People-Centered Initiatives for Increasing Energy Savings

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November 2010

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FOREWORD: THE CRITICAL ROLE OF PEOPLE-CENTERED INITIATIVES

There is an undeniable and growing interest in understanding the human dimensions of energy use, energy efficiency, and energy conservation. Indeed, the evidence suggests an amazing variety of social influences that drive new innovations and behaviors that, in turn, significantly change the patterns of technology adoption and energy consumption. For example, in a talk at the GridWise Global Forum about the future of clean energy, Department of Energy Secretary Steven Chu noted: "It's not all high-tech stuff. We are also funding the human factor. We want to know how people think about and use energy."

Past assessments by the American Council for an Energy-Efficient Economy (ACEEE), by well-known researchers like Tom Dietz, Gerald Gardner, Loren Lutzenhiser, and Paul Stern, and by the co-editors of this volume, all suggest that understanding and shaping behaviors can provide a significant boost in the more efficient use of all energy resources. Indeed, internal discussions within ACEEE indicate that "the behavioral resource" in all of its many forms might provide about a 25% efficiency gain above normal productivity improvements should we choose to understand and develop that resource. In this respect, policymakers and researchers increasingly recognize the importance of addressing behavioral change to reduce costly energy production and consumption and carbon emissions as most energy-efficient technologies require proper human interaction to achieve their promised savings.

Despite the building interest in the social and behavioral dimensions of energy consumption, there remains a large gap in the available information that might help policymakers and program managers more effectively integrate "people-centered insights and initiatives" into current efforts to accelerate cost-effective energy savings. It is for that reason that ACEEE chose to invest time and effort in this volume as part of efforts to organize the third Behavior, Energy and Climate Change conference held November 15–18, 2009 in Washington, D.C. The original idea came from Karen Ehrhardt-Martinez, who along with Skip Laitner, agreed to organize this volume as an initial contribution that might help fill that void. The nearly three dozen authors have done yeoman-like work in making this information available. At the same time, we recognize that the many variations on a theme in this volume may or may not reflect how ACEEE itself might view the research and the resulting recommendations. As a result, we offer this book as an effort to open up the discussion by providing a useful resource that we hope will be a highly valuable reference to help guide future research on this critically important topic.

Steven Nadel, Executive Director
American Council for an Energy-Efficient Economy

ACKNOWLEDGMENTS

This book has a very rich intellectual history. For example, the collaboration and hard questions would not have been possible without the feedback, financial support, and commitment of many individuals involved in the design, development, and general success of the very first Behavior, Energy and Climate Change Conference. In that regard we must thank all of the members of the BECC Advisory Committee as well as all of the organizations who generously sponsored the first-ever conference in 2007. Without their advice and financial support, the now annual BECC conference would not have been the success that it has become. Perhaps more critically, this legacy extends through its successor events, now culminating in the fourth annual BECC being convened November 14–17, 2010 in Sacramento, California (for more information on this event, see www.BECCconference.org).

At the same time, we would like to extend our deep appreciation to all of the individual chapter contributors to this volume. Without their willingness to pitch in, and without their willingness to lend their many insights and recommendations, this book would have been substantially diminished; we certainly could not have carried out this effort on our own. Yet, there are several key individuals who deserve a special note of thanks. They are among those who helped generate the momentum that enabled such a project as this to be conceived and carried. We begin in that regard with Linda Schuck as the prime mover who got BECC off the ground in 2007; and in doing so, helped all of us build the momentum. We also include our colleague Jerry Dion for his own recognition of the many critical issues reflected in this volume, and his ground-breaking efforts that further enabled the participation of the U.S. Department of Energy in this direction. And we would like to especially acknowledge the many and varied contributions of Paul Stern and Loren Lutzenhiser for their long-standing commitment to research on these issues during a very long hiatus when such perspectives had so little support. Finally, we would like to thank David Holzman whose early copy editing helped us get this book off the ground, and Renee Nida whose patience and hard work to help us massage this volume into a publishable shape aided us in making this book available in a timely way. In short, our heartfelt thanks to everyone.

Karen Ehrhardt-Martinez
John A. "Skip" Laitner

ABOUT ACEEE

The American Council for an Energy-Efficient Economy (ACEEE) is a nonprofit research organization dedicated to advancing energy efficiency as a means of promoting economic prosperity, energy security, and environmental protection. For more information, see www.aceee.org. ACEEE fulfills its mission by:

- Conducting in-depth technical and policy assessments
- Advising businesses, policymakers, and program managers
- Working collaboratively with businesses, public interest groups, and other organizations
- Organizing technical conferences and workshops
- Publishing books, conference proceedings, and reports
- Educating consumers and businesses

Projects are carried out by staff and selected energy efficiency experts from universities, national laboratories, and the private sector. Collaboration is the key to ACEEE's on-going success. We collaborate on projects and initiatives with dozens of organizations including international, federal, and state agencies as well as businesses, utilities, research institutions, and public interest groups.

Support for our work comes from a broad range of foundations, governmental organizations, research institutes, utilities, and corporations.

Introduction: An Opening Context for People-Centered Insights

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Background

By the end of this year (2010), the United States will have expanded its economic output by more than 65% since 1990. At the same time, however, the demand for energy and power resources will have grown by only 15%. This apparent decoupling of economic growth and energy consumption is a function of increased energy productivity; in effect, we have increased our ability to generate more energy-related services from each unit of energy consumed. Many would attribute this productivity gain to more productive investments in technology. Indeed, the evidence suggests this to be a significant driver of such improvements. Yet the evidence also suggests an amazing variety of social and behavioral influences that also contribute to this success story—behaviors that drive new innovations and social influences that change energy practices as well as existing patterns of technology adoption.

Past assessments by the American Council for an Energy-Efficient Economy (ACEEE), and by well-known researchers like Paul Stern, Gerald Gardner, Tom Dietz, and others, suggest that understanding and shaping behaviors can provide a significant boost in the smart use of all energy resources. (See, for example, Dietz et al. 2009, Laitner et al. 2009, and Friedrich et al. 2010). Indeed, internal discussions within ACEEE indicate that "the behavioral resource" (including changes in lifestyles and habits, changes in how we choose to use equipment—e.g., thermostat settings, and changes in our purchasing behaviors) might provide as much as a 25% efficiency gain (possibly more) above normal productivity improvements—should we choose to understand and develop that resource. In this respect, policymakers and researchers increasingly recognize the importance of addressing improved energy practices to reduce costly energy production and consumption since even smart energy-using technologies require informed and motivated efforts to achieve their promised savings.

Fortunately, there is a growing awareness about the need to catalyze a more dynamic understanding of the role that information, attitudes, preferences, and cultures all have on energy-related behaviors. The Worldwatch Institute, for example, devoted its entire *State of the World 2010* to transforming cultures, exploring the possibilities of moving away from consumerism to more sustainable lifestyles (Assadourian 2010). Stephenson et al. (2010) write that while "improved consumer efficiency is an attractive goal," it is not "straightforward and easily achievable." For that reason, they provide a conceptual framework that incorporates a systems and behavioral perspective "to assist in understanding the factors that influence the energy decisions of consumers, and their impact on the adoption of more efficient energy practices within society." At the same time, Ehrhardt-Martinez and Laitner (2010) extend both the research and the growing dialogue by suggesting specific steps that might integrate social science and "people-centered" insights into key federal agency programs as a means to accelerate and deepen energy savings.

One notable example of the growing interest in the topic of behavioral change has been the unexpectedly large successes of the Behavior, Energy and Climate Change (BECC) Conference. Convened jointly by the American Council for an Energy-Efficient Economy (ACEEE), the California Institute for Energy and the Environment (CIEE), and the Precourt Energy Efficiency Center (PEEC), the BECC Conference drew more than 550 people in its first year and attendance has continued to grow, reaching nearly 700 total participants in 2009. The fourth annual BECC conference will be convened in Sacramento, California from November 14-17, 2010. Information about the past and forthcoming events can be found at http://www.BECCconference.org. These past conferences have generated a growing collaboration and an emerging body of research and practice.

In this volume we have two modest goals. The first is to provide a conceptual, an empirical, and a case study foundation that documents and characterizes the heft and the scale of "people-centered" insights and initiatives. The second is to present an array of policy and program options that can deepen near-term cost-effective energy savings. Toward these multiple ends we draw on the experience and learning from more than three dozen practitioners and analysts who provide their own set of insights, policy recommendations, and suggestions for further program development. We believe the resulting 21 chapters they contribute (not including either this introduction or our own concluding chapter) offer some of the best thinking on the social and behavioral aspects of energy consumption that can help us build on this previously untapped opportunity.

Establishing the Context: A Chapter Review

The volume is organized into both topic sections and chapters. There are a total of seven topic sections, each containing two to four chapters. The following section serves as a guide and overview to the larger book by specifying each of the topic areas and introducing each of the chapters.

Section I: The Social and Behavioral Wedge

Logically enough we open the book with a section that helps us frame what we might call "The Social and Behavioral Wedge." The intent is to provide readers with a sense of scale that might be possible from the "behavioral resource." This includes three chapters, beginning with a reprint of an article by Thomas Dietz, Gerald Gardner, Jonathan Gilligan, Paul Stern, and Michael P. Vandenbergh entitled "Household Actions Can Provide a Behavioral Wedge to Rapidly Reduce US Carbon Emissions." Originally appearing in the *Proceedings of the National Academy of Science* (Dietz et al. 2009), the authors describe what they call the "the best available behavioral evidence" and offer a guide as to what might be achieved through an active promotion of household behaviors that reduce greenhouse gas emissions. They find a reasonably achievable emissions reduction of approximately 20% within the U.S. household sector within 10 years if the most effective non-regulatory interventions are used. This amounts to about 7% of total national emissions—an amount slightly larger than the total national emissions of France.

In Chapter 3, Skip Laitner and Karen-Ehrhardt Martinez use a slightly different methodological approach to estimate the size and characteristics of potential behavior-related energy savings in the near term. Their chapter, "Examining the Scale of the Behavior Energy Efficiency Continuum," highlights the potential impact of changed habits, lifestyles, and technology-based behaviors in terms of potential energy savings within the United States for the residential sector. Their findings suggest that efforts to reshape existing energy practices could reduce U.S. household use of energy by an estimated 22% beyond normal cost-effective efficiency improvements.

In Chapter 4, Alan Meier provides an inside glance at the level of electricity savings that can be achieved in a crisis situation when people are forced to rethink their energy consumption practices in dramatic ways. The chapter, "A 30% Reduction in Electricity Use Is Not Only Possible but Actually Occurred in Juneau, Alaska," provides case study evidence of real crisis-driven energy savings. The natural experiment resulted from an avalanche (in April 2008) that took down critical electric transmission lines and resulted in a five-fold increase in electricity prices. While the dramatic jump in electricity prices clearly provided the motivation for rethinking existing energy practices, it is important to note that the majority of the 30% energy savings were accomplished through the establishment of new energy practices. Meier concludes that when "compared to programs using economic and regulatory instruments, programs relying on changes in people's behaviors are relatively easy to establish, inexpensive, highly visible, and suitable for mass media." He further notes that during an energy crisis, "it is important to make it socially acceptable–indeed patriotic–to wear warmer clothes, switch off lights, and modify lifestyles in ways that people would resist under ordinary circumstances." In short, "Juneau's success hinged on quickly establishing a consistent, positive, message." According to Meier, Juneau has maintained roughly one-third of the reduction in electricity use one year later, "showing that at least some of the crisis-borne behavioral change is durable."

Section II: Behavior-Savvy Policy

In this section we explore the direct links between smart policy and program development and the expansion of overall energy savings. Chapter 5 begins this exploration with a contribution from Marilyn Brown, Jess Chandler, Melissa Lapsa, and Moonis Ally entitled "Adding a Behavioral Dimension to Residential Construction and Retrofit Policies." Using a uniform set of policy evaluation criteria, they examine three promising policy options that might boost residential energy efficiency in new construction and in existing homes. These policies—(i) advancing and enforcing state building energy codes; (ii) expanding the use of home energy performance ratings; and (iii) mandating the disclosure of energy performance information about the home—"hold great promise to transform building practices in the United States."

Chapter 6 is a contribution from Jeffrey Harris, Rick Diamond, Carl Blumstein, Chris Calwell, Maithili Iyer, Christopher Payne, and Hans-Paul Siderius. In this chapter they suggest a need to enhance energy efficiency by re-introducing energy conservation as a legitimate and desirable social and behavioral policy. The chapter, "Towards a Policy of Progressive Efficiency," draws attention to trends in energy consumption as well as energy efficiency. They find that framing policy goals in terms of energy consumption or greenhouse gas emissions rather than energy efficiency "can help us decide how much efficiency is needed, and how much additional conserving may be required to manage energy consumption and emissions in the face of unsaturated markets, growing population, growing disposable incomes, and the consequent increase in consumer needs and desires."

In Chapter 7, "Rebound, Technology and People: Mitigating the Rebound Effect with Energy-Resource Management and People-Centered Initiatives," Karen Ehrhardt-Martinez and Skip Laitner summarize the evidence regarding the prevalence and characteristics of the rebound effect. They document its historical contribution to U.S. energy consumption and then consider the causal relationships that result in rebound, suggesting potential rebound mitigation strategies. The second part of this chapter explores the impact of different types of people-centered approaches on energy efficiency and energy conservation. The chapter concludes with a discussion of the strengths and weaknesses of people-centered versus technology-focused approaches to reduce energy consumption and accelerate carbon savings.

Section III: Diversity in Energy Consumption and Energy Beliefs

Edward Maibach, Anthony Leiserowitz, Connie Roser-Renouf, Karen Akerlof, and Matthew Nisbet open this section of the book by introducing us to "Global Warming's Six Americas," or six segments of the population with distinct views on climate change. Their chapter, "Saving Energy Is a Value Shared by All Americans: Results of a Global Warming Audience Segmentation Analysis," notes the striking commonality among the Six Americas with regard to their efforts to save energy. Thus, although the Six Americas strongly disagree about the importance of reducing global warming, they agree on the importance of saving energy. In fact, they are remarkably similar in their energy-related actions and intentions, and in the barriers that hinder their conservation efforts. These commonalities present important opportunities to create programs that assist households—as well as companies and governments—to reduce their energy consumption.

Chapter 9 provides a continuing discussion of "[Market] Segmentation in Practice." In this review, Linda Dethman, Phil Degens, and Sarah Castor characterize market segmentation as a powerful tool in speeding customer adoption of products, services, or desired behaviors. But they also note that segmentation is "not for the faint of heart" since "more than one useful segmentation scheme exists." They caution that that market segmentation requires more commitment and work than utilities and other firms might initially believe. They also note that segmentation results often contradict conventional assumptions about customers and their actual behaviors. At the same time, they conclude that while that segmentation has limits, these techniques "can help utilities identify new and substantial opportunities for greater energy savings." Their view from the trenches is that segmentation offers utilities and other agencies a powerful tool for charting new pathways to energy savings.

Loren Lutzenhiser and Sylvia Bender use Chapter 10 to "unmask" the "average American" by highlighting different social structures as they shape differences in household energy use and carbon emissions." In drawing on social theory and past research, they suggest that household energy use is highly structured by household composition/dynamics, status-appropriate dwellings and appliances, and lifestyle-based behavior patterns. They report the results of detailed household-level modeling of electricity and natural gas use in a recent sample of 1,627 northern California households. They combine that survey data with the billing histories of electricity and gas consumption and matched weather data to model consumption at the household level, and then explore how social status, lifestyle, culture and institutions may be implicated in shaping consumption.

Section IV: Transportation Structures and Behavior

In Chapter 11, Thomas Turrentine and Kenneth S. Kurani help us examine “Car Buyers and Fuel Economy?” This is an article reprinted with permission from Energy Policy (vol. 35 (2007) 1213–1223). Their research is designed to help analysts and policy makers ground their work in the reality of how U.S. consumers are thinking and behaving with respect to automotive fuel economy. Their data are from semi-structured interviews with 57 households across nine lifestyle ‘‘sectors.’’ As they report in the chapter, their research revealed that none of the households had analyzed their fuel costs in a systematic way in their automobile or gasoline purchases. Almost none of these households tracked gasoline costs over time or consider them explicitly in household budgets. Among their other notable findings, the authors conclude that consumers assign non-monetary meaning to fuel prices. Importantly, their research provides strong evidence that consumer responses to fuel economy technology and changes in fuel prices are more complex than standard economic assumptions otherwise suggest.

Allen Greenberg uses Chapter 12 to highlight aspects of behavioral economics that offers insights on designing usage-based or what he calls “pay-as-you-drive-and-you-save” (PAYDAYS) insurance products. The chapter is entitled “Applying Behavioral Economics Concepts in Designing Usage-Based Car Insurance Products” to maximize profitability, consumer acceptance, and public benefits. Greenberg proposes a pilot experiment design to increase understanding about the application of behavioral economics to PAYDAYS insurance.

Section V: Household Energy Consumption and Energy Management

Kat Donnelly opens this section with Chapter 13, “Residential Feedback Devices and Energy Saving Behavior.” Here she both characterizes household energy consumption feedback devices and programs, and describes how current and future feedback initiatives can empower consumers by facilitating new and smarter energy usage practices that reduce waste and save energy. Donnelly uses the term consumer behavior to include energy conservation, energy efficiency, and reductions in peak demand. Her information provides an assessment from the user’s perspective. She concludes that the consumer-facing side of the grid may be the most important factor in achieving large-scale energy savings. Done right, she concludes, a variety of change management campaigns that use both technology and behavior techniques have the potential to make a large and positive impact in residential electricity consumption.

In Chapter 14, Karen Ehrhardt-Martinez takes us “Inside the Black Box: Household Response to Feedback.” She confirms that providing households with contextualized feedback and targeted energy-saving tips holds the potential for large scale energy savings. Citing a recent meta-review of residential sector feedback studies from three continents (Ehrhardt-Martinez et al. 2010), she underscores an average world-wide program-level savings in the range of 4 to 12%, but she also suggests that higher levels of savings might be possible. The heart of the chapter is focused on providing an in-depth look at the energy-saving actions and practices that households engage in as they respond to the feedback. Her assessment of past feedback studies reveals that most feedback-induced energy savings result from changes in everyday practices, habits, and routines.

Next, Yael Parag and Deborah Strickland use Chapter 15 to explore ways in which "Personal Carbon Budgets" can help individuals better live in a carbon constrained world. The authors use the lens of budgeting to gain some ideas about what people might need to know and learn in order to manage their personal carbon budget. Parag and Strickland argue that individuals may already hold the necessary skills to successfully manage their allowance but that they will inevitably need a more holistic and supporting policy environment that is conducive to monitoring and curbing carbon emissions. They also suggest that targeting an individual's behavior should be accompanied by a systemic change in the societal and economic environments within which individuals make choices. Hence thought should be dedicated also to altering social norms and challenging existing economic beliefs.

Section V: Social Norms and Community Response

In Chapter 16, Laura Mamo and Jennifer Fosket discuss "Influencing the Mainstream: How Green Planned Communities Can Shape Social Behaviors and Address Climate Change." They write that while it remains true that individual home ownership has been emphasized as an essential indication of successful adulthood with high value placed on things like independence, private property, consumerism, and the nuclear family, this view is being challenged today by ever-increasing demands for means of living sustainability in meaningful communities. They offer a number of important lessons that readily emerge from studies of master-planned communities in ways that the use of innovative sustainable design practices enable building new communities and empowering people.

Wesley Schultz uses Chapter 17 to help us explore ways of "Making Energy Conservation the Norm." The chapter reviews the existing research on the role of feedback in energy efficiency programs. Contrary to current claims, the evidence suggests that simple feedback is not sufficient to motivate new energy practices. The available data, he writes, clearly show that feedback is only effective at reducing energy use when the individual is already motivated to use less. This motivation can come from existing personal factors such as environmental concern, or it can come from secondary information provided in combination with the feedback. For example, coupling feedback with information about the social norm for use has been shown to effectively reduce consumption. The chapter concludes that feedback is a promising strategy, but that more research is needed to clarify the effect. Schultz then makes the case that a substantial investment into behavioral studies of energy use and energy efficiency is likely to provide greater understanding, which will translate into more effective conservation strategies.

Section VI: The Human Dimensions of Utility and Market Transformation Programs

In Chapter 18, we hear again from Marilyn Brown, Jess Chandler, and Melissa Lapsa, "Adding a Behavioral Dimension to Utility Policies that Promote Residential Efficiency." In this chapter, they present case studies of three policies that could motivate and enable utilities to promote residential energy efficiency. These policies are based on understanding how utilities interface with their residential customers and how residential customers view investments in energy efficiency. They apply seven criteria to evaluate and narrow the set of candidate policy options.

In Chapter 19, Edward Vine provides "A Conceptual Framework for Integrating Behavior and Behavioral Change in the Energy Efficiency Program Cycle." In this chapter he examines different components of the program cycle—program planning, program design, program implementation, and program evaluation—to highlight key issues of behavior and behavioral change that are specific to each of these components. By using this framework, he offers program designers, implementers, and evaluators new insights into how behavior and behavioral change in energy efficiency programs might promote larger energy efficiency opportunities as well as to reduce energy consumption overall.

Carl Blumstein, Seymour Goldstone, and Loren Lutzenhiser then use Chapter 20 to highlight "Energy Efficiency: Choice Sets, Market Transformation, and Innovation." A central theme of this chapter is the need for researchers and policy makers to give more attention to the study of energy markets and the ways in which they act to shape the choices that are available to consumers. Real markets, they note, have a structure that consists of rules governing the conduct of the market actors, relationships among the actors, and physical arrangements to facilitate exchange. They argue that "real markets are heterogeneous" and their structure varies greatly depending on the goods being exchanged. Markets for electricity are very different from markets for durable manufactured goods and markets for buildings. They conclude that a better understanding of energy-related markets is needed to improve the success of market transformations efforts.

In Chapter 21 Kenneth Tiedemann writes of "Behavioral Change Strategies That Work: A Review and Analysis of Field Experiments Targeting Residential Energy Use Behavior." He observes that research on energy conservation has been dominated by a paradigm from engineering economics, which assumes that economic agents adopt the most cost-effective technologies and practices. Yet, research on energy-related behaviors suggests an alternative view. Toward that end, Tiedemann reviews energy-related behavioral field experiments by focusing on information strategies, goal setting strategies, reward strategies, and feedback strategies. His conclusions, based on a statistical assessment of the energy savings of each strategy, indicate that behavioral-related improvements in energy efficiency have shown reductions in consumption ranging from 0 to 23% with an unweighted average in the range of 7 to 11% depending on the quality of the program design and implementation, and on the kind of program being developed.

Conclusions and Next Steps Forward

Building on the prior chapters, Ehrhardt-Martinez and Laitner use Chapter 21 to draw out critical insights by: 1) documenting the energy savings that could be achieved using a people-centered rather than a purely technological perspective, 2) highlighting new ways of perceiving and understanding America's energy culture and the diverse attitudes within it, and 3) identifying potential mechanisms and strategies for engaging and empowering Americans to take action. By extending energy efficiency "best practices" throughout the entire country, in conjunction with regulatory reform designed to enable or empower consumers to be more proactively involved in day to day energy decisions, these best practices could reduce the many barriers faced by consumers in ways that greatly expand the opportunity for large-scale energy savings within the United States.

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Household Actions Can Provide a Behavioral Wedge to Rapidly Reduce U.S. Carbon Emissions[1]

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Introduction

Global greenhouse gas emissions and associated climate change have been increasing at accelerating rates in recent years. For example, atmospheric CO_2 concentration increased by an annual average of 1.5 ppm/yr in 1980–1999, 2.0 ppm/yr in 2000–2007, and 2.2 ppm in 2007 (Global Carbon Project 2008). Prompt change in this trajectory is necessary to reach the ambitious stabilization targets now being discussed, but most policy attention has been directed to slow-acting options. New technologies for low-carbon energy supply, energy efficiency, and carbon sequestration must overcome various technical, economic, institutional, and societal obstacles and will take decades to develop and penetrate markets (National Research Council 2009a, 2009b). The most prominent policy approaches to the climate commons dilemma—national and international cap-and-trade regimes—face issues of implementation feasibility that could delay achievement of carbon emissions reduction objectives for years (Ostrom 1990; Tietenberg 2002; Dietz et al. 2003). For the United States, these include setting meaningful caps, promulgating regulations to implement the program, monitoring emissions and emissions offsets, and controlling offshoring and other responses of covered entities that could undercut the objectives of the regime (Northtrop and Sassoon 2008; Stavins 2008).

Cap-and-trade programs and policies to induce technologic innovation may not be sufficient to achieve ambitious near-and long-term emissions reduction targets. Time lags likely from implementation of complex policy (e.g., the 1,400-page Clean Energy and Security Act of 2009) and from getting to emissions caps that are substantially more stringent than business-as-usual levels also may make it difficult for the United States to demonstrate international leadership. Complementary strategies are probably needed and certainly advisable. Among these, opportunities for short-term emissions reductions have been relatively neglected.

[1] This chapter was reprinted from: Dietz, Thomas, Gerald T. Gardner, Jonathan Gilligan, Paul C. Stern, and Michael P. Vandenbergh. 2009. "Household Actions Can Provide a Behavioral Wedge to Rapidly Reduce U.S. Carbon Emissions." In *Proceedings of the National Academy of Sciences of the United States of America*. Washington, D.C.: National Academy of Sciences. Further supporting information can be found online at www.pnas.org/cgi/content/full/ 0908738106/DCSupplemental.

We focus on a short-term option with substantial potential for carbon emissions reduction: altering the adoption and use of available technologies in U.S. homes and nonbusiness travel by means of behaviorally oriented policies and interventions. This potential ‘‘behavioral wedge’’ can reduce emissions much more quickly than other kinds of changes and deserves explicit consideration as part of climate policy (Pacala and Socolow 2004). It can potentially help avoid ‘‘overshoot’’ of greenhouse gas concentration targets; provide a demonstration effect; reduce emissions at low cost; and buy time to develop new technologies, policies, and institutions to reach longer-term greenhouse gas emissions targets and to develop adaptation strategies.

Individual and household behavioral change faces well-known barriers (Brown et al. 2008), but more is known about how to overcome these barriers than is commonly recognized (Stern 1986; National Research Council 2002; Stern 2008; Gardner and Stern 2002). Lack of familiarity with this knowledge among scholars and policy makers is a major obstacle to achieving prompt, large, low-cost emissions reductions. We apply a behavioral approach that complements engineering and economic approaches to estimate the reasonably achievable potential for near-term emissions reduction from behavioral change in households. We focus on U.S. households because they are a major emitter and because there is a significant body of knowledge about the potential to achieve near-term reductions in that sector.

Direct energy use by households accounts for approximately 38% of overall U.S. CO_2 emissions, or 626 million metric tons of carbon (MtC) in 2005 (Gardner and Stern 2008; Energy Information Administration 2006). This is approximately 8% of global emissions and larger than the emissions of any entire country except China. National policy initiatives have addressed households only indirectly, mainly through setting motor vehicle, lighting, and appliance efficiency standards. Recent reviews of the available research suggest a large near-term potential for emissions reductions from behavioral changes involving the adoption and altered use of available in-home and personal transportation technologies, without waiting for new technologies or regulations or changing household lifestyle (Gardner and Stern 2008; Vandenbergh et al. 2008). We develop a quantitative estimate of this potential at the national level, aggregated across behaviors.

Results

We find that the national reasonably achievable emissions reduction (RAER) can be approximately 20% in the household sector within 10 years if the most effective nonregulatory interventions are used. This amounts to 123 MtC/yr, or 7.4% of total national emissions—an amount slightly larger than the total national emissions of France (Energy Information Administration 2006). It is greater than reducing to zero all emissions in the United States from the petroleum refining (69 MtC), iron and steel (38 MtC), and aluminum (13 MtC) industries, each of which is among the largest emitters in the industrial sector (Energy Information Administration 2009). The cost of achieving such a reduction through behavioral change may be far lower than the cost of many alternatives (Gardner and Stern 2008; Vandenbergh et al. 2008).

We analyzed 17 types of household action that can appreciably reduce energy consumption using readily available technology, with low or zero cost or attractive returns on investment, and without appreciable changes in lifestyle. We first estimated the potential emissions reduction

(PER) from each action, that is, the reduction that would be achieved nationally from 100% adoption of the action (Gardner and Stern 2008; Vandenbergh et al. 2008). We then estimated plasticity (York and Dietz 2002)—the proportion of current nonadopters that could be induced to take action—from data on the most effective proven interventions. This introduces a behavioral realism to our estimates that is not included in analyses grounded solely in engineering or economics.

We based our plasticity estimates on empirical studies of responses to interventions at the individual and household levels aimed at changing energy consumption and related environmentally significant behaviors (National Research Council 2002; Gardner and Stern 2002; Stern et al. 1986; Abrahamse et al. 2005) and on studies of interventions to induce adoption of health-promoting behaviors that resemble energy-saving behaviors (Abroms and Maibach 2008; Synder and Hamilton 2002; Snyder et al. 2004). These studies make it possible to consider how plasticity is affected by types of intervention (e.g., media campaigns, information, and financial incentives) separately and in combinations and also by the type of behavior (National Research Council 2002; Stern 2008; Gardner and Stern 2002). Our approach contrasts with methods that rely on generic indicators of plasticity, such as price elasticity of demand. It facilitates consideration of the effects of both economic and non-economic stimuli in the same analysis. This is important because evidence from past energy efficiency interventions indicates that responsiveness to price can vary by a factor of 10, depending on nonfinancial aspects of policy implementation (Stern et al. 1986).

Our plasticity estimates reflect what has been achieved by the most effective documented interventions that do not involve new regulation of technology or behavior. These interventions have been demonstrated in field experiments or in organized programs implemented at the community, city, regional, or state level—many of them in response to the energy crises of the 1970s. Our estimates of emissions reductions are based on scaling the interventions up to national application.

The most effective interventions typically (*i*) combine several policy tools (e.g., information, persuasive appeals, and incentives) to address multiple barriers to behavior change; (*ii*) use strong social marketing, often featuring a combination of mass media appeals and participatory, community-based approaches that rely on social networks and can alter community social norms; and (*iii*) address multiple targets (e.g., individuals, communities, and businesses) (National Research Council 2002; Gardner and Stern 2002; Abroms and Maibach 2008; McKenzie-Mohr and Smith 1999).[2] Single policy tools have been notably ineffective in reducing household energy consumption. Mass media appeals and informational programs can change attitudes and increase knowledge, but they normally fail to change behavior because they do not make the desired actions any easier or more financially attractive. Financial incentives alone typically fall far short of producing cost-minimizing behavior—a phenomenon commonly known as the energy efficiency gap (Jaffe and Stavins 1994). However, interventions that combine appeals, information, financial incentives, informal social influences, and efforts to reduce the transaction costs of taking the desired actions have demonstrated synergistic effects beyond the additive

[2] Multiple targets can create community-level effects that enhance behavioral change above what can be achieved with a single target. We do not include ‘‘spillover’’ savings from businesses and other organizations in our calculations, so we are underestimating the overall impact of the approach we propose.

effects of single policy tools (National Research Council 2002; Stern 2008; Hirst 1988). The most effective package of interventions and the strongest demonstrated effects vary with the category of action targeted.

We combined PER and plasticity to estimate RAER for each action. PER and RAER estimates for actions were corrected for double-counting (e.g., lower thermostat settings yield smaller emissions reductions when combined with more efficient furnaces).[3] Details of all our calculations are provided in the *Supplemental Text* referenced in Footnote 1. Table 1 shows the actions and the associated estimates of 10-year emissions reductions.

Table 1. Achievable Carbon Emissions from Household Actions

Behavior change	Category*	Potential emissions reduction (MtC)†	Behavioral plasticity (%)‡	RAER MtC)§	RAER (%I/H)§
Weatherization	W	25.2	90	21.2	3.39
HVAC equipment	W	12.2	80	10.7	1.72
Low-flow showerheads	E	1.4	80	1.1	0.18
Efficient water heater	E	6.7	80	5.4	0.86
Appliances	E	14.7	80	11.7	1.87
Low rolling resistance tires	E	7.4	80	6.5	1.05
Fuel-efficient vehicle	E	56.3	50	31.4	5.02
Change HVAC air filters	M	8.7	30	3.7	0.59
Tune up AC	M	3.0	30	1.4	0.22
Routine auto maintenance	M	8.6	30	4.1	0.66
Laundry temperature	A	0.5	35	0.2	0.04
Water heater temperature	A	2.9	35	1.0	0.17
Standby electricity	D	9.2	35	3.2	0.52
Thermostat setbacks	D	10.1	35	4.5	0.71
Line drying	D	6.0	35	2.2	0.35
Driving behavior	D	24.1	25	7.7	1.23
	D	36.1	15	6.4	1.02

Notes from Table 1 above:
*See text below for definitions of categories W, E, M, A, and D.
†Effect of change from the current level of penetration to 100% penetration, corrected for double-counting. Measured in millions of metric tons of carbon (MtC).
‡Percentage of the relevant population that has not yet adopted an action that will adopt it by year 10 with the most effective interventions.
§Reduction in national CO_2 emissions at year 10 due to the behavioral change from plasticity, expressed in MtC/yr saved and as a percentage of total U.S. individual/household sector emissions (%I/H). Both estimates are corrected for double counting.

The 17 types of actions include both adoption of more efficient equipment and changes in use of equipment on hand. We divide the actions into 5 categories on the basis of behaviorally relevant attributes: W (home *weatherization* and upgrades of heating and cooling equipment); E (more efficient vehicles and nonheating and cooling home *equipment*); M (equipment *maintenance*); A (equipment *adjustments*), and D (*daily* use behaviors). This behavioral classification elaborates on previous ones that do not distinguish W from E or A from D (Stern and Gardner 1981; Kempton et al. 1984; Clayton and Myers 2009). W and E both involve adoption of equipment, but the equipment differs in the salience of product attributes other than energy savings and cost. A and D both involve changes in equipment usage but differ in the ease of maintaining emission

[3] Our estimates are not corrected for potential ‘‘takeback’’ (i.e., a portion of achievable reductions from improved technical efficiency that consumers forgo to gain other benefits, such as increased thermal comfort).

reductions: adjustments made once maintain their effects automatically, but D behaviors must be repeated over and over to achieve their potential.

W actions [weatherizing with attic insulation, by sealing drafts, and installing high-efficiency windows, and replacing inefficient home heating, ventilating, and central air conditioning (HVAC) equipment] are one-time investments in energy-efficient building shells and equipment that have few salient product attributes other than energy savings and financial costs and benefits. Plasticity is estimated from the most effective documented weatherization programs, which have combined financial incentives (grants or rebates covering most of the retrofit cost), convenience features (e.g., one-stop shopping), quality assurance (e.g., certification for contractors, inspection of work), and strong social marketing. The highest recorded plasticity is 85% over 27 months (Hirst 1988); rates of 15–20% per year have been recorded several times (Stern et al. 1986). Assuming the most effective interventions are deployed, we estimate plasticity of 80% in 5 years and 90% in 10 years, except for furnaces and central AC equipment, for which we assume replacement only at the end of the useful life of existing equipment, resulting in 80% plasticity in 10 years. RAER for W is thus estimated at 5.1% of total household use, or 32 MtC. Strong financial incentives are necessary but insufficient to achieve this plasticity; in the past, plasticity with identical strong incentives has varied by a factor of >10, depending on other aspects of their implementation (Stern et al. 1986). By supplementing financial incentives with program elements such as energy audits, convenience, and quality assurance, the most effective programs significantly reduce nonfinancial costs of action as well as financial ones (Gardner and Stern 2008; Stern et al. 1986).

E actions (e.g., adopting more energy-efficient appliances, equipment, and motor vehicles) involve purchases to upgrade the energy efficiency of household equipment, but in most cases product attributes other than cost and energy savings matter to consumers.[4] We assume replacement at the end of useful life with products of the same type (e.g., size, performance, convenience, and appearance features) that are more efficient. As with heating, ventilating, and air conditioning (HVAC) equipment, we estimate 10-year plasticity at 80% for most equipment classes. We estimate only 50% plasticity for motor vehicle efficiency. The new vehicle fleet may not change fast enough to allow higher plasticity unless consumers forgo other product attributes (e.g., size and acceleration). The most effective interventions probably combine improved rating/labeling systems, other information for households and retailers, financial incentives for households and/or vendors, and strong social marketing (Gardner and Stern 2002; McKenzie and Smith 1999). RAER for this class of actions is 9.0% of total household emissions, or 56 MtC.

M actions (e.g., changing air filters in HVAC systems, vehicle maintenance) are infrequent, low-cost, or no-cost actions that can be maintained by habit. *A actions* (reducing laundry temperatures, resetting temperatures on water heaters) are infrequent, no-cost actions that, once taken, are maintained automatically. *D actions* (e.g., eliminating standby electricity, thermostat

[4] More efficient lighting is omitted from our analysis because the 2007 Energy Independence and Security Act mandates phaseout of incandescent lighting and forces a shift to compact fluorescents, yielding PER of 30.2 MtC or 4.8% of household sector emissions in year 10. Further savings can be obtained by voluntary shifts to solid-state (light-emitting diode) lighting, but this technology is new to consumers and we have no basis for estimating plasticity.

setbacks, line drying, more efficient driving, carpooling, and trip chaining) are frequently repeated actions maintained by habit or repeated conscious choice.

The most effective interventions for M, A, and D actions generally involve combinations of mass-media messages, household-and behavior-specific information, and communication through individuals' social networks and communities, with specifics depending on the target behavior (Gardner and Stern 2002; Abrahamse et al. 2005; McKenzie-Mohr and Smith 1999. Plasticity is probably behavior-specific in ways not fully understood at present. Few studies exist of interventions targeting single behaviors of these types. However, studies of daily or continuous energy-use feedback, a form of household-specific information, typically show reductions in total in-home energy consumption by 5–12%, probably by inducing change in multiple A and D behaviors (Fischer 2008). Multipronged interventions have produced reductions of 15% or more of home energy use by changing these behaviors (e.g., Rothstein 1980; Staats et al. 2004). We conservatively estimate that feedback supplemented by other communication can achieve the plasticities shown in Table 1 for A and D behaviors, which reduce total energy use in homes and in driving by approximately 4%. Very little is known about the plasticity of the M behaviors. Analogies from health behavior campaigns suggest plasticity of 8% to 9% from mass media campaigns (Snyder and Hamilton 2002; Snyder et al. 2004) and more if communication uses individuals' social networks and communities (Abroms and Maibach 2008). We believe 30% plasticity is achievable for these maintenance actions because they involve less-difficult changes than most health behaviors. RAER for M, A, and D, respectively is 1.5%, 0.2%, and 3.8%, or 34 MtC/yr in total for these actions.

Discussion

Our estimates of RAER are based on the best available behavioral evidence and provide a reasonable initial guide to what can be achieved by active promotion of household behaviors to reduce greenhouse gas emissions. More precise estimates can be developed with better data. However, decades of research on proenvironmental and health behaviors demonstrate that behavioral interventions can have substantial impacts and show how to design them for maximal effect.

Two kinds of knowledge seem most critical for developing firmer estimates of RAER and achieving more of the potential. One concerns the current penetration of energy-efficient equipment and practices. We could find no data to estimate the penetration of trip chaining, low rolling resistance (LRR) replacement tires, and reduction of standby electricity and very limited data on other actions, including important ones such as water heater temperatures. Better data would yield better estimates.

The other type of knowledge, perhaps even more important, is knowledge related to plasticity, in particular about how the features of interventions, including incentives, education, information, social marketing, quality assurance, and convenience improvements, work separately and together to affect adoption of specific emissions-reducing activities. Energy conservation policies often go without evaluation or are evaluated in ways that are not useful for understanding plasticity or learning how to make interventions more effective. On a related note, there is insufficient information on the costs and institutional requirements (e.g., staffing, program management) of highly effective, large-scale behavioral change initiatives. The experience of successful programs over the last several decades suggests that these are not insurmountable barriers, but additional data would be valuable.

The American Recovery and Reinvestment Act of 2009, commonly known as the stimulus package, and the Consumer Assistance to Recycle and Save (CARS) Act of 2009, better known as the ‘‘cash for clunkers’’ program, represent a missed opportunity in this regard. The stimulus package provided $5 billion for low-income home weatherization, $4.3 billion for a 30% tax credit for certain home energy-efficiency investments, and $300 million in rebates for the purchase of Energy Star appliances, as well as additional funds that state and local governments could use for various purposes, including residential energy efficiency (Alliance to Save Energy 2009). The CARS program provided $3 billion for incentives for owners to trade in qualifying older vehicles for more fuel-efficient new ones, with the old ones being scrapped. It is too soon to estimate the effects in terms of emissions reduction, but 2 observations are worth making. First, the programs are quite different in behavioral terms. Although there are questions about the cost effectiveness of CARS, it was a great behavioral success, probably due in part to outstanding marketing, paid for by the industry, and convenience (it featured one-stop shopping, removed all paperwork burdens from the consumer, and provided an instant rebate). This contrasts, for instance, with the tax credit program, which also provides a large financial incentive but has not been as well marketed, does not make shopping easy, and requires paperwork and up to a 1-year delay in collecting the credits. More could have been done to apply the lessons of past behavioral research. Second, they do not include an evaluation component that would allow for learning from these major policy experiments. Of course, these programs were intended primarily to provide quick stimulus to the economy, so these deficiencies are not surprising, but the opportunities for more effective, behaviorally based programs and for learning by doing should not be missed in future policies.

Our analysis suggests that most of the 10-year RAER (>13% of total household emissions or 5.2% of total U.S. emissions) can be achieved in 5 years because most actions will ramp up quickly in the early years of an effective program. An average of 60% of the 10-year plasticity could probably be achieved by year 5 in all categories except weatherization, for which, as noted, we anticipate 80% plasticity by year 5. The significance of these reductions can be illustrated in relation to the metaphor of climate ‘‘stabilization wedges.’’ Pacala and Socolow (2004) argued that adoption of any 7 of 15 existing technologies could be ramped up sufficiently over 50 years to stabilize CO_2 emissions at approximately 7 billion tons of carbon (GtC)/yr to allow time for the development of new technologies that could reduce emissions further. Each wedge would provide a cumulative total of 25 GtC in reductions over the 50-year period compared with ‘‘business as usual.’’ If the United States, which emits roughly 20% of global greenhouse gas, were to take a corresponding share of the burden of emissions reduction, it would contribute 7 U.S. wedges of 200 MtC/yr each after 50 years, or 40 MtC each after 10 years. The changes in household behavior outlined above result in a 123 MtC total year-10 RAER or roughly 3 such wedges—44% of the U.S. contribution at year 10.

Extending beyond the United States, similar percentage reductions are likely possible in Canada and Australia, which have carbon profiles roughly comparable to that of the U.S., and percentage savings of perhaps half the U.S. level may be achievable in the European Union countries and

Japan, where the household sector is less energy intensive. Analyses similar to this one would be needed to estimate the potential in other countries. Because the behavioral wedge can ramp up in 10 years, and significant portions of it even more quickly, it provides both a short-term bridge to gain time for slower-acting climate mitigation measures and an important component of a long-term comprehensive domestic and global climate strategy.

Our estimate for U.S. households is conservative. Further 10-year emissions reductions will be achieved by adoption of technologies now almost ready for mass market penetration (e.g., heat pump water heating and space conditioning, electric vehicles, light-emitting diode lighting). Reductions are also likely from household actions that are already being taken but that may not meet our cost criterion, such as purchases of solar technology, green electricity services, carbon offsets, and consumer products with low life-cycle emissions. Still other reductions are possible from behavioral changes that moderately alter lifestyle, such as travel mode changes, telecommuting, and downsizing larger homes and cars. The potential reductions from shifts in consumer purchase patterns, downsizing, and some of these other actions are calculable, but available data are inadequate for making the estimations. For example, carbon calculators, which typically include estimates of emissions associated with purchases of food and other consumer goods, yield inconsistent results and so far do not provide enough information for validation (Padgett et al. 2008).

Lifestyle changes may become necessary in the out-years under constrained energy supply or economic growth scenarios, and they may become more attractive as a result of changes in social attitudes or national or community priorities, some of which might evolve from grassroots efforts to achieve the emissions reductions analyzed here. Additionally, policies that add a financial incentive for carbon emissions reduction are likely to increase behavioral plasticity and may also induce downsizing of household equipment. A U.S. demonstration of leadership on achieving the behavioral wedge might help induce other countries to do the same (Sunstein 2008). The potential of behavioral change deserves increased policy attention. Future analyses of the potential of efficiency in meeting emissions goals should incorporate behavioral as well as economic and engineering elements.

Materials and Methods

We analyzed 33 specific actions that constituted the 17 action types (e.g., ‘‘driving behavior’’ combines slower acceleration, 55 mph speed for highway driving, and reduced idling in nontraffic situations). We defined each action precisely enough to allow us to estimate its current penetration, or the proportion of the relevant population that has adopted an action (e.g., the proportion of motor vehicles being driven at 55 mph on the highway). We estimated penetration from the strongest empirical evidence we could find. The precise definitions of the actions and the bases for estimating emissions reductions and current penetration for each are presented in *SI Text*. PER was calculated by multiplying the PER from an action by the size of the population that has not yet adopted it, aggregating across fuels weighted by carbon emission factors for each, and correcting for double-counting of actions that have overlapping effects (e.g., slower driving has a smaller effect in a more energy-efficient vehicle). The methods are described further in *SI Text*. Plasticity was estimated from data on the most effective documented nonregulatory interventions as described above. We estimated RAER by combining plasticity and PER after recalculating the double-counting corrections for the incomplete penetrations of overlapping actions. *SI Text* presents and illustrates the calculation method.

Acknowledgements

We thank Jennifer Kelly for her assistance in manuscript preparation. This research was funded in part by support from the Michigan Agricultural Experiment Station.

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Examining the Scale of the Behavior Energy Efficiency Continuum[1]

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Introduction

By the end of this year (2010), the United States will have expanded its economic output by nearly 65 percent since 1990. Likewise, per capita disposable incomes will have grown by 38 percent. At the same time, however, the demand for energy and power resources had grown by only 15 percent. This apparent decoupling of economic growth and energy consumption is a function of increased energy productivity; in effect, the U.S. increased its ability to generate more energy-related services from each unit of energy consumed. Many would attribute this productivity gain to more productive investments in technology. Indeed, the evidence does suggest this to be a significant driver of such improvements (see, for example, Ehrhardt-Martinez and Laitner 2008). Yet the evidence also suggests an amazing variety of social influences and human dimensions that have also contributed to this success story—behaviors that *drive* new innovations and behaviors which, in turn, change energy practices and the patterns of technology adoption and energy service demands (Laitner, Ehrhardt-Martinez and Knight 2009).

The real debate isn't about whether the change in behavior has contributed to the dramatically reductions in energy consumption growth rates in the U.S. Instead it is about the scale of savings that might be attributed to the changing human and social dimensions that affect our existing energy practices, the potential scale of behavior-based savings in the future, and the need to recognize behavior as an important but often overlooked resource for achieving large-scale reductions in energy consumption and carbon emissions. Unfortunately, many analysts continue to suggest that while behavior-oriented programs provide a useful way to help deploy smart technologies, they are best thought of as boutique or niche strategies that can only round out a technology-based deployment of more energy-productive investments. We suggest to the contrary; and in this paper we argue that the social or human dimension may have a surprising scale which rivals a pure technology-based perspective in terms of expected long-term, cost-effective energy savings.

Past analyses by the American Council for an Energy-Efficient Economy (ACEEE), and by well-known researchers like Gerald Gardner, Paul Stern, Thomas Dietz and others, suggest that understanding and shaping behaviors can provide a significant boost in the more efficient use of all energy resources (see, for example, Gardner et al. 2008, Ehrhardt-Martinez 2008, Dietz et al. 2009, and Friedrich et al 2010). Indeed, internal discussions among the staff at ACEEE indicate that "the behavioral resource" (including changes in lifestyles and habits, changes in how we choose to use equipment—e.g., thermostat settings, and changes in our purchasing behaviors) might provide as much as a 25 percent efficiency gain (possibly more) above normal productivity improvements. But that would be true only if we choose to recognize, invest in, and develop that resource. In this respect, policymakers and researchers increasingly recognize the

[1] An earlier version of this chapter appeared as a conference paper for the 2009 Summer Study organized by the European Council for an Energy Efficient Economy.

importance of addressing behavioral change to reduce costly energy production and consumption and carbon emissions as most energy-efficient technologies require proper human interaction to achieve their promised savings.

In this chapter we highlight the potential impact of changed habits, lifestyles and technology-based behaviors in terms of potential energy savings within the United States for the residential sector (including personal transportation uses within the control of households). We explore the level of potential savings along what we call a Behavior Energy Response Continuum. In other words, we explore the energy savings that could be achieved if new energy-wise habits became the social norm, and if new energy-wise lifestyles were encouraged by smart policies oriented toward reducing residential energy consumption. Preliminary research suggests that changed behaviors offer potential reductions of 20-25 percent of current levels of residential energy consumption over perhaps a 5-8 year period within the United States. We characterize the elements along this behavior continuum, estimate the potential impact, and describe potential next steps in the needed research.

Methodology and Analysis

In 2008 (the base year for our analysis), there were an estimated 114 million households in the United States. Taken together, they consumed a total of 23.2 Exajoules (EJ) for all residential end uses whether space heating and cooling or lighting and appliances. The use of personal vehicles for work, shopping, errands and recreational activities added another 17.4 EJ of energy. Total energy use among residential users was an estimated 40.6 EJ in 2008 (EIA 2008).[2] The table below highlights the energy use for these major end uses in 2008.

Table 1. Major Residential Energy End Uses in the United States for 2008

End Use Category	Energy Consumed (EJ)	Percent of Total
Space Heating	6.5	16.1%
Air Conditioning	2.5	6.1%
Lighting	2.4	6.0%
Hot Water	2.6	6.3%
Refrigeration	1.5	3.8%
Consumer Appliances	3.5	8.6%
Other Uses Note Specified	4.2	10.4%
Personal Transportation	17.4	42.8%
Total End Use Energy	40.6	100.0%

Source: Energy Information Administration (2008)

In a typical economic policy assessment, most economic modelers and analysts assume that changes in energy consumption will depend on some form of financial incentive (or penalty) to drive the changes energy consumption pattern. This might be in the form of increased energy prices and/or some form of financial enticement to encourage the adoption of energy saving

[2] While the original data avalable from the Energy Information Administation were in quads or quadrillion Btus, this chapter was originally presented before a European audience; hence the use of exajoules (EJ) as the primary energy unit rather than quads. For those readers who wish to make a conversion, simply divide the number of exajoules by 1.055 to approximate the number of quads. Hence, 40.6 EJ is roughly the same as 38.5 quads.

technologies (Laitner 2009). Yet, behavioral actions might be motivated by a wide range of perceptions, beliefs, information, and changes in attitudes (Ehrhardt-Martinez 2008). In this regard, both the mix of conventional incentives and behavioral actions might provide a dynamic complement if policy makers better understood the impact and/or the potential scale of behaviorally-related outcomes.

For our purposes here, we define behavioral actions in two ways: (i) the frequency of actions and measures that might be taken by individual households, and (ii) the level of cost needed to bring about a more efficient use of energy (see chart in Figure 1 below). Both categories of behaviors (frequency of action and consumer cost) reflect actions that might be taken over a 5-8 year period of time. There is nothing that dictates a specific stretch of time within our analysis. Rather we chose this period of analysis as a means to emphasize short-term behaviors as without impacting the complete turnover of the existing capital stock under the immediate control of households.

Figure 1. Categories of Household Behaviors that Impact Energy Use

Cost	Frequency of Action: *Infrequent*	Frequency of Action: *Frequent*
Low-cost / no cost	**Energy Stocktaking Behavior** Install CFLs Pull fridge away from wall Inflate tires adequately Install Weather Stripping	**Habitual Behaviors and Lifestyles** Slower Highway Driving Slower Acceleration Air Dry Laundry Turn Off Computer/Other Devices
Higher cost / Investment	**Consumer Behavior** New EE Windows New EE Appliances Additional Insulation New EE Car New EE AC or Furnace	

By way of providing a reference point our 5-8 year time horizon, automobiles, for example, might have a typical life of 15-17 years. Residential heating systems might have an average life of 9-20 years, while refrigerators might last an average of 13 years. Hence, a 5-8 year period is on the order of about one-third to one-half of the effective life of nonstructural capital stock within the relatively easy control of households (other than (i.e., other than the residential dwellings themselves). This period of time also reflects an expected simple payback that might motivate consumers to adopt a new behavior that might be deemed "cost-effective." For example, a 5-year payback anticipates perhaps a 20 percent annual return on investment while a payback of 8 years might reflect an expected 12.5 percent return on investment. While this time horizon tends to constrain the impacts that might result from the evolution of longer-term behaviors, we adopt it here as a way to manage the analysis and to provide a context for policy makers.

The actions that we summarize for this paper include a range of behaviors which are influenced by habits, lifestyles, and a general awareness of environmental or climate-related impacts that are driven by energy consumption. These generally fall into the low-cost/no-cost category of actions. They can involve infrequent actions such as installing compact fluorescent lamps, installing weather-stripping around doors and windows, and inflating automobile tires to their correct pressures. We refer to these as *energy stocktaking behavior* in which households from time to time step back and think through specific actions they might take to reduce what they might see as wasteful energy consumption. The behaviors can also involve more frequent actions ranging from slower highway driving, slower acceleration and gentle braking to air drying household laundry and turning off unneeded lights, computers and appliances. We refer to these as changes in *habits and lifestyles*. Finally, there are a set of *consumer behaviors* which include more informed purchases or investment decisions such as buying more energy-efficient window and appliances, or purchasing a more fuel efficient or a smaller car.

Pulling from 22 different studies we were able to generate a range of estimates on potential energy savings for roughly 120 separate measures or actions that will result in varying levels of future energy savings. Drawing from that same literature, and in review with ACEEE professional staff and others, we then established a likely range of participation rates for each of the actions as well as a range of overall effectiveness. For example, Blasnik (2008) suggests that secondary refrigerators can use between 400 and 2,000 kilowatt-hours (kWh) per year. Other studies suggest that as many as 30 percent of households may actually have a second refrigerator.

A reasonable assumption is that within the next 5-8 years perhaps one-third to two-thirds of U.S. homes that have second refrigerators might be induced (through a variety of means) to get rid of those second units. As such, the eventual energy savings associated with this specific behavior might range from 14 to 46 billion kWh. According to the Energy Information Administration (EIA 2008) it appears that total refrigerator electricity consumption approached 349 billion kWh in 2008. Hence, this single behavioral response might save anywhere from 4 to 13 percent of electricity associated with household refrigerators. Table 2 highlight the key range of savings expected from these 120 measures as they are aggregated and summed according to the eight major end uses defined in this analysis.

Table 2. Range of Savings and Participation Rates by End Use Category

Major End Uses	Range of Potential Savings	Range of Policy-driven Participation	Expected Savings
Space Heating	18-36%	3-40%	27%
Air Conditioning	19-47%	2-75%	33%
Lighting	10-53%	20-80%	32%
Hot Water	6-26%	3-75%	16%
Refrigeration	17-55%	5-75%	36%
Consumer Appliances	6-20%	40-80%	13%
Other Uses Not Specified	12-24%	30-50%	18%
Personal Transportation	14-33%	30-80%	24%
Total End Use Impacts	18-28%	n/a	23%

Note: This set of energy end-uses and their associated range of potential energy savings are working estimates generated by the authors as they have drawn information from a set of 22 separate studies cited in the separate bibliography, "Data and Analytical References," identified at the end of this paper.

Several analytical points are worth noting in Table 2. First, the range of savings potential reflects the efficiency gains that might be possible within a given end use category. For example, we've identified approximately 12 different measures within space heating. The aggregate of those measures might lead to a possible savings of 18 to 36 percent of the 6.5 EJ now used for that purpose. One can imagine both higher and lower values depending on other assumptions that might impact that end use. These might include different assumptions about the interaction of measures, for instance. If we dial down the thermostat, then actual energy savings are likely to be less for a more efficient furnace. Other influences include the quality of the housing stock, the assumption about cooling degree days, and the mix of furnaces and their requisite fuels used within the households. Second, the range of policy-driven participation rates reflects different levels of involvement as a function of individual measures. Again looking at space heating, the 3 percent value is the low-end of response for those who might have their chimney cleaned while the 40 percent participation might reflect those who insulate their heating duct or weather-strip their doors and windows. The expected savings is an approximate engineering estimate that we might anticipate given the full mix of actions and a likely pattern of activity involving the individual measures.

After compiling information for the full set of the 120 action items, we set up a Monte Carlo simulation to determine the range of likely outcomes. Such simulations belong to a class of computational algorithms that rely on repeated random sampling to estimate their net effective outcomes. Such methods are often used when replicating physical and mathematical systems. Monte Carlo methods are especially useful for modeling phenomena with significant uncertainty in assumptions or inputs, such as the calculation of risk in business; or in this case, such as the likelihood of adopting energy efficiency improvements and/or the level of actual energy savings from those improvements or measures. While there is no single "Monte Carlo method," the approach used here followed five separate steps:

1. Defines a domain of possible energy efficiency measures or actions that might be undertaken by households.
2. Characterizes a range of energy savings that might likely follow the adoption of those measures or actions.

3. Anticipates the likelihood of adoption or use of a given energy efficiency measure within 5-8 years.
4. Maps the possible range of interaction effects that might reduce the net energy savings.
5. Aggregates the results of the individual computations into the set of outcomes.

The simulation uses an upper and lower range of participation in each of the identified measures, and incorporates a range of potential savings, and accounts for potential interactive effects associated with appropriate measures. The final estimates of the potential behavior-related energy savings were estimated by running 1,000 individual calculations to determine the magnitude of impacts that might result from a well-designed set of behavioral programs. The results of that effort are summarized in Table 3 that follows.

Table 3. Potential Impact of Behavior on U.S. Household Energy Use

Category of Actions	Potential Savings (EJ)	Percent of Total
Low-Cost/No-Cost	5.2	57%
Smart Investment Decision	3.9	43%
Total Energy Savings	9.1 ± 2.6	100% ± 29%

Implications

As suggested in Table 2 our "engineering estimates" suggested a 23 percent savings potential from among all of these end use savings. In fact, the reported Monte Carlo simulation suggested a 22 percent savings with a plus or minus 29 percent interval. The end result of this preliminary analysis indicates the potential for a 9.1 EJ energy savings within U.S. households, including both residential and personal transportation savings. The actual range of potential savings might be as low as 6.5 EJ or as high as 11.7 EJ. In short, cost-effective behavioral responses should be recognized as a significant energy efficiency resource. Even if we constrain our definition of behavioral resources to include only those practices associated more with lifestyles, habits, and the conservation ethic, one can reasonably argue that a 5.2 EJ impact (that is, the impact shown in row one of Table 3) is still a very large opportunity to be pursued. And by including investment-related decision-making among the relevant behavior mix, then the scope of the behavior opportunity is even broader.

But, is the scale of these savings worth pursuing? How big is 9.1 EJ (±29%)? As previously noted, when compared to direct household savings, 9.1 EJ is about 22 percent of the current residential and personal transportation energy needs in U.S. households today. That represents about 12 percent of total U.S. delivered energy use in 2008. It is also equivalent to 600 gallons of gasoline savings per household. From a climate perspective these energy savings would equal the amount of energy that might be generated by about 240 medium coal-fired power plants. And from an international comparison, it is roughly equal to the total annual energy consumption of either Brazil or South Korea, and just slightly less than total annual energy consumption in the United Kingdom (10.6 EJ), France (12 EJ), and Germany (15.3 EJ).

At this point the question naturally arises as to how this information might be useful to policy makers? Generally we suggest perhaps two aspects of value to this initial analysis. The first is that it might inform economic policy modellers in their effort to evaluate future energy or climate policies. The second is that it might spur greater interest to understand the kinds of non-price motivations and perceptions that might drive a greater response to future energy and climate policies.

In the case of economic policy modelling, a standard assumption is that a change in energy prices will reduce overall energy use. Economists typically adopt the assumption of an elasticity that captures such behavior. For example, if a 10 percent increase in energy prices reduces energy use by 2.5 percent, the price elasticity is said to be on the order of -0.25. And this response is generally assumed to be invariant over time. Should the policy makers want to reduce energy use to 75 percent of current consumption, then the economic models might suggest that prices would have to increase by nearly three times the current levels to achieve that result. However, if we understand that better information, a greater awareness of energy alternatives, or a growing concern about the emerging climate problems might change perceptions about the need to act, consumers may generate the same magnitude of response with a much smaller prices signal. For example, if behaviors were to change such that the measured elasticity is not -0.25 but perhaps -0.5, then prices may need to increase by only 80 percent to achieve the same reduction to 75 percent of current consumption. In other words, additional research in this area could inform economic policy models about a more dynamic and a richer set of outcomes that may possibly show a more beneficial economic impact as a result of an improved characterization of energy-related behaviors (Laitner 2009).

In a different vein, if policy makers believe that behaviorally-related responses have a sufficient magnitude of impact, they may be willing to invest more time and effort to explore improved ways of expanding those positive returns. As one example here, a variety of studies have suggested that positive feedback might increase energy savings from 4 to 12 percent over prior levels of consumption (Ehrhardt-Martinez, Donnelly, and Laitner 2010). In other words, if consumers are able to know through their monthly utility bills or through real-time metering of energy use within there homes that, compared to their neighbours or others within their income class, their energy savings are below some level of performance, then they are more likely to take actions which modify energy use in ways that still maintain their quality of life. If one kind of feedback generates only a 5 percent response, an improved understanding of consumer motivation and learning might generate instead a 15 percent response—without requiring higher prices or other financial incentives. In effect, expanding the behavioral response may increase the benefits of energy saving opportunities in a highly cost-effective manner (Ehrhardt-Martinez 2008).

Further Research Needs

If we take a step back and relax our assumptions about the nature and role of behavior and its potential contribution to the adoption of more productive technologies, then results we show here are not quite so surprising. The question then becomes one of how we close the gap between current choices and levels of (in)efficiency and developing the full opportunity to become much more energy-efficient. To that extent we now suggest several areas of inquiry which may help us understand and confirm the prospect of a more robust and a significantly more energy-efficient future.

A first area is to expand the range of inquiry so that we better understand people as more than economically rational actors. This is critically important if we want to fully comprehend what motivates human behaviors. People are more complex and there are many other dimensions that are equally if not more important in determining how to encourage an optimal level of energy-efficiency. For instance, while economics will clearly play an important role in the adoption of future energy efficiency measures, improved perceptions about the contribution of energy efficiency technologies in reducing air pollutants and greenhouse gas emissions can accelerate the adoption of more productive energy technologies. And consumer attributes like convenience and perceived social status associated with new technologies can further accelerate the adoption of energy efficiency measures (See Ehrhardt-Martinez and Laitner 2009, Ehrhardt-Martinez 2008, and Ehrhardt-Martinez, Reed, and Laitner 2008).

A second area of inquiry is to build on the research reported here and to place these results into a larger context to quantify and give policy makers a real sense that the behavior resource can play a significant contribution in addressing critical issues such as energy and climate change policies. Gardner and Stern (2008), for example, have used a different methodological approach to determine what they call "the behavioral wedge" at the household and level (also including personal transportation). This refers to the segment of efficiency improvements that can be made without further incentives or without waiting for new technologies, but that depend instead on more informed decision-making and a greater awareness of impacts that follow from the choices typically made within households.

Both this paper (which focuses on the economy-wide impacts) and the "wedge paper"—while generating comparable analytical results—examine only direct household and personal vehicle savings associated with the behavioral resource. We think there are still more opportunities to be included in future assessments of this kind. If properly evaluated, we believe the full spectrum of efficiency gains would grow to perhaps 30 percent or more over perhaps a 10-year period (Laitner 2009). This compares to the 22 percent savings identified by these two current research efforts. Overlooked are producer behaviors that might amplify consumer response. Also not included are the potentially very large indirect savings that accompany a host of consumer decisions ranging from a changing size of households to the recycling and dematerialization of most consumer goods and services. The potential contributions and synergies from more "productive behaviors" in the commercial and industrial sectors are also overlooked. Finally, choices that help move the international community to emphasise the transition to a greater service economy, as well as integrating broadband technologies and services that promote more flexible work schedules, greater levels of telecommunication and teleworking, and different patterns of industrial production flexible work schedules can all help change patterns of energy consumption and production.

Conclusion

Unfortunately, many economic policy analysts continue to suggest that while behavior-oriented programs provide a useful way to help deploy smart technologies, they are best thought of as boutique or niche strategies which can only round out a technology-based deployment of more energy-productive investments. We suggest to the contrary. Changed patterns of behaviors might reduce household use of energy by 22 percent within the United States. Indeed, a greater understanding of behaviors, and an improved categorization of behavioral responses might expand that potential magnitude of savings. When expanded to the non-household sectors, and including a wider array of consumer options not included in this assessment, the economy-wide impact of the behavioral wedge might grow to a 30 percent efficiency gain or more. Should we take the time to understand the behavioral perspective, and if we recognize its full "resource potential," it can be a very big deal—but only if we choose to develop it.

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A 30% Reduction in Electricity Use Is Not Only Possible but Actually Occurred in Juneau, Alaska

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Saving Electricity in a Hurry

It is difficult to imagine living comfortably with significantly lower electricity consumption absent huge investments in energy-efficient appliances and equipment. But in fact, hundreds of tiny adjustments in people's daily activities can accomplish the same savings as strictly technical improvements in new appliances. An electricity crisis in Juneau, Alaska, demonstrated how a mobilized community can quickly reduce power use mostly through changes in behavior.

Utilities provide electricity to their customers with near-perfect reliability. However, severe weather, earthquakes, and other environmental incidents can lead to temporary interruptions. Typically, power is restored within hours, but truly severe events may require days, weeks, or even months to re-establish normal supplies. In such cases, regions must quickly reduce electricity demand or suffer black-outs (International Energy Agency 2005). For example, in 2001, a severe drought drastically curtailed hydroelectric supplies in Brazil. To avoid the economic repercussions of widespread and unpredictable blackouts, the federal government took immediate responsibility for managing the crisis. The prime minister created a "crisis cabinet" (Parente 2002) to manage an aggressive conservation campaign. In less than three months, the entire country's electricity consumption fell 20%. The savings persisted such that, in 2008, average household electricity consumption was still below 2001 levels (Geller 2008).

California's electricity shortage in 2001 was caused by a combination of drought, supply shortages, and market manipulation. The state launched a massive and creative (Bender et al. 2002) conservation program that reduced statewide electricity usage by 6%, and average monthly peak demand by 8% compared to the previous year (Goldman, Eto, and Barbose 2002). That savings was sufficient to enable the state to avoid blackouts during the critical summer period. These, and many other temporary shortfalls in electricity supply, are described in the recent book, *Saving Electricity in a Hurry* (International Energy Agency 2005). Each shortfall has unique characteristics but most successful strategies involved a vigorous effort to reduce electricity demand.

Sometimes sufficient electricity supplies exist but the cheapest source is temporarily unavailable. In these cases, the problem is a price crisis rather than an actual electricity shortage. This happened in Norway in 2002–2003, when a drought and a cold wave reduced the supply of cheap hydroelectric power (Moen 2003). Juneau, Alaska was also struck with a price crisis, in 2008. There a loss of hydroelectric power stimulated the largest voluntary reduction in electricity consumption in history. Juneau's experience offers important lessons for dealing with future electricity shortages but it also illustrates the role of behavior and energy use.

An Avalanche Severs Juneau's Electric Transmission Line

Juneau is a coastal city in southern Alaska with a population of 31,000. As Alaska's capital, Juneau plays a critical role in the state's operation, despite its small size. It is geographically isolated from the rest of the world, including the state it governs, by steep mountains, glaciers, and water; the only access to the city is via sea or air (see Figure 1). The majority of supplies arrive weekly, by barge, from Seattle, Washington, about 1,400 km to the south.

Figure 1. Location of Juneau, Alaska.

Adapted from Britannica (2010)

Juneau's principal industry is government, with federal, state, and regional offices. It also has a small fisheries industry. During the summer, cruise ships regularly stop at Juneau, bringing over half a million tourists. Juneau is too small to support a local TV station, but nevertheless has a vibrant local media scene.

The majority of electricity consumption is in the residential and commercial sectors. Twenty percent of homes use electric resistance heating, although many homes can also burn oil or wood. A greater fraction of homes heat water with electric resistance heat. Electricity represents a major financial outlay for many Juneau residents.

Over 90% of Juneau's electricity is generated by hydroelectric facilities, and about 85% of that is transmitted via a single transmission line from the Snettisham reservoir, about 60 km south of the city. A privately-owned utility, Alaska Electric Power & Light (AEL&P), is responsible for generating, transmitting, and distributing the electricity to customers. AEL&P is a small utility and has no experience operating conservation programs.

On April 16, 2008, a huge avalanche severed the transmission line between Snettisham and Juneau. American utilities are required to maintain sufficient reserve generating capacity to make up for the loss of their largest power plants. In AEL&P's case, the reserve is a bank of diesel generators. The diesel generators immediately switched on, and from that point on, Juneau's electricity was generated almost exclusively from diesel fuel. Repairs were expected to take at least three months. The timing was particularly unfortunate because the price of diesel was at record levels. The price of a kilowatt-hour of electricity delivered to customers rose from about 11 cents/kWh—the normal level for the city's hydropower—to over 50 cents/kWh, a nearly 5-fold increase.

The utility immediately sought to pass through the increased generation costs to its customers. The city government recognized that many of its citizens could not afford the higher bills and feared that the high electricity prices would destroy the city's economy (Golden 2009; JEDC 2008). It responded first by trying to shift the costs to the state or federal government. This tactic was at least partially justified by Alaska's tradition of subsidizing fuel deliveries to villages. However, unlike Juneau, villages receiving this subsidy are remote and lack other, cheaper supplies, so most state politicians opposed a subsidy. The controversy was further complicated by citizens' hostility towards the privately-owned AEL&P. The political discussions continued for months and delayed the appearance of the higher bills.

In the meantime, the citizens acted without any special plan or program (Skinner 2008). They rushed to stores to buy energy-saving equipment but quickly exhausted the stores' supplies of insulation, compact fluorescent lamps (CFLs), and switchable power strips. The stores even ran out of clotheslines. Thus, there was a little opportunity to make improvements in efficiency, and the weekly barge from Seattle did little to replenish supplies. Moreover, the technologies that could achieve larger electricity savings would take even longer to order, deliver, and install.

Knowing that their utility bills would soon skyrocket, Juneauites lowered thermostat settings, switched to wood stoves, switched off lights, and unplugged appliances. Juneau's AIRPORT—the city's third largest end user—switched off the airport runway lights from midnight to sunrise, when the airport was closed anyway. Within a few days after the avalanche, electricity demand had fallen about 10%, although most of the reduction was a result of milder weather and increased sunlight. Still more savings would be needed to minimize the impact cost and the risk of blackouts (Yardley 2008).

Juneau's Conservation Plan

Juneau's government realized that the only way to reduce its residents' and business' electricity bills was to use less electricity—much less electricity—immediately. The city began to search for strategies. They were especially concerned about the estimated 40% of homes relying on electricity for space or water heat. There was no time to insulate homes, install alternative heating systems, or replace inefficient appliances. Moreover, many of these households were too poor to afford such investments. Many of the poorest citizens spoke little or no English, and were probably unaware of the avalanche, and thus were unable to prepare for the huge increase in electricity prices.

The city was also concerned about its own electricity bill since it had not budgeted for this unexpected electricity price spike. Juneau requested the U.S. Department of Energy (DOE) to send the city an expert to advise them on conservation programs. The expert—the author of this chapter and also the International Energy Agency's book on saving electricity in a hurry—arrived several days after DOE received the request.

The Juneau Economic Development Council (JEDC) took the lead in organizing the campaign to save electricity. Because the situation was so politically charged, it was important for a neutral group to take the leadership role. For the same reason, the utility needed to keep a low profile. The JEDC assembled city leaders, including merchants, heads of nonprofit welfare groups, church elders, politicians, and school representatives, in an effort to establish a single voice and message. One of the earliest actions was to brand the campaign with the slogan, "Juneau Unplugged" and an accompanying logo (see Figure 2).

Figure 2. Juneau's Slogan and Logo to "Brand" the Conservation Campaign

JUNEAU
UNPLUGGED
live more, use less

The message was crafted to be positive and upbeat, and to avoid criticizing any particular group. An important element of that message was that conserving electricity is good citizenship, and not something to be embarrassed about. Linking conservation to civic responsibility would encourage all sectors to switch off lights and otherwise to conserve electricity. Stores placed placards with the "Juneau Unplugged" logo in their windows. The placard both labeled the stores as good citizens and advertised the program to the general public, reminding them to conserve. (It also explained to tourists why the lights were off in so many stores.)

The International Energy Agency had found earlier that the most effective conservation campaigns used humor to overcome the initial awkwardness inherent in trying to change peoples' habits, and so this strategy was used in Juneau. The DOE expert utilized PSAs from the California electricity conservation campaign of 2001, including this one of a baby forcing his mother to use the vacuum cleaner, by tossing his cereal onto the floor, but waiting until exactly 7:00 PM to do so, in order to avoid brownouts: http://www.youtube.com/watch?v=H0kdU2oEVIg. Other PSAs from the campaign, though not as funny, offered clear, simple conservation advice: http://www.youtube.com/watch?v=FLFu64Y2tOI&feature=related .

One major challenge the campaign faced was providing reliable advice to residents on actions to achieve the greatest reduction in consumption in the shortest time. The need for quick action changes the desirable strategy from one of purchasing energy efficiency—in the form of better appliances, insulation, etc., because of the time and money required, to one of quickly changing behavior with respect to electricity use. During a crisis, the politics becomes much more flexible than normal. Thus, the authorities were able to ask for sacrifices that would have been unacceptable during normal times, such as taking shorter showers, switching off lights, and unplugging appliances when not in use.

The centerpiece of the information campaign was a flurry of appearances on television and radio programs by the visiting expert. The newspapers interviewed him, and he gave talks on how best to conserve, as well as televised energy audits.

The public information campaign had two goals. First, the campaign helped residents set priorities by rating the effectiveness of the various measures. For example, the expert explained that hot water represents a large, almost invisible, use of electricity in many homes. Thus, the first measure should be to lower the temperature of the storage tank—something that required a single action to achieve lasting conservation. These should be followed by a sequence of additional measures requiring progressively greater effort and/or vigilance, such as switching off the outside light for a few hours. Other measures, such as unplugging mobile phone chargers, saved so little electricity that they were merited only very low priority.

The second goal was to warn residents against conservation measures that could backfire. For example, residents were cautioned against raising the thermostat in their refrigerators and freezers because a small error could lead to expensive food spoilage.

The campaign played an important psychological role, too, defusing fears of the unknown, by providing residents with concrete actions they could take to reduce the impact of the higher prices.

The city was also concerned about the influx of tourists, which was likely to begin before the transmission line would be repaired. Over half a million tourists visit Juneau each summer, usually arriving on large cruise ships. These tourists needed to be informed of the electricity shortage before arrival so that they would also conserve, and possibly more importantly, so they would understand that the stores, which appeared unusually dark, were in fact open for business. The increased electricity demand caused by the ships themselves—they were required to plug into the city's grid while docked so as to minimize air pollution—also needed to be considered.

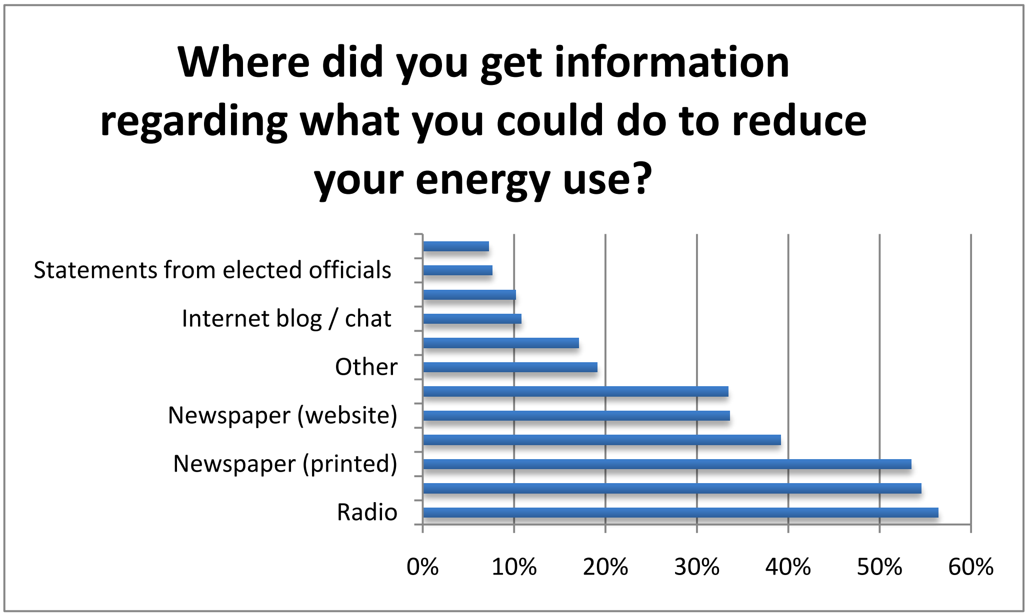
Separate strategies needed to be developed to conserve electricity in state and federal office buildings. Curiously, the staff were often more receptive than the management in implementing conservation measures. The office workers actually took the initiative to switch off and unplug equipment before management could formulate its own policy.

The city government of Juneau also needed to conserve power. Streetlights were an obvious target for conservation. Crews quickly started rewiring streetlights to enable switching off alternating lights. Two of the three largest municipal loads were the sewage treatment system and the water supply system. That led to an unexpected electricity-saving recommendation: citizens should conserve cold water as well as hot water. Each liter conserved—both cold and hot—reduced municipal electricity consumption, first in the water supply system, and then in the sewage treatment plant.

The utility, AEL&P, kept the public updated daily on the transmission line repairs' progress on its Web site, with photos showing the new towers being airlifted into place and installed—information that was picked up by the local news media. These updates reminded the community that they were getting closer to the end of the crisis.

During the crisis, consumers obtained information from diverse sources, according to a survey conducted about ten months after the avalanche (Leighty and Meier 2010). The survey was not rigorously representative, but we believe the responses reflect the views of the community as a whole, based on large sample size (539 responses from a population of about 30,000) and indications from responses to questions about demographics that respondents represent a true cross-section of the community. The three most frequently mentioned information sources—radio, word of mouth, and newspapers—ranked nearly equal in importance (see Figure 3). To some extent this breakdown reflects Juneau's uniquely isolated geography, but it also reveals the impact of the early blitz of information. The good results reinforce the hypothesis that recommendations must be disseminated through many sources if one wants to reach a large portion of the population *and* stimulate them to undertake energy-saving measures.

Figure 3. Survey Responses to Question about Where Citizens Obtained Information about Saving Electricity during the Crisis



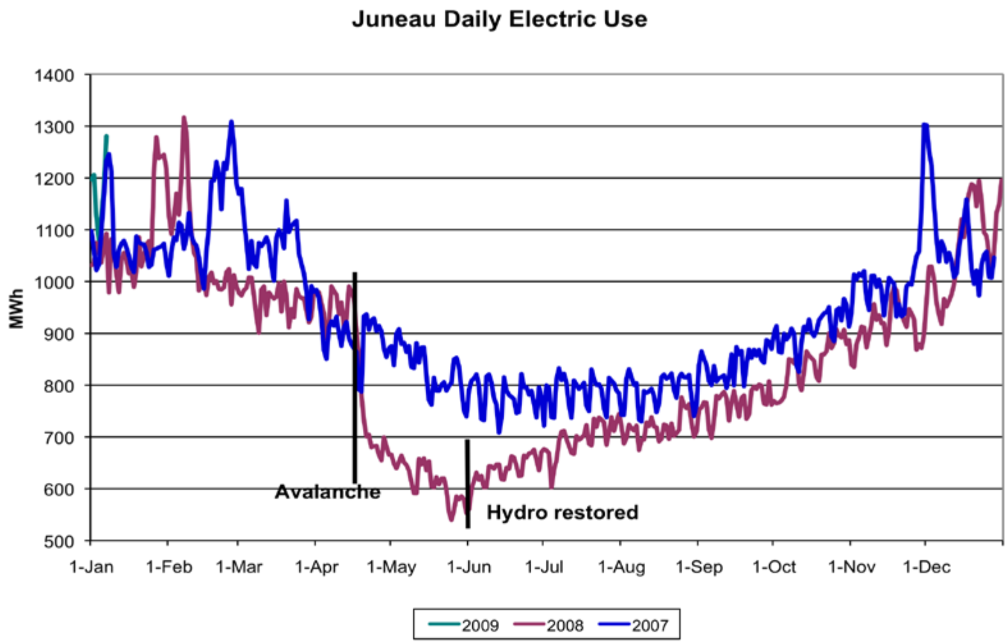
Electricity Savings Exceed 30%

The information blitz was amazingly successful. Juneau's electricity consumption, about 1,000 MWh/day prior to the avalanche, fell more than 40%, to less than 600 MWh/day six weeks later (see Figure 4). To be sure, some of the savings probably resulted from longer, warmer days as spring progressed. Nonetheless, compared to the same period during the previous year, the savings was still 30 percent—and perhaps slightly more when the historical annual growth rate of electricity consumption is factored in.

A more precise estimate of savings is unlikely given differences in weather between the two years.

Curiously, the residents never saw the higher electricity rates on their utility bills until the crisis was almost over. The regulatory authority did not allow AEL&P to bill consumers at the higher rates until only a few weeks before the transmission line was restored. Thus, most of the conservation occurred while consumers were still paying the lower, pre-avalanche rates. The price signal was communicated only through the media and word of mouth rather than through actual utility bills.

Figure 4. Juneau's Daily Electricity Use before and after the First Avalanche



How Juneau Saved Electricity

The aforementioned survey is the only non-anecdotal source of information about the measures undertaken. The responses are not sufficient to know exactly which conservation measures were undertaken or how much energy each measure saved. Nevertheless, they provide a broad picture of the how Juneau saved electricity in the residential sector.

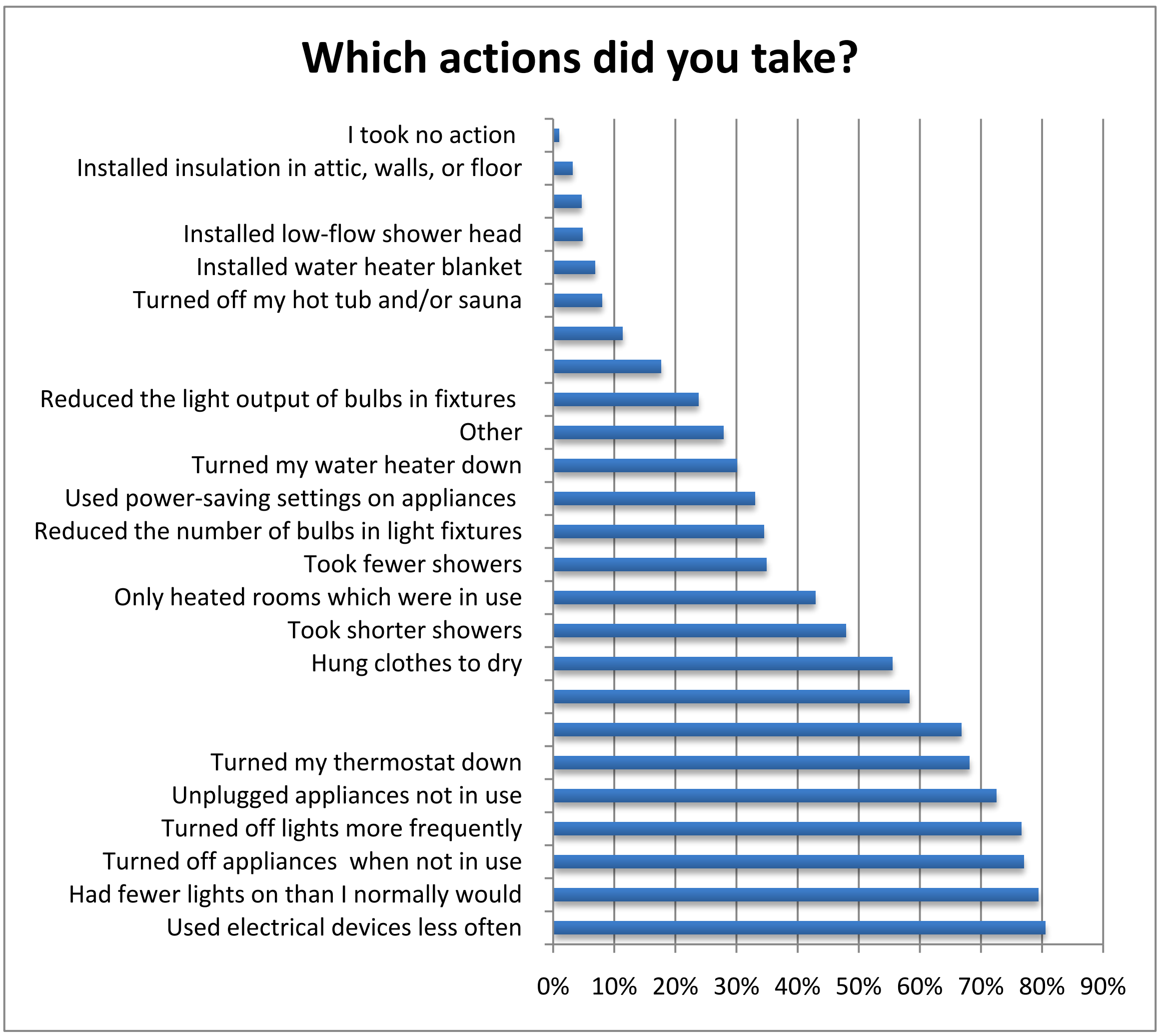
Most of the savings were achieved by changing habits rather than through major purchases of energy-saving materials or new equipment. The most popular measures were reducing lighting and appliance use, including taking shorter showers, completely filling washing machines and dishwashers before running them, and reducing clothes dryer operation.

The savings from these measures cannot be accomplished with a single action: instead, they require continuous, small deviations from old habits, cumulatively resulting in a new, energy-saving behavior. These actions often begin with negotiations with other family members to encourage—or at least to avoid undermining—the new behavior.

About 15% of the homes reported switching to alternative fuels—mostly to wood, as many homes have wood stoves. The low percentage switching to wood—despite the high proportion of houses that have wood stoves, and despite the large savings that could thus accrue—reflects the inconvenience of using this fuel: the hauling and storing of the wood, and the constant monitoring of the stove.

Barely 10% of the respondents reported adding weatherstripping, and less than 5% of survey respondents installed insulation. In the latter case, the crisis' short duration, the lack of insulation materials available in Juneau on short notice, and the lack of skilled installers undoubtedly discouraged this highly effective measure. Residents reported no other major efficiency investments.

Figure 5. Reply to Survey Question about the Type of Conservation Actions Taken



Only three low-cost measures to improve efficiency were reported: installation of low-flow showerheads, water heater blankets, and CFLs. Of the three, installation of CFLs was by far the most popular; it occurred in over 70% of the homes.

The Transmission Line Is Repaired and the Crisis Ends

On June 1, the transmission line was repaired and hydroelectric power was restored to Juneau. The repairs were finished six weeks ahead of schedule, partly due to favorable weather, and partly because the utility had deliberately overestimated the time it would need to finish the repairs. The mayor immediately declared an end to the emergency (even though the disposition of additional fuel costs had not been fully settled). While Juneau's economy did not exactly flourish during the crisis, there is no record of businesses failing as a result of the electricity crisis.

Electricity consumption quickly rebounded, but not to original levels. During the rest of 2008, consumption remained roughly 10% less than it had been in 2007. A more precise estimate of the savings is impossible because of variations between the winters, fluctuations in economic conditions, and lumpiness in demand caused by mines and large commercial customers. Thus, the persistent savings could easily be as little as 5% and perhaps as large as 15%. This difference probably represents the savings accomplished through some technical efficiency improvements, notably CFLs; certain semi-permanent changes in operation (such as lowering the temperature in water heater storage tanks); and new, energy-saving habits. Whatever the underlying causes, Juneau's electricity demand underwent a permanent downward shift as a result of the avalanche.

