy, IAQ and moisture);
11. Evaluation of whole house lighting retrofits from a redesign approach, rather than a bulb replacement perspective; and,
12. Evaluation of field performance of retrofit systems designed to achieve deep energy reductions, while simultaneously increasing passive survival and responsiveness to climate change and increase in severity of weather events and natural disasters (wind, rain, fire, and drought).

APPENDIX E: CHALLENGES and OPPORTUNITIES

The existing home market presents the following unique challenges and opportunities:

1. Energy efficiency is viewed predominantly by occupants and policy makers as a function of widgets rather than systems;
2. Citizens and professionals are not viewed as having a central role in a technical fix or widget paradigm; reshifting the focus to people rather technology has the potential to tap a much larger resource than technology alone;
3. Solutions will be limited if our assumptions are not accurate. Consensus of policy and clear signals for occupants is very difficult to achieve when assumptions are changing;
4. Action may be delayed by vested interests and widely divergent views of the urgency of movement;
5. One strategy does not fit all; customized solutions in response to climate and housing stock pose barriers to conveying the concept;
6. We lack consensus on a set of metrics that serve as indices of performance particularly in terms of push goals, as well as useful indices to convey household energy consumption;
7. Data regarding baseline residential energy use needs to be improved, using the indices of performance, to clarify similarities and differences with existing housing stock by climate, age, operation, construction, type;
8. We lack the data needed to verify modeling and rating assumptions;
9. Reliance on HVAC equipment standards and the failure to understand true system performance is a barrier to system innovations that minimize parasitic losses. Financial incentives should be tied to system performance. It is critical that the intermediate indicators of performance such as SEER, EER, and AFUE deliver the savings as assumed;
10. We lack the green collar workforce needed for deployment;
11. Lifestyle change has been branded as the "Un-American Way". While defining quality of life and the concept of sufficiency as opposed to consumption relates to many American's core values, it is viewed by many as political suicide;
12. Our current financial and rating systems reward rather than deter the trend to larger homes, and lower occupancy per square foot.

Market Fragmentation

There are over 120 million households in the U.S. alone. Collectively they represent a huge energy reduction potential, but the challenge is that each home must be dealt with on an individual basis. Even homes of the same type (e.g., in a subdivision or multifamily complex) have unique owners. Also, unlike the new home market, which is dominated by large production building companies, the home remodeling market consists of thousands of individual contractors and small businesses.

Fortunately, many home owners are now highly motivated to reduce the environmental impact of their homes, so the market is ripe for innovative policies, incentives, and technical approaches. We can and should optimize available resources by developing strategies for achieving deep energy reductions in a large number of similar homes at the same time by leveraging economies of scale and mass deployment of retrofit measures.

Market Diversity

Because the existing housing stock varies significantly in age, construction type, climate, level of maintenance, occupant lifestyle, and energy loads, there is no simple or easy way to prescribe deep energy savings, and different strategies will be needed depending on individual circumstances. We can and should, however, develop guiding or universal principles that save time and resources by steering people in the right direction and building upon lessons already learned by others. For example, local or regional organizations could maintain online resources with information about local home performance contractors and HERS raters, utility information, financial resources, and case studies. We also need to develop tools for assessing trade-offs to make it easier to combine or integrate options for efficiency, lifestyle, structural repairs, HVAC, plug loads, renewables, and local power generation such as micro generation.

Occupant Lifestyle

Occupant behavior is a very strategic part of deep energy reductions. Discretionary energy uses are increasing and vary significantly. The more efficient a home becomes, the more significant lifestyle becomes as a determinant of total use.

In the classic study addressing lifestyle on energy use, it was found that energy use varied two to one in the same house type and general location. This impact is enormous and can either contribute to energy consumption or to energy reductions.

Feedback devices (bills and / or smart meters) are needed, and should be coupled with other interventions to support lifestyle change. We also need to develop systems (rating, benchmarking) to provide accurate site-specific information to occupants and professionals regarding the potential to achieve moderate or deep energy reductions.

Market Infrastructure

The home improvement and remodeling industry is huge, but not very responsive to regulatory strategies. A confounding challenge is that many home improvement and remodeling transactions, including do-it-yourselfers (DIY), are likely not reported for tax purposes. In this market, voluntary programs may be more effective than regulatory approaches at stimulating deep energy reductions.

Some aspects of deep energy reductions can be done by DIY, and there is also an opportunity for applying a "train the trainer and peer to peer" model using demonstration projects / house parties for renovations such as superinsulation of walls. With online resources, highly motivated do-it-yourselfers can learn the details of, for example, flashing and drainage planes.

