Realizing residential building greenhouse gas emissions reductions: The case for a Web-based geospatial building performance and social marketing tool

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ABSTRACT

As the United States joins the global effort to mitigate climate change, we will need to develop and deploy a variety of tools for catalyzing, monitoring, and verifying greenhouse gas (GHG) emissions reductions in diverse economic sectors. This paper proposes a Web-based geospatial building performance and social marketing tool that will: (1) effectively and transparently track the GHG emissions associated with energy and water consumption in residential buildings; (2) provide tailored feedback to foster household behavior change toward energy conservation and efficiency improvements; (3) speed the integration of building performance and GHG emissions reductions into property valuations and real estate transactions; and (4) standardize residential GHG emissions data sharing among utility providers and within carbon markets.

In making the case for the tool, this paper addresses a range of questions about the science, technology, and market factors currently converging in its support. What does the growing body of social science research suggest about social networks, social norms, and maximizing behavior change interventions in energy efficiency and conservation? How is this tool unique within the industry? In what ways does it expand upon a foundation of current information technologies? How will the tool interface with existing third-party green building programs such as the U.S. EPA ENERGY STAR® and the U.S. Green Building Council (USGBC) Leadership in Energy and Environmental Design (LEED) Rating System? Why do emerging carbon markets and energy efficiency policies and programs in the European Union and the United States necessitate transparency in GHG emissions data at the household level? What will utility providers, building professionals, REALTORs®, and homeowners respectively gain from utilization of the tool?

INTRODUCTION

At its core, this paper makes the following four major points and associated sub-points:

1. The climate challenge is fundamentally a built environment & behavior change challenge.
    a. Energy efficiency interventions & programs are failing to live up to their potential primarily due to the failure to facilitate building occupant and building industry behavior change.
    b. Building science cannot be separated from its associated social science counterparts.
2. Feedback is critically needed but is scarce.
    a. Distributed energy and water consumptive use transparency is imperative for the following purposes:
        i. Improving energy modeling tools,
        ii. Catalyzing behavior change,
        iii. Fostering carbon market products such as energy efficiency certificates (EECs) as one or more climate stabilization mitigation wedge(s).

3. A Web 2.0 strategy merged with community-based social marketing (CBSM) can provide both a platform & a process for energy efficient behavior change.
   a. CBSM offers tools and strategies to unify social science with building science.
   b. Web 2.0 philosophies and practices can allow for creative adaptation and building marketplace transformation through data transparency and social networking phenomena.
4. Climate change & peak oil are synergistic in both positive and negative ways.
   a. Both challenges are real and appear to be already affecting the linked environmental, social, and economic systems underlying sustainability.
   b. Both challenges need mitigation immediately and potential solutions for each will fail if both are not addressed in tandem.

CLIMATE CHANGE AND BUILDINGS

The Intergovernmental Panel on Climate Change Fourth Assessment Report (AR4) Synthesis Report states "warming of the climate system is unequivocal…[and] most of the observed increase in global average temperatures since the mid-20th century is *very likely* (>90%) due to the observed increase in anthropogenic greenhouse gas [GHG] concentrations" an increase in likelihood since the IPCC Third Assessment Report [1, pp. 2, 6]. Of these anthropogenic GHGs, "the largest known contribution comes from the burning of fossil fuels" which lead primarily to atmospheric increases in carbon dioxide (CO_2), though human activities also result in emissions of other greenhouse gases such as methane (CH_4), nitrous oxide (N_2O), and the halocarbons [2, p. 100].

The Building Sector: A Heavy Footprint

Globally, buildings use 30 to 40% of primary energy [3]. Though this energy is typically generated from biomass in low income countries, it comes mostly from the burning of fossil fuels in middle and high income nations [3]. Within the United States, the building sector accounts for approximately 48% of annual GHG (greenhouse gas) emissions, with 36% of the direct energy related GHG emissions and an additional 8-12% of total GHG emissions related to the production of materials used in building construction [4-6]. Incorporating the transportation of materials and other activities related to constructing buildings would add even more CO2 emissions to the building sector [4]. Additionally, the ratio of embodied energy consumption for the building sector is estimated at approximately 15-25% from the construction phase and 75-85% from the operations phase assuming a 50-year building lifespan [4, 7].

Specifically, the residential sector within the U.S. consumes approximately 20-25% of primary energy use meaning households account for about 50% of the CO2 emissions within the U.S. building sector [8-10]. Grid connected utilities provide the vast majority of the electricity to power these buildings and are expected to undergo market pressures to reduce these associated GHG emissions.

The Building Sector: Wedge(s) of Efficiency

The greatest potential for an effective near-term mitigation wedge for climate change comes from energy conservation and efficiency improvements in the built environment [11]. The climate stabilization triangle envisioned by Pacala and Socolow proposes GHG emissions reductions via "seven [originally, but now eight] equal pieces, or 'wedges,' each representing one billion tons a year of averted emissions 50 years from now (starting from zero today)" [12]. As there is no silver bullet for mitigating climate change, the 15 wedges proposed by Pacala and Socolow transcend all sources of GHG emissions and sequestration strategies and must be used in combination [11]. However, each 25% reduction in combined electricity use in residential and commercial buildings worldwide can account for one mitigation wedge [12].

The IPCC AR4 Working Group 3 concluded with "*high agreement, much evidence*" that the building sector can substantially reduce GHG emissions by "using existing, mature technologies for energy efficiency that already exist widely…have been successfully used…[and are] cost-effective,…[but] to a significant extent [have] not as yet been widely adopted" [13, p. 406]. A recent report by the U.S. Climate Change Science Program estimates that homes can achieve carbon emission reductions up to 70% with current best practices [14], and the U.S. Department of Energy Building America program aims to reduce the energy use of new homes by 70% by 2020 [15].

Furthermore, the American Institute of Architects estimates that the U.S. built environment will undergo 75% turnover via new or significantly renovated buildings and infrastructure during the thirty year period from 2005 to 2035 [5, 6]. With the technology available to improve residential energy efficiency, existing programs in use to promote these technologies, and major redevelopment trends anticipated in the next quarter century, one could argue that the primary limiting factors to achieving these efficiencies are individual behavior change and the public policies necessary to catalyze these changes.

The Building Sector: Cost Negative U.S. GHG Emissions Abatement Potential

In one estimate of U.S. GHG emissions abatement potential per year through 2030, energy efficiency in buildings and appliances is projected to eliminate 710 megatons (mid-range) to 870 megatons (high-range) of GHG emissions [16, p. xiv]. The authors of the McKinsey & Company report [16, p. 20] go on to state that slightly over 50% of the abatement potential for either their mid-range or high-range cases can be attributed to the combination of the buildings-and-appliances and the power sectors. Most importantly, the report concludes that many of the mitigation strategies in the buildings-and-appliance sectors are negative cost options, meaning they provide a higher long-term monetary savings than the immediate-term investments necessary for implementation.

> "This large cluster of negative-cost options includes: lighting retrofits; improved heating, ventilation, air conditioning systems, building envelopes, and building control systems; higher performance for consumer and office electronics and appliances, among other options" [16, p. xiv]. "[However,] misaligned incentives that pervade the utility system today…often place power producers' sustained earnings at odds with resource efficiency" [16, p. 20].

Green Building Rating Systems: Proliferating But Questionable Effectiveness

Green building rating systems and other metrics are proliferating at the international, national, statewide, and regional scales. National scale government run programs include the U.S. EPA ENERGY STAR® program and the U.S. DOE Building America program. Examples of non-governmental organizations at the international and national scale include Audubon International, the Green Building Initiative's Green Globes, and the most widely known of all programs, the U.S. Green Building Council (USGBC) Leadership in Energy and Environmental Design (LEED) suite of rating systems. Statewide programs include non-governmental organizations such as the Florida Green Building Coalition, while regional programs include utility led efforts such as the Green Built Homes of Florida and a host of diverse local government controlled voluntary ordinances and incentives often based on one or more of these other independent third-party systems.

However, one might question the effectiveness of these programs. Since its inception in 1992, the ENERGY STAR® program has gained recognition and increased in scope of impact. According to the ENERGY STAR® Qualified New Homes program Web site, the national market presence averaged 12% in 2006. Though ten states have over 20% participation, in many parts of the country its suite of services are still under utilized. Florida is a prime example. Despite having led the United States in new single-family homes permitted for 12 of the last 16 years [17], in any given year, less than 3% of the homes permitted in Florida have utilized the ENERGY STAR® Qualified New Homes program. It could be argued that the scope of this program and many others is failing as judged by the low market presence of participating buildings. Yet, even if their scope of impact were to be judged a success, the mere use of these programs and the award of their various labels may belie the true scale or depth of their impact. As described later in this paper, these programs are typically based on theoretical models of building performance that often stop short of measuring the actual performance of buildings, which is highly dependent on occupant behavior.