The survey provides clues as to which energy-saving habits persisted post-crisis and which have not. For example, about half of the respondents abandoned line-drying their clothes and have ceased unplugging appliances when not in use. But they continue to reduce heating of unused rooms.

The citizens of Juneau appear to be proud of their accomplishment. Some were aware of Brazil's electricity conservation campaign—the most successful program to date—and felt special pleasure that they had surpassed Brazil's record.

One Year Later: Another Avalanche

In January 2009, a second avalanche cut the transmission line. This time, consumption fell 10% almost immediately, amidst a "been there, done that" atmosphere (Golden 2009). Circumstances were somewhat different: the interruption occurred during the coldest month, but as only two transmission towers were damaged, the interruption was expected to be much briefer. Additionally, the price of diesel had fallen dramatically, so the cost of the replacement electricity was not so breathtaking. The transmission line was repaired before further conservation measures could be put in place.

Conclusions

Juneau's 30% reduction in electricity consumption was the quickest and greatest that has occurred anywhere in the world in the absence of blackouts. A five-fold increase in electricity prices provided the stimulus but the savings were accomplished mostly through behavioral means. Adoption of energy-saving habits was clearly responsible for most of the savings simply because new, efficient technologies could not be installed soon enough. When compared to programs using economic and regulatory instruments, programs relying on changing consumers' behavior are relatively easy to establish, inexpensive, highly visible, and suitable for mass media. During an energy crisis, it is important to make it socially acceptable—indeed patriotic—to wear warmer clothes, switch off lights, and modify lifestyles in ways that people would resist under ordinary circumstances. However, if savings need to be sustained, then technical efficiency improvements must complement the new, energy-saving behavior.

Juneau's experience demonstrates the key role behavior plays in reducing energy use. Juneau's success hinged on quickly establishing a consistent, positive message. And, notably, a year later, Juneau has maintained roughly one-third of the reduction in electricity use that it achieved during the crisis, showing that at least some of the crisis-borne behavioral change is durable. Addressing longer energy shortages and tackling climate change may require different strategies, but the results from Juneau show that large energy savings are feasible given the right combination of conditions, incentives, and strategies.

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Acknowledgments

This work was supported by the U.S. Department of Energy. I am indebted to Wayne Leighty for the results of his survey and Scott Willis of AEL&P for the electricity consumption data.

Adding a Behavioral Dimension to Residential Construction and Retrofit Policies[1]

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Introduction

Much could be done to improve energy efficiency in both new and existing homes. Energy upgrades of new construction reduce baseline consumption over the buildings' lifetimes. Retrofits of older homes can deliver large near-term savings (McKinsey & Company 2007). In practice, however, much of this potential savings lies unrealized. These lost opportunities result from complex, non-technical barriers including industry fragmentation, high up-front costs, perverse incentives, incomplete and asymmetric information, and a workforce knowledge gap (Brown et al. 2008). In this chapter we explore three different policies that hold great promise to transform building practices in the United States for both new construction and the retrofit of existing residential dwellings.

The building industry is large, diverse, and fragmented with numerous players whose interests often do not align. Besides builders, decision-makers influencing the industry include investors, owners, occupants, tradesmen, architects, equipment manufacturers, suppliers, lenders, insurers, codes and standards setters, zoning officials, realtors, etc. A similar gamut of stakeholders, notably building occupants, is involved in decisions on existing home improvements. The lack of concert among them stymies the quest for efficient buildings (Alliance to Save Energy 2005; Loper et al. 2005).

The speculative builder-buyer and landlord-tenant relationships are classic examples of misplaced incentives, AKA the principal-agent problem (CCCSTI 2009; Brown, Laitner et al. 2009; Murtishaw and Sathaye 2006). In the case of new buildings, developers seek to limit construction costs, but disregard operating costs, since their financial interests end with the building's sale. Similarly, landlords have little or no incentive to invest in energy efficiency when tenants are responsible for paying utility bills.

Information barriers occur when consumers lack the knowledge necessary to make "rational" decisions. Information deficiencies may be compounded by a lack of publicly available, reliable, credible, and/or understandable facts about the cost and energy savings of alternative technologies and practices. Information may also not be specific enough to be useful. For example, monthly electric bills provide no information on the cost of operating individual appliances.

[1] This chapter covers part of a report sponsored by the Climate Change Technology Program (led by the U.S. Department of Energy) under the project leadership of Dr. Robert Marlay and Lindsay Roland, who contributed significantly to the project's design and execution. Valuable comments on earlier drafts of this chapter were provided by Roderick Jackson (Oak Ridge National Laboratory), David Holzman, and Charlotte Franchuk, which are greatly appreciated.

In addition, the degree to which consumers act on information depends on the type of decision and the type of consumer (Barr, Gilg, and Ford 2005). More experience with the actual result of a decision can improve future decisions. People tend to put greater weight on options grounded in the greatest personal experience—specifically options with which they have recent experience (Dawnay and Shah 2005).

Even when individuals have experience with making a particular decision, they may not have experience with the outcomes. Providing feedback can improve decision making by connecting decisions with outcomes. This is particularly apparent in energy and water consumption when we consider the once-monthly bill that summarizes thousands of individual decisions made over the course of weeks and long since forgotten by the time the bill arrives. Personalized information has been shown to be more effective than general information—while we "know" that some actions and goods are more efficient than others, we may not use the information if it doesn't describe our particular characteristics or meet our economic or environmental concerns (Benders et al. 2006). These differences suggest that consumer education efforts should take into account the general perspectives of the target population.

In the buildings industry, there is also a workforce knowledge gap. Few builders or tradespeople have access to sufficient training in new technologies, new standards, new regulations, and best practices. Lowe and Oreszczyn (2008) describe this lack of knowledge as a remnant of the traditional, low-tech construction industry. That legacy is incompatible with the industry's current need to become a producer of human capital in order to support a new generation of residential buildings. Local government authorities tend to face this difficulty as well with building code officials working without skills necessary to evaluate compliance with building energy codes.

These market barriers leave residential buildings far less energy efficient than they otherwise might be. But the barriers are behavioral, not technological. Policymakers are seeking policies to encourage changes in that behavior, both within the buildings industry and among home owners. This chapter builds on a behavioral research literature review and the results of the "Buildings Workshop on Behavioral Research and Energy Use" that was held in February 2008 in Washington, DC. Following the Workshop, a team of researchers evaluated alternative policy options available to the federal government, resulting in a report *Making Homes Part of the Climate Solution* (Brown, Chandler et al. 2009).

In the following case studies, we use seven criteria to evaluate the strengths and weaknesses of three proposed policies. (See the companion chapter by Brown, Chandler, and Lapsa for a definition of each evaluation criterion in the context of three proposed federal policies that involve partnerships with utilities.) We selected these three policies because of their favorable performance on these criteria.

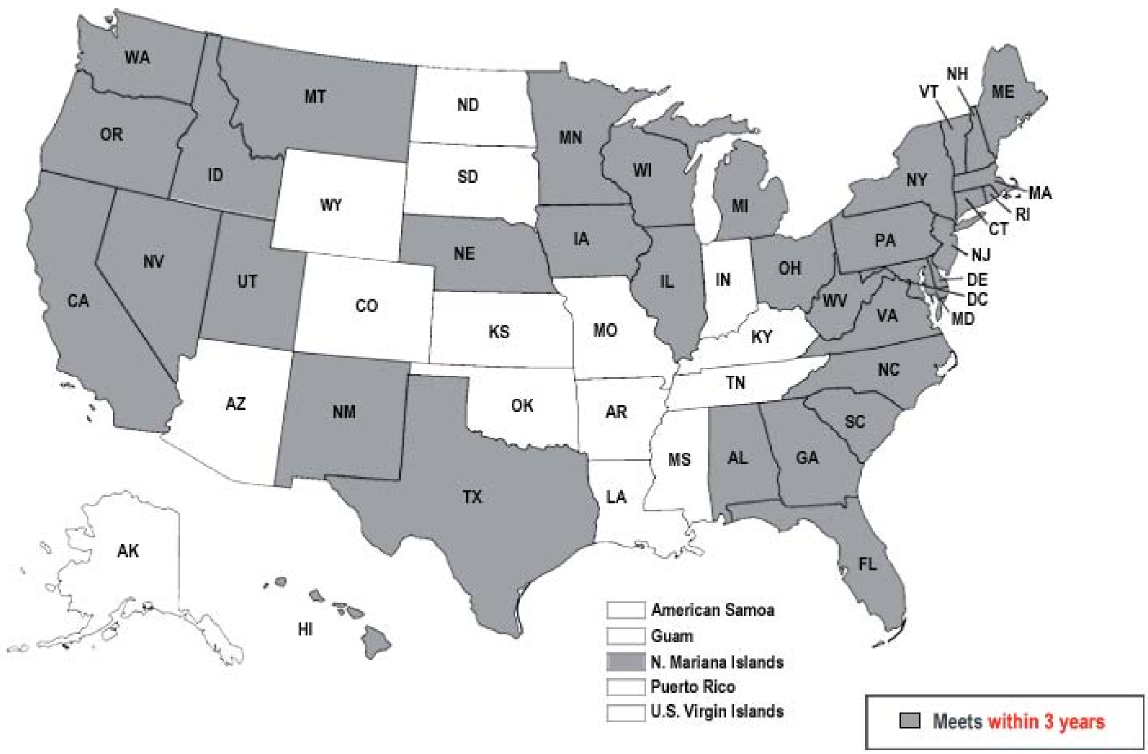
Case Study 1: Advancing and Enforcing State Building Energy Codes

We propose a two-pronged federal approach. First, technical assistance should be provided to states to accelerate their adoption of advanced building energy codes. Uniform adoption and enforcement of codes would reduce market risks, ensuring that no one builder takes on all the first-of-a-kind costs while others reap the benefits. Over time, improved building construction practices can reduce technical risks as builders and users learn by doing. Second, the federal government should provide technical and financial assistance to establish and expand training and certification programs focused on third-party verification of building energy code compliance. Strong compliance enforcement can prevent building owners who seek to reduce their costs from evading strict building energy code guidelines. This is particularly important when the owner or builder does not bear the building's future energy costs. Federal technical and financial assistance could support development of a cadre of third-party verification auditors and inspectors to work with local officials charged with building permitting.

Policy Rationale and Experience

As of June 2010, only 35 states and the District of Columbia had enacted legislation to adopt within three years the 2009 residential International Energy Conservation Code (IECC). Some states still have residential energy codes that predate the 1998 IECC.[2] As Figure 1 shows, most of the states along the eastern and western seaboard have modern codes, while clusters of Mountain, Upper Midwestern, and Southeastern States have outdated codes.

Figure 1: Status of Residential State Energy Codes as of June 2010



Source: DOE EERE Building Energy Codes Program:
http://www.energycodes.gov/states/maps/states_meet3yrs_res.stm

[2] The Energy Code that applies to most residential building is the IECC, which supersedes the Model Energy Code. The 2000 IECC is the most recent version for which DOE has issued a positive determination. The Federal Energy Conservation and Production ACT (ECPA) was amended in 1992 to require states to review and adopt the MEC (and its successor, the IECC), or submit to the Secretary of Energy its reasons for not doing so.

In addition to have outdated codes, many states attempt to enforce complex performance-based codes using a limited number of code compliance staff (Smith and McCullough 2001). The resulting inadequate enforcement substantiates the need for third-party verification. A 2007 survey found an estimated compliance rate of 80% for commercial energy codes among those respondents who provided an estimate. But most inspectors either did not know the compliance rate or were unwilling to respond (Zing Communications 2007).

Policy Evaluation

Appropriateness of the federal role. The federal government uses a network supported by the Building Codes Assistance Project (BCAP) to train code officials, liaisons, liaisons, construction professionals, and third-party verifiers. Training and providing assistance to state and local jurisdictions has precedence. Recently, the U.S. Congress has shown some evidence of motivation to aid enforcement of building codes, when it inserted the "Community Building Code Administration Grant Act (CBCAG)" into the Green Act (HR 2336) after two years of deliberation, and passed the Act in April 2010. If passed by the Senate, enacted, and funded, this act would authorize a grant program through the U.S. Department of Housing and Urban Development (HUD) to provide competitive matching funds grants to local jurisdictions to improve their building code administration and enforcement capabilities.[3]

Broad applicability. Building energy codes prescribe minimum efficiency standards for new construction. Energy codes can improve construction practices in virtually all types of buildings. Codes and code assistance programs can be flexible enough to meet the specific conditions of each climate zone and can help local and state planners to achieve their development and sustainability goals while reducing energy costs and mitigating greenhouse gas emissions.

Significant potential benefits. The 2009 edition of the IECC—currently the national model energy code of choice for states, cities and counties—is expected to boost energy efficiency approximately 15% compared to the 2006 edition, according to BCAP.[4] Lucas (2006) estimated that West Virginia's adoption of the 2003 IECC (unamended) in place of the 2003 International Residential Code (IRC) resulted in annual residential energy savings of 16-17%.

If every state adopted the most recent commercial and residential model energy codes, and improved compliance levels, and if all states applied model energy codes to manufactured housing, the United States would reduce energy use by about 0.85 quads annually (Brown, Laitner et al. 2009). Upgrading residential building codes could save an average of about $650 million in homeowner energy bills over a 30 year period, according to an estimate by Prindle et al. (2003).

Solutions not dependent on future R&D. Building energy codes do not depend upon future R&D. Nonetheless, because materials, technologies, and practices will improve, most analysts assume that codes will be strengthened regularly to reflect such advances. Indeed, building codes and R&D are complementary, as has been well-documented in the case of the household refrigerator, where advances in motor, compressor, and insulation technologies occurred

[3] http://www.iccsafe.org/gr/Pages/code-grant.aspx
[4] http://www.iccsafe.org/news/nr/2009/0128_2009IECC.pdf

simultaneously with the promulgation of successively more stringent state and federal energy standards for the manufacture of new refrigerators (National Academies 2001). By making more efficient building designs and products the norm, efficiency standards can assure markets for innovative technologies. Updating building codes as building technologies and designs evolve can help expand knowledge and maintain a pipeline of new and improved technologies.

Cost effectiveness. The costs of residential code compliance can be estimated based on a modeled "standard home" in various climate zones. This analysis (detailed in Brown, Laitner et al. 2009) shows how energy bills may shrink from 2010 to 2030 as residential codes improve over time while costs stay about even, as generally expected. These calculations assume that public costs include training, but not verification costs; private costs include incremental construction costs estimated at $1,000 per home and $0.30 per commercial square foot.

Administrative practicality. Up-to-date code programs and training curricula already exist, most notably the BCAP. Such programs provide an infrastructure for expanding efforts to advance state policies. The only new administrative effort needed would be enabling third-party verification at the state level. Federal assistance will help these governmental bodies and industry-based auditors and inspectors accomplish their goals.

Additionality. Policies that provide improved information to building occupants or home buyers could drive demand for further improvements. Utility programs could also provide complementary and supportive assistance. In fact, utilities in several states offer incentives for builders to meet or exceed model energy codes in residential and commercial construction. Utility residential construction programs have achieved near 100% compliance in California, Oregon, and Washington, while residences built outside of the utility program fell short of compliance with the then-current state code by at least 6% (Vine 1996). An example of such a program is that of Pacific Gas and Electric. The utility provides an incentive of $400 or $500 to builders per ENERGY STAR® home and additional incentives for outfitting these homes with energy-efficient appliances (PG&E 2008).

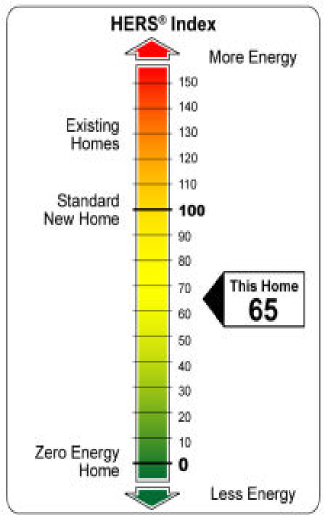
Case Study 2: Expanded Use of Home Energy Performance Ratings

The federal government should provide technical and financial assistance to states to develop policies that incorporate home energy performance ratings, and that ensure a qualified home energy performance rating workforce. As part of this effort, the federal government should develop a uniform home energy performance reporting method. These policies could be designed to verify building code compliance, to measure savings achieved by demand reduction efforts, and/or to help determine where the most need for improvement exists within the existing stock. States might need to take additional action, such as certifying companies that meet their criteria for training home energy performance raters, and developing a method of collecting and storing home energy performance ratings for public use. In addition, the federal government should coordinate training of a home energy rating workforce that has a sufficient understanding of building science, by supporting "train the trainer" programs and curriculum development. Since significant non-governmental capacity already exists for training this workforce, it may be most cost-effective to work within this structure.

Policy Rationale and Experience

DOE already supports state efforts to create home energy rating systems, and the Environmental Protection Agency (EPA) contributes financial support to the Residential Energy Services Network (RESNET) and the National Home Energy Rating Systems Council.[5] Together DOE and EPA have developed rating guidelines for a particular home energy performance rating system called the Home Energy Rating System (HERS).

Figure 1. The HERS Index



The HERS Index is a scoring system established by RESNET in which a net zero energy home (NZEH) scores a HERS Index of zero; a home built to the specifications of the HERS Reference Home (based on the 2006 International Energy Conservation Code)[6] scores a HERS Index of 100, and homes that fail to meet that standard score greater than 100. HERS was originally developed by the mortgage and real estate industries as a way to account for energy efficiency in calculating a home buyer's ability to pay the mortgage. The Housing and Community Development Act and the Veteran's Home Loan Amendment Act both required pilot testing of Energy Efficient Mortgages, which rely on standardized home energy ratings to provide confidence among lending institutions that provide favorable financing for energy-efficient homes. In 1999, the National Association of State Energy Officials adopted guidelines for home energy ratings, which helped to launch the creation of HERS.[7]

Most recently, DOE has announced plans to establish a National Building Performance and Rating Program.[8] Designers of the Program aspire to create a home energy rating system that will:

[5] RESNET is a network of mortgage lenders, utilities, housing, and residential energy efficiency professionals
[6] International Energy Conservation Code® (2006) at http://www.iccsafe.org/e/prodshow.html?prodid=3800S06,
[7] HERS history from http://www.natresnet.org/ratings/overview/resources/primer/HP02.htm.
[8] http://www1.eere.energy.gov/buildings/news_detail.html?news_id=16083

" * Reflect a uniform metric allowing comparisons
* Be generated by trained 3rd parties
* Be neutral to number of occupants or occupant behavior
* Have a sufficient level of accuracy at a reasonable cost" (Glickman 2010)

Development and adoption of state and local policies using performance ratings has been mixed. While more than half the states have home energy performance rating systems, many are inactive, unproductive, or in startup. California, Colorado, Florida, Indiana, Utah, Vermont, and Virginia have active home energy performance rating systems. These states have multiple nonprofit organizations serving as rating certifiers and coordinators for a network of professional raters and contractors. Federal efforts to expand existing state programs unite these organizations, in order to capitalize on decades of experience, rather than funding only one organization. An example of how to use the existing experience can be found in California's Home Energy Rating Systems program where the California Energy Commission approves providers to oversee home energy performance raters.[9]

Federal action could increase use of home energy performance ratings, develop a common home energy performance reporting method, and coordinate workforce training. A standard rating system would provide a strong foundation for boosting efficiency. Home buyers and renters would now have numbers that they could use to comparison-shop houses and apartments the way car buyers compare MPG ratings. That, in turn, might stimulate competition among developers to build homes with greater efficiency. Furthermore, if home energy performance ratings were standard practice for compliance with energy codes, builders complying with energy codes would face lower market risks.

States and localities would benefit from making every effort to ensure that raters are familiar with the specific conditions of their climate, and consider the type and use of dwellings when rating. Nonetheless, the ability to adapt to new technologies and practices as they become available must be built into both the rating systems and workforce training programs.

Policy Evaluation

Appropriateness of the federal role. Providing guidance, training, funding, and model legislation to states is already part of the federal role in environmental and energy policy. Existing channels, including existing federal programs, could be used to help states develop policies that incorporate home energy performance ratings.

Broad applicability. Home energy performance ratings are applicable to all of the more than 112 million housing units in the United States.[10] The way that home energy performance ratings are used in policies will affect their applicability. Each dwelling should be rated as soon as it is constructed, but before it is occupied, and again following any renovation. Ratings should not be affected by behavioral characteristics of residents, even though these will undoubtedly influence the home's performance. While energy performance ratings are not yet cost-effective, this will change as these costs decrease, while energy prices escalate.

[9] http://www.cheers.org/default.htm
[10] There are more than 127 million housing units, but about 12% are vacant (U.S. Bureau of the Census 2006; 2007; 2008).

Significant potential benefits. In addition to providing the means for home buyers to comparison-shop, and potentially stimulating competition for efficiency among home builders, home energy performance ratings can support many other policies that promote energy-efficient buildings. For example, under the Federal Housing Administration, buyers of rated homes can qualify for Energy-Improvement Mortgages if a home's performance is poor, or Energy-Efficient Mortgages if a home's performance is exemplary. Both of these financing options are currently underused. There are also numerous benefits of combining the use of Home Energy Rating Systems with Energy-Efficient Mortgages.[11] Home energy performance ratings would likely increase awareness of the homes' energy expense, much like EPA fuel efficiency stickers did for cars. Increased awareness, along with recommendations for improvement, as provided with an energy performance rating, can help consumers make cost-effective investments that improve home energy efficiency. Attaining scores of 100 could be a goal of energy efficiency retrofit programs. As shown in Figure 1, typical scores are approximately 130, while a standard new home would score 100.

Using a conservative set of assumptions about the capacity to conduct ratings over the next few years, we estimate that retrofitting 100,000 homes annually, or 0.1% of existing homes, to attain scores of at least 100 would boost savings each year by the equivalent of 13,400 million cubic feet of natural gas (Brown et al. 2009). If 100,000 homes (or about 0.1% of existing homes) are retrofitted each year to meet a score of at least 100 (from an assumed score of 120, this would represent a 20% decrease in energy consumption for those homes), annual incremental energy savings could be up to 230 GWh or 13,400 million cubic feet of natural gas.[12]

Solutions not dependent on future R&D. The current barrier to widespread home performance ratings is a lack of skilled raters, both for new construction and existing buildings. "In discussions with interviewees, it became apparent that energy auditing was not a primary profession for many certified energy auditors but an ancillary qualification." (MEEA 2006 p. 20). Nonprofit organizations have established a niche of training and certifying home energy performance raters; these organizations have more experience in states where pilot programs funded their development.

Cost effectiveness. Experience to date suggests that rating costs should range from $300-$700 per house. Saving 20% of electricity costs could pay back the lower rating cost in one year; reduced natural gas consumption could pay back the higher cost within five years. In general, a home energy performance rating will seem very cost-effective when making expensive retrofits, but it may negate savings for less costly improvements, such as programmable thermostats or upgraded lighting fixtures.

Administrative practicality. This federal action to support home energy rating systems requires additional funding for existing training programs, and development of a common system of reporting. But both of these goals would be easy to accomplish. At the state and local level,

[11] http://yosemite.epa.gov/OAR/globalwarming.nsf/UniqueKeyLookup/SHSU5BUK22/$File/energyandthehome.pdf

[12] This assumed savings is intentionally conservative—except with regard to the number of houses. 100,000 homes nationwide represents about 2,000 per state. There are not sufficient raters in some states to cover enough homes to achieve this number of homes that follow the rating with energy-improving retrofits. Energy savings presented are based on saving 2,300 kWh or 13.4 thousand cubic feet per home based on average home energy use from 2005 Residential Energy Consumption Survey (RECS) Table US8. Average consumption by fuels used http://www.eia.doe.gov/emeu/recs/recs2005/c&e/detailed_tables2005c&e.html.

ordinances may need to be amended to allow home energy performance ratings to qualify for certain state and local building permits or programs. In addition, states that lack rating systems may need to legislate them. The likelihood of such policy actions is not great, based on state and local actions to date.

Additionality. Because a rating system is an enabling policy, it will be difficult to determine exactly how much energy it will save. Nonetheless, ratings are a proven method for motivating energy-saving retrofits. The following policy shows how rating systems can be an integral component of regulatory programs.

Case Study 3: Mandated Disclosure of Energy Performance Information

Federal legislation should require that information regarding the energy consumption or energy performance for a home be disclosed at the time the home is listed for sale. States may need to modify existing disclosure laws to match this new federal requirement. Common reporting methods should be established concurrently to ensure that potential buyers have access to the information when considering the purchase or lease of a home (Stern 2005). Experience in Denmark shows that program effectiveness is a function of monitoring, verification, and evaluation. In older homes where efficiency upgrades will provide the most savings per dollar, audits should be more comprehensive (Ea Energianalyse 2008). In newer homes, comprehensive and relatively expensive audits may not drive investment sufficient to recover costs in the near term.

The success of disclosure will depend upon how well the public understands the energy performance data. A case study in California demonstrated that consumer understanding of the meaning and usefulness of home energy performance data was a necessary prerequisite in most cases for consumer interest in home energy performance (Robert Mowris and Associates 2004). Simple reporting methods as well as public information or education campaigns can boost understanding. Consumers should be educated not only about the specific rating scheme, if one is created, but also on the norms of home energy consumption, the benefits of greater efficiency, and the cost of retrofits.

Policy Experience

Policies that would require disclosure are in place or under consideration in several jurisdictions both in the United States and abroad. Generally, policies require disclosure of either or both of the following: energy use history and energy performance rating. The disclosure must be certified at the point of sale or lease, although in practice it is generally revealed much earlier during the sale or rental transaction.

Montgomery County, MD, requires sellers to provide prospective buyers with a guidebook to energy-efficient retrofits and 12 months of energy use history, if available (Montgomery County 2008).[13] Austin, TX, requires that an energy audit be performed prior to the sale of a home. The municipal utility also offers a voluntary program for implementing cost-effective upgrades prior

[13] Bill 31-07, Real Property—Energy Performance Audits; http://www.montgomerycountymd.gov/content/council/pdf/bill/2008/20080804_31-07.pdf

to the sale. The voluntary upgrade program is run by Austin Energy with a spending cap of 1% of the home's value. Eligible energy upgrades must produce enough energy savings to pay back the retrofit investment within seven years.[14]

Denmark began requiring energy performance disclosures on new and existing residential and commercial buildings in 1997.[15] The Danish scheme includes a rating, a plan for savings, and direct consumption information; ratings are required annually for large buildings and upon construction or sale for small buildings (Laustsen and Lorenzen 2003).[16] Due at least partly to these measures, the cost of heating Denmark's homes dropped by 20% from 1997 to 2005. (Miguez et al. 2006).

Policy Rationale

Mandating disclosure of energy performance information by homeowners could help address perverse incentives in the existing housing market, such as the misplaced incentives caused by the landlord-tenant relationship, as described earlier in this chapter. In the rental market, knowledge of a dwelling's efficiency could motivate investments in energy efficiency by owners because prospective renters would be given estimates of the utility bills that they would be paying either directly (for renters who pay the utility bills) or indirectly (where landlords recoup their utility costs through adjustment to the rents they charge).

Consumer decisions to boost their energy efficiency are based on many factors including rising energy costs, the ability to estimate a short-term return on investment, sufficient income or financing options, and credible information on cost-effective improvements (Russell 2006). Mandated disclosure will provide reliable information and should make identification of return on investment simpler.

Mandates could also address the dearth of information on energy performance, and the absolute absence of uniform disclosure among the 400-plus separate real estate multiple listing services (MSL) that operate nationwide. For example, MLS's in just two states, Alaska and Washington, have fields for energy efficiency ratings; two others, Colorado and Wyoming, have a field for energy consumption history; while a third, Utah, has a field for yearly consumption zeniths and nadirs (Combs 2008). But across these states, the fields made available for energy performance documentation typically go unused for varying reasons: some laws and guidelines have declared the information to be private; there is a high potential for mistakes in entries; and real estate agents are generally non-supportive (Combs 2008). One regional MLS, for Portland, OR, has made additional searchable fields available on their MSL forms to record certifications such as ENERGY STAR, and products, such as solar tubes (Hawkins and Shepherd 2008). Other MLS's

[14] These goals were established by the task force and formally adopted by the Austin City Council as Resolution No. 20081106-048 (http://www.cityofaustin.org/edims/document.cfm?id=123402).

[15] *Act to Promote Energy and Water Savings in Buildings No. 485 of 12 June 1996.* Denmark. http://soeg.ekn.dk/Afgorelser/L_585_Act_to_promote_energy_savings.pdf

[16] The example energy rating is available (in Dutch) at http://ens.dk/graphics/Energibesparelser/Ny_energimaerkningsordning_og_ny_kedelordning_PDF_filer/Eksempel_Enfamilieshus.pdf; no similar one-page label to the one published by Miguez et al. (2006) was found on the Danish Energy Agency Web site.

may follow suit, but for realtors and consumers, the patchwork of variable information can be confusing.

A variety of hurdles must be overcome in order to standardize disclosure. MLS organizations and realtors will need to agree that the form of disclosure is not unnecessarily burdensome, in order to proceed. The U.S. Green Building Council (USGBC) and the National Association of Home Builders are competing to get their standards adopted nationally, and the situation is further confused by the existence of more than 80 state and local green building councils, many of which are proposing their own standards (Alsever 2007). Various private stakeholders that currently rate home energy performance will undoubtedly push their own pet requirements, for their unique benefit. And utilities will no doubt weigh in, with their own interests foremost.

Policy Evaluation

Appropriateness of the federal role. The lack of energy consumption data at the time of sale or lease of a home is a classic market failure. As a result, federal action to require disclosure of home energy consumption or home energy performance at the point of sale or lease is appropriate. In fact, the federal Office of Management and Budget (OMB) suggests that policies or measures explicitly designed to alleviate asymmetric information should be given preference over other measures, as a general rule-of-thumb (OMB Circular A-4).[17] While real estate transactions are generally regulated by local government, federal action to require or aid local governments to adopt such measures could still be warranted. To this end, the federal government should also develop a model rule, in order to save promulgation time and associated costs (Kaplow 1992), and to standardize reporting requirements among jurisdictions, thus alleviating confusion that might result from a patchwork of different requirements.

The federal government has experience in this area. It already promotes green leases in its own transactions. Through DOE and EPA, it also provides extensive information on energy-efficient practices. It could easily provide information such as a Green Lease Toolkit, within current initiatives. Its efforts, currently focused on commercial space, could easily be adapted for use in the residential sector.

Broad applicability.[18] Roughly one-quarter of the housing stock turns over every five years. Thus, despite wide variation in individual unit turnover rates, a sustained disclosure program will reach most housing units within 20 years.

Significant potential benefits. This policy addresses key information barriers:[19] it internalizes the now-externalized cost of energy performance in homes; and it provides for development of a uniform performance assessment system preventing greenwashing. For the home buyer, or

[17] "A regulatory measure to improve the availability of information, particularly about the concealed characteristics of products, provides consumers a greater choice than a mandatory product standard or ban" (Circular A-4 p.9). http://www.whitehouse.gov/sites/default/files/omb/assets/omb/circulars/a004/a-4.pdf

[18] The potential for savings in the rental market is less clear (leasees still have no incentive to improve their leasor's property); therefore, savings estimates from green leases are not included here. However, renters could demand more efficient properties and drive investments by owners.

[19] Freeman and Kolstad (2006) argue for seller to buyer disclosure in reference to industrial sites; while they are concerned with environmental contamination rather than energy consumption, the point is the same.

renter, it places efficiency on a par with designer kitchens; with the disclosure of energy performance, the home buyer knows whether or not the property has state-of-the-art energy efficiency just as it can be seen if the house has a granite or a painted counter top (Alsever 2007). Favorable energy performance ratings increase home values to the buyer and the seller (Faiers, Cook, and Neame 2007).

Our assessment of benefits assumes that energy-related retrofits to an estimated two million homes per year—less than the 46% offered by Robert Mowris and Associates (2004), to be conservative—could achieve savings of approximately 29 million Btu. Over 10 years this could save 0.5 quadrillion Btu—about 0.5% of U.S. energy consumption. Presumably, as technologies improve, houses reentering the market will undergo additional retrofits, resulting in increasing energy savings over each home's lifetime.

Solutions not dependent on future R&D. Mandated disclosure could be implemented immediately. No new technologies are necessary. Energy performance rating systems already exist, as do audit and inspection protocols.

Cost effectiveness. Cost-effectiveness will depend upon both the program's final form, and on future energy prices. The least costly measure is to require provision of consumption history, and utilities can probably provide this history more cost-effectively than consumers. The most costly option would be a requirement for a detailed home energy performance assessment at time of sale. Seattle's Green Building Task Force verified that an audit or a performance rating, while administratively feasible, would be more expensive than reporting consumption (GBTF 2008). A performance assessment by checklist would cost less than by audit. Unless disclosure is through energy consumption history, costs will likely outweigh benefits for the first few years.

One benefit unrelated to energy savings is that mandatory rating will quickly boost employment, as it will require a large rating workforce.

Administrative practicability. The administrative burden of disclosing home energy performance information is anticipated to be low, although experience, especially nationally, is lacking. A reporting burden will be created for those listing properties for sale or rent, and a monitoring and verification burden will fall on the agency charged with ensuring disclosure. Common reporting requirements and an informed public could help identify inadequacies in the information disclosed.

Additionality. Numerous related policies effectively address residential building energy efficiency, and could capture a portion of the energy savings that a mandatory disclosure policy would enable. Such policies include utility-operated demand-side management programs and on-bill financing of energy efficiency, decoupling of utility profits from energy sales, appliance and equipment standards, expansion of low-income weatherization, tax credits or refunds for efficient major purchases, consumer information campaigns on benefits of efficiency, and training programs for remodeling and repair professionals. To estimate the additionality of disclosure programs would require an assessment of the full portfolio of residential energy efficiency programs operating simultaneously across communities and states.

Conclusions

Using a uniform set of policy evaluation criteria, this chapter presents three promising policy options that target residential energy efficiency in new construction and existing homes. Table 1 shows the relative strengths and weaknesses of each policy along with the anticipated time necessary to generate the policy benefits. Updated building codes would take longer to generate significant savings as they address new construction, which represents only about 2% of the nation's housing stock in any single year. Similarly, the effects of mandated disclosure requires new legislation and affects homes only at time of sale, therefore requiring significant time to generate savings. Expanding home energy performance ratings would probably have a more immediate impact, depending on how the ratings are used in concert with other policies.

Table 1. Summary Assessment of Policy Options

	Strengths	Weaknesses	Time Horizon*
Advancing and Enforcing State Building Energy Codes	Significant Potential Benefits, Cost-Effectiveness, Additionality	Administrative Practicability, Stricter Codes Require Improved Technologies	Medium to Long
Expanded Use of Home Energy Performance Ratings	Broad Applicability, Potential Benefits, Cost-Effectiveness	None	Short to Long (depends on policy using them)
Mandated Disclosure of Energy Performance Information	Appropriateness of the Federal Role, Broad Applicability, Technology Is Commercially Available Today, Cost-Effectiveness	Administrative Practicability, Additionality	Medium to Long

*Time horizons when significant energy savings begin: short (five years or less), medium (five to 10 years), and long (more than 10 years).

Both improved codes and mandatory disclosure are expected to have issues with "administrative practicability." The anticipated issue with building codes is creation of a third-party compliance system, while new legislation is required for mandating the disclosure of energy performance information.

Mandated disclosure of energy performance information is judged to be weak in terms of additionality because the gap it fills could also be addressed to some extent by other policies that increase the perceived value of efficiency.

Advancement of building energy codes faces the need for ongoing technology R&D. It is likely that stronger future codes will require new and improved technologies. While the benefits of other policies typically would be enhanced by the availability of improved technologies, their cost-effectiveness is favorable based on current best-practice technologies.

The three energy efficiency policies described in this chapter hold great promise to transform building practices in the United States. By investing in policies that address known barriers to energy efficiency, policymakers and program implementers have the capacity to enable significant change. Table 2 highlights some of the high-potential social science research that could further help inform the design and implementation of the policies discussed here.

Table 2. Illustrative Social Science Research to Support Residential Energy Policy Design and Implementation

#1: Advancing and Enforcing State Building Energy Codes

- How can homeowners be made aware of residential building code features so that they can exert "demand pull" to ensure effective construction practices?
- How can homebuilders and inspectors become better informed about the mechanics and importance of building code compliance?
- What is the best way to train the workforce of building code enforcement officials?

#2: Expanded Use of Home Energy Performance Ratings

- In what units should ratings be presented (abstract scales like the 1-100 HERS, energy units, dollars)?
- What rating information would be most credible and influential to each of the potential user groups (home buyers, home renters, rental property owners, architects, builders, mortgage lenders, real estate agents, etc.)?
- Should ratings take into account variations in building use due to household size, life cycle, behavioral differences, etc.? If so, how?

#3: Mandated Disclosure of Energy Performance Information

- How, when, and by what media should information disclosure be mandated?
- What specific information should be disclosed?
- If peer pressure is as highly influential as research suggests, how can the disclosed information be packaged to provide homebuyers and sellers with useful comparative information?

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Towards a Policy of Progressive Efficiency

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An Overview of Energy Efficiency and Energy Consumption

Energy Efficiency Is Not Enough

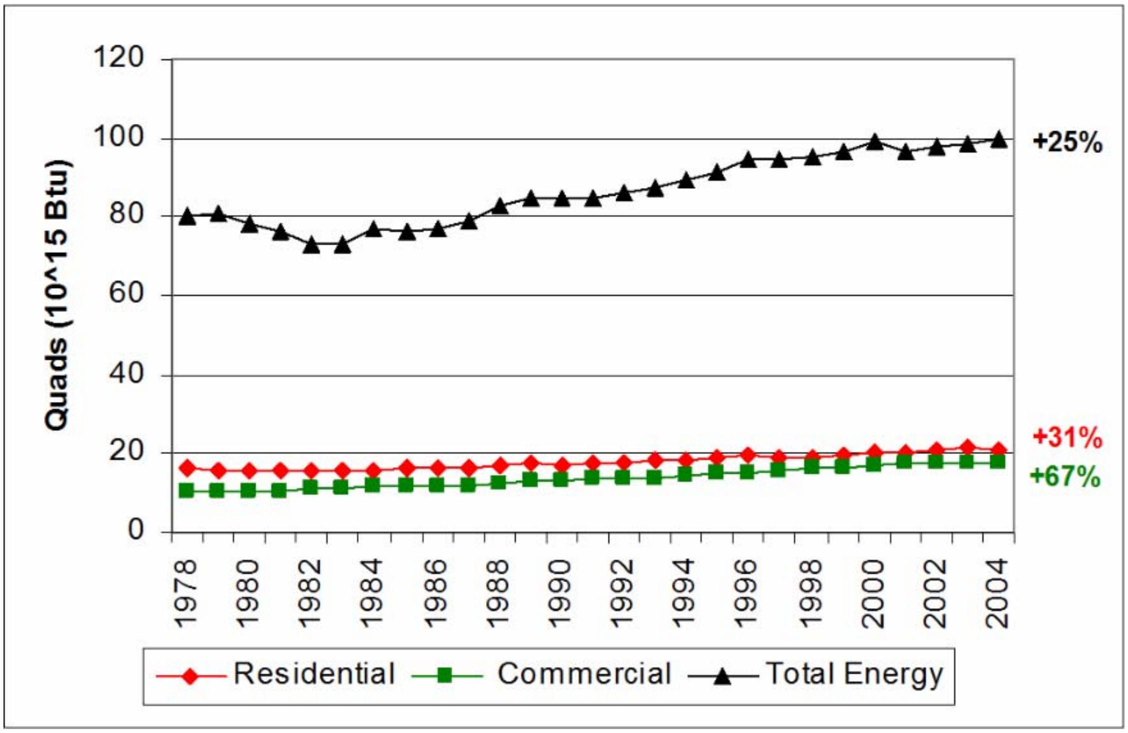
For the past quarter century, the energy efficiency community has focused on energy efficiency and productivity (more services per unit of energy) and has sharply distinguished its goals from conserving, that is, from consuming fewer energy consuming services. A few voices have challenged this approach, arguing that energy consumption does matter and that energy efficiency is not the only way to reduce energy use (Moezzi 1998; Rudin 2000; Wilhite et al. 2000; Wilhite and Norgard 2004; Moezzi and Diamond 2005; Siderius 2004). Meanwhile, headlines about climate change, peak oil, event-triggered fuel or electricity shortages and price spikes, and water and air pollution all send the message that absolute energy consumption, and not just energy efficiency, does matter. These realities call into question our unconstrained appetite for energy services and our future ability to afford them.

Despite notable gains in the energy efficiency of building envelopes; lighting; heating, ventilating and air conditioning (HVAC); and plug loads, total primary energy use has increased over 30% in U.S. residential buildings since 1978 and more than 65% in commercial buildings (Figure 1). The growth in buildings sector energy has been significantly faster than for all U.S. energy (25%). Of course, there are many ways to explain (i.e., disaggregate) this growth in energy use in the U.S.: growth in building floor space, population shifts to the south along with increasing penetration of central air conditioning, growing saturation of appliances and miscellaneous loads (especially consumer and office electronics with their continuous standby energy), and consumers' desire and ability to pay for thermal comfort and conditioned fresh air. But, the fact remains that growth in energy consumption, though forecast to continue indefinitely, cannot be sustained indefinitely.

An energy policy that seeks to mitigate climate change, avoid pollution, and/or reduce oil dependency must measure its success in terms of lower fossil fuel energy consumption—or at least slower growth in consumption. At present, there is ambiguity about the main thrust of energy-saving policies at both national and state levels. In some cases the focus remains strictly on efficiency without regard to consumption; in others, consumption-management (conservation) is creeping in, especially where the policy drivers include oil dependence, electric grid capacity and reliability, climate change, air pollution, or water consumption for cooling power plants.

And in many cases, policy-makers seem confused, or deliberately vague, about efficiency *versus* conservation, perhaps in the hope that efficiency improvements will be powerful enough to reduce absolute energy use and carbon—without any constraint on consumers or consumption.

Figure 1. Primary Energy Use in U.S. Buildings, 1978–2004



Source: EIA 2004a

Some observers have suggested that energy efficiency itself can lead to increased consumption, by lowering the cost of energy services (Binswinger 2001, Howarth 1997, Birol and Keppler 2000). Others maintain that a pre-occupation with energy-saving hardware leads us to overlook non-hardware behavioral changes that may both improve the efficient operation of buildings and equipment, and in some cases, reduce the demand for energy services (Herring 2006). The purpose of this chapter is not to further debate the so-called snapback effect of efficiency on energy consumption (wherein greater efficiency results in greater consumption of energy services) nor the merits of technology *versus* behavior change. Nor do we anticipate or advocate an imminent mass movement toward voluntary simplicity—welcome though that might be to help ease any number of environmental problems.

Rather than discard energy efficiency, we seek to enhance it by (re-) introducing energy *conservation* as a legitimate and desirable policy goal, and by drawing attention to trends in energy consumption as well as energy efficiency. Framing policy goals in terms of energy consumption or greenhouse gas emissions rather than energy efficiency can help us decide how much efficiency is needed, and how much additional conserving may be required to manage energy consumption and emissions in the face of unsaturated markets, growing population, growing disposable incomes, and the consequent increase in consumer needs and desires.

The Concept of Progressive Efficiency

We recognize that it may be impractical today to propose a quantum leap from a policy of pursuing all economically justified energy efficiency to a broader policy framework based on a sustainable energy balance, i.e., a concept where energy consumption equals sustainable energy production. Instead, this chapter outlines some initial steps toward the goal of managing total energy consumption, with efficiency as a means towards that goal. The central idea, which we term “progressive efficiency,” is that the level of energy efficiency, rather than remain constant, should increase as the scale of energy use or energy service increases, e.g., with larger appliances, homes, or vehicles. This concept is also known as “variable” efficiency (Meier 2000). In some cases, physics alone would dictate increased efficiency with increased scale: surface-to-volume ratios suggest that a larger building envelope, larger refrigerator, or larger water heater tank should have proportionately lower thermal losses or gains. In practice, though, efficiency criteria for large units are sometimes less stringent instead of equally or more stringent (Calwell 2010). The four sketches in Figure 2 illustrate schematically the current approach to energy efficiency (Cases 1 and 2) and our alternative formulation of progressive efficiency (Case 3). At the limit (Case 4), this concept of progressive efficiency becomes a criterion of “sufficiency” (Princen 2005, Darby 2007). In practice, Cases 3 and 4 can both approach a sufficiency limit and cease to increase; progressive efficiency curves tend to do so more gradually and smoothly than linear specifications that reach that limit abruptly (Calwell 2010).

Case 1 shows energy efficiency remaining constant with increased scale of energy or service consumption; energy use is a linear function of size. When policy-makers want to improve energy efficiency, they tend to change the slope of that line (and perhaps the intercept) while keeping the linear relationship (Case 2). A real-world example is shown in Figure 3, below, for U.S. refrigerator efficiency standards adopted in 1993 (upper dashed lines) and then tightened significantly in 2001 (lower solid lines).

Case 3 shows our alternative formulation, with efficiency (i.e., the slope of the line) as a curve that varies with scale. Under this variable (“progressive”) efficiency criterion we would expect (or require) a higher level of efficiency for a larger home or appliance. This still allows energy consumption to increase with unit size, but at an ever-slower rate.

Case 4 shows a further variant: above a certain size, for a very large home or appliance to be considered “efficient,” it would have to offset *all* of its upsizing with improved energy performance, thus keeping energy consumption below a defined maximum level of consumption. Of course, it is far from obvious where to set such a maximum level, at least absent the concept of a sustainable energy balance as discussed above.

Figure 2. Efficiency Varying with Scale

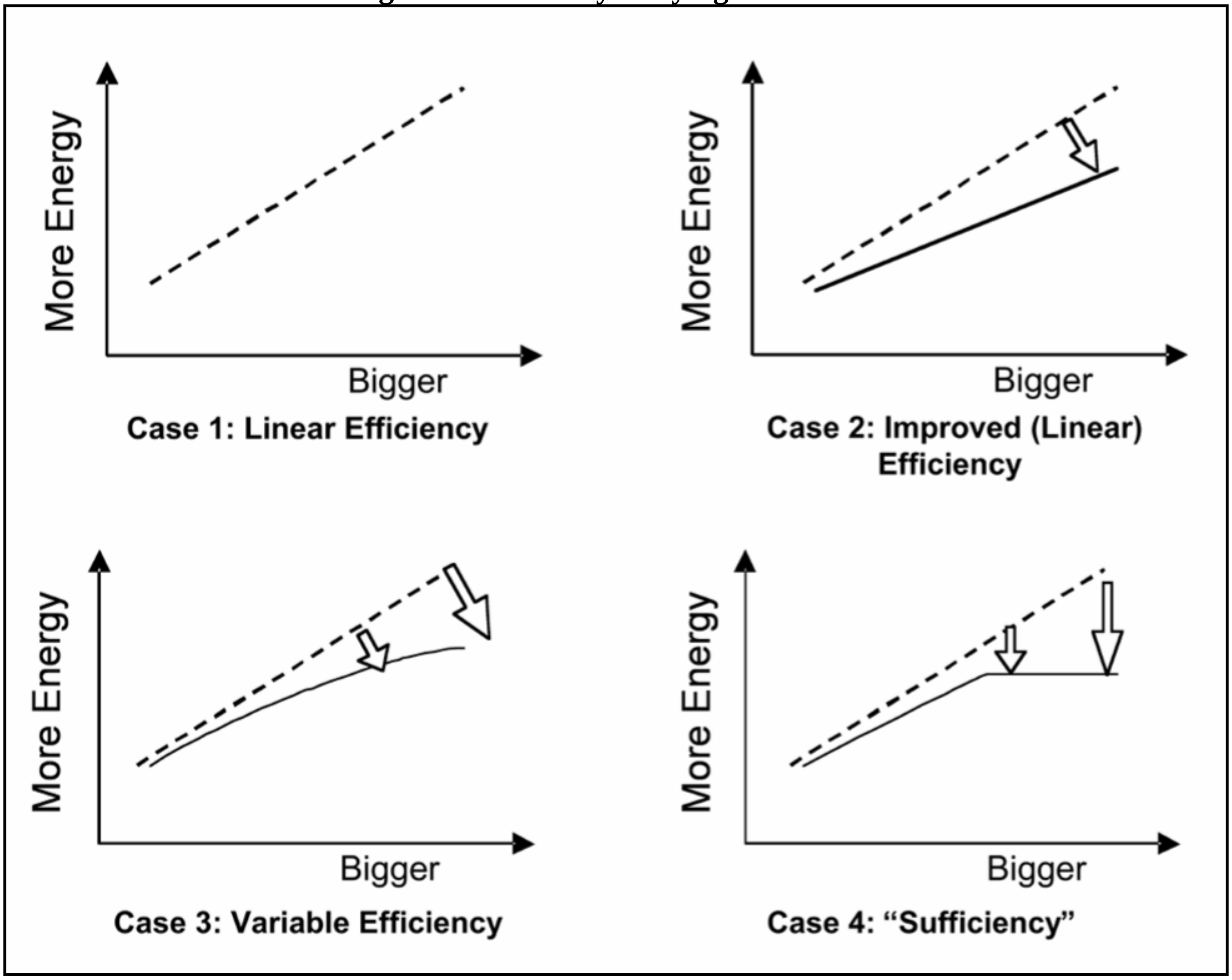
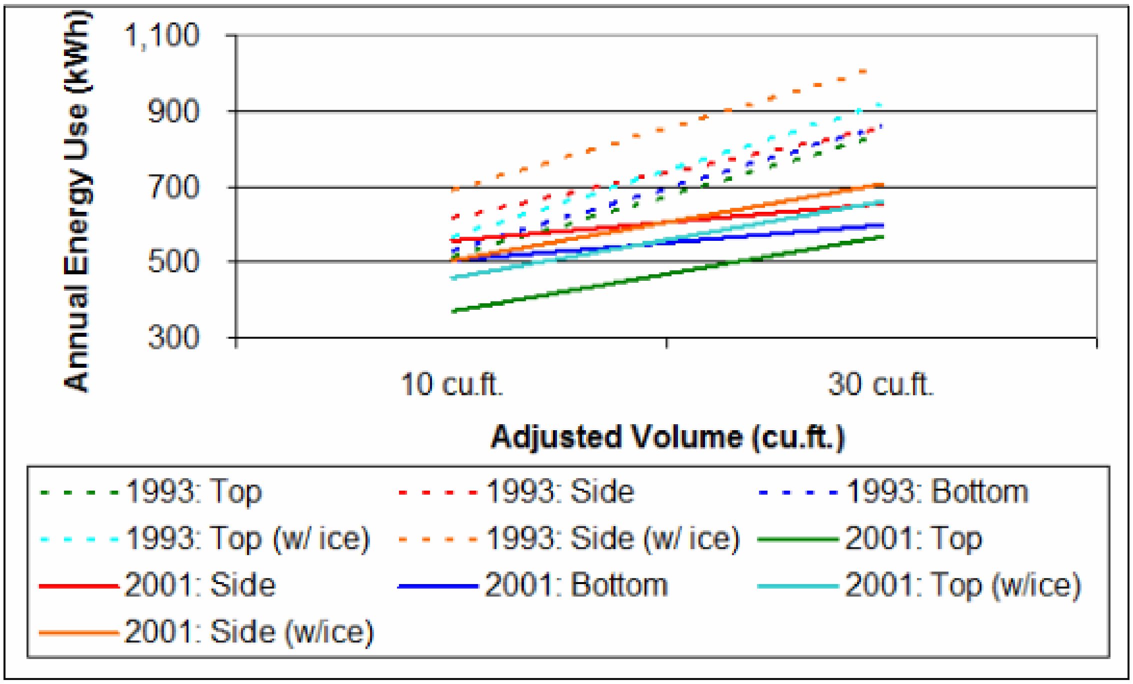


Figure 3. Linear Efficiency for Refrigerators



Source: U.S. Code of Federal Regulations (2002)

Illustrating the Concept through Examples

In this section we explore some practical steps toward a policy of progressive efficiency, beginning with voluntary information and incentive programs and potentially also including mandatory standards. We offer three short illustrations of how to incorporate energy consumption along with energy efficiency: first in the choice of energy indicators, next in setting criteria for rating energy-efficient homes, and finally in the definition of categories for appliance labels (and perhaps standards) that might discourage rather than reward upsizing—or at least to help consumers make more explicit trade-offs. For these programs and others, the practice of considering energy consumption along with energy efficiency can also help energy experts, policy-makers, and the public begin to acknowledge a world of finite resources and atmospheric limits, and begin to frame policy choices and public debate in terms of how best to achieve a sustainable energy balance—moving beyond assumptions of indefinite growth toward some vision of sustainable sufficiency.

What You Measure Is What You Get

The debate between energy efficiency and energy conservation can be framed in terms of intensive versus extensive variables.[1] Extensive variables are scale-dependent; intensive variables are not. For example, the size of the economy, as measured by gross domestic product (GDP), is an extensive variable; the energy *intensity* of the economy, measured by energy use per unit of GDP, is an intensive variable. For purposes of our present discussion, energy

[1] The phrases "intensive variable" and "extensive variable" are more commonly used in the physical sciences than in the social sciences. For example, many thermodynamics texts discuss the distinction in an introductory chapter.

conservation and energy consumption are extensive variables; energy efficiency is an intensive variable.

For years, energy efficiency advocates have taken pains to distinguish efficiency from conservation, asserting that efficiency means providing the same service with less energy (e.g., using a more efficient furnace) while conservation means using less of a service (warming the air only to 18 or 20°C rather than 22°C). The politics of increasing efficiency has generally been preferred—especially in the U.S.—to the politics of advocating energy conservation. Objectives are then defined in terms of intensive variables: miles/gallon, energy per square meter of floor space, electricity per ton of steel, or MJ of energy per dollar of GDP.

Previous U.S. goals for greenhouse gas mitigation were framed in terms of an intensive variable: tons of CO_2 per dollar of GDP (White House 2002). But it is the extensive variables—carbon emissions, fossil fuel consumption, or oil imports—that should be the ultimate policy objectives. Indeed, the ultimate policy objective is to bring *atmospheric concentrations* of greenhouse gases down to a point that minimizes the impact of climate change, which explains why 350.org and other organizations have focused their efforts there. Recent U.S. goals have recognized this distinction, and in Executive Order 13514 (October 2009), President Obama issued absolute greenhouse gas (GHG) reduction goals for the federal government by 2020 of 28% for Scope 1 and 2 emissions, and 13% for scope 3 (indirect), all compared with a 2008 base. Thus, the policy goal is shifting from reducing greenhouse gas emissions per dollar GDP to absolute reductions of CO_2 in the atmosphere.

There is no *a priori* reason to prefer efficiency over conservation as the means to reduce energy consumption or slow its growth; the two could be combined in any proportion. Only by shifting the focus of energy policy and public debate from efficiency (intensive) to consumption (extensive) can we determine what gains are needed in energy efficiency to achieve our aspirations for economic well-being (per capita GDP) for energy services (housing, health care, leisure activities, travel), and for climate change mitigation, air quality improvement, and reduced oil dependency.

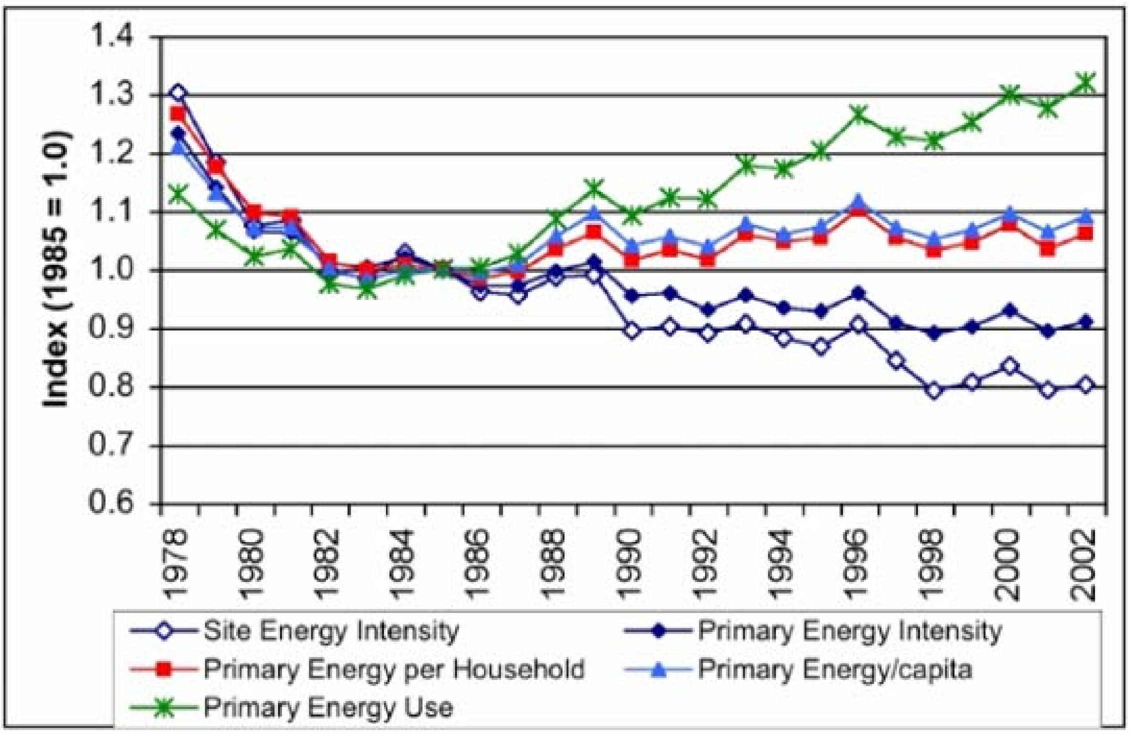
Analysts may reach different conclusions about the effectiveness of energy policies when they choose to focus on intensive rather than extensive indicators. Consider some of the trends in U.S. residential buildings, as shown in Figure 4 (and indexed to 1985). The indicator cited most often, site (delivered) energy intensity (energy per unit of floor space), declined 20% since 1985 following an even sharper drop from 1978 to 1985 (open diamonds in the figure). However, in primary energy units (including electricity system losses), energy intensity declined only half as fast, or 10% from 1985 to 2002 (solid diamonds).

However, we use energy in homes to provide shelter and amenity services to people, not for the benefit of “floor space.” Introducing “households” and occupants to the equation tells yet a different story. Average household size in the U.S. has been shrinking: down 3% from 1978 to 1985 then down another 6% from 1985 to 2002. At the same time, the physical size of houses grew 17% from 1985 to 2002, and this was a stock average; the average size of new homes has grown even faster. The net effect has been an *increase*, rather than a decrease, in per household energy use from 1985 to 2002 (up 6%, squares in the figure) and in energy use per occupant (up

9%, triangles). After factoring in the 21% population growth from 1985 to 2002, our final (extensive) indicator, total residential primary energy, increased 32% from 1985 to 2002 after an initial decline from 1978 to 1985 (crosses).

So, what do the data tell us—over this period did we gain ground by 20% based on the reduction in site energy per square foot? Or fall behind by 32% based on the increase in total primary energy? Or something in between? The answer depends on the specific indicator chosen, and even more fundamentally, whether we are thinking in terms of energy consumption or energy efficiency.

Figure 4. Indices of U.S. Residential Energy

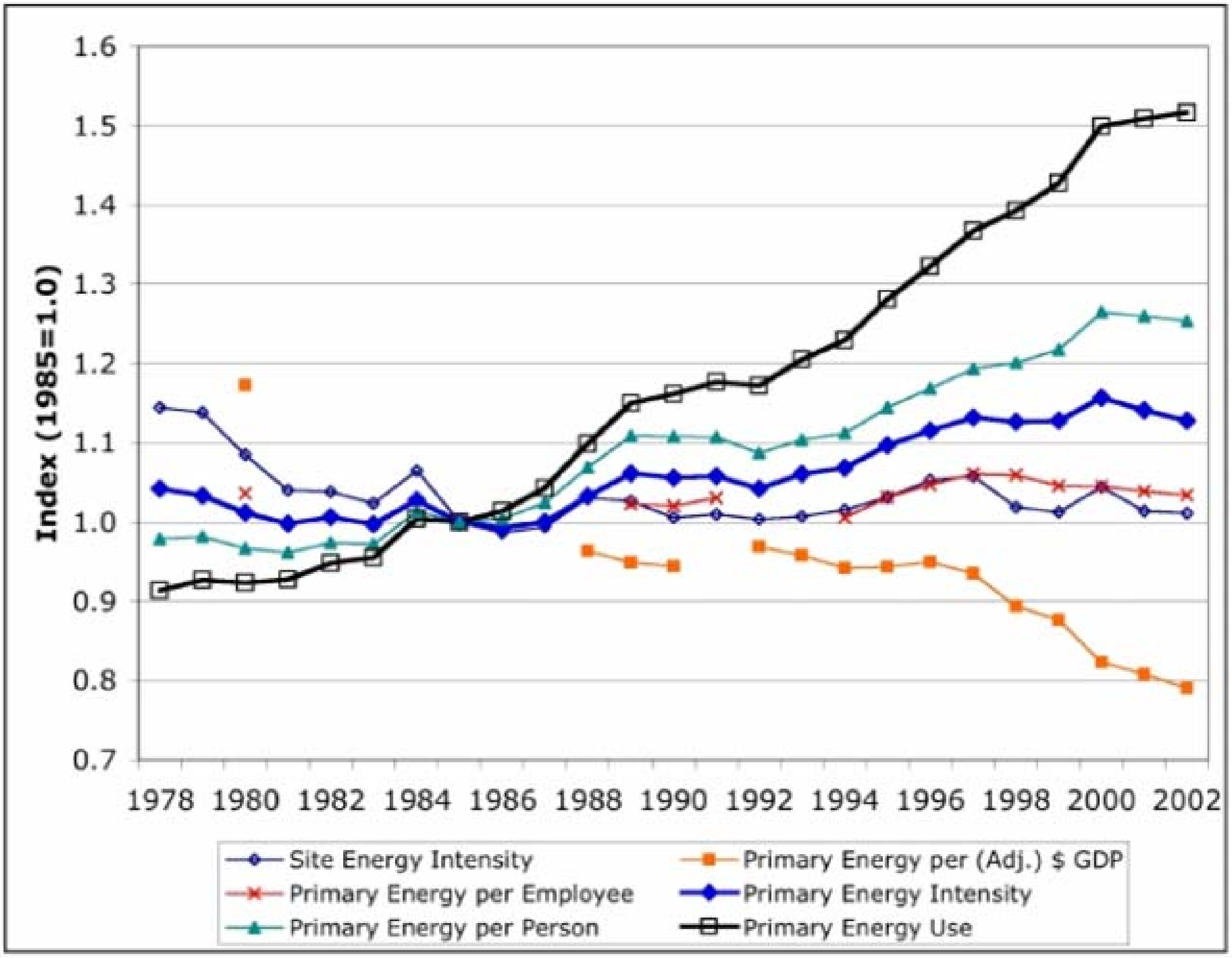


Source: PNNL (2005)

Figure 5 shows a similar series of indicators for site and primary energy use in U.S. commercial buildings. Once again, the most common indicator is site (delivered) energy intensity (energy/per unit of floor space), which actually declined about 12% from 1978 to 1985 then stayed roughly constant for the next 17 years (open diamonds in the figure). In contrast, primary energy intensity grew by 13% over the same 17-year period (solid diamonds). And on a per capita basis, commercial sector primary energy use per person first increased slightly from 1978-85 then more rapidly: up 25% from 1985 to 2002 (triangles).

From one perspective it makes sense to normalize commercial energy use by the total population ultimately served by the commercial activity in offices, retail shops, health care and educational buildings, and hotels and restaurants. Another viewpoint emphasizes the "energy productivity" of commercial buildings, arguing that we are finding more efficient ways to use commercial buildings to increase GDP and to provide workspaces. The next two indicators in Figure 6 show primary energy use per employee (crosses) and primary energy per dollar of "adjusted" GDP (solid squares).[2] Commercial sector energy per dollar of GDP declined dramatically, by more than 20% from 1985 to 2002, while energy per employee remained roughly constant. After factoring in the growth in both GDP and commercial floor space, total primary energy use in commercial buildings—our extensive indicator—first increased about 10% from 1978-1985 and then shot up by more than 50% in the next 17 years (open squares).

Figure 5. Indices of U.S. Commercial Buildings Energy



Source: PNNL (2005), US DOC (1992-2006)

From these simple examples we conclude that both policy targets and tracking of progress are most meaningful when they consider multiple indicators, reflecting both energy consumption (extensive) and energy efficiency (intensive). While normalizing energy use may add useful

[2] Figure 5 shows GDP in constant (2002) dollars. The data exclude GDP and employment related to manufacturing, construction, mining, and agriculture. Energy use per employee is obviously a more meaningful metric for some types of commercial buildings (offices, and perhaps retail and schools) than for warehouse or public assembly buildings with intermittent or highly varying occupancy, but a breakdown by building type was beyond the scope of this paper. Finally, a comparison of 1992 and 2003 CBECS data shows that floorspace per worker has declined in most types of commercial buildings, averaging -7% for the sector as a whole, so the roughly constant trend in primary energy per employee is even more noteworthy.

information, the variable chosen for the denominator will significantly influence the result. If the ultimate value of using energy is to provide services to people then energy consumption per person should always be one of the metrics we consider, along with intensive indicators of energy per unit of floor area, dollar of GDP, ton of industrial output, etc.

Homes or Castles?

In recent years, numerous articles and news stories in the popular press have highlighted, and often decried, the growth in average size of new U.S. homes. Increasing house size is a major factor driving growth in total residential energy and in energy per household or per capita. A second factor is the growing saturation of major appliances (more than 100% in some cases); convenience appliances; home electronics; and amenities like pools, spas, and home saunas/steam rooms. Among these trends, let us consider home upsizing in more detail.

Figure 6 shows that in 1950, the average floor area for a new house in the U.S. was 93 m^2 (1,000 ft^2). By the year 2000, the average floor area for new homes had more than doubled to 204 m^2 (2,200 ft^2) (Diamond and Moezzi 2004). Recent years have shown continued growth, with this value increasing to 234 m^2 (2,519 ft^2) in 2008 (U.S. Census 2009). Combined with fewer people per household, this growth in house size resulted in a three-fold increase in average floor area per capita, from 27 to 77 m^2 (286 to 847 ft^2) per person over those five decades.

In theory, bigger houses with lower surface-to-volume ratios should be more efficient in enclosing space and thus reducing heat loss and gain. In practice, though, larger houses in the U.S. tend to be *less* efficient per unit of floor area than smaller houses, for a number of reasons. Today's large houses often have complex perimeters (more bay windows, dormers, and other features) that add to surface area and often complicate construction detailing for insulation and air-sealing. Consequently, regardless of the code-prescribed insulation levels and air barriers, these new homes in reality may be less efficient in terms of actual envelope thermal performance, compared with a smaller, simpler design. Larger homes also tend to have longer runs of air ducts and domestic hot water pipes, with corresponding increases in distribution losses for both HVAC and domestic hot water (DHW) systems; this loss of system efficiency is directly related to scale. Bigger houses also have more room for energy-using appliances, entertainment, and convenience devices. Finally, the higher ceilings and two-story entries and other dramatic spaces in today's new homes also increase the volume of space to be heated and cooled.[3]

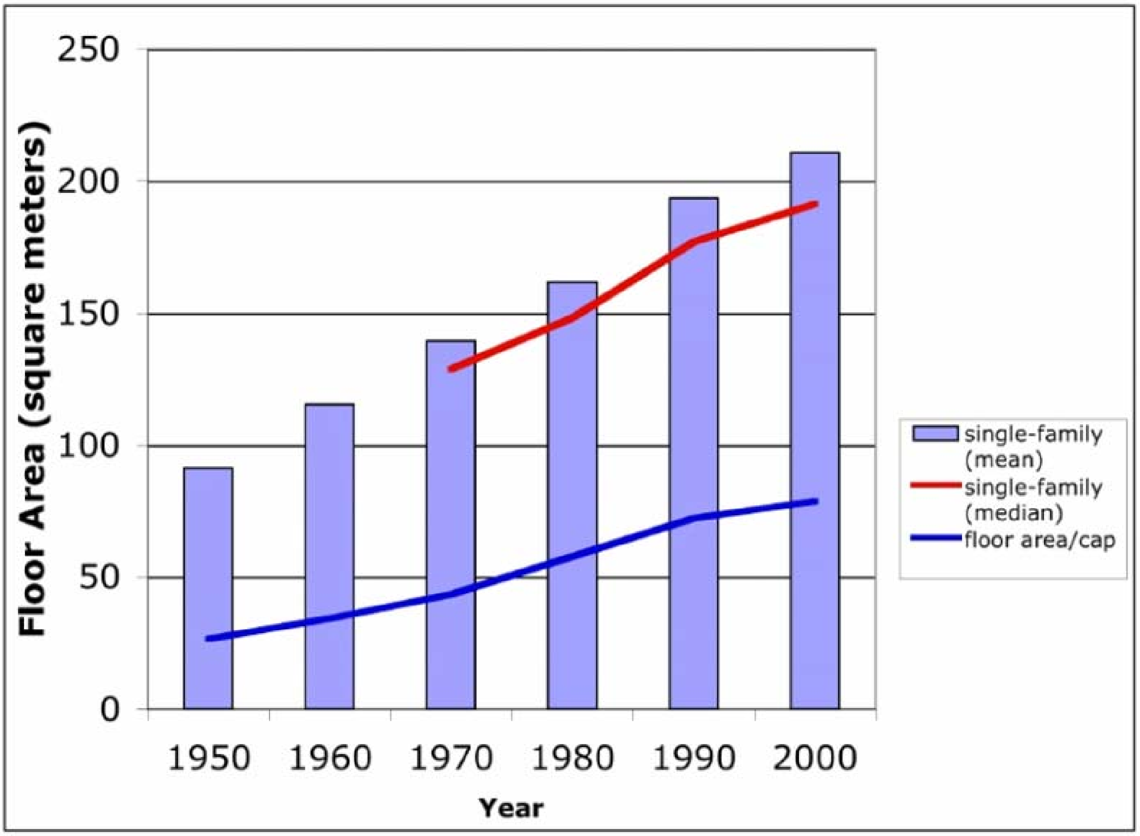
Faced with a goal of managing energy consumption towards a sustainable energy balance, we clearly need specific policies to counteract these tendencies for large houses to use more energy per unit of floor space, not less.

Perhaps we first need to better understand some of the reasons why U.S. house size is increasing. Part of the answer may be simply that U.S. cultural norms assume that bigger is better. But in the

[3] Even though stratification could theoretically be used in high-ceiling spaces as a strategy to reduce summer cooling requirements (while increasing them in winter), the overhead placement of air supply ducts and occupant ignorance about proper use of ceiling fans for summer comfort cooling *versus* winter de-stratification tend to make high ceilings a net energy penalty rather than an advantage, even in cooling-dominated climates.

case of housing, there may be other forces at work as well: easy mortgage loans with favorable tax treatment, zoning and real estate practices, and the pre-2008 expectation of continued increases in property value that encouraged households to invest in housing rather than other assets. The high rate of turnover in single-family homes also contributes to a preference for larger houses, as expected resale value becomes more important in deciding the number of bedrooms and bathrooms than the actual needs (or even the desires) of the current residents. Mortgage lenders may discourage modest size homes by requiring the value of the house to be three times the value of the land. According to Art Castle, Executive Vice President of the Home Builders Association of Kitsap County, Washington: "If you put a house outside of these perimeters, you create a market aberration… A lot of lenders are unwilling to support smaller houses" (California Energy Circuit 2004).

Figure 6. U.S. House Size (Floor Area) Mean and Median 1950–2000



A study by Prahl (2000) suggests that the Home Energy Rating System (HERS) used by ENERGY STAR Homes and a number of utility-sponsored programs in effect require smaller houses to have higher levels of energy efficiency in order to achieve the same HERS score as a larger house. With water heating efficiency held constant, the study found that a typical 143 m^2 (1,537 ft^2) home in Pittsburgh, Pennsylvania would need to install a furnace rated at 96% efficient furnace to achieve a HERS score of 86, whereas a 517 m^2 (5,564 ft^2) house would require only an 80% efficient furnace.[4]

Building a bigger house to be energy efficient will save more energy than building a smaller house at the same level of efficiency—but the larger house will still use more energy. And since smaller houses tend to be designed for the lower end of the market and sited on less expensive lots, the added energy efficiency investment becomes a larger proportion of their total purchase price. A progressive efficiency policy would call for larger homes to be not only equal in efficiency to their smaller counterparts, but to deliver proportionately more efficiency and energy savings.

Some green building rating programs have started to incorporate efficiency requirements based on house size. Like many green building programs, the Portland [Oregon] Gas and Electric certification program, Earth Advantage, combines required measures and additional points that are earned for a home's green features. In 2003, Earth Advantage created four advanced certification levels, two of which include added requirements based on house size. For example, to meet the requirements for an Earth Advantage "Gold" rating, a 232 m^2 (2,500 ft^2) home needs to earn 50 more points for environmental responsibility or resource efficiency than a 186 m^2 (1,999 ft^2) home (Baker 2004).

The Vermont Builds Greener (VBG) program, started in 2003 and often considered to be the most comprehensive program in the country, takes this idea one step further. To earn VBG certification, a home must meet 54 separate requirements and also earn at least 100 points. Under this system, the easiest way to qualify after meeting the minimum requirements is to build a very small house. For example, a two-bedroom house earns 100 points if it has a floor area of 93 m^2 (1,000 ft^2), but only 25 points with a floor area of 139 m^2 (1,500 ft^2). Moreover, a four-bedroom house at 483 m^2 (5,200 ft^2) starts with a negative (-)100 points, meaning that other features will have to earn 200 points—twice as many—for VBG certification (Baker 2004).

The new Leadership in Energy and Environmental Design (LEED) rating for homes was introduced in 2007 by the U.S. Green Building Council (USGBC), after an extended trial period. The LEED credit for Home Size is designed to "promote the construction of homes that are smaller than the national average." Houses are penalized if they are larger than the national average for their category, based on the number of bedrooms, and get up to 10 points (out of 108 possible points) if they are smaller than average. As an example, the national average floor space for a new three-bedroom house is 176 m^2 (1,900 ft^2). A house that is 269 m^2 (2,900 ft^2) or larger would lose 10 points under the LEED rating, while a house under 84 m^2 (900 ft^2) would gain 10 points. Between these two extremes, a proportional number of points are added or subtracted. Realizing that the consumption of both materials and energy increases with house size, the

[4] There are a number of degrees of freedom to achieve a given HERS score. But when other parameters were varied, all pointed to lower efficiency requirements in the larger house.

USGBC doubled the original maximum of 5 points associated with home size (USGBC 2005, p.75).

LEED may need to give greater weight to home size in the future if it wants to minimize the overall environmental impact of homes. *Atlantic* reports that the highest scoring home ever in the LEED program is a 519 m^2 (5,600 ft^2) home that will be completed in Silicon Valley in November at a cost of more than $5 million (Green 2010). The magazine refers to it as "the world's greenest home," praising its 100 solar panels and their ability to meet the home's electricity needs as well as "charge five electric cars." This home may be LEED platinum certified, but the sheer number of resources consumed to build and maintain a home of this magnitude makes it an unappealing example to emulate globally.

Just as some home rating systems are beginning to recognize the issue of house size and total energy use ("ecological footprint"), a small but growing number of communities are adopting local policies to discourage home super-sizing. In Colorado, Pitkin County and the town of Aspen now charge new homeowners a fee if their homes exceed 464 m^2 (5,000 ft^2) and another fee up to $100,000 if they exceed the "energy budget" for their property based on the local building code. This Renewable Energy Mitigation Program (REMP) helps encourage new homeowners to offset their energy consumption with onsite renewables, while generating millions of dollars in fees that fund rebates for energy efficiency and renewable energy installations on the homes of other, less wealthy individuals (City of Aspen, Colorado 2002). In 2002, Marin County, north of San Francisco, California, adopted an ordinance requiring that new homes larger than 325 m^2 (3,500 ft^2) could not exceed the energy budget for a comparable 325 m^2 house unless they used renewable energy sources to do so (County of Marin 2002).

While these are promising developments, the country's largest energy efficiency program for new homes, ENERGY STAR for Homes,[5] still allows a house of any size to qualify for the ENERGY STAR label based on a HERS rating. ENERGY STAR has proposed a revised specification approach for 2011 (Version 3) that would begin to address this issue by requiring a lower HERS score, i.e., having a higher efficiency, for homes larger than a given "typical" size based on the number of bedrooms they have (US EPA 2010). This approach is intended not to penalize homes for including a larger number of bedrooms than average, but to size normalize to some extent for a given number of bedrooms. Such an approach should bring an element of progressivity to home efficiency labeling in the U.S., though it may also encourage builders to characterize as bedrooms many of the additional multi-purpose rooms they include in their large houses (Calwell 2010).

At least four major studies have now been conducted since 2002 in Wisconsin, New York, Arizona, and Nevada comparing the annual energy use of ENERGY STAR-labeled homes to non-labeled homes in the same locations. Most of the studies found that ENERGY STAR homes tend to use a similar amount of energy or more than non-ENERGY STAR homes, mostly because the labeled homes are, on average, larger. They are more efficient per square foot, but contain more square feet of living space. The Arizona study in particular indicated that electricity

[5] More than 1 million ENERGY STAR homes have been built in the U.S. since the program first began labeling homes in 1995. http://www.energystar.gov.

use averaged 12% higher in ENERGY STAR homes in the region.[6] The "green" aspects of ENERGY STAR homes are, on average, more attractive to affluent buyers and the builders that cater to them, which explains much of the increase in house size (Calwell 2010).

Categorical Illusions

U.S. appliance energy labeling offers further examples of how to combine energy consumption and energy efficiency considerations. In this section we discuss both the Federal Trade Commission (FTC) "EnergyGuide" comparison label and the ENERGY STAR endorsement label. Both programs are typically based on the same appliance energy test methods adopted by DOE, and both use the same set of categories to group models for purposes of comparison. The core of the problem lies in the narrow definition of product categories. This was perhaps appropriate for the original purpose (setting mandatory national appliance efficiency standards), but it begins to pose problems when applied to labeling. Narrow categories make it difficult or impossible for consumers to compare products that might be close substitutes but use very different amounts of energy. In other words, the use of narrow labeling categories leads consumers to consider (at best) efficiency rather than consumption.

Appliance energy testing, labeling, and standards were originally authorized in the 1975 Energy Policy and Conservation Act (42USC77, Sec. 6201) at a time of intense concern over oil imports, electricity supply, and sharply higher prices for all forms of energy. Thus the Congressional statement of purpose in that law clearly includes both energy efficiency *and* energy conservation (reduced consumption). The labels and standards were designed:

> "...to conserve energy supplies through energy *conservation* programs, and, where necessary, the regulation of certain energy uses [and] to provide for improved energy *efficiency* of motor vehicles, major appliances, and certain other consumer products..." [emphasis added]

While the efficiency of many consumer appliances has increased notably over the years, total appliance energy consumption has remained constant and in some cases has increased, due to growth in the number of appliances, their size and features, and the introduction of entirely new categories of appliances and new combinations. For example, not only do some refrigerator-freezers offer thru-the-door-ice, water, and other chilled beverages, but some models now feature door-mounted LCD displays.

As already noted, both the FTC EnergyGuide labels and the ENERGY STAR label currently compare energy *efficiency* within a narrowly-defined group of models with very similar size and features. As a result, the FTC labels may be shortchanging Congress's objective to help consumers make energy-*conserving* decisions, which would ideally involve a broader set of comparisons. In the case of refrigerator-freezer labels, for example, the narrowly defined product categories do not allow the consumer to readily compare models with similar (not identical)

[6] See Martin Holladay, "Raising the Bar for Energy Star Homes," posted at: http://www.greenbuildingadvisor.com/blogs/dept/musings/raising-bar-energy-star-homes, April 29, 2009.

levels of functionality but significantly different levels of energy use.[7] The effect of refrigerator size and freezer configuration on energy consumption remains largely invisible to all but the most attentive buyers.

This issue was highlighted in recent comments by the Consumers Union, as part of an FTC rulemaking on possible revisions to the EnergyGuide label:

> "Consumers trying to select a refrigerator based on energy efficiency must be able to compare across categories, instead of within the current very narrowly defined subclasses. ... The ratings of energy efficiency of refrigerators published in *Consumer Reports* allow consumers to directly compare refrigerators across types..." (Consumers Union 2006).

This issue is shown graphically in Figures 7a and 7b, which compare the range of rated energy use for 16 of the most common refrigerator-freezer categories used for the FTC comparison label (four capacity ranges and four freezer configurations). Figure 7a shows the large range of energy consumption, as a function of freezer location, among refrigerators that deliver roughly the same level of service (i.e., storage capacity). Close inspection of the data in Figure 7a reveals that—even within these narrow size categories, the *least* efficient (highest-energy use) top-freezer model often uses 10–15% *less* energy than the most "efficient" side-by-side model with the same capacity.

These same data, regrouped in Figure 7b, show that there is significant overlap in the range of energy use for refrigerator models with the same freezer configuration, but whose capacities differ by up to 40%. Note also that, for a given freezer configuration, neither the minimum levels of energy use nor the maximum levels are (with one exception) well correlated with capacity.

In other words, grouping refrigerator-freezer models for purposes of the EnergyGuide label first by size (capacity) and then by freezer type will completely mask many of the differences to which consumers should pay attention. In particular, the energy use implications of choosing a side-by-side model are simply not communicated. In fact, the current label may lead buyers to conclude that a ~700 L (25 ft^3) side-by-side model using 578 kWh/year is "efficient" in an absolute sense, even though it consumes 10-30% more energy than a top-freezer model of the same capacity. The net effect is that consumers can purchase an ENERGY STAR side-by-side model and think they are saving energy, even though the unit may use more energy than a non-ENERGY STAR labeled refrigerator of similar size with the freezer on the top or bottom. All this argues for broader categories for comparing models (or eliminating the categories altogether), making it easier for consumers to see the full range of energy use and operating costs associated with the models they are comparing.

In contrast, the EnergyGuide label for clothes washers was changed a few years ago to include within a single comparison group both the newer horizontal-axis models and the conventional vertical-axis models. Prior to that change, horizontal-axis washers were placed in a separate

[7] Refrigerator-freezers are first subdivided into styles based on defrost type, freezer location and door type, and then capacity within two-cubic-foot categories.

category for purposes of labeling, even though there was relatively little difference in energy use between the most efficient and least efficient horizontal-axis models—but large differences in both energy and water consumption between any horizontal-axis washer and any vertical-axis model. With this consolidation of the two categories, the FTC label now allows consumers to compare energy performance across the full range of clothes washer models. The current range of energy use is about 6:1, and even after normalizing for washer tub capacity, the energy consumption range is more than 5:1.

Figure 7a. Range of Refrigerator Energy Use by Capacity (Adjusted Volume in ft^3)

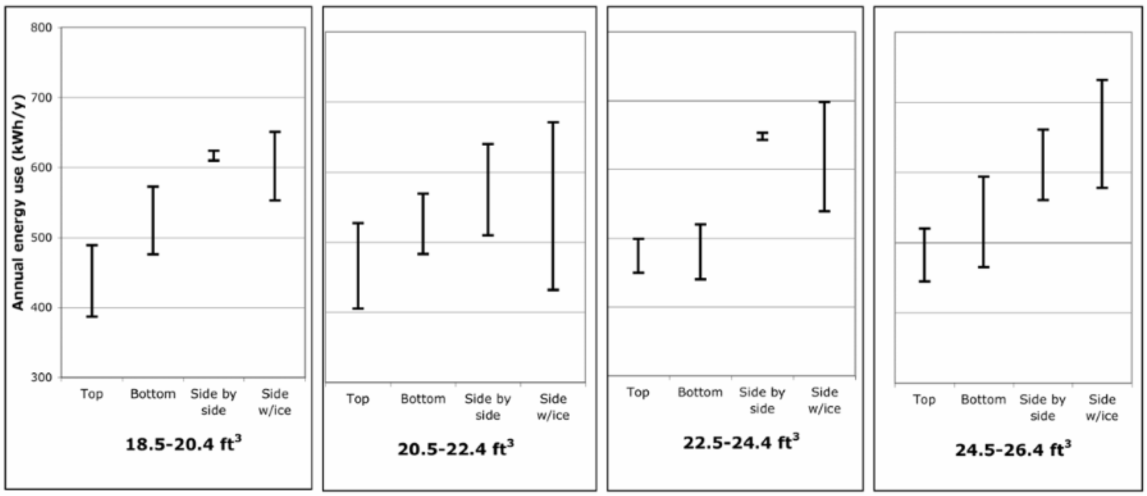
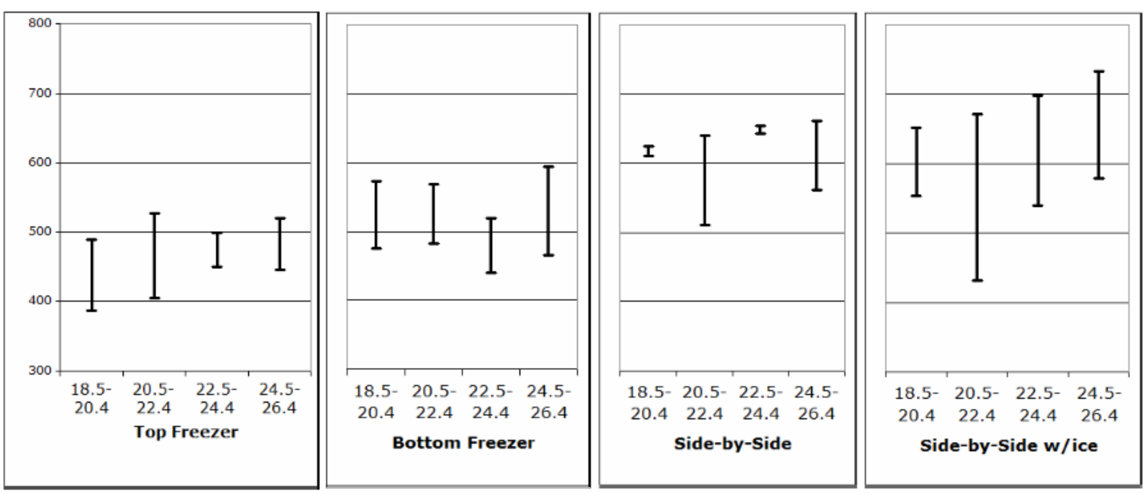


Figure 7b. Range of Refrigerator Energy Use by Freezer Location



Source: US FTC (2006)

EPA has already laid important groundwork for addressing refrigerators in a progressive fashion in the work it did developing the ENERGY STAR version 5.0 draft specification for televisions. Previous versions of the specification had proven not stringent enough to recognize only the top 25% of the market. Its efficiency metric for televisions established power consumption limits in active mode as a function of screen area. Version 3.0 consisted of linear specifications of different slopes joined together by step jumps at particular screen sizes. This had the effect of allowing one TV model that was twice the screen area of another to consume approximately twice as much power and still bear the efficiency label. As TV prices dropped, the market migrated rapidly toward larger screen sizes, undercutting a substantial share of the anticipated energy savings.

Version 4.0 (in effect since May 2010) addressed some of these problems, employing a flatter, more linear specification that nonetheless still allows substantial potential energy savings to be traded off for larger screen sizes. Now that it has become the basis for California's Title 20 requirements for televisions, it also seems likely to quickly be met by more than 25% of available models. Anticipating a rapid market response from manufacturers, EPA undertook the unique step of publishing its draft version 5.0 requirements at the same time it released version 4.0 requirements, to give manufacturers additional time to plan for, and anticipate, design changes needed to be compliant by mid-2012.

More dramatically, though, Version 5.0 for the first time establishes an upper bound, or sufficiency limit at 108 watts, beyond which power consumption may no longer increase, regardless of how much larger the screen size becomes. In effect, EPA determined that if the purpose of an ENERGY STAR label is to point consumers toward products that will reduce their energy consumption, it was important to send a signal that products with larger screen sizes than 50 inches would need to be progressively more efficient to ensure that their power consumption was no larger than that needed by a 50 inch model.