Homeowners with accurate information and municipalities armed with incentives have the potential to stimulate demand for home performance contractors and energy professionals. A bold initiative that goes well beyond "business as usual" has the potential to attract remodelers, designers, and trade contractors who want to differentiate themselves from their competition. We need to find ways to train, certify and promote residential contractors who specialize in the systems approach to deep energy reductions.

We also need to identify other essential skills and services needed as part of an effective deep energy reduction team, including designers, auditors / raters, contractors, performance analysts or technicians, financiers, real estate agents, and appraisers.

The Low Load Conundrum

The smaller the end uses, the harder it is to justify the cost of efficient technologies. With an improved building enclosure, it might cost $200 per year to heat a home with electric baseboard units. Adding a high efficiency furnace and gas lines with gas service would cost $4,000, plus $120 per year for gas service. Installing a geothermal heat pump could cost $10 - $20,000; a ductless heat pump would cost $3 - $4,000. Optimistically, each could save a maximum of $100 per year. Some technologies are only possible if you get the loads below a certain threshold. Tunneling through the cost and performance barrier to deep energy efficiency can dramatically save energy cost and first costs. For example, with a highly efficient building enclosure the heating / cooling system can be downsized or eliminated. An ERV or HRV can provide ventilation, indoor air distribution and humidity control. We need to stimulate development of efficient packaged (plug and play) systems for low load homes.

APPENDIX F: RECOMMENDED ACTIONS BY SECTOR

In addition to the general recommendations cited previously, these recommendations are focused on the four key drivers: federal government, private sector and foundations, energy efficiency stakeholders, and local government.

Federal Government

a) Support the Thousand Home Challenge, a large scale project to demonstrate the potential for deep energy reductions in existing homes.
b) Increase funding for development and consensus building, information sharing, and supporting the operation of regional centers of excellence.
c) Advance loan guarantees as authorized under Title XVII of the Energy Policy Act of 2005 (EPAct) for qualified deep energy reduction projects.
d) Accelerate research to support deep reductions in existing homes (see research section).
e) Launch a 'Green Collar Workforce Development Initiative' and volunteer Environmental Corps.
f) Fund a Deep Energy Reduction contest / demonstration equivalent to the Solar Decathlon project.
g) Revisit assumptions regarding benchmarking and metrics to address accuracy and generate the equivalence of MPG (miles per gallon) rating that is independent of house size.
h) Stimulate development and deployment of the ultra high efficiency products and systems that are needed to accelerate deep energy reductions and net zero new homes.

Private Sector and Foundations

a) Fund or implement social marketing campaigns to demonstrate the environmental, economic, and lifestyle benefits of smaller homes (Less is More), and convey the potential for lifestyle choices to impact energy and environmental use while maintaining or improving quality of life.
b) Fund national, regional, and local ecumenical efforts to collaborate on supporting and stimulating education and exploration on "Reducing the Environmental Impact of our Lives."
c) Fund efforts to convey accurate customer-specific information about lifestyle choices that impact energy and environmental impact.
d) Stimulate and reward development of ultra-low energy appliances, products and technical systems.
e) Fund demonstration and pilot projects.
f) Serve as a catalyst to encourage verified performance and high levels of energy performance within existing initiatives.
g) Support local and regional efforts to stimulate the infrastructure needed to obtain deep energy reductions within carbon action plans.
h) Support higher energy efficiency standards for new construction; encourage verification of whole house energy performance.

Energy Efficiency Stakeholders (program implementers and administrators, utilities)

a) Evaluate ways that current programs and policies serve as barriers to deep energy reductions and explore opportunities to increase alignment.
b) Evaluate analysis tools that impact investment in energy efficiency to determine how non energy benefits can be monetized.
c) Evaluate the housing stock at a local level to identify characteristics of those most suitable for deep energy reduction from a technical and cost perspective.
d) Partner with other organizations to develop demonstration projects.
e) Identify research and product needs that can help to stimulate deep energy reductions. Pursue partnerships to address them.
f) Consider opportunities for collaboration and joint specification to stimulate the development of ultra low energy use products.