As evidenced in these passages, the building sector is a prime mover in the global economy that also results in its extraordinary contribution to anthropogenic climate change. However, within the U.S., mitigation opportunity abounds as this sector is anticipated to undergo rapid turnover in the next three decades. The knowledge and technology to make our buildings more energy efficient, less carbon-intensive, and less expensive to operate exists today. Programs to foster green building abound. The question remains, will we collectively act on this knowledge?

DISTRIBUTED NON-POINT EMISSIONS SOURCES AND THE INTERACTION OF SOCIETY AND TECHNOLOGY

Arguably, the most persistent barrier to market implementation of building energy efficiency strategies is the complex and dynamic nature of behavior change. More specifically, a "lack of information and lack of financing," seem to disrupt the significant potential for energy efficiency improvements [10]. Trends in recent years show a shift in the proportionate impact of pollution vectors from large point-sources (such as large companies, factories, etc.) to smaller, more distributed non-point sources (such as small groups, households, and individuals) [18-22]. Policymakers and researchers are increasingly recognizing the behavioral considerations of diverse challenges and the potential for solutions via social processes and interventions to modify individual choices [18-22].

> "Paul Stern, who directs the Committee on Human Dimensions of Global Change for the National Research Council…said one recent test suggests that about 30 percent of U.S. contributions to climate change are 'attributable to individual choices.'…Stern said that in the long run, the nation needs to 'make it easy to change individual choices' by making environmentally friendly actions easier. He cited automobile fuel-efficiency mandates, now up for debate in Congress, and land-use policies that discourage sprawl as examples." [22]

Buildings, Cars, and Complex Social-Technological Systems

Unfortunately, making it easier to change individual choices isn't so easy after all. For better and for worse, the energy efficiency wedge is an intricate mix of building science and social science. Occupied buildings are complex social-technological systems, not unlike organisms and their collective populations. An organism's or population's ability to adapt to its environment and new selection stressors such as climate change can be expressed as a combination of its ability to disperse to more suitable habitats, its genotypic response (the evolutionary component) and its phenotypic response (the plastic component) [23, 24]. Metaphorically within a residential building, one could describe the less changeable components, such as the building envelope and the mechanical, electrical, and plumbing (MEP) systems, as a home's DNA or "hardware." This genetic hardware is based on forms and functions inspired by previous construction generations and lessons learned. As such, a home's genotypic response is slow to change, requires higher capital investment, and likely follows only after the simple phenotypic (i.e., operational) responses have been exhausted.

A residential building's phenotypic responses might include the home's occupant behavior and other controls. These operating system or "software" style characteristics are controlled in relation to environmental response, occupant identity, cultural norms, economic cost/benefit ratios, and a variety of socially driven processes. As such, a home's phenotypic response is rapidly mutable, requires lower capital investment, and is likely the first line of attack in a building's shift toward energy efficiency.

<u>Evolution and Plasticity of Light-Duty Vehicles: The Example of Producer and Consumer Behavior Change</u>

A good metaphor for understanding the relationship between the genotypic and the phenotypic responses of a social-technological system is the ebb and flow of automobile purchasing trends and driving trends in the face of rising energy costs. In their April 2008 monthly sales reports, all of the major automobile makers reported markedly lower sales of light trucks (which includes pickup trucks and SUVs) while posting either gains in car sales or decreases in car sales that were much less than the steep declines in light truck sales [25]. This response to higher gas prices could be described as a genotypic response as car buyers look for more efficient "hardware" solutions and thus selection pressure drives the evolution of vehicles toward more efficient models.

Simultaneously, drivers that either cannot afford or are not in a position to switch out their current vehicles for a more fuel efficient model are now becoming aware of the behavioral and maintenance conditions that can contribute to poor fuel economy (*Table 1*). In other words, the social part of a car's social-technological system offers a phenotypic response by making "software" changes to maximize the efficiency available in their existing "hardware." Recently, the European Petroleum Industry Association in association with the European Commission created an "eco-driving" campaign to foster the rapid behavior change strategies possible within the personal vehicle sector [26].

Table 1. Phenotypic (or Plastic) Conditions Affecting Vehicular Fuel Economy

Behavioral or Maintenance Condition	**Affect on Vehicular Fuel Economy**
Aggressive driving	↓ up to 33% highway and 5% city
Excessive speed	↓ between 7 – 23% for speeds above 60 mph
Excessive weight	↓ of 1 – 2% per 100 lbs of excess weight with increased effects for smaller vehicles
Others: excessive idling, using roof racks, not using cruise control, not using overdrive gears, etc.	Uncalculated
Improperly tuned engine	↓ approximately 4% for minimally out of tune, up to ↓ 40% for serious maintenance issues such as a faulty oxygen sensor
Dirty air filter	↓ up to 10% for clogged air filter
Improper tire inflation (both under and over inflated)	↓ approximately 0.4% for every 1 psi drop in pressure for all four tires
Improper motor oil	↓ approximately 1 – 2% for using improper motor oil for vehicle's engine type

Source: U.S. Department of Energy

Other phenotypic conditions include the frequency of vehicular use, distance driven, and the number of occupants within the vehicle (i.e., driving alone or carpooling). Given enough time, rise in energy prices, and increase in consumer demand, the vehicles with poor fuel economy will either fill an increasingly narrow market niche, change their genetic design heritage to improve efficiency, or they will go extinct to be replaced by some competing design that will be selected for in the new socioeconomic conditions of a climate change and peak oil induced carbon constrained future.

When Building Technologies Fail Society

Similarly, behavioral and maintenance issues are critical factors in the real world energy consumption and associated GHG emissions for buildings. For example, recent field studies from the Energy Center of Wisconsin have suggested that programmable thermostats may be achieving lower savings than their estimated potential [27]. These social "software" failures of a technologically proven "hardware" product result from misuse, misunderstanding, indifference, or other behaviorally driven factors. This has led the EPA to withdraw this product's ENERGY STAR® certification mark as of May 1, 2008 [27].

There is evidence that a similar phenomenon may cause some ENERGY STAR® Qualified New Homes to fall short of their pre-occupant U.S. Home Energy Rating System (HERS) Index [10]. "Research has shown that actual occupant behavior is probably the single most significant determinant of actual energy use…even if there are no HERS system differences, the predicted energy use or energy cost can be off by 50% or more due to occupant behavior" [10, p. 342]. The best levers for influencing energy efficient genotypic and phenotypic responses in the residential built environment are likely to be those that alter social norms, skew cost/benefit ratios toward energy efficient investment, and provide rapid feedback on relative comparable homes, occupants, and systems. Together these levers will lead to cross generational hardware improvements in new construction and/or renovations and ultimately foster evolutionary change in energy efficiency through an adaptive management paradigm.

BUILDING ENERGY ANALYSIS TOOLS

Building energy software tools arose in the 1970s, followed by refinement within the professional realm in the 1980s, and expansion of scope, scale, and diverse user applicability in the 1990s [28]. Today, the U.S. Department of Energy lists 342 tools on their Web directory [29]. There is clearly no dearth of options for our collective energy efficiency toolbox. In a thorough review of North American residential energy analysis tools, Mills suggests the ideal status these tools may achieve is as follows [28, p. 865]:

> "The long-term vision held by many in the building science community is one [energy analysis tool] involving virtual (collaborative) 'life-cycle' building tools that simulate actual buildings and their construction coupled with intelligent systems that monitor and archive design intent and performance and feed the results back to the simulation tools, which in turn, grow more refined through integrating better empirical data."

Information Obscurity: The Limiting Factor for Energy Analysis Tools

Though this vision is logical and worthwhile, there are many existing limitations to the usefulness of these tools as they currently exist. The primary limitation involves "the availability of measured end-use data, and manipulations of that data (e.g., weather normalization) to facilitate meaningful comparisons to tool outputs" [28, p. 874]. The scarcity of feedback regarding actual energy and/or cost savings from residential energy efficiency retrofits also hampers tool validation and improvement [28].

After reading the thorough Mills [28] review, one is left wondering how effectively these tools foster end-user energy efficient behavior and drive market transformation toward high performance buildings. Despite the reality that millions of grid-connected households across the country have records of their energy and water consumptive end-use on file in disparate utility databases, Mills [28] found it expedient to test the various analysis tools on only two actual residential building historical records.

In one of the few studies systematically comparing the U.S. Home Energy Rating System (HERS), the authors lament, "there exist very little published data on HERS' predictive ability" and despite "tens of thousands of houses [having] been rated in the last several years, few HERS providers were willing and able to supply us with data" [10, p. 343, 345]. Even worse, the utility which sponsored the research (Florida Power and Light), prevented the authors from making a full public disclosure of the report or data [10, p. 344].