This seemingly small change is actually profound in its implications for climate change, recognizing that, at some point, the endless quest for ever-greater product size, capability and amenity does not trump the constraints of climate and the ultimate need to limit absolute energy consumption of individual products and the whole stock of energy-using products, if we wish to stabilize the climate. ENERGY STAR has opened the door to consider progressive specifications with other product categories. At the same time, the European Council for an Energy Efficient Economy (eceee) has conducted a workshop with stakeholders across Europe to consider ways of applying progressive efficiency specifications to buildings and various plug loads, first through voluntary labels (as the British government has already done with TVs), then with mandatory labeling criteria, and eventually with mandatory standards.

Toward a Policy of Progressive Efficiency

In the preceding pages we discussed the reasons why energy consumption, rather than energy efficiency, should be the main focus of energy policy in a resource-constrained and climate-limited world. We suggested that the concept of sustainable energy balance provides a framework for *both* energy efficiency and energy conservation. The choice is not between pursuing energy efficiency or advocating energy conservation; both have a role to play in managing energy consumption and its consequences. Energy efficiency is often the most attractive way to slow and possibly reverse growth in energy demand. And while energy conservation does not always involve sacrifice, in some cases it may. In that regard, energy consumption is similar to other important personal and societal goals that sometimes call for sacrifice: sending our children to college, caring for an aging parent, or countering terrorism. The question is how much sacrifice is avoidable, how much is necessary, and how much we are willing to accept. Slowing growth in energy consumption can mean real sacrifice for many in the developing world who still await access to electricity or clean water. But for most of us fortunate enough to live in the U.S. or other industrial countries, a great deal of conserving can result from only a modest shift in our aspirations. The question is whether we can learn to be satisfied with sufficiency rather than pursuing excess, in the form of oversized houses, cars, and fleets of household devices for our convenience and entertainment.

There are many difficulties—conceptual, practical, and ethical—in proposing a transition from unbounded consumption to comfortable sufficiency. Many will disagree on the necessity or merits of doing so. Rather than press the point in this chapter, we have proposed that the concept of progressive efficiency be built into energy policy and program design. We believe that progressive efficiency represents a useful and politically feasible first step to help us manage energy consumption in response to oil, climate, and grid constraints. Considerations of both thermodynamics and equity argue for energy efficiency requirements that vary with scale. Starting with information and endorsement programs like home energy rating and appliance energy labels, we can begin to educate both consumers and policymakers that in the case of energy use, “size matters.” Once the principle of progressive efficiency is embedded in voluntary information and incentive programs, policymakers and program sponsors can consider how to extend the concept to mandatory codes and standards. This is easier to envision for appliances, vehicles, and homes; it is admittedly more of a challenge to apply progressive efficiency in the case of offices, retail space, health care, or industrial processes.

We do not argue that progressive efficiency is, by itself, sufficient to meet the challenges at hand. Many other considerations affect the continued growth in consumer product energy use, including the rising population, the rising number of devices per person, the growth in hours of use, and other factors (Calwell 2010). We should be measuring our progress by the extent to which we have turned total energy consumption or greenhouse gas emissions downward for the overall stock of a given product type, rather than just tracking changes in the efficiency of individual new products. Consumption-based indicators can be used to calibrate policy goals, helping us decide how much we need to increase efficiency and when we need to move beyond efficiency in order to assure a sustainable energy future.

Acknowledgements

The authors would like to thank our colleagues Kathryn Janda and Alan Meier who provided thoughtful review comments on earlier versions of this chapter, and our two anonymous reviewers who added enormous value in clarifying our arguments. This chapter was based on an earlier paper, “Towards a Sustainable Energy Balance: Progressive Efficiency and the Return of Energy Conservation,” by Jeffrey Harris, Rick Diamond, Maithili Iyer, Christopher Payne, Carl Blumstein, and Hans-Paul Siderius in *Energy Efficiency* (April 2008).

This work was funded by the U.S. Department of Energy under Contract No. DE-AC02-05CH11231, and the California Energy Commission’s Public Interest Energy Research Program. The views expressed in this chapter are solely the views of the authors, and not necessarily those of the funding institutions.

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Rebound, Technology, and People: Mitigating the Rebound Effect with Energy-Resource Management and People-Centered Initiatives

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Introduction

In the United States, and worldwide, large-scale investments and improvements in energy efficiency are urgently needed that can mitigate greenhouse gas emissions, as well as minimize the impact of inflation and the volatility in energy prices (Laitner et al. 2009; American Physical Society 2008; Committee on America's Energy Future 2009; Laitner 2009a). Perhaps more critically, investments in energy efficiency can accomplish these goals while maintaining our country's robust production of goods and services, and while actually boosting overall employment, according to many recent analyses (Laitner and McKinney 2008; McKinsey 2009; Laitner 2009b; Roland-Holst et al. 2009).

Yet, reducing energy use may not be quite as simple as putting efficiency-improving technologies in place. Other recent studies also suggest that such measures are likely to fall short in delivering the expected level of energy savings. The reason: as greater efficiency reduces the cost of buying the services that energy provides, the demand for those services—warmth and coolness in winter and summer, respectively, and travel, for example—may rise (Calwell 2010), a phenomenon known as the rebound effect (Sorrell 2007).

In this chapter we summarize the evidence regarding the prevalence and characteristics of the rebound effect and document its historical contribution to U.S. energy consumption. We then describe the causal relationships which result in rebound, and suggest potential mitigation strategies that might minimize the impact of the rebound effect. Finally, we explore how behavior-based approaches affect efforts to reduce overall energy use and the rebound effect. We conclude with a discussion of the strengths and weaknesses of people-centered versus technology-focused approaches as means of reducing energy consumption and accelerate carbon savings.

Defining the Rebound Effect

The rebound effect, also known as the take-back effect, is the rise in demand for the services energy provides that happens when big improvements in efficiency reduce the energy cost of those services. The rebound effect is generally thought to offset some of the energy saving benefits of the new technology or improvements.

Rebound is generally quantified as the ratio of the lost energy savings to the total expected savings from efficiency. For example, if a 25 percent improvement in residential space heating actually results in only a 20 percent drop in natural gas consumption, the rebound effect would equal 20 percent (calculated as (25 – 20) / 25 * 100% = 20%). The five percent of expected energy savings missing from the total savings realized is the extra energy consumed by the new, more efficient furnace, because the household residents boosted the setting on their thermostat.[1] The existence of the rebound effect is generally accepted. But public policy analysts debate the size of the effect, and of the bite it will take out of the energy savings that would accrue if human behavior were absent from the equation. Because human behavior is such a wild card, three very different outcomes are possible:

- ***Negative rebound***—actual energy savings are higher than expected. This is unusual but can occur when success in saving energy makes an individual feel challenged to save ever greater amounts of energy. For example, a family that installs a new energy-efficient hot water heater may be motivated to find other ways to save energy by taking shorter showers, washing clothes in cold water, or by limiting dishwasher use to full loads. Similarly, anecdotes of Toyota Prius owners altering their driving styles to squeeze out the greatest possible miles per gallon are common, including instances of once-aggressive drivers who have foresworn their previous behavior in their quest for maximum efficiency. (Note: this last actually describes one of us—Laitner—who actually does monitor the feedback display on the dashboard of his 2001 Prius.)
- ***Typical rebound***—actual energy savings are less than the expected savings. As suggested earlier, if the anticipated 25 percent savings turns out to be only 20 percent, the rebound effect is equal to 20 percent. On the other hand, if there are zero net energy savings, the rebound effect is equal to 100 percent. As discussed below, studies of rebound suggest that it usually falls in the range of 0 to 60 percent.
- ***Back-fire, or sometimes known as the Jevons Paradox***—actual energy savings are negative. (In other words, the rebound effect is greater than 100 percent.) Some economists argue that efficiency gains stimulate a set of effects in the economy—resource substitution, cost-reductions, or more general productivity benefits—that paradoxically increase overall energy use (Sorrell 2007).[2] For example, Ayres and Warr note that there may be a direct link between greater levels of energy efficiency and the larger productivity of an economy (2009). In that case, a two percent efficiency gain might translate into a two percent productivity benefit which might lower energy use initially, but as the economy expands it might also increase total overall energy use. At the same time, there are other factors at play which can also positively impact economic productivity so it is difficult to separate the two sets of consequences.

Prevalence and Characteristics of the Rebound Effect

Since the OPEC oil embargoes of the 1970s, huge gains have been made in energy efficiency. In fact, between 1970 and 2010, three quarters of the growth in energy service demand in the

[1] This methodology assumes that estimates of expected energy savings are reasonable. If estimates of expected energy savings include errors, then rebound will be overestimated or underestimated, depending on the direction of the error.

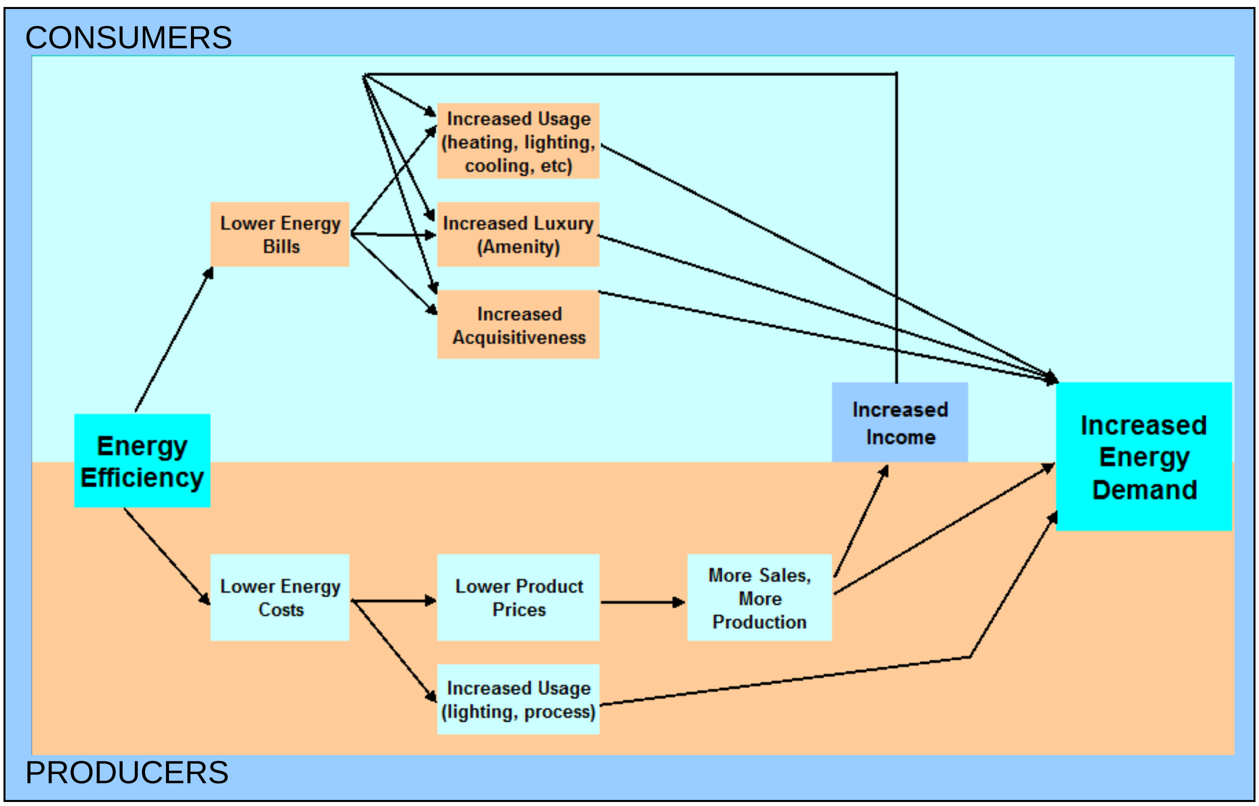
[2] Sorrell (2007), drawing on an analysis by Saunders (2007) published a "proof" that efficiency gains always lead to back-fire. However, the back-fire result depends on a multiplier or productivity factor that always ensured a greater than 100 percent take-back. Yet, Saunders provides little proof or data in this regard; nor does the real world analysis support that large-scale productivity impact—especially given other factors which also impact productivity. Hence, our paper here focuses on the more common impact of rebound as somewhere within the lower range of zero to 100 percent. At the same time, there is clearly more work needed to understand the full implication of the efficiency link to economic productivity.

United States has been met by the general rise in energy efficiency (Ehrhardt-Martinez and Laitner 2008, as updated by author calculations to 2010). Nevertheless, U.S. energy consumption grew during that period from 68 quads to nearly 100 quads today. How much of this growth was the result of rebound effects and how much of it could have been avoided? Can energy efficiency result in a negative net change in energy demand? Or will new energy service demands continue to outpace gains in efficiency?

A Brief Literature Review

Studies show that investments in energy efficiency often result both in increases in energy productivity and energy savings, and—paradoxically—in subsequent growth in the demand for energy services (Herring and Sorrell 2009; Geller and Attali 2005; Schipper 2000; Nadel 1993). By increasing energy productivity, less energy is used to meet the energy needs of consumers and producers, resulting in a hypothetical decline in energy prices. However, rather than an actual lowering of energy costs, in some cases, the energy that is "freed up" through efficiency, may instead be put to other uses. The degree to which energy resources are applied to new uses rather than conserved is referred to as the rebound effect.

Figure 1: Causal Diagram of Direct and Indirect Rebound Effects



The rebound effect can be studied at different scales (from national-level effects to household level effects) and includes both direct and indirect measures. Direct rebound effects are those that result from an increase in the use of a device that is deemed more energy efficient. Cars and furnaces provide the best examples. When a more efficient car results in an increase in vehicle miles traveled or a more efficient furnace results in a warmer temperature setting, the lost energy savings are considered to be direct rebound effects. Indirect rebound effects are those that have less direct causal chains and result from increases in consumerism (acquisitiveness), production, and the shift toward increased luxury. Figure 1 provides a causal diagram of the principal drivers of both direct and indirect forms of rebound among consumers and producers.

On the micro level, rebound may occur as a result of either lower energy costs or from the growth in affluence associated with a growing economy. As an example of the former, more efficient furnaces or better insulation may result in lower heating bills and, as a result, households may choose to increase home heating a few degrees rather than save on their energy bill. Similarly, lower energy costs may result in a shift in consumer preferences such that consumers opt to purchase more energy services rather than other goods and services (Sorrell and Herring 2009). Moreover, consumers may choose to purchase and use an increased number of energy-using devices and/or increase the level of luxury or amenity associated with those devices (Calwell 2010). For example, today's households are more likely to have a television in multiple rooms (often one in every bedroom), several refrigerators, music playing devices, DVD players, set top boxes, video game consoles, and computers. Similarly, the size of the average new home, car and television has continued to increase; cars are more powerful, and devices have become more elaborate. SUVs now come with their own entertainment centers, cars have heated seats and electric coolers, and washing machines have special steam washing functions. At the macro level, indirect rebound effects may occur as a result of the additional energy demand needed to produce and install energy-efficient equipment, products and services, or it may be a consequence of a number of secondary effects such as those highlighted in Figure 2 (Herring and Sorrell 2009).

Estimates of Direct Rebound Effects: Rebound by Sector and End Use

Most primary studies of direct rebound effects have focused on rebound in relation to a limited number of household energy end uses (primarily space heating and cooling), and personal transportation (which are the most thoroughly studied end uses). Herring and Sorrell's meta-review (2009) suggests that direct rebound for households is typically in the range of 10 to 30 percent of the efficiency-driven energy savings. Table 1 summarizes the findings from the meta-review.

Herring and Sorrell suggest that increased efficiency in personal transportation is likely to result in a direct rebound effect, over the long run, of 10 to 30 percent. Thus, for every 10 percent gain in efficiency, 1 to 3 percent of the energy savings will result in more driving. However, a note of caution: most of the studies in the meta-review did not study how gains in efficiency affected travel. Instead they studied how changes in fuel prices affected the fleet's fuel efficiency, and assumed that consumers' response to fuel prices increases was equal in size (but opposite in sign) to the variable of interest: consumers' response to a gain in fuel efficiency. Given that the elasticity of fuel efficiency is likely to be less than that of fuel cost per mile, Sorrell (2009) concludes that the direct rebound effect of transportation is likely to lie closer to 10 percent.

Figure 2: Secondary Rebound Effects

- Energy cost savings from energy efficiency may be used by consumers to purchase other goods and services which require energy to produce or provide.
- Energy cost savings may be used by producers to increase output thereby increasing consumption of capital, labor and materials, all of which require energy to provide
- Energy efficiency will increase the energy productivity of the economy and encourage economic growth and increased consumption.
- Efficiency induced reductions in energy demand may result in lower energy prices and result in a resurgence in the use of energy resources.
- Energy efficiency and reductions in energy costs may disproportionately reduce the cost of energy-intensive goods and services, encouraging consumers to disproportionately increase their demand for such products and services.

Source: Sorrell and Herring (2009)

As with personal transportation, Sorrell (2009) found that the rebound effect for residential space heating probably falls between 10-30 percent. Overall, studies of residential space heating, primarily from Europe, find that increased efficiency of this end use leads to household temperatures which range from 1.6˚F to 2.7˚F higher. That may increase energy consumption for space heating by 10 percent or more relative to where it would be absent the rebound effect. Importantly, he found that direct rebound effects tend to be higher for low income groups who can’t afford to spend a lot to heat their homes. These groups are more likely to exchange some energy savings for increased thermal comfort (Sorrell 2009).

Table 1: Estimates of Long-Run Direct Rebound Effects for Consumer Energy Services in the OECD

End Use	Range of Values in Evidence Base	“A Best Guess”	Number of Studies	Degree of Confidence
Personal Vehicle Transport	3-87%	10-30%	17	High
Space Heating	0.6-60%	10-30%	9	Medium
Space Cooling	1-26%	1-26%	2	Low
Other Consumer Energy Services	0-41%	<20%	3	Low

Source: Sorrell (2009)

In a literature review of econometric studies, Greening, Greene and Difiglio came to similar conclusions (2000). They found a small to moderate rebound effect (generally on the order of 10-40%) for residential space heating, water heating and automotive transport, a small rebound effect (<10%) for residential appliances and lighting, although a considerably larger range for residential cooling of 0-50 percent. They also estimated a range of rebound effects for business end uses (see Table 2).

An earlier meta-analysis by Nadel (1993) found that “takeback can occur, but it is not a widespread phenomenon”. This study looked at not only overall energy savings, but also the various mechanisms by which rebound may be occurring, such as changes in thermostat setting. Results of this study are summarized in Table 3.

Table 2: Summary of Empirical Evidence of the Rebound Effect

Sector	End Use	Size of Rebound Effect
Residential	Space Heating	10-30%
Residential	Space Cooling	0-50%
Residential	Water Heating	<10-40%
Residential	Lighting	5-12%
Residential	Appliances	0%
Residential	Automobiles	10-30%
Business	Lighting	0-2%
Business	Process Uses	0-20%

Source: Greening, Greene and Difiglio (2000) and IEA (1998) as presented in Geller and Attali (2005)

Table 3: Summary of Findings from "The Take Back Effect: Fact or Fiction"

Sector	End Use	Number of Studies	Results
Residential	Space heating	15	Very little take back. Average change in indoor temperatures of about 0.25 degree F, resulting in about 1% increase in energy use. Many of these studies were of low-income households.
	Space cooling	8	Inconclusive but probably some take back in moderate climates and seasons where use of air conditioning is optional.
	Water heating	5	No evidence of take back.
	Lighting	6	Efficient lights used for 5-12% more hours.
	Refrigeration	2	Little or no take back.
Commercial	Lighting	2	New lights brighter on average, indicating some take back.
Industrial	Process	11	Of 11 case studies, one found 12% increase in production and one additional factory reported that production may increase in the future.

Source: Nadel (1993)

Importantly, the time costs of using certain devices can dampen the associated rebound effects. One obvious example is driving. Although rebound effects have been widely documented for cars with greater fuel efficiency, the energy savings aren't always translated into longer driving distances because of the time costs associated with driving. Similarly, there are limits to how much time people will spend with their electronics, and even with their washing machines. In other words, when the constraining force of the dollar cost of energy services is mitigated, the cost of spending time with ones' devices will sometimes emerge as a new constraint.

The rebound effect notwithstanding, energy efficiency is by no means a failure. As Geller and Attali have commented, "energy efficiency improvements still contribute to an improvement in "general welfare" whether by enabling a higher level of comfort, increased activity, or lower energy cost, or some combination of these responses" (2005). Nor is the rebound effect inevitable. A better understanding of rebound will provide the means to formulate mitigation strategies that can minimize the impact of rebound.

Estimates of Indirect and Economy-Wide Rebound Effects

Some energy analysts and energy efficiency critics argue that large-scale gains in energy efficiency can have profound macroeconomic effects that boost energy consumption (see Figure 1). Generally, rising energy efficiency can increase energy consumption in two ways: by reducing the cost of energy relative to other inputs, and by stimulating economic growth, including in the energy sector. In fact, Brooks (1992) and Inhaber (1997) argue that although energy efficiency reduces energy demand and lowers energy prices in the short term; in the longer term, low energy prices stimulate growth in various sectors of the economy, which fuels demand for energy, or by means of increased product demand. In addition, rising economic productivity can stimulate investment of savings in energy cost into production, spurring demand for new production equipment and services (Ayres and Warr 2009). Sorrell and Herring (2009) echo these conclusions in their review:

> *…economy-wide rebound effects are generally not negligible and in some cases could exceed unity. Rebound effects therefore need to be taken seriously in policy appraisal.*

Sorrell and Herring (2009) do, however, recognize that the indirect effects of rebound appear to vary widely across different technologies, sectors, and income groups. Moreover, while these same authors do attempt to assess the size of the indirect effects of rebound, they are also careful to recognize that the limited number of studies on this topic makes it impossible to draw general conclusions. Still, they note that:

- CGE modeling studies estimate economy-wide rebound effects of 40 percent or more following energy-efficiency improvements by producers, with half of these studies predicting backfire (Allan et al. 2007).
- Macro-econometric models of national economies used by Barker and Foxon (2006) estimate an economy-wide rebound effect of 26 percent from energy efficiency policies in the U.K.

Most researchers on this topic (Herring and Sorrell 2009; Geller and Attali 2005; Schipper 2000) agree that rebound effects occur and that they matter in determining the amount of potential energy and carbon savings that can be achieved through energy efficiency programs and policies. In the next section, we use this information to provide our own estimates of the potential scale of the economy-wide rebound effect.

Potential Scale of the Economy-Wide Rebound Effect

To illustrate the magnitude of a potential future rebound effect[3] under two scenarios, we use an estimation approach based on the functional relationship between four principal variables: delivered energy consumption, income (expressed as total Gross Domestic Product or GDP), energy prices, and technology policy. The purpose of this exercise is to highlight the nature of these relationships as well as the impact that changes in key economic variables could have on

[3] This estimate follows the methodology presented in Laitner (2000).

energy use between the years 2010 and 2035[4]. In addition to the four principal variables, our estimates of future rebound effects and energy consumption also rely on estimates of long-run income and price elasticities. We estimate these elasticities using data from the *Annual Energy Outlook 2010* (EIA 2010).

To illustrate the potential impact of strong efficiency policies, our estimates include two scenario outcomes: a Business-as-Usual Scenario and an Aggressive Policy Scenario. The two equations are identical with the exception of the policy measures. As illustrated in the following equations, the Business-as-Usual Scenario estimates future energy consumption in the absence of new efficiency policies, while the alternative scenario includes new efficiency policies.

Business-as-Usual Scenario Equation

$$\text{Quads}_{2035} = \text{Quads}_{2010} \times \text{GDP}^{\text{ElasGDP}} \times \text{NRGprice}^{\text{ElasNrgPrice}}$$

Aggressive Policy Scenario Equation

$$\text{Quads}_{2035} = \text{Quads}_{2010} \times \text{GDP}^{\text{ElasGDP}} \times \text{NRGprice}^{\text{ElasNrgPrice}} \times \text{TechPolicy}$$

Both equations use the current level of energy consumption (Quads_{2010}) as a baseline for determining future consumption and rebound. The anticipated level of energy consumption in 2035 (Quads_{2035}) is estimated for a business-as-usual scenario using the historically persistent relationships between energy, GDP and energy prices. More specifically, we estimated future levels of consumption as a product of current consumption (Quads_{2010}), the anticipated growth in the nation's GDP ($\text{GDP}^{\text{ElasGDP}}$) and a positive increase in energy prices ($\text{NRGprice}^{\text{ElasNrgPrice}}$). If energy prices increase (as indicated by the AEO 2010) they will put downward pressure on energy use since the elasticity will be negative.

The second scenario includes the aforementioned variables as well as the estimated effects of a set of aggressive policies (TechPolicy) that could result in accelerated investment in energy efficiency technologies and programs. Such policies could catalyze development of new technologies, accelerate adoption of existing technologies and reshape energy use management and practices. A comparison of the energy implications of these scenarios provides a useful assessment of the potential benefits of smart energy policies

Next, we set parameters for these equations using values and projections drawn from the *Annual Energy Outlook 2010* as presented in Table 4.

[4] This time period was chosen due to the availability of relevant data which were drawn from the most recent Annual Energy Outlook (AEO) which extends out to the year 2035 (Energy Information Administration 2009).

Table 4: Delivered Energy Consumption according to Three Scenarios

Coefficient or Variable	2010	CAGR (%)	BAU 2035	Policy 2035	Policy w/Rebound 2035
2010 delivered Energy (quads)	69.5	n/a	69.5	69.5	69.5
GDP (2010 = 1.00)	1.00	2.7%	1.95	1.95	2.11
Income Elasticity	0.75	n/a	0.75	0.75	0.75
Energy Price (2010 = 1.00)	1.00	1.4%	1.43	1.43	1.26
Price Elasticity	-0.94	n/a	-0.94	-0.94	-0.94
Technology Policy	1.00	n/a	1.00	0.70	0.70
2035 Delivered Energy (Quads)	69.5	n/a	82.1	57.5	63.8

According to the AEO reference case (which provides business-as-usual projections), delivered energy use for 2010 is estimated to be about 69.5 quads. The AEO business-as-usual estimates also assume that between 2010 and 2035 the economy will grow by 95 percent and that energy prices will increase by 43 percent. These measures can be used to parameterize the previous equation with the addition of income and price elasticities as suggested by the AEO and shown in Table 3. The results indicate that in 2035, the United States is likely to consume 82.1 Quads of delivered energy in a business-as-usual scenario.

An alternative assessment of future energy demand can be calculated based on assuming that a more aggressive set of policies stimulate accelerated adoption of energy-efficient technologies and practices (see Laitner 2009b). If this more aggressive path should prove successful in reducing delivered energy use to 70 percent of the 2035 reference case projection, energy use in 2035 would be roughly 58 quads as expressed in the following relationship:

$$\mathbf{Quads_{2035} = 69.5_{2010} \times 1.95^{0.75} \times 1.43^{-0.94} \times 0.70 \sim 57.5\ Quads}$$

A further iteration is needed to factor in the likely effects of rebound. As noted above, rebound theory suggests that efficiency-induced reductions in energy consumption (as shown in Scenario B) are likely to result in either an increase in GDP or a reduction in energy prices or both. Therefore, projected energy savings are likely to be somewhat lower than anticipated in Scenario B. We can account for potential rebound effects and revise our estimates of total energy consumption in 2035 by increasing the level of GDP growth and reducing energy prices. As shown in the following equation, and consistent with Laitner (2009b), the estimates presented here assume an increase in the annual GDP growth rate of approximately 0.3 percent (due to a slightly larger productivity gain than in the reference case) and a reduction in energy costs by approximately 5 percent below the reference case as a result of reduced energy demand. By factoring in potential rebound effects, the revised estimate of delivered energy consumption equals 63.8 Quads in 2035. The following equation includes the rebound-related adjustments:

$$\mathbf{Quads_{2035} = 69.5_{2010} \times 2.11^{0.75} \times 1.26^{-0.94} \times 0.70 \sim 63.8\ Quads}$$

To recap, estimates of future energy demand that are based strictly on an engineering analysis and a business-as-usual approach are likely to suggest that delivered energy use will rise 18 percent, from 69.5 Quads in 2010 to 82.1 Quads in 2035. Estimates that factor in the potential impact of technology policy are likely to suggest a 17 percent decline in delivered energy use from 69.5 Quads in 2010 to 57.5 Quads in 2035—a decrease of about 30 percent compared to the business-as-usual scenario. However, we must also factor in the potential effects of rebound. These suggest that energy-efficiency induced energy savings are likely both to boost income—in the form of a larger GDP—and to lower energy prices. Once we adjust the equation to account for these effects, efficiency-induced energy savings are likely to be more moderate. This exercise suggests that rebound-induced reductions in future efficiency-related savings are on the order of 26 percent [(82.1-57.5) - (82.1-63.8)} / (82.1-57.5) ~ 26 percent].

Given the established range of technologies, as well as historically-rooted price and income elasticities, it appears that the economy-wide rebound is likely to be well under 100 percent. Nevertheless, even a 20 to 30 percent take-back has serious implications for the nation's energy and climate policy. The next section considers the potential role of people-centered programs and policies in mitigating the rebound effect. More specifically, we explore how social and behavioral programs and policies can reduce energy consumption by reshaping behaviors and lifestyles that contribute to rebound.

The Impact of People-Oriented Initiatives on Energy Efficiency and Energy Conservation

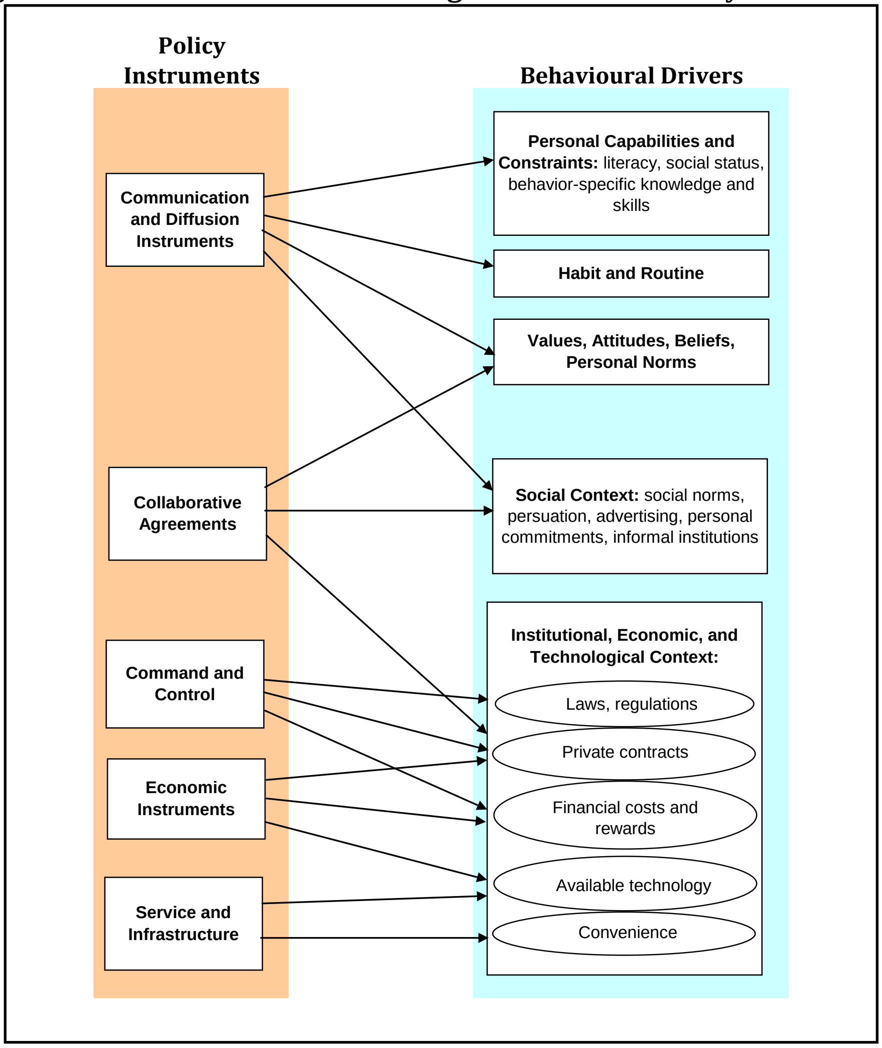
People-oriented initiatives are programs and policies that identify and address the many social, cultural, psychological and environmental factors that shape and constrain energy-related behaviors and practices (Ehrhardt-Martinez and Laitner 2010). They put people first in trying to understand and solve today's energy and climate problems and see technology as a set of tools for achieving individual, social and environmental goals. They recognize that energy-efficient technologies constitute one of several important means of reducing energy consumption and carbon emissions, but they focus on understanding how these tools are put to use by people.

Unlike traditional approaches, that emphasize energy-efficiency-boosting technology, people-oriented approaches focus on understanding changes in energy service demands and the many factors that shape those changes (as illustrated in Figure 3, above). As such, people-oriented initiatives offer a viable opportunity for mitigating rebound-induced losses from investments in energy efficiency technologies.

Indeed, a variety of studies suggest that applying social and behavioral insights in energy policy might begin to close the gap between the expected and the actual energy savings from traditional efficiency programs (Ehrhardt-Martinez et al 2009; Lutzenhiser 2009). Such savings could be as great as 9-10 quads, annually (Laitner et al. 2009; Dietz et al. 2009; Leighty and Meier 2010). People-oriented strategies could reduce energy consumption in both personal transportation and residential buildings by about 25 percent (Laitner et al. 2009; Dietz et al. 2009). These strategies would work in part by *unlocking new sources* of energy savings while ensuring a significant level of persistence of energy savings into the future (Ehrhardt-Martinez et al. 2010; Meier 2009).[5]

[5] Note that the references in the above paragraph and throughout the balance of this chapter are also updated as contributions to this volume as Chapter 2 (Dietz et al. 2009), Chapter 3 (Laitner et al. 2009a), and Chapter 4 (Leighty and Meier 2010).

Figure 3: Drivers of Behavior Change and Related Policy Instruments

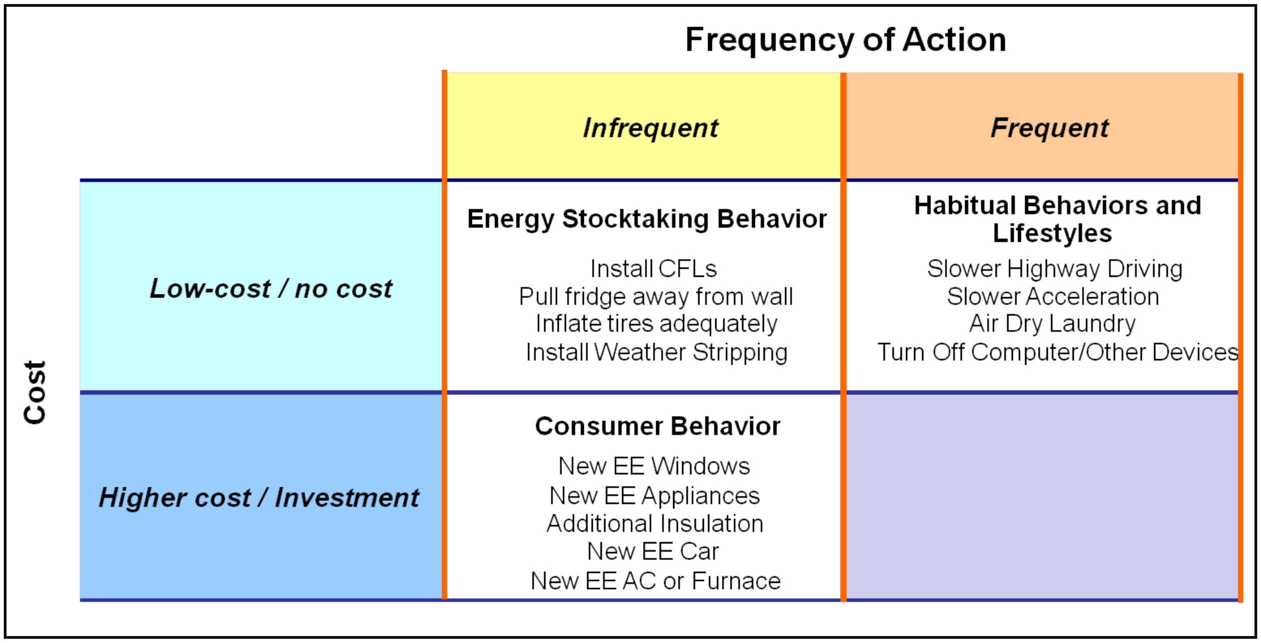


Source: Stern (2002)

The human dimensions of energy consumption and climate change are comprised of the many social, cultural and psychological factors that shape patterns of human behavior associated with lifestyle choices, habits, technology choices, and everyday practices. Addressing the human dimensions of energy consumption requires a people-oriented approach; one that attempts to understand energy consumption in the context of individual and organizational needs, abilities, resources and motivations as well as the social and cultural constraints and opportunities that impede behavior change and result in specific energy service demands. The focus of such approaches may include individuals in residential, industrial and commercial settings, although most studies of energy-related behaviors have focused on individuals and households rather than the actions of industrial or commercial groups.

At the macro level, indirect rebound effects may occur as a result of the additional energy demand needed to produce and install energy-efficient equipment, products and services, or from secondary effects such as those highlighted in Figure 2. Human behavior is nothing if not widely variable, and so researchers have worked to classify those related to energy use. This is valuable in determining the most effective ways to encourage people to reduce consumption. Laitner et al. (2009a) have defined three categories of household behaviors according to frequency of action and economic cost. They distinguish among the low-cost and no-cost behaviors, and i*nfrequent energy stocktaking behaviors* (such as installing compact fluorescent light bulbs or properly inflating tires) and the *frequent energy-related behaviors* associated with daily habits and lifestyles (such as slower highway driving or the air drying of laundry as shown in Figure 4). The third category, *consumer investment behavior*, includes infrequent and higher-cost investments in more energy efficient appliances, devices and products.

Figure 4: Household Behaviors Associated with Energy Consumption, Efficiency and Conservation



Source: Laitner et al. (2009a)

Fully 57 percent of behavior-related energy savings estimates were associated with energy stocktaking or changes in routines and habits, according to these investigators. Such low-cost and no cost behaviors could save approximately 4.9 quads (Table 4).

Table 4: Potential Impact of Behavior on U.S. Household Energy Use

Category of Actions	Potential Savings (EJ)	Percent of Total
Low-Cost/No-Cost	5.2	57%
Smart Investment Decision	3.9	43%
Total Energy Savings	9.1 ± 2.6	22% of household energy

Source: Adapted from Laitner et al. (2009a)

These estimates are supported by studies of countries and communities around the world that, when facing temporary shortfalls in electricity supplies, were able to dramatically reduce electricity consumption to avoid blackouts (Meier 2005). Brazil, for example, cut electricity demand by 20% when faced with a severe drought in 2001. Juneau, Alaska reduced electricity consumption 30% within just six weeks when an avalanche knocked out a major transmission line that fed power to the community (see, chapter 4 in this volume for a more detailed review of the Juneau experience, and also Leighty and Meier 2010). These examples clearly show that significant energy savings can be achieved quickly given the right set of programs and policies.

Recent reviews of residential sector feedback-induced energy savings provide additional evidence that people-centered programs can reduce consumption, by 4 to 12 percent historically across three continents. With further refinement of approaches, savings could potentially be higher (Darby 2006, EPRI 2009, Ehrhardt-Martinez et al. 2010, and see also other chapters in this volume for further references). These studies explore different ways to make energy consumption more visible to households. Most of the energy savings achieved through feedback programs has come from changes in behaviors rather than from investments, according to one recent meta-review of 57 feedback studies (Ehrhardt-Martinez et al. 2010)[6]. Regardless of the action taken, this study found that the motivating factors included not only self-interest—savings on energy bills—but civic concerns and altruistic environmentalism. And, notably, available but limited evidence indicates that feedback-induced savings persist over time if the feedback is maintained. This suggests that traditional energy efficiency programs—aimed solely at the installation of new, more energy-efficient technologies—are likely to fail to achieve most of the potential behavior-related residential energy savings that are possible. Similarly, programs that limit their appeal to self-interest are unlikely to leverage the broad range of factors that motivate people to action.

All this suggests that people-oriented programs and policies with wide-ranging strategies could both help mitigate rebound and reduce energy consumption in ways that avoid inducing additional rebound.

Strengths and Weaknesses of People-Centered Versus Technology-Focused Approaches for Saving Energy and Reducing Rebound

Traditional Technology-Focused Programs

The United States has mostly taken the “techno-economic” approach to reducing energy consumption: boost the energy efficiency of technologies, and then promote them to consumers by emphasizing their cost-effectiveness (Stern 1986). This model assumes that consumers behave in rational economic ways—making decisions based on rational calculations involving the price of energy, the cost of technologies, and the level of disposable income. The model further posits that energy-efficient behaviors and choices may be enhanced through the introduction of carefully crafted economic incentives and disincentives (Archer et al. 1987). Unfortunately these assumptions have not been proven in practice (Parnell and Popovic Larsen 2005).

The model’s weakest assumption is that people are economically rational actors. For example, a study of solar technology adoption found that even when it is available, most people fail to consider information that is essential to calculating costs and benefits (Archer et al. 1987). This applies to other big purchases. For example, even the most financially skilled consumers fail to

[6] Although it is true that people who invest tend to save the more energy.

use payback calculations as part of their vehicle purchase decision-making (See Chapter 7 by Turrentine and Kurani in this volume for a further discussion). Some such studies actually conclude that the behavior they observe actually contradicts a central tenet of the rational actor model—namely, that human decision-making is rational.

And in fact, additional studies (NRC 2002; Feldman 1987; Stern and Aronson 1984) indicate that consumers consider energy-related technology purchases as more than investments. In reality, people are influenced by a variety of non-economic variables including structural and institutional factors, cultural values and norms, individual beliefs and attitudes and interpersonal dynamics.

In terms of rebound, the use of traditional, technology-focused programs results in an exclusive focus on efficiency as opposed to energy stocktaking behaviors, changes in habits, routines, and lifestyles or other behaviors focused on waste reduction, energy conservation, and smart energy practices. As shown above, strategies that focus exclusively on efficiency often result in a rebound in household and personal transportation energy consumption of 10-30 percent. So while energy efficient technologies will undoubtedly play an important role in reducing future levels of energy consumption, those savings will be diminished by both direct and indirect rebound effects.

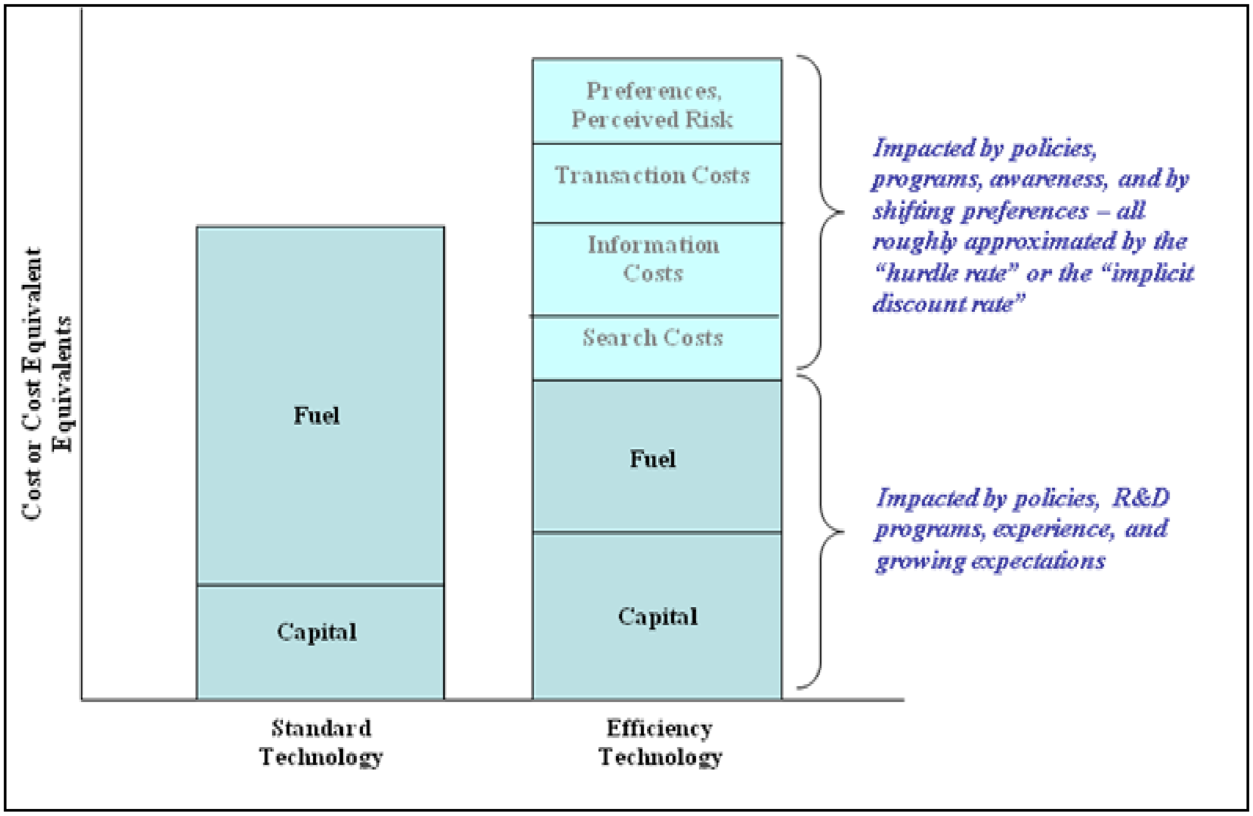
Traditional Behavior Programs

These programs seek to understand how new technologies diffuse through the population, and they use social science to try to make it happen more quickly. They often try to mitigate the time and dollar costs of information that consumers must bear, the risks involved, as well as other barriers consumers encounter as they consider adopting new, more efficient technologies. As illustrated in Figure 5, policies are focused on making cost-effective energy-efficient technologies more attractive to would-be adopters. But they do nothing to offset both the direct and indirect rebound effects associated with initiatives that are exclusively focused on energy efficiency.

Integrated People-Centered Programs

People-centered programs go beyond traditional programs in several important ways. They begin by considering the actual needs of people and society—the characteristics of existing energy service demands, and the social and behavioral factors that shape them. They seek to empower people and communities to become better energy managers, and they view energy-efficient technologies as simply one tool set in a larger box of tools designed to help achieve sustainability Within this perspective, people are more than energy consumers; they are potential producers, managing small-scale renewable technologies within distributed energy systems (see Ehrhardt-Martinez and Laitner 2010).

Figure 5: Impact of Policies on Different Costs Relating to Technology Choices



Source: Laitner (2009a)

Moreover, people are viewed as the source of energy savings as opposed to obstacles to technology-based efficiency. Conservation, curtailment and efficiency approaches are among the spectrum of potential energy-saving behaviors that households and others might employ to reduce energy consumption and carbon emissions. Ideally, integrated, people-centered programs use tailored energy information and technologies appropriate for the people and communities that seek to achieve sustainable levels of consumption as well as low-carbon types of energy consumption. People-centered programs provide motivation as well as information to encourage energy-smart behaviors. Finally, people-centered programs recognize and address economic and structural barriers that may serve to restrict the choices of individuals, households and businesses.

Because people-centered programs are frequently focused on sustainability, sufficiency, and smart energy management as opposed to having a strict focus on energy efficiency, they are more accepting of strategies that involve conservation, curtailment, and the elimination of wasteful energy practices. Unlike technology-centric energy efficiency programs, these practices are also more likely to minimize waste and maximize quality of life without necessarily increasing energy consumption or economic output. For example, investments in higher quality products and services (luxury) can occur without increased energy consumption such as when people choose to buy locally grown produce. Similarly the energy impacts of increased use can be tempered by energy stocktaking behaviors including the installation of weather stripping or closing vents in unused rooms.

Conclusions

Technocratic approaches that reduce energy consumption exclusively through adoption of efficiency technologies are more likely to suffer from large rebound effects. Conversely, people-centered energy strategies are likely to boost energy savings beyond levels achieved by technology-focused strategies, while avoiding or reducing the rebound effect. That's because, on top of adopting efficiency technologies, people-centered approaches motivate people to actively manage their energy consumption through a broader array of actions, including conservation, curtailment and the elimination of wasteful energy use practices—strategies that generally are absent from the techno-economic approach. They do this by encouraging people to develop new behaviors—new routines, habits, and lifestyles that reduce overall energy consumption. These new habits might range from consolidating errands and shopping into a single car trip to paying more attention to the purchase of smarter and more energy-efficient as well as maintaining better care of those appliances. Technologies then become tools that are used as but one of several opportunities to improvement the management of energy consumption at all levels within household and businesses.

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Saving Energy Is a Value Shared by All Americans: Results of a Global Warming Audience Segmentation Analysis

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Anthony Leiserowitz, Yale Project on Climate Change
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I don't accept the conventional wisdom that suggests that the American people are unable or unwilling to participate in a national effort to transform the way we use energy. I don't believe that the only thing folks are capable of doing is just paying their taxes. I disagree. I think the American people are ready to be part of a mission. I believe that.
–President Barack Obama, Earth Day 2009

Global warming—and what America should do about it—is hotly contested. The politicization of this issue over the past decade or so has polarized the nation, much of that along party lines.[1] More recently, in response to serious debates about national climate change legislation, striking divisions have emerged between Congressional Democrats from various regions of the country, based largely on regional differences in the economic consequences of putting a price on carbon emissions. As this goes to press, in the summer of 2010, the U.S. Senate—solidly controlled by the Democratic Party—has so far failed to pass climate change legislation due to political concerns held by some Democratic members. Our research—introduced below—indicates that there are indeed clear divisions among members of the American public on this issue (although we, the people, are not nearly as divided on the issue as are our federal representatives—an important point that should not be overlooked). The bottom line, however, is that the politics of global warming in America today are challenging.

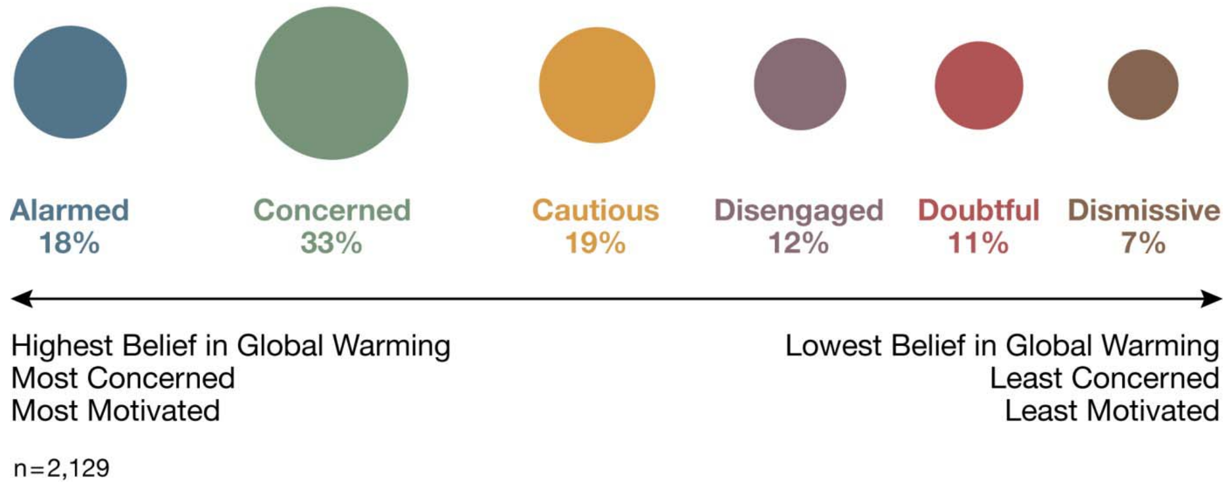
In this chapter we will provide evidence that President Obama has it right: despite political differences about global warming, most Americans are indeed willing to participate in a national effort to transform the way we use energy. Even many of the relatively small proportion of Americans who don't believe global warming is occurring —or are otherwise unconcerned about it—do believe that our country needlessly uses and wastes energy in harmful ways. Most Americans are eager to reduce their own energy use, and they support a range of policies to reduce the nation's energy use.

Some critics hurl the accusation that relabeling global warming containment measures as "clean energy" and "energy use reduction" measures is mere political spin. We provide evidence that global warming and energy are different—albeit related—conversations. The difference in these conversations has important implications for our governments—counties, cities, states and the federal government. The challenging politics that currently impede climate change decisions and actions around the nation need not impede opportunities to embrace clean energy and to help

[1] In 1997 only 4 percentage points separated Democrats and Republicans on the question of whether the effects of global warming had already begun (52% of Democrats agreed, compared to 48% of Republicans). By 2008, that split had grown to 34 percentage points (76% of Democrats agreed vs. 42% of Republicans) (Dunlap & McCright, 2008).

households, businesses, and municipalities reduce their energy use. Saving energy is a value shared by nearly all Americans.

Figure 1: Proportion of the U.S. Adult Population in the Six Americas



Notes: In this and all subsequent figures, the area of the circles represents the proportion of the American public in each audience segment. Respondents with incomplete data (n=35) were dropped from the analysis.

In this chapter we will present and discuss findings from a nationally representative survey of adults conducted in the fall of 2008 (n=2,164).[2] We've previously described the results of that survey in three detailed reports: *Saving Energy at Home and on the Road; Climate Change in the American Mind; and Global Warming's Six Americas.*[3] The last of those reports describes six distinct groups of Americans (i.e., audience segments) who were identified based on their global warming beliefs, issue involvement, policy preferences and behaviors.[4] Here, we will briefly introduce readers to those six distinct groups of Americans—Global Warming's Six Americas—and then focus in greater depth on their energy policy preferences, and efficiency and conservation behaviors, intentions, barriers, motivations, and beliefs. To add richness to the survey findings, we will also provide some direct quotes collected during in-depth interviews with approximately a dozen people in each of the six Americas. Although the six Americas have sharply clashing views of global warming, they have remarkably similar views, actions and intentions toward energy use.

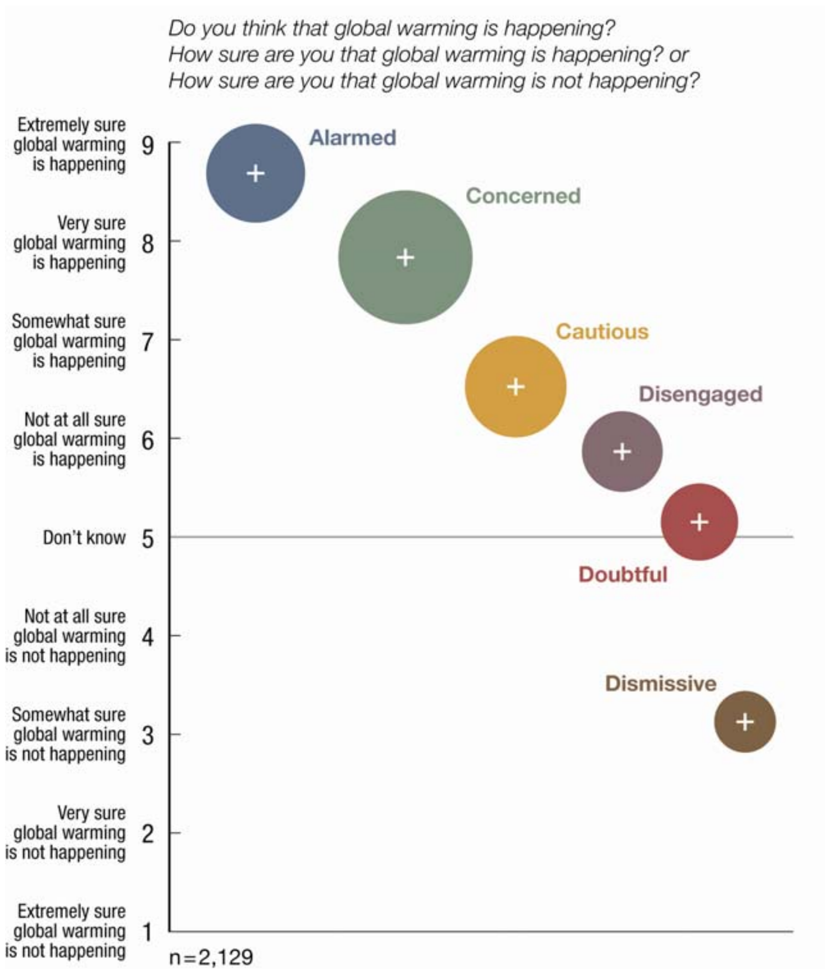
For ease of reading, we will speak about the Six Americas in the present tense. It is important, however, for readers to recognize that our survey was conducted nearly two years ago—two very historic and tumultuous years ago.

[2] The survey was conducted using an online panel developed by Knowledge Networks. Participants completed two separate questionnaires conducted two weeks apart. The response rate of 54%.
[3] The reports are available for download at http://climatechange.gmu.edu.
[4] We subjected thirty-six of the variables on the survey—representing questions on global warming beliefs, issue involvement, policy preferences and behaviors—to Latent Class Analysis, and considered four, five, six and seven segment solutions. Six segments provided the best fit to data and had the most face validity.

Meet Global Warming's Six Americas

The six audience segments—whom we have named the Alarmed, Concerned, Cautious, Disengaged, Doubtful and Dismissive—range in size from 7 to 33 percent of the U.S. adult population, and they form a clear continuum of concern regarding global warming (see Figure 1). The Alarmed are the most convinced that global warming is an immediate problem and the most personally invested in finding solutions, while the Dismissive are the most convinced that global warming is not a problem and are most opposed to government policies to address global warming.

Figure 2: Combined Measure of Belief and Certainty on Whether Global Warming Is Happening



Note: In this and all subsequent figures, the small cross at the center of each circle represents the segment's average response to the question.

The ***Alarmed*** (18% of the U.S. population) are the segment most engaged on the issue. They are very convinced global warming is happening (see Figure 2), is human-caused (88%), and is a serious and urgent threat. Over two-thirds believe people in the United States are being harmed now. Most of the Alarmed are taking personal action on global warming, and they to intend to take further actions in the future. In the past year, 26% percent have contacted a government official to urge action on global warming, 32% have volunteered with or donated to an organization working to reduce global warming, and 71% have used their consumer purchases to reward companies for the steps they are taking to reduce global warming. The majority of the Alarmed support a full range of policies that would reduce carbon emissions including research on renewable energy sources (99%), tax rebates for purchase of energy-efficient cars and solar panels (96%), regulating CO_2 as a pollutant (96%), stronger vehicle fuel efficiency standards (94%), signing an international treaty to limit CO_2 emissions (94%), providing government subsidies to improve home energy efficiency (92%), mandatory utility renewable portfolios (91%), establishing a fund to make buildings more energy-efficient (88%), national cap-and-trade legislation (60%), and an increase in the national gasoline tax (51%). The only CO_2 reduction policy we asked about that was not supported by a majority of the Alarmed was building more nuclear power plants (50%).[5] The Alarmed also want citizens (100%), industry (98%), and government (local, 93%; state governor and legislators, 97%; Congress and the president, 100%) to do much more to address the threat of global warming.

Figure 3: Personal Importance of Global Warming

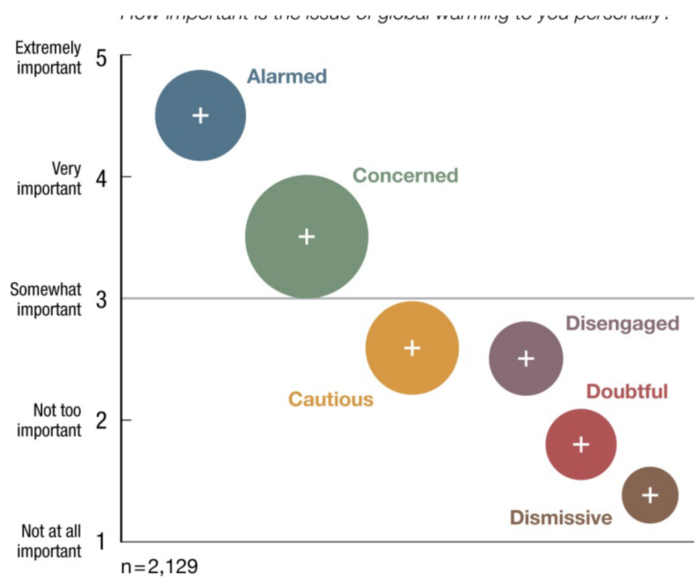
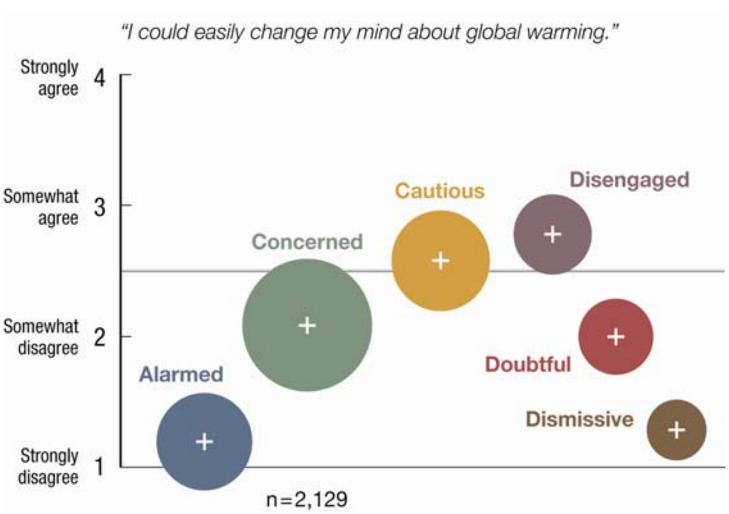


Figure 4: Attitudinal Certainty



The ***Concerned*** (33% of the population)—the largest of the Six Americas—are also convinced that global warming is real, human caused, and a serious problem, but they are somewhat less certain in their convictions than are the Alarmed. Moreover, compared to the Alarmed, they are less likely to perceive global warming as a direct threat to themselves or their family, or to future generations of people. While they support a vigorous national response—specifically, two-thirds or more of the Concerned support 8 of the 11 CO_2 reduction policies we

[5] To see the complete list and corresponding data values, see pg. 94 of Global Warming's Six Americas 2009: An Audience Segmentation Analysis, available at http://climatechange.gmu.edu.

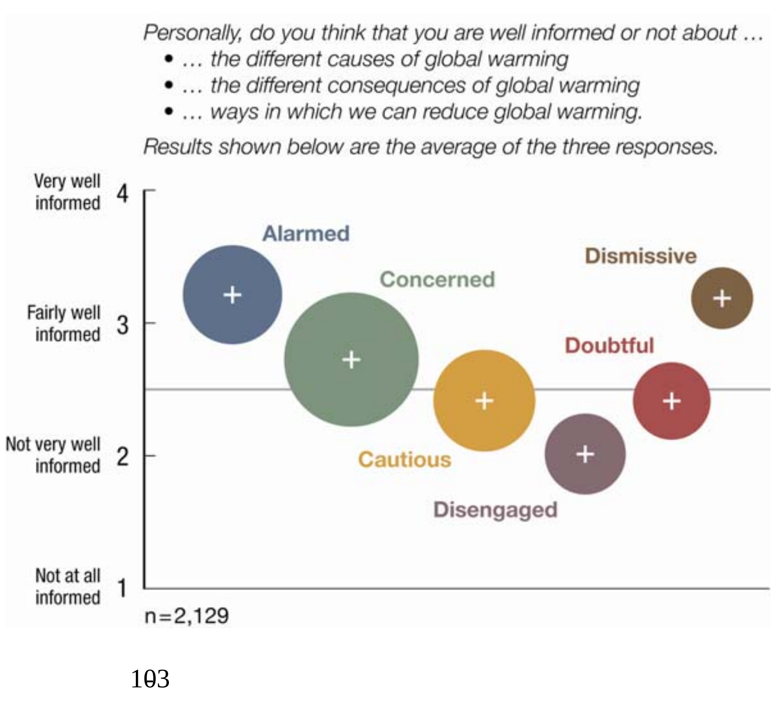
queried them about—they are distinctly less involved in the issue than are the Alarmed, and less likely to be taking personal action. Only 7% have contacted a government official on global warming, 16% have volunteered or donated to an organization working on the issue, and 43% have used their consumer purchases to reward companies for the steps they are taking to reduce global warming.

The ***Cautious*** (19% of the population) also believe that global warming is real, however, they are even less certain than are the Concerned: Only 32% report that they are "sure" or "very sure" that global warming is occurring. Additionally, the Cautious are less likely than the Concerned to believe that climate change is particularly dangerous or threatening. They are less likely than the Concerned to rate global warming as a top national issue priority (37% rate it a high or very high priority, compared to 71% of the Concerned), nevertheless a strong majority of the Cautious (66% or higher) support 6 of the 11 CO_2 reduction policies. They are markedly less likely than the Concerned to be taking personal actions of any kind to address global warming per se.

The ***Disengaged*** (12% of the population) haven't thought much about the issue (41% had never given the issue any thought). By their own admission, they don't know much about global warming (see Figure 3), and are the segment most likely to say that they could easily change their minds about it. Interestingly, a strong majority of the Disengaged (66% or higher) support 5 of the 11 CO_2 reduction policies, but they themselves are doing very little to address global warming.

The ***Doubtful*** (11% of the population) are evenly split among those who think global warming is happening (33%), those who think it isn't (32%) and those who don't know (34%), and they are the segment with the highest proportion of people who believe that if global warming is happening, it is caused by natural changes in the environment (81%). They tend to say that they have thought about the issue "only a little," yet they also indicate they are somewhat unlikely to change their minds about the issue. Despite their clear doubts about global warming, a strong majority (66% or higher) support 3 of the 11 CO_2 reduction policies: funding renewable energy research; providing tax rebates for purchases of efficient cars or solar panels; and building more nuclear power plants.

Figure 5: Combined Measure of Global Warming Knowledge, Self-Assessed



Finally, the ***Dismissive*** (7% of the population)—like the Alarmed—are actively engaged in the issue, but as opponents of a national effort to reduce greenhouse gas emissions. The majority of the

Dismissive believe that warming is not happening (70%) and is not a threat to either people or the environment. Ninety-four percent report global warming will not harm people in the United States, and 87% report that it will not harm plants and animals. The Dismissive believe global warming should be a low priority for the government (89%), and say that local, state & federal government (69%, 73%, and 80%, respectively), corporations (61%) and citizens (62%) should be doing less to address the issue. While they strongly favor increased drilling for oil in the Arctic National Wildlife Refuge (89%) and off the U.S. coast (96%), a strong majority (66% or higher) also support 2 of 11 CO_2 reduction policies: building more nuclear power plants, (88%); and funding research into renewable energy sources (72%). Most members of the Dismissive segment report that they have thought "some" or "a lot" about global warming, and virtually all (97%) say they are "very unlikely" to change their minds about the issue.

There are some demographic differences between the Six Americas, however, with the exception of the Disengaged (who are less well educated, have lower incomes, are less likely to be employed, and are more likely to be from a racial or ethnic minority), the differences are not large. Conversely, there are large differences in political ideology, values and religious beliefs among the Six Americas. Those segments most concerned about global warming are more politically liberal and hold stronger egalitarian and environmental beliefs. The less concerned segments tend to be more politically conservative, and hold strongly individualistic and religious beliefs.

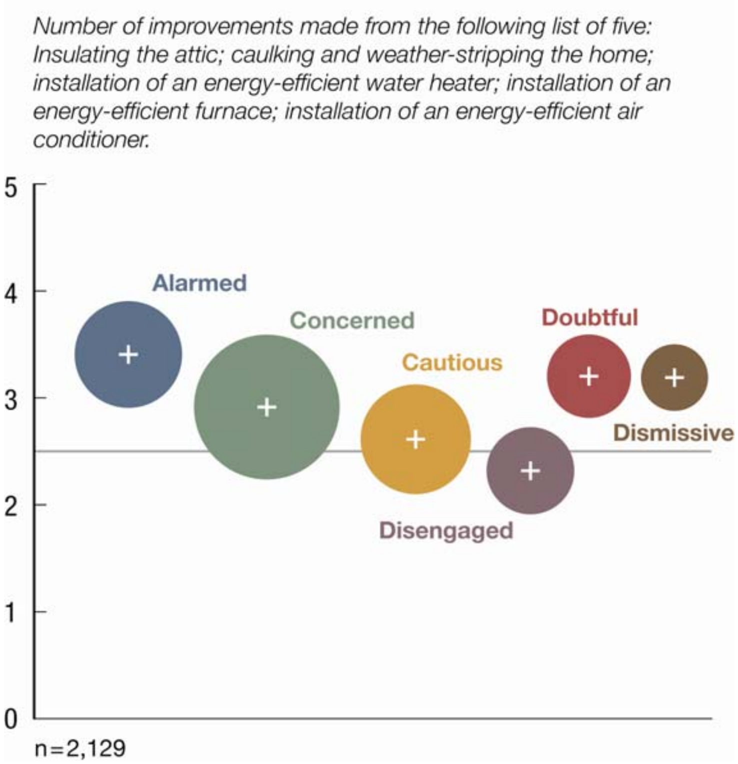
The Six Americas' responses to our global warming questions typically follow one of the three patterns seen in Figures 3, 4 and 5: a downward sloping trend, an inverted V-shaped trend, and a V-shaped trend. The strongly downward sloping trend line is seen in response to virtually all of our questions about global warming concern, perceived risk, and actions taken. Conversely, the V-shaped (or inverted V-shaped distributions depending on if the question was asked in the affirmative or in the negative) are seen in response to virtually all of our about opinion strength, perceived knowledge and issue engagement.

These pictures—Figures 1 through 5—truly are worth a thousand words in conveying the dynamics of global warming as an issue in America today. We've received feedback from numerous public officials, business managers and non-profit organization officials indicating that these figures—especially Figure 1—have helped them to better understand the breadth and depth of support among Americans for taking action against global warming, and to better understand the small but passionate group of Americans who remain opposed to action.

All Six Americas Value Saving Energy

It is not surprising that the Six Americas have sharply contrasting views of—and behavioral responses to—global warming per se; internally homogeneous groups with distinct between-group differences are precisely what an audience segmentation analysis is intended to accomplish. What is surprising, however, is the striking *commonality* among the Six Americas with regard to their efforts to save energy. Thus, although the Six Americas strongly disagree about the importance of reducing global warming, they agree on the importance of saving energy, and are remarkably similar in their energy-related actions and intentions, and in the barriers that hinder their conservation efforts. These commonalities present important

Figure 6: Number of Home Energy Efficiency Improvements



opportunities to create programs that assist households—as well as companies and governments—to reduce their energy consumption.

Energy Efficiency: Using Products that Reduce Energy Consumption

Americans have warmly embraced energy efficiency at home. It would be fair to say that an aspiration to achieve energy efficiency at home has become the American norm: indeed, most people report that they have already taken a number of energy efficiency actions in their homes. This is true of people in all Six Americas (Figure 6). Moreover, large numbers of people in all six Americas report that they want to take further action to improve the energy efficiency of their homes over the coming year. The actions they want to take include insulating the attic (9-17%), caulking & weather-stripping (12-28%), getting a more efficient furnace (12-29%), getting a more efficient air conditioner (AC) (14-27%), getting a more efficient water heater (14-30%), and changing most of their lighting to compact fluorescent lights (CFLs) (28-51%).

Well, I think the initiatives undertaken by our new president really stand out as a dramatic change and the way that he's looking at the stimulus money and investing in energy and new technology, green jobs, the way he's positioned the country internationally along these issues, really, to me represent a very significant and positive step in a different direction, so I'm happy about that. (Alarmed Female, Age 31-50)

Although it is by no means yet the norm, a substantial proportion of all six Americas have also already taken action to improve their energy efficiency on the road: 18 to 28% drive cars that average 30 miles per gallon or better—with members of the Dismissive segment leading the way at 28%. However, stunning large proportions of all six Americas—49 to 67%—indicate that over the coming year they would like to purchase a car that averages 30 mpg or better.

There is one interesting exception to the finding that energy efficiency actions have equal allure to people in all six Americas. Use of CFLs—an iconic (albeit possibly regrettable) symbol of global warming action—is much more widespread among members of the more concerned Americas. Use rates by the Alarmed and Concerned are 60% and 50%, respectively, whereas use rates by the Doubtful and Dismissive hover around 33%. This dramatic difference reveals the power of symbolism, and suggests the importance of wielding that power thoughtfully.

Motivation—in this case, the desire to take additional energy efficiency actions—is generally a necessary but insufficient precondition for behavior change. Many people in all six Americas told us that they would like to make various energy efficiency changes in their lives over the coming year, but probably won't make most of them. We inquired as to their reasons why (to identify their specific barriers to change). For large numbers of people in all six Americas, and for most of the energy efficiency actions we asked them about (specifically, insulating the attic, caulking & weather-stripping, new furnace, new AC, and new car), their most common response was: "I can't afford to." Furthermore, regarding water heaters, lighting, cars, AC and furnaces, large numbers of people in all six Americas explained their lack of intention to take action in the coming year by reporting "I don't need a new one yet." Conversely, very few people in any of the Americas said that they are simply unwilling to spend money on energy-efficiency (as indicated by the response "I could afford to, but don't want to spend the money").

Like I said with the cars, I think we're on the right track with lower emissions and more fuel efficient cars, so we're not using up all the natural resources, that we're not putting as much pollutant back into the atmosphere. (Concerned Female, Age 50+)

Cost-constraints (i.e., not being able to afford to do everything one would like to do) and thrift (i.e., aversion to the idea of getting something new when the old one still works), however, are not the only barriers. Many people say they simply don't know how to take some actions or don't have the time to research the options or do the work. For two actions—insulating one's attic and caulking and weather-stripping one's home—approximately 20 percent of people say they don't know how, and 20 to 26% say they haven't taken these actions because it would take too much effort or they were too busy. Members of the least concerned Americas were particularly likely to report these barriers.

My wife, she doesn't like Obama, I don't really care for him either but yet he's got some good ideas. Using wind power, I think that's a great idea, man. I really do. Using all this alternative energy, I think that's a great idea. We live in a place where there's constantly a breeze—it generates winds. We wouldn't have to rely on these power companies. If you can afford to buy a wind generator and throw it up in your yard, I'd do it. I'd do it in a heartbeat. (Concerned Male, Age 50+)

These data on barriers to behavior change are revealing. It is not surprising that the major barriers to taking energy-efficiency actions—among people who want to take actions—are feeling cost-constrained and being thrifty; nor perhaps is it surprising that the barriers vary so little across the six Americas. They reveal, however, the importance of finding ways to reduce the up-front costs of energy efficiency actions, and to address people's aversion to disposal of working appliances. Moreover, they reveal that such strategies are needed to help coax people in all six Americas past these two important barriers to action. This strongly suggests that homeowner tax breaks and subsidy programs to support the purchase and installation of energy efficient heating, cooling, and insulation systems can make a significant difference in reducing household energy use. It also suggests that explicit guidelines should be promoted to help people recognize when the truly thrifty response is to retire an old but still operable piece of equipment.

So there needs to be real investments in alternative energy. We need to figure out how we can harness wind, solar, hydro, electric options. And I know it's expensive. I get it, but the only reason gas is cheap as it is, is because we're not really paying the price of it, right? (Cautious Male, Age 31-50)

Indeed, in light of these findings about the barriers of greatest concern across all six Americas, it's easy to understand why the "cash for clunkers" program was so very successful in coaxing a broad cross-section of Americans into action: the program reduced up-front costs appreciably, and it labeled old fuel-inefficient cars as "clunkers," thereby helping people to see their long-in-the-tooth cars in a new light. (It should be noted that cash for clunkers did little to boost fuel efficiency, as the fuel economy requirements for the replacement cars were not particularly stringent, but it illustrates the power of money to stimulate people into action.)

> *I mean those light bulbs do cost more in the long run but I have a friend that has an energy efficient fridge and they pay so much less in their bills than we do. They have energy efficient appliances and their electricity bills are so much smaller, it's unbelievable.* (Disengaged Female, Age 18 to 30)

Heating and cooling systems are relatively big-ticket items that are purchased infrequently, with product lifetimes that can last decades. The "cash for clunkers" model can potentially be adapted to accelerate the pace at which households and businesses replace their most wasteful home heating and cooling systems. Given that the oldest, least-efficient systems are likely to be owned by lower-income households and businesses, cash-for clunkers programs can have the added benefit of providing the most assistance to those who need it most.

These results also suggest that there is a large potential market in affordable retail home insulating services, especially if supported through homeowner tax breaks or subsidy programs. One-stop services that combine a home energy audit with a simple menu of affordable energy efficiency products and services throughout the home may find a significant market.

> *… like this whole correlation between the greenhouse gas emissions and global warming. I don't think there's a link but I mean if it's getting people to reduce car emissions, I don't see what's wrong with reducing car emissions, making cars more efficient, making things more efficient. I mean I don't see anything wrong with any of those. And if this does*

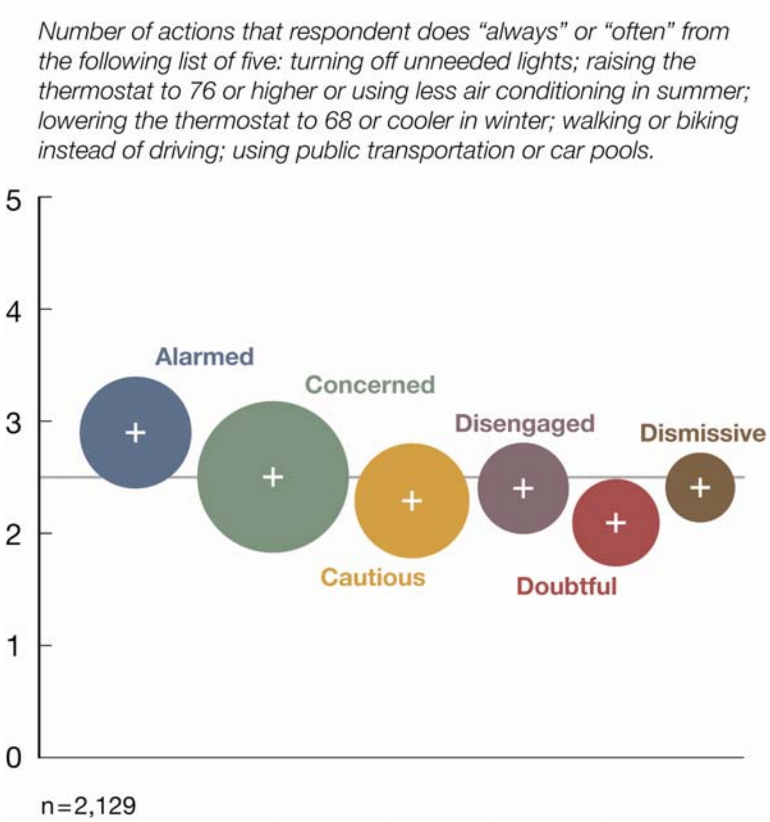
Energy Conservation: Changing how We Interact with Energy-Consuming Products

The story of people's responses to energy conservation options is a bit more nuanced—mostly because certain energy conservation behaviors are widely embraced, and others not so—but the moral of the story remains the same: people in all six Americas report that they are routinely performing energy conservation actions at more or less the same rate (Figure 7). Regularly (always or often) turning off lights is a well-ingrained habit for the vast majority of people (93%); that rate varies only slightly among the six Americas (87 to 97%). Adjusting the heat and air conditioning to use less energy are somewhat less well-ingrained habits. Specifically, 56% of people regularly set their thermostat higher or otherwise use less AC in the summer (a rate that varies across the six Americas by 51% to 64%), and 63% regularly set their thermostat lower in the winter (a rate that ranges from 56% to 74% across the six Americas).

> *I do see some value in reducing emissions just because it increases fuel economy and there's a practical element to that.* (Dismissive Male, Age 18-30)

Most Americans are still driving, and mostly alone. On average, only 17% of people (ranging from 7 to 26% across the six Americas) always or often use public transportation or car-pool instead of driving, and only 19% (ranging from 9 to 33%) always or often walk or bike instead of driving. It is worth noting, however, that members of the most concerned Americas—the Alarmed and the Concerned—are indeed far more likely than members of the least concerned Americas to use non-single occupancy motor vehicle options.

Figure 7: Number of Habitual Conservation Actions



Many people in all six Americas report that they intend to take one or more of these conservation actions more frequently in the coming year. Among those who don't intend to perform these actions more frequently, the most commonly reported reasons they don't intend to take more frequent action at home—consistent across all six Americas—is that people feel they are already performing the action as much as they can: 85% (ranging from 75 to 90%) say they turn the lights off as frequently as they can; and 54% (50% to 58%) say they are already adjusting the heating and cooling system settings as much as they can. In all likelihood, many of these people could do more, but the important thing is that they feel they've done as much as they as they can. The most commonly reported reasons for not intending to conserve more frequently on the road—which, again, are remarkably consistent across the six Americas—are the inaccessibility (70%) and inconvenience (27%) of public transportation and car pool options, and the distances involved being too far for cycling and walking (54%).

We asked people who intended to conserve more frequently in the coming year why they intended to do so. Their answers to these questions were immensely revealing. With only one exception—walking & biking instead of driving—the top-tier motivations among all six Americas are saving money (92%, 87%, 89% and 73% for lighting, cooling, heating, and public transportation, respectively) and saving energy (86%, 82%, 81%, and 62%). Improving health (76%) is the top-tier motivation for intending to walk & bike more, followed closely by saving money (74%).

There are interesting and potentially important differences as well as commonalities among the second-tier motivations across the six Americas. As one might expect, reducing global warming is a very common motivation for the Alarmed (ranging from 68 to 85% across the five behaviors), dropping significantly from there for each of the other Americas, to 35-64% for the Concerned, 15-29% for the Cautious, 4-26% for the Disengaged (4 to 26%), and negligible and non-existent, respectively for the Doubtful and Dismissive. Conversely, a sense of morality ("it is the moral thing to do"), feeling good about oneself ("it makes me feel good about myself"), and complying with the wishes of another person ("someone asked me to") are important second-tier motivators for at least some portion of all six Americas.

For the three forms of home energy use we measured—lighting, heating and cooling—conservation appears to be a less promising avenue to reduced energy use than efficiency improvements. The vast majority of respondents say they are already turning off the lights as much as they can, and campaigns to remind people of the importance of turning off lights tend not to reach people at the point when they need to be reminded—i.e., when they're leaving a room. The most promising way of reducing the electricity consumed by lighting is therefore likely to be through the installation of energy-efficient lighting and light-sensing switches that turn off lights automatically when the room is empty.

Similarly, over half our respondents feel they are already reducing heating and cooling of their homes as much as possible, so programmable thermostats that control the temperature automatically are the simplest way to overcome the forgetting to which we are all vulnerable. Further, improvements in home insulation can maintain home comfort while still reducing energy use, thereby overcoming people's unwillingness to live with the discomfort of a house that's too warm in summer and too cold in winter.

In terms of transportation choices, changes to our physical environment, rather than changes in people's motivations, are the most likely path to reduced energy use. With an average commute distance of 16 miles,[6] walking and cycling to work is an infeasible commuting option for most Americans. Communities in which home and work are minutes apart—as well as more convenient, safe, and comfortable public transit options—are needed to overcome the barriers people face in reducing the time they spend in the car. The good news is that if these barriers can be reduced, the American people appear ready and eager to make changes that will reduce their time spent on the road—only 16% report that they enjoy commuting alone, and a mere 3% believe that conserving energy in transportation is unimportant.

Educational campaigns that focus on energy conservation can be useful, nonetheless, to enhance the salience of the issue, remind (or cue) people to perform the actions, and to reinforce the benefits large number of Americans already associate with the actions– saving money, conserving energy, feeling good about oneself for acting in a moral way, and sharing the benefits of conservation with loved ones. And for those who are concerned about global warming, the message that conservation behavior is contagious—that, on average, the actions of a single individual influence 1,000 other people who learn from example—can be highly empowering.[7]

[6] Data from an ABC poll conducted in 2005; poll results are available at http://abcnews.go.com/Technology/Traffic/story?id=485098&page=1

[7] Thompson, Clive (Sept. 10, 2009). Is happiness catching? The New York Times, available at, http://www.nytimes.com/2009/09/13/magazine/13contagion-t.html?_r=1&hpw

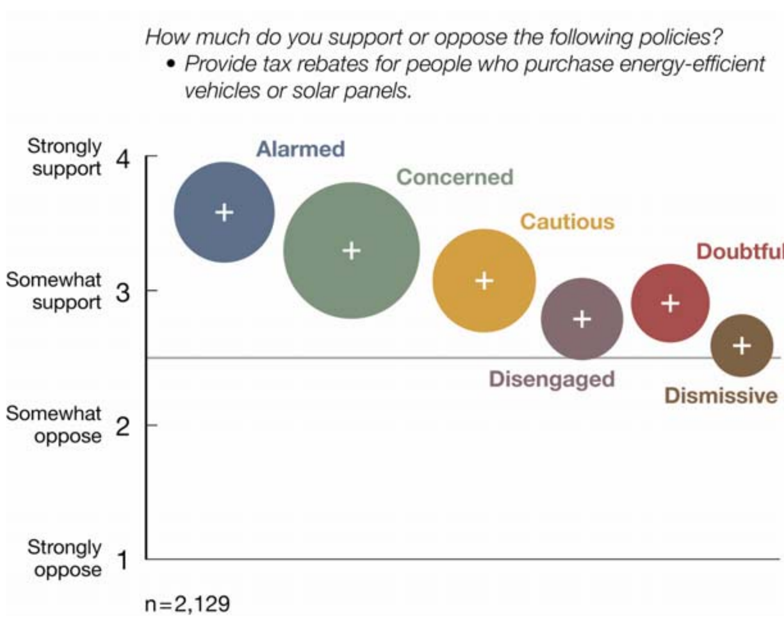
Policy preferences

Only two of the energy policies we inquired about earned support from a majority of each of the six Americas: funding more research into renewable energy sources (92% support overall, ranging from 72 to 99% across the six Americas) and providing tax rebates for energy efficient vehicles or solar panels (85%, ranging from 58 to 96%; see Figure 8). Excluding the Dismissive segment (who compose only 7% of the population), however, a number of additional energy policies receive majority support from the remaining five Americas: regulating carbon dioxide as a pollutant (80%, ranging from 53 to 96%); requiring automakers to increase the fuel efficiency of vehicles (79%, ranging from 62 to 94%) (Figure 9); and requiring utilities to expand their renewable energy portfolios (72%, ranging from 50 to 91%). With the exception of regulating carbon dioxide, these policies target increasing energy efficiency and changing to cleaner energy sources either through government funding or implementation of new industry standards with no economic drag on energy usage.

The overwhelming support for each of these policies provides a very strong basis to invest in these areas.

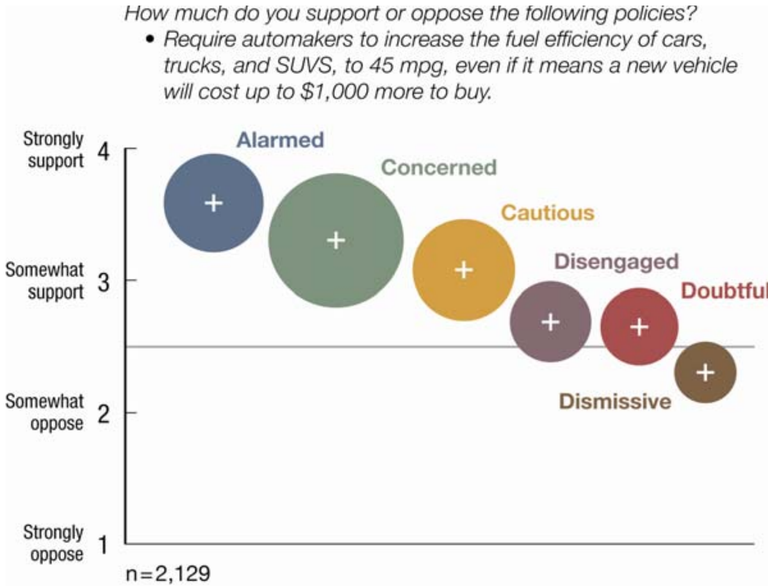
Conversely, the least popular policy options—a gas tax (supported by 33%), and cap-and-trade (53%)—impose direct or indirect costs upon individuals that are intended to reduce carbon-based energy consumption. As people are extraordinarily loss averse—in this case regarding money and energy use—it is not surprising that the latter two policies have drawn little enthusiasm from among the public.