Local Government

a) Convene a local summit to explore carbon neutrality in existing homes. Use this as a catalyst to form a local task force to continue the effort.
b) Explore financial, regulatory and educational mechanisms to minimize lost opportunities for energy efficiency during remodeling and renovation.
c) Investigate ways that current and proposed energy efficiency initiatives support or conflict with the deep energy reduction paradigm.
d) Move to 'life-cycle plus' modeling for energy efficiency improvements (health, externalities, beyond) to stimulate deeper energy reductions in affordable housing projects.
e) Form partnerships to ensure technical support for do-it-yourselfers or self-help projects.
f) Consider local policy for overcoming disincentives for smaller homes including financing, taxes, prototype designs for renovation and zoning, and local codes.
g) Support partnerships (industry, energy providers, trade, educational, environmental, and housing) to create deep energy reduction demonstrations to develop regional specific recommendations for typical housing types.
h) Collect house-specific data that could be used to identify and understand the potential for energy reductions in local housing stock.
i) Verify the accuracy and assumptions related to energy efficiency and conservation for educational materials, programs, and initiatives using measured utility data.
j) Stimulate education and training efforts that support deep energy reductions.
k) Investigate ways to integrate improved disaster resistance and passive survivability with local strategies for deep energy reductions.

APPENDIX H: QUESTIONS of INTEREST

To quote Jim White, "One of the most important parts of a new endeavor is to identify all possible questions as the basis for exploration and discovery." This section is an effort to do that.

General

1. What can we learn from the tremendous range in energy use in existing homes that can help support an effort to achieve deep energy reductions?
2. What are the triggers needed to get action at all levels to start, approve, or require change?
3. What changes will be essential to deep energy use reductions and which will be less vital? Under what conditions do less-important items become crucial?
4. Does the deep energy paradigm provide a vision that is captivating enough to spur owner investment and provide a framework for environmentally conscious occupant decision making?
5. What location and historical factors change a not-salvageable house to a must-renovate status?
6. What portion of existing housing justifies a deep energy use reduction and who decides that?
7. How will purchase price plus renovation value be rewarded by the marketplace?
8. Will new homes be held to a higher environmental standard if existing homes improve?
9. Are demonstrations (case studies) most needed in single homes, small groups of homes, whole neighborhoods, communities, or all of the above?
10. What will the frequency of unique renovation opportunities be, which make trying this approach an easy sell? How good is the data on this and where do we get it?
11. What indoor environmental conditions are most comfortable / acceptable, across ethnic types, ages of occupants, and regional climate conditions?
12. What packages of strategies have the potential to impact a large number of homes?
13. What strategies can take deep energy reductions from a customized craft to mass deployment?
14. What mix of energy prices, climate, local regulatory activity, energy supply, transmission and distribution, housing types and age create the best opportunity for community-based reductions?
15. What are the guiding or universal principles that guide development of deep energy reduction strategies?
16. How can this new paradigm accelerate and enhance existing efforts (Home Performance with ENERGY STAR, 2030 Challenge)?
17. What embodied energy must be invested to get to deep energy – does it make sense from a net energy perspective?

Process

1. If we do not use deep energy reductions in our existing housing, where else can we get the energy?
2. How do we introduce solar thermal and PV and other renewable site power and when? The low-load house begs their use, but at what point is even further house efficiency no longer competitive?

3. How can we define a deep-reduction job when it will be staged over time?
4. How do we convince various actors to apply final use targets when the project will be staged?
5. How do we successfully communicate all the non-energy benefits of the deep-reduction approach? (Some of the best input will come from users at the house or the utility or the city, etc.)
6. Who sets the metrics? Total energy per house is the only metric that is fair; wealthy people can retrofit large houses to low use, while occupants of small homes look worse on a 'per area' basis.
7. What existing projects can provide early data and lessons on what does and doesn't work, and why?
8. Who will be best able to help us convey to occupants that deep energy reductions are the way to go?
9. Why has it taken so long to properly insulate stove and microwaves, etc.? Why are some refrigerators and freezers still poorly insulated?
10. How do we get nay-sayers to share their objections so we can change problems into opportunities?
11. How do we ensure that systems, sub-systems and components perform to occupant expectations when most standard associations only look at safety, not performance issues?
12. Do we need building codes and code changes for deep energy retrofits?
13. Will local building officials be supportive? If they are in opposition, how do we change that?
14. How are the benefits assessed, by whom and with what training, provided by whom?
15. Do we need minimum performance requirements? Will that discourage interested participants?
16. What external benefits are there and how do we give value to them?
17. Whose value program will count and who will use which, if there is not a centrally-accepted one?
18. What parts of the process will stimulate the marketplace to help? What parts will be problems?
19. How will we manage 'failures' during the demonstration phase? How can we minimize them?
20. Can we collaborate with existing programs like Habitat for Humanity to demonstrate this approach?
21. How do we get the support of new home builders and the residential new construction industry?
22. Why are some energy groups and standards still endorsing systems that do not properly control indoor relative humidity?
23. Are conditions that cause degradation of the structure acceptable under any circumstance? Can't we define a high cost for this scenario?
24. Can we sell the idea that houses that do not meet all occupant needs are acceptable? Can we maintain any standard that doesn't meet many occupants' wants and not suffer irreparable backlash?
25. Can we ever separate the need to produce a joint minimum in effective long-term cost that includes all of the components: capital cost; cost of money; cost of insurance; cost of energy; cost of maintenance; cost of replacement or repair? Do we then not have to go the final step to accounting for improved value (resale value +), level of satisfaction, etc.?