Buildings and Society: The Needed Convergence of Two Sciences

Mills [28, pp. 878-879] concluded by stating, "the design of residential energy analysis tools should be grounded in social science as well as engineering, with close attention given to the intended use and audience." While Stein and Meier [10, p. 344] announced, "perhaps the most valuable finding of the FSEC analysis is the fact that it was possible to improve significantly the predictive ability of the rating tool based on the data collected." Both of these papers only accentuate the need for massive data transparency and the creation of a more powerful performance monitoring system that incorporates feedback loops for both behavior change and continual tool improvement. In order for building energy analysis tools to realize their potential to serve as catalysts for a more efficient built environment, they will need to infuse social science into their building science protocols.

COMMUNITY-BASED SOCIAL MARKETING

People often fail to change their behavior or engage in a new activity because they either don't know about the activity and its benefits, they perceive of significant internal or external barriers to activity engagement, or they perceive of benefits in the continuation of present behaviors [30, p. 2]. Community-based social marketing (CBSM) has been proposed as a process to overcome these obstacles. As described by McKenzie-Mohr and Smith [30, p. 150], "community-based social marketing involves four steps: (1) identifying the barriers and benefits to an activity, (2) developing a strategy that utilizes tools that have been shown to be effective in changing behavior, (3) piloting the strategy, and (4) evaluating the strategy once it has been implemented across a community."

Perceptions of barriers and benefits to new activities can vary dramatically among individuals and the choice to undertake one behavior often limits the ability or desire to adopt another behavior [30]. Because of these complex dynamics, the tools of behavior change work best in combination and include: (1) commitment; (2) prompts; (3) norms; (4) communication; (5) incentives; and (6) removing external barriers [30]. The previous sections of this paper detailed some evidence within scientific literature and popular media of how and why we are failing to achieve the vast potential for energy efficiency in buildings. Community-based social marketing offers one potential avenue to unify social science with building science and engineering in an effort to foster energy efficiency in the social-technological systems of our built environment. Later in this paper, the connection between CBSM and the Web 2.0 meme is made.

The Power of Commitment and Social Norms

In general, household energy conservation interventions have shown mixed results with the most successful interventions consisting of combined campaigns using both antecedent (specifically goal setting and commitment) and consequence (specifically feedback) protocols [9, 31-35]. Part of these mixed results arise from the fact that approximately 80% of Americans regularly express strong environmental concern, yet barely 20% of Americans actually translate this concern into concrete changes in their everyday practices [36, 37].

However, insights into potential pathways for bridging the "value-action gap" are emerging in the social sciences. When social capital and information networks are strong and interconnected, sustainability and environmental planning initiatives tend toward greater degrees of success [38, 39]. Meaningful social norms and networks visibly convey social approval/disapproval, group performance feedback, and allow for the establishment of group identity [40, 41]. Congruently, buildings and land may suitably serve as tangible indicators of group identity [42]. Actively engaging individuals and groups in energy efficiency interventions via non-coerced commitment and the clear visualization of new social norms and peer performance can help people to view themselves as concerned about mitigating climate change and improve the speed and depth of behavior change [30].

Incentivizing Efficiency through Transparent Markets

Additionally, these "communicative tools are more likely to be effective when combined with regulatory or economic instruments" [43]. Potential regulatory and economic instruments, such as cap-and-trade carbon markets and carbon tax schemes, are currently transpiring at scales from local to international. It is specifically these trends in building science know-how, social science research, recognition of the need to address the numerous disparate non-point source causes of energy resource depletion and GHG emissions, the emergence of carbon markets, and the confluence of software and hardware in the Web 2.0 paradigm that raise the possibility for a Web-based geospatial building performance and social marketing tool.

The Emergence of Building-Related Consumptive Use Transparency

In response to the growing realization that energy efficiency efforts are stalling under the weight of data scarcity, California has taken the call for data transparency to a new level. On October 12, 2007, the State of California approved Assembly Bill No. 1103, Chapter 533, Section 25401.10 of the Public Resources Code which mandates that by January 1, 2009, all electric and gas utilities will disclose "energy consumption data of all nonresidential buildings to which they provide service, in a format compatible for uploading to the United States Environmental Protection Agency's Energy Star Portfolio Manager (Energy Star Portfolio Manager), for at least the most recent 12 months" [44].

Europe is entering the 21st century information age as well. Beginning on December 14, 2007, all for sale properties in England and Wales will be required to include Home Information Packs in the property transaction [45, 46]. These packs are "designed to reduce the stress of both buying and selling by containing all essential information about the property you are considering buying upfront," including the Energy Performance Certificate, a European Union mandate for energy performance labeling for buildings by January 2009 [45-47]. In contrast, the ENERGY STAR® for Homes program in the U.S. uses the HERS Index to rate new construction, but doesn't actually keep records of the scores for each certified address. ENERGY STAR® for Homes does not have a similar rating system for existing dwellings.

Information Alone is an Insufficient Driver of Behavior Change

Though these preliminary efforts are a meaningful first step, the problem with programs such as the European Union Energy Performance Certificate and ENERGY STAR® for Homes are that they are very static, require accredited energy assessors such as HERS raters, and assume simply providing basic information will lead to behavior change. Using accredited energy assessors is important and provides third-party verification, but a system that allows for more continual feedback and social networking, especially at the moment that renovation decisions are made, is likely to provide a significantly more meaningful affect on actual behavior change especially when linked to regulatory policies.

As suggested earlier, meaningful social norms (e.g., those that may foster energy efficient behavior) require visible feedback on policies (e.g., taxes or incentives), performance (e.g., existing consumption behavior), and perceptions (e.g., attitudes of what is acceptable) [34, p. 10]. Another paper suggesting that the European home energy label is only a partial solution and an incomplete one at that, states as follows:

> "In general, through the analysis of the interviews, we have shown that people are not empty recipients of the new information given by the energy-performance label. They rather are actors that interpret or reject new information on the basis of their previous knowledge and of the norms of their social network…Summing up, this paper shows that the idea of households as rational economical actors who will renovate their homes in an energy efficient way if they are just given the right knowledge has to be abandoned. This does not mean that people in general are irrational or that they do not take care for their own interest, it rather means that rational behaviour from an everyday life perspective includes many other elements than just economy, as for instance identity and social comparison, convenience, time use, etc. This does however not mean that they energy labels on buildings are a bad idea but that should be seen as one input among others to people's own knowledge and communication about their house and its renovation." [33, p. 2886-2887]

These studies and the references regarding behavior change in the previous sections provide the impetus to move beyond merely logging the GHG emissions performance data from the built environment, to fully integrated interdisciplinary feedback and monitoring platforms that foster energy efficient social norms through a social marketing process. Government agencies and academia have long known the value of tracking pollutants and generating emissions inventories. The growing body of social science has opened the door for these regulatory and research efforts to move beyond backdoor tracking and into the limelight offering useful feedback for the average consumer.

A NEW INFORMATION REVOLUTION

Should building energy and water consumptive use data stay private or enter into the public domain? If the data were publicly availably, how might it affect the marketplace? In states with both municipally owned utilities and sunshine laws for governmental operations, this utility data already resides in the public domain. It is merely invisible until someone makes the appropriate request for the data. Unfortunately, these requests are rare and come only when a proactive potential renter or homebuyer wants to investigate the operational costs of a dwelling under consideration. Most people do not realize the data is out there nor how it might affect their behavior through the establishment of social norms. Just like the computer software industry has begun a shift toward open source programs and platforms, maybe it is time for a new information revolution in building performance, one that makes transparent each individual source of energy and water consumptive end-use so that the cultural chips will fall where they may.

From Conspicuous Consumption to Conspicuous Reduction

Some people or organizations might question a call to release the data, as evidenced in the Stein and Meier account of Florida Power and Light's reticence to share the full results of research they funded. However, many types of consumptive end-use are already highly conspicuous and have a significant affect on consumer behavior. Expensive designer products from clothing brands to watches, from cars and SUVs to certain desirable addresses in town have been suggested as means of conspicuous consumption to visibly reflect social status or “serve as a signal of non-observable abilities” [48]. A simple search for the term “conspicuous consumption” on Google Scholar returned 21,200 articles as of May 2008.

Conspicuous feedback plays a critical role in social networks, cultural norms, and behavior change. “A consumer’s choices are not isolated acts of rational decision making…[but rather] significant parts of an individual’s attempt to find meaning, status, and identity” [49, p. 14]. In a world seemingly defined by the race to “keep up with the Joneses,” those striving for sustainability or a stabilized climate all-too-often view production as the problem and regulating production as the answer [49, p. 5]. However, Princen, Maniates, and Conca [49] suggest if we stop viewing “consumption as sacrosanct” and we tap into the “significant portion of American society [that] yearns for a less harried, less materialist, less time-pressed way of life, and that [knows] that their individual consumption and consumption of their society as a whole are threatening environmental life-support systems” we may be able find solutions via the beneficial use and modification of the phenomena that have thus far led to the “social embeddedness of consumption” [49, pp. 5, 13-15].