Figure 8: Support for providing rebates for purchases of solar panels and fuel-efficient vehicles



Conclusion

Figure 9: Support for requiring automakers to manufacture more fuel-efficient vehicles



The aggregate choices of individuals, businesses and municipalities can alter U.S. energy use through transformation of consumption patterns, increases in equipment efficiency, and new transportation behaviors (EPA, 2009). Our data show that there is ample opportunity to promote a wide range of energy efficiency and conservation actions, and a somewhat more constrained set of national energy policy options based on broader support on the issue of energy across the six Americas. Although we did not dwell on it here, there is also strong public support for more action by state and local governments, and a strong degree of both consumer sentiment and consumer behavior intended to encourage businesses to do more as well.

In light of our findings, the case for energy efficiency programs—in addition to aggressive energy policies -- appears particularly compelling. Consumer demand is strong, and the barrier to action can be reduced through development and appropriate programs (e.g., cash for clunkers) and supportive informational campaigns.

Of particular interest, Gardner and Stern (2008) found that energy efficiency improvements—which must only be performed one time - save more energy and reduce more emissions than conservation habits, which must be performed repeatedly. For example, installing attic insulation and ventilation can save up to 5% in home heating energy and 2% in cooling energy compared to 2.8% and 0.6% savings gained via thermostat adjustments in winter, and summer, respectively. Buying a fuel-efficient car similarly result in fuel savings of 13.5% on average, compared to carpooling (up to 4.2%) or combining errands to reduce mileage traveled (up to 2.7 percent).

One additional finding about the motivations for energy-saving actions is well worth noting. By more than a 2-to-1 margin, Americans believe that making changes to reduce their use of energy will improve—not undermine—the quality of their lives. This suggests that programs to promote energy savings should not be framed as requiring sacrifice (Nisbet, 2009; Nordhaus & Schellenberger, 2007) but rather should be framed as an important opportunity to accrue many compelling benefits, some directly to ourselves, and others to the nation and the world.

Funding for our research was provided by The Yale Center for Environmental Law and Policy, the Betsy and Jessie Fink Foundation, the 11th Hour Project, the Pacific Foundation, and a

RWJF Investigator Award in Health Policy Research from The Robert Wood Johnson Foundation.

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Segmentation in Practice

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"The good news is that in our analysis, the high priority segments appear to make up 50-60% of residential customers."

Introduction

Market segmentation has been shown to be a powerful tool in speeding customer adoption of products, services, or desired behaviors, from computers and software to beverages and restaurants, to reducing tobacco use.[1] Consider, for a moment, the success of Apple's Mac strategy to capture the creative thinkers (and their pocketbooks) of the world, first by focusing on educators and graphic artists and then by appealing to other segments who want to "think different." Who doesn't know these two guys?

Our research began because utilities and other energy efficiency organizations across North America have become increasingly interested in better understanding the various subgroups—segments—of their residential customers. We set out to see what might be learned by examining how seven of these organizations[2] are conducting and applying segmentation research. We also secretly hoped that a magical set of customer segments would reveal themselves. This was naïve, as you shall see below. Be prepared: more than one useful segmentation scheme exists and segmentation is not for the faint of heart.

Overall, we hope readers will gain a better understanding of both the benefits and challenges of incorporating market segmentation into the design and evaluation of their energy efficiency programs and marketing. We also hope the journey through this chapter will lead you to embrace our conclusions:

[1] Moss (2008), p. 6; McDonald and Dunbar (2008); Lutzenhiser (2008)

[2] Many thanks to Energy Trust of Oregon for funding the research project upon which this chapter is based and for its evaluation staff who provided Energy Trust's segmentation research and continuing analytical help. Thanks also to the six other organizations who kindly made their segmentation research and insights available: Tacoma Power, Puget Sound Energy, BC Hydro, Sacramento Municipal Utility District, Snohomish County Public Utility District, and Bonneville Power Administration.

- Segmentation requires commitment (more than you think)
- Segmentation produces surprising, even startling, consumer insights
- Segmentation can lead to substantial energy savings
- Segmentation is powerful
- Regional segmentation approaches may be especially potent
- Segmentation leads to more communication with customers: this is very good marketing

We used a variety of resources in our analysis, including a review of materials provided by the seven agencies, interviews with key contacts at those agencies, and other articles and books on segmentation. Still, it is important to note that segmentation is a complex topic and we had to make some leaps of faith to be able to compare the process and results of disparate approaches.

Segmentation Basics

The next sections briefly define segmentation and its history and rationale, provide a cautionary note about the art and science of segmentation, discuss the need to integrate segmentation research into a broad cycle of activities, and list essential steps in the segmentation process.

First, a Definition

Segmentation schemes divide markets into distinct groups based upon their shared characteristics, needs, and preferences. Programs and marketing can then be tailored to reach the groups with the most potential to use services, buy products, or make behavioral changes. Segmentation assumes that markets (for instance, the residential energy consumer market) are heterogeneous rather than uniform, and that they require targeted marketing and program approaches that recognize their diversity. Segmentation is consistent with key marketing principles such as "know your customers" and "put customer needs and preferences first."

A Brief History

Although energy efficiency agencies have used complex consumer segmentation approaches in the past (e.g., collecting consumer lifestyle, value, and attitude data and using software, such as PRIZM and VALS to segment customers), most segmentation has **not** been based on a nuanced understanding of consumer preferences and needs. Rather, customers are pegged into conventional utility categories such as type of customer or rate structure (e.g., residential, commercial), geographic location ("east of the mountains") or climate zones, building types (e.g., single family, multi-family), and types of appliances (e.g., washing machines). In some cases, demographics and building or business characteristics have been added into the mix. And while attitudinal and behavioral questions have been asked on many surveys, these have generally not been factored into segmentation schemes, although they have been used to craft marketing messages.

In addition, by focusing on policies and programs that favor reducing energy use through technological fixes, as per the "physical-technical-economic model" or PTEM,[3] the energy

[3] See, for instance, Lutzenhiser (2008) and Sullivan (2009).

efficiency industry typically targets one type of behavior change—adopting energy efficient technologies over less efficient alternatives—rather than a broader set of behaviors that could influence adoption of a wider conservation ethic. The PTEM approach assumes consumers—whether business or residential—are rational, knowledgeable decision-makers who are influenced primarily by a positive cost-benefit calculation over the life of a product. While programs based on this paradigm have been effective, most efficiency experts would agree that "a significant gap...exists between the level of energy efficiency investment that is economically justified and the level of such investment that is being achieved." (Sullivan 2009).

Thus, it is time to revise the paradigm to include a behavioral perspective.[4] Over the last several decades, behavioral economics and brain research have questioned our most basic assumptions about how people think and make decisions. This research suggests that human decision-making often is neither rational, nor economically driven (see, for instance, Ariely 2009, Thaler and Sunstein 2008, and Medina 2008), but is ruled by habits, expectations, brain structure, and social norms.

When done correctly, segmentation can incorporate this new knowledge into efforts to change behavior in ways that reduce energy use, from buying highly efficient appliances to turning off computers when not in use.

A Cautionary Note

Across the board, our sources all emphasized that successful segmentation requires experience, judgment, science, flexibility, patience, and organizational commitment.[5] Clear thinking, multi-talented, and persistent people with research design, statistical analysis, and data management skills need to be on board, along with program and marketing experts. Studies have shown, for instance, that even small changes in consumer data or analysis approaches can result in different segmentation solutions. One contact reported that in their second segmentation survey they added a single question about a customer's willingness to trade off comfort and energy use. During their analysis, they eventually discovered this question confounded their results (Pederson 2009). After considering various explanations, they concluded that while the variable may be important, the way they measured it needed to be improved. When they removed the question from the analysis, the previous segments fell into place.

As Horn and Huang (2009) state when comparing statistical methods for segmentation approaches: "*Although there can be a great deal of sophistication in the analysis stage, segmentation is not a purely scientific pursuit. Sadly, there are no magic buttons to press to generate the "best" segments. Given that . . . the basics are addressed, category experience and expert judgment are the final guides to the selection of the "best" segmentation solution.*" In other words, segmentation is as much art as it is science.

[4] Note ACEEE's April 2009 testimony on the need to support behavioral research and apply behavioral insights to energy efficiency efforts before the United States House Committee on Science and Technology, Subcommittee on Energy and Environment.

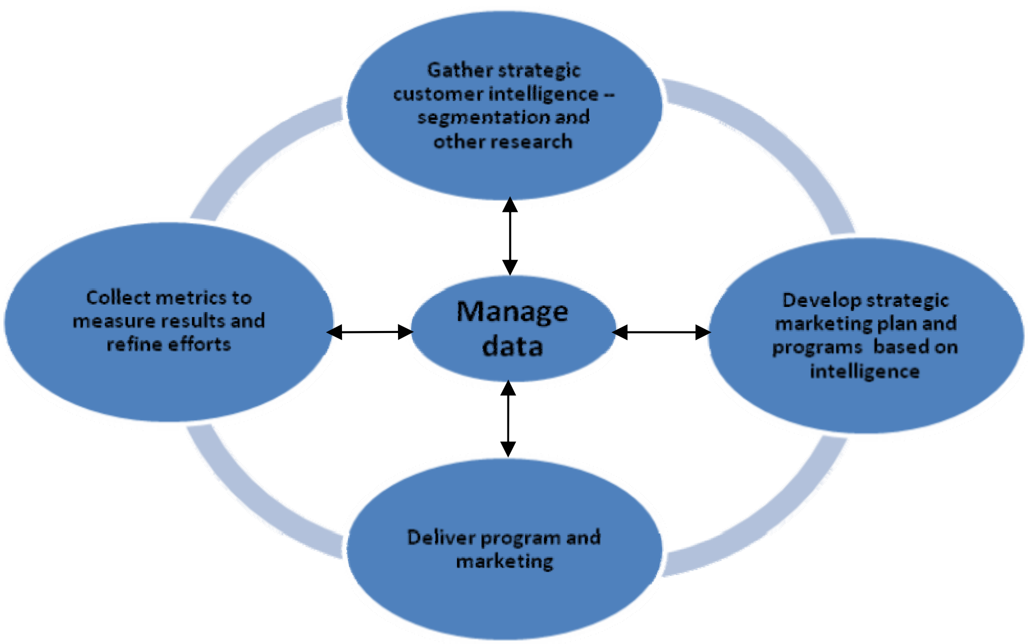
[5] See, for instance, Horn and Huang (2009) and McDonald and Dunbar (2008). Interviews with utilities representatives who are using segmentation research also support this viewpoint.

Horn and Huang recommend trying more than one statistical approach and matching approaches to segmentation uses. For instance, they say some techniques are better for marketing (e.g., factor segmentation) and some are better at analyzing patterns of needs for new product development (e.g., cluster analysis and K-means analysis).

Using Segmentation Research

Sources agree that segmentation research helps build an evolving roadmap of how to reach and influence customers, especially when used in conjunction with the process of developing, marketing, delivering, and evaluating programs (see Figure 1). But without this type of concerted process to use them, segmentation studies are likely to sit on the shelf. As one contact noted, many energy organizations put the cart before the horse: they design programs and then try to find customers rather than seeking to understand customers' needs. This means that most planning and implementation is based on "experience and the seat of their pants." He added that taking a customer-based focus and relying on research to make decisions can require difficult changes in organizational thinking and action.

Figure 1. Using Segmentation Research to Design and Refine Programs



Source: Adapted from Carlson (2009)[6]

[6] This presentation is available on request from the author of this report.

Steps in the Segmentation Process[7]

As we've mentioned, effectively conducting and applying segmentation research requires broad organizational support and long-term commitment. This section amplifies the process shown in Figure 1 by listing essential steps for a successful marketing/segmentation process:

1. **Assemble a cross-department team that meets regularly from the beginning, and for the long term.** Top management must be invested from the get-go. Six of the seven agencies included in this research had done this. The earlier the team was formed, the more inclusive and integrated it was, and the more regularly it met, the better the progress. The one organization lacking a team had not yet been able to apply the research. Depending on the organization and who is involved with understanding and reaching customers, members might represent:
   - Evaluation
   - Market research
   - Marketing and communication (internal and external)
   - Program planners and implementers (including contractors)
   - Data management
   - Research vendors

   In addition, one or more of the team members needs to evolve as a segmentation champion—someone who ensures continued resources to support segmentation efforts over time. Such champions need to have high enough status within the agency to work effectively with top management.
2. **Develop a research plan.** In any research plan, the big question is, "What do we need to learn from this research?" A segmentation research plan is no different. It needs to:
   a. **Define objectives, the ultimate objective being to implement the program. Some important questions include:**
      - How large is the target market? How large is each segment?
      - What is the best way to describe each segment?
      - What segments should be the highest priority?
      - What segments fit what program designs?
      - How do program participants fit (e.g., the percent in each segment)?
      - What are the primary needs of each segment?
      - What does each segment value about programs or services offered?
      - How sensitive is each segment to price?
      - What messages best connect with each target?
      - What channels of communication work the best for each target?

   b. **Decide on approaches, methods, and other issues:** Reviewing experience at other utilities can help, and data gathering may need to include both qualitative and quantitative approaches:
      - Qualitative research, such as focus groups, in-depth interviews, and ethnographic observations, can prevent important consumer dimensions from being missed in the quantitative research.

[7] This process is adapted from Carlson (2009), McDonald and Dunbar (2008), and from reports and interviews with the organizations included in this study.

- Quantitative research for segmentation has mostly been done with fairly typical survey questionnaires, often with quite large sample sizes and of considerable length (30+ minutes).
- Other important issues include how to collect data; whether to hire an outside vendor; whether to provide incentives to respondents; mapping out statistical approaches to develop segments;[8] defining the population, the sample size, and sampling methods; how to link results to other data (e.g., customer databases or media); and determining what metrics to use to assess the effectiveness of the segmentation scheme.

c. **Define quantitative variables:** This step entails thinking about which dimensions you want to drive the segmentation and which variables will be used to further describe the segments. Taken together, variables might include behaviors, attitudes, or values related to energy use (e.g., about the environment, the utility, comfort, costs, empowerment, community well-being), program participation, housing characteristics, media use, sources of energy information, energy use, and demographics.

- Basis variables are a fairly contained group of variables that sort customers into the segmentation categories. SMUD, for instance, decided that its basis variables needed to be those that matched information in its customer database, such as program participation and kWh usage. At BC Hydro, however, the basis variables are psychographic, mostly a mix of attitudes and behaviors.
- Profiling variables are then added to better describe each of the segments; these will vary depending on the selection of the basis variables. For instance, segments might be profiled by their income and education levels, their home's square footage, or by the fuel they heat their homes with.

d. **Develop survey instrument and collect data:** The final survey instrument will vary according to segmentation purposes, methods, variables, and resources. The segmentation team needs to be involved throughout, even if design is primarily in a vendor’s hands.

e. **Develop segments and apply profiling variables:** To be a workable, segmentation schemes need to be made up of segments that are:[9]

- Consistent with customers who make decisions affecting energy use that we want to influence
- Measureable in terms of characteristics and size
- Large enough to justify spending time and effort on reaching and influencing them; most schemes have five to eight segments.
- Reachable through available marketing communications tools
- Unique, with each segment homogeneous and heterogeneity between segments
- Actionable—identifiable and responsive to influence

[8] See Horn and Huang (2009) for a good primer that compares statistical approaches.
[9] This list is a composite based upon several resources already listed and from personal communication with Arien Korteland at BC Hydro who provided a list from De Gouw and Rustenburg, Dutch segmentation experts.

- Aligned with business/organization purposes, capabilities, and interests, so that the sponsoring organization can make the needed changes to focus on the segments
- Relatively stable over time (at least in terms of characteristics)

f. **Present findings and design strategic marketing:** Once the segments are in place and well defined in memorable and understandable terms, then it's time to present the findings to a wider group of top management, planners, program management, and communications people. The segmentation team will then need to begin work with others in the organization to:
   - Prioritize and select customer segments to target based on their size, their reachability, programs available or planned, media outlets, utility priorities, and other factors
   - Develop statements of customer needs and values that align with program design
   - Develop marketing and communications plans, including messaging and media
   - Define how success will be measured and tracked

g. **Implement program and communications campaign:** A key element of program delivery will be to set up ways to track response. For instance, direct mail response cards can be coded; unique phone numbers can be used to monitor incoming calls; Web site activity can be tracked; programs can have Web components where participants fill out "short form" surveys that will show sponsors what segment they fall into; and contact centers can be trained to code incoming calls. If a pilot program is to be launched, market assessment or follow-up surveys can include the short form segmentation questions.

h. **Create and apply metrics and feed results back into next steps (program and communications refinement and further research):** Elements for this step include:
   - Creating a data system that allows easy storage of and access to data, and the ability to link different data sources
   - Creating metrics such as participation rates, segment response, cost per recruited participant, Web site activity, energy savings, return on investment, cost-benefit analysis, etc.
   - Identifying needed customer intelligence, program gaps, and program improvements

The Seven Studies

The following studies are included in this analysis. All were based on surveys of residential consumer households.

1. **Energy Trust of Oregon (Energy Trust or ETO)—**covered the entire service territory, which includes the areas served by four investor-owned electric and gas utilities in Oregon, and encompasses most of the state's metropolitan areas.
2. **Northwest Segmentation (NW)—**used a similar survey and segmentation approach, encompassing the residential customers from the utilities listed below. The results can be examined at the utility level but could also be aggregated across the utilities,

which the sponsors hope would foster a more unified and region-wide understanding of residential customers.

a. **Puget Sound Energy (PSE)—**covered the entire service territory,[10] which includes 11 counties (6,000 square miles) in the Puget Sound area.

b. **Snohomish PUD (SnoPUD)—**covered the entire service territory of 2,200 square miles, including Snohomish County and Camano Island in Washington State.

c. **Tacoma Power (Tacoma)—**covered the entire service territory of 180 square miles, including the City of Tacoma, several surrounding cities, and other areas of Pierce County, Washington.

d. **Bonneville Power Administration (BPA)—**covered the entire service territory, excluding the three *Puget Sound Area* (PSA) utilities that had conducted their own studies (PSE, SnoPud, and Tacoma) and any customers of electric investor-owned utilities (IOUs). In addition to the whole sample, the study looked at four regions.[11]

3. **BC Hydro—**covered the entire service territory, which includes 94% of customers in British Columbia.
4. **Sacramento Municipal Utility District (SMUD)—**covered the entire service territory of 900 square miles and which includes Sacramento County and a small portion of Placer County in California.

Segmentation Study Purposes and Methods

Purposes and methods varied across the studies. Table 1 is based upon our interpretation of the purposes of the seven segmentation studies. A large check reflects what appeared to be a key purpose, a smaller check reflects a secondary purpose, and no check means we found no evidence of that purpose. As the table shows, the studies were similar in purpose, at least at a general level. Most efforts were focused on informing energy conservation program design and outreach/marketing efforts; some studies were more focused on improving programs, either current, future, or both.

Five of the studies were singularly focused on developing segmentation schemes, while two (Energy Trust and BC Hydro) had other information needs unrelated to segmentation. For Energy Trust in particular, multiple purposes reduced the amount of survey space available for segmentation questions. The BPA study incorporated some unique purposes since it is a wholesale electricity provider to many Northwest utilities. For instance, BPA hoped the study could provide tailored information to its wholesale utility customers and be combined with other segmentation results in the Northwest to gain a regional perspective.

[10] Based on an interview with PSE staff and other sources, BPA, Snohomish PUD, and Tacoma Power all based their segmentation analysis on the same set of variables as those used for the PSE study, which was the first study to be conducted. The PSE segments were then used as “starting points” to develop segments for the other three. However, each sponsor also included some non-segmentation items that were tailored to its needs. The BPA survey instrument is used to represent the variables used by all four sponsors.

[11] The four regions were Western Washington; Western Oregon; East/Central Washington/Eastern Oregon (and California); and Idaho and West Montana/Nevada/Utah/Wyoming.

All the segmentation studies are fairly recent, and two have been repeated this year; only information from ETO's 2009 study is presented in Table 1. The segmentation studies varied widely along a number of methodological dimensions (see Table 2). Even the PSE, SnoPUD, Tacoma, and BPA studies, intended to be alike, had some notable differences. Sampling approaches and sample sizes varied considerably. These utilities used different methods to contact their customers, including telephone, mail, and e-mail. Most used just one method, but BC Hydro and SMUD used a mix. Survey length also varied. All studies used high level statistics in their analyses. While the specific statistical methods varied, some studies used more than one approach. Energy Trust, the PSA utilities, and BPA relied strongly on outside consultants to conduct the segmentation studies, while BC Hydro and SMUD used both internal resources and consultants. The resulting number of segments ranged from 5 to 8.

Table 1. Comparison of Stated Segmentation Purposes

	ETO	PSE	SNOPUD	TACOMA	BPA	BC HYDRO	SMUD
Segmentation primary or shared study focus	**Shared w/ tracking study**	**Primary**	**Primary**	**Primary**	**Primary**	**Shared w/ tracking study**	**Primary**
Develop workable segments	✓	✓	✓	✓	✓	✓	✓
Better understand customer motivations	✓	✓	✓	✓	✓	✓	✓
Support/improve current program implementation	✓	✓	✓	✓	✓	✓	✓
Support marketing, messaging, and communications	✓	✓	✓	✓	✓	✓	✓
Better target communications channels	✓	✓	✓	✓	✓	✓	✓
Develop new programs	✓				✓	✓	✓
Provide tracking data/benchmark for future	✓					✓	
Prioritize targets/predict, improve participation	✓	✓	✓	✓	✓	✓	✓
Provide utility customers tailored, local info					✓		
Develop regional "playbook"		Persuaded others to join	✓	✓	✓		

Table 2. Comparison of Key Methods across Studies

	ETO	PSE	SNOPUD	TACOMA	BPA	BC HYDRO	SMUD
Year Fielded	2008 (also 2009)	2007	2008	2008	2008	2006 (also 2009)	(also 2003) 2007
Sample Size	1,205 (904)	1,002	800	800	2,001	4,338	3,629
Method of Contact	Phone	Phone	Phone	Phone	Phone	Mail and on-line	Phone & on-line + customer database
Survey Length	19 minutes	34 minutes	34 minutes	34 minutes	34 minutes	30+ minutes	30 minutes
Included Energy Use	Yes	No	No	Yes	No	Yes	Yes
Special Notes	RDD by zip code, and purchased renter list Quotas	Utility-drawn sample Quotas $10 incentive	Utility-drawn sample Quotas $10 incentive	Utility-drawn sample Quotas $10 incentive	Listed sample Quotas Oversampled rural $10 incentive	Utility-drawn sample Weighted by housing type Over 14,000 surveys sent—31% response Rs entered in $500 drawing as incentive	Chose segments based on overlap of database and survey variables. Segmentation solution then applied to survey respondents and then whole customer database scored.
Segmentation Statistical Approach	Factor Analysis, Regression, Two-Step Cluster Analysis	Latent Class Cluster Analysis	Latent Class Cluster Analysis	Latent Class Cluster Analysis	Comparison to PSE distributions Latent Class Cluster Analysis	Principal Components Analysis (like Factor Analysis) Cluster Analysis	Cluster Analysis followed by Discriminant Function Analysis
Segment Design	Consultant	Consultant	Consultant	Consultant	Consultant	In-house + consultant	Consultant plus in-house
Number of Segments	5 (6 in 2009)	7	7	5	8	6	8

Comparison of Segmentation Variables

> *Demography is not the only or the best way to segment markets. Even more crucial to marketing objectives are differences in buyer attitudes, motivations, values, patterns of usage, aesthetic preferences, and degree of susceptibility. Daniel Yankelovich, Harvard Business Review, 1964*

The seven segmentation studies we analyzed used hundreds of variables and their variations. Our detailed analysis, too large to present here, showed that about 50 key basis and profile variables overlapped to some degree but that many variables were unique.[12] While our detailed analysis was rather unwieldy, it taught us that only at a more granular level can one understand the complexity and variety of these schemes. While higher levels of comparison are useful, the devil is in the details. For example, Table 3 shows that the key variables used in Energy Trust's 2008 segmentation scheme may or may not be represented in the other six schemes, and, even if they are represented, they may be used differently.

These disparities clearly stem from valid but dissimilar research goals and priorities. ETO's 2008 study focused on predicting energy use, relied largely on awareness and behaviors, and didn't use attitudes at all; it also had limited space for segmentation variables. SMUD wanted segments that could be applied to its customer database to predict program interest and participation. This resulted in a smaller set of basis variables that matched its customer database. The other five studies put greater emphasis on marketing, messaging, and in-depth descriptions of customers, so they gathered and used a much wider range of attitudes, beliefs, and behaviors to form their segments and to profile them. While this resulted in very rich customer descriptions, these utilities share the challenge of how to identify members of the segments.

[12] Please contact the author if the more detailed analysis would prove useful.

Table 3.Comparison of Eto 2008 Basis Variables to Presence in Other Studies*

VARIABLES ETO BASIS VARIABLES ARE 1-11	ETO 2008 11 BASIS VARIABLES	PSE	SNOPUD	TACOMA	BPA	BC HYDRO 33 BASIS VARIABLES—10 KEY DRIVERS + 23 OTHERS	SMUD 3 TYPES OF BASIS VARIABLES
		20 OF BPA'S 90% GEARBOX** ITEMS USED AS BASIS VARIABLES					
Energy Use	**Profile**	Not included	Not included	Profile	Not included	Profile	Basis
1. Aware of sponsor's EE programs	**Basis**	Profile	Profile	Profile	Profile	Not included	DK
2. # of EE programs R aware of	**Basis**	Not included	Not included	Not included	Not included	Not included	DK
3. Aware of OR Tax Credit	**Basis**	Not applicable	Not applicable	Not applicable	Not included	Not applicable	Not applicable
4. Know where to get renewables info	**Basis**	Not included	Not included	Not included	Not included	Not included	DK
5. Participate in EE programs/get rebates	**Basis**	Profile	Profile	Profile	Profile	Not included	Basis
6. Energy Star/EE appliance purchase(s)	**Basis**	Profile	Profile	Profile	Profile	Not included	DK
7. CFLs in home (presence/#)	**Basis**	Profile	Profile	Profile	Profile	Profile	DK
8. Number of CFLs installed	**Basis**	Profile	Profile	Profile	Profile	Profile	DK
9. Home ownership	**Basis**	Profile	Profile	Profile	Profile	Profile	Basis
10. Home heat source	**Basis**	Profile	Profile	Profile	Profile	Profile	Basis
11. Households w/children	**Basis**	Profile	Profile	Profile	Profile	Profile	Profile

* This table analyzes basis variables from ETO's point of view. It does not show the profile variables used for the ETO analysis or other basis and profiling variables used in other studies. Please see Table 4 for a comparison of other key variables.

** The BPA "Gearbox" is a short set of 24 variables that can predict with 90% accuracy in what segment a customer belongs. Based on the Tacoma full findings report, we classified 20 of these variables as basis variables; the 4 remaining gearbox questions and other descriptive variables were classified as profile variables.

Finding Meaningful Comparisons across Segments

The seven studies produced 28 segments, dashing our initial hope that a smaller set of profound and useful segments would emerge from our efforts. In addition, it simply wasn't clear how to compare the segments. In our larger study, we compared them on three fronts: their priority as targets for conservation programs; their relative rankings in terms of energy use; and their position on the 'green to brown' scale of attitudinal rankings that the four Northwest utilities used.

Our first comparison of segments—according to their priority as targets for energy conservation efforts—is based on whether segments have enough:

- **Concern** to take action[13]
- **Capacity** for savings
- **Conditions** that permit action

All three of these characteristics are necessary in order for people to take positive conservation actions. All of the studies allowed analysis of these segments through this lens, so that we could prioritize segments and suggest marketing themes for testing. We were able to reduce the segments to the following ten broad, but fairly distinct, types of customers.[14] *The good news is that in our analysis, the high priority segments appear to make up 50–60% of residential customers.*

1. **The Usual Suspects—High Priority.** Stable, affluent, homeowners who are very concerned about green issues, who have taken steps to save energy—including participation in utility programs—but who have high use and could save more.
2. **The Well Intentioned—High Priority.** Stable mid-income homeowners whose actions do not match their high green concerns.
3. **The Average—High Priority.** Stable, less affluent homeowners who have little concern for green issues and have taken few steps to save. Most could cut use and they want to save money.
4. **The Too-Busy—Medium Priority.** Stable low-to-mid-income homeowners with families who have some concern for being green but don't have time to do much more than keep up with their other obligations.
5. **The Value-Driven—Medium Priority.** A mix of older stable homeowners with various levels of income whose values drive them both to purchase efficiency improvements and to conserve through behavioral means. Their energy use is already low.
6. **The Comfort-Driven—Medium Priority.** Stable affluent homeowners interested in home improvement and comfort but who are not interested in reducing energy use for its own sake, and who do not identify with being green.

[13] Adapted from a theory by Kunkle et al. (2004).
[14] We hesitate to add more segment monikers, but have tried to make them as clear as possible. We also acknowledge that ten segments may be too many.

7. **The Cost-Driven—Low-Medium Priority.** While they are often stable homeowners who are driven by the desire to save money, they already use very little energy.
8. **Tomorrow's Suspects—Low-Medium Priority.** Young lower-income renters who identify strongly with being green, and want to do much more than their situation allows.
9. **The Young and Clueless—Low Priority.** Young lower-income renters with little interest in the environment.
10. **The Disinterested—Low Priority.** This group of stable homeowners has ample opportunity for energy savings, but cares neither generally about the environment, nor specifically about reducing energy use.

Applying Segmentation Results

This section summarizes the progress of at each of the seven energy agencies and the lessons learned so far. As shown in Table 10, PSE, BC Hydro, and SMUD, which have been pursuing segmentation the longest, have top down support, strong champions, and are going strong. This has lead to an integrated approach of using the data to help formulate marketing and programs and then collecting data during program operation to feed back into the segmentation work. SnoPud and BPA are also moving ahead with a variety of efforts, while Tacoma and Energy Trust have faced more challenges and are less far along.

Table 4. Indicators of Segmentation Use Progress

	ETO	PSE	SNOPUD	TACOMA	BPA	BC HYDRO	SMUD
Organizational Buy In?	Low	Strong champion, high level support, sold on it	Good high level support	No clear champion, limited high level support	Strong champion and good high level support	Strong champion, good high level support	Strong champion, high level support, sold on it
Use So Far by Organization?	None	Ongoing and active integration	Ongoing and evolving integration	Some integration with marketing	Much in the works/affects BPA and utility customers	Ongoing and active	Ongoing and active
Time Involved	2 years	3 ½ years	3 years	3 years	3 years	3 ½ years	6 years
Integration with Customer Database or Other Data?	Low	Some and working hard to develop	None yet due to data issues; new database coming	Low though sample included use	Low	High	High
Used in Marketing?	No	Yes	Yes	Yes	In process	Yes	Yes
Used in Program Design?	No	Yes, some	Yes, some	No	In process	Yes	Yes
Used for Further Research and Refinement?	Refined segments in 2009 study	Yes, focus groups, survey panel, surveys	Yes, focus groups, will use with survey panel	No	Segmented utilities, more to come	Yes, focus groups, surveys	Yes, focus groups, surveys
Short Form Questionnaire?	No	Yes	Yes	Yes	Yes	Yes	DK

Conclusions

Segmentation Requires Commitment

Almost every utility contact said that segmentation required more commitment and work than they had ever imagined. Support and buy-in for the long term needs to be built throughout the organization, and must include top management and interdepartmental involvement, especially for data management. There must be ample resources for ongoing research and tracking efforts, and for publicizing and integrating program results and consumer insights. One utility added a liaison who makes sure that segmentation is considered in the development of program designs and in evaluation plans. Segmentation requires a highly integrated approach, as we suggested in Figure 1.

Even leaders in the agencies whose segmentation efforts are well underway said they had a long way to go, or that they could still be surprised at the level of resistance to certain segmentation efforts. For instance, one contact said they had undertaken a branding effort—in part based on the segmentation research—to change the utility's image from one focused on reliability to one focused on helping customers save energy today to ensure a better life in the future. They had done a great deal of research which was then applied in a successful campaign. However, it has been difficult to get top management to buy into this change so that the new image would be maintained over the long term.

Segmentation Can Produce Surprising Customer Insights

Representatives from several utilities said it is all too easy to rely on anecdotal, habitual, and seat of the pants approaches to reaching customers, rather than carefully trying new approaches and measuring the results. However, they said that the requirements of segmentation research forced them to take a more rigorous approach to understanding the complexities of their customers. They emphasized that one of the beauties of segmentation is that it forces those who use it to take a customer-based approach to marketing—a precept that is central to marketing, but that is often forgotten by those who are not marketers.

Some utility sources also noted that their segmentation results contradicted conventional assumptions about their customers. For instance, some were surprised to find out that customers who ranked as quite green—environmentally aware—may have done little to reduce their energy use, and conversely, that others who ranked as brown—who lacked environmental consciousness—had actively pursued energy savings, although not for environmental reasons. Still others said the segmentation helped them see holes in their program offerings, such as offering limited assistance to renters.

Overall, then, our contacts found the segmentation schemes eye-opening. The schemes suggested how they could better communicate with customers and how they could offer better services.

Segmentation Can Point Out New Sources of Energy Savings

Our analysis across the studies also revealed that segmentation efforts can help utilities identify new and substantial opportunities for greater energy savings. For instance, SnoPud has launched two programs based in part on segmentation results—one to promote solar energy and another to solicit pledges to reduce electricity consumption by 10%. Both are doing better than predicted. BC Hydro and SMUD have also seen strong responses to programs relying on segmentation analysis. And PSE has used segmentation research to assess markets for new programs.

Segmentation Is Powerful but Has Limits

Those who have worked hard to segment their customers have become enthusiastic supporters of their research, saying that it has helped them think about customers in new ways, fostered more innovative approaches to achieving savings, and provided more useful data on why different customers respond differently to the same program. Its supporters believe that the resulting energy savings will support the investment in segmentation. Yet they also caution that one needs to respect the limitations of segmentation. As one source put it, “segmentation is not a scalpel, but it gives you broad strokes on the market” that can be refined over time.

Regional Segmentation Approaches May be Especially Potent

Representatives of utilities involved in developing a regional segmentation approach say they hope it will provide a common language for talking about customers, enable them to learn from one another, and allow them to rely on a more unified, regional understanding of consumers. They envision that over time they will be able to work more cooperatively to design and market energy efficiency programs.

Segmentation Leads to More Interaction with Customers

Most of the energy organizations we spoke with report that their segmentation efforts have sparked more customer research. For instance, BC Hydro has held segmentation focus groups, used the scheme in a pilot program, and implemented Team Power Smart, an on-line, interactive program where participants answer key segmentation questions. PSE and SnoPUD have on-line research panels that also have completed a core set of segmentation questions. BPA is developing a toolkit and training to help its utility partners apply segmentation. SMUD is following the precepts and process of program research and refinement shown in Figure 1. Some utilities have added staff specifically to help ensure that customer segments are considered in all marketing, program, and evaluation decisions and to make sure the data are well managed. And Energy Trust has completed a more robust segmentation study, which resulted in some different but more usable segments.

Customer segmentation is still relatively new to the energy efficiency industry, and thus, not surprisingly, the practitioners we spoke with are still learning its demands as both an art and a science. They are also learning how to bolster organizational interest, collaboration, and on-going support for this type of research. The view from those in the trenches is that segmentation offers utilities and other agencies a powerful tool for charting new pathways to energy savings.

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The "Average American" Unmasked: Social Structure and Differences in Household Energy Use and Carbon Emissions

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Introduction

Although we hear routinely that "average Americans" consume twice as much energy as "average Europeans," studies of household consumption have shown considerable variation within the United States. However, policy analysis and forecasting still rely heavily on consumption averages for typical end-uses of energy, and efforts to segment consumer populations tend to look either at broad distinctions (e.g., single family vs. multi-family dwellings) or at psychological traits from small samples. Social theory and past research suggest, however, that household energy use is actually highly structured by household composition/dynamics, status-appropriate dwellings and appliances, and lifestyle-based behavior patterns. To date, relatively little attention has been given to systematically analyzing and reporting the respective effects of those factors.

We report the results of detailed household-level modeling of electricity and natural gas use in a recent sample of 1,627 northern California households. We combine detailed survey data with billing histories of electricity and gas consumption and matched weather data to model consumption at the household level, and to explore how social status, lifestyle, culture, and institutions may be implicated in shaping consumption. We provide evidence of distinctive social patterns of energy use. The research goes beyond prior work, to estimate total and fuel-specific carbon emissions for households, which vary widely and follow closely the lines of social structure, but sometimes in surprising ways.

Problem and Research Strategy

This chapter examines the highly diverse household-level patterns of energy use in northern California. While conventional energy analysis tends to focus on commonalities and population averages, we are concerned with understanding *variability* in energy use across the population. Our analysis uses utility and survey data that measure annual electricity and natural gas consumption, weather and climate conditions (locations and temperatures), dwelling characteristics (types, sizes, and ages), and household demographics (income, home ownership, ethnicity, and household composition). All of these variables have been used previously in energy analysis at the household level, where they have been found to be associated—sometimes quite strongly—with one another. Our research has primarily been concerned with factors that influence electricity use, although we also present preliminary results of analyses focused on natural gas consumption and carbon dioxide emissions.

Variability in electricity consumption across the sample is extreme: from a few thousand kilowatt-hours per year in some cases, to over thirty thousand in others. Common measures of central tendency (e.g., mean, mode, and median) are misleading in this case because of a highly skewed distribution, which we discuss below. Two primary components of the California Energy Commission (CEC) residential demand forecasting model—housing type (e.g., single family detached, multi-family, mobile homes) and climate zone (e.g., five zones in this sample, ranging from coastal to hot valley climates)—are associated with energy demand patterns. However, their effects are sometimes not as large as might be expected, and a number of other factors not explicitly taken into account in demand modeling—dwelling size, income, ethnicity, family form—are also important in explaining variations in consumption.

The use of average values—e.g., average annual electricity use, average dwelling size, and average number of televisions per household—is a common and necessary practice in energy forecasting and policy analysis.[1] These averages are useful in *aggregate* estimation of trends and impacts. Given the usual limitations of available data and resources, their use is unavoidable. However, the extreme *variability* of energy consumption, particularly in the residential sector, means that these averages do not provide the detail needed to understand underlying patterns of demand or to carefully target programs and policies.[2] The averages also do not provide information about different rates of technology adoption or levels of energy use in the population—information that is increasingly necessary to understand the dynamics of trends and to identify differential equity outcomes. Moreover, if averages are taken to mean “typical” or “widespread,” this can lead to blind spots in policy and ineffective interventions.[3]

The analysis reported here uses the best available household electricity and natural gas consumption data, disaggregated to the household level. When combined with detailed survey information about these same households, a series of highly disaggregated models can be estimated that account for the individual and joint effects of a variety of factors that influence consumption.

Relatively little work of this sort has been done in the past to support energy efficiency policy intervention and forecasting. Although, large data sets are routinely assembled by the federal government, the CEC, and utilities, their level of resolution and access are often limited.[4]

Lacking adequate information from those sources, we were able to use data collected for other purposes in California—data of high quality, with a reasonable sample size, but lacking a total set of the variables that would be desired to fully analyze patterns of energy use at the household level. For example, we have good consumption, building, climate, and demographic information, but insufficient knowledge of appliance stocks and specific behaviors.

Key elements of the CEC residential demand forecasting model that could be used to examine these data—e.g., differences in housing type and climate—served as the starting point for the analysis. Another key element of the CEC model is appliance or technology stocks (CEC 2004). Unfortunately, we had very limited information about electrical end use technologies in our data. However, these technologies are, in some cases, fairly universal (e.g., refrigerators, furnaces,

[1] Most often the arithmetic mean is used, but sometimes also median and modal values.
[2] See Lutzenhiser & Lutzenhiser (2006) for a more detailed discussion.
[3] See Stern (1986) for a discussion of “blind spots” in energy policy analysis.
[4] For example, the DOE/EIA Residential Energy Consumption Survey (RECS) and the California Residential Appliance Saturation Surveys (RASS).

water heaters, televisions), or are less common but strongly associated with consumer characteristics (e.g., spa heaters, pool pumps, central air conditioners).

This analysis uses a variety of socio-demographic variables—which turn out to be very powerful in our models—to capture the effects of both behavior of household members and the presence of high consumption appliances. It can be considered a form of segmentation analysis, but one in which factors other than the social characteristics of consumers are explicitly taken into account.

We also report a preliminary investigation of variation in natural gas and carbon dioxide emissions.[5] As efforts accelerate to develop policies aimed at reducing fossil fuel emissions and the rate of climate change, this information can be of considerable value in targeting interventions and regulations, as well as in recognizing uneven equity impacts of alternative policies.

Relevant Literatures

The relevant literatures are found in sociology, anthropology, psychology, and economics. We provide only short summaries here. Along with the architecture and assumptions of the CEC forecasting model, they inform variable selection in our analysis.

Following a thorough search and review of the economics literature focused on household energy use, Kriström (2006) concluded that many empirical studies have used data only from the U.S., and a majority have focused on electricity, employing a "…smorgasbord of different estimation methods, data sets and levels of aggregation…" As a consequence, the results have been quite varied, although Kriström identifies some common themes: (1) demand for energy is generally price-inelastic in the short run although it seems to respond to price over the long run, (2) demand is associated with income (but that relationship varies substantially across studies), (3) there is no agreement across studies about the effects of age and number of children on energy use, (4) temperature is a key exogenous factor, and (5) to the degree that the impact of demographic variables on energy consumption can be detached from the influence of income, research suggests that energy consumption varies over the family lifecycle, between ethnic groups, and in terms of cultural practices.

On the latter point, non-economic studies have considered the demographic correlates of household energy use since the 1970s (Newman and Day 1975; Uusitalo 1983; for a review, see Lutzenhiser 1993). Sociologists and anthropologists have offered theoretical explanations for observed demographic differences that emphasize differences in cultural behavior patterns, social-structural conditions, consumption regimes, lifestyles, and status-ordering (e.g., Hackett & Lutzenhiser 1991; Lutzenhiser 1992; Lutzenhiser & Gossard 2000; Schipper et al. 1989; Shove et al. 1998). However, very little empirical work has been done in any of these areas over the past two decades. We can have some confidence that as people engage in their myriad every-day activities and behaviors, they are involved with other social actors, as well as with their buildings, equipment, work, lifestyles, and their interactions with the natural environment.

[5] CO_2 from the combined effects of power plant emissions and direct combustion of natural gas in the residence.

Together, all this behaving and interacting results in energy flows and emissions patterns that vary across the population. Considerable work remains to identify the precise nature of these differences and of the "drivers" involved—some of which are clearly behavioral, while others implicate buildings and machines with somewhat autonomous effects. The point of the research reported here is to begin to identify significant sources of difference in energy demand within a specific population and to assess the relative effects of those sources.

The Sample

The data set used in this study was constructed in connection with a survey of northern California natural gas customers who were facing steep increases in gas prices in early 2006.[6] Energy use data included a one-year period prior to the price increase, during which customers' use of both gas and electricity could be assumed to be "normal"—in the sense that it took place several years after the 2001–02 California electricity supply crisis and there was no inkling that anything was likely to change in the future. The sample size was 1,627 households. Since natural gas usage is expected to be strongly influenced by weather conditions (e.g., for space heating and water heating end uses), we included temperature data in the analysis.

Past experience and the literature suggests that renters, high energy users, and very low energy users are often under-represented in residential energy surveys, simply because they are more difficult to contact, less likely to be available to interview, and/or are less willing to participate. So we used data from the 2000 U.S. Census Public Use Micro-Data Samples to estimate population characteristics at the county level and weighted the sample accordingly. These included: *home ownership* (own/rent), *number of persons in household*, and *dwelling type* (single family, townhouse, apartment/condo, mobile home). About 76% of sample households owned their homes (vs. 60% in the population); sample household size was 3.4 persons (vs. 2.8 in the population); and 80% of the sample lived in single-family detached dwellings (vs. 63% in the population). The use of weights brought all of these into closer alignment with population parameters. The weighting also brought the sample closer to the population in distributions of *income* and *ethnicity*, although the lowest income group and Latino/Hispanic households continue to be under-represented in the sample (although sufficient numbers participated to allow confident analysis).

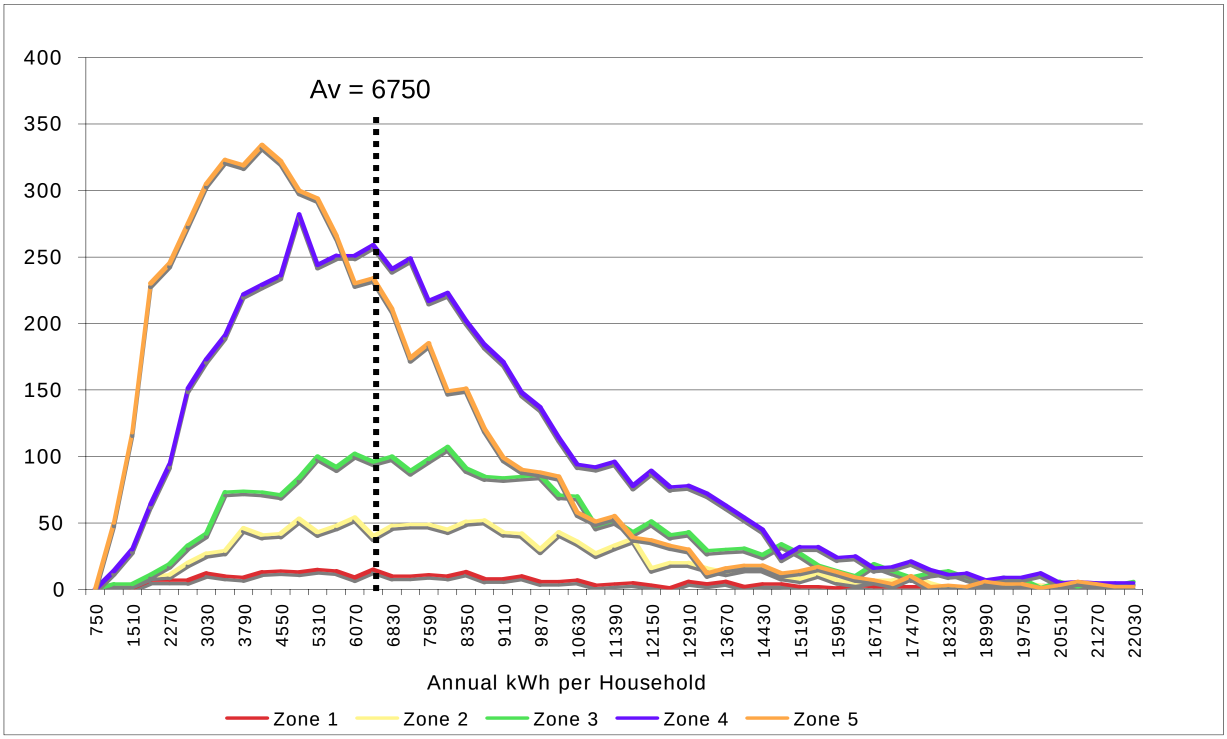
Key Variables

There are two fundamental variables in the analysis. The first is electricity consumption, measured as annual kilowatt-hours (kWh). In the sample, this variable ranges from a low of a few hundred kWh to more than 30,000 kWh. The sample mean is 6,750 kWh per year. However, this is in a highly skewed distribution. The second variable is weather/temperatures to which the household is exposed. Since even northern California has seasonal extremes of hot and cold, with accompanying rain, wind and humidity, the CEC has identified five *Climate*

[6] Because the sample comes from a natural gas study, a number of all-electric homes (i.e., accounts without natural gas) and customers that purchase their electricity from municipal utilities in the Bay Area and Sacramento are not included. The remaining cases purchase both gas and electricity from PG&E and represent about 88% that utility's residential customer base and the vast majority of all Northern California residential consumers.

Zones in northern California.[7] When consumption averages are estimated for households living in each of these zones, we find that mean annual electricity use actually varies from 5,544 kWh (zone 5) to 8,454 kWh (zone 3). The distributions of consumption for each zone are presented in Figure 1 (also in proportion to their population size, with numbers of households on the Y axis).

Figure 1. Distributions of Annual Electricity Consumption within Climate Zones



We also were able to use finer-grained measures of weather/climate conditions than those afforded only by the CEC climate zone designation—specifically heating and cooling degree days (HDD and CDD), which capture a range of differences among the five CEC forecast climate zones. And when developing the household survey instrument, we included questions that would allow us to collect information on factors that have been shown by previous research to be key influences on residential energy consumption, including:

- **Building Characteristics.** Measured by building type (single-family detached, multi-family, mobile home), building size (number of rooms and square footage estimated by occupants), and building age (also estimated by occupants).
- **Social Characteristics.** Annual household income, home ownership (owner/renter status), self-reported ethnicity, and household composition. Household composition is measured as numbers of adults [18+ yrs] and numbers of children. 31% of California households have one adult member and 47% have two adults; about one-fifth of the former and one-half of the latter also have children. The remaining 22% of California households have three or more adults, with or without children (USBC 2004).

[7] See a CEC forecast climate zone map at http://www.energy.ca.gov/2006publications/CEC-400-2006-005/CEC-400-2006-005.PDF.

Relationships among Independent Variables

The correlation matrix in Table 1 reveals a large number of associations among the causal variables and with the primary dependent variable, annual kWh. We looked closely at the relationships between the housing types and key social variables, including home ownership, ethnicity, and lifecycle stage. There are notable associations between dwelling type and size, income and size, income and ownership, building size and household size and consumption. Home ownership almost exclusively involves single-family detached units in the sample; Hispanics, African Americans, and Asians are much more likely to live in multi-family units than are Whites; and young people, older people, and singles are less likely to live in single family detached dwellings.

Table 1. Correlation Matrix: Buildings and Social Dimensions

	S Fam	Du/T/Rw	Apt/Con	Mobile	Sqft	Bldg Age	Income	Owner
Single Family	1.000	NA	NA	NA	.523**	.028	.183**	.502**
Du/Tri, Town/Row	NA	1.000	NA	NA	-.032	.030	.075*	.019
Apt or Condo	NA	NA	1.000	NA	-.474**	-.016	-.186**	-.626**
Mobile home	NA	NA	NA	1.000	-.213**	-.083*	-.144**	.133**
Bldg Sqft	.523**	-.032	-.474**	-.213**	1.000	.111**	.367**	.453**
Bldg Age	.028	.030	-.016	-.083*	.111**	1.000	.154**	.124**
Income	.183**	.075*	-.186**	-.144**	.367**	.154**	1.000	.292**
Owner	.502**	.019	-.626**	.133**	.453**	.124**	.292**	1.000
Latino	.041	-.050	.003	-.041	-.061	.025	-.162**	-.087**
White	.004	.031	-.069*	.110**	.093**	-.078*	.176**	.145**
African-American	-.037	-.018	.070*	-.043	-.042	-.006	-.159**	-.119**
Asian	-.030	.064*	.013	-.043	-.057	.109**	.018	-.022
N adults 18+	.234**	.022	-.245**	-.066*	.282**	.074*	.118**	.125**
N Kids 0-17	.111**	-.057	-.062*	-.063*	.125**	.100**	.075*	-.019
kWh	.353**	-.045	-.315**	-.128**	.416**	.170**	.296**	.308**

	Latino	White	Af-Amer	Asian	N Adults	N kids	kWh
Single Family	.041	.004	-.037	-.030	.234**	.111**	.353**
Du/Tri, Town/Row	-.050	.031	-.018	.064*	.022	-.057	-.045
Apt or Condo	.003	-.069*	.070*	.013	-.245**	-.062*	-.315**
Mobile home	-.041	.110**	-.043	-.043	-.066*	-.063*	-.128**
Bldg Sqft	-.061	.093**	-.042	-.057	.282**	.125**	.416**
Bldg Age	.025	-.078*	-.006	.109**	.074*	.100**	.170**
Income	-.162**	.176**	-.159**	.018	.118**	.075*	.296**
Owner	-.087**	.145**	-.119**	-.022	.125**	-.019	.308**
Latino	1.000	NA	NA	NA	.134**	.253**	-.039
White	NA	1.000	NA	NA	-.176**	-.243**	.015
African-American	NA	NA	1.000	NA	-.012	.035	-.008
Asian	NA	NA	NA	1.000	.172**	.082**	.017
N adults 18+	.134**	-.176**	-.012	.172**	1.000	.231**	.350**
N Kids 0-17	.253**	-.243**	.035	.082**	.231**	1.000	.250**
kWh	-.039	.015	-.008	.017	.350**	.250**	1.000

* **-** sig at .05 level (two tailed)

* **-** sig at .01 level (two tailed)

Multivariate Models

Because of the correlations among predictor variables, it is clear that their effects on energy use are complex and entangled. For example, some of the home ownership correlation with energy use is likely due to building type (as noted, owners being more likely to live in single-family detached dwellings). Some of the income/energy correlation may actually be a climate effect, since incomes are higher in some climate areas than in others. But we can also see that the effects of a number of these factors on energy use are likely important. Weather has an effect. Housing characteristics have effects. So do the preferences and behaviors and technologies associated with the lifestyles of different social groups. But what can we say about the relative strength of these effects? Are they the same for gas and electricity? Do they vary by climate? How can they be most concisely presented?

In an effort to address these questions, we estimated a large number of ordinary least square regressions of electricity use, natural gas use, and carbon dioxide emissions on combinations of causal variables. We varied the specification of the models, the coding of the variables, the order of entry, and various ways of handling missing data. We examined the models for influential cases, collinear relationships among predictors, and patterns in the residuals. We were concerned about getting the correct variables in the models. We were interested in the statistical significance of controlled relationships between predictors and the dependent variables. We also explored possible interaction effects, and compared the overall fit of various models.

The models that we present in Tables 2 and 3 are the most parsimonious and stable to have emerged from the analysis. Their relative simplicity is the result of considerable work, and their parameter estimates are quite stable with changes in specification.

Whole Territory Models

The models presented in Table 2 are for annual electricity consumption: (1) across all climate zones and (2) for zones 2-4 only. Zone 1 is quite small in terms of population, and the similarities of the two models suggest that consumption there has little effect on the overall pattern. The model that excluded zone 1 was estimated in order to provide a basis of comparison with the fully interactive four-equation model presented in Table 3.

The results show significant effects for particular climate zone locations. They also would show significant effects for cooling (but not heating) degree days if the zone variables were not included in the models. It turns out that the zone variables alone and the degree day variables alone are much poorer predictors than the two together. The zones are carrying information about more than just climate, and the CDD variable captures subtle differences within zones.

The models also show significant effects for single-family detached units (but also for multi-family units—all in comparison to mobile homes, the omitted category), building size (but not for age), income, home ownership, Latino and Asian ethnicities, and numbers of adults and older children in the household. The overall fit of the model is fairly good by social science standards, with an R square of .40, meaning that approximately 40% of the variance in the dependent variable is accounted for by the combined effects of the independent variables included in the model. The model parameter estimates can be used to compare the magnitudes of particular effects and combinations (discussed below).

Table 2. Whole Territory Models of Annual Electricity Use (kWh)

	ZONES 1-5		ZONES 2-5	
	B	**Sig.**	**B**	**Sig.**
CDD (100s)	-27.70	.53	-25.70	.56
HDD (100s)	-43.00	.25	-44.00	.24
Zone 2	-1,162.24	.31	ŠŠ	ŠŠ
Zone 3	-212.02	.85	943.41	.07
Zone 4	-2,592.61	.02	-1,409.97	.02
Zone 5	-3,216.19	.00	-2,037.75	.00
Single Family	2,648.55	.00	2,650.40	.00
Duplex/Tri, Town/Row	1,619.58	.04	1,625.30	.04
Apartment or Condo	1,860.78	.01	1,849.14	.01
Bldg Sqft (1000s)	642.21	.04	629.14	.04
Blt_84_96	319.29	.32	353.16	.27
Blt_97-04	308.42	.48	331.51	.45
Income ($1000s)	13.44	.00	13.56	.00
Owner	773.72	.01	767.38	.01
Latino	-1,296.16	.00	-1,283.58	.00
Af-Amer	631.40	.19	647.11	.18
Asian	-1,005.11	.07	-1,013.77	.07
N of adults 18+	857.97	.00	855.03	.00
N 13- 17 yrs	1,326.28	.00	1,327.14	.00
N 6- 12 yrs	421.94	.02	425.17	.02
N Infant - 5 yrs	16.90	.94	-32.65	.88
(Intercept)	3,384.01	.08	2238.259	.16
	R-sq = .40		R-sq = .40	

Interactive Model Differentiated by Climate Zone

Based on earlier research and our initial modeling, we believed that climate zones might differ in a fairly wide variety of ways, including housing stock, cultures, and very different temperature regimes. To test this notion, we estimated a separate equation for each of climate zones 2-5 (omitting zone 1 because of small size). This is the fully interactive model, in which it is assumed that most other variables in the equation interact with climate zone to produce different levels of effects upon the dependent variable.

Table 3 presents this combined model. It shows that the climate zones are, indeed, different from one another. Some of the significant terms in the all-zone model seem to apply mostly in certain zones and not in others. The heating and cooling degree day effects are significant only in zone 5. Building size and age are only significant in zone 5. Income effects are visible in zones 3-5. The effects of ownership are weakened but still present across several zones.

Table 3. Interactive Model: Patterns of Electricity Use Differentiated by Climate Zone

	ZONE 2		ZONE 3		ZONE 4		ZONE 5	
	B	Sig.	B	Sig.	B	Sig.	B	Sig.
CDD (100s)	288	.60	6	.98	72	.29	-169	.00
HDD (100s)	338	.57	-108	.54	47	.37	-176	.00
Single Family	6,004	.72	2,865	.06	3,233	.00	-1,164	.40
Duplex/Tri, Town/Row	11,559	.50	994	.67	1,550	.20	-1,890	.19
Apartment or Condo	6,322	.70	3,341	.04	1,440	.19	-1,756	.22
Bldg Sqft (1000s)	1,416	.41	138	.89	321	.52	891	.03
Blt_84_96	-1,516	.27	-1,182	.16	134	.79	2,054	.00
Blt_97-04	-1,019	.63	-489	.66	114	.86	663	.38
Income ($1000s)	10	.47	49	.00	16	.00	7	.01
Owner	3,256	.09	562	.51	848	.10	759	.08
Latino	1,021	.56	-1,007	.24	-985	.11	-1,461	.00
Af-Amer	5,271	.07	1,654	.28	29	.98	412	.49
Asian	53	.99	ŠŠ	ŠŠ	-900	.26	-101	.89
N of adults 18+	1,155	.03	1,423	.00	935	.00	383	.04
N 13- 17 yrs	917	.44	1,644	.00	1,153	.00	852	.01
N 6- 12 yrs	228	.89	589	.16	418	.15	-10	.97
N Infant - 5 yrs	1,214	.33	-895	.24	-110	.73	677	.05
(Intercept)	-17,705	.51	1,967	.79	-2,094	.30	8,758	.00
	R-sq = .47		R-sq = .53		R-sq = .43		R-sq = .36	
	Overall Interactive Model R-sq = .44							

Latino households consume considerably less (controlling for all other factors) in zones 4 and 5. But African Americans seem to consume more (controlling for other factors) in zone 2. And the effects of Asian ethnicity have disappeared in the interactive model. Numbers of adults is still a potent predictor, but the effects of numbers of children are less noticeable, except for teenagers in three of four zones.

For three of the four sub-models, the fit (measured by R square) is better than in the whole territory models. The fit of the overall interactive model can be estimated by comparing the total regression sum of squares with the total sum of squares for all sub-models. The overall R square value for the interactive model is a fairly impressive .44 (44% of variance explained), despite the fact that to explain the patterns of effect revealed in the interactive model is not straightforward (and certainly not intuitive). Our conclusion is that continued work to discover and measure differences—environmental, social, and structural/technological—across climate zones can be productive.

Relative Contributions of Environment, Building, and Social Variables

We were interested in estimating independent, additive effects for environmental, dwelling, and socio-demographic variables in our regression analysis. We have also identified interaction effects with climate zone, the other independent variables, and the target electricity variable. But because the predictors are all correlated to some degree, it would also be useful to try to get a sense of the unique and joint contributions that environmental, dwelling, and social variables make to explained variance in the model.

To do this, we estimated a series of regression models in which the different sets of predictors were entered in different orders into the equation. At each step, we compared the explained variance (R square) to that of other orders of entry, allowing us to estimate the "unique" and "joint" explanatory powers of sets of variables. In this analysis, the unique contributions to explained variance of the social variables were 36%; for building characteristics, 9%; and for environment, 17%. The remaining 39% is the result of the undifferentiable joint effects of people, environment, and buildings.

The somewhat surprising finding is that the social factors—not the environment and buildings—provide the greatest amount of unique explanatory power. Also, considering that an equal amount of explained variance is attributable to joint effects (which include the social dimensions of behavior, status, etc.), social factors turn out to be by far the most potent predictors of electricity use.

Household Types and Modeled Consumption

Model coefficients can be used to estimate the annual consumption of households, as defined by a combination of factors considered in the model. Table 4 shows the results for nine household types that should be familiar to the reader. What is especially interesting here is the very wide—but now much more explicable—variation in total household electricity use resulting from the combination of social, environmental, and building factors. The consumption levels of these households range from a modest 1,461 kWh for a single urban lower-income adult, to over 13,000 kWh in a probably quite typical middle class suburban family. In none of these examples are the household composition, housing characteristics, or environmental conditions in any way extreme. But the different patterns of factors result in very different end-use patterns and total consumption levels that warrant much closer examination in future research.

Table 4. Model-Estimated Annual kWh for Typical Households Defined by Combinations of Environment, Building, and Social Characteristics

Typical Households	Modeled kWh per Year
Zone 2, SF, 1200 sqft, pre-1984, $35k/yr, owner, white, 1 adult	6,376
Zone 2, SF, 3600 sqft, 1997-2004, $140k/yr, owner, white, 2 adults, 2 children	13,151
Zone 3, apt, 1200 sqft, 1984-96, $50k/yr, renter, Latino, 2 adults, 3 children	6,652
Zone 3, SF, 3200 sqft, 1997-04, $80k/yr, owner, white, 2 adults, 3 children	13,410
Zone 4, SF, 1800 sqft, 1997-04, $75k/yr, owner, white, 2 adults	7,252
Zone 4, townhouse, 1500 sqft, 1984-96, $65k/yr, owner, white, 1 adult, 1 child	5,036
Zone 5, apt, 1000 sqft, $80k/yr, renter, Asian, 2 adults, 1 child	3,223
Zone 5, SF, 1800 sqft, pre-1984, $100k/yr, owner, white, 2 adults	6,613
Zone 5, apt, 800 sqft, pre-1984, $20k/yr, renter, Asian, 1 adult	1,461

Modeled Annual Household Natural Gas Usage, Carbon Dioxide Emissions and Total Consumption in Btus

Table 5 shows the results of regression analyses of natural gas consumption, carbon dioxide (CO_2) emissions, and combined electricity and gas energy use expressed in British thermal units (Btus). The same predictors are used as in the electricity analysis above. The fit of the models is not quite as good for natural gas and Btus as for electricity and CO_2.

Hot weather (CDD) has significant, but negative effects in several models, as do single-family detached structure and building size. Vintage of building is only significant in the natural gas model, where units built in the late 1980s to early 1990s used less energy than older and newer units. Income effects are strong across models. Ownership effects are weaker. Controlling for other factors, Latino households produce significantly less carbon, while African Americans may produce more. Factors such as housing quality and equipment efficiency that are not included in the model, but are possibly correlated with ethnicity, may play a role here. Numbers of adults and older children affect CO_2 emissions, but not natural gas consumption or overall Btu levels.

Table 5. Models of Natural Gas, Carbon Dioxide (CO_2) and Total Btus

	Therms Natural Gas (100k Btus)		Pounds Carbon Dioxide (CO2)		Total Btus (1000s)	
	B	sig.	B	sig.	B	sig.
CDD (100s)	-12	.00	-155	.01	-1,289	.00
HDD (100s)	-4	.20	-73	.13	-523	.00
Zone 2	-111	.21	-2,071	.16	-15,100	.14
Zone 3	-74	.40	-987	.49	-8,102	.16
Zone 4	-205	.02	-4,130	.01	-29,380	.44
Zone 5	-157	.08	-4,004	.01	-26,630	.01
Single Family	70	.18	2,628	.00	16,060	.01
Duplex/Tri, Town/Row	14	.82	1,280	.20	6,952	.01
Apartment or Condo	-120	.03	-88	.92	-5,682	.34
Bldg Sqft (1000s)	82	.00	1,383	.00	10,439	.40
Blt_84_96	-54	.03	-400	.33	-4,351	.00
Blt_97-04	-40	.25	-241	.67	-2,931	.15
Income ($1000s)	0	.00	15	.00	95	.48
Owner	23	.36	792	.05	4,907	.00
Latino	-9	.74	-997	.02	-5,323	.10
Af-Amer	143	.00	2,067	.00	16,461	.10
Asian	-21	.63	-931	.19	-5,511	.00
N of adults 18+	-1	.91	579	.00	2,815	.29
N 13- 17 yrs	14	.37	1,079	.00	5,966	.02
N 6- 12 yrs	4	.78	336	.14	1,836	.00
N Infant - 5 yrs	21	.21	256	.36	2,205	.27
(Intercept)	641	.00	9,647	.00	75,691	.28
	R-sq = .25		R-sq = .37		R-sq = .33	

This first cut at modeling CO_2, in particular, is a promising start at informing climate policy with more rigorous understandings of how the variability in consumption of multiple forms of energy produce variegated patterns of household carbon emissions.

Conclusions

The analysis shows that residential energy use and carbon emissions are highly variable in the population of interest. A large proportion of the observed variation can be explained by a relatively small set of variables, including: climate zone/temperature, dwelling type and size, building age, home ownership, household income, ethnicity, and household composition. This is true for both electricity and natural gas consumption, as well for CO_2 emissions.

The relationships between forms of consumption and the independent/predictor variables are not simple, however. Many of these variables have significant correlations with other predictors (e.g., income and dwelling size, household composition and building type, even income and climate zone). These correlations do not violate the assumptions of the models used, but they make interpreting results somewhat challenging. Also, there are unmeasured factors that influence consumption and emissions levels that could not be considered in this analysis. These include appliance characteristics, building condition, household behavior, and more subtle weather variations, to name a few.

The fit of the various models that we estimated was fairly good, and we conclude that the approach is promising. Household consumption is neither merely "average" nor idiosyncratic or otherwise random. Residential energy use and CO_2 emissions are structured—by past decisions about dwelling form and technology, current patterns of occupancy and behavior, and changing climate/temperature conditions.

Although we cannot apply the specific findings with confidence beyond the population of combined gas and electric customers in northern California, the strength of the patterns revealed in our analysis give us confidence that we have demonstrated the general principle that variations in residential demand can be traced to the *combined effects* of weather, building, technology, and social behavior. How they interact in other contexts remains to be seen. But they certainly all complexly co-determine demand, although quite possibly in different ways in different places.

Future Research Needs

More complex models can be estimated, plus more complete data can be obtained, to further develop our understanding of the structuring of household energy consumption and emissions. Further analyses should:

- Explore in greater detail the social, environmental, and structural/technological differences among climate zones that seem influential in determining differences in energy use patterns.
- Use other data to apply this approach, but in an expanded form in which appliance stocks are explicitly taken into account (in the current analysis, they are subsumed in the environment, building, and socio-demographic terms).
- Develop suggestions for a more refined set of questions that might be included in future data collection in order to develop a richer base of information for forecasting, policy analysis, and program planning.
- Explore the policy implications of the social patterning of demand for: simulation modeling and forecasting; the development of rates, regulations and subsidies; and program design and implementation (e.g., targeting specific social groups and patterns of usage).

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Car Buyers and Fuel Economy?[1]

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Introduction

It's a Gut Feeling

B., the male head of household, starts by saying, "$2000. . . I'm so wanting a spreadsheet right now." He laughs.
M., the female head of household, makes a joke about a colleague writing the spreadsheet program. They both laugh.
Then M. says, "$4000. . . it's a gut feeling."
B., "I was trying to calculate it [in my head], but I didn't carry it through very far."
M., "We probably drive each car about 7000 or 6000 miles every year." She then suggests they might save 1000 gallons per year [for one car]; B. thinks this might be too much.
B. summarizes their initial responses, saying "$2000 to $4000."
Then, in unison, M. and B. say, "Call it $3000."

M. and B. are responding to our inquiry about their willingness to pay for a 1.5 times improvement in the fuel economy of an SUV they have designed during their interview—we have proposed to increase its fuel economy from 11 to 17 miles per gallon (MPG). They both work as financial service professionals. They appear to negotiate a lot with each other, having done so throughout the interview. Prompted by a desire to buy a vacation home, they have been reviewing their expenses to determine how much they can afford. They eventually offered a single number as their answer—$3000—but their dialog illustrates they do not think about their vehicle purchases in this way.

If a household in which both household heads are financial professionals has trouble providing realistic answer to a willingness to pay question in our extensive interview, how valid could their response be to the same question during a phone survey? How could we expect less capable households to answer such a question? Does it make any sense to even ask such questions?

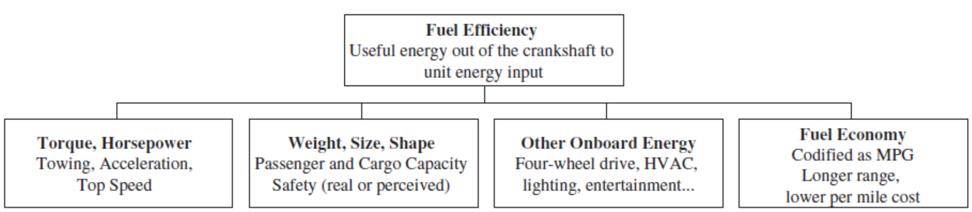

Fig. 1. Physical model of fuel efficiency–fuel economy relationship.

[1] This chapter was reprinted with permission from Turrentine, Thomas S. and Kenneth S. Kurani. 2007. "Car Buyers and Fuel Economy?" *Energy Policy* 35 (2007) 1213-1223. The U.S. Department of Energy and the Energy Foundation supported this research. The authors are solely responsible for the content and conclusions presented.

Expert Views on Efficiency and Fuel Economy

There are at least three ideas behind most experts' thinking about efficiency and fuel economy. The first is a physical model: energy out of the crankshaft of an engine can be apportioned to a variety of end-uses. This model is summarized in Figure 1 (on the previous page). Increases in efficiency can be apportioned to more power, moving a larger or less aerodynamic vehicle, facilitating other on-board energy use, and increasing fuel economy. Fuel economy is codified as miles per gallon (under specified test conditions). This physical model imposes a design envelope on choices offered to consumers—the more energy apportioned to one use, the less is available to others.

The second idea is basic economics: maximum profit occurs when automakers offer consumers their most highly valued distribution of the possible end-uses of the energy produced by a vehicle's engine. In practice and regardless of any abstractions such as units of "utility" or "happiness," the value of these end-uses is typically measured in dollars, e.g., willingness-to-pay. In this view, the value of fuel economy is measured in cents per mile (of fuel savings).

Unfortunately, this idea has lead to the confusion of the measure for the thing being measured, i.e., that the only value to consumers of fuel economy is private monetary savings. Saving money is related to household income and budgets. As the price of gasoline goes up, consumers may, according to their incomes, buy more fuel economical vehicles or take other actions to stay within income and credit limits.

A third idea is that consumers, for the most part, value power, size, energy-consuming options and accessories (and according to a widely cited anecdote, cup holders) more than they do fuel economy, at least as long as fuel costs are low and incomes are high.

How do these three ideas relate to how consumers actually think about fuel economy? How do we reconcile M. and B.'s story, and those of the other 56 households we interviewed with these "expert" ideas? These households' personal histories with automobiles will prove to be crucial.

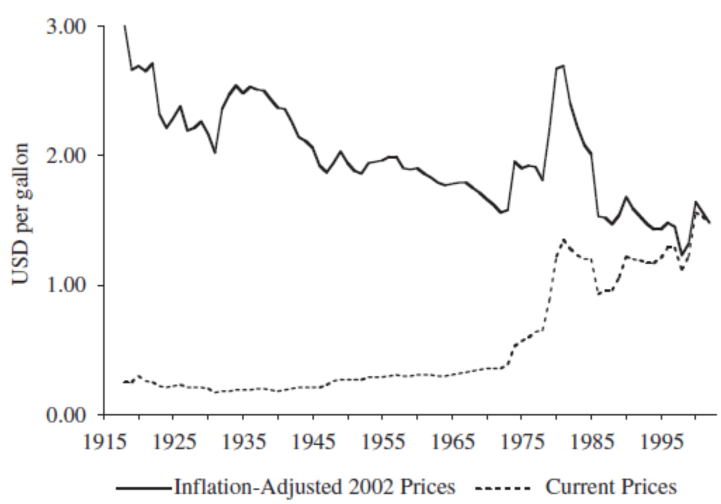

Fig. 2. Current and 2002 inflation-adjusted US prices for gasoline from 1918 to 2002. (American Petroleum Institute, 2002)

A Short History of Fuel Prices, Fuel Efficiency, and Fuel Economy

For most of the past 90 years the real cost of gasoline declined. Notable exceptions include the Great Depression, the two "oil crises" of the 1970s and early 1980s, and recent years. This history is summarized in Figure 2 (on the previous page). For most of our households, their personal history with this trend dates back no further than the 1960s. Even people as old as 40 had no direct consumer experience with prolonged rising gasoline prices until the last few months of our study period (in 2004).

Over this time manufacturers delivered roomier, stronger, and faster vehicles, as well as more amenities such as automatic transmissions, all-wheel drive, air conditioning, and entertainment systems. What was the effect on fuel economy? Systematic data on fuel economy for the US fleet of light-duty vehicles is available starting in the mid-1970s.

Since then, only during the oil crisis of the 1970s and early 1980s and following the deployment of corporate average fuel economy (CAFE) standards did average fuel economy increase. This trend is illustrated in the Figure 3, which shows a simple index of weight, power, and fuel economy plotted against fuel economy, and traced over time.

Once oil shocks were over, CAFE standards ceased to increase, and gasoline prices dropped, then automakers quickly shifted back to increased power and size while fuel economy improvements stopped. Figure 3 understates this effect since it does not include increasing number of SUVs and pickup trucks so large they are medium-duty, not light-duty, trucks. Automakers believed car owners wanted more power and bigger vehicles, and exploited the lower CAFE standard for light-duty trucks (and the absence of any standard for medium-duty trucks) to use truck platforms to provide consumers with minivans, SUVs and larger pickup trucks.

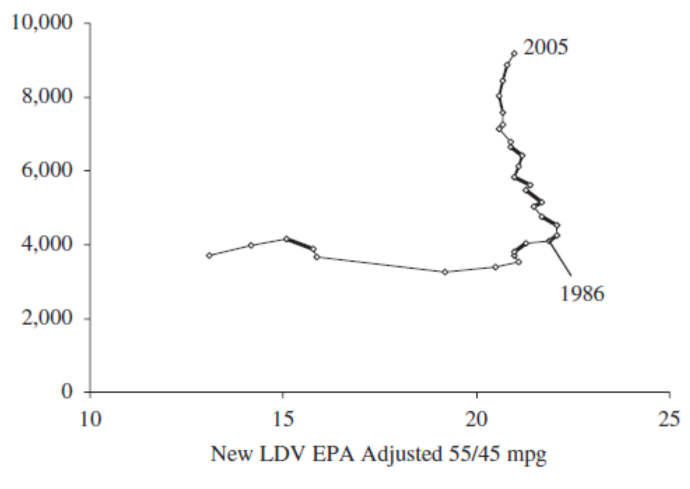

Fig. 3. Trends in new US LDV weight, power, and fuel economy, 1975 to 2005. (US Environmental Protection Agency, 2004)

Figure 3 depicts two distinct periods in recent automotive history. Following the model of expert thinking presented earlier, the first episode is read as an aberration caused by temporary spikes in fuel price (and actual supply disruptions) and regulations, while the second marks a return to "true" consumer preferences. Our contentions are that (1) neither period can be dismissed as unrepresentative of what consumers want and (2) in all periods, consumers choose from what is offered to them.

Individual consumers may experience these historical periods of average improvements in power, size, and fuel economy quite differently than illustrated in Figure 3. The most salient experience consumers bring to a new vehicle purchase is their past experience with their own vehicles, not improvements to vehicles in general. At any new vehicle transaction, their most recent vehicles are typically 2–7 years older than new vehicles being offered. Every time a household shops for a new vehicle they may find most new vehicles provide more power, size, and amenities—with similar fuel economy—than their past vehicles. People may experience new automobile purchases not so much as tradeoffs between new vehicle options, but mostly trading-up compared to their past vehicles. This would be true especially if the findings discussed in this paper regarding consumers are right, that they do little calculated decision-making, relying most on what information is immediately available.

Transportation Energy Research and the Rational Car Buyer

Transportation energy research extends the above model of expert beliefs about consumers and fuel economy a few steps further, applying more esoteric economic ideas about consumer decisions such as payback periods and net present value calculations. While many analysts admit that something is wrong with rational choice, they still create models and debate fuel economy policy as if drivers keep records on vehicle and gasoline costs, estimate their purchase costs and future ownership and operating costs, and discount future cost and benefit streams, as from higher fuel economy. Consumers are assumed to consider the cost of gasoline and fuel economy both in their travel and vehicle choices, and to consider such costs over time.

Studies based on this model have addressed, for examples, household response to higher gasoline prices (Espey and Nair 2005; Kayser 2000; Pitts et al. 1981; Puller and Greening 1999), aggregate economic impacts of inaccurate EPA mileage estimates including impacts on consumer surplus (Senauer et al. 1984), competing effects such as gasoline cost savings versus safety (Yun 2002), and the range of implicit inter-temporal discount rates in consumer decisions, (Calfee 1985; Greene 1983; Train 1985; Verboven 1999).

Based on this extended ideal model of consumer response to fuel costs, automobile makers and regulators debate how much more consumers would be willing to pay for vehicles with improved fuel economy, and over what period of time consumers will want their "investment" in fuel economy returned. Automotive manufacturers oppose higher CAFE standards, arguing that automobile buyers want to get back their money on new fuel economy technology sooner than the relative increases in vehicle prices and fuel economy will allow. In one review of national survey data, Steiner (2003) reported that on average consumers said they would want back an "investment" in higher fuel economy in 2.9 years, despite the fact they also said they expect to own vehicles, on average, for more than 5 years.

What could be wrong with this model? Imagine for a moment that at least some consumers do not value future gasoline savings entirely as dollars saved, but also out of a commitment to lower resource consumption, a belief in a link between efficiency and greenhouse gas emissions, or automobile buyers lead us to think that the rational actor model is not an accurate or useful view of how consumers think about fuel economy and automotive fuel costs. A multi-year project on markets for alternative fueled vehicles in the 1990s left us with the impression that automobile owners did not have any idea how much they spend on fuel and often did not know the fuel economy of their vehicles (Kurani et al. 1994; Turrentine et al. 1992). Research on diesel vehicle buyers lead us to believe that consumers use retail fuel prices to gauge their satisfaction with their vehicle purchase, but did not record fuel costs over time (Kurani and Sperling 1988). CNG buyers we studied in New Zealand did not calculate fuel costs, but similarly used relative natural gas and gasoline prices (a difference subject to government policy) to gauge satisfaction with their vehicle conversion (Kurani 1992).

But these results are more than 10 years old. Have consumers changed? Have rising gasoline prices in the past few years produced more rational consideration by consumers?

Hybrid Electric Vehicles (HEVs) and the Extended Model of the Rational Consumer

These expert ideas about fuel economy we outline also frame a newer debate around the future sales of high fuel-economy HEVs. Strong sales to date of HEVs have surprised many analysts and automakers. HEVs can cost more to buy than conventional vehicles, and some consumers wait months for delivery. On the other hand, resale value of HEVs (as a percentage of purchase price) is among the highest of any vehicle and sales of Toyota’s Prius are reaching 100,000 units per year in the US.

Still not convinced, reports in the news and popular press continue to question the “rationality” of HEV buyers. Writing to consumers the Wall Street Journal (White 2005) and the automotive market research firm Edmunds.com (2005) have recently published analyses of private financial costs that indicate HEV buyers are not being smart—if buyers of HEVs are trying to save money through fuel cost savings.

A number of energy analysts are afraid that hybrid technology, like fuel injection and many other technologies, will be put in service of increasing power, larger vehicles, or conveniences and accessories, instead of increased fuel economy. Carmakers have focused in the last 2 years on applying hybrid technology to larger and more powerful vehicle lines creating “performance HEVs” and hybrid SUVs. Are they signaling a belief that the success of “economy HEVs” is limited and ephemeral?

Developing a Wider View of Consumer Behavior with Respect to Fuel Economy

We do not argue with the belief that all things equal, under conditions of declining real gasoline prices many consumers have wanted more power and room in their vehicles. But the value of fuel economy, relative to power and room, is also not a simple matter of household economics and gasoline prices. First, we hypothesize that several factors confound calculated, rational decision-making around fuel economy, including the following:

1. Until recently, cars with good fuel economy (in the USA) were most likely to be small, light, “cheap” vehicles, also known derisively as “econo-boxes.” Fuel economy was part of this “economical” package, for folks with fewer economic resources.
2. The automotive market offers many sizes, designs, power-trains, brands, interior fabrics, technologies, optional amenities, and colors. Fuel economy is one variable in this complex market, a variable which is easily forgotten when gas prices are low and falling.
3. Most vehicles still have crude fuel use instrumentation designed primarily to provide notice of the need to refuel, not to track fuel use or costs.
4. Given number 3, calculations and systematic record keeping are not “normal” behavior. Those people who do keep records, do so to track engine functioning.
5. Years of declining (real) gasoline prices and increasing vehicle power, size, and energy consuming features eroded the context for higher fuel economy of the 1970s and early 1980s.

But there are new reasons for buyers to pay more attention to fuel economy:

1. Rising and volatile gasoline prices over the past few years.
2. New fuel economy instrumentation.
3. Obvious effects of global climate change due in part to CO2 emissions from transportation.
4. Increased national dependence on imported oil, highlighted by another war in a key oil-producing region. Even some radical conservatives have recently embraced the idea of “oil independence” in the US and therefore high automotive fuel economy as a strategic national policy.
5. Very high fuel economy of early HEVs opens a new direction in automotive symbols and values.

The combined effects of these two lists of variables create a complex milieu for the value of fuel economy.

Fuel Economy in the Lives of 57 California Households

We report here on the role of automotive fuel economy in vehicle purchases and use decisions of 57 northern California households. Our data was collected in 2003–2004 through a pre-interview survey and a 2-hour household interview.

We do not challenge the engineering idea that allocates energy to size, power, or fuel economy, but we do explore consumer values, knowledge, and calculations for fuel use and fuel economy decisions in much greater detail than previous studies. We explore whether fuel economy is only about saving money, and whether the extended model of consumer rationality in transportation research, that sees buyers as making calculated decisions about fuel costs overtime, has any base in observed behavior.

We learn that almost none of our participants know or track how much they spend on gasoline over time. Many do not know the fuel economy (MPG) of their current vehicle(s), much less what they spend cumulatively on gasoline in a month or a year and therefore have no way of knowing how much they might save with a more fuel economical vehicle. Even the accountants, bankers, and financial analysts we interviewed do not keep track of their gasoline costs other than to note the price of a gallon or tank of gasoline the last time they went to the gas station—the same as any of our households. Moreover, we have some evidence that good fuel economy is sometimes viewed as a moral value.

Household Interviews

We interviewed these households over a 12-month period. Because we review their entire history of automobile ownership, we discussed over 400 vehicles and delved into over 125 specific vehicle transactions. With a few exceptions, interviews were conducted with all relevant household decision makers present. Most of these interviews were conducted at respondents' homes; two were conducted at their place of business and three in restaurants. Their home puts the participants at ease and seeing the home gives researchers greater information about the household.

Primary Sampling Attributes

Our goal was not to attempt a representative sample, but to explore the range and variety of behaviors with regard to fuel economy, with some structuring of the sample. We identified nine different "sectors," defined by economic, lifestyle, and knowledge considerations, for which we had simple hunches about their potential choices and values.

We interviewed six households from each of these illustrative sectors, plus three pilot interviews. The households live along a 100-mile stretch of US Interstate 80 in northern California. In addition to families and couples, there were single person households as well as some students with roommates. Participating households had recently purchased or were in the middle of a purchase of a new or used car or truck. Households in our sample own slightly more vehicles, are more likely to live in a small city or a rural area, and are less likely to be retired than if the sample had been drawn at random from the population of California.

These are the ten groups that comprise the sample, with and a brief description of our interest in them:

1. Pilot interviews: three households used to develop interview methods.
2. College and graduate student's nearing graduation or recently graduated: limited income, well educated about environmental issues, at a transition point in their lives.
3. Off-road vehicle users: possibly more aware of fuel economy because of their fuel-consuming hobby.
4. State resource agency employees: might know more about environmental and energy issues in California.
5. Farmers and ranchers: business people who make financial calculations and budgets over annual cycles.

6. Computer hardware and software engineers: probably better connected with global technology developments, high level of quantitative skill.
7. Military households: personal connection to the social costs of the geo-politics of oil, for enlisted personnel lower income creates more budget constraints.
8. Financial services sector: high level of financial quantitative skills they use professionally on a daily basis.
9. Outdoor recreation industry: lifestyle driven, aware of environmental issues, whether or not they are sympathetic to environmental "causes."
10. HEV buyers: already buying fuel-efficient vehicles.

The interviews were conducted in four parts:

- First, we listen carefully to households talk about past vehicles and purchases, listening for past attention to fuel economy. We are careful not to probe for fuel economy, as we want to elicit past interest in fuel economy, not prompt it during the interview. Here we learn about the development of individual tastes and major influences on vehicle choices such as family, friends, and co-workers, episodes of financial upturns and downturns, experience with past vehicles, etc.

- Second, we ask about the most recent vehicle purchase in much greater detail. As with the first step, the intent in the second step is to listen for clues as to whether fuel economy was a consideration: again, we do not probe about fuel economy.

- The third section of the interview was intended to insure that we could listen to households talk about fuel economy as one of several vehicle attributes. Further, we wanted to establish as realistic as possible a context for introducing a "1.5X" fuel economy vehicle in Part Four of the interview. We asked most households to design the next vehicle they imagined themselves buying. In a few households, we asked them to reconsider their recent vehicle purchase rather than their next possible vehicle. Because the HEV itself was the context for discussing fuel economy with HEV buyers, we did not conduct this exercise with them. The exercise uses a priority evaluator (PE) table. After establishing whether they want a truck-or car-based vehicle, we offer a list of vehicle attributes: performance, number of seats, cargo capacity, safety equipment/ rating, fuel economy, pollution rating, options packages, and for trucks towing capacity and four-wheel drive. Each attribute is offered in three levels. For example, the seating options for an SUV were four, six, or eight seats, which cost one, two, or three points, respectively. We constrain their vehicle design by limiting their total points. Once they have completed an initial design, we change their available points and ask them to redesign the vehicle. Within this exercise we require households to spend more to get higher fuel economy—just as they are being asked to do now by so many researchers, but contrary to their (later revealed) expectations that "economy" cars cost less.

- In the fourth part of the interview we let on that we are most interested in fuel economy. Our goals here are to observe households respond to questions about paying more for higher fuel economy and payback periods, and to discover whether households track the basic “building blocks” of rational consideration of fuel economy such as annual fuel costs, MPG, and other data on household travel and fuel use.

Findings

Past and Present Vehicle Purchases

In the absence of prompts from us, few households mention fuel economy when discussing any past vehicle purchases or use. Those who had considered fuel economy did so at a time when they had modest income, when a household member had a long commute, or during the oil price shocks of the 1970s. Also, younger households may recall their parents first buying “economy” cars in the 1970s.

Fuel economy also rarely surfaces when talking about the most recent vehicle purchase. As a group, college students were the most interested in fuel economy. For them, money may be short and gasoline can be the entire cost of operating a vehicle otherwise paid for by their parents. Additionally we heard some mention of fuel economy from enlisted military personnel and other less affluent respondents.