26. Why can't standards require that large houses meet smaller total energy use requirements than smaller houses? Those who want larger houses likely have the capital to meet higher standards.
27. Don't we have to implement a waste tax that is totally transparent, making energy reduction a self-serving process and massive energy reductions a really good idea? The costs of waste are real at the planet level, just not obvious to most. The U.S. and Canada have some of the highest percentages of truly caring people anywhere; others may need a big stick because they do not believe in truth as a valued reality (reference Dr. David Hawkins).
28. By what mechanism do communities, states and feds help determine the revise / rebuild / replace decisions that are so socially value sensitive?
29. Should we ramp up penalties for poor construction ("I've always done it that way…)?
30. What is the opportunity and role of local community-based initiatives that can stimulate action and use benchmarking so usage can be compared and potential improvements recognized?
31. How do we create and implement an approach that maximizes the use of packaged components, i.e. "plug and play" -- so deep energy reduction implementation is as simple as possible?
32. How do we stimulate and support initiatives to develop the systems that are needed?
33. Can we afford to invest in measures that could be obsolete in one to five years … or are already obsolete depending on one's assumptions?
34. What changes are needed in residential mortgage lending and home insurance to provide an incentive for annual maintenance?

Equipment

1. What pre-packaged units make sense and in what markets?
2. How can we stimulate the development of efficient packaged (plug and play) systems that are ideal for low load homes?
3. Are combustion systems compatible with deep energy reductions if they can be made insensitive to over-sizing and totally resistant to spillage? Were should they not be used?
4. What types of feedback devices (bills, smart meters) are needed, and how can they be coupled with other interventions to support lifestyle change?
5. How high can compressor-driven cooling efficiency go, for loads like freezers, refrigerators, dehumidifiers and air conditioners? Does any group in the industry even know how to do the improvements and how much they would cost?

Documentation and Training

1. How will we train a work force to do complex tasks well when that is not part of our tradition?
2. What supporting documents are needed? Who should write them and who should review them?
3. How many systems people are out there and how quickly can we get them together to develop appropriate training programs?

4. What are the essential skills needed within a deep energy reduction custom team and how can various models be supported to deliver the requisite mix of services (designer, auditor / rater, re-modeler, contractor, performance tester, financier, and educator)?
5. What present protocols are good enough, which need changing, and what new ones need to be developed to support deep energy reductions?

Testing / Evaluation

1. What testing / evaluation / measurement is really needed and what is just more paperwork?
2. What tools are needed to assess trade-offs to make it easier to combine or integrate options for efficiency, lifestyle, structural integrity, HVAC, plug loads, renewables, and local power generation?
3. How can we develop systems (rating, benchmarking) to provide accurate site specific information to occupants and professionals regarding the potential to achieve energy reductions?
4. How can those who specialize in deep energy reductions be recognized, trained, certified?

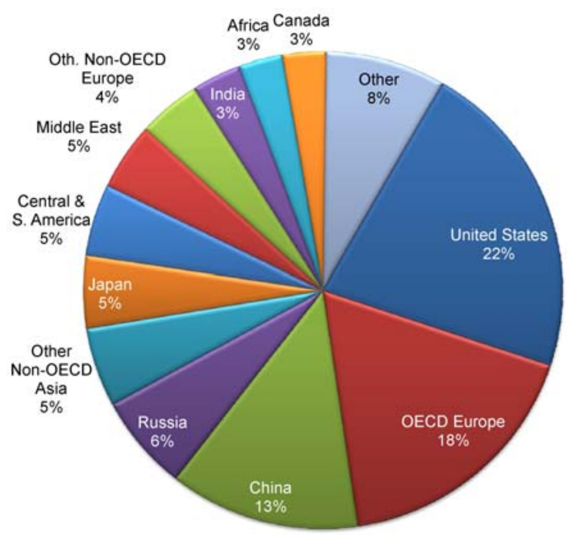
APPENDIX I: ABBREVIATIONS and DEFINITIONS