Reinforcement for this perspective can be found in two recent medical studies documenting the power of social networks in both facilitating the obesity and smoking epidemics while also offering solutions through healthy social networks and intervention programs that utilize peer support strategies based on positive social norms [50, 51]. In layman’s terms, both positive and negative behaviors concerning personal health (or environmental protection for that matter) are highly dependent on the dynamics of social networks and group identity.

The U.S. EPA Fuel Economy Label: A Catalyst for Social Norms

Light-duty vehicles are a good example of both the conspicuousness of energy end-use in consumer behavior but also the subtle difficulties in understanding the difference between estimated or perceived performance and actual performance. Most Americans would likely answer a question correctly about which vehicle has better fuel economy when given a choice between a 2008 Cadillace Escalade (12 mpg city / 18 mpg highway) and a 2008 Honda Civic DX Sedan (26 mpg city / 34 mpg highway). Yet, all is not always what it seems, especially when comparing vehicles within the same class or even within the same model line. When looking at a Honda Civic, one might have trouble differentiating between the Honda Civic DX Sedan and the Honda Civic Hybrid Sedan since the cues are subtle changes such as different rims and the Hybrid nameplate on the trunk.

The story of the Toyota Prius is slightly different and may reveal why its sales record has been so strong and it has become the poster car for fuel efficiency. Highlighting the important motivational power of social networks and conspicuous consumption, a recent CNW Marketing Research study cited by a July 4, 2007 New York Times story on why Toyota Priuses have enjoyed such success even while other hybrid models struggled to sell, determined the most obvious choice of higher fuel economy was third (at 34% of respondents) on the list of top reasons customers cited for purchasing the model [52]. The top choice, at 57%, was that the Toyota Prius “makes a statement about me” [52]. And why does the Toyota Prius make a better statement than its competitor, the Honda Civic Hybrid? It is likely because the Toyota Prius is a stand alone hybrid model with no alternative lower fuel efficient drivetrain options. One Prius looks and performs like all Prius models, but the somewhat less obvious drivetrain of the multiple model Civic line is important to know if one wants to make an identity statement.

Though it is tough to make the guts of a Civic visible to the outside world and a bit tougher to make truly accurate comparisons of different vehicles fuel economies upon first glance, the federal government understands the value in making the energy performance of vehicles visible in the public domain. At the point of sale, all new cars are required to have a U.S. Environmental Protection Agency (EPA) Fuel Economy Estimate sticker on the window. This also allows buyers and sellers in the used car marketplace to incorporate the fuel economy of a vehicle into its valuation at the point of transaction though historical fuel economy records available at www.fueleconomy.gov and ultimately picked up by the major automobile research and sales sites such as www.edmunds.com, www.autotrader.com, and others.

Models vs. Reality

However, as mentioned earlier, models do not always reflect reality. These U.S. EPA Fuel Economy Estimates are based on a series of testing assumptions and are not necessarily indicative of real world performance. As described in the previous section about genotypic and phenotypic responses, driving behaviors are very fluid. Though these driving behaviors have changed over time, the process for evaluating a vehicle's fuel economy has stayed relatively the same leading to a growing gap between modeled performance and actual results. As a result, the U.S. EPA altered its vehicle evaluation methodology to come up with a more accurate estimate starting with the 2008 vehicle model year. This alteration to the US EPA evaluation process was made possible through the comparison of modeled outputs with actual data collected in the real world fuel efficiency performance of vehicles.

Though people likely make their purchase decisions about a new or used car on a wide variety of characteristics such as comfort, safety, design, cargo capacity, and a multitude of others, the very fact that the marketplace can place a value on the energy performance of vehicles should the marketplace so desire it, is dependent on freely shared and clearly visible performance information. The same cannot be said for buildings. Even though the size of a home might offer an approximation as to the energy and water performance and their associated GHG emissions, just like the vehicle example, the devil is in the details and the relationship of the internal "hardware" and operational "software."

In support of previous studies suggesting energy models do not necessarily reflect reality, preliminary evidence from research being undertaken at the University of Florida suggests that there are large discrepancies in the energy performance between geographically and demographically comparable homes qualified under similar programs such as Energy Star® and Building America. Energy and water use at the meter is what matters and labels may only cause confusion if they are a poor reflection of reality and the uncertainties that come from the combination of a home's hardware and software. Is it possible to replace the "conspicuous consumption" model of the latter half of the twentieth century with a twenty-first century model of "conspicuous reduction" whereby social networks and community norms foster a non-linear and interconnected web of GHG emissions reduction behavior. Maybe, but it will hinge on the freedom and usefulness of information.

THE WEB 2.0, TAILORED FEEDBACK, AND A CBSM TOOL FOR BHEAVIOR CHANGE

In a follow-up to their paper, *A review of intervention studies aimed at household energy conservation* [32], Abrahamse, Steg, Vlek, & Rothengatter [9] highlight "the internet as a potentially effective medium for tailored [energy efficient behavior change] interventions, because it offers the possibility of reaching a relatively large number of households, while at the same time providing custom-made information and electronic feedback to individual users." The authors key messages include the benefit of multi-disciplinary approaches to intervention, the value of web tools, the impact of linking direct and indirect energy use, and the need for larger sample sizes to validate the findings [9]. Taking into account all that has been discussed in this paper to this point, it seems intuitive that the World Wide Web offers a platform for unifying building science and social science.

Though there is debate about what Web 2.0 is, and is not, this philosophical paradigm offers at least a different way of looking at what the Web can be [53]. In the Web 2.0 meme (i.e., culturally shared way of thinking or behaving), the Web is viewed as a platform based on characteristics such as the following [53]:

1. Potential for emergent functionality without predetermined user behavior.

2. Joyful and rich user experience.
3. Trust in the users as they add value.
4. Adaptable and self-improving the more people use it with the right for user remixes (though some rights reserved).
5. Power of the Web as vehicle for harnessing collective intelligence.
6. Existing in a state of perpetual beta.
7. Data and database management as the core or the "Intel Inside" where "SQL is the new HTML" and software evolves into "infoware."

A Vision for a Web-Based Geospatial Building Performance and Social Marketing Tool

A geospatial Web-based tool based on the Web 2.0 meme could offer a foundational building block to help realize residential energy efficiency and GHG emissions reductions. A Web 2.0 response to the critical need for data transparency in building related energy and water consumptive use might look like a fusion of the geospatial and database management of www.zillow.com and the data from disparate grid-based utility providers, energy modeling tools, and green building rating systems. Whereas www.zillow.com has put a user friendly, interactive face on property valuation for the real estate marketplace, a similar building performance Web tool would remove the obligate need for the user to input their own utility bill records into the various self-assessed energy audit tools such as the Home Energy Saver (http://hes.lbl.gov/) and the Home Energy Yardstick (http://www.energystar.gov/index.cfm?c=home_energy_yardstick.index). These existing energy audit tools would become value-added features instead of hurdles for the average person.

The Benefit to the Marketplace: Decisions Driven by Data

With a "data driven" mentality, this fully transparent interface would ideally be programmed to automatically calculate consumptive use data and trends for each address and provide relative comparisons across different house sizes and different geographic scales including medians, baselines, while also providing a more accurate representation of models versus reality. The importance of these relative comparisons and the value of more meaningful information is documented through research into the concept of "Innovative Billing," which provides "individualized energy information for a mass audience – the entire residential customer base of an electric or gas utility" via comparison groups with the best groups based on "street name, meter book, or multiple house characteristics" [54]. This tailored feedback functionality would not require end-user input but it would necessitate the sharing of energy (e.g., electricity, natural gas, etc.) and water consumptive use data from grid connected utilities. The participation of all utility providers nationwide would optimize comparison groups across geographic regions, maximize the number of households reachable, and offer the most useful feedback for existing building energy analysis tools.

Currently, most energy efficiency campaigns are developed and delivered via individual utilities with financing available through a combination of the utilities and local, state, and federal government incentives. The campaigns are often prescriptive in that they provide rebates or other incentives based on end users installing energy efficient technologies such as solar thermal water heaters, solar photovoltaics, more efficient HVAC systems, improved R-value insulation, compact fluorescent lighting, etc. However, they rarely verify the actual effectiveness of these technologies and the incentives are provided even if the estimated efficiency gains are not realized. A transparent Web tool such as the one proposed here would allow for campaigns based on performance, thus rewarding both technological and behavior improvements. It would also detach these campaigns from the sole direction of utilities by allowing local governments and the free market to visualize which individual homes, streets, neighborhoods, or any variety of groups are most in need of energy efficiency retrofits.