Particularly in middle and upper middle-income households with children, their primary goal for at least one household vehicle was often a vehicle large enough for children, friends, dogs, vacation baggage, and large shopping items. Many were interested also in four-wheel and all-wheel drive for access to winter and off-highway recreation activities (often whether or not these activities were actually undertaken by the household). Families with young children had a strong interest in safety.

Using the Priority Evaluator Table to Re-Examine the Current Purchase or Design the Next Vehicle

In the PE exercise, we explicitly place fuel economy in a competition with other vehicle attributes. (Recall we did not use the PE exercise in households that had purchased a HEV.) No household appeared to make a strong commitment to high fuel economy for a future vehicle (or a revisited version of a recently purchased vehicle) based on then current (circa 2002–2003) gasoline prices. Households who did choose high or mid-level fuel economy for their vehicles appeared to be doing so out of longer-term commitments to environmental and social issues, or because of high fuel costs at some point in their personal or household histories. Still, in some high fuel use households, fuel economy was surprisingly (to us) undervalued. Some people towing or traveling long-distances seemed satisfied with low fuel economy ratings in the PE table (mirroring what they are achieving in the real world) and choose to spend points elsewhere, even when offered more points. Some full-size truck buyers are interested in lowering their fuel costs. They are likely to see alternatives, such as diesel engines, as desirable.

Fuel Efficiency and Fuel Economy

In the final section of the interview we finally reveal to households our interest in fuel economy. Here we learn how typical consumers think, or even if they think about it. We start by asking whether fuel economy and fuel efficiency mean the same thing or different things to them. It is clear that the definitions of our lay respondents differ from those of experts. The most common "off-the-top-of my-head" response is that the two terms mean the same thing. To many people this meaning is rather abstract—"It's the gasoline it takes to get around, to go all the places we go." As some of them continue to talk, they convince themselves that fuel economy is about saving money while fuel efficiency is about saving gasoline.

When we ask our respondents to tell us what type of automobile comes to mind when we say "good fuel economy," most think of the smallest, cheapest vehicles. In contrast, "good fuel efficiency" tends to split the respondents into those for whom there is no different image and those who say fuel efficiency evokes images of higher quality vehicles and HEVs.

Willingness to pay for higher fuel economy—do households understand the question? We then ask households how much they would be willing to pay up front for an automobile with higher fuel economy. The reference vehicle is the one they designed in the PE exercise in Part Three. The fuel economy increase we posit is usually a 1.5X increase. While we occasionally choose a different multiplier than 1.5, we typically chose this number for two reasons. First, it is the maximum possible change in the PE table (and thus might be a change the household actually made in the PE exercise). Second, a 1.5X change is large enough on the one hand to get the attention of people who for the most part are not paying attention to fuel economy, but on the other is within the realm of technical plausibility. Once they have answered the question of how much they would pay, we follow up by asking how they arrived at their answers. We summarize their willingness-to-pay answers in Figure 4.

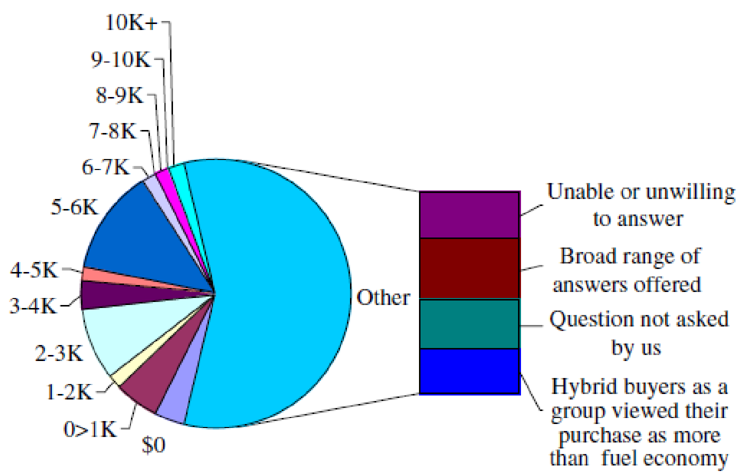

Fig. 4. Distribution of responses to willingness to pay for increased fuel economy.

In eight of the early interviews we did not ask this question about willingness to pay directly, so no values were solicited. In eight interviews in which we did ask the question, the household could not or would not offer a value. Ten other households offered a range, e.g., "$2000 to $4000" or "$5000 to $7000." Sometimes this range conveyed obvious uncertainty; sometimes these ranges represented disagreement between household members who were unable to agree on an amount in the course of the interview. Among the households who offered specific dollar amounts (or answers in a range less than $1000), values ranged between zero and $10,000. Even excluding the eight households from whom we did not solicit a value, half the households are unable or unwilling to offer a numeric answer.

Basis for willingness to pay responses. How people arrived at their willingness-to-pay responses is summarized in Figure 5. Only two individuals offer plausible willingness to pay answers arrived at through a process that could be described as economically rational (rather than through simple guessing). We judge the plausibility of their answers based on their producing a consistent set of answers to this question and later questions about the time they are willing to wait to be paid back, how much they drive, and what price they pay for gasoline. Their rationality is limited in the sense that neither based their answer on a net present value calculation but rather on simple payback period, and both implicitly assumed gasoline prices would not change (up or down) appreciably. It is also apparent that these two have not actually calculated a payback period for any of their past motor vehicle purchases.

The most rational response we heard in all the interviews was, "I don't know." A banker immediately recognized the "how much would you pay?" question. He sat up straight and started to verbalize his calculation. As he described the parameters, he realized he had no knowledge of one of them—future gasoline prices. He slumped back in his chair and motioned to his wife to offer her answer because he had none.

At least 14 of our respondent households has one or more member who is either a professional in the financial services sector, likely had at least one collegiate level course covering the topics of payback periods and net present value calculations, or otherwise has high quantitative skills.

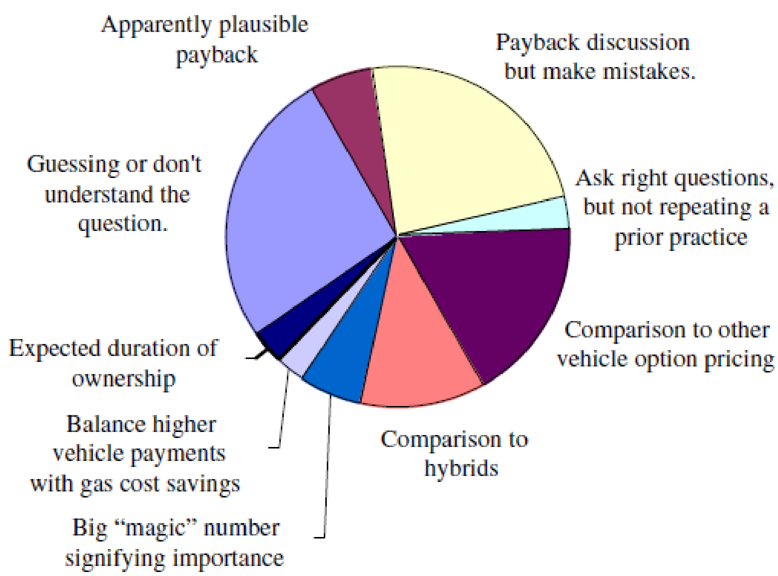

Fig. 5. Basis for willingness to pay answers.

These include our financial services sector households, our computer hardware/software households, and other households who happened to include a banker and a mathematics professor. These include the eight households in the table who discuss the problem in terms of payback (but make mistakes), the two people who offer plausible payback discussions, and the one person who was asking the right kinds of questions, but clearly had never previously thought about fuel economy in this way.

It was clear that many our respondents were not telling us how much they were willing to pay for 1.5 times higher fuel economy, but rather were guessing what it would cost. In nine households, our respondents admitted they were guessing or did not really understand the question. Six households arrived at a dollar value through a comparison to other vehicle types, the cost of options packages, and what they experienced as incremental price differences in the market for things like more powerful engines. Some (non-hybrid owners) were already familiar with what they believed was the price premium for hybrids and used that as their basis for answering.

In eight households, their answers followed from a discussion of time—along the lines of a payback calculation—how long they expect to own the vehicle, balancing gasoline cost savings with monthly payments, etc. That is, they tried to "back into" a dollar amount by first addressing the question of how long it might take to be paid back.

A few households offered large round numbers, e.g., $5000, with little explanation. We call these "magic numbers," signals that within the context of an interview, respondents are representing that higher fuel economy was seen a good thing they would like to be seen to support.

How long will people wait for fuel cost savings to payback a purchase premium? Following the question about how much they would be willing to pay for higher fuel economy, we asked whether they expected this purchase price premium to be paid back by fuel cost savings, and if so, how they arrived at their estimate of how long they would be willing to wait. Figure 6 summarizes their responses.

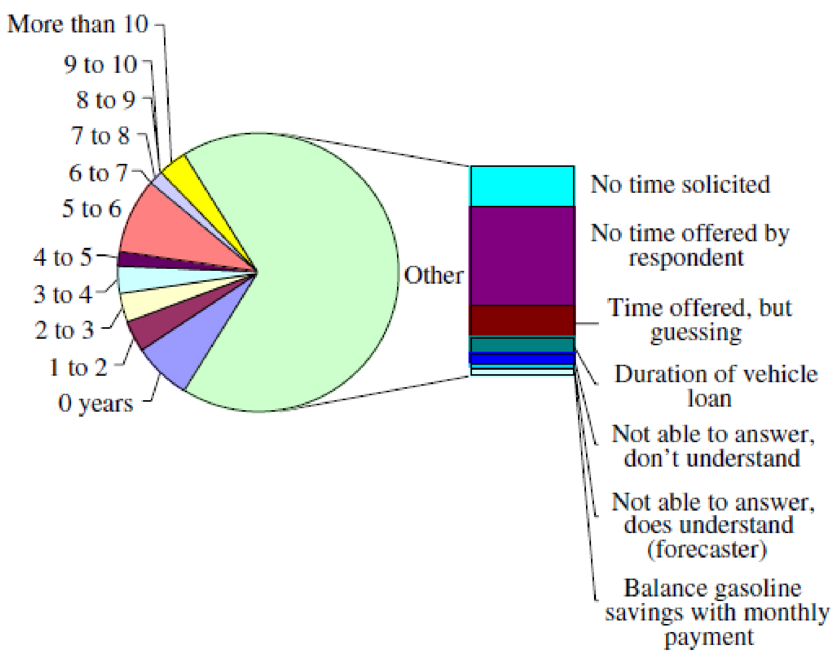

Fig. 6. Willingness to wait to be paid back by higher fuel economy.

Almost two-thirds of all the households to whom we posed this question would not or could not offer a payback time; most of these said it was just not the way they thought about it. The idea of a payback period for an "investment" in higher fuel economy is not part of the vehicle purchase decision-making even in the most financially skilled of our households. These respondents tend to understand the question immediately, but as one accountant responded, "Oh yea, payback calculations; I would never have thought about it that way."

Six households were clearly guessing; some offered a serial string of numbers in a questioning tone suggesting they hoped we would stop them when they arrived at the correct answer. Another group, either immediately or after some discussion, settled on a time period that corresponded to the term of their vehicle loan. We call this a "temporal anchor," a familiar time period offered in response to an obviously unfamiliar question. The other temporal anchor offered was the time they expected to own the vehicle.

Those who gave the shortest (non-zero) payback periods, i.e., 1–3 years, were being optimistic rather than impatient. When we asked about how they arrived at their answer to the question of how long they would be willing to wait, it became clear these people were over-estimating how much they thought they would save on gasoline. The two households who said they would not be willing to wait at all explained that they believed their spending was so constrained by cash flow they could not pay anything upfront. The three households who offered the longest payback periods based their replies on the belief they would own their vehicles for long periods of time; in effect saying, "I want any purchase price premium to be paid back while I still own the vehicle, but I expect that to be a long time."

The most common mistake respondents made was to overestimate fuel cost savings, and therefore to underestimate the time for fuel savings to payback upfront costs. Inflated estimates of fuel savings are usually the result of overestimating how much fuel they consume. (We discuss the quality of peoples' knowledge of their fuel expenditures in the next section.) Some households made the mistake of assuming they save their entire fuel cost for a year instead of just the savings from a 50 percent improvement in fuel economy. Even households who offered large willingness to pay values often think they can get their "investment" back in a couple of years.

The Building Blocks of Rational Decisions

It is clear few households understand the financial calculations that lie behind questions about "an investment in fuel economy" and payback periods, and that even those few do not apply such knowledge to their household vehicle purchase and use. Do any households have the basic building blocks of rational decision-making—the perfect, or really good, information consumers are assumed to have about their own costs and options for improved fuel economy?

The answer is, "no." Nineteen households admitted they could not tell us the fuel economy rating for one or more of their vehicles. In most households one person could offer the MPG rating of their vehicle while others could not. Even the self-identified knowledgeable person knew their vehicles' MPG with varying degrees of certainty. Only owners of HEVs that have obvious, precise, and visible fuel economy instrumentation consistently offered confident estimates of their MPG. The fuel economy values offered by households came from a variety of sources. Some measured MPG from tank-to-tank of fuel. Some recalled the estimate provided on the window sticker when the vehicle was purchased. A few recalled reading the owner's manual. All respondents who track their fuel economy from tank-to-tank do so as a diagnostic tool to assess vehicle performance over time, not to track fuel costs or economy per se.

Knowledge of fuel expenditures. We asked households how they best understand their fuel expenditures over time, and prompted them with, "annually, monthly, or weekly?" Most chuckled at the idea of knowing their annual fuel cost, it is an unknown number for all but two households who track vehicle mileage and expenditures for business purposes. The time periods for respondents understanding their gasoline expenditures are summarized in Figure 7.

The largest number of households (27) either said they had no idea of their gasoline expenditures over any period of time (14) or knew only what they spent per tank of gasoline (13). Many of these households tried to develop a "monthly" estimate by summing their recollection of typical gasoline purchases—starting with their estimate of the cost of a tank of gas and multiplying that by their guess as to how many times they refuel per month.

As with the issue of whether people conduct payback or net present value calculations though, the simple fact that people would offer a guess as to their monthly gasoline costs is not the same as their actually measuring gasoline use and expenditures on an ongoing basis. These households were constructing their estimate of fuel costs over time for the first time in their interview.

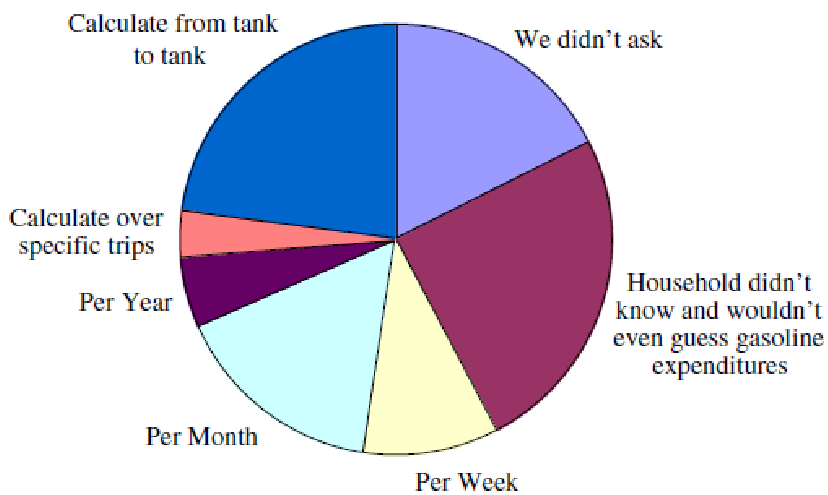

Fig. 7. Basis for households' responding to questions about their gasoline expenditures.

We conclude that in general our respondents do not track or sum their automotive fuel costs over time. Overall, the most common way people knew their gasoline costs was by the cost of a tank of gas, and this usually from their most recent refueling event. Thirty-one households could recall with some confidence how much they paid for the last tank of gasoline. But, it takes only a few days for the specific data to appear to be forgotten, and a "typical" amount substituted. A few households do have credit cards dedicated to their gasoline purchases, and they seem to have a better handle on monthly costs. Still, many of these households buy gasoline for several vehicles on the same card, and thus do not know how much they spend on gasoline for any one of their vehicles. Of the three households who offered estimates of their annual gasoline costs, one was clearly guessing and two were undertaking broad reviews of annual household expenses at the time of their interviews.

HEV Owner Interviews

We interviewed HEV buyers because they appeared to have paid for a high-technology approach to better fuel economy. We wanted to explore how they made this decision. The interview protocol for these households was different; we did not prospect the purchase of a vehicle with better fuel economy using a priority evaluator table; instead we spoke directly about their real decision. Additionally we spoke with hybrid buyers about the wider meanings of their purchase, as well as what it was like to own a vehicle with this new technology

None of the eight hybrid owners in our study tracked fuel economy over time. Nor were they any more likely than the other 49 households to know their annual fuel costs. We emphasize that no hybrid owner we interviewed was solely or even importantly interested in saving money on gasoline. They did know a lot more about the vehicle and the environmental issues it addresses than they did about their own gasoline costs.

Buyers of HEVs talked about making a commitment. In addition to any financial commitment, buyers of Toyota’s Prius generally had to wait several months for delivery of the vehicle. For several hybrid buyers the idea of commitment included setting an example, being a pioneer, talking to other people about their car. Several had shifted from a larger vehicle to the smaller hybrid. One hybrid buyer also started biking and walking more. For one household, their Civic Hybrid was part of a larger project to reduce their environmental impacts. This household had moved to a “hobby” farm in a remote rural area, which given their job locations and other interests resulted in lots of driving. They are hoping to buy a second hybrid.

Among this group of HEV buyers, the high fuel economy of their hybrid signified some other important value. Some HEV buyers were attracted by the new technology; others by the low emissions of criteria pollutants; and others still by a sense of “living lighter”—getting around while consuming fewer resources.

HEV owners did not in general perceive a specific price difference that they paid for their HEV. One respondent said, “I looked at the whole package, and judged it was worth the price.” Further, assessing what is the relevant difference in price and fuel economy (as a determinant of private fuel cost savings) depends on detailed knowledge of the households’ vehicle holdings and transactions. Many HEV buyers crossed vehicle classes in order to buy hybrids available at the time of this research. One traded in his Jaguar XJ6, another traded her compact pickup truck, and another bought a Prius rather than a compact SUV.

Discussion

Based on what we heard in these interviews, many findings from past and ongoing energy research and analysis that report consumer willingness to pay and payback periods for new fuel economy technology in automobiles seem unrealistic. We expect that most participants in past survey research were responding for the first time to novel questions, not recalling past or probable future behavior. In short, the consumers we spoke to do not think about fuel economy in the same way as experts, nor in the way experts assume consumers do. The problems posed by this mismatch between experts' questions and laypersons' reality are not avoided by inferences based on a rational analytic interpretation of parameters in models correlating vehicle and fuel prices and sales.

We consistently watched consumers overestimate their gasoline cost, express willingness to pay values out of line with an objective view of their potential savings and past behavior, and then offer payback periods that do not reflect their estimate of their expenses. For these people, pointing out their true annual fuel costs and the difference in their costs made possible by higher fuel economy might not be the best strategy to foster purchases of more fuel economical vehicles—if we assume higher fuel economy or fuel efficiency have only private monetary value to economically rational consumers.

Based in part on consumers more positive images of the term fuel efficiency, as compared to fuel economy, it might be strategic for those interested in promoting good fuel economy to shift their terminology and focus to good fuel efficiency—so long as higher efficiency is put to the service of lower fuel consumption.

We heard from households who were attracted by non-incremental, non-marginal improvements in fuel economy and fuel efficiency such as those offered by hybrids and as offered by us in the course of their interview. The actual buyers of HEVs appear inspired by large changes in fuel economy beyond even what those changes might save them in the cost of gasoline.

If households do not have access to the basic building blocks of information regarding their fuel use and costs, if they demonstrate a lack of understanding or express no experience with algorithmically correct rational calculations, and if some demonstrate they understand such calculations but have never applied this understanding to their household vehicle purchase, then what are consumers doing?

Much recent psychological and sociological theorizing focuses on the use of heuristics, or cognitive shortcuts. Reich (2000), reviewing the work of German social theorist Gerd Gigerenzer, argues that "…rules for decision and action may well be grounded on simplifying and biased assumptions and lead to incoherent results—in short, these rules may be heuristical algorithms instead of determinable algorithms…" Kahneman (2002) argues that such shortcuts are the normal way of making decisions (even among experts) and that calculated rationality occurs only as a deliberate override to such heuristic—or in his terms, intuitive—practices. Of particular importance is that certain types of quick decision tools and information are more accessible, and therefore far more commonly used in making decisions.

It may be that such heuristics are used when we ask participants to answer questions like, "How much would you pay for higher fuel economy," or "What is an acceptable payback period?" They may be answering with an accessible rather than an accurate number, just as we heard some households respond with answers that matched their vehicle loan period or expected duration of ownership.

However, fuel economy may be more complicated than a simple set of heuristics, which offer consumers a few quick ways of making decisions in situations of limited information or high complexity. Fuel economy is becoming a public issue, a topic of conversation, advertising, news stories, and display. Automotive advertisements now feature fuel economy ratings and tout the number of vehicles a manufacturer builds that achieve high fuel economy. The prices of a gallon of gasoline and of a barrel of oil are stories on the evening news, in the morning paper, and on automobile-related web sites.

Further, motor vehicles are assigned symbolic meanings. As we find in our interviews, many households express considerable anger towards owners of large SUVs, and are willing and even eager to talk about it. Even owners of small and mid-sized SUVs express anger at drivers of full-size SUVs. Oil companies are also targets. Evidence from this study suggests that a common consumer response to rising gasoline prices is not to change travel or buy more fuel economical vehicles, but simply to get angry with oil companies. Fuel economy is conflated with many of these symbolic meanings and has become part of conversations about larger issues than household budgets.

We offer two hypotheses from this set of interviews.

1. Over the past several decades of declining real gasoline prices and rising personal incomes, consumers engaged in a limited economic rationality, possibly using simplifying heuristics in the place of algorithmically correct evaluations. Abetted by limited fuel use and cost instrumentation, consumers give little attention to fuel economy. If gasoline prices increase enough, consumers will develop more calculating, economically rational decision-making regarding fuel economy.
2. Automobiles are repositories of many high value meanings, some which have important but non-quantifiable/ non-monetized value. Because of these meanings, few automobile buyers paid much attention to the small financial differences provided by the historically available differences in fuel economy of otherwise similar vehicles. Even if gasoline prices rise, buyers may respond to shifts in these other meanings rather than respond solely to shifts in fuel costs in economically rational ways.

The first hypothesis simply implies that gasoline has been too cheap for the past few decades for it to be "sensible" for consumers to be "rational." The second states that the value of fuel economy is more than differences in fuel costs, but includes other symbols, meanings, and values, and that those are unlikely to be processed in an economically rational algorithm under any conditions.

Contrary to the first hypothesis though, we found that automobile buyers do not have the basic building blocks to make calculated decisions about better fuel economy, and most do not keep track of fuel cost over any significant time period, be that the life of the vehicle, their duration of ownership, annually or even monthly. Refueling does not always happen on a regular schedule, so even in the context of our interviews, households can only make rough estimates of costs over time. It is clear that even our most financially skilled buyers have not purchased their cars and trucks based on the application of payback or net present value analyses.

Behavioral vestiges of the last dislocation in gasoline prices and supplies during the 1970s and early 1980s were heard in the interviews, faint echoes of remembered shifts toward more economical vehicles. Under these conditions, policy makers, automobile manufacturers, and consumers pushed the vehicle design envelope in the direction of higher fuel economy. Claims—based on the past twenty years of pushing the design envelope toward greater power, size, and energy-consuming options and accessories—that consumers do not value fuel economy ignore context, assuming that “what consumers want” is invariant.

Even in a sample constructed such as the one in this study, if economic rationality is pervasive in the population, we should have found someone who articulated their automotive purchase and use decisions in a manner consistent with the assumptions of that model. We did not. Therefore, we cannot support the continued assumption that economic rationality is the sole sufficient behavioral model for policymaking and policy analysis of automotive purchases and gasoline consumption. We have presented initial evidence to contradict the first hypothesis and in support of the second. Still, choosing between them would require further study.

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Applying Behavioral Economics Concepts in Designing Usage-Based Car Insurance Products

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Introduction

Behavioral economics, a discipline combining economics and psychology to explain consumer decision making, offers insights on marketing and designing usage-based or pay-as-you-drive-and-you-save (PAYDAYS) insurance products to maximize profitability, consumer acceptance, and public benefits. By converting fixed insurance costs to per-mile or per-minute-of-driving charges, PAYDAYS insurance encourages voluntary reductions in driving that reduce congestion, air pollution, and crashes. General behavioral economics research findings strongly suggest that different product offerings among the myriad of PAYDAYS insurance product possibilities would result in substantial differences in vehicle miles traveled (VMT) and in the magnitude of related benefits. This chapter examines the full array of existing and potential designs for PAYDAYS insurance plans, analyzing how well each attracts and retains customers, and discourages driving. Tables herein identify target markets, product structure, and pricing and related attributes that would maximize participation and mileage reductions among participants. Following an overview of the PAYDAYS concept I propose a pilot experiment that would illuminate consumer response to this kind of insurance program, and improve the application of behavioral economics principles to the design of PAYDAYS insurance products.

The Paydays Framework

PAYDAYS insurance uses traditional rating factors, such as residential location, gender, age, and driving record, but they become subordinate to usage-base factors and are incorporated into usage-based rates, which also account for the specific coverage a driver chooses. PAYDAYS insurance is likely to result in charges that more accurately reflect crash risk, based, as they are, on usage.

Under a basic design of PAYDAYS insurance, consumers would pay in advance for a pre-determined number of miles per unit of time. At the end of the time period, they would either pay extra, or receive a rebate, depending on whether they drove more or less than their allotted distance. Motorists could also be billed based on monthly mileage, similar to utility billing.

Under conventional insurance policies, by contrast, consumers have little opportunity to save by driving fewer miles despite the fact that insurance claims are directly related to miles driven. The projected success of PAYDAYS is, in part, predicated upon the hypothesis that in exchange for reducing fixed insurance costs, many drivers—especially lower income ones—would readily accept mileage premiums that they could reduce by driving less. They could do so through

[1] The views expressed are not necessarily those of the Federal Highway Administration or the U.S. Department of Transportation.

voluntary trip consolidation, carpooling, alternative transportation use, and forfeiting of low-value trips.

As noted above, by reducing vehicle miles traveled, PAYDAYS would decrease congestion, carbon dioxide emissions, air pollution, vehicle crashes, the cost of maintaining infrastructure, and the balance of payments deficit. These benefits have piqued the interest of government, environmental and other non-profit organizations, insurance companies, and consumers. The benefits of allowing drivers to share in the savings from reduced insurance claims resulting from driving less are well documented. Studies estimate VMT would drop between 8 and 20% if all fixed automotive insurance costs were converted to usage-based, with the more recent estimates tending to be on the lower side of this range (Litman 2004; Barrett 1999; Parry 2005; Bordoff and Noel 2008).

Interestingly, reductions in VMT result in disproportionately large reductions in crashes, claims, and fatalities. The reason is simple and can be illustrated by using data on crashes involving fatalities, which is by far the most extensive type of crash data available. For multiple vehicle crashes resulting in fatalities—which accounted for 45% of all motor vehicle fatalities in 2000, and likely a similar proportion of crash claims—if one of the cars had not been on the road, the crash likely would not have occurred. For single car crashes, the result is more linear. Overall, a 10% reduction in the number of VMT that normally would be associated with 1,000 crashes would reduce that toll by 140 crashes, or 1.4 times the reduction in VMT. A similar disproportionate reduction in claims should also occur (Greenberg 2002).

For those readers who wish to understand the details, here's the logic: All else being equal, a 10% reduction in VMT would be expected to result in a 10% crash reduction from single vehicle and vehicle/pedestrian crashes. For multiple vehicle crashes, a 10% reduction in VMT should reduce these by 19%. The 19% reduction is derived thus: Had the 10% VMT reduction been achieved, the chance for each vehicle involved (using the simplifying assumption of only two vehicles) that it would still have been on the road is 90%; the chance that both would have been on the road is 0.9 X 0.9, or 81%. Therefore, for every 1,000 crashes resulting from a particular level of VMT, a 10% VMT reduction would initially appear to reduce single vehicle crashes from 550 to 495 and multiple vehicle crashes from 450 to 364.5; thus there would be 140.5 fewer crashed vehicles or a 14% overall reduction (Greenberg 2002).

Benefits of Paydays Insurance

PAYDAYS is a win-win from a multitude of perspectives. For every mile not driven, three to five cents that would otherwise need to be spent on infrastructure to accommodate that mile of driving could be saved, according to Federal Highway Administration models (Greenberg 2002). Between $50 and $60 billion in net social benefits would accrue in the US from reduced driving related externalities if PAYDAYS premiums became the standard insurance product, according to the Brookings Institution (Bordoff and Noel 2008).

Moreover, government incentives to promote PAYDAYS would be far more cost-effective than alternative transportation related expenditures for reducing air pollution and saving lives. For example, the Federal government would, under one proposed incentive scheme, pay $2,700 per ton of emissions reduced through incentives for PAYDAYS pricing, compared to an average of $63,600 to reduce that ton through typical measures funded under the Congestion Mitigation and Air Quality Improvement Program (Greenberg 2002).

PAYDAYS is better even than gasoline taxes for providing public benefits. While a gas tax would reduce fuel use partially through drivers' driving their gas sippers instead of their guzzlers, or replacing their gas guzzlers with high-mileage cars, PAYDAYS achieves the same reductions in fuel use entirely by curbing driving, with concomitant reductions in congestion and crashes that come only from driving reductions (Parry 2005).

Of course, a package of policy measures aimed at reducing VMT can do more than each policy alone, as is shown in the report, "Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions," a joint effort of multiple Federal agencies, environmental organizations, and Shell Oil. Significantly, when PAYDAYS insurance was added to a bundle of land use/transit/non-motorized transportation measures (one of a number of policy bundles evaluated), it led to a 44% greater reduction of transportation-related greenhouse gas emissions through 2050 than the bundle did absent PAYDAYS (Cambridge Systematics, Inc. 2009).

By providing affordable insurance to low-income motorists who are willing to limit their mileage, PAYDAYS could reduce the number of uninsured motorists (Litman 2004). Indeed, it has been projected that 63.5% of households would save an average of 28% on their premiums (including the "comprehensive coverage" portion, which was assumed not to vary with mileage), or about $496 annually (Bordoff and Noel 2008).

Some Paydays Insurance Offerings

Three insurance companies in the U.S., GMAC Insurance, Progressive Insurance, and MileMeter Insurance, are setting premiums based at least in part on mileage. GMAC Insurance offers low-mileage discounts in 35 states, reducing premiums by 54% for those driving fewer than 2,500 miles per year, with progressively smaller discounts as driving distance rises to 15,000 miles per year (GMAC Insurance 2009). The company uses OnStar to monitor its customers' mileage.

Progressive Insurance's MyRate and Snapshot programs, available in a total of 23 states, offer usage-based premium discounts predicated upon observed VMT, as well as driving safety (determined by monitoring of G-forces in cornering and braking). Snapshot is the newer of the programs (all MyRate customers will eventually be moved into the Snapshot program) and only monitors driving for a relatively short time period for the purpose of establishing general driving patterns (i.e., how much, how, and when customers drive) (Progressive Insurance 2008; Progressive Insurance 2009; Progressive Insurance 2010).

MileMeter Insurance Company began offering ''insurance buy the mile" in Texas in 2008. Instead of purchasing insurance for six months or a year, a Texas motorist may purchase between 1,000 and 6,000 miles of coverage and make additional purchases as needed. MileMeter only needs to confirm mileage when a claim is filed to determine if the vehicle is insured at the time (e.g., if 2,000 miles of coverage between 86,567 and 88,567 miles had been purchased, a claim will be honored so long as vehicle mileage falls within that range) (MileMeter Insurance Company 2009).

Issues that companies need to consider when selecting amongst the many possible options of PAYDAYS insurance products include costs, ease of implementation, actuarial accuracy, and impacts on claims. For public relations purposes, and also to bolster consumer acceptance and market share potential, companies may also want to consider privacy issues, the relative environmental benefits of different product approaches, and equity issues, such as impacts on low-income drivers. Tradeoffs among all of these concerns are inevitable. For example, it is likely that the more parameters that are tracked and used for pricing, the greater the actuarial accuracy, and the greater the safety and environmental benefits will be for each PAYDAYS policy underwritten in the marketplace, although privacy concerns associated with monitoring more driving parameters could detract from consumer acceptance and purchase of the product and thus the overall benefits conveyed to society.

Learning from Behavioral Economics

Behavioral economics offers many insights to help assess the tradeoffs associated with product designs. It reveals the bounds of human rationality, and it demonstrates how easy it is to manipulate the way humans view choices and decisions, just by reframing them. And through behavioral economics, one can determine how different product designs and marketing could strongly influence both consumer acceptance of the product and how effectively the product encourages consumers to curb their driving.

General Consumer Decision Making

As a group, consumers avoid making decisions they see as complex, and if they can't avoid such decisions, they often apply only minimal mental effort to the task. They rarely reconsider past decisions that continue to influence their current circumstances. In consideration of complex products, such as of PAYDAYS insurance, this bodes ill for consumer adoption.

While consumers consider economic factors beyond just the straight product price in their decision-making, such factors generally have relatively little influence. Consumers typically formulate very rough budgets in their heads that cover short periods of time, with little economic concern for the long term; they consider savings' opportunities only where potential savings appear to be significant relative to price; they look for deals that make sense to them and appear fair; and they are strongly biased toward accepting a default option even if better non-default options are readily available. All this is especially true in markets where the products are complex.

Consumers are most likely to shop for new insurance when premiums rise or when changes occur in household composition, circumstance, or vehicle fleet. Financial pressure is a major motivator for changing insurance policies. For example, from Oct. 2008 to March 2009, a period of sharp decline in the economy, 25% of surveyed car insurance shoppers reduced their insurance coverage, while 31% increased their deductibles. During this period, quotes for coverage on the website, Insurance.com, dropped by an average $100 (Kuykendall 2009).

Consumers readily categorize spending decisions into different budgets, such as food and transportation (see below), and they tend to calculate trade-offs within each category without regard to changes in other budget categories (Thaler 1999). Put another way, consumers may view spending related to driving within the broader context of their predetermined car insurance and travel budgets. This suggests that advocates of PAYDAYS insurance seeking reduced VMT should persuade consumers that they can actually reduce their car insurance budget relative to its size under traditional insurance. A possible pitch to consumers who have chosen PAYDAYS pricing would be: "You switched to PAYDAYS insurance as part of a promise to yourself to save money. Here are some ideas to help make sure you do..."

Consumers appear generally to be more sensitive to their immediate cash flow needs than to longer term budgets (although this is less true for affluent consumers). For example, when making car-buying or leasing decisions, they are much more sensitive to the size of monthly payments than to the total number of monthly payments (Gourville 2002). Because of consumers' cash-flow concerns, PAYDAYS will be more effective in encouraging reduced driving if billing is frequent—thus reminding PAYDAYS customers that they incur insurance costs every time they drive.

As noted above, consumers concern themselves with opportunities to save only when the potential savings seems significant relative to the price. Thus, if PAYDAYS insurance is sold in use-or-lose packets of 2,500 miles—about two months worth for the average American driver, this may do little to discourage short trips; however, such packets would be likely to influence longer-term decisions, such as whether to join a carpool, purchase a commuter rail pass, or negotiate with one's employer to telecommute a couple of days per week. Conversely, two-week packets of PAYDAYS insurance might also encourage buyers to avoid or consolidate individual trips, while longer-term packets probably would not.

Marketing PAYDAYS insurance as a better and fairer deal could help it gain acceptance. Consumers generally are very sensitive to the fairness of the deal (transaction utility) and they are much more willing to spend on a perceived good deal, regardless of the purely economic value they may derive from use of the particular product or service. In one classic experiment, someone offers to get the beer for his friend who is lying on the beach, paying with his friend's money, and mentions that he will be making his purchase at a nearby establishment that is either a fancy resort hotel or a small run-down grocery store. When asked by his friend how much he would be willing to pay for the beer, the answer is invariably substantially more when the first type of establishment is mentioned than the second (Thaler 1999).

Many consumers don't believe it is fair to use credit scores, as is common, to partially determine car insurance rates under conventional policies. Indeed, the various statewide battles over whether credit scores should be allowed to be used in rate-setting are motivated by public perception that credit scores have no bearing on crash risk, although actuarial data show otherwise. Some states have responded to this public perception by banning the use of credit scores to set insurance rates.

Conversely, in the late 1990s, consumer focus groups responded positively to the Progressive Autograph Insurance product, which was a pure PAYDAYS insurance product then offered experimentally in Texas, because the relationship between the amount of driving, especially in areas and at times of high crash rates, and claims risk seemed intuitively obvious, and thus fair to use in setting premiums, especially since consumers could control their costs by driving less.

As alluded to earlier, consumers are much more likely to pick a default option than an alternative, even if choosing the alternative involves no more effort than checking a box on a form. Thus, for PAYDAYS to become highly successful, insurance companies should offer it as the default. This propensity to pick the default has been shown in a variety of markets, including automobile insurance. In Pennsylvania, for example, where full-tort insurance coverage is the default option, more than half of drivers sign up; in New Jersey, where it is not, fewer than one in 12 sign up (Leonhardt 2005).

Consumer Responses to Financial Gains and Losses

One of the major lessons from behavioral economics is that people generally value what they have now far more highly than anything that they gain in the future. In fact, Thaler estimates that people see the value of a dollar lost as roughly 2.25 times that of a dollar gained (1999). This is at least partly why people are more likely to hang onto stocks that are sinking than to sell them, and use the money to buy more robust offerings. This bears importantly on how best to design PAYDAYS pricing schemes in order to get the greatest reduction in mileage. Consumers will drive fewer miles if they have to pay for them directly now than if they are offered a rebate for miles not driven—which is something they view as a windfall, each dollar of which is less valuable to them than the dollars they have now--even if the effective cost of each mile is the same in each case. Thus, crafting the most effective mileage-reducing insurance policy is a matter of framing the policy in a way that emphasizes the cost of each mile as a loss, not a gain.

Unfortunately, virtually all U.S. pilot projects testing consumer response to mileage pricing have not been designed to take advantage of loss aversion. The problem: they give participants bank accounts which are incrementally depleted for each mile driven, with the money remaining at the pilot's end given to the participant. People perceive money that is given to them as a windfall, rather than as their own hard-earned cash that they saved through driving less, and they would therefore value it commensurately less. Thus, these pilot studies were far less effective at reducing miles driven than they would have been had there been direct mileage pricing.

Similarly, various PAYDAYS insurance offerings in the marketplace (and most especially the GMAC Insurance product that utilizes OnStar) are, as discussed earlier, framed as offering low-mileage discounts instead of basing premiums directly on mileage. This also likely results in higher VMT than if the products were to be framed the other way.

How Payment Frequency and Payment Method Affect Propensity to Conserve

The timing and frequency of payments have a profound effect on propensity to conserve. Part of this stems from humans' general aversion to decision-making. Just as people avoid complex decision-making, most people also avoid making financial decisions where the consequences aren't immediate and/or transparent. Thus, if as in the previous example PAYDAYS insurance could be purchased only in use-or-lose buckets of, say, 2,500 miles, consumers would restrict their worrying about the financial consequences of short trips to when they approach the end of a bucket of miles—that is, when delaying the need to purchase more miles would have immediate financial consequences.

It follows from this that payment frequency would also influence propensity to conserve. With frequent payments, people would be acutely aware a greater percentage of the time that their driving was costing them money.

How payments are made also influences decision making. People spend more freely when paying by credit card (an observation that accounts for merchants' willingness to accept credit cards even though the credit card companies take their cut) than by cash or check. This is because credit cards reduce the frequency of the pain of paying to once monthly, as well as because the impact of individual charges are somewhat masked by the size of the overall bill (Thaler 1999). (One study showed people bidding twice as much for Boston Celtics tickets by credit card as by cash even though ample time was provided to retrieve cash if needed (Thaler and Sunstein 2008).)

Perspectives on Price Bundling

Consumers may prefer all-inclusive pricing over per-use pricing for a variety of reasons. People love to feel that they are getting something for nothing, even if the freebie requires paying far more for something else with which the freebie is bundled than that something else is worth (Anderson 2009). *Nevertheless, unbundling, or pay-per-use pricing has been shown to be an effective strategy in the marketplace if deployed with particular attention to consumer concerns and desires.*

Consumers often prefer buying in bundles partly because this way, they need not worry about usage and having to pay again. Reasons for this that could apply to PAYDAYS insurance purchase decisions include: 1) inability to estimate usage costs; 2) laziness regarding tracking expenses; and 3) excessive concern that they will pay dearly for those few times when they need to drive a lot, combined with undervaluing the savings that will accrue from driving less overall. Telecom industry research shows that most consumers are ignorant of the price of individual phone calls, and may over-estimate that cost by a factor of three. Since bundled products seem to come with more price certainty than unbundled products, a general preference for bundled products should not be unexpected. This is especially the case since "most people are risk averse and, other things being equal, will choose an option with a known price over one with an uncertain price." (Bonsall 2004) It would seem, then, that, especially when considering that PAYDAYS insurance starts with the disadvantage of price uncertainty when compared with conventional insurance, the design of Progressive's MyRate and Snapshot products, where consumers are not informed about the precise relationship between their behaviors and their renewal premiums, might especially discourage some consumers from signing up.

Many urban car owners could save substantial sums by selling their cars and taking taxis or participating in car-sharing programs for the times they need a car. But they resist this, because the switch from largely fixed to completely variable transportation costs makes their grocery and movie costs appear to rise (Thaler 1999).

The idea of driving less, both by living close to work and stores and by otherwise organizing one's life to reduce driving, however, is catching on, especially among young adults, in part because of concerns about the environment. Americans believe that global warming is at least partially a result of their own behaviors. Seventy-eight percent agreed with the statement that mass transit is either a "very important" or "somewhat important" way to reduce energy consumption, according to a Zogby poll. About 40% said mass transit was important to them personally, and 50% of 18 to 29 year olds agreed with this statement. Further, 38% said that transit is important in their selection of where to live, rising to 47% among 18 to 29 year olds. Finally, while a May 2007 survey showed only 1% had carsharing memberships (the numbers continue to grow at a hefty pace), 5% said they were very likely to join in the future and an additional 12% said they were somewhat likely to do so (Zogby 2009). This is an interesting case—there are others—where people's values are at least partially responsible for their interest in reconsidering bundled car ownership and insurance.

Car-sharing is a great way to convert the fixed costs of car ownership to variable, usage-based charges. The survey results cited above would suggest, especially among the young, a genuine willingness to accept usage-based car pricing as a substitute for car ownership. But even car sharing businesses have experimented with bundling. For example, Flexcar (recently subsumed into Zipcar) used to feature a few multi-hour bundled monthly pricing plans, perhaps in part to avoid this negative cost perception surrounding taking some individual car trips. Today, Zipcar offers discounted hourly rates for moderate and heavy users, but presently it would be difficult to offer a bundled product because the fleet is too diverse, and hourly prices vary by vehicle type.

Not all purchasing in bundles is done by consumers to avoid the risk of paying more with per-use pricing. Purchasing in bundles (e.g., all-you-can-use monthly gym memberships instead of single-use one-day passes) has been shown to be especially prevalent with health club memberships, because consumers typically overestimate how much they will use their memberships and also want to motivate themselves to use them more (DellaVigna and Malmendier 2004). In the context of PAYDAYS insurance, this overestimation of personal discipline suggests that consumers might perceive PAYDAYS pricing as offering even greater savings than they would typically ultimately realize. Thus, if consumers view reducing driving as virtuous, and are optimistic about their ability to do so, PAYDAYS insurance might seem very attractive.

Bundling monthly transit passes where individual trips are free with PAYDAYS for a nominal additional fee could provide a powerful lure for consumers to sign up. Even if they do not fully live up to their own expectations in reduced driving, the fact that they paid something for the transit pass which then allows them to ride free, while at the same time they are paying per mile for insurance, boosts the likelihood that they will reduce driving in favor of transit.

And while many might still be reluctant to sign up for PAYDAYS—probably due to fear of the unknown, or inertia—luring them with a trial run can make the unfamiliar familiar, with positive results. Participants in a Minnesota PAYDAYS leasing simulation pilot—entailing a reduced fixed monthly vehicle charge in combination with a variable per-mile charge—who were randomly assigned the pricing treatment were substantially more likely than control group participants to be interested in securing a similar leasing arrangement and PAYDAYS insurance after pilot completion ("Pay-As-You-Drive Experiment Findings," 2005).

The preference for purchasing some products in bundles is not boundless and a maximum monthly charge might be useful in encouraging acceptance of pay-per-use plans. Among six separate PAYDAYS focus groups I observed in Minnesota, in April 2003, participants showed substantial preference for scenarios where the maximum monthly lease payment was capped, even though mileage charges in excess of caps were rolled into subsequent bills. The latter presumably would keep consumers from driving excessively after breaching the mileage corresponding to the maximum monthly payment. Progressive Insurance applied a cap designed in this fashion with its "Autograph" pilot discussed earlier.

Surveys associated with the Minnesota leasing pilot showed that interest in leasing tripled (from 6% to 18%) as the top choice of respondents for acquiring their next vehicle when new leasing plans were presented that combined a reduced fixed monthly charge and a variable mileage charge. When two variants of this new type of lease were presented, two-thirds preferred the option with the higher per-mile price and lower fixed-monthly price over the reverse ("Market Assessment Survey Results," 2004).

But introducing too many pricing schemes at once could be risky by creating confusion and discouraging consumers from trying something new. Indeed, on balance, it has been called a bad idea (Bonsall 2004). It has been shown, for example, that offering too many mutual fund choices reduces 401(k) plan participation, and the same might also be expected if too many variants of PAYDAYS insurance (e.g., more than two or three) were offered (Schwartz 2004). As the market for cell phone services suggest, however, PAYDAYS insurance could ultimately be offered by different companies in many different forms, but behavioral economics says that individual companies would be wise not to confuse customers with too many different offerings.

A number of surveys and real-world marketing experiences of insurance companies show how consumers react to bundled PAYDAYS insurance versus traditional insurance. A survey in Minnesota found that 32% of respondents prefer PAYDAYS insurance pricing over having to pay traditional insurance premiums ("Pay-As-You-Drive Experiment Findings," 2005). Progressive Insurance representatives have said that with TripSense, the predecessor program to its MyRate and Snapshot offerings, 34% of its customers who signed up for insurance by telephone and the Internet chose TripSense over Progressive's standard product in the three states where TripSense was offered. Progressive also reported interest among over half its customers for PAYDAYS policies, so long as they could save money (Hutchinson 2008).

A second survey shows similar results about consumers' growing desire for unbundled PAYDAYS insurance. The 2010 comScore "Online Auto Insurance Report" includes a year-to-year comparison of survey responses about PAYDAYS insurance. In 2010, 20% of respondents claimed to have heard of the term pay-as-you-drive insurance, versus 17% in 2009. More significantly, of those who had heard of it, 31% in 2010 said that they would definitely purchase it, versus only 17% in 2009. (Multiplying the 20% who have heard of PAYDAYS insurance by the 31% who would definitely purchase it shows 6% of total 2010 survey respondents saying they would definitely purchase the product.) Also, while 18% of 2009 respondents who had heard of it said that they definitely would not purchase it, only 11% said that in 2010 ("Online Auto Insurance Report," 2010).

Usage data for cell phones suggests the importance of variable pricing over fixed rates to curtail demand: usage has been found to more than double with unlimited calling plans, although self-selection may play a role in this (Thomson 2003).

Bonus Strategies from Behavioral Economics

Various other strategies—reflective of new research areas in behavioral economics—could further encourage PAYDAYS customers to ratchet down their driving. These strategies would be very unconventional to use as part of an insurance product, however, and instead might be offered in addition to the risk-based pricing of the PAYDAYS insurance product. In fact, in some states, they might be prohibited, because contrary to some state insurance regulations, they are not closely tied directly to claims costs. Nevertheless, they have proven very cost effective for motivating behavior change, including reduced driving.

Recent research designed to improve health outcomes points to some particularly successful behavioral incentives. One is the so-called regret lottery. Regret lotteries have been designed to encourage healthy behaviors, such as remembering to take one's medication, or meeting a weight loss target. Those who meet their goals become eligible to win a small sum of money in a lottery, while those who fail may learn of their being selected as a winner, but also would regret that because of their own failure they would be ineligible to keep the prize. Several studies have demonstrated effectiveness. In a regret lottery study involving patients on anticoagulation medication, mean non-adherence dropped to 1.6% and 2.3% from a historical 22% (Volpp 2008a). The draw offered a 1% chance of winning $100 and a greater chance of winning less money.

In a study of weight loss, both regret lotteries and deposit contracts were tested. Deposit contracts required participants to invest some of their own money (they had discretion on the amount), which was matched one-for-one plus $3 by the study. Subjects with deposit contracts got all their money back plus the additional funds if they lost at least a pound per week, for 16 weeks, and received nothing if they fell short. Participants assigned to the regret lottery and deposit contract conditions lost an average of 13.1 and 14 pounds, respectively, while control group participants lost an average of only 3.9 pounds (Volpp 2008b).

A regret lottery has been suggested for PAYDAYS insurance in which subjects would be eligible to win based on meeting specific driving reduction goals that could increase month to month. Unpublished research shows regret lotteries are vastly more cost effective than standard lotteries at achieving behavior change (Loewenstein 2009). Other research shows that consumers respond more favorably to low-value traditional lottery awards than to cash payments equal to the expected value of the lottery awards.

An innovative lottery strategy designed to encourage commuters to take company buses to work outside of the highest peak commuting hours, by linking status and rewards to the desired behavior, was tested in Bangalore. This scheme rewarded participants who shifted their travel away from the peak with points that established a status level, with higher status corresponding to both greater probabilities of winning and more substantial payouts. The strategy was very effective at shifting demand, and employees who were temporarily “gifted” with high status worked hard at shifting their schedules to maintain their status (Merugu 2009). A number of other, related strategies offering only modest cash and non-financial rewards have also shown good results, once again demonstrating the value of applying behavioral economics with imagination and ingenuity to reducing energy use.

Research shows that these kinds of strategies—unusual as they would be as factors in determining automobile insurance premiums—would be highly effective motivators of reduced driving. In states where they might be prohibited as part of insurance policies, there might be other ways to deploy them. Awards could be offered separate from insurance, provided by a third party such as a government partner, and thus evade insurance regulatory prohibitions. Nonetheless, insurance company cooperation might be necessary in order to provide the driving data necessary to determine award eligibility (with participant approval, of course).

Optimal Customer Profile and PAYDAYS Insurance Product

Once PAYDAYS insurance becomes available, the human biases and foibles described above—especially an aversion to decision-making, and specifically to making financial decisions that are not pressing—suggests that adoption may be somewhat slow, at least absent superb product design and marketing efforts. Nonetheless, behavioral economics can help guide selection of product design features that will enhance PAYDAYS’ attractiveness to the most promising segments of the customer base.

Tables at the end of this document profile the most receptive potential customers (Table 1), identify marketing features to appeal to such customers (Table 2), and specify product characteristics that would achieve the highest possible mileage reductions among these customers (Table 3).

Table 1. Targeting the Most Receptive Potential PAYDAYS Insurance Customers

Customer Attribute	Effect of Attribute on Mileage Reductions	Boosting Mileage Reductions Where Feasible
Low mileage	Would yield smaller mileage reductions than with higher-mileage drivers.	"Skimming" of profitable low-mileage drivers would in time force traditional time-based policy rates to rise and thereby expand the PAYDAYS insurance market beyond low-mileage drivers.
High premiums	Large reductions would result because of high per-mile savings.	
Low income	Because low-income drivers are the most price sensitive, large driving reductions would result.	
Urban	The relatively higher number of transportation and home-delivery options would suggest large driving reductions.	Consider subsidizing customer transit passes to encourage transit use.
Environmentalists	Large driving reductions would be expected.	Reinforce environmental benefits of reduced driving in communications.
Current transit, vanpool, carpool, and non-motorized commuters	Potential peak-period mileage reductions would be much lower than for current drive-alone commuters.	Work with Transportation Management Associations and service providers to co-market PAYDAYS insurance to both existing and potential alternative transportation customers.
Vehicle lessees	Positive effect on reductions was found in Minnesota, most likely since vehicle lessees are more accustomed than others to managing their mileage (Gourville 2004).	Work with vehicle leasing entities to allow customer rebates, reflective of increased residual value, for vehicles returned from lease with lower than allowable mileage.
Owners of multiple vehicles driven infrequently, including car collectors and do-it-yourself mechanics	Pricing of low-mileage vehicles would result in less per-vehicle mileage reductions than pricing of higher mileage vehicles. Nevertheless, households with many vehicles tend to drive more than other households, even if mileage on individual vehicles may be low.	

Table 2. Marketing PAYDAYS Insurance

Product or Marketing Attribute	Effect of Attribute on Mileage Reductions	Boosting Mileage Reductions Where Feasible
Default option (but with traditional time-based policy readily available)	Has the potential to boost participation substantially if company already has a large customer-base.	
Limited, free miles of PAYDAYS insurance provided upfront with the purchase of a transit pass, carsharing membership, or commuter bicycle	Should be negligible, since almost all drivers would need to purchase additional miles because the initial provision would be small.	
Simple pricing (but algorithm to determine a policyholder's price need not be)	Unknown.	
Savings	Customers who continue to focus on overall premium savings after switching to PAYDAYS insurance would be less motivated to reduce mileage than those focusing on per-mile or per-minute costs.	After customers switch to PAYDAYS insurance, immediately refocus communications to emphasize cost per mile or minute. When marketing policy renewal, focus back onto total savings.
Control over total premiums	There should be some positive effect.	
Low premium payments with some timing discretion	Unknown.	
Cap maximum premium billed	While this may be critical to some to accept PAYDAYS insurance, it reduces disincentives for high mileage.	Charges in excess of cap need not generally be forgiven but rather rolled over into subsequent bills until paid off.
Promise to compare after-the-fact costs with traditional premium	Unknown, but consumers are willing to take greater financial risks (e.g., accepting a new insurance product) if they know they will see a later cost comparison with the alternative not chosen (Gourville 2002).	
Societal benefits (model after hybrid car marketing)	Some additional reductions among environmentalists and other socially conscious customers may occur.	

Table 3. Maximizing Mileage Reductions Across Customers

Strategy	Effect on Customer Acceptance	Improving Customer Acceptance Where Feasible
Direct and transparent per-mile charges (no rebates or requirements to purchase miles in large use-or-lose bundles)	Customers would sometimes like to forget about their per-mile costs and might be reluctant to accept a PAYDAYS insurance product with these price-related attributes.	Avoid focusing on per-mile or per-minute charges until after customer has chosen PAYDAYS insurance. Refocus to total savings and away from per-mile pricing when seeking policy renewal.
Frequent billing emphasizing tangible (check or even cash) as opposed to less tangible (credit card) payment forms		
Reinforce pricing through e-mail reminders and taxi-like in-vehicle meters.		
Negotiate transit pass discounts and matching funds to buy down prices of alternative transportation modes.	Would be very popular, especially in urban and other areas with good transit options.	Engage in joint marketing campaigns with transit providers (e.g., “Wouldn’t it be great if your insurance company helped pay for your transit trips? Now it might!”)
Provide individualized assistance to customers to reduce driving by identifying alternative transportation, trip consolidation, and trip elimination (e.g., through Internet shopping) options.	Would be positively construed generally and potentially very useful to some.	
Establish reasonable driving-reduction goals for participants and provide frequent-flyer-program-like status-related designations and rewards, and “regret lottery” rewards, contingent upon achieving such goals.	Would be positively construed, since the only consequence of not achieving a program-established goal would be not receiving an extra reward. Customers who achieve a high status would be expected to be especially loyal.	

Proposed target customers who would benefit most from PAYDAYS insurance pricing include those with the following characteristics: low mileage, and so can easily save money right from the start; high premiums, so they could enjoy substantial savings with even modest driving reductions; low income, so they need to save money; urban, so they have many options to reduce driving; environmentalists, who want to reduce pollution; current transit, vanpool, carpool and non-motorized commuters; vehicle lessees; and owners of multiple vehicles driven infrequently, including car collectors and do-it-yourself mechanics.

A great marketing idea, aimed at likely receptive customers, would be to bundle 100 (irresistibly) free miles of insurance per month (or, for non-car owners, $10 worth of carsharing or bicycle supplies/repairs per month) with a transit pass. Free miles of insurance could also be offered to those purchasing commuter bicycles and carsharing memberships (replacing their second vehicle). Such short-lived bundling might encourage recipients of the small amount of already-paid-for PAYDAYS insurance to switch from traditional insurance to PAYDAYS.

Regarding the product itself, PAYDAYS pricing should, as reflected in Table 2, be the default option unless the customer explicitly chooses standard pricing; and pricing should be clearly explained and simple (Bonsall 2004), with a cap placed on the maximum billable premium, because many consumers will not choose such a product without a cap. Marketing materials should highlight potential personal savings, control over premium size and payment terms, and environmental and other societal benefits.

To maximize mileage reductions, as outlined in Table 3, per-mile or per-minute-of-driving charges should be direct and transparent, and billing should be frequent, with interim pricing reminders sent through e-mail or conveyed via taxi-like meters in the consumer's car, such as have been deployed in the Washington State mileage-pricing pilot that tested pricing alternatives to a fuel tax. Transportation alternatives should be made more appealing through negotiated price discounts for unlimited ride transit passes and by providing individualized assistance in identifying appropriate options.

Marketing should cater to each of the different types of customers: low-mileage drivers and current transit users who would experience immediate financial benefits versus higher-mileage drivers who might reduce their driving more but for whom PAYDAYS insurance would initially be less appealing (Table 1). Marketing strategies would need to adapt to changing circumstances, from attracting new customers by focusing on potential savings, to encouraging the new customers to drive less, once on board, by keeping them aware, as they drive, that the meter is running, to encouraging renewals by emphasizing once again the money saved (Tables 2 and 3). Clearly, appropriately timed customer communications are essential to meeting multiple insurance company and societal objectives.

A major product design issue is whether premium charges--and related vehicle monitoring—should be based only on miles or minutes of driving, or whether other usage-based factors should be part of the reckoning: time of day of driving, driving style (aggressive vs. calm), and the relative safety of the types of roads driven. Research shows that tracking more factors and incorporating them into premiums improves actuarial accuracy. Rewarding calmer, presumably safer driving would further enhance safety and reduce fuel consumption.

Some PAYDAYS insurance products are priced in part based on how customers are observed driving by using electronic means. It has been noted that 90% of drivers view themselves as "above average" (Thaler and Sunstein 2009), meaning that many would be amenable to products that base their rates partially on "how" they drive—e.g., avoiding hard braking and swerving—when compared to others, even if they are really no better than the average driver. In fact, in surveys conducted as part of a pilot that involved the North Central Texas Council of Governments and Progressive Insurance where participants were paid for reducing their driving, as if they had PAYDAYS insurance, some said that they would like having the quality of their driving monitored as part of determining their discounts because they believed they were better drivers than others even if they were not sure that they could reduce their mileage ("PAYD Insurance Pilot Program" 2008).

Of course, some consumers might avoid products that track multiple parameters, out of concern for privacy, or the cost of tracking equipment (if they're required to help pay for it), or because their driving doesn't fit the low-cost characteristics of the parameters. But a variety of PAYDAYS insurance products could be offered, giving drivers the choice between heavy monitoring with steep discounts, and simpler, less intrusive pay-per-mile or pay-per-minute products, probably offering somewhat lesser savings (Greenberg 2007).

Other, complementary measures not directly related to behavioral economics could lead to further reductions in driving from PAYDAYS insurance. These include providing comparison data on peers' success in achieving low mileage, creating contests to maximize reductions in driving that reward participants with status that is communicated to peers, and providing feedback on performance that is frequent, graphic, and compelling.

Designing PAYDAYS Insurance Pilot Projects to Learn More

While it is possible to make theoretical projections of the success of different PAYDAYS insurance product designs, in terms of accuracy, these cannot replace pilot studies. Unfortunately, federally funded pilot studies in four states were not designed as well as they could have been.

How to Design a Pilot Study

First, it is important to start with what not to do. The studies mentioned above all gave participants a "bank account," a specific sum from which deductions were made for each mile driven. Participants got to keep whatever cash was left in these accounts at the pilot's end. As noted earlier, people perceive such cash as a windfall that they value far less than their own hard-earned dollars, and they therefore put far less effort into preserving the windfall by curbing their driving than they would if required to pay outright for each mile driven.

A better pilot design, assuming the commercial product cannot initially be offered in a test environment where before and after data can be collected, would entail providing a stipend up front, instead of the "bank account." Subjects would be allowed to spend that stipend whenever and however they choose—conditioned upon signing a contract to complete the pilot which would entail direct per-mile pricing. Behavioral economics has shown that once people take mental ownership of such a stipend, which they generally do after a bit of time elapses, but which they never got to do with the "bank accounts," they quickly come to see it as their own, rather than as a windfall. Thus, most participants would discount the importance of their initial stipend and consider money spent related to the pilot to be their own. Of course, this might lead some to try to abscond with the stipend without paying all of their incurred per-mile charges, but such risk is often part of high-reward research. Deposit contracts, as discussed earlier, would also be a good alternative if they could pass regulatory muster.

The pilot should include sufficiently large numbers of urban, suburban, and rural households to draw conclusions about responsiveness from each. Households with a range of incomes and insurance premiums should also be included, as should others with limited-mileage leased vehicles. Comprehensive surveys should be administered to subjects in order to learn how their views about the need for environmental protection—especially related to driving—and openness to alternative transportation options affects their propensity to reduce their driving distance.

Surveys should also ask subjects whether they prefer PAYDAYS or traditional insurance pricing, in order to determine how their insurance preferences influence their propensity to curb their driving under PAYDAYS pricing. (A good pilot program should include subjects with both preferences; a generous stipend can motivate subjects to allow themselves to be assigned randomly to PAYDAYS or a control group with a traditional insurance plan. Multiple billing protocols should be tested, perhaps including weekly, monthly, quarterly, and semi-annual billing, as should pricing reminder protocols including regular e-mails and in-vehicle taxi-like meters. Testing the effects of co-marketing transit pass subsidies with PAYDAYS insurance should also be considered. For projects designed to assess product demand, test groups should include permutations of PAYDAYS that bundle transit passes as well as some free miles of car insurance as sweeteners. The opportunity to buy more miles of insurance should also be provided to test how effective a combined offer of some free miles of insurance with a simple system to purchase additional miles is in persuading drivers to accept PAYDAYS premiums. Finally, some participants should be offered extensive hand holding in mapping out and determining their travel options to see how such information, in concert with the pricing signals, influences their mileage. (This strategy has been the subject of much research and has been shown, even absent pricing incentives, to be quite effective.)

An inherent challenge in marketing any new product, no matter how thoughtfully designed, is that customers overvalue the features that they anticipate losing, and undervalue those that they anticipate gaining (Schwartz 2004). This was expressed in the Minnesota PAYDAYS lease focus groups. There, the fear of the occasionally high variable lease payment—an unpleasant potential novelty for those new to PAYDAYS—overwhelmed the anticipation of peace of mind from eliminating the risk of a potentially sizable repair cost—which participants were used to facing in conventional leases or car ownership—that would be newly covered by the proposed "all in one" lease.

Inevitably, some consumers may refuse a product where payments vary with mileage. Nonetheless, given the interest in PAYDAYS insurance from insurance companies, governments, advocacy groups, and consumers, along with the marketplace successes of other PAYDAYS pricing products such as carsharing, PAYDAYS is very likely to succeed in the market.

Conclusions

The PAYDAYS insurance pricing strategy promises to benefit individuals, insurance companies, and the nation. Many individuals will be able to reduce their insurance premiums by driving less. The overall reduction in driving will cut CO_2 emissions, lessen traffic, improve the public health through a reduction in car crashes, improve the nation's balance of payments, and reduce the funds that go to hostile, oil-producing countries. All this is widely acknowledged. Moreover, the basic concept can be offered in many forms, each designed to appeal to a different segment of the market, raising the potential market penetration of this revolutionary concept.

Insights from behavioral economics will continue to improve the design, marketing, and pricing of PAYDAYS.

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The Technological and Human Dimensions of Residential Feedback: An Introduction to the Broad Range of Today's Feedback Strategies

Kat Donnelly, Empower Devices

Introduction

Efforts to reduce energy waste in the residential sector have met with limited success; however, a growing body of evidence suggests that a mix of innovative feedback technologies, targeted behavioral initiatives, and forward thinking policies can engage residential energy consumers in developing better energy management practices and reducing waste. Recent research on residential energy consumption has begun to quantify the energy saving opportunities in the residential sector, suggesting that households currently waste a considerable proportion of the energy that they consume. Not surprisingly, the literature indicates that current and past efforts by utilities (and other organizations) to manage residential energy demand through programs that encourage the adoption of more energy-efficient appliances and technologies have only achieved a fraction of potential energy savings. In light of these past failures, academics and energy practitioners alike have begun to formulate more effective approaches that draw on the considerable insights in the social and behavioral sciences. This chapter explores the potential role of one such approach that uses feedback technologies to reduce energy waste in the residential sector, focusing on the ability of innovative feedback programs to motivate consumers to take action and to provide them with the ability to manage their own energy consumption.

Consumers reduce energy waste when it is *easy*, *contextual* (i.e., personally and socially relevant), and *convenient*. Any technology deployments in the consumer-side of the smart grid will need a firm foundation in behavioral science to ensure that these details are considered. A major research conclusion is that understanding specific consumer needs and motivators could produce cost-effective technology solutions that contribute to climate change mitigation by reducing household energy waste. This chapter seeks to describe recent feedback approaches so as to inform consumers, policy makers, utilities, technology developers, and vendors about key insights into achieving highly effective feedback technologies and initiatives.

Among the core principles of this chapter is the recognition that both technology, and the behavioral actions required to use that technology, are closely integrated. Yet the role of psychology and consumer behavior receives surprisingly modest attention in most technology and service designs (Midden, Kaiser, & McCalley 2007). The same shortcoming is found in most policy designs. However, the success of these efforts requires an integrated approach that bridges the gap between economical, technological, and social-psychological approaches (ibid) (Ehrhardt-Martinez & Laitner 2009). Therefore, this review is particularly concerned with those technology and service vendors that provide energy management by focusing on behavioral strategies.

This chapter will provide a conceptual framework to providing technology and behavior solutions for the residential consumer. Next, the chapter dives into the importance of feedback and the contribution of the social and behavioral sciences. Then, four types of feedback technologies will be discussed, including: vendor provided utility feedback, in-home energy displays, "smart" devices, and home area networks. The overarching smart grid, including utility-side advanced metering systems, will not be discussed in this section;[1] however, companies that present Web-based, e-mail, and "snail" mail feedback of utility data are explored. The chapter concludes with policy insights and conclusions.

Conceptual Framework: Applying Enabling-Technologies AND Behavior Approaches

From a perspective at the dawn of the third millennium, we might look back with amazement at how little bang for the BTU our early industrial age forebears obtained from coal, or wood, or whale oil, or whatever else they burned. Yet a recent report from the UK government, echoing the consensus among energy experts, said pretty much the same about today's society:[2]: "Most energy is consumed highly inefficiently" (DTI 2006). But, getting people to actually consume less energy is not easy. In fact, the energy system is hugely complex, involving feedback, behavior, and technology approaches. This chapter explores ways that technology could be used to help motivate people to use less energy or to use it more efficiently through different combinations of technology and behavioral approaches, such as the following:[3]

1. Providing feedback and/or automation using enabling-technologies, such as programmable thermostats, in-home energy displays, sensors, power strips, and switches (purchases, one-time behaviors, habits, and convenience); and
2. Using behaviorally focused approaches to change existing energy end-use behaviors (Habits, Norms);[4]

Contrary to current utility programs, a review of the literature on energy use programs suggests that an effective energy management system for the residential user should include each of the following elements: 1) tailored feedback, 2) dynamic pricing, 3) automation, and 4) behavioral strategies such as commitment and goal-setting. Moreover, recent literature is starting to recognize the importance of additional social and psychological strategies, such as those described elsewhere in this e-book.

While past experiments indicate a range of results for many of the individual program approaches (i.e., feedback, dynamic pricing, and enabling-technology), and some basics about applying behavior change strategies, it is not well understood how the different approaches will

[1] This paper is a subset of a wider review of utility advanced meters and residential feedback programs (Ehrhardt-Martinez, Donnelly, & Laitner, 2010), which explicitly discusses the smart grid and advanced utility meters in detail. During this review, consumer behavior was broadly assessed including behaviors associated with energy conservation, energy efficiency, and reductions in peak demand. This information was analyzed from the user's perspective with a focus on the consumer behavior approaches, energy savings, and market characteristics. For a broader smart grid technology and vendor review see The Smart Grid in 2010: Market Segments, Applications, and Industry Players (Leeds, 2009).
Although they are very important issues, it is also outside the scope to consider issues of data ownership, security, standards and interoperability, or privacy.

[2] The UK is a world leader taking action on greenhouse gas (GHG) abatement using behavior and technology techniques.

[3] Behavioral categories are noted in parentheses.

[4] Of the five behavior types indicated in parenthesis, these are by far the newest, as well as least understood and least utilized approaches.

interact. This means the total impact or how to cost-effectively deploy an optimum combination of behavior and enabling-technology strategies for residential energy management systems is also not well-understood. This chapter will examine current feedback and enabling-technology approaches that operate with a focus on the end-user's behavior.[5]

The Importance of Feedback

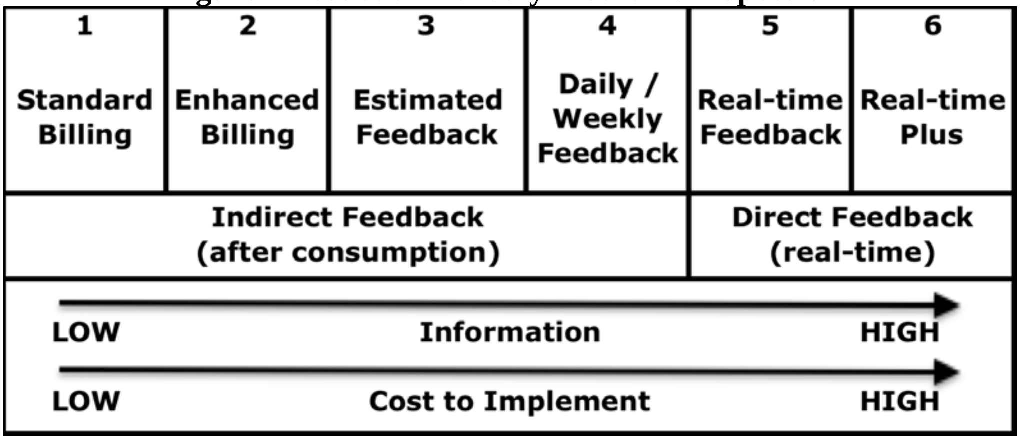
More than 40 studies have identified how direct and indirect feedback on energy use *can* reduce energy consumption (Abrahamse, Steg, Vlek, & Rothengatter 2007; Darby 2006, 2008; EPRI 2009; Fischer 2008). Indirect feedback provides energy consumption data that is supplied to consumers at some point after consumption. Historical programs that have used indirect feedback have resulted in a range of average household energy savings of between zero and ten percent. (Darby 2006; Fischer 2008) Alternatively, direct, real-time, feedback initiatives using in-home energy displays and other enabling-technologies have resulted in average reductions in electricity use of up to 15% (Darby 2006; energywatch 2006; EPRI 2009). The energy consumption data displayed on some devices enables consumers to figure out how best to reduce energy use (ibid), and people may actually change their habits based on the information these devices provide (energywatch 2006). Additional savings can be achieved by providing information about the energy consumed by specific appliances and by providing households with tips about effective ways of changing wasteful energy practices. These approaches have proven particularly effective in achieving behavior modification in space heating habits, and large appliance purchase decisions (Darby 2006).

A recent Electric Power Research Institute (EPRI) study resulted in a comparison of the effectiveness of different feedback approaches as depicted in the following spectrum of feedback delivery mechanisms (Figure 1). A subsequent study further developed this classification scheme to assess both direct and indirect feedback approaches and their impacts (Table 1). According to the categorization scheme, standard billing is the monthly utility bill that is provided to consumers as much as 45 days after consumption. The second type of feedback, enhanced billing, generally includes utility-designed feedback and sometimes household advice (5.6% average household savings) (Ehrhardt-Martinez et al. 2010). Estimated feedback uses Web-based energy audits,[6] billing analysis, and estimated individual appliance use to provide meaningful information about household energy use (6.8% average household savings) (ibid). The fourth type of indirect feedback, daily and weekly feedback, provides feedback by mail, email, or self-meter (11.0% average household savings) (ibid).

[5] Although it is an important aspect, dynamic pricing strategies and specific behavioral approaches will not be considered in this chapter. For more details on dynamic pricing, see (Faruqui, 2009; Faruqui & Sergici, 2009; Faruqui, Sergici, & Sharif, 2009; Faruqui & Wood, 2008). For more detailed behavior strategies, see the citations in this chapter.

[6] It remains unclear if many consumers will actually fill out the web audit that asks the customer to provide details about home appliances, work and home schedules, comfort preferences, etc. For instance, the author has a special interest in this subject and has yet to complete a full web-based audit due to complexity and length (0/5 attempts).

Figure 1 Feedback Delivery Mechanism Spectrum



(EPRI 2009)

Table 1 Meta-Review of Utility Feedback Programs Savings Results by Program Type

			Range Low		Range High	
	Average Household Savings	Participation Plan Type	Participation Rate	Overall Savings	Participation Rate	Overall Savings
Enhanced Billing	5.6%	Opt out	75%	4.2%	85%	4.8%
Estimated Feedback	6.8%	Opt in	5%	0.3%	10%	0.7%
Daily / Weekly Feedback	11.0%	Opt in	5%	0.6%	10%	1.1%
Real-Time Feedback	7.0%	Opt in	5%	0.4%	10%	0.7%
Real-Time Feedback	7.0%	Opt out	75%	5.3%	85%	6.0%
Real-Time Feedback Plus	14.0%	Opt in	5%	0.7%	10%	1.4%
Real-Time Feedback Plus	14.0%	Opt out	75%	10.5%	85%	11.9%

(Ehrhardt-Martinez et al. 2010)

Indirect feedback is usually less effective then real-time feedback (direct feedback). Real-time feedback can be provided using in-home energy displays that sometimes have the capability to receive pricing signals (7.0% average household savings). Real-time plus feedback includes specific appliance disaggregation and/or automation (14% average household savings). For the real-time and real-time plus feedback scenarios, opt in and opt out participation types were compared. While both opt-in and opt-out programs achieved the same average households savings, the opt-out programs had much higher overall savings results when considering both participants and non-participants. (Ehrhardt-Martinez et al. 2010)

The Contribution of Social and Behavioral Science

To date, human psychology and behavior change methodologies have been surprisingly lacking in technology development, as well as government and utility energy efficiency programs (McKenzie-Mohr 2008; Midden et al. 2007). Of the programs that are designed to encourage behavior change, the most common approach is to include one of the following two approaches: (1) information-based campaigns that seek to affect attitudes to result in behavior change, and (2) economic self-interest programs focused on tapping into human's purported economic rationality (McKenzie-Mohr 2008). Neither is particularly effective, and little attention has been given to the application of other well-established methods of establishing new behaviors or ensuring the permanence of new practices (ibid). Short-term information-based campaigns that aim to educate consumers, to enhance knowledge, or to change attitudes frequently have little or no effect upon behavior (ibid). Moreover, changing people's behavior over the long haul can take time. For instance, sometimes people change attitudes slowly as new norms develop, which can be evidenced by the change in public attitudes towards, for example, smoking cigarettes over the last few decades.

Of particular importance is the well documented disconnect between attitudes and/or knowledge and behavior (ibid). For instance, a study on the attitudes of recyclers and non-recyclers found that attitudes did not differ (De Young, 1989). Instead, several recent publications on social influence have found that normative messaging can provide an important means of bridging the gap. Despite the evidence, however, normative messaging is rarely considered or applied as a component of feedback initiatives. Interestingly, normative influences are often underdetected by most people, (Chen, Lupi, He, & Liu 2009; Goldstein, Griskevicius, & Cialdini 2007; Griskevicius, Cialdini, & Goldstein 2008; Lindenberg & Steg 2007; Nolan, Schultz, Cialdini, Goldstein, & Griskevicius 2008; Schultz, Nolan, Cialdini, Goldstein, & Griskevicius 2007), which means that a large opportunity may exist to develop policies and programs around social norms. More research is needed prior to large-scale deployment.

However, what is clear is that program designers can emphasize behavioral strategies to tap into underlying social and personal motivations and benefits to influence the actions that people take. In fact, a big portion of the remaining cost-effective energy efficiency potential could depend on changing the *behavior* of the technology *users* (Sullivan 2009). For instance, behavior-driven changes could enable households to reduce residential energy consumption by almost 30% (about 11% of total U.S. consumption) in the next 5 to 10 years. (Choi Granade et al. 2009; Gardner & Stern 2008; Laitner, Ehrhardt-Martinez, & McKinney 2009; Nadel, Shipley, & Elliot 2004). However, these are early projections and more research is needed to better understand potential impacts.

A variety of different types of today's feedback technologies are discussed in the next section to illustrate and discuss the range of existing technology characteristics and the degree to which they integrate social and behavioral insights. The following section divides feedback technologies into four categories: 1) vendor-provided indirect feedback, 2) direct feedback using in-home displays, 3) direct feedback and automation using smart devices, and 4) direct feedback and automation using home networks. Each of these categories is discussed in turn.

Four Types of Feedback Technologies

Many U.S. electric utilities are engaged in the deployment of millions of advanced meters (also known as smart meters) to residential consumers throughout the country. Notably, however, while these advanced metering systems are capable of providing energy feedback and management services to residential consumers, thus far this capability has been woefully underutilized. And as the distribution of these meters continues to accelerate, the scope of potential feedback-induced energy savings continues to grow, representing an ever-expanding pool of lost energy-savings opportunities. Nevertheless, some U.S. utilities are attempting to provide consumers with feedback and simple in-home automation. For instance, several utilities have implemented pilot programs and/or are considering the deployment of smart thermostats, in-home energy displays, and utility-controlled devices for customers.

Despite the opportunities for savings and the emerging interest on the part of utilities, the best means of providing cost-effective, large-scale feedback programs in the residential sector remains unclear. While some regulators and utilities have made attempts at designing systems for the consumer, utilities have not traditionally been in the business of providing in-home energy management services. Fortunately, third-party vendors have stepped up to meet the consumer's demand for, as well as the utility's need for, feedback and automation. The next section discusses the work of several vendors who are providing consumers with indirect feedback (derived from utility data) via Web-based, e-mail, and "snail" mail.

Vendor Provided Indirect Feedback of Utility Data.

Several different types of indirect feedback, including whole-home feedback and deeper contextual feedback (*e.g.*, estimated appliance-specific, historical comparisons, social comparisons, *etc.*) can be provided by means of websites on the Internet using one or more data sources. Most of the energy data are generally provided by the utility, although other types of data such as, assessor parcel maps, home audits, census data, *etc.* can also be used to assess the location, size and age of the building, its likely level of efficiency, and other factors that play a role in determining current energy use as well as potential means of energy savings. Many of these approaches are able to deliver energy use feedback on the consumer's computer, smart phone, iPad, and/or other electronic device, And numerous service providers are leveraging multiple data sources to provide consumers with targeted information about their own consumption as well as information about how their consumption patterns compare to other people in their neighborhood. Table 2 briefly describes three such companies that provide behaviorally focused indirect feedback of residential energy use (after consumption with no automation).

Technology. The feedback is primarily derived from monthly utility data or in very limited cases more frequent advanced metering interval data. The effectiveness of waiting for the utility to process the data adds a potentially costly delay to indirect feedback approaches. On the other hand, several vendors use statistical software algorithms to analyze existing data and user input to provide deeper personalized and contextual knowledge. Most utility-side indirect feedback vendors communicate feedback over the Internet, although several have mobile, TV, and other enabling-technology applications. In fact, many indirect feedback vendors can add enabling-technology to the solution, such as energy displays and smart appliances (both described in the next two direct feedback subsections).

Table 2 Example Vendors providing Indirect Feedback of Utility Data

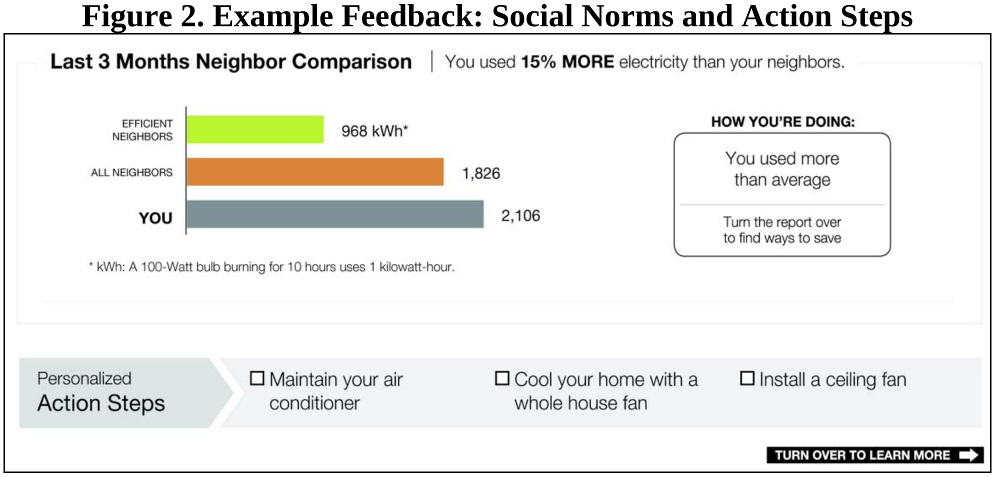
Company	Feedback Technology	Behavior Principles	Maturity
OPOWER	Depending on utility, send monthly or quarterly mailings, and/or provide Web site with newly forming social networks.	Indirect Feedback Types: Household information/ advice, web-based energy audits, billing analysis, estimated appliance-specific, CO_2, Energy, and $. Behavior Principles: Social Comparisons, Goals, Personal Comparisons, and Action Steps.	Growth Stage
Efficiency 2.0	Social community Website with energy and water consumption feedback.	Indirect Feedback Types: Household information and advice, web-based energy audits, billing analysis, estimated appliance-specific, CO_2, Energy, Water, $, and other units. Behavior Principles: Social Comparisons, Goals, Competitions, Social Networks, Personal Comparisons, and Action Steps	Start-Up
Google.org	Google.org PowerMeter on Website, including Google social networks.	Feedback Type: Indirect including: Household information, estimated household and monthly bill, estimated appliance-specific. Behavior Principles: Social Comparisons, Goals, and Personal Comparisons.	Start-up

Market. Using utility data is a relatively new approach to providing feedback. OPOWER, who kicked off the market in 2007, and others are just beginning to gain traction. For instance, OPOWER (formerly known as Positive Energy) has 35 partnerships with utilities (Kavazovic 2010). Efficiency 2.0 recently embarked upon a partnership in Illinois to enable ComEd's customers to use the software engine. They also have upcoming partnership announcements (Frank 2010). In addition, Google.org announced partnerships with nine diverse utilities in May 2009 (Lu 2009) and has also recently partnered with Itron (with 8,000 utility partners), G.E., Tendril, two in-home energy displays, two more utilities, and a microchip manufacturer (Google 2010). In the long-term, Google.org plans to get involved in the home area network industry to make energy information more accessible and useful to end-users (Olsen 2009). Another big software player, Microsoft, recently introduced Hohm energy management software (Fehrenbacher 2009), and also has partnerships with advanced metering companies, including Itron and Landis+Gyr (Leeds 2009). In fact, there are numerous vendors with free products on the "consumer-side" of the market, including (but not limited to): Carbonrally, Earth Aid, Pachube, etc.

Feedback and behavior. Web-based software vendors provide indirect feedback that often includes several different types of energy use data, the contextualization of the data in ways that make it meaningful to consumers, and recommendations for ways of reducing consumption. Much of the basic energy consumption information is useful to consumers because it allows people to learn about the consumption practices through a process called "learning by doing". For example, a person who first learns the cost of running the air conditioner (through feedback), may decide to set back the thermostat and/or reprogram it from time to time. Through continuous feedback, the person is able to learn the effect of their actions. Contextual data can also help people reduce their energy consumption. Personal context is gained through information about: monthly, historical, and specific device-level energy usage, allowing people to make comparisons to other time periods or alternative uses and evaluate how best to use energy resources. Providing people with a social context allows them to make comparisons with neighbors, friends, and communities and evaluate whether their personal consumption patterns are above or below average.

OPOWER's feedback programs include several different home energy report versions that are mailed to participating residential consumers, usually separate from the utility bill. The mailed reports offer consumers information about their level of energy consumption, personal contextualization, social contextualization, and semi-targeted recommendations about ways to reduce consumption. Recommendations attempt to engage consumers to incrementally learn about energy and are targeted to circumstances of the consumer. For example, OPOWER recommends tactical action steps for renters and more strategic steps for homeowners. Since OPOWER knows that a renter that is unlikely to make any large, strategic investments on new appliances, renters are provided with recommendations like "cool your house with a fan" (Figure 2) (Kavazovic 2009). Recommendations for homeowners are more likely to include the purchase of a new Energy Star appliance and rebate information. Trying to invoke social motivations, OPOWER has also developed an on-line carbon calculator for SMUD, to motivate certain customers to "do the right thing" with respect to climate instability. Finally, OPOWER has developed a web portal with a dynamic efficiency database, where users can provide additional personal household information and find tips most relevant to them (Kavazovic 2009). The Web interface enables contextual learning, allowing users to dig deeper into their energy consumption patterns.

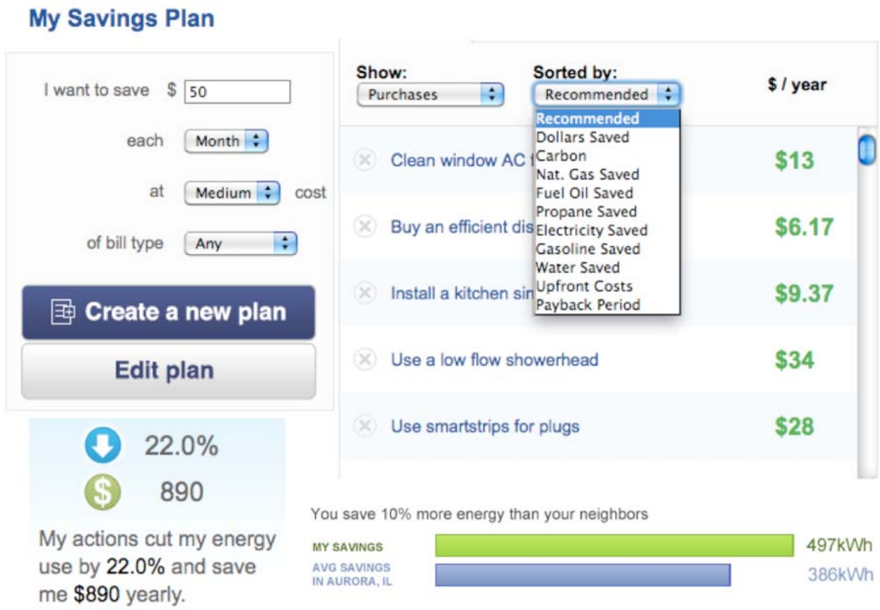
Figure 2. Example Feedback: Social Norms and Action Steps



(Kavazovic 2009)

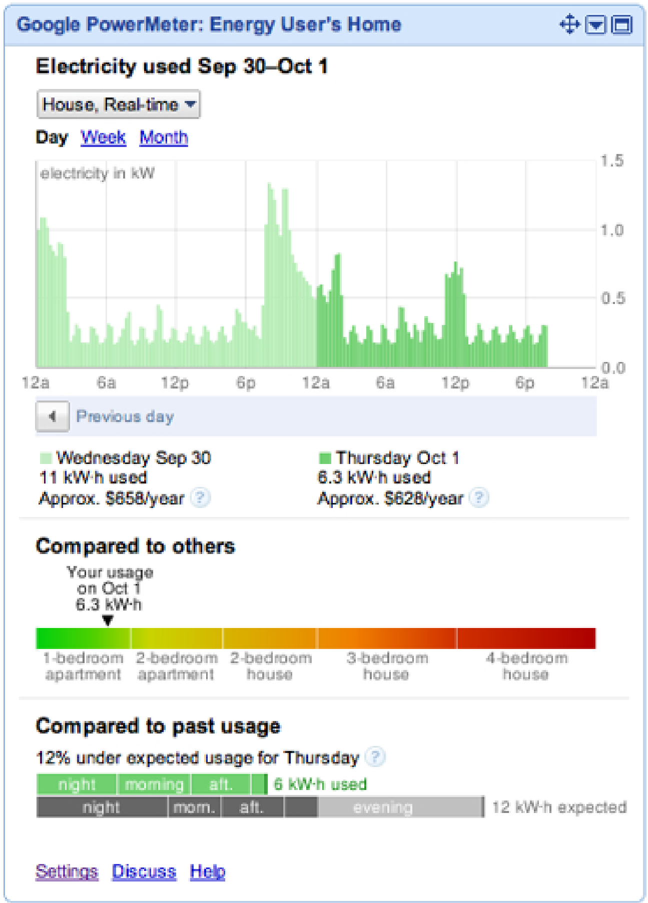
Efficiency 2.0 (Figure 3) provides feedback online using similar data acquisition, analysis, behavioral, and feedback techniques as OPOWER. The software is designed to create a customized Savings Plan based on user parameters and inputs, such as desired spending, savings goals, rates, and personal values.[7] Efficiency 2.0 tries to increase engagement in energy decisions and to influence passive consumers (Frank 2009). To personalize the feedback, algorithms evaluate the costs and benefits of hundreds of actions. Comparisons are made in terms of baseline energy use as well as from estimated savings confirmed by billing data. (Frank 2009)

Figure 3. Efficiency 2.0 Savings Plan: Information, Goal-Setting, and Feedback



[7] Results vary based on the amount of user input and participation.