Carbon footprint	The amount of carbon dioxide or other GHG equivalent emitted into the atmosphere from any given source (building, event, person, etc)
Carbon neutrality	Having completely and effectively lowered, offset, and / or sequestered the greenhouse gas emissions attributable to any given source
CFA	Conditioned floor area
Conservation	Reducing the amount of energy used to produce a given good or service without reducing the consumption of that good or service.
Curtailment	Reducing the amount of energy used through reducing the amount of goods or services consumed.
Deep energy reduction	Reducing home energy consumption by at least 70% of original usage.
Energy conservation	Reduction or elimination of unnecessary energy use and waste (Source: www.natsource.com/markets/index.asp) Note: This has also been used to mean reducing energy use, even if the use was real and its reduction might have unfortunate consequences. It is this latter use and implementation that has resulted in a sometimes negative connotation of the term.
Energy efficiency	Reducing energy or demand requirements without reducing the end-use benefits. (Source: www.liheap.ncat.org/iutil2.htm) This assumes that the requirements that are inferred by that use are adequately known and maybe even quantified. In this context, energy efficiency is very important in the systems approach to deep energy use reduction.
Factor 10	The concept that energy consumption among European and North American homes must be reduced to 10% of current levels if we are to reduce GHG emissions so that human populations are sustainable – in reality it must be reduced to about 5% in North America, because of our higher use (a 20 times reduction factor).
Finished Floor Area (FFA)	The enclosed area in a house that is suitable for year-round use, embodying walls, floors, and ceilings that are similar to the rest of the house. (ANSI Z765 – 2003)
GHG, greenhouse gas	Gas–particularly carbon dioxide and methane–that contributes to global climate change. (Derived from: www.epa.gov/ocepaterms)
MMTCE	Million metric tons carbon equivalent
Site Energy	Energy used at the building or end-use; also referred to as delivered energy.
Source Energy	Total energy used at the source and in the process; includes fuel input to electric power plants, and the energy lost in conversion and distribution and transmission; also referred to as primary energy. Source energy provides a more accurate assessment of the environmental impact and greenhouse gas emissions than site energy.

APPENDIX J: ENERGY DATA and DEMOGRAPHICS

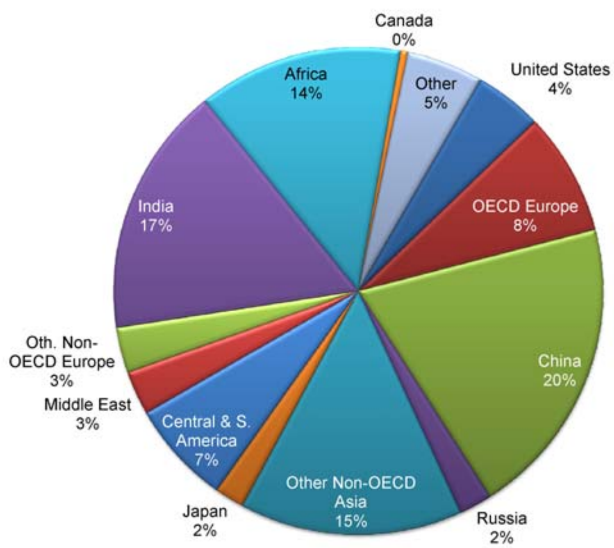
This section contains U.S. energy consumption and housing demographic data. Additional information excerpted from the Buildings Energy Data Book (BEDB) can be viewed or downloaded from http://buildingsdatabook.eren.doe.gov.

Figure 1. 2004 World Primary Energy Consumption by Country / Region[18]



Total: 446.7 Quadrillion Btus

Figure 2. 2004 World Population by Country / Region[19]



Total World Population: 6.388 Billion

[18] BEDB 2007 1.1.10 (Source: EIA, International Energy Outlook 2007, May 2007)
[19] BEDB 2007 1.1.10 (Source: EIA, International Energy Outlook 2007, May 2007)

Table A. Total Primary Energy Consumption and Population, by Country/Region[20]