Free market campaigns to improve energy efficiency and reduce GHG emissions, such as the San Francisco Climate Challenge (http://www.sfclimatechallenge.org), a collaboration between the local government and two non-governmental organizations, could more easily evolve and prosper in a transparent data driven paradigm. The San Francisco Climate Challenge was unaffiliated with PG&E, the local utility, and provided teams of five or more households an opportunity to compete for prizes (including cash) by lowering their utility bills during the competition billing period as compared to the same billing period one year prior. With a transparent Web tool, performance could be tracked such that annual competitions could reward early adopters and allow for floating baselines that would foster continuous improvement over time. It would also allow for multi-year averages to be used for baseline quantification reducing the potential for unusual behavioral or weather conditions in one particular period to lead to over or under reporting of energy efficiency gains.

The Benefit to the Marketplace: Integrated, Participatory, and Continuously Improving

Another benefit of this type of Web tool would be the unification of the disparate green building rating systems via common performance benchmarks. Each system offers its own protocols and marketing benefits, and though their respective means are important, their respective ends also matter. With an open and transparent Web tool, the green building rating system used and its associated modeled energy performance could be documented for each individual residential address and ultimately compared to actual performance over time. This would offer more accurate marketing benefits by showing how the designed performance of specific rating systems, specific energy raters, and/or specific architects and builders reflected the real world operational conditions of their intent. This clarity of models vs. operations would reduce the market value of poorly predictive rating systems, raters, and builders while simultaneously increasing the value of those that lived up to their claims.

The cycle of continuous improvement of energy models could also be mirrored through a cycle of continuous improvement of the Web tool itself. This might take the form of a three tiered structure of participation and data quality. Tier One data would consist of raw consumptive end use data from grid connected utilities and raw building characteristics from property appraisers or the Multiple Listing Service (MLS) used by REALTORS®. This would be the lowest quality data, but offer the most accessible user interface because the basic performance of each individual address and groups of addresses would already be logged into the system with trends and comparables rapidly and readily visible to all users of the Web site. This would minimize the selection bias concerns inherent in the current energy analysis Web tools whose comparisons are based on the small number of participants who voluntarily enter their utility billing data. Tier One data would also offer simplistic green building case studies by merely archiving the green building rating system used, the certified score and the credits pursued, and the actual performance as a result of these green design and construction principles.

Tier Two data would consist of end-user self-assessment and information posting. In this tier users would voluntarily perform a self-assessed energy audit (e.g., the Home Energy Saver previously discussed) to update the details on their individual home, such as window size and type, attic insulation R-value, water heater type and fuel source, etc. Here, much like users of www.zillow.com can claim their house and post photographs and other information about improvements that might increase their market valuation of their property, users of the Web tool would be able to document the date and type of energy efficiency improvements made to the house. Each technological or behavior improvement might show up as an icon on the long-term trend graph of energy and water use which would provide a means of visualizing how and why trends may improve over time. As property appraiser and MLS data may be incomplete and/or incorrect, this would allow end-users an opportunity to increase the quality of the building characteristics archived on the Web site. However, since Tier Two relies on end-user input, there is still a chance for errors and/or "gaming the system."

Tier Three data would consist of "certified" building and consumptive use data from one or more independent third party agents. These agents might include the HERS raters currently used for the ENERGY STAR® program and the various green building rating systems, home inspectors used during real estate transactions, local building inspectors, or any other agent of the local government or another approved program. The Web tool might offer standardized Web-applications and downloadable forms for these agents to use for collecting and posting the data on the Web site. This is the realm where the Web tool would most effectively integrate with the existing green building rating systems and the real estate marketplace. By utilizing a multi-tiered approach to continual data quality improvement, such as the approach proposed above, the Web tool can combine the best of near-term functionality for social networking and cultural norms that lead to energy efficient behavior change with the long-term functionality of improving building science research and diversifying the type and source of energy efficiency incentives. Tracking the three tiers and placing a premium on the quality of the data would drive the marketplace toward self improvement and third party verification.

The Benefit to the Marketplace: Mitigating GHG Emissions Via Carbon Markets

Though the timing is uncertain and the details unspecific, most near-term projections point to a mandatory cap-and-trade carbon marketplace being initiated in the United States similar to the marketplace(s) in other countries which began implementing the Kyoto Protocol in January 2008. "As of mid-February 2008, lawmakers [in the 110th U.S. Congress] had introduced more than 180 bills, resolutions, and amendments specifically addressing global climate change and greenhouse gas (GHG) emissions"[55]. Additional statewide and regional efforts have begun emerging across the country increasing the likelihood that some form of carbon market and/or carbon taxes will be implemented in the United States.

The three most significant challenges to voluntary carbon offset markets are defining additionality, monitoring and verification of the actual offsets, and enforcement of ownership [56]. Other critical considerations include establishing baselines, leakage, securitization, and permanence. With regards to mitigating GHG emissions via energy efficiency, many of these challenges will necessitate the behavior change campaigns, energy modeling, actual building performance tracking, and address-based archives of carbon offset purchases only made possible through an interface similar to the Web tool described in this paper. Background on energy efficiency related carbon market products, establishing baselines, and these challenges to voluntary carbon offset markets are discussed in further detail in an unpublished white paper from the Conservation Clinic at the University of Florida Levin College of Law [57]. Mandatory carbon markets will pose many of the same challenges.

The Benefit to the Marketplace: Meaningful Norms, Prompts, Communication, and Incentives

As discussed earlier, energy efficiency interventions are most effective when they combine behavior change and communication tools with public policies in a seamless interface of social networks, free market innovation, and a thoughtful invisible hand of combined governmental regulations and voluntary incentives. By making the energy and water consumptive end use data freely available and grouped into a variety of relevant comparables, utilities will allow the natural social networking phenomena to motivate individuals and groups to create new social norms of conspicuous reduction. Though social norms will self emerge, they must be guided toward valuing energy and water efficiency through noticeable, self-explanatory, and timely prompts closest in proximity to where action is taken and decisions are made [30]. This guidance will be dependent on the communication of captivating and useful information with comparative feedback from credible sources [30]. Lastly, these new norms must be reinforced through highly visible incentives closely paired with the desired behaviors offering rewards based on early and continuous adoption of established and increasingly more stringent performance thresholds [30].

A functional Web tool would help foster these norms, prompts, communication, and incentives by evolving over time into a holistic platform for the diverse processes of community-based social marketing. For example, in the near-term, the Web tool might only serve as a platform for the visualization and valuation of building performance within the real estate and home building markets. The Web tool might eventually piggy-back on existing home energy audit tools to provide end users with customized reports of the most effective strategies to reduce energy and water use. These reports might take the form of printable spreadsheets consumers could bring with them to home improvement or hardware stores as they search for new products to buy.

Over the long-term, these auditing and product recommendation services might become more dynamic and self-evident. Emerging technology is already allowing Japanese consumers to use their mobile phones to scan various product bar codes to download useful information such as nutritional information from McDonald's hamburgers, house details from real estate sales signs, movie trailers from outdoor billboards, expiration dates and source farm names on meat and eggs, and ticketless air travel using the phone as the key to board [58]. With a Web tool such as this, consumers who have completed a self-assessed energy audit and/or had the details of their home updated via an authorized third party could be offered extremely tailored feedback from product manufacturers, retail stores, and green building rating systems. Theoretically, if product bar codes included detailed information about a product's manufacture and performance characteristics, a consumer walking the aisles of a home improvement store might be able to use their mobile phone to scan the codes and evaluate the projected energy and water performance benefits of a particular product according to their home's unique characteristics.

Furthermore, the potential rebates or other incentives that could be realized by installing a particular product or technology could be tagged to the product's bar code as well. Even the Tier Three independent certifying agents could be provided with a process for smoothing the reporting and tracking of energy efficient retrofits by scanning bar codes of energy efficient products, signing off that these products have been installed, and tagging these products to the individual address where they are being used. Incentives might then take the form of a dual benefit where a partial discount is provided at the point of purchase and installation and the remaining discount is only realized when actual performance achieves a specified acceptable percentage of its designed intent. The Web tool could create a platform for creative incentives such as feebate structures rewarding good energy performers and penalizing poor energy performers based on comparable classifications revolving around floating pivot points tied to GHG emissions reduction goals at local, national, and/or international scales.

PEAK OIL AND CLIMATE CHANGE

With the case for Web tool presented and some potential benefits of the tool described, one other critical point must be made. Climate change mitigation will take place in an era of depleting and cost-escalating conventional oil resources. This era will be defined by a global peak in oil production driven by a combination of geology, geopolitics, economics, and uncontrolled energy demand as a result of global population growth. There is the potential for both positive and negative synergies in the success of climate change mitigation depending on how the world collectively responds to this changing paradigm of petroleum.

Peak Oil: Past, Present, and Future

Peak oil, or the point at which maximum rate of oil production is reached followed by terminal decline, originated in 1956 when M. King Hubbert, a Shell geoscientist, accurately predicted the United States domestic oil production would peak around the late 1960s to early 1970s [59]. Peak oil theory applies across scales to individual oil fields, producing countries, and the globe as a whole. A recent report from the U.S. General Accounting Office described the importance and context of oil in the global economy, concluding oil has no known energetic equal in terms of "extractability, transportability, versatility, and cost," has a finite supply, will undergo a voluntary and/or involuntary peak, and will subsequently decline [60, pp. 6-7].