Figure 4. Google.org PowerMeter Example



Finally, the Google PowerMeter (Figure 4) also leverages existing data sources to make information accessible and useful to consumers, to leverage commitments from users, and to create smarter energy choices. Google.org considers the impact of the feedback to be the "most important metric of success." Google.org contends that personal energy use data belongs to the consumer and that it should be available in a standard, non-proprietary manner. In the short-term, Google.org plans to harvest data from utilities, but they have also partnered with an in-home energy measurement and display device, The Energy Detective (TED 5000) with the goal of having more direct access to energy data. TED 5000 uses current clamp hardware to measure, monitor, and report electricity consumption data. Google.org is training the software to recognize peaks in energy use patterns and correlate them with appliance-specific usage like the dryer or refrigerator. (Olsen 2009) This would allow for more detailed energy use data and more targeted recommendations.

The following section describes a variety of in-home energy displays that provide real-time feedback to consumers and enable a more dynamic learning process.

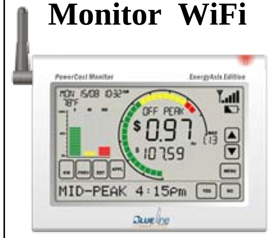
Direct Feedback using In-Home Energy Displays

Real-time, direct feedback provides a wide range of contextual knowledge to users enabled by learning by doing or by providing more detailed personally- and socially-relevant feedback. For instance, in-home energy management displays provide the potential for "learning by doing" when the user carries the device through the home while switching on and off devices. The user receives immediate, appliance-specific feedback that allows the consumer to learn about energy in an incremental fashion. A few behaviorally focused in-home energy displays are shown in Table 3. The specific features are discussed next.

Technology. Almost all in-home energy displays provide whole house nearly real-time electricity consumption information. There are numerous other energy displays on the market that contain some combination of the standard features shown in Table 3 with most of them being very similar to the Efergy. In most cases, the data is sent from the home's main circuit panel, where it is measured using two to three current clamps that wrap around the home's electricity mains. In some cases, such as The Energy Detective (TED 5000), the energy display can monitor the whole home, more circuits (in this case, up to four 220 Volt circuits, or eight 110 Volt circuits, sensitive to one Watt). On the other hand, with simple installation requirements, the PowerCost Monitor optically "reads" 90 percent of existing utility meters by clamping around the meter ("reading" the spinning dial or receiving an optical pulse), which means easier installation, but also lower device accuracy.

All but a few energy displays transmit wirelessly near real-time whole-home (or in limited cases circuit-level) data to the display. Communication ranges to the display vary from 30 meters up to 70 meters, depending on the home's signal obstructions. A few devices communicate over the home's electricity lines, using what is called powerline communication. Most of the units include batteries, but the newer energy displays are deploying rechargeable units. Data storage capabilities vary greatly and are dependent on the number of on-board components. For example, the Wattson holds 28 days worth, TED 5000 up to 10 years, and in between are the PowerCost Monitor and Efergy with one and two years, respectively. Features also vary greatly among the representative displays shown in Table 3 from the Efergy and Wattson with simple, easy to read displays to the TED 5000 that includes web, mobile, and stand-alone display technologies that can coordinate with a complete home generation and automation network (discussed later). In addition, the PowerCost monitor was previously a simple $100 in-home energy display, while a more advanced WiFi edition will be coming out in mid-2010 for a similar price.

Table 3. In-Home Energy Display Device Examples (Real-time Feedback)

	The Energy Detective 5000 	**Wattson** 	**PowerCost Monitor WiFi** 	**Efergy Elite** 
Technology Description	Display, Supportive Software, Mobile Applications	Display, Supportive Software with Holmes Community	Display, Supportive Software, Mobile Applications	Display
Feedback Mechanisms	Displays real-time kW, $/hr, CO_2; daily kWh and $; billing cycle in kWh, $, peak use, min/max V, and projected cost and demand. Viewable in seconds, minutes, hours, days, months. Alarm: red flashing light, beep.	Displays near real-time usage in W, kW, estimates bill. 3 to 20 s readings. Glows by usage: blue=low, purple=average, red=high.	Displays near real-time (30 s) kW and $/hr, peak usage in last 24-hrs, counting kWh (reset), appliance measurement feature.	Displays near real-time in kW and $/hr (6, 12, or 18 s readings), hourly, daily, weekly, monthly, and average information. Alarms for high usage.
Consumer Behavior Principles	<u>Feedback Types:</u> Direct including: Household feedback and advice, web-based energy audits, billing analysis, estimated appliance, CO_2, $. <u>Behavior Principles:</u> Social Comparisons, Goals, Personal Comparisons, and Action Steps.		<u>Feedback Types:</u> Direct: Household feed-back, billing analysis, est. appliance, CO_2, $. <u>Behavior Principles:</u> Goals and Personal Comparisons.	<u>Feedback Types:</u> Direct: Household information, billing analysis, Elec., $. <u>Behavior Principles:</u> Goals and Personal Comparisons.
Cost	$239.95 (& up for addl. circuit sensors and/or solar/wind connections)	£99.95 (UK only)	$250	£39.95

Market. The market for in-home energy displays appears to still consist primarily of early adopter types, but there is evidence that interest is growing quickly. Certainly, the product offerings are becoming more and more consumer-focused with several companies on their second third, or higher product release. In addition, there is market evidence of increasing partnerships with energy display companies. For example, The Energy Detective has partnered with Google.org's PowerMeter to combine indirect and direct feedback. Another example, the PowerCost Monitor, initially gained market position through utility channels, such as rebates and giveaways, but currently Blue Line Innovations Inc. is also focusing on direct-to-market partnerships with Black and Decker, Elster meters, SmartHome.com, newegg.com, Fry's electronics, *etc.* (Porteous 2010).

Feedback and behavior. As shown in Table 3, the application of consumer behavior principles varies widely by energy display. For instance, some devices display information in ambient ways through colors and alarms and some provide indirect feedback through websites or on a digital T.V. (Darby 2008). At a minimum, devices provide household energy use information, some billing analysis, and estimated usage for some period of time. Most of the stand-alone displays show household information in near-real time (2 to 30 seconds), such as electricity use and cost per hour, while some display carbon dioxide, voltage, peak-use, and other information. Most in-home energy displays do not support utility-based products, such as automated demand response and dynamic pricing, but, most of the energy displays are programmable for various fixed-rate structures, including: increasing block rates or time of use rates.

Some supplemental web software packages provide additional personal and social contextual information, including household baselines, trends, projections, alarms, and goal tracking. A few energy displays also include on-line communities, such as the Wattson, that can provide social comparisons to potentially help consumers gauge their own consumption patterns. Community members may also turn to each other for advice about what types of steps to take to reduce waste. Another example of social context, users of the Wattson can save 20 percent on average household energy bills (based on results from user responses to an online survey). As a result, Wattson users can join the 20TEN community to commit to save 20 percent of their electricity in 2010. Some devices are also taking open developer communities with the aim to increase innovation and product flexibility. The WiFi edition of the PowerCost Monitor has an open platform for certified partners to build Web and mobile phone applications. The goal is to enable access for the consumer to their data and to improve consumer choice about how to use the energy display (Porteous 2010).

The next section presents information about direct feedback technologies that are combined with automated appliances and devices. These technologies are typically layered on top of software interfaces and/or in-home energy displays to provide highly specific, real-time feedback and automation..

Direct Feedback and Automation with "Smart" Devices

Energy efficient and "smart" (automated) appliances can provide direct, real-time plus feedback, including appliance-specific information as well as automation (Table 4). In some cases, smart devices also have the capability to receive pricing signals from utilities that can enable energy saving settings or cause some devices to cycle off. Table 4 details the broad range of feedback, behavior, and automation devices available. Most of these devices would be classified as do-it-yourself or vendor-installed energy management, including sensors (measurement, diagnostics, automation), in-home energy displays (discussed previously), smart thermostats, smart plugs, lights, and appliances.[8]

Table 4. Automation, Settings, User Behavior, and Cost for "Smart" Devices

Appliance Attributes	Resultant User behavior	Regular Device and Appliance Examples	"Smart" Examples	2010 Cost Range
Low automation Many settings	User required for part of operation. Settings easily altered during operation.	Grill, Stove, Oven, Simple Thermostat, Iron, Vacuum.	Dimmer Light	\$10 to \$70
Low automation Few settings	User required for operation. Simple automation (turns off when not in use).	PC, TV, Light, Oven hood	Smart Outlets and Lights	\$15 to \$150
			Smart Power Strips	\$25 to \$200
High automation Many settings	User not required during operation. Difficult to change settings, causes interruption of operation.	Washing Machine, Dryer, Dishwasher	Smart (two-way) Thermostats	\$175 to \$250
			Energy Displays	\$100 to \$250
			Smart Appliances	Near-term Market*
High automation Few settings	User not required during operation. Settings easily altered during operation and rarely need changed.	Coffee Pot, Heater, Air Conditioner, Freezer, Refrigerator, Pool Pump, Water Heater	Utility Load Control Devices	\$15 to \$150
			Sensors/Networking Chips	\$7 to \$150

*This is accomplished today using smart outlets and network chips.
Source: Builds upon Wood and Newborough (2007).

Technology and cost. In Table 4, a general behavior framework, which categorizes different appliances by the degree of automation and the complexity of settings (Wood & Newborough 2007), has been expanded to categorize examples of "smart" devices and appliances by automation, behavior, and cost features. The simplest data collection and automation technique is a sensing and/or communicating networking chip, such as those found in smart outlets, smart appliances, as well as lighting and automatic utility load control devices. Costs vary widely by the complexity of the automation features. For instance, numerous types of networking chips can be purchased for under \$10 each at large volume. Smart outlets and smart power strips that range in cost (\$25 to \$200) and features generally allow control of individual electrical devices and appliances. For instance, a smart power strip generally has one or more "always-on" plug(s)

[8] Smart thermostats, in-home energy displays, and utility load control devices are often used in utility projects.

for the T.V. control box, and five or so plugs that (manually or automatically) turn off other entertainment devices when not in use. A more expensive smart power strip will also have a "control" appliance that automatically turns off all of the other plugged-in devices when the control appliance is turned off.

With higher degrees of automation and more settings, smart thermostats currently cost between $175 and $250, and include features such as wireless, two-way utility communication and utility load control functions. In comparison, a high-end programmable thermostat (without communication) is around $150 (Delage 2009). In the next couple of years, smart appliances such as washing machines, dryers, dishwashers, and water heaters will enter the market. Smart appliances have delayed start features and can also receive signals such as price and/or carbon emissions to decide when to operate. Some utilities use one-way load control sensors where, with the customer's permission, the utility "cycles-off" a customer's air conditioner, water heater, or other appliance for a short time during peak period conditions.

Market. The market is almost exclusively do-it-yourself, although, there is a small segment that purchases the devices and hires an electrician (or friend) to install individual components or a more complete home automation system. As has been the case for approximately 30 years, these systems are mostly purchased and installed by early-technology adopters that have a broad interest in energy management, carbon emissions, home automation, or entertainment and security systems. The do-it-yourself market and costs are discussed in the next subsection.

Behavior and automation. This topic is discussed in detail in the next subsection on home automation networks, as well as in the conclusions.

The next subsection describes an approach to complete home energy management that leverages all of the previously described feedback and automation technologies.

Direct Feedback and Automation using Home Automation Networks

Home automation networks comprise a combination of indirect and direct feedback, as well as energy efficient and automation enabling-technologies. Typically, these networks include residential wireless and wired sensor networks, display and feedback devices, and automation that may or may not communicate with the utility (example companies described in Table 5).[9] The home automation (or area) network can provide complete home energy management, including feedback and automation, through a wide selection of (mostly) interoperable products and services. This means that different products and service components are integrated together and act as one system.

[9] To include real-world company experience about utility-centric and direct-to-consumer market approaches, in-depth interviews were conducted from five home automation service and technology providers. These companies were selected because they focus on whole home systems and they incorporate consumer behavior principles, and not to select marketplace winners.

Table 5. Consumer-Focused Home Automation Network Sample Companies

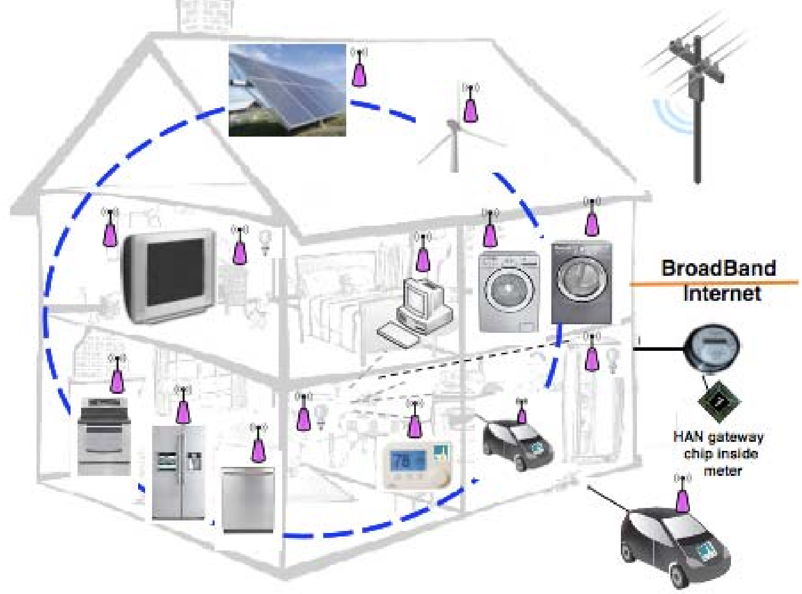
Company	Feedback Technology	Behavior Principles	Automation
Control4	Whole-home touch panels, TV, DVD, mobile, Web partners.	Feedback Type: Direct (<2s) and Indirect, including: Whole-home, device specific, enhanced billing, estimated usage and budget, daily/weekly feedback, historical, real-time, and real-time plus. Behavior Principles: Norms, Goals, Pricing, and Actionable Steps.	Full energy, entertainment, comfort, and security automation, including all analytics and control. Partnering with 5,500 load control devices for lighting, audio, video, security, and energy, such as water heaters, pool pumps, HVAC, *etc.* Any appliance can bridge to the utility.
Tendril	Whole-home touch panel, smart thermostat, mobile, Web.	Feedback Type: Direct (~10s energy display) and Indirect (15 min. Web interface), including: Whole-home, device specific (2s), enhanced billing, estimated usage/budget, daily/ weekly feedback, historical, real-time, and real-time plus. Behavior Principles: Norms, Goals, Networks, Competitions, Comparisons, Pricing, and Actionable Steps.	Full energy automation, including all analytics and control. Partnering with load control devices for water heaters, pool pumps, HVAC, *etc.* Any appliance can bridge to the utility.

Technology. Some people have their energy usage information and automation available in the kitchens, hallways, and family rooms of their homes through home automation network installations. The home automation network ranges from piece-meal parts of the network to a full-fledged interoperable network of water, gas, and electricity devices that can communicate with the utility. The complete home network can result in a system that optimizes household performance based on supply conditions and time-of-use electricity market prices, as well as consumer budgets, comfort levels, and environmental preferences.

The complete home automation network includes the following components (Figure 5):

- **In-home smart devices and appliances**: Networking and/or communicating chips embedded in and attached to devices for wireless and/or wired automation;
- **Advanced network systems and software**: Wireless mesh networks and algorithms that provide measurement and feedback of appliance specific data; and
- **Potential for two-way communication with the utility**: Interface tools that analyze and display data from smart meters and utilities to in-home energy displays, smart thermostats, Web, T.V., mobile phone, etc.

Figure 5. Elements of a Home Automation Network (PG&E 2009)



For example, a complete home automation network provides monitoring and automation of appliances, lighting, space conditioning (heating, air conditioning, and ventilation systems), and/or specific electrical plug-load devices (anything that plugs in) (Figure 5). It also includes some form of a consumer interface for direct, real-time feedback. The simplest home automation network begins with a smart thermostat that controls heating and air conditioning equipment and that communicates with a central computer and/or the utility's metering system. Incremental components, such as smart appliances, distributed renewable generation, and plug-in vehicles, can be added to grow the home energy network.

Like Google.org, several of the vendors analyzed were taking an open-development approach. For instance, an open-licensing model as used by Control4 allows vendors to bring their software and devices onto the Control4 platform. This, in turn, should enable user and supply chain innovation leading to product developments. For example, in January 2009, LG announced that it would embed Control4 home automation capability into their television sets, which will also enable T.V. energy efficient features, such as dimming T.V. backlights, turning off devices instead of standing-by, *etc*. Where customers are planning to purchase a new T.V. or other appliance, embedded approaches are more energy and cost-efficient than buying a separate piece of hardware. In the case of Control4, consumers can add functionality with small incremental fees to unlock functionality to enable features when they want them. (Nagel 2009)

Market. Home automation technologies have been on the market for more than thirty years, but the industry was a relatively niche market dominated by higher-end custom home automation systems, and then followed by do-it-yourself "gadgets" and piecemeal systems purchased directly by technology early-adopters (Galvin 2007) (ABIresearch 2009). Today, the home automation industry is made up of numerous large, established companies, and countless small start-ups and recent industry entrants and is in continuous flux, continuing to grow and change on an almost daily basis. In fact, Research identified more than 400 active players in the residential technology and service provider segment. For instance, new players are entering the marketplace daily, including information technology (IT) network companies, telecommunication corporations, software system integrators, intelligence device manufacturers, and private infrastructure developers (Galvin 2007). In addition, many broadband suppliers plan to enter these new home automation markets and are conducting pilots delivering managed home automation services as part of a bundled offering (Nagel 2009). Many of the major players in the residential energy management space are also engaged in commercializing tools to expand product lines, and improve their offerings in the communications and sensor space aimed at the comfort, security, and entertainment markets (Galvin 2007). The complicated interdependent collection of technology and service vendors are often working through a web of flexible partnerships and joint ventures to implement new business models, many aimed at capitalizing on future utility demand response opportunities (Galvin 2007). Many companies are also expanding into nonresidential market segments (*e.g.*, hotel, residential via contractors, consumer electronics, light commercial, and elderly care, utilities, *etc.*). These experiences should raise vendor experience levels and also lead to lower costs as the scale of the technologies increase.

Currently, the main customer demographic of vendors includes single-family homes with large energy use patterns that enable cost-effective automation (Delage 2009), although multi-dwelling installations are beginning to occur with some frequency. Companies are beginning to see the value of both approaching the customer through the utility and/or going directly to the consumer. Most companies have traditionally approached the market through the utility and provide devices that communicate with the utility advanced metering and/or backhaul systems, for example with ZigBee-enabled communication protocols. However, most vendors are fairly platform-agnostic, communicating with standards-based and open systems. Many home automation network vendors, like Tendril, currently primarily focus on a utility-centric approach, but many are looking at or are soon releasing direct-to-consumer solutions. On the other hand, Control4 focuses on the direct-to-consumer experience, but has also recently launched a division to work within the utility market.

Exact installation numbers per company are unknown, but Control4 has approximately 80,000 customers using their home automation systems, and have shipped over one million ZigBee devices. They offer 5,500 total TV, security, irrigation controllers, door locks, and other devices that operate on a common and affordable platform. They also support a large selection of interoperable products and platforms (including legacy systems such as Ethernet, serial, infrared, *etc.*) to enable a custom home automation system (CEPro 2008, 2009). Despite current economic conditions, forecasts indicate that while advanced utility metering penetrations are growing, consumer interest in energy issues is also growing. In fact, worldwide home energy management users have been forecasted to reach 28 Million by 2015, including 14.4 Million in-home energy display devices shipped by 2015, 11.1 Million users of Web-based energy dashboards, and 2.6 Million mobile phone applications (PikeResearch 2009). The increasing number of devices available from vendors and retail outlets is further driving the do-it-yourself and mainstream segments' market growth (Gallen 2009). Since some luxury systems cost $40,000 and up, the most mature home automation segment is the only segment that could be negatively impacted by the recession (Lucero 2009).

Costs. Costs are broken out by three market segments. For instance, do-it-yourself technology, software, and networks cost between $200 to $5,000 and include smart devices discussed previously; Standards-based third-party technology, software, and network systems cost between $1,000 to $25,000, with a few monthly fee models; and luxury systems cost over $25,000 (ABIresearch 2009); CEPro 2009). System costs vary depending on a variety of deployment characteristics. Market research finds that product prices are expected to decrease fairly rapidly in the next few years, which will also drive technology adoption. Research indicates that many potential customers do want to remotely monitor their homes, as well as manage their spending and use. If it is relatively convenient some of them are willing to pay between $1,000 and $5,000 for systems (Lucero 2009, CEPro 2009, Galvin 2007).

Automation and behavior. Home automation service and technology options range from cost-effective to moderate to high-end in-home theater, audio/video, gaming and media servers, amplifiers, thermostats/space heating and air conditioning, lighting, window and shade control, intercoms, security, *etc.* (CEPro 2009). Home automation companies usually provide flexible and integrated home control systems, including simple-to-use, touch-screen interfaces that pull together various devices (see Figure 6). Installation difficulty ranges from a complete-line of customer-installable devices that are programmable and controllable from a central consumer interface (Tendril's first release is expected soon) (Ruth 2009) to completely professional installation required for every system component (most companies)).

A sophisticated home automation network provides opportunities to set up comfort or savings targets, or targets somewhere in between. This enables the systems to appeal to customer's cost-, eco-, and/or social-conscious motivations. For instance, several vendors described a layered approach to developing a "rulebook" made up of algorithms based on the consumer's preferred comfort levels (*e.g.*, target temperature in the weekly schedule). The customer can also set up acceptable hourly prices, or budgets, and the system automatically adjusts heating, cooling, and other conditions. In most cases, the customer has the choice to override the system at any time or to simply "set and forget" about it and let the home network optimize household energy use. The systems provide action-based tactical messages, such as: set back the thermostat four degrees, as well as objective-based messages that indicate the need for immediate individual energy conservation, because "X" is happening in the electric grid. The individual then chooses how they want that event to affect their lives. For instance, they can ignore the event and pay higher peak rates where applicable, or they might choose to cycle the freezer or pool off for a couple of hours.

Figure 6: Control4 Touch Screen Whole-House Automation

In addition to automation, several companies apply several of the behavior principles discussed earlier: norms, goals, competitions, networks, comparisons, pricing, and actionable steps (see Table 5). Many home automation companies are also at the beginning stages of providing community and social networking platforms designed for community comparisons and challenges. Control4 summarizes the general outlook of many of these companies by indicating that whole house automation technologies can provide "energy efficiency cruise control for the home" (Figure 6) (Nagel 2009).

Findings and Conclusions

This research focused on understanding the enabling technology approaches that would contribute to reducing residential energy waste, which led to the follow three conclusions:

1. **Existing data should be mined.** Like OPOWER and Efficiency 2.0 have learned, there are mountains of existing data sources that can be leveraged to provide meaningful personal and social feedback. As advanced utility meters come on board, sophisticated analysis of data will enable even more meaningful feedback. In addition, these analyses can help regulators and utilities identify the buildings and consumers that would benefit most from technological and behavioral improvements.

2. **Social mechanisms are underutilized.** We know that descriptive normative messaging and other social approaches have been powerful levers of change in utility pilots as well as other fields. It's time to explore the best social approaches to bring down the costs of running feedback programs.

3. **Where possible, solutions should be embedded into existing technologies**. While many programs are looking at installing home area networks and other enabling-

technology approaches, it is important to step back and recognize the existing networks that are already installed in customer's homes. These technologies can include software applications embedded into them to provide energy feedback and automation for customers.

This chapter discussed several consumer-focused third-party vendor and do-it-yourself solutions that ranged from presentment of existing utility data to complete home automation systems, as well as various systems in between. In fact, consumer-facing feedback and automation may be the most important factor in achieving large-scale energy savings. Change management campaigns that use technology and behavior techniques have the potential to make a large impact. However, for these systems to appeal to consumers will require embedding social and psychological principals into the technology solutions. Technology solutions designed in isolation of the end-user will not motivate, enable, and engage the residential consumer.

Acknowledgements

The author would like to thank Karen Ehrhardt-Martinez, Skip Laitner, Sanjay Sarma, Harvey Michaels, Dan Ariely, and K. Carrie Armel for discussions related to this topic. The author would also like to extend grateful appreciation to several interviewed companies for sharing their time and expertise, including: Matthew Spaur (formerly of Itron), Andy Frank of Efficiency 2.0, Kirsten Olsen of Google.org, Ogi Kavazovic of OPOWER (formerly Positive Energy), Michael Delage of Energate, David Wechsler of EnergyHub, Michael Ruth of Tendril, Richard Mueller of Widefield Technologies, Paul Nagel, Collin Breakstone, and DeAnn Zebelean of Control4, Eric Miller and Nathan Ota of Trilliant Networks, and James Pace of Silver Spring Networks.

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Inside the Black Box: Household Response to Feedback

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Introduction

A variety of new feedback initiatives are making energy resources visible to residential consumers throughout the United States (and many other developed countries). These initiatives are opening the door to potential, short-term, energy savings that, on average, can reduce individual household electricity consumption 4 to 12 percent (Ehrhardt-Martinez et al. 2010). In so doing, feedback is proving a critical first step in engaging and empowering consumers to thoughtfully manage their energy resources.

While it is clear that feedback programs have resulted in significant reductions in energy use and that more sophisticated forms of feedback offer the promise of even greater levels of savings, few studies have explored what actions people are taking to bring about these reductions. This knowledge is essential to assess patterns and trends in consumers' responses to feedback, identify the types of energy-saving behaviors that are not being stimulated by feedback, develop better feedback programs that engage households in a broader array of energy-saving behaviors, and to begin to recognize and address the variations that exist between households in how they translate feedback into energy savings.

This chapter represents a first attempt to look inside the black box of American households to understand how they are translating energy feedback into energy savings. The chapter begins with a discussion of energy as an invisible resource in modern society and a description of current patterns of household energy consumption. The following section introduces a categorization scheme that serves to classify different types of energy-saving behaviors into three broad categories. The third section provides preliminary evidence regarding energy-saving actions in households, and the chapter concludes with a discussion of lessons learned and future research directions.

The Invisibility of Energy Resources and Characteristics of Residential Energy Consumption

Household energy resources are in many ways invisible to residential energy consumers. This makes energy management and conservation practices both difficult and unusual. When compared to the use of wood and coal, the more modern energy resources provide an increasingly *invisible* means of meeting demands for heating, cooling, lighting, refrigeration, food preparation and entertainment. Today, both natural gas and electricity supplies flow seamlessly and silently into our homes, fueling our furnaces, powering our air conditioners and other equipment, and meeting our demands for a wide variety of energy service demands without any notable trace of their presence.

For most people, the only measure of their energy consumption is the bill that they receive up to 45 days after consumption. Unfortunately, the monthly bill—even for the best energy detective and the most energy-conscious consumer—is an inadequate tool for managing energy resources. Monthly bills may report the number of kilowatt-hours (kWh) of electricity consumed and the costs that are incurred, but they don't indicate which end-uses are demanding the most energy, how energy intensive or energy-efficient existing appliances might be, and how changes in our own choices and behaviors can either enhance or offset energy demands associated with changing weather patterns, new appliances, and other electronic equipment. Unfortunately, most people in the United States are among the energy blind; we cannot see the energy that we consume.

The dysfunctionality of our current energy system has been recognized for many years. More than a quarter century ago, Kempton and Montgomery (1982) illustrated the paradox of consumption without meaningful information in the following way:

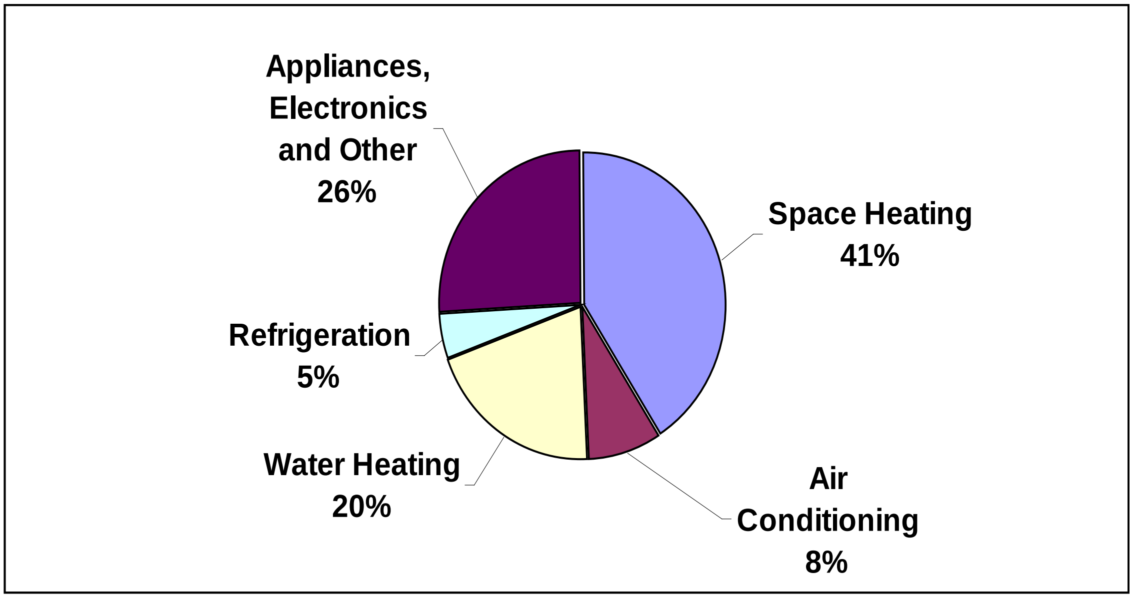
> [Imagine a grocery] *store without prices on individual items, which presented only one total bill at the cash register. In such a store, the shopper would have to estimate item price by weight or packaging, by experimenting with different purchasing patterns, or by using consumer bulletins based on average purchases*.

The invisibility of modern energy resources also impedes the establishment of social norms concerning "appropriate" levels of energy consumption. Not only are most energy consumers blind to their own level of energy consumption, but they are also equally unaware of the energy consumed by others. Without an appropriate frame of reference, individuals and households have a hard time determining whether their patterns of energy consumption are excessive or moderate and whether some type of intervention is warranted.

In the U.S., homes are responsible for approximately 21 percent of the nation's energy demand or roughly 22 quads of energy in 2010. Notably, total residential energy demand has grown by roughly 30 percent since 1978 despite a much more rapid growth in the prevalence and use of energy consuming technologies. During the past 30 years, efficiency-oriented, and technology-focused efforts have been the primary driver of the majority of the energy savings that have been achieved. Nevertheless, many of the recent efficiency gains have been offset by three countervailing trends: an increase in the number of households, larger residences, and an increase in energy service demand associated with changing behaviors and lifestyles.

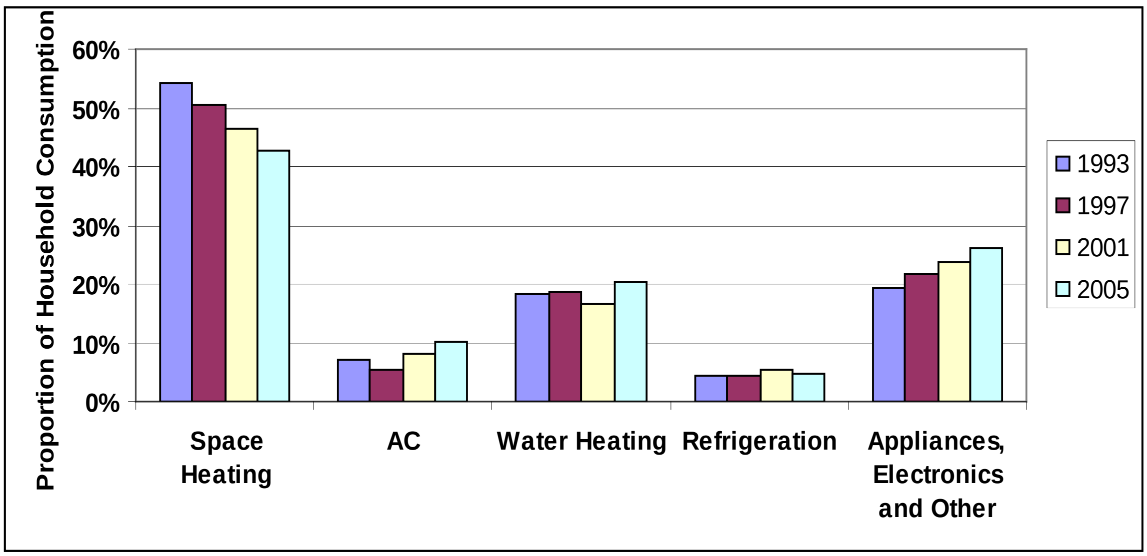
At the household level, heating and cooling currently account for about 49 percent of total residential energy consumption (see Figure 1), somewhat less than in 1993 when heating and cooling were responsible for 58 percent of total household energy use. In absolute terms, average energy consumption for heating declined dramatically from 56.3 million Btus per household in 1993 to just 40.5 million Btus per household in 2005. Conversely, the proportion of energy used for air conditioning and for appliances and electronics has experienced a notable increase during the same period as shown in Figure 2. Most recently, consumer electronics have come to represent one of the fastest-growing segments of residential energy use.

Figure 1. Energy End Uses as a Percent of Total Residential Energy Consumption, 2005



Source: EIA, Residential Energy Consumption Survey (2005)

Figure 2: Average Household Energy Use by End Use, 1993-2005



Source: EIA Residential Energy Consumption Surveys (1993, 1997, 2001, 2005)

In addition to the overall trends, it is equally important to take note of the variation that exists in residential energy use across households. This variation is not simply the result of differences in design or technology but is also a function of socio-demographic differences (household size, member's ages, income, ethnicity and race) as well as differences in values, beliefs, norms and habits. In fact, non-physical factors have resulted in variations of as much as 3 to 1 in homes with similar construction (Hackett and Lutzenhiser 1991). So where do we turn for additional energy savings? Technology? Or, behavior? Which holds the larger energy saving potential?

According to Gardner and Stern (2008), readily available technologies provide the opportunity to reduce current residential sector energy demand by more than 25 percent:

Potential Technology-Based Efficiency Gains:

- Upgrading attic insulation (up to 7% of total)
- More efficient heating, ventilation, and cooling systems (up to 5%)
- Use of compact fluorescent lamps (up to 4%)
- Caulking/weatherstripping (2.5%)
- Efficient refrigeration (1.9%)
- Efficient water heater (1.5%)
- Projection versus plasma TV (1.3%)
- Efficient clothes washer (1.1%)

However, it is also important to recognize that technology adoption doesn't occur in a social vacuum. Social and behavioral considerations are important because they both shape and constrain technology adoption decisions, technology choices, and the operation and everyday use of technologies. In addition, behavioral approaches can also reduce energy consumption more directly by changing habits, lifestyles and everyday energy use practices. From a technology perspective, consumers must choose whether or not to buy a new technology (such as an HVAC system, lighting, refrigerator, water heater, TV or clothes washer) and which technology to buy. Proper use includes decisions and choices associated with the installation, maintenance, and use of equipment while habits and lifestyles include choices about how we live, where we live, how much we consume, how much we travel, and how we otherwise spend our time.

In summary, total residential energy consumption has increased over the past 30 years but at a much slower rate than might otherwise be the case due to significant efficiency gains achieved through new, more efficient technologies. These gains have allowed residential energy use per household, per capita, and per square foot to remain relatively stable despite significant increases in energy service demands. Nevertheless, substantial amounts of potential energy savings continue to be left unrealized. Therein lays the challenge. An expanded model of energy savings that recognizes and addresses the human dimensions of energy consumption offers the promise of notable declines in residential energy consumption whether by means of the expanded adoption of more efficient technologies, more thoughtful energy use choices, or less energy-intensive lifestyles and energy use habits.

Categories of Energy-Saving Behaviors

While efforts to reduce energy consumption require a well-researched understanding of existing energy end-uses and everyday practices, they also benefit from an understanding of the malleability associated with these actions. By recognizing which behaviors are the most malleable, policymakers and program managers can determine which behaviors and interventions are likely to yield the most energy savings and can target their efforts appropriately. (See Chapters 2 and 3 in this volume for a more in-depth discussion of this topic.) However, feedback initiatives are different from standard efficiency programs in several important ways. Rather than requiring a discrete focus and advocacy for engagement in a particular energy saving behavior, feedback programs let the consumer decide which actions he or she finds most appealing or most feasible. As such, feedback initiatives themselves can provide valuable insights into the malleability of different types of behaviors while allowing for greater flexibility in how people meet their energy saving goals.

Whether defined by end use or malleability there are hundreds of different types of behaviors that people can choose to engage in to save energy. A useful way to simplify this very long list of behaviors is to categorize them by significant attributes such as the economic costs associated with a particular activity and the frequency with which people need to engage in the behavior. Cost can be an important barrier that will keep many people from engaging in a particular behavior, while the frequency of the action will be an important factor in determining the types of programmatic support that are likely to be most effective. Figure 2 provides a typology of energy behaviors as a function of the frequency of the action taken and the economic cost associated with the undertaking of the action. When broken down in this way, three categories of behavior emerge.

The first type of behavior might be thought of as *Energy Stocktaking Behaviors* and *Lifestyle Choices*. These include energy saving behaviors that are performed infrequently and can be performed at a relatively low cost (or at no cost) such as installing compact fluorescent lamps (CFLs) and weatherstripping, or choosing to live in a smaller house or apartment. The second type of behavior involves energy saving actions that must be performed or repeated frequently. These are generally referred to as *Habitual Behaviors* but they also involve some lifestyle choices. Examples include laundry routines and whether we tend to wash our clothes in cold water, use a mechanical drier, or air dry our clothes and linens. This category of behaviors also includes habits associated with appliance use and lighting and the frequency with which we turn off computers and other devices when not in use.

The final type of actions involves infrequent but higher-cost behaviors. These actions are generally referred to as *Consumer Behaviors, Technology Choices* or *Purchasing Decisions* and involve the adoption of more energy-efficient products and appliances (Laitner et al. 2009).

Providing consumers with feedback on their energy consumption patterns has been shown to have an impact on a variety of different behaviors associated with each of the three categories. The fact that people have multiple means of reducing their energy consumption means that some people/households may be more likely to pursue energy savings through investment decisions in more energy-efficient technologies while others prefer to take stock of their energy consumption patterns to make thoughtful adjustments in everyday practices. The following section discusses some of the specific ways in which people have responded to feedback and which of the three categories of behaviors best represents the types of behaviors that people are most likely to engage in. These findings are then compared to research on behavioral responses to information campaigns and energy crises.

Figure 3. Energy Behaviors* as a Function of Frequency and Cost

Cost	Frequency of Action: *Infrequent*	Frequency of Action: *Frequent*
Low-cost / no cost	**Energy Stocktaking Behavior** Install CFLs Pull fridge away from wall Inflate tires adequately Install Weather Stripping	**Habitual Behaviors and Lifestyles** Slower Highway Driving Slower Acceleration Air Dry Laundry Turn Off Computer/Other Devices
Higher cost / Investment	**Consumer Behavior** New EE Windows New EE Appliances Additional Insulation New EE Car New EE AC or Furnace	

Preliminary Evidence of Feedback-Induced, Energy-Saving Behaviors

What are the means by which feedback results in residential sector energy savings? Many utilities and researchers have begun to explore this topic with greater interest as a result of the push for the development of a more modern and technologically sophisticated electric grid in the United States and the opportunities that such a system holds for providing millions of consumers with real-time feedback. While these studies continue to collect evidence that must be brought to bear in future assessments, this chapter relies primarily on the findings of 16 historical studies. Among the most influential is a 2004 study of the impact of a pilot residential time-of-use pricing program in Sacramento, California in which researchers explored energy-saving behaviors in the most detailed fashion (see Wood et al. 2004). In addition, this assessment draws from the insights provided by 13 additional feedback studies that report on associated changes in behavior (Elliot et al. 2006, Martinez and Geltz 2005, Sulyma et al. 2008, Sipe and Castor 2009, Hayes and Cone 1977, Abrahamse et al. 2007, Benders et al. 2006, Haakana et al. 1997, Mountain 2008a, Mountain 2008b, Ueno 2006, and Kantola and Syme 1984). Finally, the insights from the feedback studies are compared to two studies that looked at the effect of energy crises on energy-related behaviors (Lutzenhiser et al. 2003 and Leighty and Meier 2010).

Although the survey results from Wood et al. (2004) are not based on a representative sample, the study's findings provide some preliminary insights as to the ways in which people choose to change their habits, lifestyles and choices in ways that result in energy savings. Participation in the Sacramento feedback program was voluntary and most participants reported that they chose to participate either because they wanted to save money (88%) or because they wanted the ability to control their energy usage (54%). In addition, roughly one-third indicated that their participation was motivated by a concern for the environment. In terms of actual energy savings, the study's findings showed a high level of participation: 86 percent of participants used less energy during high or critical periods and 67 percent of participants used less energy overall. Moreover, the energy savings that resulted from the program were significant. Energy use during critical price periods declined by 16 percent, while overall energy use declined by 4 percent. But how did people achieve these savings?

As shown in Table 1 (below), households were found to engage in a variety of different activities to save energy. Nearly all participants (95%) reported engaging in new habits to minimize energy use during critical price periods. The principal strategy involved shifting usage to nonpeak periods. In particular participants were less likely to use air conditioners, dishwashers, and clothes washers during peak periods. They also reported taking fewer showers or baths during these periods and cooking indoors less often.

Respondents also reported taking energy stocktaking behaviors including repairing air ducts (8%) and changing the default temperatures on their thermostats (42%). Notably, among the respondents who saved the most energy overall were those that invested in energy-efficient products. More than half of all participants (59%) invested in compact fluorescent light bulbs. A smaller proportion of households invested in more costly energy-efficient upgrades to their homes including new windows (11%), a new refrigerator (9%), a new air conditioner (5%), or added insulation (5%).[1]

Table 1. Categories of Change and Behaviors in Sacramento Study

Type of Change	Behavior	Percent
New Habits	Shifted Usage	95%
	Checked thermostat display for critical periods	83%
Energy Stocktaking	Repaired air ducts	8%
	Changed default temperatures on thermostat	42%
Low-cost Investments	Installed CFLs	59%
Higher-cost Investments	Replaced single with dual-pane windows	11%
	Replaced inefficient refrigerator	9%
	Replaced inefficient air conditioning	5%
	Installed ceiling or wall insulation	5%

Source: Wood et al. 2004

These findings contrast with an earlier and larger study of conservation behaviors by residential consumers during and after the 2000-2001 California energy crisis (Lutzenhiser et al. 2003). The 2003 study used data obtained from 1666 in-depth telephone interviews with randomly selected residential households in five major California utility service territories. Some interesting findings from the 2003 study indicate that "more than 75 percent of households participating in the survey reported taking one or more conservation actions", and that reductions in energy demand were largely due to changes in behavior (65-70%) as opposed to investments in hardware solutions or on-site generation projects (25-30%). Table 2 shows reported

[1] Higher-cost investments were relatively rare despite the fact that the sample population was found to have higher incomes compared to the general population in the same geographic area. More specifically, 50 percent of pilot participants had annual incomes over $100,000 per year compared to 12 percent of people in the general population.

conservation behaviors. Note that the top three behaviors involved changes in habits and routines as opposed to investment decisions.[2]

Table 2. Behaviors in Response to California Electricity Crisis as a Function of Technology Categories

Type of Behavior	Description	Percent
Lights Behaviors	Behaviors related to turning off lights or using fewer lights	65.5%
Other Heat/Cool Behaviors	Behaviors related to heating and cooling other than not using the AC at all (e.g. using AC less, using ceiling fans, changing thermostat, etc)	48.5%
Small Equipment Behaviors	Behaviors related to household appliances (using them less, turning them off and unplugging them)	32.2%
Light Bulbs	Hardware related purchase/use of CFLs or other energy saving bulbs	22.2%
Peak Behaviors	Behaviors related to using energy during off-peak hours	20.0%
H20 Behaviors	Behaviors related to using less water or using less hot water (e.g. shorter showers, wash in cold/warm water, turn water heater down, etc)	12.2%
Appliances	Hardware-related purchased/use of new non-fixed appliances (e.g. refrigerator, washer/dryer, window AC, fans, etc.)	10.4%
Turning off AC	Behavior related to not using the AC at all	9.6%
Shell Improvement	Hardware related to one-time improvements to the house (e.g. windows, insulation, a new piece of fixed equipment such as water heater, AC, furnace, etc.)	7.9%
Large Equipment Behaviors	Behaviors related to pools, spas, irrigation motors (e.g., turn off, use less often)	6.0%

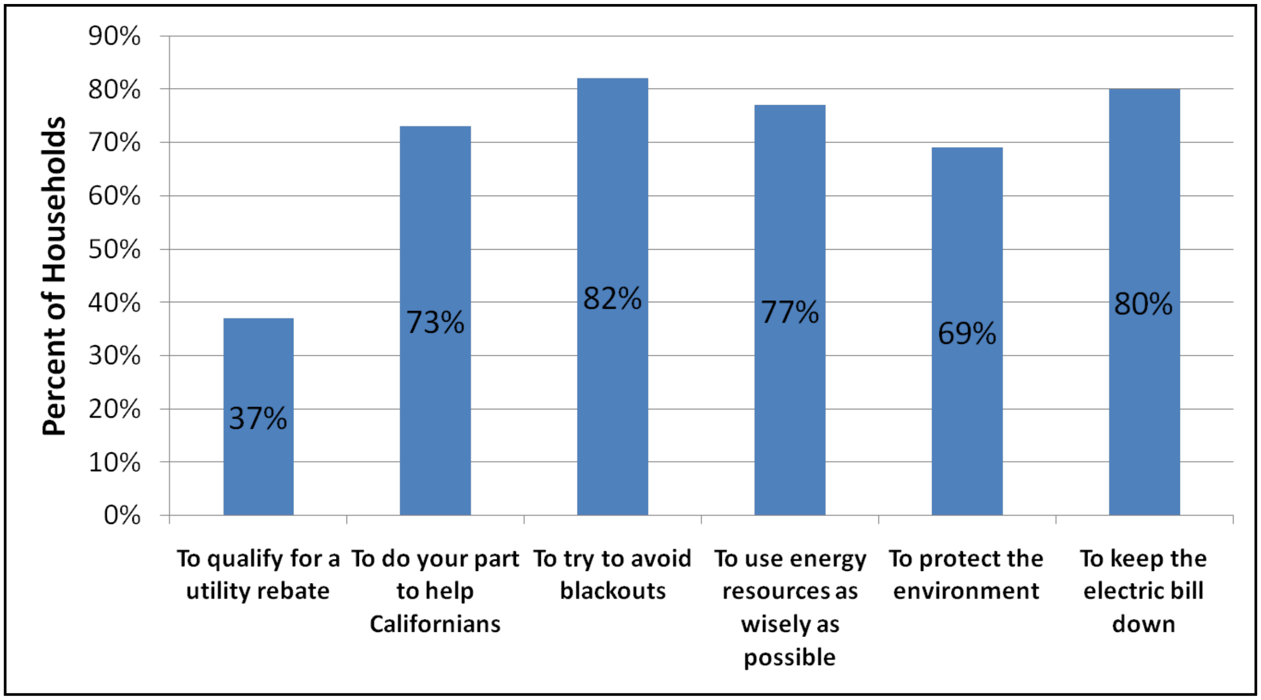
Source: Lutzenhiser et al. 2003

Another important difference between the two studies involved the question of motivation. In Figure 4, from a study by Lutzenhiser et al. (2003), survey respondents reported that their conservation efforts were motivated by a wide variety of factors. While minimizing energy costs was among the principal motivators, respondents also reported being motivated by their desire to avoid blackouts (82%), to use energy resources as wisely as possible (77%), to do their part to help Californians (73%), and to protect the environment (69%). According to the report, “qualifying for a utility rebate was the least common motivation, and available utility rebates were not relevant to most of the actions consumers took.”

[2] Similar results are reported by Leighty and Meier in their 2010 report on the impact of a recent energy crisis in Juneau, Alaska.

These findings are further supported by the evidence of thirteen additional studies on the effect of feedback on energy-related behaviors (see above references or Ehrhardt-Martinez et al 2010). According to the evidence from nearly all 13 cases, people were most likely to report turning off lights and/or changing their thermostat setting. Among the other frequently reported behaviors were: turning the air conditioner off, installing energy efficient light bulbs, and reducing the use of the clothes dryer, dishwasher and oven.

Figure 4. Motivations of California Households Reporting Various Conservation Behaviors 2001



Source: Lutzenhiser et al. (2003)

On the other hand, few people reported having reduced their use of electronic devices such as televisions, stereos and computers although they did report a willingness to turn off computers and monitors when not in use. Table 3 illustrates the frequency of different energy saving behaviors as reported by the various study participants. Caution should be used in interpreting the results since many of these programs provided specific energy saving tips or suggestions as to the actions that households could or should take to save energy and these tips may have influenced both actual and reported behaviors.

The findings from the combined group of studies clearly suggest that:

- behavior-related energy savings opportunities are available in the residential sector,
- people are willing to change their energy-related behaviors, and
- feedback is likely to be an effective mechanism for unlocking potential energy savings.

Table 3: Relative Frequency of Reported Energy-Saving Behaviors

Conservation Behaviors		Frequency
Lighting, Electronics	Turned off lights	VH
	Install energy efficient light bulbs	MH
	Used task lighting	L
	Reduced Television use	M
	Reduced use of Stereo	ML
	Reduced use of Computer CPU	M
	Reduced use of Computer Monitor	M
	Reduced use of stand-by settings	M
Heating & Cooling	Turned off AC	MH
	Turned down electric space heating	M
	Reduced heating/cooling demand (thermostat)	VH
	Reduced the number of hours heating is on	L
	Reduce number of rooms heated/cooled	L
	Pulled Window Shades	L
Appliances	Turned down refrigerator thermostat	M L
	Opened refrigerator less often	M L
	Reduced use of clothes washer	M
	Used cold water wash in clothes washer	M
	Reduced use of clothes dryer	H
	Reduced temperature on dryer	ML
	Reduced use of electric range	M
	Reduced use of electric oven	MH
	Reduced use of microwave oven	L
	Reduced use of dishwasher/only full loads	MH
	Used cold/short cycle on dishwasher	ML
Hot Water Heating	Reduced hot water demand	L
	Turned down water heater	L
	Reduced number or length of showers	M
	Turned down electric water heating	ML
Other Behaviors	Reduced use of Hot tub	M L
	Turned off pool filter	L
	Reduced use of ventilation fans	L
	Ironed in batches	L
	Turned off pool pump	L
	Reduced meat consumption	M L
	Reduced food waste	M L
	Transport mode shifting	L

VH = very high
H = high
MH = med. high
M = medium
ML = medium low
L = low

Source: Ehrhardt-Martinez et al. 2010

Among the many potential types of energy efficiency and conservation behaviors, people were most likely to make changes in habits, routines and everyday practices and/or engage in energy stocktaking behaviors. Notably, only a small proportion of people reported having made investments in more energy efficient products and appliances. Interestingly, however, investments in new equipment and appliances appeared more likely within more affluent populations and were generally undertaken in conjunction with a change of residence or a remodel or part of a stylistic (as opposed to functional) upgrade (Lutzenhiser et al. 2003).

Importantly, these energy-conservation behaviors are likely to be motivated by a variety of factors including self-interest (energy bill savings) as well as civic concerns and altruistic motives (Lutzenhiser et al. 2003). These findings suggest that narrowly defined energy-efficiency programs aimed at the installation of new, more energy-efficient technologies alone (the practice of traditional utility programs) are likely to realize only a small fraction of potential behavior-related residential energy savings. Similarly, programs that limit their appeal to self-interest alone are unlikely to leverage the broad range of factors that motivate people to action.

Conclusions

Providing households with contextualized feedback and targeted energy-saving tips holds the potential for large scale energy savings. Average program-level savings from past programs across several continents indicate savings in the range of 4 to 12 percent (Ehrhardt-Martinez et al 2010) but also show several instances where significantly higher levels of savings were achieved. Moreover, providing residential energy consumers with feedback is important because it makes energy visible, allows for active participation of households in energy management practices, and provides flexibility as to how energy savings are achieved. Among the many potential actions that people may choose to engage in to reduce their energy consumption, most people choose to make adjustments in their everyday habits and routines. Energy stocktaking behaviors are also important. Notably however, existing research indicates that only a relatively small amount of feedback-induced energy savings are likely to come from investments in energy-efficient technologies. More research is clearly needed to better understand this pattern and to determine if households are likely to engage in different types of behaviors as they receive feedback over longer periods of time. In other words, the first steps that people choose to take may be more likely to include new habits and routines, but as time passes and households begin to exhaust low-cost options and build their understanding of energy management options, they may be more likely to make investments in more energy-efficient appliances and products.

Of equal importance is the need for research that reveals the diversity of feedback-induced energy saving strategies across different types of households. This type of research should take into account the important ways in which socio-demographic and psycho-demographic variables are likely to mediate the relationship between feedback and energy conservation or energy efficiency behaviors. Such research could provide critical insights for program and policy designs and improve the accuracy of energy demand projections.

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Personal Carbon Budgets: Helping Individuals to Live in a Carbon Constrained World

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Introduction

Among the more developed countries of the world, individuals could contribute greatly to reducing national and global carbon emissions through changes in their choices, habits, and everyday practices (Laitner et al. 2009). This chapter proposes the use of personal carbon allowances (PCA) to motivate individual action and actively engage people in carbon emissions management. A PCA scheme entails the allocation of carbon budgets to individuals. Personal carbon budgets represent a unique approach to carbon emissions management because they seek to engage the broader public (rather than a few, large-scale organizations) in achieving emissions reductions by providing an equitable means of setting per capita limits to carbon emissions and by providing a mechanism for monitoring and managing carbon allocations.

A PCA instrument is a downstream cap and trade policy mechanism in which emissions rights are allocated to individuals. It has been suggested and discussed, to some extent, within the UK Government. In this scheme, all individuals would receive annual carbon emissions budgets. PCA would cover emissions under direct personal control, such as household energy use (electricity and gas), private transport (not including public transport) and aviation. It would not include carbon embedded in products and services purchased by the individual, as presumably this would be covered by other policies, such as the European Union's Emissions Trading Scheme (EUETS).

Under PCA, for each purchase of carbon-based energy, allowances would be deducted from the individual's carbon budget. Those who overspend their carbon allowance would need to buy additional credits. Those whose emissions fall within their carbon budget could sell the excess credits on the carbon market. Annual personal carbon allowances would be reduced periodically to meet shrinking national emissions targets.

In this chapter we introduce PCA and place it in the policy context of other suggested policies for reducing emissions from individuals' activities. We then describe the mechanisms through which PCA would reduce emissions, and describe current thinking on PCA within the UK. We continue by laying out the rational for applying a budgeting framework as a means for understanding personal carbon allowances and as an emissions management tool. The final section discusses the prerequisites for effective carbon budgeting.[1]

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[1] This chapter is a short version of Parag and Strickland (2009) *Personal Carbon Budgeting: What people need to know, learn and have in order to manage and live within a carbon budget, and the policies that could support them.* UKERC Research Report, Demand Reduction Theme. Available at http://www.eci.ox.ac.uk/research/energy/downloads/paragstrickland09pcbudget.pdf
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PCA in the Policy Context

Anthropogenic climate change is the most dire threat civilization has ever faced. The global community responded with the Kyoto Protocol, under which many of the more affluent nations agreed to limit their greenhouse gas emissions. Some countries set even more ambitious goals. In the UK, for example, the 2008 Climate Change Act mandates 80% reductions (based on 1990 emissions) in GHG emissions by 2050, with a 34% reduction by 2020. Such ambitious targets will require radical changes in the way that we use, perceive, and produce energy.

Emissions from the individual sector make up a significant proportion of total emissions globally. For example, within the UK around 42% of total emissions come from the domestic sector (see box 1 for detail) (BERR 2007)—almost half of total emissions are therefore generated directly by individuals and households rather than industry and governments. Although one can argue that personal carbon emissions are individually insignificant, collectively they are very large and delivering emission reductions by altering millions of individuals' energy-use choices and behaviour remains an unmet policy challenge.

A wide range of policy interventions are being used to greater and lesser extents by global governments to tackle different aspects of individuals' energy use. These include taxation, information schemes, feed-back, smart metering, grants for installing low carbon technologies, tax reductions and rebates, market transformation, changes in standards, and legislation. These and other policies and programmes tackle different aspects of individuals' energy use, and thus contribute to a countries overall national emission reductions. Yet, many governments lack an overarching approach to reducing personal energy consumption that could link together these policies and schemes.

Energy/carbon taxation is one such 'umbrella' policy option for attempting to deliver energy demand reduction across all end energy uses. The mechanism through which taxation would lead to reduced consumption is fairly well understood; ultimately taxation is visible to the final energy user as a price rise, which consequently leads to demand reduction. However, people do not necessarily react to price signals imposed by taxes in the manner predicted by neo-classical economics. Energy demand has been shown to have rather limited elasticity with respect to price rises (e.g., Halvorsen and Larsen 2001; Reiss and White 2005), thus weakening the potential effectiveness of taxation schemes in delivering demand reduction. Further, energy costs constitute a relatively low proportion of the total household budget for many countries. For example, in the UK energy consumption per unit of household disposable income fell by 44 percent between 1970 and 2000 (DTI 2008). Consequently the price signal has a relatively weak impact on behaviour and may be largely overlooked by energy consumers (Baker and Blundell 1991). The substantial global energy price rises since 2003 might have been expected to change this finding; however, the inflation has demonstrated that only major energy price rises actually have any impact on reducing energy demand and that rises of this scale significantly impact the poor.

An alternative overarching approach to energy demand reduction is a downstream carbon cap and trade instrument, namely personal carbon trading. To read more about personal carbon trading, see Parag and Fawcett (2010). The concept of capping personal emissions was first proposed in the UK by David Fleming in 1996 under the name of Domestic Tradable Quotas (DTQ), which later changed to Tradable Energy Quotas (TEQ) (Fleming 1997). Several variants have been proposed in which carbon is capped in different parts of the economy and with different allocations. All versions of the schemes are similar in approach, but vary in terms of the participants, scope, and allocation. The three main personal trading schemes are: PCA, Tradable Energy Quotas, and Cap and Share. A brief summary of the key likes and differences can be found in Roberts and Thumim (2006) and Fawcett and Parag (2010). The PCA scheme was proposed by Mayer Hillman in 1998 (Hillman 1998) as a variant that is restricted to personal energy use.

Box 1: The UK Perspective on Emissions and Policy Instruments

To meet international requirements for reductions in GHG emissions the UK, like many countries, will require additional policy interventions to those currently in place if the 80% reduction targets are to be met by 2020 and beyond (BERR 2007). In the UK there is evidence that GHG emissions have been reduced from 1990 levels, but in recent years they have stabilised (Defra 2007), resulting in an even greater challenge needed to meet reduction targets.

Individuals and households (domestic sector) provide a significant opportunity for reductions since they constitute around 42% of the UK's CO_2 emissions. Of the emissions under direct personal or household control, 30% arise from space heating, 10% from water heating, 9% from appliances, 4% from lighting, 3% from cooking, 29% from personal travel, 12% from holiday air travel, and 2% from other travelling (BERR 2007). In other words almost half of UK emissions are generated from energy-using activities that fall directly under the control of individual citizens, rather than corporations or government.

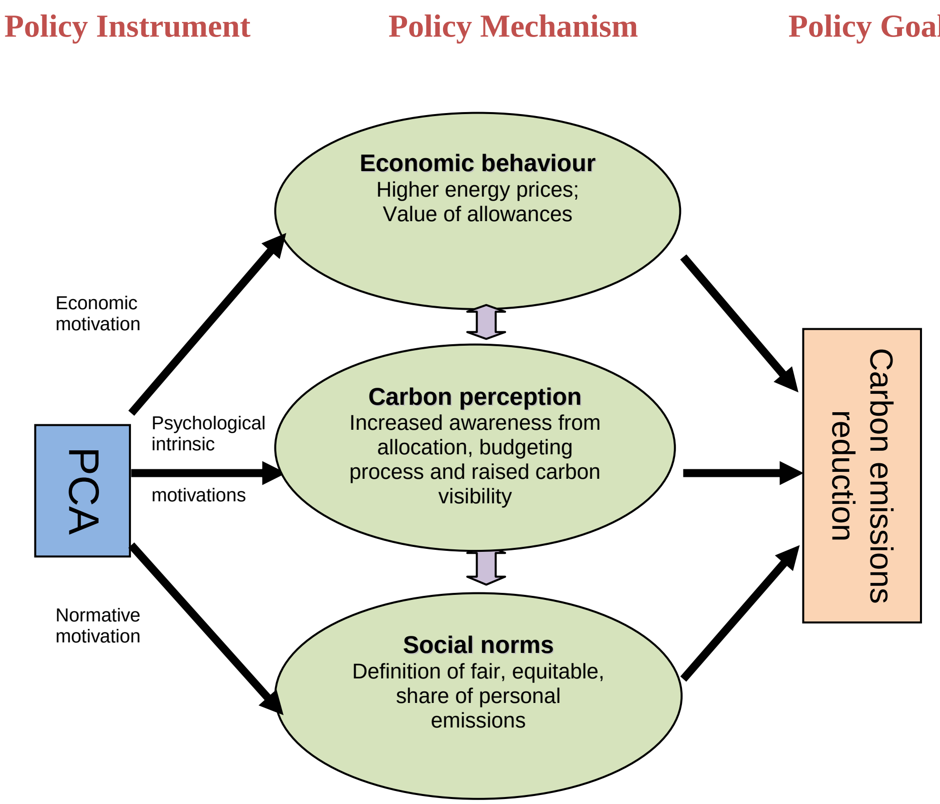
The array of existing and planned policy instruments available to deliver cuts in emissions from private end-users in the UK consists mostly of information schemes, feedback, and smart metering. Economic incentives exist to a lesser extent and include, for example: grants (e.g., for installing solar photovoltaic panels), rebates (e.g., for stamp duty on low carbon homes), VAT reductions for some insulation materials, and soon—feed-in tariffs that pay individuals for electricity that they generate and export to the grid. In addition, market transformation schemes aim to eliminate energy inefficient electric devices from the market and tighter building regulations aim to improve household infrastructure. More efficient homes and appliances can provide the same utility (benefit and comfort) while consuming significantly less energy. A voluntary agreement with the car industry is doing the same for cars.

PCA Mechanisms

Significant emission reductions could be achieved by reducing the carbon content of energy. However, this would require fundamental, expensive, and time consuming infrastructural changes to our energy supply systems. Therefore, until low carbon energy is widely available, emission reductions will need to come from reducing energy demand, which entails behavioural change. It is suggested that PCA would impact individuals' energy-related decision making through three basic interacting mechanisms, which broadly conform to three different approaches to behaviour change: economic, psychological and normative (see Figure 1).

Ideally, PCA will promote behavioural change by (1) posing a constraint on energy consumption via the pricing of personal carbon emissions; (2) providing an intrinsic psychological motivation to change patterns of energy consumption via the increase in carbon literacy and awareness; and (3) introducing and reinforcing a new, equitable, and fairer social norm of personal carbon footprint.

Figure 1: Policy Mechanism: The Routes by Which PCA can Deliver Emissions Reduction



The *economic* motivation is driven by the price of carbon that arises in the market of traded allowances. The price is set by the following: the extent of the 'shortage' in allowances; the value of the services carbon-based energy can deliver; and the extent to which there is a well-behaved market. The price provides the economic incentive for reducing emissions and this is independent of the initial distribution of allowances.

However, evidence suggests that the traditional economic paradigm (within which carbon is interchangeable with other resources) may not adequately reflect the way that people actually manage their affairs. For example, it is known that price effects are not always symmetrical: the willingness to pay for additional allowances may be different from the willingness to accept payment for allowance sales (Capstick and Lewis 2008). In this case, it is plausible that both the distribution of allowances between individuals, and the personal cap, may affect behaviour. Such an assessment contradicts traditional economic approaches that would suggest that behaviour is a function simply of the allowance's total value. A good example of the complexity of behavioural determinants is illustrated by the experimental work carried by Capstick and Lewis (2010). Their work suggests that people may be inclined to respond to PCA partly based on the absolute size of the allowance and whether they are in credit or debit, rather than responding with pure economic rationality.

The *intrinsic psychological* motivation to emissions reduction provided by PCA will be rooted in a growing level of carbon awareness and the relationship between emissions and activities. Lorenzoni et al. (2007) describe different barriers to engagement in respect to climate change by members of the UK public. These include among others, the feeling of helplessness (‘drop in the ocean’), concerns about free riders, and lack of enabling initiatives. Whilst other schemes—such as information campaigns, personal advice programme, and more informative billing and metering—can help with reducing these barriers (for a review, see Abrahames et al. 2005), it is reasonable to suppose that a cost penalty/bonus linked to other policies will increase the effectiveness of personal engagement. Additionally, increasing people’s knowledge of their carbon emissions will help correct any incorrect perceptions regarding actual energy consumption (Steg 2008; Whitemarsh 2009). Carbon visibility, awareness, and correct information are crucial for promoting behavioural change. Their impact also has implications for political acceptability, which increases when people are aware of the problems resulting from their energy use, feel responsible for it, and feel morally obliged to do their bit to help solve these problem (De Groot and Steg 2008; Steg et al. 2005). PCA’s intrinsic motivation route has the potential to raise the perception and visibility aspects of carbon.

The *normative* mechanism moves away from individualism and recognises that decisions, even about individually allocated resources, are shaped by social forces (Schultz et al. 2007). Individual decision-making, even on such personal matters as setting thermostats or driving, can be modulated by social forces like peer pressure. Energy-conserving behaviour that arises from perceived social pressure—as opposed to cost, or even belief that it’s, say, good for the planet—is more durable (Lindenberg and Steg 2007). By suggesting a fair, socially accepted personal carbon footprint, a PCA would reinforce energy conserving behaviour by more than just the limits it places upon consumption.

PCA may also create new institutions around allowances trading. It might as well provide a hothouse environment for new businesses and other institutions, such as ones that might promote alternative approaches to living within carbon budgets, to grow up around carbon trading. That, in turn, may reinforce energy conserving behaviour still further.

The main difference between PCA and carbon taxation is that while taxes are designed primarily to target economic behaviour, through changing prices within existing markets and social frameworks, PCA is more likely to impact via the other mechanisms because of the use of a new carbon market, budgets, and the potential for social and institutional change.

Theoretically PCA avoids some of the pitfalls associated with carbon taxation schemes. First, it increases the visibility of carbon, and delivers a message that is broader than pure supply and demand economics. Second, it meets a basic standard of fairness, as all individuals receive an equal allowance. In addition, PCA is broadly progressive, because the high emitters (who will pay more) have a propensity to be on higher incomes (Thumim and White 2008). Fairness is important because policies that are perceived as fair are more likely to be politically acceptable (Bamberg and Role 2003; Jakobsson et al. 2000; Schuitema and Steg 2005).

But PCA has its own weaknesses. The simple conception that PCA meets equity and fairness requirements is not unproblematic, as an equal allocation does not necessarily imply 'fair' fulfilment of basic needs, which can vary significantly between individuals (Starkey and Anderson 2005; Starkey 2007). Furthermore, a minority of the lower income deciles might find themselves worse-off under PCA (Thumim and White 2008). Hence PCA has the potential, if designed without compensation mechanisms, to increase fuel poverty in those countries where it is a problem. In addition, it might not be supported by politicians because policies, such as PCA, which restrict choices (rather than increase them), target absolute reduction (rather than efficiency), and aim to reduce energy from transport (i.e., restrict mobility, rather than focusing solely on energy use at home) are less acceptable (Poortinga et al. 2003; Steg et al. 2006). Moreover, PCA not only puts current constraints on individuals but guarantees further restrictions into the future, as inherent to the scheme, the budget will shrink over time. From a more favourable perspective, however, one could argue that PCA does not audit or limit individuals' preferences and within a given cap—or budget—it allows for personal choice.

Several acceptability studies into PCA have been carried out in the UK. These show that it is the least opposed option when compared against taxation and upstream cap and trade instruments (Owen et al. 2008; IPPR 2008; Wallace et al. 2010), and that there is a degree of willingness for people to accept some level of responsibility over their actions. In particular, the UK Government's Department of Food and Rural Affairs (Defra) (2008) study found that "*resistance to behaviour change was less than expected*." At the same time some participants in these studies felt ill-prepared for such a scheme, which they describe as too complex. This highlights the need for improving carbon literacy in advance of such a scheme, and building the capacity for personal carbon budgeting, and thus keeping the concept on the table.

PCA Status

In the last four years the idea of personal carbon trading has been raised onto the policy agenda and discussed by the UK Government. In 2006 the then Secretary of State for Environment, The Rt Hon David Miliband, decided to conduct a pre-feasibility study into personal carbon trading. In May 2008, Defra completed this study that looked at the following aspects: social acceptability, economic and technical feasibilities, equity and distributional impact, and the scheme effectiveness in the context of the existing policy landscape (see summary report: Defra 2008). He concluded that "*personal carbon trading has potential to engage individuals in taking action to combat climate change, but is essentially ahead of its time and expected costs for implementation are high*." Accordingly, Defra announced that while the Government remains interested in the concept of personal carbon trading, it will not continue its research programme at this stage.

The UK Parliament Environmental Audit Committee (2008), which published its own report on PCA few weeks later, concluded that "*carbon trading could be essential in helping to reduce our national carbon footprint. …Although we commend the Government for its intention to maintain engagement in academic work on the topic, we urge it to undertake a stronger role, leading and shaping debate and coordinating research*." Both reports agree that PCA remains an un-exhausted field of research, and offers a promising prospect to aid the UK to meet its targets.

The potential of PCA was also promoted by the Sustainable Development Commission,which chose Personal Carbon Budgets as one of the 21st Century's breakthrough ideas (SDC 2009). Additionally, in 2009 the idea of personal carbon trading was highlighted by the Chair of the UK Environment Agency as a possible future development (Smith 2009).

To date PCA is an innovative policy instrument that is not yet implemented anywhere worldwide. Consequently, there is no comparable policy experience to learn from or to help predict the possible effects of PCA on the policy goal of reducing domestic sector carbon emissions (Parag 2008). As a novel and radical instrument, PCA introduces unfamiliar policy elements such as a carbon price for the domestic sector, cap-and-trade at the personal level, and carbon budgeting for individuals. It also raises many policy design questions such as: what would constitute effective and acceptable enforcement and monitoring mechanisms; how would the carbon allocation system work; what would the costs of the scheme be to the state and to individuals; and who would the governing institutions be? These issues and others, on top of the high implementation costs of the scheme, make PCA very risky for politicians and policy makers alike (Parag and Eyre 2010).

One way to reduce this risk is by investing in PCA research in order to develop a deeper understanding of what it would mean to actually live under such a framework and with individuals each managing their own personal carbon budgets.

With this in mind, the remainder of this chapter raises some of the PCA policy design issues and looks more deeply at PCA through the lens of budgeting in order to highlight some of the questions that are likely to arise from living with a carbon budget.

PCA and Budgeting

In effect, PCA introduces a new currency into our lives—carbon. Under PCA everyone receives a sum of carbon credits, or units, which they need to administer. In order to manage a personal carbon allowance, it is likely that people will need to start budgeting carbon emissions from household gas and electrical activities, personal transport, and flights. This will involve making rational tradeoffs between competing demands that emit carbon. While budgeting is a familiar act to many individuals in their daily lives, some might find it a more conscious process than others. One challenge for policy designers is to understand how people would manage their carbon budget, what assistance they might need, and what schemes could assist/advise them.

To illustrate: people need to know what their budget limits are, as well as what their current carbon balance is and how much they use for any given purpose. To enable informed choices, activities and services need to be labelled not only with their monetary cost but also with the carbon units they consume, i.e., their carbon cost. In order to stay within their carbon limits, many people will need to have low-carbon alternatives to their current choices such as public transport or energy-efficient appliances. For these alternatives to be valid and attractive they need to be easy, accessible, and cheap (or at least not excessively more expensive). People might need advice, such as how to reduce electricity consumption; options for optimal insulation material; availability of credible suppliers and installers; and knowledge about grant availability. Consumers will also need clear information explaining how to live with a personal carbon allowance and how to trade in the new carbon market. Inevitably some people would need financial support to improve their home's energy efficiency in order to reduce their carbon emissions. There will also need to be some information on how to trade one's carbon allowance in order to maximise the trading potential for influencing the price of—and therefore demand for—carbon.

As with any new policy, the consideration of personal carbon allowances raises questions such as: who should supply the information, how should the information should be presented, who should bear the costs, and what is the most appropriate level to manage such scheme. There is clearly scope for involvement at all levels, from households to communities, local authorities, and ultimately central government. However, it is largely unknown what the required interplay and responsibilities between the relevant bodies should be in order to maximise the impact of PCA, let alone the impact that the new distribution of power resulting from the new policy (e.g., among institutions, citizens, utilities) will have on public acceptability. Many of these unknowns should be better explored, yet, without direct experience there is no empirical evidence available to do so. Hence, here we rely instead on learning from theory and other schemes from which we can draw parallels to some aspect of living with a carbon budget. One field from which we can learn is psychology, and more specifically behavioural economics and mental accounting. From this literature we can get an idea of how individuals might respond to managing their own personal allowance.

Budgeting Psychology

Our assumption is that people would find is easier to understand and manage a personal carbon allowance if it was framed as a budgeting process. Budgeting is already familiar to many individuals through other aspects of their personal administration such as income and expenditure management. Budgeting money requires mentally assigning payments to different accounts as a means of keeping aware and in control of spending (Heath and Soll 1996). It is therefore possible that budgeting carbon may encourage self control over one's carbon emissions in the same way. Further reinforcing the possible advantages of framing PCA as a budgeting process, the mental accounting literature suggests that money is more likely to be spent in the way that reflects how it was received: money received as a gift is more likely to be spent frivolously than money earned (Thaler 1999). Carbon budgeting may therefore avoid the possible association of the personal carbon allowance as windfall that can be frivolously spent. Budgeting also has the potential to help give individuals a sense of ownership over the problem of climate change and may empower them to take part in reducing their emissions. Taking ownership of a problem improves the public acceptability of policies that tackle it (Steg 2008), and public support is crucial for policy success.

Heath and Soll (1996) use psychology to show that individuals mentally label money in order to categorise expenditures. The process of budgeting affects consumption decisions when expenses have been noticed and assigned to a particular account (Heath and Soll 1996; Tversky and Kahneman 1981). Tversky and Kahneman (1981) have demonstrated that once a mental account has been spent to capacity, further money is not likely to be borrowed from another mental account. Allocation of money into different mental accounts therefore reflects the likelihood of spending it on that use only and can help facilitate self control. If mental accounting could be applied to energy use or carbon emissions then the natural cognitive process of budgeting might help control people's energy use and carbon emissions and keep them within their allowance.

Many individuals are well aware of the ongoing flow of money through their lives and it is likely that they would be able to allocate carbon expenditure into mental accounts in the same way that money is allocated between rent, food, bills, entertainment, and savings. Additional support is provided by Seyfang (2007) who argues that consumers are already familiar with complimentary currencies such as air miles or loyalty points and are well prepared for understanding currencies other than money. Many individuals are also familiar with budgeting non-monetary commodities such as calorie intake, alcohol units, and mobile phone time credits. For the case of budgeting with carbon, as supported by Lewis and Capstick's (2009) experimental work on carbon budgeting, it is reasonable to assume that people will allocate expenditure between household-related energy (e.g., appliances, heating, and water), personal travel, and airfares. To achieve this, individuals should know what proportion of their budget is needed for each pool. This requires understanding current consumption for each segment with respect to the total budget allocation.

Carbon is emitted as a consequence of our direct actions such as heating our homes, using appliances, and driving cars. Yet, despite the regularity with which our actions generate emissions, under PCA the carbon transactions (where we surrender credits for these emissions) would be relatively minimal and made up of only three main transaction types: filling up a car with petrol, payment of utility bills (gas and electricity), and purchasing air tickets. It would therefore be quite feasible to channel information about an individual's carbon budget through these relatively few transactions. However, within these transactions, there are behaviours and activities, which occur day by day (or even minute by minute) that will affect our carbon budgets, and ultimately dictate the carbon units we are charged for. Behaviours include whether we choose to drive or walk, if we wash clothes at 30°C or 40°C, if we turn down the thermostat, or if we drive in the most efficient gear. Aside from emissions linked to individuals' own behaviours, there are also emissions derived from contextual factors over which the individual has little direct control. For example, individuals have negligible control over the availability of public transportation, the proximity of local shops, or the energy efficiency of their rented home.

Many of the individual behaviours, such as whether to dry laundry outside or in the machine, are miniscule in the carbon they emit, but when grouped into a single transaction such as a monthly or quarterly electricity bill they become a more noticeable part of the carbon budget. To illustrate, deciding to wash all clothes at 30°C rather than 40°C (based on 2 loads of washing per week, an average A rated machine, and 3,000 carbon credits per year) will save almost 1 kg of CO_2 per month and more than 4% of a monthly carbon budget. Importantly for budgeting, both these daily behaviours (choosing which temperature to use for washing clothes) and the more carbon-intensive decisions (whether to take a flight for your next holiday) need targeting for people to conduct informed carbon-emitting choices.

The discussion given above outlines key aspects of the psychological literature that suggest that framing PCA as carbon budgeting may encourage self control over personal energy consumption in the same way it does with money and thus help individuals to remain within their carbon allowance limits. Hence, the budgeting process has potential to help individuals prioritise their behaviours and may lead to emission reductions. However, the successful management of a PCA is not something that will happen overnight; it relies on a host of awareness raising, information, policies, incentives, schemes, subsidies, and other mechanisms to enable the public to make the choices necessary for living in a carbon-constrained world. Some examples of the kinds of changes to current thinking that may be needed are given below.

Prerequisites for Carbon Budgeting

If individuals are to know their actual carbon footprints and the corresponding carbon income and expenditure from their budgets, then carbon literacy needs to be improved. This has implications for how we design energy and carbon labelling, give feedback on usage, and display the carbon account and transaction information. Information presented to consumers needs to be meaningful, in consistent units, personal to the activity undertaken, and crucially timed in order to affect the behaviour before it happens. For example, people would be likely to make more informed choices if, just before they load the tumble dryer, the information displayer informs them how many carbon units are about to be emitted by an average cycle, alongside the corresponding percentage of their weekly carbon allowance that drying the washing will consume. The challenge remains to identify the relevant activity and the most suitable time to inform, and to supply the most accurate piece of information.

Affordable low carbon alternatives are another prerequisite for budgeting because they give individuals the necessary options for making tradeoffs between competing carbon-emitting activities and thus give options for minimising emissions. Low carbon alternatives also enable individuals to take advantage of the trading component of PCA and sell their unused credits for money. Critical to the potential of PCA, low carbon options need to be affordable for many people and not just the wealthy. Unaffordable alternatives will prevent individuals from being able to budget and would consequently reduce the effectiveness of PCA, as well as public support. Hence, boosting appliances' market transformation, promoting low carbon innovations and technologies, and making them widely available are all essential to reduce the costs of low carbon alternatives. These alternatives could be supported by encouraging social innovations such as car clubs; community engagement such as the Big Green Challenge; and choice architecture by manufacturers in favour of low carbon choices, such as lower default thermostat settings.

Individuals will need both the *motivation* and *opportunity* to make low carbon choices. Schemes and policies are needed for the promotion of low carbon options and innovations as well as for the removal of barriers that obstruct people's ability to make low carbon choices. A variety of mechanisms can be used to help widen individuals' opportunities to make low carbon choices. These include: 1) economic incentives (e.g., for insulating homes, for encouraging public transport use), 2) new legislation (e.g., new efficiency minimum standards, feed-in tariffs for renewable electricity), 3) information campaigns (e.g., more accurate personal carbon footprint calculators, simulation of carbon budgeting), 4) skills training (e.g., for builders on how to build low-emitting homes or install micro-generators), 5) community-led initiatives (e.g., for promoting community-owned wind turbine or car-sharing clubs), and 6) targeted schemes that respond to the specific energy needs of a given community or segment in society (e.g., elderly, fuel poor).

The introduction of a PCA scheme should be accompanied by programs that provide information, support, and advice that explain the practicalities of living with the scheme and also provide guidance on how to reduce households' emissions. Formal advice to individuals as well as institutions needing to adjust to PCA could be provided through mass media and information campaigns at all levels, from government down to local communities. Social support and norm reinforcement could be achieved by informal and organised community organizations and activities (e.g., faith-based organizations, schools, community centres, and grassroots organizations). Those would play a vital role in sharing experiences and changing social norms. Financial support would most likely be needed to give extra support to targeted individuals within communities.

Trading is also an important prerequisite for budgeting. Trading allows flexibility over budget limits such that over-emitters can buy extra credits and under-emitters can sell their extra credits in the personal carbon market. Hence, knowing how to trade is important for those who want to take advantage of the economic benefits gained by reducing emissions. The trading procedures should be kept simple and well communicated, allowing people to learn how to trade as well as correcting errors. A 'pay as you go' option should be offered to those who do not wish to trade (A 'pay as you go' option means that people could sell all their allowances upfront and then pay for the carbon cost at the point of sale). In that instance, further thought should be dedicated to the impact that the design, implementation, and governance of the new personal carbon market will have on the public's perception of the scheme and the likelihood that they will participate in trading.

Some of the changes needed to support better carbon literacy and carbon budget management are relatively simple and low cost while others are more complex and costly. Examples of simple changes include changes to the way we display emissions-related data or schemes that encourage social innovations and networking between individuals and communities. On the other hand, more complex and costly changes are likely to be needed to ensure that the PCA policies are seen as just, fair, and legitimate. These may also require long preparation times. Examples of more complex initiatives include setting acceptable budget limits, designing the trading elements, and providing financial support for a variety of vulnerable groups.

Summary

PCA is a novel radical policy instrument that if carefully and thoughtfully designed has the potential to change behaviours in ways beyond those achievable by price or taxation policies or information schemes alone, while still guaranteeing given emissions reduction from the domestic sector. It is an idea that had gained some momentum, particularly in the UK, but as yet remains untested as a policy instrument and would take a bold and progressive government to propose its use within society. Much research is needed to reduce some of the risks and uncertainties surrounding PCA and to design a clever, implementable, and enforceable PCA policy.

In this chapter we have used the lens of budgeting to gain some ideas about what people might need to know and learn in order to manage their personal carbon budget. We have argued that individuals may already hold the necessary skills to successfully manage their allowance but that they will inevitably need a more holistic and supporting policy environment that is conducive to monitoring and curbing carbon emissions. Viewing PCA as a budgeting process has led to a number of insights into the kinds of changes that would be needed alongside such a policy, many of which could start being initiated by governments, communities, and citizens in order to prepare us all for a carbon-constrained world.

Targeting individual's behaviour should inevitably be accompanied by a systemic change in the societal and economic environments within which individuals make choices. Hence thought should be dedicated also to altering social norms and challenging existing economic beliefs.

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Influencing the Mainstream: How Green Planned Communities Can Shape Social Behaviors and Address Climate Change[1]

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Introduction

It is a paradox of North American society that the rise in environmental awareness since the 1970s has not been fully translated into action (Hostentetler and Hostentetler 2005). People worry about climate change, resource use, and general environmental degradation, yet few change their behavior to reflect their concerns. Why not? How can city planners, builders, architects, and energy policy experts encourage resource-conserving behavior?

Research from two Master Planned Communities; Dockside Green in British Columbia and High Point in West Seattle, Washington, provide some answers to this conundrum. These two “sustainable communities” were designed both to embody green building innovations and to encourage residents to adopt energy-conserving behaviors. We have documented the mechanisms by which this takes place.

Our findings show that a combination of thoughtful building and community design practices *along with* social innovations can actually change the way people run their lives in ways that augment energy savings beyond what technology and building design by themselves might accomplish. The right combination of measures can inspire people to become better environmental stewards. We begin the chapter with an overview of the relationships among the built environment, community characteristics, individual behavior, and environmental outcomes. We then discuss the attempts of two specific neighborhoods to build communities of conservation. We conclude the chapter with a discussion of social elements that enhance green built environments.

Understanding the Relationship between the Built Environment, Community Development, and Everyday Practices

The fact that Americans spend 90% or more of their time indoors (EPA 2009) suggests that buildings, as well as the broader built environment, play an important role in most people’s lives. How can we understand the impact that the built environment has on people and society? Attempts to understand the relationship between human behavior and the built environment have given rise to many schools of thought. Architectural determinism holds that if an environment is designed and built right, desired behaviors will result. Conversely, others see the built environment as merely a stage upon which the human drama unfolds. We think that the built environment is a technology that shapes, organizes, and structures human activity and is itself shaped by human action.[2] For example, a building’s structure, form, and materials influence how

[1] This research was supported by the National Science Foundation (Grant #0820788).
[2] See Gieryn (2002) for an excellent articulation of a sociological and scientific approach to built environments.

we move and where we go, and can ease or impede mobility. Buildings can influence communities, such as where and how people congregate—or not. They can determine how much privacy is available, and they can isolate people from one another. The less visible aspects of buildings—the glue, steel, nails, insulation, and other materials that make up their substance and the systems that keep them warm and cool—can have their own consequences: they can get under our skin, we breathe them in as particles in the air, we ingest them as dust. They shape how we feel in a space, our somatic experience of being.

Perhaps because of the way they shape our lives, built environments have also emerged as focal points for activism, both on the local level (as, for example, a town might rally around the preservation of a beloved landmark) or on a larger scale (as communities organize against, say, an incinerator in their neighborhood or the paving over of green space to make way for big box stores). Buildings are also a contributor to and consequence of social inequality and a site of environmental justice concerns. For example, materials used in buildings are now often understood as being either toxic or clean, as sustainable or finite. And common building practices may either exacerbate or ameliorate inequalities among groups. As with most everything else, the underprivileged often bear the brunt of the worst environmental conditions. Certain communities—often poor and communities of color—are more likely to suffer the consequences of environmental degradation as a result of the types of built environments established there (Agyeman 2005). Improving built environments, then, has important implications for environmental and social justice issues more generally because buildings can shape human rights and contribute positively or negatively to human health and well-being.