	Energy Consumption (Quad)				Population (million)			
Region/Country	1990	2004	2004	2010	1990	2004	2004	2010
United States	84.7	100.7	22.5%	106.5	254	294	4.6%	310
OECD Europe	69.9	81.1	18.2%	84.1	497	532	8.3%	543
China	27.0	59.6	13.3%	82.6	1,155	1,307	20.5%	1,355
Russia	39.0	30.1	6.7%	32.9	148	144	2.3%	140
Other Non-OECD Asia	12.5	24.9	5.6%	30.3	743	962	15.1%	1,054
Japan	18.4	22.6	5.1%	23.5	124	128	2.0%	128
Central, S America	14.5	22.5	5.0%	27.7	360	448	7.0%	486
Middle East	11.3	21.1	4.7%	26.3	137	191	3.0%	216
Other Non-OECD Europe	28.3	19.6	4.4%	21.9	200	198	3.1%	198
India	8.0	15.4	3.4%	18.2	849	1,087	17.0%	1,183
Africa	9.5	13.7	3.1%	16.9	636	887	13.9%	1,007
Canada	11.1	13.6	3.0%	15.5	28	32	0.5%	34
South Korea	3.8	9.0	2.0%	9.6	43	48	0.8%	49
Mexico	5	6.6	1.5%	8.3	84	106	1.7%	113
Australia, N. Zealand	4.4	6.2	1.4%	6.8	20	24	0.4%	25
Total	347.3	446.7	100%	511.1	5,278	6,388	100%	6,841

Table B. 2005 U.S. Electricity Generation by Fuel Source (billion kWh)[21]

Coal	1956	52.0%
Nuclear	780	20.0%
Natural gas	546	14.0%
Renewable - hydro	269	6.9%
Combined heat/power (CHP)	178	4.6%
Petroleum	111	2.9%
Renewable – other	54	1.4%

[20] BEDB 2007 1.1.10 (Source: EIA, International Energy Outlook 2007, May 2007)
[21] BEDB 2007 1.5.2 and 1.5.3

Figure 3. Past and Projected Site and Source U.S. Residential Energy Use[22]

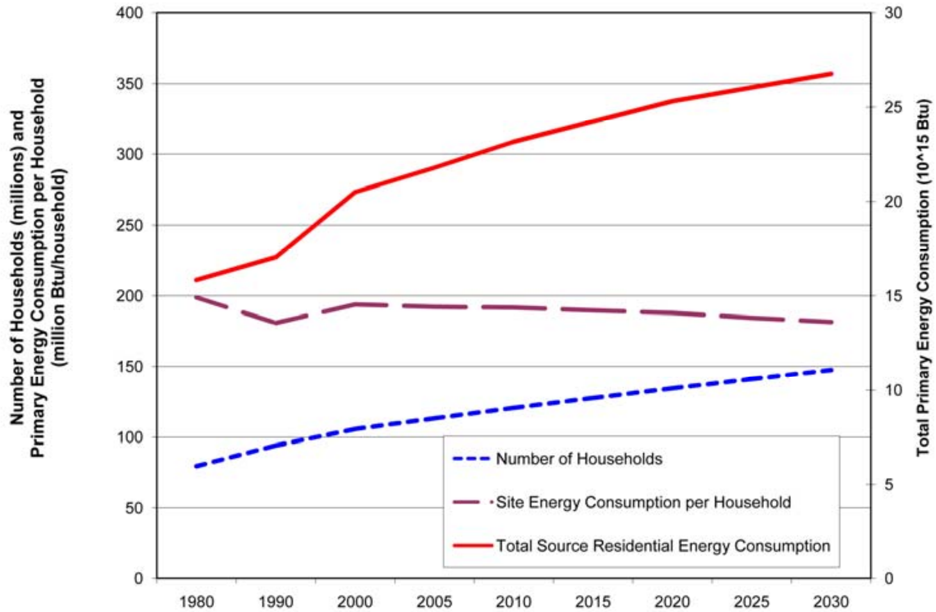
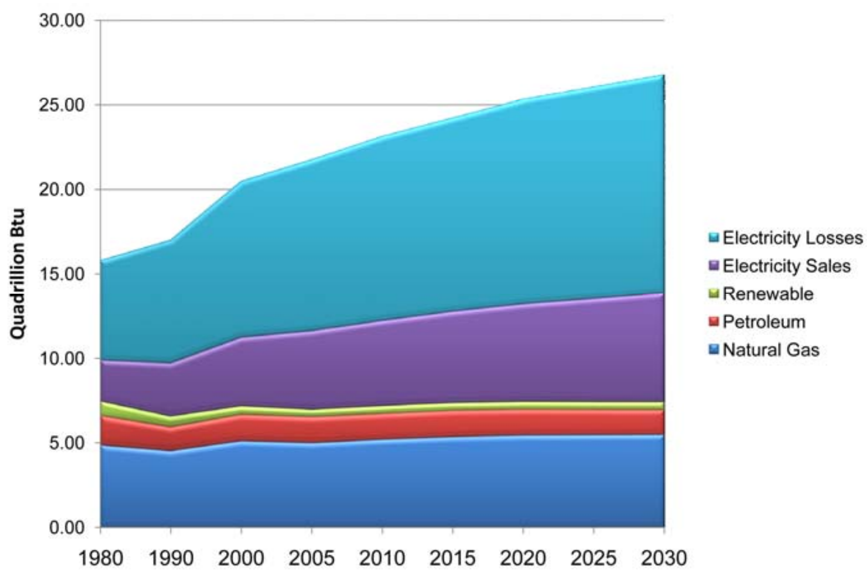