Estimates of global peak oil vary considerably with the "pessimists" projecting an imminent peak and fairly steep decline anytime within the next 1-10 years while the "optimists" project a peak with an extended plateau and slow decline beginning in about 30 years [60-63]. Khebab, a regular contributor to The Oil Drum, regularly provides updates to major international peak oil models dividing production estimates into three categories based on their respective major prediction agencies and individuals as follows [61]:

(1) *Business as usual* (EIA, IEA, CERA) projecting peak oil generally within the 2030-2038 window.

(2) *Bottom-up analysis* (Skrebowski, ASPO, Koppelaar, Bakhtiari, Smith, Robelius, ACE from The Oil Drum) projecting peak oil generally within the 2005-2012 window.

(3) *Curve fitting* (Deffeyes, Laherrere, Hubbert linearization via Staniford, loglet analysis, Generalized Bass Model via Guseo, Shock Model via WebHubbleTelescope from The Oil Drum, Hybrid Shock Model) projecting peak oil generally within the 2005-2018 window.

"Key uncertainties in trying to determine the timing of peak oil are the (1) amount of oil throughout the world; (2) technological, cost, and environmental challenges to produce that oil; (3) political and investment risk factors that may affect oil exploration and production; and (4) future world oil demand." [60] Regardless of these uncertainties and the disagreement in the timing of a global peak in oil production, a U.S. Government sanctioned report concluded a peak oil crash mitigation program would require initiation a minimum of 20 years before the peak occurs in order to avoid a world liquid fuels shortfall and serious economic damage [64].

Only the most optimistic predictions for oil production provide more than a 20 year cushion, but just barely. Every year we delay a mitigation program shrinks the gap. However, some speculate a transition to unconventional oil resources and other fossil energy alternatives (e.g., oil sands, oil shale, and coal liquefaction) may negate the peak in global conventional oil production [65, 66]. Although this perspective raises increasingly difficult questions about our ability to mitigate climate change as discussed in the next section. Unfortunately, recent trends news stories seem to reinforce the pessimists projections for a near term peak within the 2005-2018 window with many influential leaders in the energy and transportation industries extolling the virtues of conservation and efficiency improvements [67-72].

Why Peak Oil Matters to Building Energy Efficiency and Climate Change Mitigation

The building and transport sectors currently utilize separate energy resources. The global transportation sector is almost entirely (i.e., > 95%) petroleum based [60, 73]. More specifically, the transportation sector accounts for approximately two-thirds of all U.S. petroleum consumption with approximately 60% of transportation uses coming from light vehicles [60, pp. 9-10]. Conversely, the U.S. building sector is reliant on utility-based electricity from a mix of fuels with approximately 49% coal, 20% natural gas, 19% nuclear, 7% hydroelectric, <3% other renewables, and <2% petroleum [73].

Future climate change and peak oil mitigation strategies may lead to competition for common energy sources between the transportation and building sectors through both direct and indirect means [64, 66, 74]. Direct competition may include grid connected light rail, plug-in hybrid electric vehicles, hydrogen fuel production via electrolysis, and other means. Indirect competition may include synthetic liquid transportation fuels derived from coal liquefaction, oil sands (whose production requires significant energetic inputs such as natural gas), and other processes that use energy resources previously used primarily in the generation of electricity for building operation.

A recent energy and climate change policy paper for the Garnaut Climate Change Review, an independent study commissioned by Australia's State and Territory Governments, projects the electrification of the transportation sector to result in "a currently unforeseen 20 – 50% addition to [Australian] national electricity demand by 2030" [74, p. 2]. Furthermore, Farrell & Brandt [66, p. 5] state:

> "the oil transition brings more long-term environmental concerns than long-term economic or security threats because tradeoffs have strong potential to be resolved by accepting increased environmental damage in order to avoid economic or security risks…other technologies could also diversify the supply of transportation energy such as advanced, environmentally friendly biofuels; hydrogen; or partially or fully electric vehicles utilizing low carbon electricity (possibly including fossil fuels plus CCS [carbon capture and storage], renewables, or nuclear power). Demand reduction, through fuel efficiency and better transportation planning should also play a role. These other approaches have their own challenges, but at least they do not have the climate change risks of fossil SCPs [substitutes for conventional petroleum]."

Taking a lowest cost and/or SCPs approach to mitigating peak oil without considering the environmental impacts at local, regional, and international scales will only hinder the worldwide effort to mitigate climate change [65, 66]. Simultaneously, mitigating climate change without considering the need for a rapid response to peak oil and the dynamics of the global petroleum industry will only place nation-states and individual households at economic risk as oil resources become more expensive and less available. The increasing politicization of this oil transition may even facilitate and accelerate global military conflict.

The near term focus on mitigating each challenge should be in technologies and strategies that have dual benefits for both challenges. Energy efficiency in the building sector offers these dual benefits by reducing the use of fossil fuels to heat, cool, and light buildings while simultaneously creating an opportunity for the transportation sector to move toward grid-based electrification. The horizontal infrastructure corollary to energy efficiency in the vertical built environment includes urban planning and design elements that foster walkable communities with multi-modal transportation options. Though not discussed in this paper, the visualization and cultural norming of these multi-modal design elements may also be incorporated into the proposed energy efficiency Web tool. Additional synergies such as utility peak load shaving may be realized as the transportation sector moves toward electrification and vehicle batteries are available for charging off-peak and discharging on-peak. No matter how the issues are approached, the climate change and peak oil challenges along with our potential to mitigate both are as inseparable as building science and social science are to successfully implementing energy efficiency strategies.

CONCLUSION

This paper aims to make a case for infusing building energy and water consumptive use data into a Web-based geospatial building performance and social marketing tool designed to foster energy efficiency in residential dwellings in a completely transparent interface. In making this case and describing some potential benefits of the tool, attention is mostly paid to the potential positive implications of a Web tool of this type. It is important to note that there are also potential negative implications, or at least critical challenges, to be evaluated such as utility database standardization, personal privacy, confidentiality, and the legality of making this data transparent and tagged to its unique address [75]. However, it is the belief of this paper's author that these challenges are not insurmountable and that the risks of failing to dramatically accelerate the depth and breadth of energy efficiency in the existing and future U.S. building infrastructure far exceed the risks posed by these challenges.

As described in this paper, the building sector is one of the most significant contributors to anthropogenic climate change, especially so in the United States. Yet within the problem of the built environment, a solution also awaits. Over the next 50 years the full realization of the potential for energy efficiency in both commercial and residential buildings worldwide could lead to between two and three of the eight mitigation wedges described by Pacala and Socolow as necessary to stabilize the climate [11]. This potential is limited not by technology, nor by cost, but by the very behaviors of the building occupants and the building professionals who perpetuate vast energy inefficiencies in our building stock.

Thus far, behavior change campaigns have failed to achieve the desired energy efficiency improvements. This paper describes why these campaigns appear to be failing and one pathway to improve their rate of success. The central tenet of this pathway involves the public release of the all-too-often private building performance data. This proposed data transparency would improve energy modeling tools and green building rating systems, catalyze behavior change, improve carbon inventories, and facilitate the use and verification of carbon market products based on building energy efficiency. These benefits would not arise out of merely publishing the data in a transparent manner, but as a result of an ever-evolving interdisciplinary collaboration and social marketing process founded upon a Web platform inspired by the Web 2.0 meme. The need for this Web tool and its potential to accelerate climate change mitigation via energy efficiency of the building sector is magnified by the synergistic challenge of peak oil. Ultimately, the building sector and the transportation sector are inexplicably united in a built environment only as good as the people who live, work, play, and move within its space.