A growing number of people are beginning to recognize the importance of buildings and the built environment as social technologies that influence, positively and negatively, people, families, and communities. Although built environments have long been implicated in various facets of environmental and social movements, what is new is the growth of various "green" building professionals, advocates, and policy initiatives at local, national and global levels. As a result of efforts by this collective green building movement, green building innovations are becoming common in mainstream residential buildings, in single-family dwellings, in towns that have been rebuilt following destruction by natural disasters, and in the redevelopment of neighborhoods long blighted by economic downturns. Green professionals are playing a key role in the integration and expanded use of green products, materials, and practices—from solar panels, to LED light bulbs, to ENERGY STAR appliances, people are interacting with their built environments in both new and old ways that explicitly address environmental concerns. Furthermore, green building professionals and advocates are going beyond the old focus of installing simple energy-saving technologies within homes, toward a philosophy of designing communities that enable energy-conserving behavior both on the individual and the community level. The net effect is a groundswell of living green and green building practices.

Finally, there is also a movement toward building green *neighborhoods*, not just green *buildings*. It is in a community where the potential to enhance social capital rests, and we argue that social capital is a critical ingredient to living green. Positive social connections and meaningful social bonds that come from a rich social network can facilitate environmental sustainability at both individual and community levels. "[S]ocial capital allows citizens to resolve collective problems more easily," according to Robert Putnam (2000, pp. 83-84), a professor of public policy at

Harvard University's John F. Kennedy School of Government and author of a seminal treatise on social capital. We have found this to be true for the collective problem of mitigating environmental degradation. On an individual level, residents can more easily recycle, compost, reduce their consumption, and avoid driving or buying a car—if they have a network of like-minded neighbors and friends to help. This aligns with Bill McKibben's argument, in his book *Deep Economy* (2007), that hyper-individualism has harmed planetary health. Our society's emphasis on looking out for Number One is not conducive to caring for the commons (McKibben 2007). Conversely, strong social networks not only encourage us to think beyond our own needs to those of our fellow community members, they also make it easier to do so. By shifting to economies that are more local in scale, McKibben says, we exploit fewer resources, and reduce the environmental toll. But, perhaps even more importantly, this engagement "requires that [we] reorient [our] personal compass a little bit," he writes. This "Requires that [we] shed a little of [our] hyper-individualism and replace it with a certain amount of neighborliness." (McKibben 2007, p. 105). That neighborliness creates the social capital that can be used to encourage energy-conserving behaviors. As the next section demonstrates, sustainable communities provide several lessons for how to best reduce energy consumption and to address climate change.

Lessons from the Field: Designing, Building, and Living in Sustainable Communities

Building sustainable communities represents part of the solution to climate change, as well as to some of the economic and social ills of modern Western society. However, truly sustainable communities must incorporate mechanisms that not only reduce energy consumption but that foster human equity, health and well-being, and strong social networks. And to have more than a negligible impact on society, sustainable communities must become mainstream; that is, they must be widely accessible, affordable, and play a substantive role in creating healthy neighborhoods and communities.

Over the past few years, we have analyzed a variety of green communities across North America. Through ethnographic observations and in-depth interviewing, we investigated how the built environment can help people reduce their carbon footprints not only as individuals but as valued participants in communities. Our goal has been to understand the social mechanisms that contribute to or impede community success in terms of the three E's of sustainability: environmental protection, economic development, and social equity (Fosket and Mamo 2009). In this chapter we focus on two mainstream master-planned sustainable communities, Dockside Green in Victoria, British Columbia and the High Point re-development in West Seattle, Washington. Our research at these two sites demonstrates that while physical attributes matters in developing successful communities, several social mechanisms must be incorporated into a community in order to encourage the kinds of changes in collective behavior that can make a real difference.

Dockside Green

Dockside Green is a 15-acre, master-planned harbor front community on a former brownfield site in Victoria, British Columbia. Dockside Green sprang out of a partnership between Vancity

Credit Union (Canada's largest credit union, internationally well-known for innovative community programs) and Windmill West (a recognized North American leader in green building and community design). Busby, Perkins+ Will were the architects for the project. When complete, Dockside Green will include three distinct neighborhoods, each a mixed-use array of residences, green spaces, offices, retail, and commercial properties. At first glance, Dockside is similar to other trendy downtown new developments cropping up in urban centers like Vancouver, Seattle, Chicago, or New York. Architects Busby, Perkins + Will created a sleek and appealing design, coupling density with ample greenspace and magnificent views.

What you might not guess just by looking is that Dockside is one of the greenest communities in North America. It was the first master-planned development to target LEED Platinum certification. In making such a commitment, the developer has agreed to face financial penalty if the project doesn't meet such goals. Fortunately, Dockside Green has: when it met that goal for its first phase in July 2008, it achieved the highest rating in the world at the Platinum level in the category of new construction. Out of a total 70 points possible—for things like water efficiency, sustainable site, energy and atmosphere, indoor air quality, and innovation in design—Dockside Green achieved 63 points.

Innovative technologies: physical features that reduce energy use. One of Dockside's significant technological innovations is the incorporation of a biomass plant. Currently in development, the renewable energy plant will use waste wood biomass to produce a clean gas for heating and hot water. This will make Dockside Green the first community-level development to be greenhouse gas positive from an energy perspective. Dockside Green utilizes a distributive system for all services: energy, water, waste, and sewage are all dealt with on a community scale. These technologies are crucial to the energy use reductions and climate savings produced at Dockside Green.

Another innovation is found in Dockside's approach to water conservation. Located on the city harborfront with spectacular views of one of the most beautiful waterways in North America, it is appropriate that Dockside emphasizes sustainable water in its design. From the start, the developers were committed to having onsite water treatment. Already committed to reducing water usage, having the onsite sewage plant created additional incentive to keeping water use down—the more water that the community uses, the more expensive it is to treat. To this end, all units include water-efficient fixtures such as dual flush toilets, 1.5 gpm showerheads, water efficient taps, and high-efficiency dishwashers and washing machines. All the water that is used at Dockside is treated on-site. The treated water is then re-used for things like flushing toilets, irrigation, and topping up ponds. In addition to water conservation, Dockside Green's approach to sewage is estimated to lower CO_2 emissions, as heat is recovered from the sewage treatment process to heat buildings.

Other physical innovations at Dockside include green roofs and green wall features that adorn the buildings. The green roofs recycle water by directing overflow into rain cisterns on each resident's balcony, providing water for planters and houseplants. Water in excess of the cistern volume is directed to naturalized creeks and ponds that pepper the site. Instead of being directed there through pipes, however, it is carried via open channels. The purpose of this design is to enable residents, visitors, and others to see the flow of water through the site—thus, it educates the public about how water is used and reused. Once water arrives at the creeks and ponds, natural ecosystems clean and control it.

Energy-efficient buildings are another way Dockside was developed to the LEED platinum standard. Their goal was to build 47% more efficiently than the Model National Energy Code specified, and they have thus far surpassed that goal. The builders understood how orientation impacts efficiency. Their passive design maximizes the power of the sun through strategic insulation, windowpanes, shades, and building location. LED lighting, motion-sensor lighting in some areas, and efficient appliances all are utilized to improve efficiency within units.

Photovoltaics, solar hot water products, native plants and trees, erosion and sedimentation control, shoreline rehabilitation, minimization of light pollution, and environmentally-friendly products and building materials are all among the elements that make Dockside remarkably green. As impressive as these accomplishments are or are gearing up to be, what stood out about this community for us was the way it has integrated social sustainability into its design.

Social mechanisms + building codes: living dockside green. At Dockside Green, the design is oriented toward community-building. Principles of new urbanism maximize the potential for connectivity and neighborliness. The project is built to a human scale; it is close to downtown Victoria and consciously developed to get people walking, meeting each other, and interacting. It is a mixed-use community—with retail, commercial, residential, and recreational spaces co-mingling—in order to enhance vitality and to enable people to live a full life close to home.

One of the favorite gathering spots amongst the first wave of residents at Dockside is a community roof garden on one of the lower-rise buildings. There, residents have found an easy way to get to know each other while exchanging gardening tips and sharing the fruits of their labors. While the commercial units were not yet occupied when we spoke with residents, they were anticipating the imminent arrival of a fair-trade coffee shop and organic bakery. And, in the meantime, the harbor shuttle made runs to a local pub.

Another way that Dockside Green is integrating the social side of sustainability into its design is in its emphasis on building for health. The recognition that built environments can play a critical role in the promotion of public health is evident at Dockside. This is true both in its location and in its buildings. One of the strategies for health was to design each unit to receive 100% fresh air. This is a vast departure from mainstream practice. An air ventilation system pumps clean, fresh air into every dwelling and, as the air is exhausted, heat is recovered to pre-warm new incoming air. Additionally, to ensure indoor air quality, all the paints, sealants, and adhesives are naturally sourced and eco-friendly with low- or no-VOC (volatile organic compounds) content. An independent test of indoor air quality is carried out before any tenants move into the building. Finally, each resident receives a six-month supply of green housekeeping supplies when they move to Dockside.

In addition to the focus on healthy buildings, Dockside Green encourages healthy lifestyles, maximizing local, health-enhancing features of the environment. The development is adjacent to a major bike trail network in Victoria and has seamlessly integrated itself into the existing framework while also making improvements. In order to encourage bike riding, bike lockers were built and a shower will be built so that people who work but don’t live at Dockside will be able to bike to work.

In describing what he was most proud of in the development of Dockside Green, the developer Joe Van Bellegham said, “Unlocking the power of the triple bottom line.” While Dockside is winning awards and breaking records for its green technologies, according to Joe, “You can’t change the system unless you change people’s minds.” And, by truly integrating social along with ecological and economic concerns in every phase of the creation of Dockside, it seems minds have definitely been changed.

Joe continued to elaborate what he sees as the power in the triple bottom line and why he is so proud of what they’ve accomplished at Dockside. It's remarkable that Dockside Green has managed to surpass expectations in terms of its environmental accomplishments as well as to do it affordably. According to Joe, they have managed to create such a watershed project at reasonable cost because a value shift has occurred. Trades people, architects, engineers, developers, financers, and community members—all of the various constituencies whose collaborative efforts are responsible for building a community—have developed a deep commitment to the project. Simultaneously, each person's commitment has helped the entire community and its residents become more deeply committed to sustainability. A sustainable neighborhood allows commitment to spread from the few to the many.

Dockside has also harnessed the power of people by designing a community that makes it easy and convenient to live lightly on the land. Some of the technological innovations built-in to the project can only be successful if implemented in collaboration with residents; these in turn shape residential behaviors in ways that lead them to deeper environmental commitments and practices. For example, as Melinda Jolley, a resident, explained: “There's a carbon footprint monitor where you can see how much you are using by the day, week, or month and can compare. Usually, it's kind of hard to see the difference it makes to turn off lights or to see the impact of having a bath versus a shower. It makes it easier to change your behavior with this information. I still love my baths, but I do take more showers now, knowing that they do use substantially less water.” Melinda refers here to an individualized meter installed in every unit that indicates how much energy a household consumes. Her observation, and behavioral change, has been verified in social science research: studies indicate that people use substantially less energy and/or water when they are able to monitor their own use and see the actual benefits of efforts to conserve (see Ehrhardt-Martinez et al. 2010). The achievement is not only to inspire and motivate people to want to reduce energy, but also, in the case of Dockside, the achievement has been to make it so easy that people will do it.

Melinda Jolley was among the first wave of residents to move into Dockside Green. In making comparisons to her past place of residence, Jolley remarked on various features including the energy monitors that make it easier to live green. Jolley and other residents expressed some surprise at how these mechanisms not only enable them to conserve resources and money, but continually press them to do more by being aware of and having a specific metric through which they can know the degree of their behavior change and energy change. For example, to make things even easier, information on your personal meter can be accessed over the Internet: you can compare your use with what you used yesterday, last week, or last year. You can also use the

Internet to remotely control heat, air conditioning, and the exterior blinds in your home. So, if you happen to be on vacation and can't remember if you turned off the heat, you can check up on your energy consumption and change settings inside your home from afar. Or, if a day turns unexpectedly sunny while you are at work, you can lift your blinds over the Internet, thus using the solar energy to warm your home before you arrive.

Like other residents, Melinda found that her transportation footprint was also greatly reduced once she moved to Dockside Green. While she still owns her SUV, she decided to let her insurance lapse and to stop driving altogether. Because of Dockside's central location with access to services and transportation as well as its car share program, Melinda felt it was easier to live car-free. While she moved from another central location, without the car share program that exists at Dockside not using her car just wasn't feasible before. Again, we see the meshing of values that green communities inspire: with the design features of a community (in this case, location and a car share program) enabling living in a greener way. The social mechanisms, like education about and access to a car share program, are essential to incorporate into the building of a sustainable community.

The High Point Re-Development

High Point is 120-acre redevelopment of a former Seattle Housing Authority (SHA) community situated in West Seattle, about ten minutes by car or express bus to downtown. It will accommodate over 4,000 residents in approximately 1,600 diverse housing types—single family attached, detached, apartments, and townhouses—each sharing a distinct style and most including front porches and a neighborly atmosphere. There is a seniors' residence and an assisted living home on-site. Approximately 50% are designed as rental units and the other half for ownership including several Habitat for Humanity homes. The neighborhood includes a public library and a community health center both situated on a main avenue at one edge of the redevelopment. A central community center is near completion and a grocery store and other retail stores are planned for inclusion.

Initially High Point was designed to house defense workers during World War II. The neighborhood mirrored many lower-income urban areas in the U.S. over the Post WWII period, populated largely by low income African Americans and Whites. High Point has a history of vibrant cultural diversity and a legacy of significant economic hardship and higher crime rates then other neighborhoods. High Point bore the brunt of environmental degradation and poor social conditions that took root in most Post WWII public housing projects. The Seattle Housing Authority's re-development of High Point is a demonstration project in which all aspects of the community—from land planning to individual buildings to social programs—were designed and built with climate change at the forefront. As such, the impetus for the redevelopment was partially rooted in concerns regarding environmental justice and partially rooted in concerns about social justice.

Physical site and sustainable building innovations. At High Point, SHA reached a new standard in green building innovations in public-supported housing by going well beyond Seattle's code requirements. All homes meet a minimum of Built Green 3-Star standards, with many achieving 4-Star level and ENERGY STAR® certification. It incorporates a natural drainage system as well as a host of energy and water conservation features. The community also includes thirty-five "Breathe Easy" homes—homes especially designed to minimize the environmental factors that trigger asthma and other respiratory diseases. Similar to the buildings at Dockside, these dwellings utilize building materials to maximize health. These features have attracted national and international attention, and won many awards for sustainable development.

There are a variety of green spaces throughout the High Point development: grassy lawns in front of and between houses that are larger and more communal than in most neighborhoods; multiple well-appointed playgrounds; a protected greenbelt that hugs the entire length of one side; a pond and wetland populated by birds; and intertwined in all of this are multiple community gardens or "pea-patches" and pocket parks. The native landscaping includes big old trees and newly planted ones lining the wide streets.

A significant achievement of the High Point neighborhood is the incorporation of a natural drainage system. Because of its location in a high rain region and its proximity to a significant local creek, Seattle Public Utilities worked with SHA to implement a large-scale natural drainage system into the design and building of the neighborhood. The system treats about 10% of the watershed feeding Longfellow Creek and "mimics" nature by using features such as swales to capture and naturally filter storm water and open, landscaped ponds or small wetland ponds to hold an overflow of storm water. The result is obvious as one walks through the High Point neighborhood on porous sidewalks separated by many feet of natural drainage landscaping.

Social mechanisms: social housing + green community. The Seattle Housing Authority's High Point re-development Senior Project Manager emphasized that "physically, High Point has gotten it right." However, he emphasized that the physical features and innovative technologies alone are insufficient for engendering the kinds of environmental saving needed to address current climate change. It's crucial that people understand and participate in the project at well. At High Point, there were two ways that the social elements were successfully addressed: first, by including multiple and diverse stakeholders in the design and planning process and, second, by providing some crucial formal and informal opportunities for education and buy-in.

In our interviews with over thirty residents, we found that from the design stages onward, a diversity of stakeholders—from residents to public officials to business owners—were actively involved in the planning process of High Point. Such inclusive "citizenship," we argue, not only provides the kind of "buy-in" needed for success, but it also produces new ideas. The original idea for the Breathe Easy homes was a resident's suggestion and later was expanded by researchers at the University of Washington to include a major public health study. In a similar vein, officials at Seattle Public Utilities conceived the natural drainage system and contributed funding for its development. Conversely, when stakeholders are not included, delays and additional costs can ensue. For example, at High Point, the fire and transportation departments were not included in the initial stages of the planning and this lack of support is believed to have contributed to costly delays in the project.

Secondly, High Point has built in multiple social mechanisms for securing buy-in from residents. Many formal and informal events have taken place since High Point residents began moving in, which have created social connections and enhanced a sense of shared purpose and buy-in of the green features. In 2006, for instance, when the first wave of residents moved into High Point, a large scale Green Expo was held on-site. This was an important first-step in developing a sense of belonging to a collective project. In addition, every resident at move-in is given materials that document how their everyday practices result in specific environmental outcomes and suggest specific, behavior-based strategies for increasing energy savings and tips on using affordable, green materials and products. On an ongoing basis, Home Ownership Associations, Neighborhood Councils, Green Committees, and other resident groups meet monthly to discuss everyday needs in the community as well as the green features of the neighborhood. Although not yet complete, a community center will hold an environmental education center among other services.

This initial buy-in has been effective and we found that most residents are engaged in conservation behaviors and practices. Nevertheless, many residents report that they do not know what more they can do, and some are unsure about what is already being done in their own homes to effectively reduce energy use and costs. Our research indicates that additional community education and mobilization efforts are needed from both the ground up and top-down. In support of these conclusions, our interviews with residents revealed that many people wanted to decrease their energy use and increase their sense of community, but they were not sure how. They wanted more information from the community and they were frustrated by challenges they faced in getting the information or buy-in that they needed. For example, residents who wanted to dry clothes outside were thwarted by ordinances against clothes-lines.

The library, public parks, and community spaces have each been important sites for gathering and creating opportunities for engagement. The most successful social building is the library. Offering education, resources, and meeting rooms, the library is well used by residents and enhances educational opportunities and social capital. The community center, with its expansive open space, playground, basketball courts, and pea-patch shared garden, has been slow to come to High Point. Once open in the fall of 2009, the center will house multiple social services and provide another needed place for social connection and education that leads to the buy-in and shared intent we think most enhances energy savings.

Energy savings at high point. Most researchers who have conducted research at High Point, (including us) have documented positive behaviors and significant energy savings at the site. A 2007 study conducted by Enterprise Community Partners and the Seattle Housing Authority compared energy savings at High Point with New Holly, a similar redevelopment built to baseline conservation guidelines, and found that High Point residents saved significantly more water, electricity, and natural gas. Residents at New Holly were found to use about 6% more water than those at High Point, 11% more electricity for lighting, 37% more natural gas for water and space heating, and 15% more electricity in all-electric units. This significant level of energy savings led to cost savings: at High Point, actual utility costs were 56% below the Seattle average, for a total savings of $500,000.

Importantly, however, even these impressive resource savings could be enhanced by addressing the social factors that shape energy consumption practices. In an interview with Tom Phillips, the Senior SHA High Point Project Director (also a resident at High Point), he reflected on ways that social issues could be built-in to maximize energy reductions and economic savings: “I got an A on the physical part, but now I need to focus on the social part." Some of the needed initiatives are at the level of policy. For instance, a major concern of Phillips was that city-level policies did not allow cost savings to be realized by the residents; instead it is the city that currently reaps the savings benefit. Since residents don't reap the rewards, they have less incentive to conserve. In contrast, water use fees are billed directly to the residents and behavioral changes are especially evident in water use practices. These observations suggest that economic savings and incentives play an important role in helping residents to reduce their resource use and address climate change. Moreover, a Seattle Housing Authority report on High Point also noted that residents who were surveyed overwhelmingly said that they'd be willing to take extra steps to conserve energy and that cost savings was the biggest incentive for doing so.

Dr. James Kreiger, one of two Principle Investigators studying the health effects of the Breathe Easy Homes, echoes the importance of putting greater emphasis on social aspects of High Point. Dr. Krieger, speaking about High Point, said, "The educational and behavioral infrastructure needs to be in place for positive health effects to be realized. You just can't build it; you need to do the ongoing work of finding people who will benefit and making sure they have the education and supports needed to do so."

In the same vein, Tom Phillips, the Senior Project Manager, stated, "High Point is in many ways a social experiment." And our research indicates that it offers many lessons for how to get it right. At the time of our interviews, most of the residents knew about the community as being a green or sustainable community, but were unaware of what makes it so or what they can do to contribute toward these ends. Unlike Dockside, High Point had significantly more work to do to establish an integrated community with a shared purpose around sustainable living. Despite, these limitations, there continues to be a great opportunity for community-based pride emerging from shared experience of living in a sustainable community and from the preliminary efforts by the community itself. As discussed in this chapter, a lot has been done to move toward this goal. In the chapter conclusions, we explore the lessons that these two Master Planned Communities offer policy makers, architects, developers, and designers.

Conclusion: Social Elements that Enhance Green Built Environments

From an individual consumer looking for a home to a large-scale municipality passing a building ordinance, green building practices are fast becoming the norm. Dockside Green, High Point, and other master-planned green building projects that emphasize community design teach us that living green is increasingly part of the mainstream and suggest that the numbers of similar sustainable communities will continue to rise. While it remains true that throughout North America individual home ownership has been emphasized as an essential indication of successful adulthood with high value placed on things like independence, private property, consumerism, and the nuclear family, this is perhaps being mitigated today by ever-increasing demands for means of living sustainability in meaningful communities. Three important lessons readily emerge from studies of these Master Planned Communities.

- Collaboration and Citizenship: Careful planning and capital investments in conservation technology by the developer; day-to-day actions by the residents; and wise public policies that reward the parties for their respective contributions are all important to reap the maximum benefits from green developments. Perhaps the most significant lesson from High Point is that the greatest benefits to the environment can be achieved when landlords, tenants, and policy makers act in concert. To date, the green building movement—and utility incentive programs—has focused primarily on capital investments in conservation technology, with less attention to the potential for community mobilization and education to generate an additional increment of savings.

- Motivation and Pragmatism: One of the things that these communities have figured out is that you need *people* to make a green development work. Green development requires that people commit to change and to living differently; it also requires that people have the necessary tools that can enable them to follow through on their commitment. Educational programs and materials, community events, and social forums are each and all key to inspiring motivation and getting residents on board with the green goals of the community. But it's then equally important to ensure that the community-level mechanisms are in place that allow for continuing engagement. Things like the energy monitors at Dockside Green, the car sharing program, and the community gardens at High Point—all of these help make living green possible within the constraints of everyday life.

- Connectivity: These developments highlight the importance of continued community connections and, more importantly, building in mechanisms for doing so. Part of the successes hinged on the developments' locations near public transportation, and, in the case of Dockside, in a mixed-use setting. While High Point has plans to incorporate retail, it is widely regarded by residents as something that they wish were there already and an important lesson for future developments is to build-in stores, cafes, and other conveniences early on. The High Point community center and library and the ample green space, gardens, and parks at both locations are other examples of built-in mechanisms for enhancing community connections. When people have physical spaces for gathering, they are more likely to do so and social capital is strengthened. This increased social capital, in turn, enables people to live in more sustainable ways—because they have people to share in the work of sustainability and because there is the positive reinforcement and mutual support for doing so. Shared social spaces and services must be incorporated from the beginning and built-in first. Policies must exist to create this capacity through incentives, cost sharing, and benefit sharing.

In all, while cynics may believe that North Americans are too individualistic to fully resonate with many of the green communities that we have described here, people across the United States and Canada are striving to live more sustainable lives, and the green building movement is now poised to change our ways of living. Mainstream residential greening, therefore, can and does offer solutions to the pressing environmental issues of our time. As these examples demonstrate, the glass is half full: we need to continue to seek ways that conserve energy and resources and live lightly on the land and, when it becomes necessary to build and rebuild, we need to turn to innovative sustainable design practices that build communities and empower people.

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Making Energy Conservation the Norm

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Introduction

A recurring theme in recent discussions of how best to mitigate climate change is the need for individual action. Technology alone will not be sufficient to avert climate change, and behavioral approaches offer a promising source of additional mitigation (Allcott & Mullainathan 2010; Charles 2009; see Gardner & Stern 2009, for a "short list of effective actions"). Indeed, efficient technology is useless if not adopted, if used incorrectly, or if overused. But developing effective programs, technologies, and campaigns that encourage more efficient use—and less use—of energy has proven difficult. The nation has made considerable investments into technologies designed to improve efficiency, but precious little has been invested in understanding the behavioral side of energy use.

This chapter reviews the existing research on the role of feedback in energy efficiency programs. Contrary to current claims, the evidence suggests that simple feedback is not sufficient to promote reductions in energy use. The available data clearly show that feedback is *only* effective at reducing energy use when the individual is motivated to use less. This motivation can come from existing personal factors such as environmental concern, or it can come from secondary information provided in combination with the feedback. For example, coupling feedback with information about the social norm for use has been shown to effectively reduce consumption. The chapter concludes that feedback is a promising strategy, but that more research is needed to clarify the effect. A substantial investment into behavioral studies of energy use and energy efficiency is likely to provide greater understanding, which will translate into more effective conservation strategies.

A Behavioral Perspective

In the absence of input from social and behavioral sciences, energy policies, programs, and technologies have been developed using an intuitive approach. Unfortunately, these intuitive approaches have been dramatically less effective than expected. In this chapter, I begin with a brief overview of research on strategies to educate individuals on how to conserve, and then examine feedback as a promising alternative. The chapter is grounded in the peer-reviewed behavioral science research, but does not provide an exhaustive review. For more thorough treatments, see Katzev and Johnson (1987) or Stern and Aronson (1984).

Throughout this chapter, I use the terms *energy conservation* and *energy efficiency* to mean different things. Conservation implies absolute reductions in energy use. These can result from curtailment behaviors, like turning off lights or using fans instead of air conditioning; but also from one-time actions like replacing an inefficient furnace with a more efficient one. *Efficiency* can result in reduced energy use, but it does not necessarily do so. Compact fluorescent lights (CFLs) produce more lumens per watt, but some consumers who install CFLs become less motivated to turn lights off (WWF 2008). As Herring and Roy (2007) describe it:

> …when we replace a 75W incandescent bulb with an 18W compact fluorescent bulb (CFL)—a reduction in wattage power of about 75%—we could expect over time a 75% energy saving. However, this seldom happens. Many consumers, realising that the light now costs less to run, are less concerned about switching it off, indeed they may leave it on all night, for example for increased safety or security.

Efficiency can also refer to shifting use from a peak period to an off-peak period, something that improves the efficiency of capital, but that does not reduce energy use.

Information and Education

By far the most widely used strategy for encouraging energy conservation is to provide information. Information abounds on how to save energy across all sectors of the economy. But in each of these sectors, the underlying assumption is the same—people are not taking action because they do not know what to do, or how to do it (Schultz 2002). From this assumption, the solution is simple: people need to be educated.

Unfortunately, research on information campaigns has consistently demonstrated their ineffectiveness at promoting conservation (Abrahamse et al. 2005; Hayes & Cone 1977; Luyben 1982). While some studies do show that information can have a small impact on behavior, most show none (McMakin, Malone, & Lundgren 2002). In a recent review of the various strategies used to promote energy conservation, Abrahamse et al. (2005) conclude that, "Information tends to result in higher knowledge levels, but not necessarily in behavioral changes or energy savings." This conclusion is echoed across a number of similar reviews (cf., Katzev & Johnson 1987).

Surprisingly at first blush, given our previous pessimistic conclusions about education campaigns, research has shown that home energy audits—a variation on the information theme—*do* result in reduced home energy use (Gonzales, Aronson, & Costanzo 1988; McMakin, Malone, & Lundgren 2002; Winett, Love, & Kidd 1982). Of course, audits are far more personalized than the typical information campaign, as they are usually conducted in person, and provide dwelling-specific information.

Nonetheless, certain subtleties belie the notion that audits are necessarily an exception to the rule that information is ineffective. The fact that audits are conducted by request shows at least a modicum of motivation on the part of these homeowners. That only a very small percentage of residents request audits, even when they are free, underlines the point about motivation (Hirst et al. 1981). And a number of studies have shown that pre-existing motivation to use less is part of what drives changes in behavior among those who request audits (Katzev & Johnson 1987).

The motivation of people who request audits can spring from a variety of sources—financial savings, environmental protection, social responsibility, and so on—but the distinguishing feature is that the individual is already interested in reducing their energy consumption. For example, Staats et al. (1996) reported a series of analyses from a government campaign aimed at communicating the importance of global warming as a social issue, and educating people about the things that they could do to help prevent climate change. The results showed that following the campaign, residents were more knowledgeable about the behaviors that contributed to global warming, but in aggregate, they were not more likely to take action. However, more refined analyses showed that there was change in reported willingness to engage in conservation behaviors among a small segment of the population. For individuals who were already motivated to take action, and who were making efforts to conserve before the campaign, the information helped to accelerate their willingness to conserve. This is an important finding that will be revisited later in this chapter.

Feedback

As argued above, information by itself is not sufficient to promote broad-based changes in behavior. But for the already-motivated, it can be enabling. For the rest of the population, a variety of approaches have been developed and tested that can motivate behavioral changes. These include commitments, financial incentives, goal setting, workshops, modeling, and feedback. Still, reviews of these approaches have shown mixed results (Abrahamse et al. 2005). But one approach in particular—feedback—has shown promise, not so much for providing the direct motivation, but in some cases for boosting existing motivation, and for guiding the response.

Feedback is fundamental for any system to function effectively. Imagine trying to remain properly nourished and hydrated without hunger and thirst. Imagine trying to reduce your grocery bill if individual items lacked marked prices.[1] In the behavioral realm, research is clear in showing that individuals require feedback in order to achieve goals (Bilodeau & Bilodeau 1961; Erez 1977).

A major recent development is systems for monitoring residential electricity use in—or close to—real time (EPA 2008). Such smart metering, or advanced metering infrastructure systems (AMI), is being tested around the world. In the U.S., a number of federal and state laws reference the ability of AMI systems to boost efficiency and conservation. Private industry is developing products that work with advanced metering technologies for home use. Two examples are Microsoft's "Hohm" (home + ohm) product (www.microsofthohm.com) and Google's "Powermeter" service (www.google.org/powermeter). Google claims that savings of 5–15% are likely to result from these services. A recent article in *Science* more conservatively estimated savings of 5–10% (Charles 2009).

Yet, some studies suggest that even this sort of feedback can be ineffective, depending on the form which it takes. In one study, households that received feedback information in units of kWh *did not* significantly reduce their consumption (Bittle, Valesano, & Thaler 1979-1980). In this study, households received feedback on a daily basis. Other studies have shown similar effects, whereby providing residents with regular feedback about their energy use failed to reduce energy consumption (Katzev, Cooper, & Fisher 1980; see also Kohlenberg, Phillips, & Proctor 1976; Seaver & Patterson 1976).

[1] This metaphor was originally described by Stern & Aronson (1984).

While these early studies showed that feedback was not effective at promoting conservation, subsequent reviews have been more optimistic. Darby (2006) concluded that "The norm is for savings from *direct feedback* (immediate, from the meter or an associated display monitor) to range from 5–15%." And similarly, a Smart Meter Working Group (2001) in the U.K. concluded that, "Although ultimately dependent on consumer reactions, our analysis, based on limited UK information, has shown that reductions in domestic consumption of 5–10 percent are possible." (See also "Motivating Energy Efficiency With Metering Technology" [EPA 2008].)

Given the current enthusiasm about the role of feedback in promoting residential conservation, my conclusion that feedback will not produce aggregated reductions in energy consumption might seem surprising. But in fact, feedback is merely a form of information. Although it can help residents connect their behavior to the outcome, by itself, feedback is not motivational. If one's budget is stretched, it can guide one toward financial savings, but if not, the consumer may have far more personally compelling ways to maximize utility. To quote a 1987 literature review on the subject, "[Feedback] acts as a spur to individuals already primed to conserve energy" (Katzev & Johnson 1987, p. 66).

One of the studies most widely cited as showing the benefits of feedback can just as easily be interpreted as demonstrating the benefits of motivation (Seligman & Darley 1977). In this study, 40 physically identical homes were assigned randomly to a feedback or to a control group. During the month-long study period, the feedback households received daily information about their consumption on a digital display mounted on the kitchen window. Results showed that households receiving feedback used 10.5% less electricity than those in the control group. However, the authors suggest that by agreeing to participate in the study, the residents in effect made a personal commitment to conserve energy. This personal commitment served as a source of motivation, and the feedback helped translate this commitment into action. Subsequent studies have shown that committing to the outcome (i.e., using less energy) can make the feedback motivational (Becker 1978; Katzev 1986).

Thus, while feedback alone is unlikely to substantially change behavior, it can be effective when coupled with motivation. And committing to reducing consumption can be motivating.

A critical element in a framework for feedback is a referent—that is, an additional piece of information that serves to make the feedback meaningful (Kluger & DeNisi 1996). While a number of referents have been studied in the feedback context, our focus here is on two approaches: monetary and social.

Monetary Feedback

In the monetary feedback approach, the consumer receives information on the cost of consumption. In one study, households provided with an indoor monitor displaying electricity consumption in cents per hour reduced consumption by 12% over 11 months, as compared with a control group (McClelland & Cook 1979).

Another study provided 325 households with feedback about the costs of their natural gas consumption over three years. Households in the study were asked to commit to reducing consumption by 10%, and those who agreed were randomly assigned to one of several experimental conditions: either continuous electronic feedback about the costs of their energy consumption, or an information-only control group. Households in the electronic indicator group received an automated device that provided updated information about the amount and cost of electricity and gas consumption in the home. Households receiving automated feedback reduced consumption by 12%, compared with a 4% reduction for households that received only information about ways to reduce their consumption, but who also made the commitment to reduce consumption (Van Houwelingen and Van Raaij 1989). For other examples, see Bittle et al. (1979), Farhar and Fitzpatrick (1989), Mountain (2006), and Hutton et al. (1986).

While the evidence for using monetary referents for feedback is encouraging, there are several complicating factors. First, the level of motivation depends on potential financial savings, and if this is low, as is often the case in the context of regulated utilities, the energy savings will likely be small.

The same phenomenon plays out in a dynamic pricing framework, where the cost of energy fluctuates throughout the day. In one study, when consumers received feedback on their peak vs. off-peak usage, they simply shifted their consumption toward off-peak hours, without reducing overall consumption (Heberlein and Warriner 1983). Greater price differences between peak and off-peak rates resulted in greater shifts toward off-peak hours (see also Winkler & Winnett 1982).

In short, when presented with energy feedback and a monetary referent, individuals attempt to maximize their own self-interest, rather than in the interest of the nation or the environment. And that means that many might actually increase their energy consumption if the numbers suggest that doing so might maximize their personal utility. In fact, Van Houwelingen found that although high energy consumers responded to monetary feedback by reducing their consumption, low energy users actually increased their consumption. Bittle et al. (1979-1980) reported a similar effect.

As a further illustration of this point, San Diego Gas and Electric (SDG&E) distributed a brochure to its customers that linked specific actions to costs (SDG&E 2009). The brochure provides information about the 4-tiered pricing structure, and then a list of costs associated with various technologies. For example:

- A coffee pot costs 3 cents per pot;
- Track lighting with three 100-watt lights costs 5 cents per hour;
- A computer and monitor cost 3 cents per hour; and
- A 3-ton central air conditioner (SEER 15) costs 36 cents per hour; and so on.[2]

When presented with this information, many of the utility’s rate-payers saw these cost estimates as “cheap.” Many residents had thought that activities like running a computer or using air-conditioning were much more costly than these numbers indicated. One resident stated, “If that’s what it cost to use my air conditioning, I’ll do it more often.”

[2] These costs are for the “low use” rate at 15 cents for kWh. The brochure also lists a “high use” rate of 33 cents per kWh.

In addition to the potential for financial framing to undermine efforts to promote conservation, there is also evidence that even when it boosts conservation, it reduces the durability of the behavior change compared with other referents. While few studies have tested the long-term impact of monetary feedback, existing data suggest that once the monetary feedback is removed, consumption returns to the prior rate (Van Houwelingen & Van Raaij 1989). The lesson: once we frame conservation as a transaction, subsequent decisions about it are evaluated in that light. Such framing has important negative implications for the durability and the generalizability of conservation efforts. While framing conservation as a transaction can produce reductions in use under certain conditions, its side effects warrant caution.

Normative Feedback

A second referent that has been studied in the context of residential energy consumption is social norms. This approach involves providing households with consumption data from others for comparison—friends, neighbors, or a community—and it can be presented in isolation or in combination with personal feedback. As Abrahamse et al. (2005) state:

> By giving comparative feedback, a feeling of competition, social comparison, or social pressure may be evoked, which may be especially effective when important or relevant others are used as a reference group. (p. 279)

In a recent study, my research team provided households with feedback on conservation-related behaviors within their community (Nolan et al. 2008). We selected behaviors that could make large reductions in overall household consumption: using fans instead of air conditioning, turning off air conditioning at night, turning off lights, and taking shorter showers. Our prior survey data had shown that a majority of residents engaged in these actions, and our normative feedback involved highlighting this fact. Over a period of four weeks, we presented residents with the normative information about different behaviors. Results showed that community members who received normative feedback used 10% less electricity in the subsequent month compared to an information-only randomized control group of households who received tips on reducing electricity consumption. Even after eight weeks, households that received normative information were still using 7% less electricity than the control group (see also Siero et al. 1996).

However, as with monetary feedback, there is evidence that under normative feedback, low energy users might increase their usage instead of conserving more (Brandon & Lewis 1999). In this study, residents received computerized feedback about their personal consumption, along with normative feedback on neighbors' consumption. Overall, feedback resulted in reduced consumption, but much more so among high than low consumers. Low consuming households actually showed a tendency to *increase* in their energy use.

My research team has also shown the potential for normative feedback to boomerang (Schultz et al. 2007). In this study, we provided residents with weekly feedback about their level of electricity consumption, coupled with normative information about consumption by similar households in their neighborhood. Primed by prior results for the possibility of boomerang, we separately analyzed high and low consumers. Results showed that while high users reduced electricity consumption, lower users actually consumed *more.*

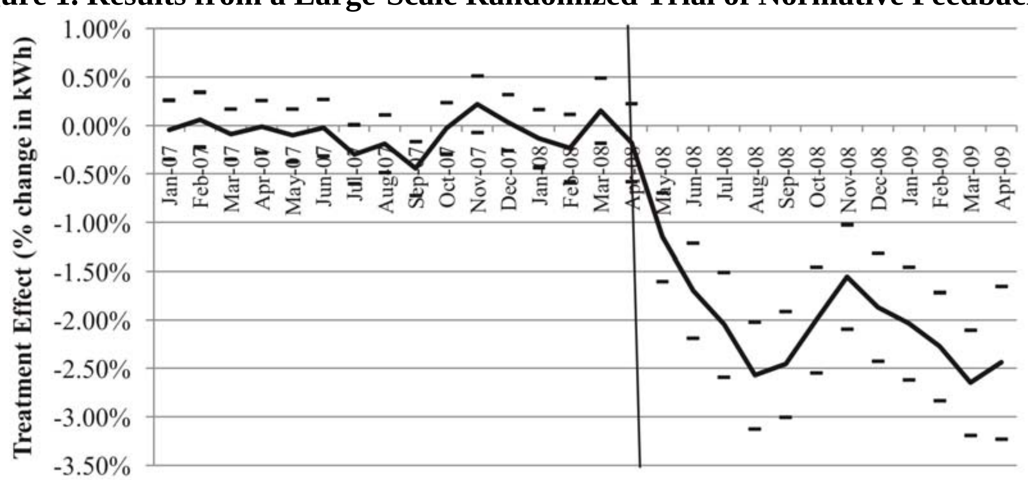
In a follow-up set of experiments, we demonstrated an effective solution to the boomerang problem. Households exceeding the consumption norm received a sad face on their evaluation sheet, while those that consumed less than the norm got a happy face. Low users who received the happy face maintained their low consumption, although they did not reduce it further, while households exceeding the norms who received the sad face accelerated their conservation.

Currently, several large-scale trials of normative feedback are underway. In one study, begun in 2008 by OPOWER and the Sacramento Municipal Utility District, 25,000 ratepayers were randomized to receive a monthly report comparing their electricity consumption to the average consumption of similar homes in their community; another 10,000 households received such reports quarterly, and 50,000 households served as a control group (Allcott 2009). In an effort to eliminate the boomerang effect, households with above average consumption received a message conveying social disapproval, whereas those with below average consumption received personal recognition, with a happy face, and “good” or “great,” depending on how far below the average they fell.

After six months, households receiving the energy reports collectively consumed 2.5% less electricity than control households. Households receiving monthly reports conserved more than those receiving quarterly reports, and high consuming households achieved greater reductions in usage than low consuming households. The conservation rates were particularly high—8%—for households that set personal conservation goals as part of a Commitment Program.

Figure 1, below, summarizes analyses by Ayres, Raseman, and Shih (2009) comparing treatment households to control households. The results are shown over a 1-year period, with statistical controls for characteristics of the dwelling, household demographics, and temperature. The program is being expanded, and a number of programs across the country are currently implementing the OPOWER home energy reports.

Figure 1. Results from a Large-Scale Randomized Trial of Normative Feedback*



* Graph shows the average treatment effect in energy consumption for the full experimental group (*N*=35,000), compared to a randomized control (*N*=50,000). Error bars show 95% confidence intervals for each month. The vertical line indicates the first mailing. The line shows results from OLS regression with statistical controls. Reprinted by permission.

Discussion

It has become clear that technical fixes alone cannot mitigate carbon emissions enough to avert climate change. Changes in human behavior are needed both to complement and to supplement efficiency technologies.

But when it comes to changing human behavior, educating people about how they can reduce their consumption has proven ineffective, largely because education alone is not motivational. This has become so well-recognized today among behavioral scientists that currently, most behavioral studies aimed at encouraging conservation use an information-only group as a control—that is, as the baseline against which to evaluate truly effective approaches.

Feedback offers a promising alternative to information-based messages by enabling people to see the direct consequences of their actions. New technologies, such as Smart Meters, will soon provide householders with access to real-time consumption data. The same technologies can enable dynamic pricing, where energy prices change as demand fluctuates, in a way that allows consumers to respond. But again, research suggests that without motivation, even the new, more sophisticated feedback technologies will be relatively ineffective at inducing reduced energy use.

Prior studies have tested a number of motivational sources that can be coupled with feedback. These include emphasizing the financial costs associated with consumption, comparing a household's consumption to the community norm, and getting individuals to commit to reduction targets. However, these strategies must be designed to guard against the boomerang effect, in which those consumers who find they use less energy than the norm may actually increase their consumption.

Unfortunately, far fewer behavioral studies of energy conservation are being conducted than is warranted by the urgency of mitigating climate change. This was not true in the wake of the energy crises of the 1970s, when many of the studies that provide the foundation for this chapter were conducted (cf., Stern & Aronson 1984). In fact, much of this chapter could have been written 20 years ago. Currently, government and industry are investing heavily in technological innovation, engineering, and in alternative sources of energy, yet they are largely neglecting the social and behavioral sciences. The result: large-scale programs, policies, and conservation efforts are based on intuitive (or flawed) theories of human behavior.

Fortunately, events like the Behavior, Energy, and Climate Change Conference (BECC) are bringing behavioral researchers together with policy makers and industry leaders. Our efforts to understand and ultimately influence behavior to reduce energy use would be well-served to draw on the work of behavioral scientists. Whether our emphasis is on promoting changes in recurring behavior—decisions to turn off lights, to forego unnecessary car trips, and the like—or on one-time or infrequent behaviors such as investments in efficient technologies, retrofitting homes, or any of the myriad of other behaviors that are related to our use of energy, behavioral science can lead the way.

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Adding a Behavioral Dimension to Utility Policies that Promote Residential Efficiency[1]

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Introduction

Utilities are in a powerful position to help consumers reduce their consumption. For example, through billing histories they have access to many years' consumption data that can reveal trends and trouble spots that are invisible to customers. They can compare consumption across cohorts. They can support smart meters and offer time-of-use rates that make consumers aware of the real cost of energy. They can also finance household energy improvements.

Residential customers need the help that utilities could provide. Numerous non-technical obstacles discourage the former from undertaking home efficiency improvements. The most important barriers include high up-front costs, misplaced incentives, and incomplete and asymmetric information (Brown et al. 2008). The challenge is to motivate utilities to turn their potential into programs that reduce household energy consumption.

In this chapter, we present case studies of three policies that could motivate and enable utilities to promote residential energy efficiency. These policies are based on understanding how utilities interface with their residential customers and how residential customers view investments in energy efficiency.

The work presented here builds on a review of the behavioral research literature, and the results of "Buildings Workshop on Behavioral Research and Energy Use" that was held in Washington, D.C. in February 2008. Following that workshop, a team of researchers evaluated alternative policy options available to the federal government, an effort that resulted in a report, *Making Homes Part of the Climate Solution* (Brown 2009). We applied the following seven criteria to evaluate and narrow the set of candidate policy options.

1) **Appropriateness of the federal role**. Many of the more effective policy options and measures in this area require state or local action, as the jurisdictional responsibilities reside most strongly at this level of government. The federal government is in a good position to encourage state and local action. At the same time, however, federal agencies must be careful not to intrude on local authority or initiative.
2) **Broad applicability**. Since the number of proposed policy options and measures to be analyzed is small, but the desired impact is large, those policy options selected for analysis should be as broadly applicable as possible.
3) **Significant potential benefits**. Those options that produce large benefits quickly should be favored over those producing fewer benefits later.

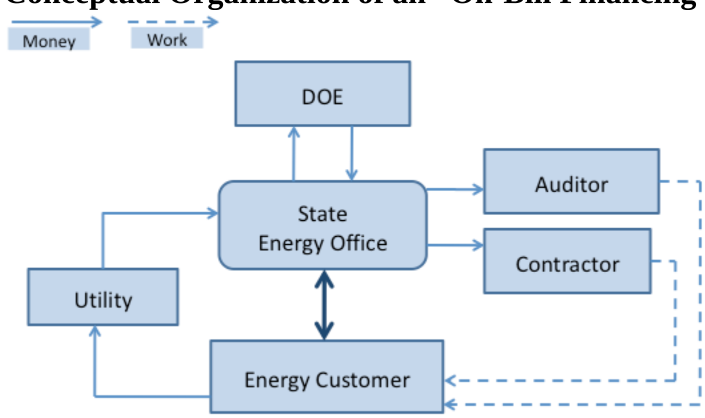
[1] This chapter was sponsored by the Climate Change Technology Program (led by the U.S. Department of Energy) under the project leadership of Dr. Robert Marlay and Lindsay Roland who contributed significantly to the project's design and execution.

4) **Technology readiness**. The policy options selected should address barriers and/or risks of mainly an institutional, policy, or non-technical nature.
5) **Cost effectiveness.** In selecting policies to study, consideration should be limited to those that would be expected to have reasonable costs, a strong social benefit, and a relatively high benefit-to-cost ratio.
6) **Administrative feasibility**. Policies selected should be fairly easy to implement, manage, and enforce. Some may require training a large workforce for implementation, while others may be able to focus training on limited players within the delivery system. The latter is obviously more desirable.
7) **Additionality**. The selected policy options should each represent different approaches to barriers or to different market segments. Each policy option should be evaluated in terms of the independent contribution it could make above and beyond existing policies.

Case Study 1: On-Bill Financing of Energy Efficiency Improvements

The federal government could encourage energy-efficiency investments in existing buildings by enabling State Energy Offices (SEOs) and utilities to offer on-bill financing to building owners. In the proposed financing scheme, the federal government would provide seed money and program guidelines for revolving loans implemented through states, which would have the flexibility to determine their own program administrators and specific rules. State programs should include certified and bonded auditors and contractors competitively selected to promote quality and cost-competitiveness, and to ensure that monthly repayment obligations by consumers are less than the energy bill reductions from the energy savings (Figure 1).

Figure 1. Conceptual Organization of an "On-Bill Financing" Program



Source: Revised from Rogers (2007)

On-bill financing programs are designed to enable customers to pay for energy-efficiency upgrades through energy savings. Such programs' effectiveness is greatly enhanced when the utility works with the ratepayer. That's because utilities have extensive information about their customers' energy use patterns and payment histories.

Joel Rogers (2007) has developed an on-bill financing approach called "Pay-As-You-Save," which addresses previously identified barriers. As shown in Figure 1, the PAYS™ concept is comprised of six generic players including a single utility, a customer, a state energy office, the

DOE, an auditor, and a contractor that carries out the efficiency improvements. This organizational framework offers a type of mix-and-match approach with great flexibility that enables PAYS™ to benefit from the opportunity presented by the 2009 American Recovery and Reinvestment Act. In this case, DOE provides financing through SEOs, who in turn manage energy retrofits by certified contractors. The payments are collected through monthly fees on utility bills. Brown (2009) discusses two related financing mechanisms: on-bill financing through a utility tariff (tariff-based systems) and on-bill financing through loans from the utility company (on-bill loans). In both cases, the utility pays for the full installed cost of the efficiency measures and the consumers pay a monthly fee on their bills to compensate the utility.

On-bill loan programs currently exist in many states. A review of residential efficiency financing programs in the U.S. and Canada identified 18 existing programs (Fuller 2008). Capital for these programs comes from a variety of sources including lender funds, internal utility funds, and public benefits charges. The most common financing mechanism was an unsecured consumer loan (Fuller 2008, p. 37). This approach is distinct from the program design proposed in this chapter, which would rely principally on federal revenues passed through SEOs to contractors with repayment to utilities.

Several programs exist or are being established that have many of the desirable attributes of utility on-bill financing. In 2001, the New Hampshire Public Utilities Commission authorized pilot programs by the New Hampshire Electric Cooperative (NHEC) and the Public Service Company of New Hampshire (PSNH). Both pilots provided no-cash-upfront energy-efficiency improvements, with prepayment through electric bills. PSNH targeted municipal buildings, while NHEC targeted residential and small commercial buildings. In 2007, Midwest Energy Inc. (a customer-owned utility) sought permission from the Kansas State Corporation Commission to operate a program resembling these two New Hampshire programs. In its filing, the utility expressed its desire to reduce customer energy bills, and not just control rates. The state of California requires utilities to reduce energy demand, and utilities have begun offering on-bill financing as one way to meet that requirement (Zwahlen 2007).

In 2008, the Massachusetts State Legislature passed an energy bill that included provisions for establishing a pilot on-bill financing program.[2] That program will be administered by the SEO in conjunction with public utilities, and it specifically requires that payment be structured so that the customer payments are less than the energy savings achieved. That benefit could transfer to any subsequent home or building owner. Failure of a customer to repay the obligation could result in disconnection, just as failure to pay utility bills can cause services to be terminated. The utilities will benefit from this program if their financial incentives are aligned with helping their customers boost energy efficiency. In states where utility profits are tied to sales of electricity and/or natural gas, regulatory reform will be necessary for similar programs to function.

Appropriateness of the federal role. Most of these programs are administered by utility companies, often without assistance from government. However, there is plenty of room for the federal government to encourage and assist utilities in offering on-bill financing. In Massachusetts, the state provides funds to the utilities to cover the program's costs. The DOE could provide grants and funding to SEOs, which could in turn cover the costs of the program

[2] See, for example, http://www.mass.gov/legis/laws/seslaw08/sl080169.htm, section 84.

auditors and contractors. These costs would then be reimbursed to the SEOs through the utility monthly bill repayments.

Broad applicability. In the most general terms, such a financing program would be applicable to all existing dwellings and small businesses. Many utilities, particularly those with a large customer base, could easily offer on-bill financing. But municipal utilities and rural cooperatives, having less access to capital than investor-owned utilities, might need financial assistance, which DOE could provide. DOE could also provide assistance in the design and initiation of such programs. Utilities are expanding their services to include energy-efficiency programs. Indeed, this is a growing trend within the U.S. The use of DOE funds to enable on-bill financing is particularly important to allow municipal and rural cooperatives to participate, since they generally have less access to capital and would need more assistance in the initiation and design of such programs.

Significant potential benefits. To estimate the potential benefits of on-bill financing programs, we assume that the annual participation rate is 1% of residences and that the program begins in 2011, with new installations being financed for the following ten years, and with the last of the energy savings occurring in 2030.[3] This participation rate is certainly achievable, in view of greater participation rates others have achieved. For example, Bonneville Power Authority's (BPA) Energy Smart Design program achieved 3.7% participation of eligible floor space during its beginning years (Xenergy 1996).

Based on the assumption from above that 1% of single family homes would participate, and a further assumption that each retrofitted residence would save about 30% of its total annual energy use, annual energy savings within this program would range from about 27 trillion Btu in 2020 to 32 trillion Btu in 2030, excluding electricity-related losses.[4] If average measured lifetime is assumed to be 10 years, cumulative annual savings would amount to about 280 trillion Btu in 2020 and 305 trillion Btu in 2030.[5] These figures are based on the assumption that 105 million single family homes would be eligible, initially, to receive funding under this program (EIA 2008), and that that number would grow as the population of single family houses grows, from 113 million in 2006 to 141 million in 2030. (Note that because this is an estimate for single family residences, these numbers exclude the 23% of homes that are considered multifamily.)

Technology readiness. The main goal of on-bill financing is to overcome market barriers related to the costs of purchasing energy-efficient retrofits, including insulation and other building shell improvements as well as high-efficiency equipment and appliances. It is not dependent on future research and development. However, improvements in materials and equipment would likely reduce costs and boost savings over time, and reductions in the cost of completing home energy performance ratings would improve program economics.

[3] If there were no duplicity, 19% of single family and manufactured homes would be retrofit if 1% of the stock were retrofit each year from 2011 to 2030, based on stock estimates from EIA (2008).
[4] Based on a meta-analysis of weatherization savings, electric-heated homes save 10.9% of pre-weatherization consumption and gas-heated homes save 21.9% of pre-weatherization consumption, with average annual site energy savings of 29.1 million Btu (Berry & Schweitzer 2003).
[5] Many of the most effective measures, such as insulation and better HVAC units, have lifetimes longer than 10 years while some measures, like lighting, weatherstripping, and caulking, have shorter lifetimes.

Cost effectiveness. On-bill financing has proved so cost-effective that some utilities, such as First Electric Cooperative, have chosen to offer it even absent government requirements or assistance. Smaller utilities without access to sufficient capital would need assistance. A federal program providing assistance could be administered relatively inexpensively. On-bill financing enables consumers to obtain equipment, insulation, or other energy-saving measures where the savings on energy are at least as great as and usually greater than the capital cost of the investments.

Administrative feasibility. The federal government currently offers numerous funding assistance programs. It administers the Low-Income Home Energy Assistance Program (LIHEAP) and Weatherization Assistance through state programs. These state administrators are well-connected to the local utility industry and the energy needs of their communities, and would be experienced and effective implementers of on-bill financing programs. As such, the development of funding and program guidelines should not create too large an administrative burden for the federal government. State governments and utilities may need to modify their operating procedures (and potentially their billing systems) to allow such programs to function; this could be more burdensome for some states and utilities than others.

Additionality. This is a very specific policy addressing some of the market barriers to purchasing energy-efficient equipment. Other policies, such as Home Energy Rating Systems or mandated disclosure of energy use may also encourage the installation of more energy-efficient appliances and equipment, but only on-bill financing directly removes the upfront capital barrier. On-bill financing is also distinct from weatherization programs, because assistance is being offered regardless of income and involves loans rather than direct government financial assistance for energy-efficiency upgrades.

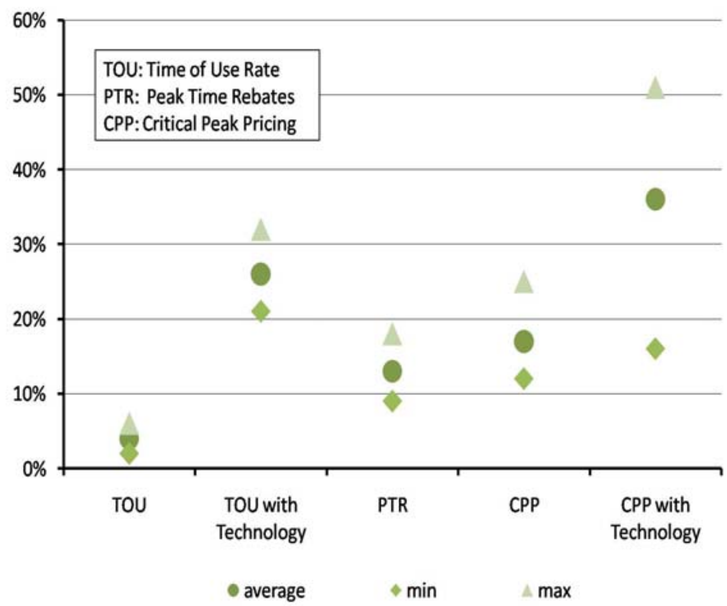
Case Study 2: Smart Meters and Dynamic Pricing

Imagine how it would be if you were billed for your groceries or your gasoline only after you had used them up, and that you had no idea how much they were going to cost until you received the bill. Obviously, under these circumstances, it would be very difficult to control your spending on these two items so that it matched your willingness to pay. This is, of course, precisely the difficulty the consumer faces in trying to control expenditures on home heating fuel and electricity.

Consumers face two related and critical information barriers. They lack both real time information on rate of consumption, and price signals (Brown et al 2008; Pfannenstiel and Faruqui 2008). Price-responsive demand – necessary for the markets for electricity and natural gas to function efficiently——requires smart meters and prices that can change with demand. However, the public is largely ignorant about smart meters. To prevent confusion, the government should define and limit the use of the term “smart meter” to those meters that: 1) record (electricity, natural gas, water) consumption no less frequently than hourly, although recording consumption on demand would be ideal; 2) can interface with an in-home device or on-line tool (TPUC 2008, p. 5).[6] In addition, federal technical and financial assistance could help develop dynamic and interactive metering practices beyond utility pilot programs.

Dynamic pricing schemes may be designed as peak and off-peak pricing, real time pricing, or critical peak pricing structures.[7] Research suggests that critical peak pricing is the most effective (Faruqui and Sergici 2009). Figure 2 shows the average, minimum and maximum savings from pricing pilots using Time of Use (TOU), Peak Time Rebates (PTR) and Critical Peak Pricing (CPP) with and without enabling technology. Enabling technologies, like smart meters, are clearly helpful.

Figure 2. Summary of Pricing Pilot Savings



Derived from Faruqui and Sergici (2009), Table 31 p. 43

The simplest form of time variant pricing is achieved by setting a higher peak rate and a lower off-peak rate; this does not exactly match the variability in the wholesale price, but it does provide a signal to customers that power is more expensive during peak periods, such as summer afternoons.

Rate design is important to the success of smart meter programs. Several pilots of various pricing schemes and home displays for the smart meters are happening across the United States (Faruqui and Sergici 2009). It is evident from these pilots that dynamic pricing should be tailored to the needs and circumstances of different types of customers. In particular, such program designs should be sensitive to low- and fixed-income consumers, because they face a greater energy burden than the average consumer (Alexander 2007).

Policy-makers should also consider how much of the market is allowed to participate. The current market for electricity lacks clear and timely price signals that it cannot operate as

[6] Water is not part of this policy discussion; however, water flows into a home, like energy, and can be measured with similar types of metering devices.
[7] These pricing structures are laid out in the Energy Policy Act of 2005,Title XII, Subtitle E, Section 1252.

efficiently as it might (King, King, and Rosenzweig 2007), and if customer participation in dynamic pricing programs remains low, the aggregate demand market will not respond to changes in supply (Sioshansi and Vojdani 2001). However, when policies are developed that allow widely differing rates at different hours, they should include protective mechanisms against market manipulation (Tierney 2008; Borenstein 2002).

Utilities, state regulators, and manufacturers of related products will also be vocal stakeholders. Utilities will want to ensure they can meet their returns to investment. State regulators will want to protect consumers and ensure compliance with other state laws. Manufacturers will look for their chance to expand their business.

Appropriateness of the federal role. The federal government has many precedents for certifying energy equipment. Previous meter standards, which were not created by the government, were developed to address the physical connection of the meters and the electronic meter reading interfaces (Levy Associates 2002). The federal government prescribes national standards to utilities, through the Federal Electricity Regulatory Commission (FERC). FERC is already regulating aspects of smart metering, including time of use rates, and demand response.

Broad applicability. Smart meters are applicable to all residential consumers of electricity and piped fuels. Nevertheless, some customers will be able to respond more than others. Renters who do not see or pay their bill separately from their rent may have no incentive to conserve. Low-income or low-use consumers may be unable to reduce energy use. Homebound individuals, especially those relying on equipment such as medical devices that must remain on all the time, may risk heath consequences if they reduce energy use. Special populations, such as night-shift workers could see real increases in their bills, a problem policy-makers should consider, in order to try to avoid inflicting undue harm.

Significant potential benefits. Substantial peak savings are possible. Pfannenstiel and Faruqui (2008) estimate that technical potential for demand response is 25% of the peak while economic potential is 12% of the peak, and the current market achievable demand response potential is 5%. Of course, it is important to note that these estimates are for demand savings (kW) and not energy savings (kWh). While increasing demand response may have many benefits, it does not necessarily lead to significant KWh savings. Indeed, some techniques for reducing peak use, like ice thermal storage, can actually use more energy.

Smart meters by themselves, as well as combined with alternative pricing, have resulted in both load shifting and actual energy savings. Darby (2006) found that direct feedback from meters or in home displays resulted in average energy savings of 5-15% over several studies. More recently, Ehrhardt-Martinez, Donnelly, and Laitner (2010) found an average energy savings of 4-12% savings in a meta-review of 57 different residential feedback programs. User-friendly in-home consumption meters led to average savings ranging from 2.7% in British Columbia to 18% in Newfoundland and Labrador (CEATI International, Inc. 2008). An analysis of pilot programs showed savings of 3 to 6% using TOU rates alone, ranging up to 13 to 20% if they were designed as critical peak rates (Faruqui and Sergici 2009). Faruqui and Sergici (2009) claim that reducing the peak demand by 5% could lead to nationwide savings of $66 billion. Sustained meaningful pricing structures are important because the long-run price elasticity is estimated to have a mean of -0.9, ranging from -0.7 to -1.4, while the mean estimate of short-run price elasticity is estimated at -0.3, ranging from -0.2 to -0.6 (EPRI 2008).[8]

Technology readiness. Effective smart meters have been developed and are already in place. The number of smart meters in use in the United States grew from one million in 2006 to 6.7 million in 2008 (FERC 2008). These meters could quickly saturate the market if demand were there, because the technology they use is commonplace. Still, 95% of meters are common technology (FERC 2008). Thus, while ongoing R&D may further reduce costs of meters and improve user-friendliness and demand response, the program's success does not depend on future research.

Cost effectiveness. Installing smart meters in the 95% of homes nationwide that lack them would cost about $40 billion (Faruqui and Sergici 2009). With advanced meters costing between $78 and $181, estimated paybacks range from 6.5 to 10.1 years absent demand response (Levy Associates 2005). Thus, smart meters with dynamic pricing and automatic load control should more than pay for themselves.

Administrative feasibility. FERC is currently working with the National Association of Regulatory Utility Commissioners (NARUC) on the Smart Grid Collaborative, and is leading efforts to define barriers and next steps in advancing the goals of the smart grid. DOE's Office of Electricity Delivery and Energy Reliability is working to further the smart grid as well. While the federal government cannot lobby state governments, they can provide the tools and analysis to aid Public Utility Commission (PUC) decisions. At the state level, rolling out advance metering infrastructure, and enabling demand response pricing may require some additional research and coordination efforts with utilities.

Additionality. Smart meters, together with time-of-use pricing and automatic load control, enable energy efficiency improvements – especially by flattening peaks. However, existing load management programs might offset some of the gains attributed to these meters and their associated load management policies. Policies to reduce total demand through energy efficiency may also interact with this policy; while savings will still accrue, they may not be completely additive.

Case Study 3: Alignment of Utility Financial Incentives with Customer Energy Efficiency

Of course, the benefits of smart meters and dynamic pricing will fail to be realized unless incentives can be developed for utilities to help their customers save electricity and natural gas. Two regulatory approaches are widely viewed as promising: financial incentives for achieving energy-efficiency program objectives, and decoupling utility revenues and profits through periodic and frequent true-up of projected sales, and other mechanisms to provide utilities with timely cost recovery and earnings opportunities for operating energy-efficiency programs. Decoupling is a way to make sure all of the utility's fixed costs are covered, but on its own, it

[8] Price elasticities are highly dependent on individual household, heating fuel, and regional characteristics (Bernstein and Griffin 2005).

does not reward programs that successfully save electricity. California and Oregon have combined decoupling with an additional reward to encourage utilities to invest in energy-saving technologies.

Fixing the problem of revenue erosion and decoupling profits from sales are critical to motivating utilities to encourage efficient use of electricity. In much of the country, the utility industry resists the regulatory reforms we propose. Nonetheless, even these utilities are coming to understand that the growing thirst for energy cannot be mitigated and the related problems cannot be addressed without effectively tackling consumer end-use issues. And now, green and energy-efficient product vendors are becoming a political force advocating utility regulatory reforms that encourage efficiency and conservation.

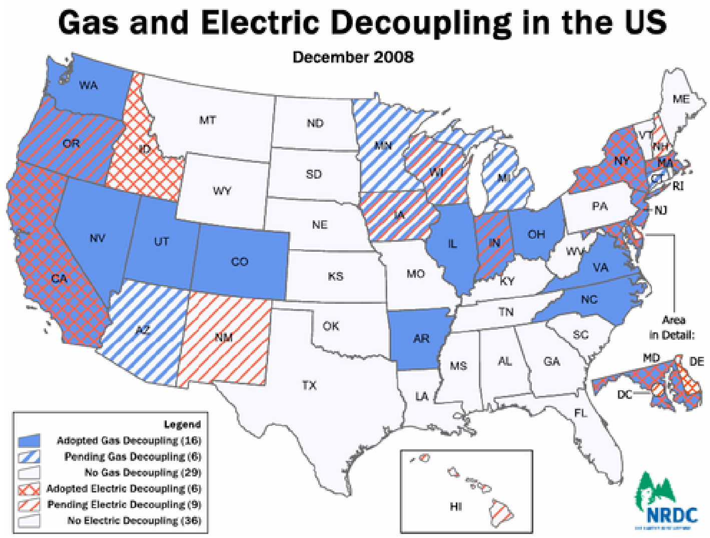
Ratemaking practices must be reformed for utilities to remain financially healthy while promoting the efficient use of energy by their ratepayers. Specifically, the National Action Plan for Energy Efficiency (NAPEE) recommends that stakeholders "Modify policies to align utility incentives with the delivery of cost-effective energy efficiency and modify ratemaking practices to promote energy efficiency investments" (Leadership Group 2006).

Appropriateness of the federal role The initiative proposed here is modeled after the Buildings Code Assistance Program (BCAP) operated by the Alliance to Save Energy, a non-profit organization, for the U.S. Department of Energy's Building Technology Program. In this case, the initiative would support the activities of an existing but under-funded non-profit organization, the Regulatory Assistance Project (RAP), which was formed in 1992 by experienced utility regulators. RAP provides public officials with research, analysis, and educational assistance on electric utility regulation.[9] RAP workshops cover a wide range of topics including electric utility restructuring, power sector reform, renewable resource development, the development of efficient markets, performance-based regulation, demand-side management, and green pricing. RAP also provides regulators with technical assistance, training, and policy research and development. RAP has worked with public utility regulators and energy officials in 45 states and Washington, D.C.

Broad applicability. The sphere of influence of this policy mechanism could be quite broad, promoting energy efficiency in the residential and commercial buildings industry – both new and existing housing – and in industry, as well. In addition, decoupling is applicable to both natural gas and electric utilities. Sixteen states and six states, respectively, have passed decoupling legislation for natural gas, and electric utilities (Figure 3).

[9] http://www.raponline.org/

Figure 3. Status of Decoupling Requirements Across States in 2008



(Source: NRDC., http://switchboard.nrdc.org/blogs/bcolander/decoupling_and_energy_efficien.html)

Significant potential benefits. Over the next 15 years, more than half of expected growth in demand for electricity and natural gas could be avoided by extending energy efficiency best practice programs to the entire country, in conjunction with regulatory reform, according to the NAPEE Leadership Group (NLG). NLG estimated that such an effort would save nearly $20 billion annually on energy bills, avoid 60 new 500 MW power plants, and reduce CO_2 emissions annually by more than 400 million tons (Leadership Group 2006). While not definitive, experience suggests that the proper incentives can strongly motivate spending on energy efficiency. The five states that spent the greatest fraction of total utility revenue on electricity efficiency in 2006 had either decoupling (i.e., California) or performance incentives (i.e., Vermont, Massachusetts, Rhode Island, and New Hampshire), according to Kushler, York, and Witte (2006).

Technical readiness. Strict enforcement by DOE of the requirement that utility financial incentives align with customer energy efficiency could begin immediately. This does not require successful completion of additional R&D or development of new technology.

Cost effectiveness. Duke Energy's recently announced "save-a-watt" initiative illustrates the type of promising new direction needed for utilities to promote energy efficiency.[10] The initiative has been incorporated into the energy-efficiency plans filed over the last two years by Duke Energy in North Carolina, South Carolina, and Indiana. It entails the pursuit of all cost-effective energy efficiency savings with no company-imposed cap on the money it can invest in efficiency. The initiative's target calls for reducing electricity use by 1% or more of Duke's customers each year, subject to the availability of cost-effective energy-efficiency programs to achieve the target.

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[10] For more information on this program, see http://www.duke-energy.com/news/releases/2007050701.asp.

Administrative feasibility. To be successful, regulators in each state need to determine a reasonable level of reward for utility investments in customer energy efficiency. This is where an expanded federal RAP could be critical to unleashing these market forces for energy efficiency in metropolitan areas.

Additionality. Many other approaches can promote energy efficiency, but reforming utility rate-of-return regulation is critical to these efforts.

Conclusions

Using a uniform set of policy evaluation criteria, we have examined three promising policy options for utilities that strive to boost residential energy efficiency. These policies provide a foundation for transforming the relationship of utilities to their customers in ways that would reduce household energy consumption. While these policies could prove highly successful in changing energy consumption behavior, other policy options might also prove successful. Indeed, the three policies described in this chapter might perform even better in concert with other approaches, such as a national performance standard that sets minimum goals for energy efficiency.

In addition to the seven evaluation criteria, Table 1 shows the anticipated time required to achieve significant savings after implementation of a particular policy.

Despite their numerous strengths, these policies could face administrative difficulties. This is largely because new institutions and rules must be established, presenting the possibility of hurdles along the way. New utility commission rate-making rules must be established to re-align utilities' financial incentives, new federal standards must be established for smart meters and demand response, and enabling policies and new billing procedures are necessary for successful on-bill financing.

Given the magnitude of public and private benefits, it seems plausible that politicians and the relevant business people will find the will to overcome these barriers. Each of these policies is expected to create meaningful savings within ten years of implementation.

Table 1. Summary Assessment of Policy Options

	Strengths	Weaknesses	Time Horizon*
On-Bill Financing of Energy-Efficiency Improvements	Appropriateness of the Federal Role, Broad Applicability, Technology Readiness, Significant Potential Benefits, Cost-Effectiveness	Administrative Feasibility	Short to Medium
Smart Meters and Demand Response	Broad Applicability, Significant Potential Benefits, Cost-Effectiveness, Additionality	Administrative Feasibility	Short (for demand response effect) to Long (for savings from smart meter performance specifications)
Alignment of Utility Financial Incentives with Customer Energy Efficiency	Broad Applicability, Technology Readiness, Significant Potential Benefits, Cost-Effectiveness, Additionality	Administrative Feasibility	Medium

**Time horizons when significant energy savings begin: short (5 years or less), medium (5 to 10 years), and long (more than 10 years).*

Energy efficiency policies repeatedly fall short of their potential impacts due to an incomplete understanding of target audiences. Table 2 highlights social science research questions that could help inform the design and implementation of these policies.

Table 2. Illustrative Social Science Research to Support Utility Policies aimed at Promoting Residential Energy

#1: On-Bill Financing of Energy-Efficiency Improvements
- What segments of the population would likely respond most favorably to on-bill financing as a means of retrofitting their homes?
- What are the sources of utility resistance to this policy and how can they be overcome?
- What are the possibilities for non-utilities to provide long-term funding of efficiency improvements (e.g., appliance retailers, NGOs, state or local government agencies) ?
- What are the possibilities for financing such improvements as part of mortgages and refinances?

#2: Performance Specifications for Smart Meters and Expanded Demand Response
- How frequent should feedback be? In what units should it be given for greatest effectiveness with consumers?
- Do different types of consumers need different types of information (e.g., Internet, home thermostat, …)?
- How can meters be designed for easy use by residential customers who vary greatly in technological sophistication?
- What consumer education is necessary to maximize the impact of smart meters, and how can it most effectively be delivered?
- How can smart whole-home meters be combined effectively with technologies for measuring use for particular outlets, switches, or pieces of equipment?

#3: Alignment of Utility Financial Incentives with Customer Energy Efficiency
- What are the causes of utility resistance to this policy and how can they be overcome?
- If concerns about measurement and verification are as critical as they appear to be, how can utility program managers gain experience and become more confident with program evaluation practices?
- Which stakeholders will benefit, and which will suffer as a result of a major shift to utility-managed efficiency programs, and how can the concerns of the opposition be best addressed?

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A Conceptual Framework for Integrating Behavior and Behavioral Change in the Energy Efficiency Program Cycle

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ABSTRACT

We present a conceptual framework for integrating behavior and behavioral change into the energy efficiency program cycle that is used by program administrators, including private and public utilities, in promoting and investing in energy efficiency. In examining each component of the program cycle—program planning, program design, program implementation, and program evaluation—this paper highlights key issues of behavior and behavioral change that are specific to each of these components. By using this framework, we hope that program designers, implementers, and evaluators will emphasize behavior and behavioral change in energy efficiency programs in order to promote energy efficiency as well as reduce energy consumption overall.

Introduction

In the last several years, interest in behavior and behavioral change related to energy consumption has increased dramatically, as reflected in the following examples:

- An annual national Behavior, Energy and Climate Change Conference (BECC) has been held since 2007—organized by the California Institute for Energy and Environment (CIEE), the American Council for an Energy-Efficient Economy (ACEEE), and the Precourt Energy Efficiency Center (PEEC). The conference's focus is on understanding the behavior and decision-making of individuals and organizations and using that knowledge to accelerate our transition to an energy-efficient, low-carbon economy. The heightened attention that BECC has brought to the role of behavior in energy and climate policy and programs has resulted in policy makers at every level—from the Executive Office of the President and the Congress to local communities—increasing the use of social science research in policy and programs.
- The U.S. Department of Energy (DOE) is developing a research and development (R&D) plan for behavior and is expected to fund R&D projects in the coming years.
- The Consortium for Energy Efficiency (CEE), a national nonprofit public goods corporation, has identified behavioral change as a key element of its organization, and has created a Behavior Committee to apply lessons from the social sciences to help members better design behavior change-focused programs aimed at reducing energy consumption. This committee includes a number of smaller subcommittees that focus on topics such as behavior change program evaluation; behavior change program design, marketing and communications; and market research. Members of this committee also seek to improve the way in which behavior change efforts are measured and evaluated.
- State energy organizations—e.g., California Public Utilities Commission (CPUC), California Energy Commission (CEC), California Air Resources Board (CARB), and the

New York State Energy Research and Development Authority (NYSERDA)—are funding research on energy, behavior, and behavioral change.

- Utility companies, notably BC Hydro, and the Sacramento Municipal Utility District (SMUD), are conducting pilot programs using behavioral tools and interventions.

As more organizations begin to support and implement behavioral change and energy studies, and to use the results in their projects and programs, there is an increasing need to develop a conceptual framework for organizing these activities. In this chapter, we provide such a framework that is particularly targeted to organizations that are involved in the design, implementation, and evaluation of energy efficiency projects and programs. By using this framework, we hope that program designers, implementers, and evaluators will emphasize behavior and behavioral change in energy efficiency programs in order to promote energy efficiency as well as reduce energy consumption overall.

In Section 2, we define behavioral change. Section 3 presents the program planning cycle that utility companies, government agencies, and other program administrators use for designing, implementing, and evaluating energy efficiency programs. Section 4 provides the conceptual framework for integrating behavior and behavioral change issues into the program planning cycle.

Behavioral Change Approaches

Throughout this chapter, we refer to both behavior and behavioral change as they relate to energy consumption. Herein, the term "behavior" refers to the actions of individuals and organizations as they relate to energy use—either directly, as in turning on air conditioners, or indirectly, as in deciding to participate in an energy efficiency program. Behavioral change is somewhat different from behavior, in that it connotes an intention—in this case, to improve energy efficiency or reduce energy use. Behavioral change in energy efficiency programs is interpreted differently by different people. As part of an ongoing effort at the Consortium for Energy Efficiency, experts classified approaches for addressing behavior change as follows:

1. **As a tool to improve the effectiveness of technology-focused programs**. Examples include using behavioral change tools and strategies specifically to: (a) increase program participation, (b) improve end-user decision-making, and (c) encourage more appropriate use of technology. An example of one tool is the use of market segmentation in the design of program marketing to increase program participation.

2. **As a primary means of reducing energy consumption through conservation** (as opposed to doing so by replacing standard technologies with more efficient technologies). This approach focuses on low-cost/no-cost measures and community initiatives and includes using feedback devices; and leveraging of social norms with feedback, education, and social marketing to encourage conservation.

3. **As a means for bringing about lasting change in the way organizations adopt and manage energy-efficient technologies**. Examples of this approach include an emphasis on market transformation programs or continuous energy management in buildings.

4. **As an area of research to inform behavioral change strategies and related programs.** Funding behavioral change research would help program administrators, regulators, and other stakeholders:

- Value behavioral change as a research goal that will inform the development of feedback devices, program design, marketing, and evaluation;
- Incorporate both upstream and downstream behavioral change approaches,[1] focusing on market actors and the supply chain as well as end users; and
- Use market research, segmentation, market characterization, etc. to improve behavioral change programs and strategies in the future.

Another useful construct in examining different types of behavior is shown in Figure 1, developed by Karen Ehrhardt-Martinez and Skip Laitner (2009).

Figure 1. Energy Efficiency Program Planning Cycle

		Frequency of Action	
		Infrequent	***Frequent***
Cost	***Low-cost or No cost***	**Energy Stocktaking Behavior and Lifestyle Choices** Install CFLs Pull fridge away from wall Install Weather Stripping Choose a Smaller Living Space	**Habitual Behaviors and Lifestyle Choices** Wash in Cold Water Take Shorter Showers Air Dry Laundry Turn Off Computer & Other Devices
	Higher cost / Investment	**Consumer Behavior & Technology Choices** New EE Windows New EE Appliances Additional Insulation New EE Car New EE AC or Furnace	

[1] A “downstream” energy efficiency program typically provides information, incentives, etc. to the customer or end user (residential, commercial, industrial, etc.). In contrast, an “upstream” energy efficiency program typically provides information, incentives, etc. to the key market actors that are upstream from the customer (e.g., manufacturers, retailers, and distributors).

Some energy consumption-related behaviors involve low-cost or no-cost choices, which may confront an individual frequently or infrequently. For example, one is confronted repeatedly with the choice of turning the lights off when leaving the room—or leaving them burning. Conversely, buying an energy-efficient furnace that costs more than the standard version is a one-time expense.

Feedback is receiving considerable attention in the world of energy and behavior, and a useful way of examining the different types of feedback mechanisms is shown in Figure 2 (EPRI 2009).

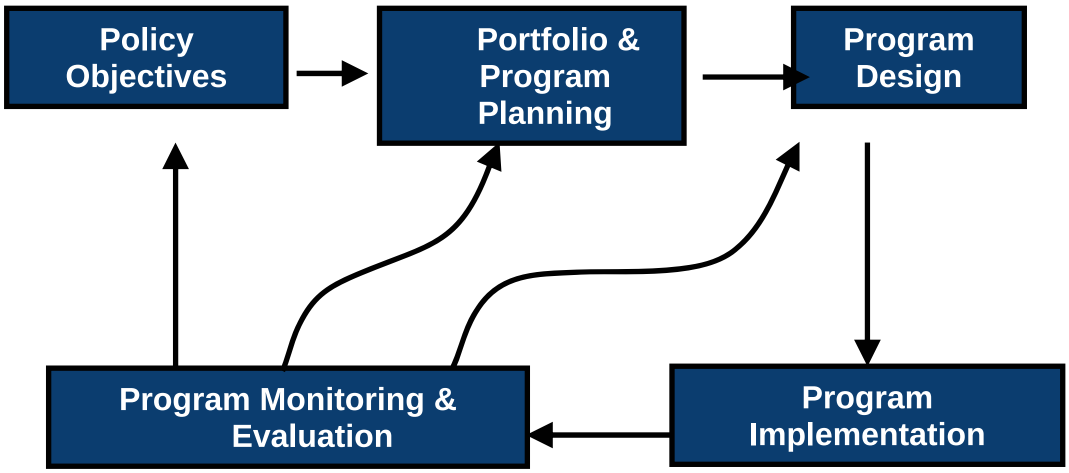
Figure 2. Feedback Mechanisms

1 Standard Billing	2 Enhanced Billing	3 Estimated Feedback	4 Daily/Weekly Feedback	5 Real-Time Feedback	6 Real-Time Plus
	Monthly Energy Reports Quarterly Energy Reports Targeted Tips	Web-based home energy audit, with and without appliance usage estimates (user inputs data) Web-based home energy audit (data periodically retrieved from utility)	Consumer reads meter Via mail (including email notification to access webpage) Via email Via web (consumer must go to webpage)	Energy display device Pricing display device Prepaid meters Real-time web portal (TV, cell phone, etc.)	End-use monitoring with web portal (or standalone display, TV, cell, etc.) End-use monitoring and control with web portal (or standalone display, TV, cell, etc.)

The earliest feedback mechanisms occurred for Types 1 and 2, adding information to utility bills. Recently, more work has focused on Types 3 and 4, and pioneering work has started on Types 5 and 6. For more information on work in these areas, see the report prepared by EPRI (2009).

Figure 3 shows the energy efficiency program planning cycle that is commonly used by program implementation and evaluation managers.

Figure 3. Energy Efficiency Program Planning Cycle



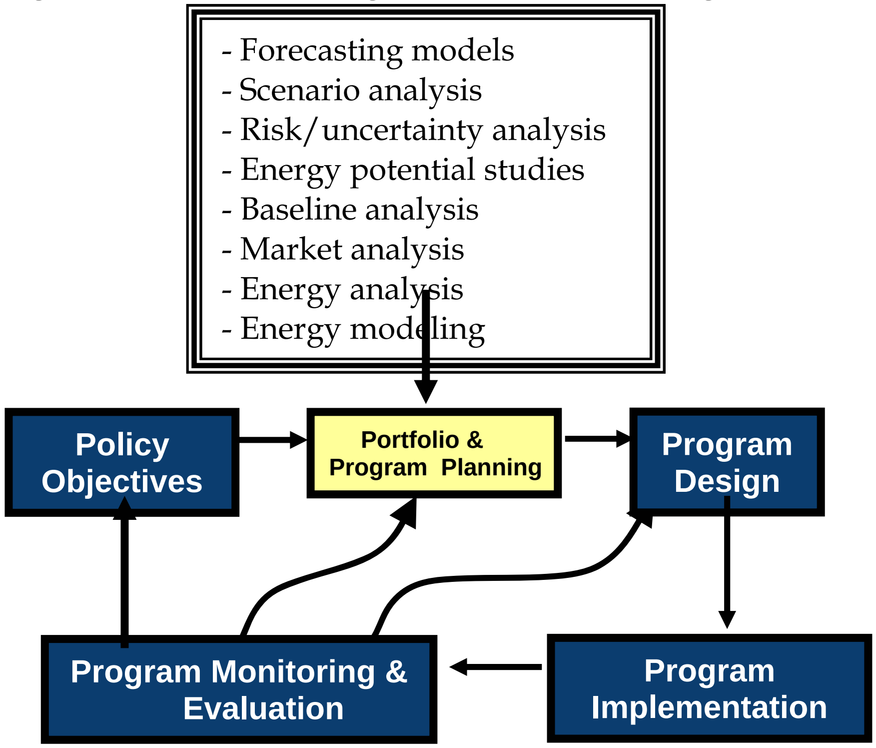
Energy Efficiency Program Planning Cycle

Consider a utility company as an example of an organization that would go through a planning cycle towards energy-saving programs. Typically, it will develop its own policy on energy efficiency. The utility must choose what types of energy efficiency programs to offer within a portfolio of programs; for example, residential programs, or residential and commercial programs; or residential lighting programs and commercial HVAC programs. Once it has created a portfolio, it then would design specific programs. For a commercial lighting program, the lighting technologies and the financial incentives must be identified, and the marketing must be planned. Implementation follows design. Lighting installers and marketing experts must be engaged. Evaluation and monitoring follows implementation. This involves collecting billing data, conducting onsite inspections, interviewing customers and key stakeholders, etc. Finally, the results from the evaluation must be fed back to the strategic planners and policymakers to determine the quantity of energy savings and carbon emissions reduction, the number of customer participants and the number of pieces of energy-related hardware installed, etc. The results from the evaluation can be used to modify the portfolio and the design of the program.

Integrating Behavioral Change into the Program Planning Cycle

The conceptual framework for integrating behavioral change into program planning starts with the portfolio design and program planning (Figure 4). The findings from program evaluation also feed into portfolio design and program plans (see below).

Figure 4. Behavioral Change and Portfolio and Program Planning

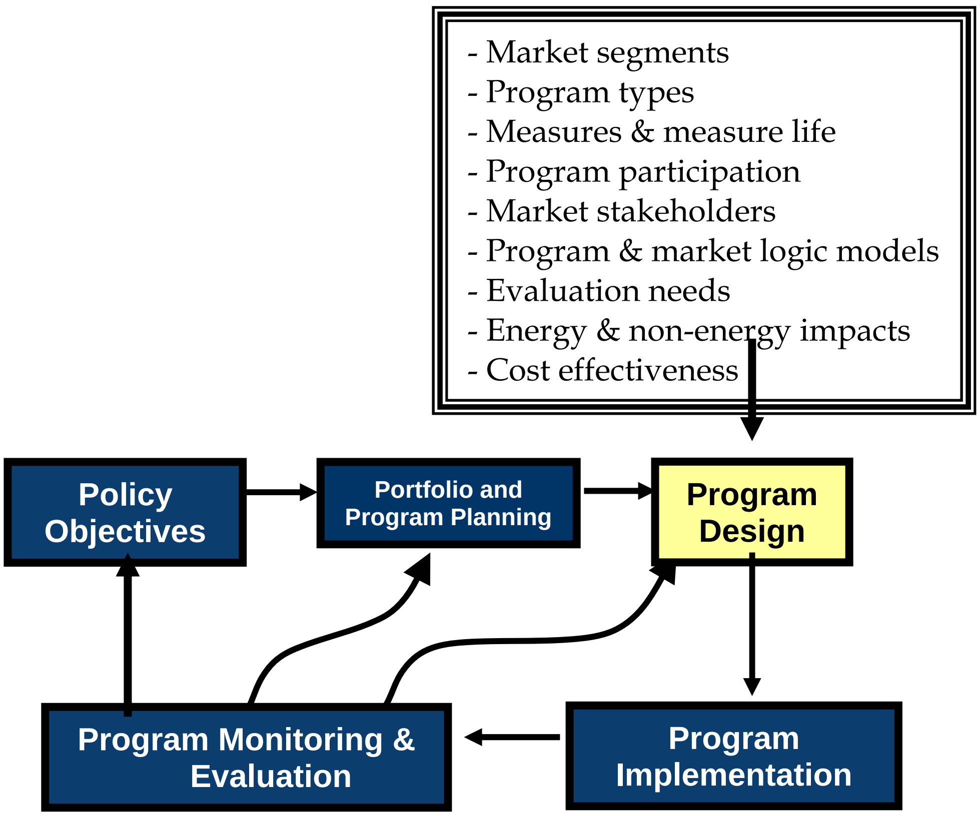


Behavioral research is used in designing portfolio and program plans (see examples in the box in Figure 4, and the descriptions below). Forecasting models are used to estimate changes in energy use and potential energy savings in key sectors (e.g., residential, commercial, and industrial) and subsectors (e.g., residential lighting and commercial air conditioning). Forecasting models include behavioral research—usually implicitly (e.g., demand elasticities and annual penetration of energy-efficient new homes) rather than explicitly (e.g., percentage of households planning to buy an energy-efficient new home). Forecasting models often rely on market research, segmentation, and market characterization. Risk and uncertainty analysis are sometimes used in the modeling exercise, particularly in the development of different scenarios. Studies of energy efficiency potential are a type of forecasting model used to express the energy savings expected from consumer adoption of energy-efficient technologies under various scenarios of energy efficiency program funding. Studies of the potential for reducing energy use can include behavior—often implicitly, but sometimes explicitly (Moezzi et al. 2009).