Figure 4. U.S. Residential Source Energy Consumption by Year and Fuel Source – Past and Projected[23]



[22] BEDB 2007 1.2.4 (Source: EIA 2004 and 2007; Statistic Abstract for the United States 2006). With current trends, electricity losses become an increasingly larger share of the residential energy mix.
[23] BEDB 2007 1.2.1 (Source: EIA 2004 and 2007)

Figure 5. 2005 U.S. Residential End-Use Energy Split – Source[24]

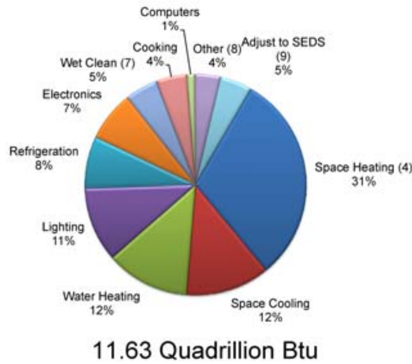


Figure 6. 2005 U.S. Residential End-Use Energy Split – Site[25]

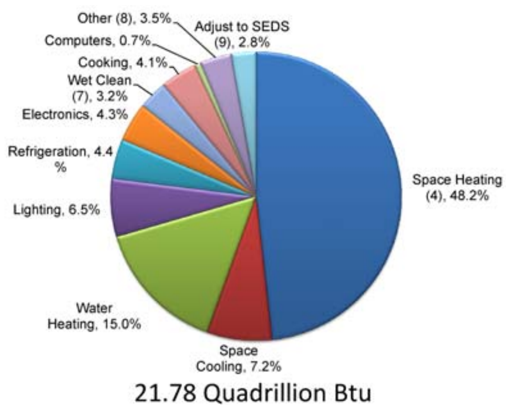
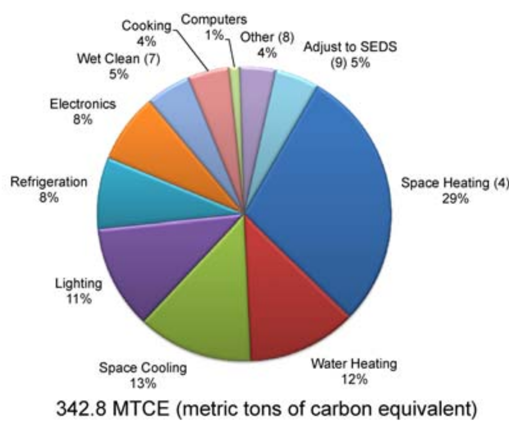


Figure 7. U.S. Residential Energy End-Use Carbon Dioxide Emissions Splits (MTCE)[26]



[24] BEDB 2007 1.2.3: 4) Includes furnace fans. 7) Includes clothes washers, clothes dryers, and dishwashers - does not include water heating energy. 8) Includes small electric devices, heating elements, motors, swimming pool heaters, hot tub heaters, outdoor grills, and natural gas outdoor lighting. 9) Energy adjustment EIA uses to relieve discrepancies between data sources. Energy attributable to the residential buildings sector, but not directly to specific end-uses. (Sources: EIA, Annual Energy Outlook (AEO) 1999, 1999, 2007; and BTS/A.D. Little, Electricity Consumption by Small End Uses in Residential Buildings, 1998, Appendix A f.)

[25] BEDB 2007 1.2.3

[26] BEDB 2007 3.1

Figure 8 , 9 , 10. 2001 U.S. Residential Site Energy Consumption Intensities, by Census Region[27]

Figure 8. Delivered (Site) Energy Use by Region – Per Square Foot (KBtu)