REFERENCES

1. IPCC, *IPCC AR4 WG3: Summary for policymakers*, in *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, B. Metz, et al., Editors. 2007, Cambridge University Press: Cambridge, United Kingdom and New York, NY, USA. p. 1-24. http://www.ipcc.ch/ipccreports/ar4-syr.htm
2. IPCC, *Climate Change 2007: The Physical Science Basis*, in *Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, S. Solomon, et al., Editors. 2007, Cambridge University Press: Cambridge, United Kingdom and New York, NY, USA. p. 94-127. http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-faqs.pdf
3. Huovila, P., et al., *Buildings and climate change: Status, challenges and opportunities*. 2007, United Nations Environment Programme, Sustainable Building and Construction Initiative. p. 87. http://www.unep.fr/pc/sbc/documents/Buildings_and_climate_change.pdf
4. Nässén, J., et al., *Direct and indirect energy use and carbon emissions in the production phase of buildings: An input-output analysis.* Energy, 2007. **32**: p. 1593-1602.
5. Architecture2030, *Climate change, global warming, and the built environment: Architecture 2030*. 2007, Architecture 2030. http://www.architecture2030.org/home.html
6. AIA, *Architects and climate change*. 2006, American Institute of Architects. http://www.aia.org/SiteObjects/files/architectsandclimatechange.pdf
7. Olgyay, V. and J. Herdt, *The application of ecosystems services criteria for green building assessment.* Solar Energy, 2004. **77**(4): p. 389-398. http://dx.doi.org/10.1016/j.solener.2004.01.011

8. Greening, L.A., M. Ting, and T.J. Krackler, *Effects of changes in residential end-uses and behavior on aggregate carbon intensity: Comparison of 10 OECD countries for the period 1970 through 1993*. Energy Economics, 2001. **23**: p. 153-178.
9. Abrahamse, W., et al., *The effect of tailored information, goal setting, and tailored feedback on household energy use, energy-related behaviors, and behavioral antecedents.* Journal of Environmental Psychology, 2007. **27**: p. 265-276.
10. Stein, J.R. and A. Meier, *Accuracy of home energy rating systems.* Energy, 2000. **25**(4): p. 339-354. http://dx.doi.org/10.1016/S0360-5442(99)00072-9
11. Pacala, S. and R. Socolow, *Stabilization wedges: Solving the climate problem for the next 50 years with current technologies.* Science, 2004. **305**: p. 968-972.
12. Socolow, R. and S. Pacala, *A plan to keep carbon in check*, in *Scientific American*. 2006. p. 50-57. http://web.ebscohost.com/ehost/detail?vid=1&hid=4&sid=5f776813-24b8-4bfd-9b78-820e40cf022d%40sessionmgr3
13. Levine, M., et al., *IPCC AR4 WG3: Residential and commercial buildings.*, in *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, B. Metz, et al., Editors. 2007, Cambridge University Press: Cambridge, United Kingdom and New York, NY, USA. p. 387-446. http://www.ipcc.ch/ipccreports/ar4-wg3.htm
14. McMahon, J.E., M.A. McNeil, and I.S. Ramos, *Buildings*, in *The First State of the Carbon Cycle Report (SOCCR): The North American Carbon Budget and Implications for the Global Carbon Cycle*, A.W. King, et al., Editors. 2007, National Oceanic and Atmospheric Administration, National Climatic Data Center: Asheville, NC, USA. p. 95-102.
15. DOE, *Building Energy-Efficient New Homes*. 2008, US DOE - Energy Efficiency and Renewable Energy: Building Technologies Program. http://www.eere.energy.gov/buildings/info/homes/newconstruction.html
16. Creyts, J., et al., *Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?* 2007, McKinsey & Company. http://www.mckinsey.com/clientservice/ccsi/greenhousegas.asp
17. USCB, *Manufacturing, Mining, and Construction Statistics: Building Permits*. 2007, U.S. Census Bureau. http://www.census.gov/const/www/permitsindex.html
18. Brewer, G.D. and P.C. Stern, eds. *Decision Making for the Environment: Social and Behavioral Science Research Priorities*. Panel on Social and Behavioral Science Research Priorities for Environmental Decision Making, Committee on the Human Dimensions of Global Change, National Research Council. 2005, The National Academies Press. 296. http://www.nap.edu/catalog/11186.html
19. CBASSE, *Board on Behavioral, Cognitive, and Sensory Sciences.* Psychological Science, 1998. **9**(2): p. 79-90.
20. Stern, P.C., *Understanding individuals' environmentally significant behavior*. Environmental Law Reporter - News & Analysis, 2005. **35**: p. 10785-10790. http://www7.nationalacademies.org/DBASSE/Environmental%20Law%20Review%20PDF.pdf
21. US-CST, *The contribution of the social sciences to the energy challenge*. 2007, United States House of Representatives Committee on Science and Technology. http://science.house.gov/publications/hearings_markups_details.aspx?NewsID=1956
22. Montgomery, J., *Personal pollution citations on rise: DNREC targets open burning, diesel idling.* 2007, Delaware Online. The News Journal. Wilmington, Delaware. http://cache.zoominfo.com/CachedPage/?archive_id=0&page_id=2020129320&page_url=%2f%2fwww.delawareonline.com%2fapps%2fpbcs.dll%2farticle%3fAID%3d%2f20070527%2fNEWS%2f705270385%2f1006%26theme%3dLEGHALL&page_last_updated=6%2f23%2f2007+1%3a49%3a55+PM&firstName=Paul&lastName=Stern

23. Gienapp, P., Teplitshy, C., Alho, J.S., Mills, J.A., and Merila, J., *Climate change and evolution: disentangling environmental and genetic responses.* Molecular Ecology, 2008(17): p. 167-178.
24. Reusch, T.R.B.a.W., T.E., *Molecular Ecology of Climate Change.* Molecular Ecology, 2007(16): p. 3973-3992.
25. Musante, K., *Car buyers lighten up: High gas prices drive buyers toward smaller, fuel-efficient vehicles*. 2008, CNNMoney.com. http://money.cnn.com/2008/05/01/news/companies/auto_sales/?postversion=2008050117
26. EUROPIA, *Save more than fuel*. 2008, European Petroleum Industry Association & the European Commission. http://www.savemorethanfuel.eu/index.htm
27. EPA, *Summary of Research Findings from the Programmable Thermostat Market*. Unknown Date, US EPA Energy Star. http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/thermostats/Summary.pdf
28. Mills, E., *Inter-comparison of North American residential energy analysis tools.* Energy and Buildings, 2004. **36**: p. 865-880. http://eetd.lbl.gov/emills/PUBS/PDF/Res_Energy_Tools.pdf
29. DOE, *Building Energy Software Tools*. 2008, US DOE - Energy Efficiency and Renewable Energy: Building Technologies Program. http://www.eere.energy.gov/buildings/tools_directory/
30. McKenzie-Mohr, D. and W. Smith, *Fostering Sustainable Behavior: An Introduction to Community-Based Social Marketing*. 2006, Gabriola Island, BC: New Society Publishers. 160.
31. McCalley, L.T. and C.J.H. Midden, *Energy conservation through product-integrated feedback: The roles of goal-setting and social orientation.* Journal of Economic Psychology, 2002. **23**: p. 589-603.
32. Abrahamse, W., et al., *A review of intervention studies aimed at household energy conservation.* Journal of Environmental Psychology, 2005. **25**: p. 273-291.
33. Gram-Hanssen, K., et al., *Do homeowners use energy labels? A comparison between Denmark and Belgium.* Energy Policy, 2007. **35**(5): p. 2879-2888. http://dx.doi.org/10.1016/j.enpol.2006.10.017
34. Bartiaux, F., *Does environmental information overcome practice compartmentalisation and change consumers' behaviours?* Journal of Cleaner Production, 2007. **In Press**: p. 1-11. http://dx.doi.org/10.1016/j.jclepro.2007.08.013
35. PNNL, *Department of Energy putting power in the hands of consumers through technology*. 2007, Pacific Northwest National Laboratory. http://www.pnl.gov/topstory.asp?id=285
36. Kempton, W., J.S. Boster, and J.A. Hartley, *Environmental Values in American Culture*. 1996, Cambridge: The MIT Press. 320.
37. Lucas, T., *Duke Survey: Why Pro-Environmental Views Don't Always Translate Into Votes*. 2005, Nicholas Institute for Environmental Policy Solutions at Duke University. http://www.dukenews.duke.edu/2005/09/nicholaspoll.html
38. Selman, P., *Social capital, sustainability and environmental planning.* Planning Theory & Practice, 2001. **2**(1): p. 13-30.
39. Blake, J., *Overcoming the value-action gap in environmental policy.* Local Environment, 1999. **4**(3): p. 257-278.
40. Schultz, P.W., *Changing behavior with normative feedback interventions: A field experiment on curbside recycling.* Basic and Applied Social Psychology, 1998. **21**(1): p. 25-36.
41. Schultz, P.W., et al., *The constructive, destructive, and reconstructive power of social norms.* Psychological Science, 2007. **18**(5): p. 429-434.
42. Ledgerwood, A., I. Liviatan, and P.J. Carnevale, *Group-identity completion and the symbolic value of property.* Psychological Science, 2007. **18**(10): p. 873-878.
43. Beerepoot, M. *The effectiveness of energy labels in improving sustainability in the building stock.* in *The 2005 world sustainable building conference: Action for sustainability*. 2005. Tokyo: SB05 Tokyo National Conference Board.