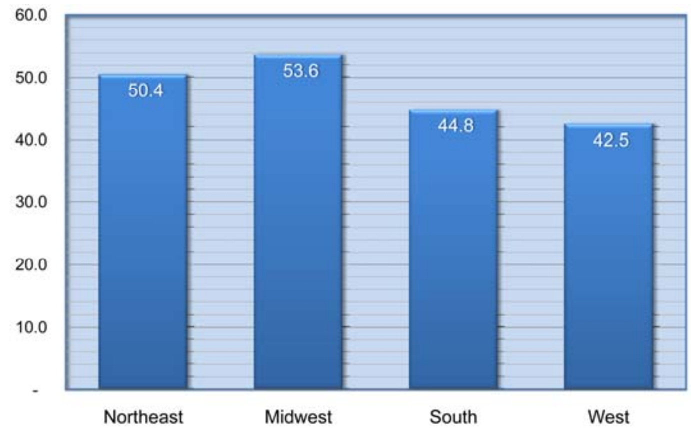


Figure 9. Delivered (Site) Energy Use by Region – Per Household (MMBtu)

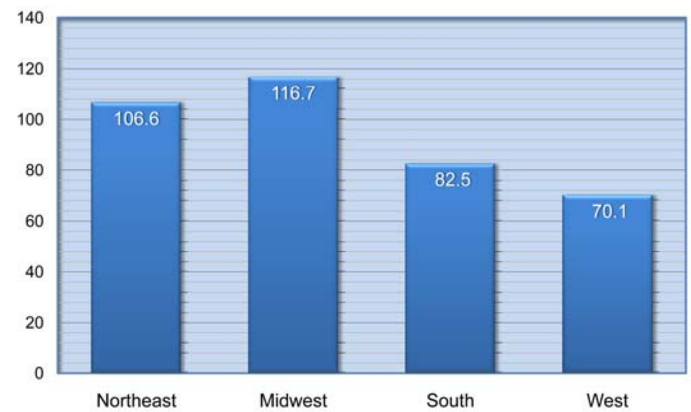
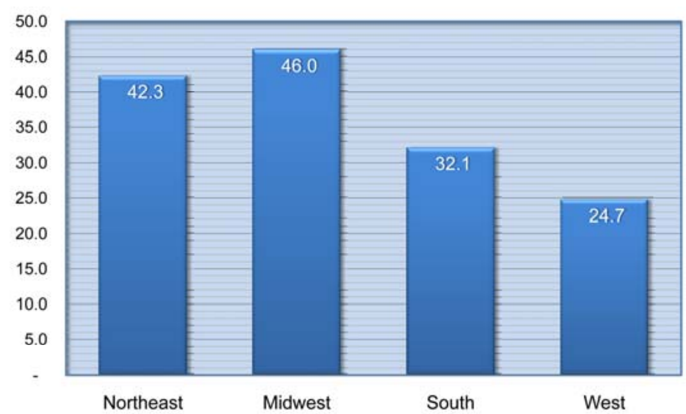


Figure 10. Delivered (Site) Energy Use by Region – Per Household Member (MMBtu)



[27] BEDB 2007 1.2.7 (Source: EIA, A Look at Residential Energy Consumption in 2001, Apr. 2004)

Table C. Share of Households by Census Region and Vintage, as of 2001[28]

Region	Before 1970	1970-1979	1980-1989	1990-2001	Total
Northeast	13.3%	2.0%	2.2%	1.4%	18.9%
Midwest	13.5%	3.4%	3.4%	2.6%	22.9%
South	13.8%	7.2%	7.2%	7.1%	36.3%
West	10.3%	5.0%	5.0%	3.4%	21.8%

Table D. 2001 Delivered End-Uses for an Average Household, by Region (million Btu/household)

End Use	Northeast	Midwest	South	West	National
Space heating	63.1%	66.8%	27.7%	29.7%	43.9%
Space cooling	3.3%	5.1%	11.5%	5.4%	7.7%
Water heating	18.0%	17.4%	13.9%	15.1%	15.8%
Refrigerator	4.2%	4.9%	6.0%	4.0%	5.0%
Other appliances and lighting	20.1%	23.7%	24.3%	20.2%	22.5%

Table E. 2001 Residential *Delivered* Energy Consumption Intensities, by Housing Type[29]

Housing Type	per square foot (1000 Btu)	per household (million Btu)	per person (million Btu)	percent of total consumption
Single-Family	**44.8**	**107.3**	**39.8**	**80.1%**
Detached	44.7	108.5	39.6	69.4%
Attached	45.6	100.4	37.5	10.7%
Multi-Family	**52.1**	**54.3**	**25.8**	**14.6%**
2-4 units	56.1	78.1	34.3	7.5%
≥ 5 units	48.5	41.0	20.5	7.1%
Mobile Homes	**72.0**	**75.9**	**293.4**	**5.3%**

[28] BEDB 2007 1.2.7
[29] BEDB 2007 1.2.6 (Source: EIA, A Look at Residential Energy Consumption 2001, 2004) Note: Small sampling for multi-family data could result in data that is not representative.

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