http://repository.tudelft.nl/consumption/idcplg?IdcService=GET_FILE&RevisionSelectionMethod=latestReleased&dDocName=MTS_1184958308275889472
44. California, *California Assembly Bill No. 1103 - Chapter 533*, in *Public Resources Code*. 2007. http://www.legisweb.net/calm/model/Retrieve.asp?ref=urn%3Acalm%3A2007%3Aab1103%3Adoc
45. EST, *Home Information Packs: Properties marketed for sale from 14th December 2007 in England and Wales will need a Home Information Pack*. 2007, Energy Saving Trust. http://www.energysavingtrust.org.uk/home_improvements/home_information_packs
46. UK, *Energy Performance Certificates and your home*. 2007, United Kingdom. http://www.homeinformationpacks.gov.uk/consumer/2_Energy_Performance_Certificates_and_your_home.html
47. EU, *Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings*. 2002. http://europa.eu/scadplus/leg/en/lvb/l27042.htm
48. Rege, M., *Why do people care about social status?* Journal of Economic Behavior & Organization, 2008. **66**(2): p. 233-242. http://dx.doi.org/10.1016/j.jebo.2006.04.005
49. Princen, T., M. Maniates, and K. Conca, *Confronting Consumption*, in *Confronting Consumption*, T. Princen, M. Maniates, and K. Conca, Editors. 2002, The MIT Press: Cambridge, Massachussetts London, England. p. 382.
50. Christakis, N.A. and J.H. Fowler, *The spread of obesity in a large social network over 32 years.* The New England Journal of Medicine, 2007. **357**(4): p. 370-379. http://content.nejm.org/cgi/content/full/357/4/370
51. Christakis, N.A. and J.H. Fowler, *The collective dynamics of smoking in a large social network.* The New England Journal of Medicine, 2008. **358**(21): p. 2249-2258. http://content.nejm.org/cgi/content/full/358/21/2249
52. Maynard, M., *Say 'Hybrid' and Many People Will Hear 'Prius'*, in *New York Times*. 2007, The New York Times Company: New York. http://www.nytimes.com/2007/07/04/business/04hybrid.html?ex=1188273600&en=6ca51be8ad9134cc&ei=5070
53. O'Reilly, T., *What is Web 2.0: Design Patterns and Business Models for the Next Generation of Software*. 2005, O'Reilly. http://www.oreillynet.com/lpt/a/6228
54. Iyer, M., W. Kempton, and C. Payne, *Comparison groups on bills: Automated, personalized energy information.* Energy and Buildings, 2006. **38**(8): p. 988-996. http://dx.doi.org/10.1016/j.enbuild.2005.11.009
55. Unknown, *Global Warming Solutions: What's Being Done*. 2008, Pew Center on Global Climate Change. http://www.pewclimate.org/what_s_being_done
56. Gillenwater, M., et al., *Policing the voluntary carbon market.* Nature Reports Climate Change, 2007. **1**(6): p. 85-87. http://dx.doi.org/10.1038/climate.2007.58
57. Knowles, H., C. Manning, and T.T. Ankersen, *Climate change, peak oil, and greenhouse gas emissions reductions: Mitigating the convergence via energy efficiency in the built environment*, in *University of Florida Levin College of Law: Conservation Clinic Papers and Work Products*. 2008: Gainesville, FL. p. 44. http://www.law.ufl.edu/conservation/pdf/EmissionsReductions.pdf
58. Story, L., *New bar codes can talk with your cellphone*. 2007, The New York Times. http://www.nytimes.com/2007/04/01/business/01code.html?_r=1&scp=1&sq=japan%20mobile%20phone%20bar%20code&st=cse&oref=slogin
59. Wikipedia, *Peak Oil*. 2008, Wikipedia, The Free Encyclopedia. http://en.wikipedia.org/w/index.php?title=Peak_oil&oldid=213084319
60. US-GAO, *Crude oil: Uncertainty about future oil supply makes it important to develop a strategy for addressing a peak and decline in oil production*. 2007, United States Government Accountability Office: Washington, DC. http://www.gao.gov/new.items/d07283.pdf

61. Khebab, *Peak oil update - September 2007: Production forecasts and EIA oil production numbers*. 2007, The Oil Drum. http://www.theoildrum.com/node/3001
62. Bakhtiari, A.M.S., *World oil production capacity model suggests output peak by 2006-07.* Oil & Gas Journal, 2004. **102**(16): p. 18-20.
63. Laherrere, J.H., *Focus exploration: World oil supply - what goes up must come down, but when will it peak?* Oil & Gas Journal, 1999. **97**(5): p. 57-64.
64. Hirsch, R.L., R. Bezdek, and R. Wendling, *Peaking of world oil production: Impacts, mitigation, & risk management*. 2005. http://www.netl.doe.gov/publications/others/pdf/Oil_Peaking_NETL.pdf
65. Greene, D.L., J.L. Hopson, and J. Li, *Have we run out of oil yet? Oil peaking analysis from an optimist's perspective.* Energy Policy, 2006. **34**(5): p. 515-531. http://dx.doi.org/10.1016/j.enpol.2005.11.025
66. Farrell, A.E. and A.R. Brandt, *Risks of the oil transition.* Environmental Research Letters, 2006. **1**(1): p. 014004. http://www.iop.org/EJ/abstract/1748-9326/1/1/014004
67. van der Veer, J., *Two Energy Futures*. 2008, Shell Oil Company. http://www.shell.com/home/content/aboutshell-en/our_strategy/shell_global_scenarios/two_energy_futures/two_energy_futures_25012008.html
68. Fletcher, S., *CERA: Action needed to avoid oil crisis, Hess chief says*. 2008, Oil & Gas Journal. http://www.ogj.com/display_article/320225/7/ONART/none/GenIn/1/CERA:-Action-needed-to-avoid-oil-crisis,-Hess-chief-says/
69. Crooks, E., *Total chief sceptical about future oil supplies*. 2007, Financial Times. http://blogs.ft.com/energyfilter/2007/10/total-chief-scehtml/
70. Voss, S. and T. Patel, *Total, Shell Chief Executives say 'easy oil' is gone*. 2007, Bloomberg. http://www.bloomberg.com/apps/news?pid=20601072&sid=aH57.uZe.sAI&refer=energy
71. Guillet, J., *IEA boss denies and confirms peak oil in same breath*. 2007, The Oil Drum: Europe. http://europe.theoildrum.com/node/2761
72. Lippert, J. and A. Ohnsman, *End of the oil age*. 2008, Bloomberg. http://www.bloomberg.com/news/marketsmag/mm_0308_story1.html
73. EIA, *Electric power annual: Net generation by energy source by type of producer, 1995 through 2006*. 2007, United States Department of Energy - Energy Information Agency. http://www.eia.doe.gov/cneaf/electricity/epa/epat1p1.html
74. Reynolds, M., *Policies to develop a low emissions transport sector in Australia: Submission regarding Garnaut Climate Change Review Issues Paper 5*. 2008, Anawhata Associates. http://www.theoildrum.com/files/AnawhataGarnaut.pdf
75. Gutmann, M.P. and P.C. Stern, eds. *Putting people on the map: Protecting confidentiality with linked social-spatial data. Panel on Confidentiality Issues Arising from the Integration of Remotely Sensed and Self-Identifying Data, Committee on the Human Dimensions of Global Change, Division of Behavioral and Social Sciences and Education*. Panel on Confidentiality Issues Arising from the Integration of Remotely Sensed and Self-Identifying Data, Committee on the Human Dimensions of Global Change, Division of Behavioral and Social Sciences and Education. 2007, The National Academies Press: Washington, DC. 163. http://books.nap.edu/openbook.php?isbn=0309104149

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DISCLAIMER

Though this paper offers many unique insights specific to the presentation given at the U.S. EPA's 17th International Emission Inventory Conference, it is based upon, and in many places, excerpted verbatim from three major sources as follows below. Unless otherwise noted, all verbatim excerpts from these three sources were written by the author of this paper in their original sources.

1. Knowles, H., C. Manning, and T.T. Ankersen, *Climate change, peak oil, and greenhouse gas emissions reductions: Mitigating the convergence via energy efficiency in the built environment*, in *University of Florida Levin College of Law: Conservation Clinic Papers and Work Products*. 2008: Gainesville, FL. p. 44. http://www.law.ufl.edu/conservation/pdf/EmissionsReductions.pdf
2. Unawarded grant proposal (February 2008). American Public Power Association (APPA) Demonstration of Energy-Efficient Developments (DEED) Grant Program. Proposed Project Title: *Establishment of Interdisciplinary Consortium and Development of Geospatial Building Performance Web Tool for Tailoring Demand-Side Management Social Marketing and Tracking GHG Emissions for Carbon Market White Tags™*.
3. Unawarded grant proposal (August 2007). U.S. EPA RFP No.: EPA-OAR-CPPD-07-08. RFP Title: Market-Based Approaches to Reducing Greenhouse Gas Emissions Through Energy Efficiency in Homes and Buildings. Proposed Project Title: *A Performance-Based Online Social Marketing and Mapping Tool: Changing Community Norms for Household Greenhouse Gas Emissions*.

KEYWORDS
Behavior change; building performance feedback; community-based social marketing; climate change mitigation; energy efficiency; geospatial; greenhouse gas emissions tracking; peak oil; transparency, Web 2.0