Baseline studies provide information on customers and key actors in the market (e.g., manufacturers, retailers and distributors, and contractor), often based on market research, segmentation, and market characterization and analysis. In addition to information on socio-demographics and appliance and buildings data, baseline studies often collect information on attitudes, awareness, and knowledge of customers and key market actors, as well as appliance sales, building permits, and product purchases. In addition to forecasting, energy modeling and analysis is sometimes conducted on residential, commercial, and industrial customers, and on market segments within these sectors, to assess the simulated impacts of programs on energy use and savings. (This is different from evaluations of the impacts of programs that have already been implemented.) The modeling and analysis can sometimes account for attitudes, behaviors, etc. when estimating energy use and energy savings.

The results from portfolio and program planning are often used for designing specific energy efficiency programs (Figure 5). Sometimes the results from evaluation are also used in designing programs, particularly if the feedback from evaluation is timely.

Figure 5. Behavior and Program Design

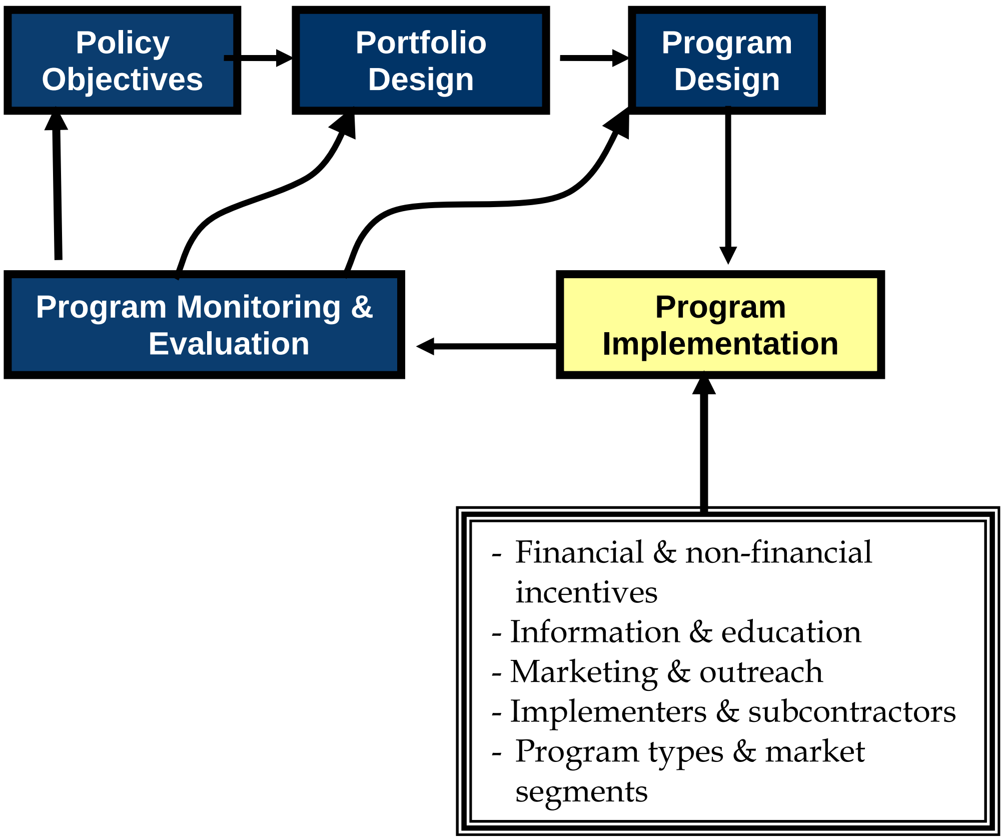


Some of the key behavioral topics that feed into program design deal with the selection of technologies, incentives, and information packages (see box in Figure 5). For example, in designing programs, one identifies specific market segments, program types, energy efficiency measures, the expected number of participants in a program, and key market stakeholders. As part of this process, market and program logic models are developed to ensure that the program activities (inputs) will lead to the desired outputs (e.g., energy savings). One of the more critical aspects of this stage is the assessment of the information needs of those who will evaluate the program. The expected energy and non-energy impacts are calculated, as is the program's cost-effectiveness.

From the perspective of behavioral change, the identification of customers and key market stakeholders (e.g., manufacturers, retailers and distributors, and contractors) is just one step in the process of program design. Another important step involves the understanding of how these market actors behave with respect to energy investments and the use of technologies in buildings. For example, what can actually drive customers to invest in energy efficiency? What makes some people use energy parsimoniously while others squander it? And how do you get people to participate in energy efficiency programs?

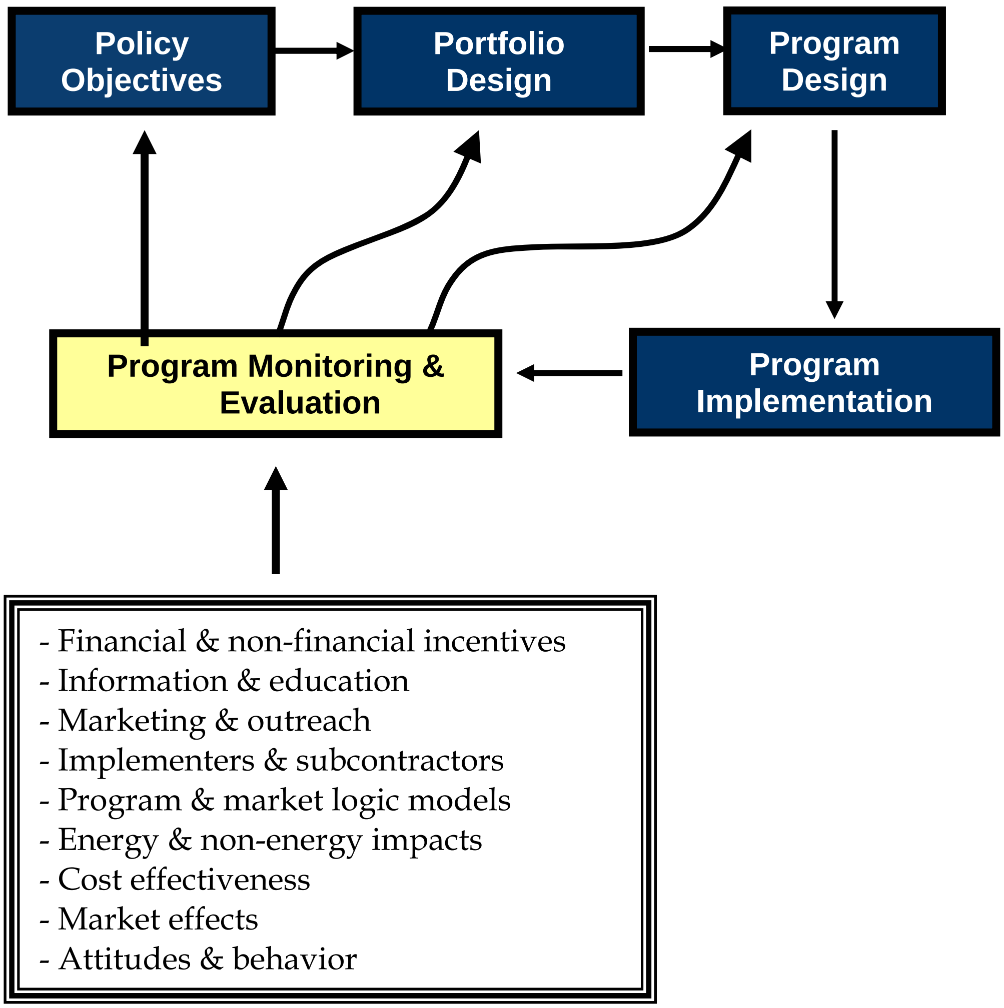
The key behavioral issues that influence program implementation are shown in the box in Figure 6, and are similar to those considered during the program design process. But they are now more specific: that is, they identify which incentives should be offered at what levels and to whom, the type of information that should be provided, and the channels to be used for sending information to particular customers.

Figure 6. Behavior and Program Implementation



After the program has been implemented (and sometimes, during program implementation—especially when monitoring and verification are required), the program will be evaluated. The key behavioral topics that will be addressed in the evaluation process are identified in Figure 7.

Figure 7. Behavior and Program Evaluation



Finally, the results from program evaluation will be used as input for reviewing policy objectives, portfolio design, program design, and program implementation.

Conclusions

Planners, designers, administrators, and evaluators of energy efficiency programs need to work together to ensure that knowledge from behavioral research is integrated into the program cycle. This reflects Moezzi et al.'s (2009) recommendation that there be better communications between social scientists and other experts involved in the planning, design, administration, and evaluation of energy efficiency programs. One way to make this happen is to ensure that implementers, evaluators, and regulators weigh in on the design and conduct of behavioral studies, and that they are made aware of the findings from behavioral studies—i.e., they all must work together as a team. In particular, regulators should provide sufficient resources for the implementation and evaluation of behavioral studies, and they should create performance metrics that go beyond direct energy savings and include factors such as non-energy impacts (e.g., comfort, convenience, and indoor air quality), customer satisfaction, and market effects.

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Energy Efficiency: Choice Sets, Market Transformation, and Innovation[1]

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Markets Are Social Institutions

Markets represent both the site of important energy-related transactions and a potential venue for reshaping energy-related behaviors. Market interventions aimed explicitly or implicitly at market transformation are frequently part of utility and government energy-efficiency programs. However, these interventions are rarely grounded in knowledge of the workings of real markets. As a result, potential energy savings are foregone and program resources are wasted. We have suggested elsewhere that better theory and models are needed to support market transformation (Blumstein, Goldstone and Lutzenhiser 2000). This chapter attempts to advance that agenda. The central themes are to highlight the shortcomings of the most commonly employed frameworks for understanding energy-related markets and to emphasize the need for research on actual market conditions, contexts, and players. We begin with a discussion of how common conceptualizations of the market shape our thinking about market characteristics, consumer choice sets, and approaches to market transformation initiatives. The following section discusses innovation and the role of innovation in market transformation. The chapter concludes with recommendations for market-related research topics.

Market Characteristics

Among the current initiatives to promote energy efficiency, many involve efforts to affect change in efficiency-related product and service markets. (These activities are often described as "market transformation" programs, which we discuss in more detail below.) Notably, however, such efforts stand only loosely on any foundation of information concerning "real" market conditions and dynamics. Instead, many designers of policies and programs have relied too readily on conceptions of "the market" as an abstraction, a place of exchange that, while it may suffer from some "imperfections," approximates the textbook model of fully informed actors making costless transactions that exchange abstract products. This is a naïve view, to be sure. And it overlooks a significant amount of work in behavioral economics (Camerer and Lowenstein 2004) and institutional economics (Bowles 1998), and insights from other perspectives (Lutzenhiser *et al*. 2009, pp.43-64). Importantly, regardless of its shortcomings, this idealized model of the market continues to be very influential in the energy policy world in the U.S., although perhaps less in Europe.[2]

[1] Many of the ideas in this paper originally appeared in a conference proceeding (Blumstein et al. 2001). We have done some updating in light of recent developments in the literature, but have not attempted an exhaustive review.
[2] Ideas can linger in the policy world long after they have been abandoned by scholars. As J.M. Keynes wrote in his famous comment about the power of ideas, ". . . the ideas of economists and political philosophers, both when they are right and when they are wrong, are more powerful than is commonly understood. Indeed the world is ruled by little else. Practical men, who believe themselves to be quite exempt from any intellectual influences, are usually the

Real markets are more complicated than this. Real markets are not just the sum of transactions among individuals. Real markets have structure. This structure consists of rules governing the conduct of the market actors, relationships among the actors, and physical arrangements to facilitate exchange. Real markets are heterogeneous. Their structure varies greatly depending on the goods being exchanged. Markets for electricity are very different from markets for durable manufactured goods and markets for buildings. Also, markets evolve over time because of technological change and because of changes in the competitors, institutions, regulations, and supply systems involved.

The rules of conduct in a market are often quite complex. These rules may either be explicit or implicit, and most markets have both types of rules. Explicit rules include those that are clearly developed and formulated such as the laws prohibiting insider trading on stock exchanges. Implicit rules derive from custom—for example, the norms regarding tipping in restaurants involve implicit rules, which vary from culture to culture.

Similarly, and contrary to the idealized model, all markets involve an assortment of actors—not simply producers and consumers. In fact, the number of agents and intermediaries can be quite large. For example, in the buildings industry people quickly recognize the importance of builders and buyers, but other important actors include designers, bankers, appraisers, brokers, real estate agents, insurance agents, and lawyers, among others (Lutzenhiser and Biggart 2001). Finally, rules and actors are not the only aspects of the market that tend to become overly simplified in common conceptualizations of the market. The physical arrangements for markets are also complex and diverse. These arrangements include retail stores, online stores, wholesale distribution networks, commodities exchanges, and electronic communications networks.

In short, markets are not simple abstractions, they are complex social institutions.

Choice Sets

Efforts to understand how people and their institutions adopt energy-efficient innovations have relied upon competing theories of consumption. In these theories, people are variously believed to make choices for reasons of economics (e.g., utilitarian value), psychology (e.g., personality, impulse), or the search for social status and cultural conformity (Wilk 1999). Often the competition among the disciplines is more distracting than illuminating. We agree with Wilk that none of these theories tells the whole story, although each has something to contribute. But we want to go beyond the pros and cons of competing theories to suggest that an equally important shortcoming of past research has been its focus on consumer behavior and its failure to recognize the importance of markets in shaping that behavior. The result has been a lack of adequate guidance for designing effective energy-efficiency programs and policies (Wilhite *et al*. 2000).

The problem we highlight is that consumer choice is constrained by market structure. Consumers are not free to choose from among all of the technical possibilities. Rather, the market provides consumers with limited choices. We call the choices that are actually available to the consumer

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slaves of some defunct economist. Madmen in authority, who hear voices in the air, are distilling their frenzy from some academic scribbler of a few years back.” (Keynes [1935] 1964, 383) the choice set.[3] To make this more concrete, consider a consumer whose water heater has just failed. If she wants a quick repair, her choice set is typically limited to the one or two water heater models that the plumber has on hand. Conversely, an appliance purchaser who has unlimited time to shop has a set of possible choices, or "choice set" that consists of the universe of models on the market. But the typical appliance purchaser with limited time has a smaller choice set that consists of the models in stock.

How do we learn about what is in the choice set? How can we understand the factors that determine the choice set? Answering these questions requires a shift in focus from consumers to producers and the intermediaries who seek both to compete for customers and to routinize the choices presented in the market in order to simplify design and production, warehousing, merchandising, and supply chain management. The influence of these upstream actors and considerations often has more influence on the contents of particular choice sets than consumer demands.

Market Transformation

In modern societies markets provide are the venue for many decisions that affect energy consumption. This leads to the proposition that energy efficiency can be promoted by transforming markets. Since a market is, among other things, a set of choices, market transformation means modifying the choices, and in this case, including new, energy-efficient options while excluding old, inefficient ones from the choice set.

Here we note that one of the elements of an alternative paradigm of economic behavior is implicit in the idea of market transformation. That is, economic behavior is not just about individual action; economic behavior is mediated by markets. This means that it is usually not possible to understand economic behavior without some understanding of the market that provides the context for the behavior. The policy implication, and the rationale for market transformation, is that economic behavior can be changed by making changes to markets.

Our thesis is that policies designed to change markets will be more effective if these policies are grounded in an understanding of real markets. While this may seem obvious, surprisingly little material is actually available to provide the necessary understanding. A realistic understanding of any given market requires going far beyond an abstract model of markets. It requires a much more detailed model that incorporates knowledge of the particular characteristics of the products being exchanged and how these characteristics are shaped by the particular institutions in which that market is embedded. To obtain this detailed knowledge requires research on the specific dynamics of those markets that we wish to transform.

To elaborate this idea we examine the relation between markets and innovation. The reason for this focus on innovation is that causing innovation is one way to change (transform) markets and

[3] We are not the first to observe that only a limited set of choices is available in the market. For example, Lancaster (1979) approached the topic from the perspective of neoclassical economics. Lancaster focused on the role of economies of scale in limiting the variety of choices. More recent work in behavioral economics regarding "choice architecture" (Thaler and Sunstein 2008) focuses on consumers' cognitive processes, not the configuration of products available to choose from selected by other market actors.

thus cause a change in the pattern of consumption. A rudimentary theory says that if markets provide a choice set, and the choice set defines what is available for consumers, then innovation changes the content of the choice set and thereby changes the pattern of consumption.

While this theory is rudimentary, it can provide some useful guidance in policy deliberations. That said, we are well aware of the theory's limitations. More research on markets and how markets mediate economic behavior is clearly needed. In our conclusion we discuss how elements of our rudimentary theory might guide a research program that will both lead us in the right direction and foster development of the expertise needed to create better theory.

The Role of Innovation in Market Transformation

The words "innovation" and "invention" are sometimes used interchangeably. Here we wish to make a clear distinction between them. We take innovation to include (1) the invention of new technology, new forms of organization and new institutional arrangements that support market action, as well as (2) the general adoption of these. To put it another way, innovation involves invention but not all invention results in innovation.[4] An invention could be a new electronic system to control heating and cooling in a building. New methods to insure that the control system was operating properly before it was placed in service (commissioning) could also be an invention. The innovation process would incorporate both of these inventions into new operating practices for buildings that would eventually come to be expected by building owners and managers as normal operating procedure.

Causing energy-saving innovation has been a major focus of energy policy at least since the Arab oil embargo of 1973. Since then efforts to secure adoption of new technologies have become increasingly sophisticated. The introduction of the phrase "market transformation" reflects awareness of the importance of markets as a context for decisions affecting technology adoption.

This was not always the case. In the early years following the Arab oil embargo, the U.S. Department of Energy (DOE) was focused on the invention phase of innovation. This approach relied on an implicit mental model for how inventions might be commercialized that might be called the "better mousetrap model."[5] The idea was that, if you invent something useful and you make it known that you have done so, then the potential users will find you.

This model of innovation derives in part from the view, prevalent after the Second World War, that innovation was a linear process, proceeding from research to development to demonstration to commercialization. It is now widely recognized that this linear model of innovation does not describe a real world process. Real innovation processes typically involve complex interactions

[4] The *Oxford English Dictionary* (OED), quoting J.A. Allen, gives the following example of the use of the two words, "Innovation is the bringing of an invention into widespread, practical use. . . Invention may thus be construed as the first stage of the much more extensive and complex total process of innovation." (OED 1989, 7:998)

[5] Apologies to our European colleagues who may not be familiar with this Americanism. It is attributed, perhaps erroneously, to Ralph Waldo Emerson. Emerson is reported to have said in a lecture, "If a man can write a better book, preach a better sermon, or make a better mousetrap than his neighbor, though he builds his house in the woods the world will make a beaten path to his door." (Webber and Feinsilber 1999, 86).

and a lot of iterations among the steps (for example, Thomas 1994, Utterback 1996, and more recently, Laitner, Ehrhardt-Martinez, and Knight 2009).

Attempts to commercialize new products reveal deficiencies that require additional development, which may reveal deficiencies that require additional research; and so on. In fact, successful innovation often depends critically on good communication of information about product deficiencies that is learned downstream (for example, by retailers, installers, end-users) back upstream (for example, to developers, designers, marketers).[6]

The Pace of Innovation

The "better mouse trap model" of innovation now seems rather quaint, but the model may be appropriate for innovation in some markets. For example, the pace of innovation in information technology is truly astonishing and it seems as if there is an amazing appetite for better mousetraps in this area.. Unfortunately, energy use, and particularly energy use in buildings, is an area where the pace of innovation is slow and the mousetrap model does not apply.[7]

Obviously the pace of innovation is determined not just by the rate of invention but also by the rate of adoption. If adoption is slow, then innovation will be slow, even if the rate of invention is rapid. But, it seems reasonable to suppose that the rate of invention and the rate of adoption are dependent on each other. A high rate of invention creates many opportunities for adoption. Conversely, when rates of adoption are rapid, the incentives for invention are greater. That is, if the rate of adoption is high, then the likelihood that invention will lead to a payoff in the marketplace is greater. Under the right circumstances, the pace of innovation accelerates as rapid adoption stimulates further invention, and further invention spurs more rapid adoption. This is particularly the case where "first movers" can capture market share for mass produced goods (the newest razor or biotechnology product). This is hardly the case in commercial buildings markets, where there is little or no first mover advantage, since a well-received product cannot be quickly and exclusively produced to capitalize on market interest.

Innovation: Changing the Choice Set

The idea of choice sets can be helpful in thinking about market transformation policies and programs. In essence, market transformation is changing a choice set.[8] This can mean including something new in the choice set, eliminating something old from the choice set, or both.

[6] Research by economists on changes in energy and environmental technology recognizes that innovation may be stimulated by interventions "downstream" (Popp, Newell and Jaffe 2009). But, the emphasis of this work is on prices and command-and-control regulation and not on more nuanced market interventions, which require more detailed knowledge of the workings of particular markets.

[7] One question about innovation that needs more research attention is, what are the reasons for different rates of innovation in different areas of technology?

[8] More precisely we might say that market transformation is changing the probabilities of selection of elements from the choice set. [Eliminating something from the choice set makes its probability of selection zero.] Note that this changing of the probabilities might be accomplished by modest means (for example, the introduction of a new product into existing distribution channels) or by more far reaching measures (for example, a restructuring of a market).

Successful market transformation usually involves permanent, or at least long lasting, changes. If something is added to the choice set that benefits the consumer, then the expectation is that consumer self interest will tend to maintain the change. If something in the choice set (say inefficient refrigerators) is proscribed by setting standards, then the expectation is that legal sanctions will maintain the change.

Innovation is one process that changes choice sets. Market transformation focuses on the latter stages of the innovation. The objective is to find efficient (that is, both low-cost and effective) methods for introducing new elements into the choice set. An early example of this approach was the Super Efficient Refrigerator Program (SERP). SERP was an effort of a consortium of electric utility companies that offered a large prize to the appliance manufacturer who was prepared to produce and market the best very efficient refrigerator. The idea was that offering an incentive to a manufacturer to produce an efficient model was cheaper than trying to elicit the production of efficient models with consumer incentives for the purchase efficient models (L'Ecuyer *et al*. 1992; Feist *et al*. 1994)

While SERP succeeded in bringing an energy-efficient model to market, the program had its critics. The SERP refrigerator was a high-end, side-by-side model, although one that may not have competed very effectively even in that niche, and its influence on other refrigerator models has been questioned. Still it serves as a useful example of a strategy for putting something new into the choice set.

The strategy pursued with SERP has come to be known as “technology procurement.” This strategy has been refined in several different market contexts (Hollomon *et al*. 2002; Nilsson 2003). A recent example involves a very successful intervention in the refrigerator market in China (United Nations 2007). In spite of the political differences between the US and China, there are striking similarities between the Chinese efforts and SERP.

Improvements in refrigerator technology made it possible to implement another strategy for changing a choice set—that is, using standards to *eliminate* certain choices. In the case of refrigerators, U.S. efficiency standards have been wildly successful; over a period of twenty-five years the electricity consumption of the average new U.S. refrigerator has been reduced by around seventy-five percent.

Thus refrigerators provide a nice example of a market transformation strategy that relies on both consumer benefits and legal sanctions. Subsidies for innovation provide consumer benefits by encouraging the addition of more efficient products or practices to the choice set. The gains are institutionalized by performance standards that remove inefficient products from the choice set. Innovation establishes the feasibility of new technology; standards make the new technology mandatory. The result is a choice set that provides a range of products that are more energy efficient through the elimination of inefficient technologies and the addition of more efficient technologies.

A Research Program

Simply put, some of the elements of theory that would inform market transformation efforts include the following:

(1) Markets are heterogeneous,
(2) Markets mediate economic behavior, and
(3) One of the ways that markets mediate behavior is by providing a choice set from which consumers adopt highly energy-efficient or less energy-efficient technologies.

One of the things that theories do is help us to decide which research topics are worthy of attention. The elements of theory listed above suggest the need for a research program on markets. Below we describe some of the topics that might be included in such a research program.

Descriptive studies

Since markets are heterogeneous, an understanding of how markets mediate economic behavior requires the study of many different and specific markets. Much fieldwork needs to be done to develop descriptions of how specific markets actually work.[9] A nice example is contained in (Lutzenhiser and Biggart 2001) where the market for new "class A" office buildings is described. Studies like this can help to determine how choice sets are constructed and where there may be points of leverage for changing choice sets. Examples of markets that would be of interest are electricity supply, appliances, automobiles, existing housing, and building maintenance services.

Taxonomy

The language for describing markets needs to be refined so that descriptions of markets can become less amorphous. Analysis of descriptive studies of markets should lead to the construction of a taxonomy that can make description more systematic and comparison more precise. The economic discipline of industrial organization (IO) is a possible starting point for taxonomy. IO is concerned especially with the degree of competition in markets. Some of the characteristics that IO has identified as important in the description of markets are

- Entry (how difficult is it for new firms to enter the market? what are the barriers to entry?)
- Concentration (how many sellers and buyers are there? what is their relative size?)

[9] We recognize that a number of efficiency industry studies of "market effects" and "market baselines" have been conducted over the past two decades (see, for example, some of the reports archived at http://www.calmac.org/). We have reviewed some of that work and believe that it holds potentially valuable findings. However, many of the studies are focused narrowly on particular technologies at the retail level, and most results are available only in consultant reports that are often difficult to access. This body work should be more carefully assessed and synthesized through future meta-analyses, as should the experiential knowledge of energy efficiency program implementers working "upstream" from the point of consumer choice (Lutzenhiser et al. 2009). However, the grey literature and undocumented expert knowledge are not substitutes for rigorous comparative studies of markets.

- Transparency (is it possible to know all prices and product variants? how much effort is required to know them?)
- (Cross-)ownership (are there particular formal (legally binding) ties among sellers or with other stakeholders?)
- Government regulation (also the sometimes double role of government as owner and regulator is relevant.)
- Delineation and separability (how well can the market be distinguished from markets for substitutes or complements; are there a lot of spill-over effects to or from other markets or non-markets including environmental effects?)[10]

To these characteristics we might add

- Homogeneity of goods (this can range from very homogeneous (for example, electricity) to highly differentiated (for example, buildings)).
- Transaction repetition (do buyers make often repeated transactions (for example, grocery purchases) or infrequent transactions (for example, automobile purchases)?)
- Production modality of the market goods (there is a continuum here from craft-based production (for example, buildings) to mass production (for example, refrigerators).
- Social networks (what is the nature of the informal relationships among market participants?)
- Norms (what are the agreed upon standards of conduct for market participants? what sanctions are applied to those who violate the norms?)

This list is meant to be illustrative, not exhaustive. The purpose of the list is to suggest the variety of descriptors that may be important. The research task is draw upon existing theory in economics, sociology, and other disciplines to create a framework that will aid in the interpretation of descriptive studies.

The Evolution of Markets

More research is needed on the ways in which consumer culture and choices in the marketplace interact with producer/retailer decisions and efforts to shape consumption. As Wilhite et al. (2000) point out, we know a good deal more than we did two decades ago about energy use behavior, but we know relatively little about the codetermination of demand and how social “needs” are created. This knowledge is required in order for us to assess whether, when and how “social marketing” might appropriately (and effectively) be undertaken in this arena. (See Chapter XX by Patricia Thompson for more information on Social Marketing.) It would also greatly benefit nascent efforts to “transform” those consumer-producer systems (Blumstein et al. 2000, Lutzenhiser et al. 1998, Lutzenhiser and Janda 1999).

Government Policy and Choice Sets

The continuing expansion of societal energy consumption is evidence of growth in the development and diffusion of energy using devices and technologies. It is also evidence of the

[10] This list, slightly modified, was suggested by an anonymous reviewer.

effects of state policies that are formulated without regard for their energy and environmental consequences—for example, zoning and land use regulations, fuel subsidies, transportation planning, building codes, industry protection arrangements, and so on. The effects of these policy approaches in erecting and maintaining constraints on consumer choice and assuring an escalation of consumption should be examined. (Wilhite et al. 2000).

While many other research efforts can be imagined, those given above can make a significant contribution to the development of a theory of market transformation. It is worth observing that the development of such a theory would ramify far beyond energy policy, providing a significantly greater understanding of economic behavior in modern society.

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Behavioral Change Strategies That Work: A Review and Analysis of Field Experiments Targeting Residential Energy Use Behavior

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Introduction

Research on energy conservation has been dominated by a paradigm from engineering economics, which holds that economic agents adopt the most cost-effective technologies and practices [Duke and Kammen (1999), Gorlove and Eto (1996), Horowitz and Haeri (2001), Jaffe and Stevens (1995), Joskow and Marron (1992)]. Investigators analyze potential energy savings by estimating life cycle costs, and assuming that actors will adopt the technologies and practices with the lowest life cycle costs. In other words, residential and business energy consumers are assumed to base their product purchase and use decisions on purely economic considerations.

Following the first oil shock in 1973, North American policy makers became interested in energy efficiency and energy conservation. Early policy milestones included passage of the Emergency Highway Energy Conservation Act (1974), development of the United States Strategic Petroleum Reserve (1975), initiation of the Weatherization Assistance Program (1976), creation of the Department of Energy (1977), and enactment of the National Energy Conservation Policy Act of 1978. These policies were based on addressing market failures, market barriers, or both, with emphasis placed on the underlying economics of efficient technologies vs. conventional technologies [Kubiszewski (2008)].

The behavioral literature on consumer decision-making as applied to energy-consuming technologies has had little impact on energy conservation policies until comparatively recently [California Energy Commission (2003), Janda et al. (2002), Katvetz and Johnson (1987), Lutzenhiser (2002), Stern (2000)]. That began to change during the California energy crisis of 2000-2001. Then, while initial efforts to reduce consumption promoted technological solutions that boosted energy efficiency, the substantial demand reductions actually observed were due largely to conservation-related behaviors promoted through social marketing. This suggests that policy makers should re-examine the effectiveness of conservation-related behaviors in reducing energy consumption, and investigate how behavior-focused strategies can best be designed to encourage conservation. They should also determine how much energy savings can result from behavior-focused strategies.

Residential energy consumption is a function both of the efficiency of housing, appliances, and other equipment, and of energy-related behaviors such as turning lights on or off, changing thermostat settings, the length and frequency of showers, and the like. This chapter focuses on field experiments examining the impact of intervention strategies designed to influence household energy-related behaviors in ways that reduce consumption. We have three main objectives for this chapter:

- To develop a simple but reasonably comprehensive framework to examine the impact of energy-related behavioral strategies;

- To apply this framework to a review of field experiments testing the effectiveness of behavioral strategies, including information, goal setting, rewards, and feedback; and
- To model the impacts of these strategies on energy consumption using meta-regression analysis.

An outline of this chapter is as follows. Section 2 provides an overview of research on energy-related behaviors. Section 3 provides the theoretical framework for the empirical work, including summaries of rational choice theory and the theory of planned behavior, and a proposed integration of the two theories. Section 4 reviews energy-related behavioral field experiments focusing on information strategies, goal setting strategies, reward strategies, and feedback strategies. Section 5 summarizes the statistical approach, which is a meta-regression analysis. Section 6 provides the conclusions.

Research on Energy Behaviors

Energy researchers divide residential energy savings strategies into two approaches: those that promote energy efficiency without sacrificing amenity, through investments in building materials or technologies that provide the same benefits using less energy, and those that promote behaviors that lower energy use, often reducing amenity at the same time, such as turning lights off or reducing indoor temperature settings during winter, and raising them in summer (curtailment behaviors) [Martiskainen (2007)]. Researchers still debate which approach is more effective in reducing household energy consumption. Some studies have found that once initiated, curtailment behaviors are often maintained, sustaining long-term reductions in energy use [Geller (1981)]. Other studies have found that efficiency investments result in superior savings, both immediately and long term [Abrahamse et al. (2005)].

Further complicating this comparison is the rebound effect. Improving energy efficiency reduces the cost of the services that energy enables, such as heating, frequently boosting consumption of those services. Recent studies suggest that the rebound effect ranges from 10% to 30% for space heating, but it is less for space cooling and for other consumer energy services [Herring and Royal (2007), Sorrell et al. (2009)]. Many studies of energy efficiency are based on engineering algorithms that fail to account for rebound effects, as they usually simply assume that full load hours of use technology are the same for the base technologies and the energy-efficient ones. However, rather than assuming how much energy households are using, the field studies included in this review use household metering, which captures any rebound.

Research on energy-related behavioral strategies has been conducted from a variety of theoretical perspectives, but two of these have motivated the majority of field experiments: rational choice and the theory of planned behavior. There are additional theoretical perspectives stemming from applied psychology and social psychology, but these have yet to motivate significant numbers of field experiments, although some are contained in several overviews of alternative theoretical approaches for analyzing the influence of behavioral change on energy consumption [Jackson (2005) and Lutzenhiser (1993)].

Table 1. Comparison of Rational Choice Theory and Theory of Planned Behavior

	Rational Choice Theory	**Theory of Planned Behavior**
Decision model	Utility maximization based on fixed and consistent preferences	Behavioral intent and perceived control drive behavior
Decision scale	Individual	Individual
Main methods	Quantitative (observed behavior)	Quantitative (observed behavior and qualitative (surveys)
Main dependent variables	Preferences between decision outcomes	Observed or self-reported behavior
Main independent variables	Costs and benefits of outcomes and their respective weightings by consumers	Behavioral, social norm, and control beliefs of consumers
Empirical basis in energy use	Extensive	Extensive
Implications for behavioral interventions	Provide information about benefits and incentives to improve perceptions of cost-benefit ratios	Identify and target barriers and design salient and personally relevant information

Source: Adapted from Wilson and Dowlatabadi (2007)

Theoretical Framework

Rational Choice Theory

The rational choice theory, which is classical economists' perspective on consumer decision-making, argues that consumers seek to maximize net benefits. Although this model was originally applied exclusively to purchasing behavior, in recent years it has been extended to cover a wide range of other behaviors. In energy conservation, purchasing behaviors include buying and installing energy-efficient products such as high efficiency refrigerators or compact fluorescent lamps. Those behaviors that save energy absent commercial transactions include turning off the lights and turning down the heat at night [Becker (1976)]. Table 1 summarizes and compares the key features of rational choice theory and of the theory of planned behavior.

Four main factors bear upon consumer decision-making within the rational choice theory: consumer income, prices of goods and services, tastes and preferences, and the assumption that *Homo economicus* will maximize her utility, a formal way of saying she will seek the greatest satisfaction and pleasure possible from her consumption of goods and services. The costs of goods and services generally are well defined, but the costs of those behaviors that conserve energy are not. Nonetheless, these can be equated to the value of the time required to perform the energy conserving action, and that can be estimated from survey data [Ueno and Nakano (2007)].

A number of studies of energy-related behaviors have used the rational choice framework [Becker (1978), Bittle et al. (1979)]. Based on these studies, we argue that the best behavioral interventions are those that provide information and/or rewards, because both boost the potential for maximizing one's utility.

Theory of Planned Behavior

Two of the leading behavioral models in the field of social psychology are the theory of reasoned action and the theory of planned behavior. The theory of reasoned action was developed by Fishbein and Ajzen (1975) in response to a widespread view that traditional attitude-behavior research in social psychology had reached an impasse because correlations between measures of attitude and performance of voluntary behaviors were often weak [Hale, Householder and Greene (2003)]. Fishbein and Ajzen argued that if a person intends to undertake a behavior, then she is likely to undertake that behavior. Furthermore, Fishbein and Ajzen argued, her intentions are determined by her attitudes towards the behavior and her assessment of any social norms that are relevant to that action. In other words, performing a voluntary action is a function of intention, and intention is a function of both attitudes and social norms. The model has been widely applied in experimental studies, particularly studies of consumer behavior and studies in health-related fields.

A number of studies have found high correlations between attitudes and behavioral intentions and between subjective norms and behavioral intentions. That would appear to support the theory of reasoned action [Miller (2005)]. However, some studies have shown that intent is not necessarily translated into action, indicating that intent cannot be the sole determinant of behavior.

Ajzen (1985, 1991) subsequently introduced the additional factor of perceived behavioral control, where perceived behavioral control refers to the individual's perception that she has influence over an outcome. He called the revised model the theory of planned behavior. The theory of planned behavior depends upon four assumptions, summarized by Ajzen and Fishbein (1989) as follows. "1. Intention [I] is the immediate antecedent of actual behavior [B]. 2. Intention, in turn, is determined by attitude toward the behavior [A], subjective norm [N], and perceived behavioral control [PC]. 3. These determinants are themselves a function, respectively, of underlying behavioral, normative and control beliefs. 4. Behavioral, normative and control beliefs can vary as a function of a wide range of background factors." They further note that "actual control [AC]… is expected to moderate the intention-behavior relationship." Meta-analysis studies have demonstrated that this additional factor often helps to better explain the relationship between behavioral intent and actual behavior [Sheppard et al. (1998)]. We argue that for the theory of planned behavior, the key behavioral interventions are goal setting and feedback, because they bear directly on the issue of attitudes, subjective norms, and perceived behavioral control.

Towards an Integrated Model

We can integrate the rational choice theory and the theory of planned behavior into a simple framework as shown in Table 2. We use this framework to: (1) organize our review of energy-related behavioral strategies; and (2) model the impacts of these alternative strategies using meta-regression analysis. Antecedent interventions are those that take place before the behavior is performed, while consequent interventions are those that take place after the behavior is performed. In this framework, a statistically significant relationship between information and behavior and/or a significant relationship between rewards and behavior is interpreted as evidence to support the rational choice model. Conversely, a statistically significant relationship between goal setting and behavior and/or a significant relationship between feedback and behavior is interpreted as supporting the planned behavior model.

Table 2. Two Models of Behavioral Interventions

Model	Antecedent	Consequent
Rational choice	Information	Rewards
Planned behavior	Goal setting	Feedback

Behavioral Change Field Experiments

To identify potentially relevant studies, we reviewed the literature and databases in sociology, psychology, energy, and economics. To be included in this review, studies had to meet the following criteria: (1) the target group had to be households rather than businesses; (2) there had to be a plausible research design involving measurement of treatment effects using a comparison group, a control group, or a comparison with pre-program consumption; and (3) it had to be possible to quantitatively compare treatment group energy savings with those of the comparison group, or the control group, or with pre-program energy use. We reviewed over 60 studies and identified some 44 studies that met our selection criteria. The appendix summarizes critical features of these field experiments. It draws heavily on previous reviews by Abrahamse et al. (2005), Darby (2006), and Martiskainen (2007), but it supplements these reviews with summaries of recently published studies. In the remainder of this section, we summarize highlights from the review of field experiments.

Information

Reductions in energy use can be achieved in two ways: through measures that improve the energy efficiency of housing and technology, or through changes in behaviors that reduce energy use. In both cases, to make informed decisions, consumers require accurate, accessible, timely, and relevant information. Information serves several functions: (1) it increases consumers' awareness of energy-related problems and opportunities; (2) it enhances consumers' interest in addressing energy-related problems and opportunities; and (3) it provides consumers with knowledge of the characteristics, costs, and benefits of various alternatives, thus helping them to make rational decisions.

Important findings on information-based interventions include the following:

- Field experiments of informational interventions show a wide range of impacts on energy consumption. Among six field studies that reported using information alone as an intervention, the reduction in consumption ranged from 0% to 21%, with an unweighted average of 8%.
- The effectiveness of information tends to be driven by how specific and relevant the information is for a particular consumer or other energy user. General information tends to be less effective than tailored or customized information [Geller (1981), Winett (1985), Vollick (1999)].

- Mass media campaigns are useful in changing customers' attitudes towards and knowledge of energy use and energy-using technologies, but there is little evidence that they are effective in reducing household energy consumption [Statts (1986)].
- Personalized information, including home energy audits and tailored energy advice, appear to be relatively effective in encouraging conservation-related behaviors and thus in reducing energy consumption [Winett (1982-1983), McDougall (1982-1983), McMakin (2002)].

Goal Setting

Goal setting involves determining how much energy to save, over a specific time period. Either the experimenters or the subjects can set the goal. The goal may have multiple steps such as: (1) reduce consumption by 5% within six months, and (2) reduce consumption by 10% within a year. Goal setting is often combined with feedback.

Some critical findings on goal setting-based interventions include the following:

- Few studies reported using only goal setting as an intervention. For those field experiments that include goal setting as one of multiple interventions, the reduction in consumption ranged from 0.6% to 23%, with an unweighted average of 10.7%.
- Some evidence suggests that goal setting is more effective when combined with feedback, but more quantitative evidence is needed [Becker (1978), McCalley (2002), Van Houwelingen (1989)].
- Some evidence suggests that for consumers, setting higher energy savings goals leads to greater conservation than setting lower goals [Becker (1978)].
- Success in goal-setting experiments did not vary according to whether experimenters or subjects set the goals [McCalley (2002)].

Rewards

Rewards can motivate customers to reduce energy consumption both through their own value, and by signaling that reduced consumption is socially desirable. Rewards can be based on various metrics, including reduction in energy use per unit of time, or achieving a threshold level of reduced energy consumption.

Some key findings on rewards-based interventions include the following:

- No studies have used rewards as a lone intervention. For those field experiments which included rewards among the interventions, the drop in consumption ranged from 0% to 19.4%, with an unweighted average of 7.2%.
- Some studies suggest—just as Econ 101 might teach if they addressed this specific topic—that larger rewards lead to higher levels of energy savings, but with diminishing returns, i.e., a falling marginal reduction in consumption falls [Winett (1978), Tiedemann (2009)].

- Some studies suggest that the effect of rewards is short lived, and that for some customers, the reductions in consumption may not be permanent [Tiedemann (2009), McClelland (1978)].
- Rewards appear to work well when combined with feedback, such as in-home displays, which provides concrete signals to consumers and which reinforces the motivation to reduce energy consumption [Hayes (1978), Slavin (1981)].
- Rewards also appear to work well when combined with customized information on how a particular consumer can save energy, such as an audit of one's home [Hayes (1978)].

Feedback

Feedback involves providing consumers with information on their energy consumption, savings, or both. Energy savings can be compared with pre-experiment consumption, or with consumption of comparable households. Feedback helps consumers by showing them what measures get the most bang—or the least loss of amenity—for the buck.

Some findings on feedback-based interventions:

- Field experiments show widely ranging results. For nine studies that reported using only feedback as an intervention, consumption fell from 4% to 16%, with an unweighted average of 9.2%.
- Feedback works particularly effectively immediately after the consumer takes action to save energy [Geller (2002), Seligman (1977)].
- Some evidence suggests that increased frequency of feedback boosts energy savings [McClelland (1979-1980), Hutton (1986), Van Houwelingen (1989)].
- The evidence is mixed that feedback comparing one's energy savings to that of one's peers boosts savings [Bittle (1979-1980), Kantola (1984), Schultz (1998)].

Meta-Regression Analysis

The review of field experiments identified 28 conservation measures for which an effect size could be calculated, where the effect size is defined as the mean savings divided by the standard deviation of the savings [Tiedemann (2009b)]. The effect size is commonly used as an outcome variable in meta-analytic studies because it has two advantages in culling information from multiple studies compared to alternative approaches. First, the effect size is dimensionless because it is defined as the savings divided by the standard deviation thereof, so that the units cancel out. This means that studies with different outcome measures can be combined into a single analysis. Second, unlike statistical measures such as t-tests for differences of means, the effect size is not driven by the sample size. This means that the effect size is a measure of materiality or importance of an impact rather than a measure of statistical significance of an impact. In other words, a larger effect size indicates a stronger or more important impact.

The critical characteristics of the sample, including means, standard deviations, and partial correlations for the variables in the statistical models, are shown in Table 3. The mean values are 0.59 for the effect size, 0.64 for the share of treatments using information, 0.50 for the share of treatments using goal setting, 0.89 for the share of treatments using feedback, and 0.14 for the share of treatments using rewards. The partial correlations are mostly below 0.50 and present no problems, but the correlation between information and goal setting is very high at 0.74. Such a high partial correlation indicates the presence of multi-collinearity, which makes it more difficult to get accurate estimates of the impacts of alternative interventions when regression analysis is used.

Table 3. Sample Characteristics (n = 28)

	Effect	**Information**	**Goal Setting**	**Feedback**	**Rewards**
Mean	0.59	0.64	0.50	0.89	0.14
St. dev.	0.45	0.49	0.51	0.31	0.36
Effect	1.00				
Information	0.30	1.00			
Goal setting	0.38	0.74	1.00		
Feedback	0.43	-0.26	-0.12	1.00	
Rewards	0.52	0.30	0.41	0.14	1.00

Table 4 presents the results of the meta-regression analysis. We used White's robust ordinary least squares estimator to estimate the regression models. The regression coefficients estimate the impact of the presence of the intervention on the effect size. All of the results described below are statistically significant, except where otherwise noted.

Model 1 says that the effect size is a function of the presence of information as an intervention in the experiment. The partial effect of information is 0.28, so the presence of information increases the effect size by 0.28, if we ignore the impact of other interventions.

Model 2 says that the effect size is a function of the presence of goal setting as an intervention in the experiment. The partial effect of goal setting is 0.36, so the presence of goal setting increases the effect size by 0.36, if we ignore the impact of other interventions.

Model 3 says that the effect size is a function of the presence of feedback as an intervention in the experiment. The partial effect of information is 0.61, so the presence of feedback increases the effect size by 0.61, if we ignore the impact of other interventions.

Model 4 says that the effect size is a function of the presence of rewards as an intervention in the experiment. The partial effect of rewards is 0.66, so the presence of rewards increases the effect size by 0.66, if we ignore the impact of other interventions.

Model 5 says that the effect size is a function of information, goal setting, feedback, and rewards. The partial effect of information is 0; the partial effect of goal setting is 0.11 but is not statistically significant; the partial effect of feedback is statistically significant, at 0.65; and the partial effect of rewards is statistically significant, at 0.43. We interpret this to mean that feedback and rewards are effective interventions in reducing energy consumption, while information and goal setting are less so.

We can compare these five models on the basis of the Akaike's information criterion (AIC), which was developed in 1971 and proposed by Akaike as a measure of quality of fit of a statistical model. AIC is based on the concept of entropy with a smaller value being preferred, so that Model 5 is the preferred model.

Table 4. Meta-Regression Models

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Constant	0.41*** (0.059)	0.42*** (0.051)	0.040 (0.045)	0.49*** (0.086)	-2.24** (0.12)
Information	0.28*** (0.13)	-	-	-	0.21*** (0.074)
Goal setting	-	0.36** (0.15)	-	-	0.11 (0.098)
Feedback	-	-	0.61*** (0.095)	-	0.65*** (0.10)
Rewards	-	-	-	0.66*** (0.21)	0.43** (0.21)
Adjusted R^2	0.05	0.11	0.15	0.25	0.40
F	2.65 (0.12)	4.39 (0.05)	5.87 (0.02)	9.77 (0.00)	5.48 (0.00)
AIC	-1.59	-1.65	-1.70	-1.81	-1.95

Note: all values are statistically significant with two stars meaning it is significant at 0.05, and three stars meaning it is significant at the 0.01 level.

Conclusions

A number of utilities and independent researchers have undertaken field experiments aimed at understanding which interventions are most effective in reducing residential energy consumption through behavioral change. These behavioral interventions fall into four main types: information, goal setting, rewards, and feedback, as well as combinations thereof.

Information

Improvements in energy efficiency can be implemented in two ways, through adoption of technologies with greater efficiency, or through changes in energy use habits and behaviors. In both cases, consumers require accurate, accessible, timely, and relevant information to make informed decisions. Critical findings include the following. For the six field studies for which information was the sole intervention, the fall in consumption ranged from 0% to 21%, with an unweighted average of 8%. The effectiveness of information tends to be driven by how specific the information is and how relevant the information is for the particular context involved. Mass media campaigns are useful for boosting consumers' knowledge of energy-saving technologies and for changing their attitudes, but probably less effective in reducing household energy consumption. Personalized approaches including home energy audits and tailored energy advice appear to be relatively effective in changing behavior.

Goal Setting

Goal setting is an effective means for reducing energy use. To whit: field studies have shown reductions in consumption ranging from 0.6% to 23%, with an unweighted average of 10.7%. Some evidence suggests that goal setting may be more effective when combined with feedback, and that setting higher goals for consumers leads to greater savings. It makes no difference to the success of this strategy whether the consumer or the experimenter sets the goal.

Rewards

Rewards are motivating both through their intrinsic value to the consumer and by signaling that reduced consumption is socially desirable. Some key findings: consumption fell from 0% to 19.4% in the field studies, with an unweighted average of 7.2%. Some evidence suggests that larger rewards lead to greater savings, but that relationship appears subject to diminishing returns. Some studies suggest that the effect of rewards is relatively short lived. Rewards appear to work well when combined with feedback, such as in-home displays, which provide concrete signals to consumers and which reinforce the motivation to reduce energy consumption. They also seem to work well when combined with information customized to the consumer's particular situation.

Feedback

Feedback involves providing consumers with information on their rate of energy consumption, their energy savings, or both. For those studies investigating feedback only, consumption dropped from 4% to 16%, with an unweighted average of 9.2%. Feedback works particularly effectively when provided to consumers in real time, or at least immediately following performance of an energy-saving action. Some evidence suggests that the frequency of feedback positively influences energy savings, and there is mixed evidence that feedback comparing one's performance to that of one's peers leads to greater energy savings.

Effect Size

The effect size is the difference in energy consumption between the experimental subjects and the control or comparison groups divided by the pooled standard deviation, so that larger effect size indicates a greater impact. We used information from behavioral field experiments to build a database to model the impact of alternative interventions on the effect size. We compared alternative regression models on the basis of a standard model selection criterion, and we found that the model that uses all of the interventions as regressors works best. The relative impact of the four interventions on effect size varies substantially. The partial effects are 0.21 for information, 0.11 for goal setting, 0.65 for feedback, and 0.43 for rewards. We interpret this to mean that feedback and rewards are relatively effective interventions in reducing energy consumption, while information and goal setting are less so.

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Appendix. Summary of Behavioral Change Field Experiments

Study	Strategy	Treatment	Fuel	Country	Savings
Abrahamse (2007)	Information Goal setting Feedback	Two N = 189 5 months	Electricity Gas	Netherlands	5.7% to 6%
Becker (1978)	Information Goal setting Feedback	Four N = 100 1 month	Electricity	USA	0.6% to 15.1%
Benders (2005)	Information Feedback	One N = 190 5 months	Electricity Gas	Netherlands	8.5%
Bittle (1979)	Feedback	One N = 30 1 month	Electricity	USA	4%
Brandon (1999)	Feedback	Six N = 120 2 months	Electricity Gas	UK	3.1% to 7.5%
Dobson (1992)	Feedback	One N = 100 2 months	Electricity	Canada	13%

Study	Strategy	Treatment	Fuel	Country	Savings
Gaskell (1982)	Feedback	Two N = 160 1 month	Electricity Gas	UK	5% to 22%
Geller (1981)	Information	One N= 80 3 months	Electricity Gas	USA	0%
Haakana (1997)	Information Feedback	Two N = 105 21 months	Electricity Heat Water	Finland	3% to 21%
Harrigan (1994)	Information Feedback	Three N = 150 14 months	Gas	USA	14% to 26%
Hayes (1981)	Feedback	One N = 40 4 months	Electricity	USA	7%
Henryson (2000)	Information Feedback	One N = 1400 12 months	Electricity	Norway	10%
Henryson (2000)	Information Feedback	One N = 700 12 months	Electricity	Finland	2%
Henryson (2000)	Information Feedback	Two N = 1500 12 months	Electricity	Denmark	2% to 4%
Henryson (2000)	Information Feedback	One N = 1000 12 months	Electricity	Denmark	3%
Henryson (2000)	Information Feedback	One 12% N = 1400 12 months	Electricity	Sweden	2%
Henryson (2000)	Information Feedback	One N = 600 12 months	Electricity	Sweden	0%
Henryson (2000)	Information Feedback	One N = 1300 12 months	Electricity	Sweden	12%
Hirst (1982-1983)	Information	One N = 850 1 month	Gas	USA	4%
Hutton (1986)	Information Feedback	Three N = 300 1 month	Electricity Gas	Quebec, BC, California	4.1% to 7%
Kantola (1984)	Information Feedback	Three N= 118 1 month	Electricity	Australia	3.3% to 12.2%

Study	Strategy	Treatment	Fuel	Country	Savings
McCalley (2002)	Feedback Goal setting	Three N = 100 1 month	Electricity (clothes washing)	Netherlands	19.5% to 21.9%
McClelland (1979-1980)	Feedback	One N = 101 11 months	Electricity	USA	12%
McClelland (1980)	Information Feedback Rewards	One N = 500 3 months	Gas	USA	6.6%
McDougall (1982-83)	Information	One N = 1451 24 months	Electricity Gas	Canada	0%
McMakin (2002a)	Information	One N =1231 12 months	Electricity Gas (related to heating)	USA	10%
McMakin (2002b)	Information	One N = 175 4 months	Electricity (related to cooling)	USA	-2%
Midden (1983)	Information Feedback Rewards	Four N = 91 3 weeks	Electricity Gas	Netherlands	0% to 19.4%
Mountain (1996)	Feedback	Three N = 557 18 months	Electricity	Canada	6.5%
Nielsen (1993)	Feedback	Two N = 1500 36 months	Electricity	Denmark	1% to 10%
Schultz (2007)	Information Feedback	Three N = 290 1 month	Electricity	USA	2.3% to 8.3%
Seligman (1977)	Feedback	One N = 40 1 month	Electricity	USA	16%
Slavin (1981a)	Information Feedback Rewards	Three N = 166 3 months	Electricity	USA	1.7% to 11.2%
Slavin (1981b)	Information Goal setting Feedback Rewards	Three N = 255 3 months	Electricity	USA	4.7% to 9.5%
Sluce (1987)	Information	One N = 56 5 months	Electricity Gas	UK	13%

Study	Strategy	Treatment	Fuel	Country	Savings
Statts (2004)	Information Feedback	Three N = 150 24 months	Electricity Gas Water	Netherlands	2.8% to 20.5%
Tiedemann (2009)	Information Goal setting Feedback Rewards	Four N = 462 12 months	Electricity	Canada	0.6% to 5.3%
Van Houwe-lingen (1989)	Information Goal setting Feedback	Two N =285 12 months	Gas	Netherlands	4.6% to 12.6%
Vollick (1999)	Information Goal setting Feedback	Three N =48 5 months	Electricity Gas Water	Netherlands	15% to 23%
Winett (1978)	Information Feedback Rewards	Two N = 129 2 months	Electricity	USA	7.6% to 12%
Winett (1979)	Information Goal setting Feedback	Two N = 71 1 months	Electricity	USA	7% to 13%
Winett (1982-1983)	Information	One N = 51 1 month	Electricity (water heat, AC)	USA	21%
Winett (1985)	Information	One N = 150 1 month	Electricity Gas	USA	10%
Wood (2003)	Information Feedback	Three N = 41 14 months	Electricity (cooking)	UK	3% to 14%

Conclusions and Insights

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Introduction

Today, only a tiny fraction of households know how much energy they consume or how best to reduce their energy consumption. As such, American households may best be characterized as dis-empowered. At the same time, the evidence suggests that people want to reduce their energy consumption, whether for reasons of thrift, economy, or the environment. In fact, 78% of American's report that they should be spending thousands of dollars to increase the energy efficiency of their homes (Gallup 2007). And some people are trying to do their part as evidenced by the results of a recent survey in which a large proportion of Americans (85%) reported having taken some action to reduce their household's use of energy in the past year (Gallup 2010).

Despite the high level of interest and good intentions, however, most of the potential energy savings continue to go unrealized. Notably, the lost opportunity is significantly large. As documented in Chapters 2 and 3, the scale of potential, near-term energy savings from the residential and personal transportation sectors alone is likely to be on the order of 20-25% of current energy consumption in these sectors, or nearly 9 quadrillion Btu (quads) of energy. This level of savings is the equivalent of the energy from 240 medium-sized coal-fired power plants, or about 600 gallons of gasoline per household. From yet another perspective, it is about the same as the total energy consumption of either Brazil or Korea and just slightly less than the total energy consumed in the United Kingdom.

An important goal of this book is to draw attention to the potential energy savings that could be achieved by paying attention to the human dimensions of energy consumption, efficiency and conservation. The chapters presented in this volume clearly indicate that the most accessible, short-term energy savings are likely to come from engaging and empowering the American public. By choosing to put people first, we can start a real energy revolution, change America's energy culture, and significantly reduce our nation's energy consumption.

The chapters in this book represent a unique collection of insights from scholars and practitioners who have spent years and (in some cases) decades researching the human dimensions of energy consumption and energy savings. While by no means comprehensive, the topics range from research on the scale of potential energy savings, to the diversity of attitudes and beliefs, while providing critical insights about: 1) the energy savings that could be achieved, 2) new ways of perceiving and understanding America's energy culture and the diverse attitudes within it, 3) potential mechanisms and strategies for engaging and empowering American's to take action. The goal of this chapter is to use these three themes as a means of highlighting some of the insights from the various authors.

What Do We Have to Lose? The Cost of the Continued Marginalization of the Public

For decades, the U.S. has chosen to focus primarily on the development of new energy-efficient technologies as a means of addressing our nation's energy problems. The primary focus on technology generally assumed that new and improved technologies would be readily adopted by the masses and that technology adoption would be most of what was needed to successfully address the nation's growing energy demands.

In fact, new technologies have considerably slowed the rate of growth in U.S. energy demand. According to one recent study that looked at U.S. energy consumption between 1970 and 2010, energy efficiency successfully met three-quarters of the growth in energy service demands while new supplies met only one-quarter (Ehrhardt-Martinez et al. 2008). Nevertheless, total energy demand has continued to grow as a result of economic growth, population growth, and the continuous progression toward increasingly energy-hungry lifestyles. In other words, a purely technological approach has failed to stabilize or reduce energy consumption levels in large part because the demand for energy services continues to increase. As such, we can conclude that technological progress may be an important means for increasing energy efficiency but taken alone is insufficient to solve our nation's energy problems. Instead, successful approaches need to begin by understanding the social, cultural, and behavioral factors that have resulted in current levels of energy consumption and those that drive the growing demand for energy services.

What are the beliefs, values, knowledge, expectations, preferences, social structures, and practices that shape our current energy culture? How do they determine the rate of technology adoption? How do they determine wasteful energy practices and shape energy use norms? While energy-efficient technologies are an important component, reducing our nation's level of energy consumption also requires that we put people first. Such an approach acknowledges that new technologies are nothing more than tools for use by people. And as stated by Internet guru Clay Shirky, "A revolution doesn't happen when society adopts new tools, it happens when society adopts new behaviors." What if we fail to heed Shirky's insights? What do we have to lose if we fail to put people first and instead continue to marginalize the public in search of effective technological solutions? Historical evidence suggests that we lose our ability to achieve net reductions in energy consumption. Perhaps more subtly, we lose our ability to question our increasingly energy-hungry lifestyles, the social and cultural practices that drive them, and their impact on the planet and implications for future generations.

Alternatively, we might ask, what do we have to gain by recognizing and enabling the potential contributions of every day American's by putting people first? This question is the focus of the first three chapters of this volume. Chapter 2 by Dietz et al. suggests that household actions can provide a behavioral wedge that could rapidly reduce U.S. carbon emissions. According to the authors who estimated the "reasonably achievable potential for near-term reductions," households could reduce their emissions by 20%—an amount slightly larger than the total national emissions of France. Notably, these dramatic savings estimates are based on the consideration of only 17 household action types (compared to hundreds of possible actions) suggesting that even greater levels of savings are also reasonably achievable. Some of the largest reductions result from the adoption of fuel-efficient vehicles, although many others result from changes in everyday practices such as thermostat settings and driving behaviors. With roughly 38% of overall U.S. CO_2 emissions under the direct control of households, the authors readily recognize that there is much to gain by opening the doors to a more inclusive approach to solving the nation's energy and climate challenges.

In Chapter 3, Laitner and Ehrhardt-Martinez provide additional support for a people-centered approach, arguing that such an approach "may have a surprising scale which rivals a pure technology-based perspective in terms of expected efficiency gains." Although the methodologies employed in the research are different from those employed by Dietz et al., the chapter concludes that by addressing the human dimensions of energy consumption, near-term household energy savings may be on the order of 22%. Of particular interest is that while 43% of the projected energy savings are likely to come from changing investment decisions, more than half (57%) of the energy savings would result from either changes in everyday practices or low-cost energy stocktaking behaviors.

The insights from Chapters 2 and 3 are further supported through an interesting case study of a recent energy crisis in Juneau, Alaska. In Chapter 4, author Alan Meier reveals that a 30% reduction in electricity use is not only possible but has actually occurred. According to Meier, the electricity crisis in Juneau provides indisputable evidence of how a mobilized community can quickly and dramatically reduce power use through hundreds of tiny adjustments in people's daily activities. Notably, even a year after the crisis, Juneau residents have maintained roughly one third of their crisis-driven savings. In short, Chapters 2 through 4 provide strong evidence that there is much to gain by addressing our energy and climate problems by putting people first. But what does it mean to "put people first"? What does it entail and how do we do it? The next section of this chapter provides a review of some of the innovative insights and approaches suggested by the authors as a means of improving our understanding of America's energy culture and the diversity that exists within it. The final section presents policy insights and strategies

New Ways of Understanding America's Energy Culture and the Diversity within It

How might we best describe our current energy culture? What are the current sets of beliefs, practices and social institutions that define how we think about and use energy resources? The many chapters in this book provide us with some important insights about the ways in which Americans think about energy and climate change, about what motivates people to change their thinking and energy use practices, about how people decide to adopt an energy efficient or an inefficient technology, and about the diversity that exists within our current energy culture. This section attempts to highlight some of the important findings and conclusions across these four themes.

What Do Americans Think about Energy and Climate Change?

As discussed by Maibach et al. (see Chapter 8) Americans are far from unified in their perspectives on global climate change, ranging from alarmed to dismissive. In fact, survey evidence suggests that there are six distinct types of views concerning climate change. Those who are most concerned represent 18% of the population. They are convinced that climate change is human-induced and they support a broad-range of policies to reduce U.S. carbon emissions. Thirty-three percent of Americans are “concerned." This group holds many of the same beliefs as the first but they are less sure in their convictions. They also tend to be less involved in the issue and are less likely to take personal action. The next two groups, the “cautious” and the “disengaged.” represent 19% and 12% of the population, respectfully. The cautious group believes that global warming is real, but they are notably less certain and are less likely to believe that climate change is particularly dangerous or threatening. Not surprisingly they are much less likely to take personal actions of any kind to address global warming per se.

The fourth group, “the disengaged," haven’t thought much about climate change and are largely uninformed. Notably this group is most likely to say that they could easily change their minds. The final two groups, the doubtful and the dismissive, represent 11 and 7% of the population, respectively. People who are doubtful aren’t sure that global warming is happening at all and if it is, they believe that it is likely to be caused by natural changes in the environment. The small proportion of the population that is dismissive tends to be actively engaged in opposing national efforts to reduce greenhouse gas emissions. Most don’t believe that global warming is happening and that it’s not a threat to humans or the environment.

While there are relatively few distinct differences between the six groups in terms of education, income, employment or race, there are notable political differences. The segments that are most concerned about global warming tend to be more politically liberal and hold stronger egalitarian and environmental beliefs, while the less concerned segments tend to be more politically conservative and hold strong individualistic and religious beliefs. The findings from Maibach et al. provide important evidence that caution should be taken before creating a strong link between energy issues and the issue of global climate change when communicating with the general public. So what did the study reveal in terms of America’s perspectives regarding energy?

Perhaps one of the most noteworthy findings of the Maibach et al. study is that while there are distinct differences in the way American’s think about climate change, there is a “striking *commonality* among the Six Americas with regard to their efforts to save energy.” Among the shared perspectives, Americans agree on the importance of saving energy, they report taking many of the same energy-related actions, and they identify many of the same barriers that hinder their conservation efforts.

On a related note, the chapter reveals that most Americans are willing to participate in a national effort to transform the way we use energy. Even among the relatively small proportion of Americans who don’t believe in global warming—or are otherwise unconcerned about it—many believe that our country needlessly uses and wastes energy in unhelpful ways. Moreover, a large majority of Americans report that they are eager to reduce their own energy use, that reducing their energy use is like to improve rather than undermine their quality of life, and that they support a range of policies to reduce the nation’s energy use.

These findings suggest that while climate change may continue to be a contentious issue in America, efforts to save energy are not. However, as some of the other chapters in this volume reveal, we still have much to learn about what motivates people to action, about how people make decisions, and about the diversity in energy use practices.

What Motivates People to Change Their Thinking and Practices?

As aptly noted by Schultz in his Chapter 17 on social norms, most energy initiatives over the course of the past 25 years have relied primarily on a single strategy for encouraging energy conservation—providing consumers with information. More specifically, most of the information-related campaigns have focused on one of three topics: the energy saving benefits of certain new devices and appliances, the types of things that individuals and households can do to reduce their energy consumption, or information concerning government or utility programs designed to reduce energy consumption. The underlying assumption behind these campaigns is that people don't act because they don't know what to do. In fact, both Ehrhardt-Martinez (Chapter 14) and Schultz agree, that while information may improve people's knowledge, it doesn't necessarily result in new energy practices or energy savings. So what is needed to turn intentions into behavior?

The immediate suggestion of most people is economic incentives. However, according to Schultz, financial incentives have an unimpressive track record within the energy field overall because the unit costs of electricity and natural gas are so low and financial forms of motivation are generally very small and insufficient for motivating action. Instead both Ehrhardt-Martinez and Schultz suggest that that a combination of feedback, social norms and goal setting practices can be use to provide consumers with the necessary context to make the energy use information meaningful and a goal to work toward. By letting people know how their energy use compares to that of other people like them, they are able to assess their consumption in a meaningful context and determine whether their energy consumption is reasonable. Schultz's research also highlights the important distinction between descriptive and injunctive norms, and emphasizes the need to use both.

While descriptive norms describe common energy use practices, injunctive norms draw on social and cultural value systems to suggest favorable and unfavorable behaviors. The use of both has proven effective at reducing the likelihood that households consuming less than average will increase their level of consumption. Schultz provides detailed examples of the energy savings that such strategies can achieve, including an assessment of OPower's increasingly popular Home Energy Report program which has achieved savings as high as 8% for those households that set personal conservation goals.

In a similar vein, Mamo and Fosket's Chapter 16 on how green communities influence residents and mainstream America reinforces the notion that individual practices and behaviors are strongly influenced by the people around them. In their research on two master planned communities, Mamo and Fosket find evidence that "a combination of thoughtful building and community design practices along with social innovations can actually change the way people run their lives so as to augment energy savings beyond what technology and building design themselves might accomplish." Such communities find ways of making it easy and convenient to live lightly on the land through the thoughtful use of technologies and design practices. However the authors' research shows that much of the success also relies on collaboration with the residents in ways that result in a commitment to deeper environmental commitments and practices.

In a community designed around a commitment to sustainability, there are fewer barriers to engaging in energy-smart behaviors. When combined with the expressed goal of greener ways of living, people are encouraged to do things differently and the community begins to build social capital that serves to strengthen and reinforce energy-smart behaviors. Among the three lessons the authors highlight is the need for collaboration and commitment. Success requires that people commit to change and to living differently.

What Factors Shape the Energy-Efficiency Investment Decisions of Americans?

While the rational-actor model might suggest a simple cost-benefit test as the best means of understanding the energy efficiency investment decisions of most Americans, the research presented in Chapters 11 and 20 portray a very different reality. While economic factors are likely to play a role in many investment decisions, the degree to which they influence decision making is likely to vary depending on the particular purchase in question. Instead, the research and insights presented in these chapters suggest that a variety of non-economic factors both shape and constrain consumer choices.

In Chapter 11, Turrentine and Kurani explore the factors that drive vehicle choice in America. Contrary to popular conceptions, their interviews of 57 households across nine “lifestyle sectors” revealed that almost no households tracked gasoline costs over time or analyzed their fuel costs in any systematic way—either in their automobile or gasoline purchases. In effect, the authors found that households typically lack the basic building blocks of knowledge assumed by the model of economically rational decision making. They conclude that consumers didn’t “think about fuel economy in the same way as experts, nor in the way experts assume consumers do.”

The research did sugges/t new, and perhaps more nuanced, ways of thinking about consumers’ vehicle choices. Notably, like Schultz, Turrentine and Kurani surmise that gasoline costs over the past two decades have been too low for it to be “sensible” for consumers to be “rational." In other words, the economics haven’t been sufficient to motivate a change in behavior. A second insight from their research suggests that the value that most Americans place in fuel economy is about more than the differences in fuel costs. Instead perspectives on fuel economy often involve other symbols, meanings and values that are unlikely to be calculated in an economically rational algorithm.

Blumstein et al. (Chapter 20) offer additional insights about the factors that shape and constrain consumer investment choices by focusing on the ways that energy and product markets operate and how they differ from idealized conceptions of “the marketplace.” The chapter argues that “real markets” seldom resemble our mental models. Instead, market characteristics vary considerably as they are defined by the diverse group of market players and their repeated patterns of interactions. A more accurate understanding of market conditions would recognize that the actions of each player are the result of their own unique set of incentives and disincentives, regulatory constraints, and established rules and practices. In short, the authors argue that markets are complex social institutions and should be treated as such. It is only through an appreciation for the real market conditions associated with specific energy-efficient products and services that efforts to design market transformation programs are likely to be effective. Such programs would be based on better information about actual market conditions.

Such “real world” assessments of markets are similarly critical in determining the effect of such markets on the choices that are available to consumers. By gaining a much better understanding of the unique configurations of specific markets, we can also gain a much better understanding of the ways in which they shape and constrain the options and choices that are available to consumers. Subsequent market transformation initiatives could then find ways to use real market dynamics to restructure the consumer choice set to include more energy-efficient options and fewer less-efficient technologies.

How Much Diversity is there in America’s Energy Beliefs and Practices?

The diversity in American’s view concerning climate change have been widely publicized, however most research on energy consumption practices has tended to highlight the average consumer or household. This practice is called into question in Chapters 9, 10, and 14 by Lutzenhiser and Bender, Dethman, and Ehrhardt-Martinez. In Chapter 10, Lutzenhiser and Bender suggest that while average household energy consumption data is sufficient for some purposes, it masks the extreme variability in energy consumption in the residential sector. Unfortunately the use of averages precludes the possibility of understanding the underlying patterns of demand and to carefully target programs and policies. In addition, averages do not provide information about different rates of technology adoption or levels of energy use in the population—information that is increasingly necessary to understand the dynamics of trends and to identify differential equity outcomes. Finally, since the measures of “average” consumption are often taken to mean “typical” or “widespread," they are likely to result in unreliable conclusions regarding the effectiveness of specific policy and program interventions.

In order to investigate, the authors begin by documenting the dramatic variability in residential sector energy consumption. Within their sample of roughly 1600 households alone, electricity consumption ranged from several thousand kilowatt hours per year to more than thirty thousand. Importantly, the authors were able to provide evidence of distinctive social patterns of energy use by means of research that combines detailed survey data with billing histories of electricity and gas consumption and matched weather data.

This particular approach resulted in a more nuanced model of consumption at the household level, and revealed the important roles that social status, lifestyle, culture and social institutions are likely to play in shaping consumption. Among their findings, Lutzenhiser and Bender found that owner-occupied household and those with higher levels of income and/or more adults and older children consumed considerably more electricity. Ethnicity was also important such that Latino households were found to consume less electricity than non-Latino households. These patterns were found to be very robust across different climate zones and after controlling for other causal variables.

In addition to revealing the contribution of several important social variables, Lutzenhiser and Bender also sought to determine the relative contributions of social variables as compared to building-related measures or environmental measures. Their assessment suggests that social variables accounted for the largest proportion of variation in household electricity use (36%), compared to 9% for building characteristics, and 17% for environmental conditions. The remaining 39% represents the undifferentiable joint effects of people, environment and buildings.

The need to recognize important differences in the attitudes, practices, and behaviors of Americans is becoming increasingly apparent in other areas as well. Chapter 9 considers the importance of market segmentation research as a means of developing programs and policies that speak to all Americans and that recognize the opportunities and constraints that they face. According to Dethman et al. segmentation can be a powerful tool in speeding consumer adoption of products, services, or desired behaviors. Not surprisingly, segmentation often results in insights that contradict conventional assumptions about customers and their actual behaviors.

Among the program interventions that could benefit from a closer look at participant diversity are the increasing number of programs providing residential consumers with feedback. As described by Ehrhardt-Martinez in Chapter 14, preliminary evidence suggests that in addition to the diversity in energy consumption patterns, there appears to be significant diversity in how people respond to energy feedback. For example, some of the early evidence indicates that while energy saving strategies for households as a whole tend to heavily favor changes in everyday habits and practices, high-income households are more likely to make investments in new energy-efficient devices, appliances, and products. Similarly, households have also reported that they are motivated by different concerns, including self-interest (energy bill savings) for some as well as civic concerns and altruistic motives for others.

This collection of research provides strong evidence that there is much to gain through the development of a more nuanced understanding of America's energy culture and the diversity within it. Of particular note is the fact that while these chapters represent some of the most influential work being done on the topic, they are only representative of a much wider body of literature revealing additional insights and lessons for program and policy development, implementation, and evaluation. New work on these topics is presented annually at the Behavior, Energy and Climate Change Conference co-convened by the American Council for an Energy-Efficient Economy, Stanford University's Precourt Energy Efficiency Center, and the California Institute for Energy and Environment.

Policy Insights and New Strategies for Engaging and Empowering Americans

Opportunities to save large amounts of energy through people-centered interventions are numerous, particularly given the relatively recent recognition of the unique benefits that they can provide: relatively low cost energy savings in a relatively short time frame. In this section we review several policy insights and new strategies for engaging and empowering Americans to save energy. The section begins with a discussion of the rebound effect and the ways in which people-centered initiatives can reduce rebound through much needed shifts in our country's energy culture. Three subsequent subsections discuss: 1) several means of empowering households to take control of their energy service demands, 2) policy strategies that can make smart-energy choices easier, and 3) utility strategies and insights for engaging consumers and reducing residential sector energy demand.

Reigning in the Rebound Effect with People-Centered Initiatives

In Chapter 7, Ehrhardt-Martinez and Laitner present historical evidence that suggests that in the absence of people-centered initiatives, efforts to increase energy efficiency often result in increased energy service demands. The phenomenon is commonly known as the rebound effect by which a portion of the energy savings achieved through the application of more energy efficient technologies is taken up to meet new energy service demands. According to the authors, the direct effects of rebound vary, but in some cases can be as high as 30% of efficiency-related savings. Similarly, evidence from the larger literature on the economy-wide effects of rebound suggests that they may result in the loss of 20 to 30% of expected energy savings.

Among the insights provided by this chapter is a rough mapping of the causal pathways through which rebound occurs. As energy demand declines, energy prices and the cost of energy services also decline, providing new financial capacity for using a greater quantity of energy services. As long as energy price, energy costs and disposable income provide the only limits to the demand for energy services, some fraction of energy-efficiency related savings is likely to be lost to the rebound effect. In other words, the application of energy efficient technologies alone is not likely to provide absolute reductions in our nation's energy consumption unless people recognize the need to manage their consumption and create a culture that values sufficiency as well as efficiency (see also the discussion by Harris et al. in Chapter 6).

Empowering Households with Energy Management Tools and Goals

How do you transform the energy culture of an entire nation? Such an effort requires that all members of society participate in the solution. Chapters 13 and 15 provide some insights and innovative thinking about ways of engaging households through the application of new energy management tools and goals.

Among the most effective means of helping people acquire a better understanding of their energy service demands and to actively manage their energy consumption practices are the many new approaches to feedback that are being developed and piloted (largely in conjunction with the development of Smart Grid technologies). Donnelly provides an overview of both the technologies and the programs that are proving to be the most effective in generating energy savings and the need for feedback programs to do more than simply provide information. Despite the promise of new feedback technologies, Donnelly's research suggests that the widespread use of the most effective forms of feedback in American households is unlikely unless utilities and utility commissions support the prominent participation of third-part providers who can respond quickly to consumer demands.

There is a growing number of companies and non-profits who are entering the field and who are providing a widely diverse set of products and programs. As Donnelly describes in detail, such programs range from printed reports delivered through the mail, to complex energy management systems that provide both feedback and automated control of discrete energy end uses. Each of these requires a different level of consumer participation and requires a different level of professional support. The variation in costs is also fairly dramatic. Of particular note however, is the growing recognition among feedback technology providers that people need more than energy data. More specifically Donnelly notes that feedback technologies need to present the information in ways that provide meaning and motivation to consumers, increasing the likelihood that they will act in ways that save energy. As such, among the contributions of her chapter, Donnelly documents some of the ways in which different feedback technologies have integrated social and behavioral insights through the incorporation of social norms, personal goal setting, and commitments. One of the real benefits of feedback programs is that they provide households with the flexibility of determining which mix of energy saving strategies is most appealing to them as opposed to efforts that only reward consumers who adopt a particular technology.

In Chapter 15, Parag and Strickland discuss the concept of personal carbon allowances (PCAs) and related policies that would allow governments to impose a cap on individual carbon emissions and provide a mechanism by which individuals would need to actively manage their use of carbon-emitting energy resources. Like Dietz et al. (Chapter 2), Parag and Strickland document that roughly 40% of carbon emissions are under the direct control of households, suggesting significant opportunities for emissions reductions. Such reductions could be achieved through the application of PCAs—a downstream cap and trade policy mechanism in which emissions rights are allocated to individuals. This approach has been suggested and discussed, to some extent, within the UK Government. In comparison with the use of personal goals in many feedback programs, this type of approach would provide all individuals with annual carbon emissions budgets.

The approach is based on the premise that while significant emission reductions could be achieved by reducing the carbon content of energy, doing so would require fundamental, expensive and time consuming infrastructural changes to our energy supply systems. Therefore, until low carbon energy is widely available, emission reductions will need to come from reducing energy demand, which entails behavioral change. The authors propose the use of three basic interacting mechanisms to shape energy-related decisions that draw on three different means of inducing behavioral change: economic, psychological, and normative.

Importantly, the implementation of PCA could avoid some of the pitfalls associated with carbon taxation schemes. First, it increases the visibility of carbon, and delivers a message which is broader than pure supply and demand economics. Second, it meets a basic standard of fairness, as all individuals receive an equal allowance. In addition, PCA is broadly progressive, because the high emitters (who will pay more) have a propensity to be on higher incomes. Fairness is important because policies which are perceived as fair have been shown to be more politically acceptable. Following a detailed exploration of the potential strengths and weaknesses of a PCA scheme, the authors conclude that PCA is especially innovative in its ability to change behaviors in ways beyond those achievable by price or taxation policies or information schemes alone—all while guaranteeing given emissions reductions from the domestic sector.

Using Policy Levers to Make Smart-Energy Choices Easier

While many chapters in this volume advocate for engaging households through thoughtful energy management practices, policies will necessarily play a critical role in making smart energy choices as easy as possible. In fact, several of the chapters suggest policies that could facilitate better energy practices. Among these, Chapter 6 focuses on the need for progressive efficiency standards, while Chapters 5 and 12 discuss means of integrating behavioral considerations into residential construction and retrofit policies on the one hand, and the ways in which behavioral economic principles may improve the design of usage-based car insurance products.

In Chapter 6, Harris et al. discuss the growing level of concern over the inability of current U.S. energy policies to generate absolute reductions in energy consumption. The authors suggest that the nation's present conundrum is the result of the persistent ambiguity about the main thrust of energy-saving policies at both the national and state levels. In most cases the focus remains strictly on efficiency although there has been a notable increase in the level of interest in energy consumption management. In response, the authors suggest the need to frame policy goals in terms of energy consumption or greenhouse gas emissions in order to determine the right mix of efficiency and conservation. They introduce the concept of "progressive efficiency" as an approach to efficiency in which the required level of efficiency is tied to the scale of energy use or energy service demands whereby increases in the later are used to determine efficiency standards.

As the scale of energy use increases, so too must the level of energy efficiency. Harris et al. illustrate the importance of the concept through its application in terms of the energy efficiency of homes, appliances and televisions. In each of these cases, most measures of efficiency indicate that much progress has been achieved. However, many of the building efficiency improvements have been offset by the growth in the average size of new U.S. homes, and the growing saturation of major appliances, home electronics and amenities such as pools and spas. As noted by the authors, although building a bigger house to be energy efficient will *save* more energy than building a smaller house at the same level of efficiency—the larger house will still use more energy. The good news is that some programs are beginning to incorporate progressive efficiency standards. In the case of green building rating programs, some require that larger homes achieve higher levels of efficiency so as to offset the larger energy demand associated with larger homes. Notably, the EPA is moving in a similar direction for their new appliance ratings. The authors conclude by suggesting that progressive efficiency represents a useful and politically feasible first step in helping people manage energy consumption. Whether through home energy rating systems or appliance energy labels, progressive energy standards convey the message that "size matters."

In Chapter 5, Brown et al. evaluate the strengths and weaknesses of three proposed federal policies using seven distinct criteria: appropriateness of the federal role, broad applicability, significant potential benefits, solutions not dependent on future R&D, cost effectiveness, administrative practicality, and additionality (the potential to catalyze additional energy saving opportunities). The three policies include the advancement and enforcement of state building energy codes, the expanded use of home energy performance ratings, and the mandated disclosure of home energy performance information. After the thoughtful evaluation of the strengths and weaknesses of each, the authors conclude that each of the three policies holds great promise to transform building practices in the United States. Among the three, the potential efficiency benefits of more stringent state building energy codes could result in residential energy savings of 15-17%, while savings from the expanded use of home energy rating systems were estimated to result in energy savings of 20% in those cases where the rating system resulted in home energy retrofits. Finally, the energy saving benefits of mandating the disclosure of energy performance information resulted in estimated savings of approximately 29 million Btu per year. Each of these policies would facilitate smart-energy decisions and practices on the part of consumers.

In Chapter 12, Greenberg explores the potential application of behavioral economics principles in efforts to reshape existing patterns in vehicle miles traveled and reduce transportation-related energy consumption. More specifically, Greenberg examines pay-as-you-drive-and-you-save (PAYDAYS) insurance products as a means of encouraging voluntary reductions in driving that reduce congestion, air pollution and crashes. Notably, Greenberg's exploration of a variety of behavioral economics research finding leads him to conclude that the application of such principles is likely to result in substantial reductions in total vehicle miles traveled. Among the proposed target customers who would benefit most from PAYDAYS insurance pricing are those that typically drive fewer miles, that pay higher premiums, that have lower levels of income, that live in urban areas with alternative transportation options, or that are highly concerned about the environmental implications of their driving practices. Among the approaches that would result in the greatest savings are insurance cost strategies that charge on a per-mile or per-minute basis with frequent billing cycles and programs that provide low-cost alternative transportation options through negotiated price discounts for unlimited ride transit passes. Interestingly, Greenberg doesn't recommend that such policies be mandates but instead uses behavioral economics principles to develop a choice structure in which people are more likely to choose to drive less.

Utility Strategies for Helping Residential Consumers Reduce Energy Consumption

Energy utilities play an important role in shaping the attitudes and practices of residential energy consumers. This final section of the conclusions, reviews the insights of three chapters that consider current utility practices, assess the effectiveness of past behavior-based initiatives, and suggest innovative ways of improving behavioral program initiatives as well as utility policies that serve to constrain consumer choices and behaviors. For example, in Chapter 21, Tiedemann provides a review and analysis of utility-led field experiments that target residential energy use behaviors. His conclusions reveal which programs were successful in achieving the most significant energy savings. In Chapter 19, Vine suggests a utility-specific strategy for integrating behavioral change initiatives into a greater proportion of utility programs so as to ensure maximum energy savings. Finally, Chapter 18 evaluates three policy case studies that could help bring about a transformation in the role of utilities by blending knowledge about the behavioral barriers to residential energy efficiency with an understanding of how utilities interface with their residential customers.

In Chapter 21, Tiedemann applies a framework of criteria to evaluate the impact of different types of utility-led behavioral strategies, including information campaigns, goal setting, rewards and feedback. The evaluation framework is applied to a review of a series of specific field experiments. The author then uses the findings to model the impacts of these strategies on energy consumption using meta-regression analysis. Among the most notable findings, the author concludes that energy savings from information programs range from 0 to 21% with average savings on the order of 8%. Importantly, however, the effectiveness of information is tied to the level of specificity provided by the information and how relevant it is for the context in question. Tiedemann's findings support the notion that while mass media can be effective in changing knowledge and attitudes, it is generally relatively ineffective in changing behaviors.

Goal setting was found to be particularly effective with energy savings of 10.7%. As suggested in other chapters, Tiedemann concludes that goal setting may be more effective when combined with feedback. Alternatively, the effect of rewards programs was found to reduce consumption by an average of 7.2%. Tiedemann's research suggests that while larger rewards often lead to greater savings, that relationship tends to be subject to diminishing returns. Also, as with information campaigns, the use of rewards is thought to be more effective when combined with feedback. Tiedemann's assessment of feedback-only programs indicates that energy consumption fell by an average of 9.2% and that feedback is generally found to work better when it is provided in real-time or shortly after the performance of an energy-saving action.

In Chapter 19, Vine presents a conceptual framework designed to help utilities to better address behavior concerns throughout their portfolio of programs and in all stages of a program life cycle with the goal of increasing the ability of utilities to maximize behavior-related energy savings. Vine's assessment indicates that an integrated, program-wide approach is needed to provide maximum benefit to utility customers. Such an approach would include a variety of essential features from program design to program implementation to program evaluation, including efforts to identify important market segments, determine program types, decide on program measures, involve market stakeholders, develop program and market logic models, determine evaluation needs, assess energy and non-energy impacts and measure the cost-effectiveness of the program. The development of a standard process for integrating behavioral insights into the practices of utilities would provide a means for the systematic design, implementation, and evaluation of programs that have the behaviors of residential consumers in mind. Such practices are likely to result in more effective programs that empower consumers to develop better energy practices.

Finally, in Chapter 18, Brown et al. explore the potential benefits of three policies that could help transform the role of utilities through the alignment of ratemaking policies and utility regulations with the vision of utilities as least-cost providers of energy services. These policies include on-bill financing of energy-efficiency improvements, performance specifications for smart meters and expanded demand response, and the alignment of the financial incentives of utilities with customer energy efficiency goals.

As part of the review, Brown et al. identify several non-technical obstacles that have continued to impede investments in home efficiency improvements by households. Among the most important barriers identified by Brown et al. are 1) high up-front costs and misplaced incentives, 2) incomplete and asymmetric information, and 3) a workforce knowledge gap. However, Brown et al. suggest that by partnering with utilities, each of these barriers could be addressed. The authors conclude that among the three policies reviewed, the expanded use of on-bill financing is likely to achieve energy savings in the range of 27 to 32 trillion Btus by 2030 while improved performance specifications for smart meters including sustained meaningful pricing structures could result in household-level energy savings of as much as 20%.

Finally Brown et al. assess the promise of policies that would decouple utility revenues and profits through a periodic and frequent true-up of projected sales and other mechanisms and that would provide financial incentives to shareholders to ensure a fair return on investment for achieving energy-efficiency program objectives. Notably the authors cite estimated energy savings as calculated by the NAPEE Leadership Group indicating that more than half of the expected growth in the demand for electricity and natural gas could be avoided over the next 15 years by extending energy efficiency "best practices" programs to the entire country in conjunction with regulatory reform. The implementation of such policies could reduce the barriers faced by consumers by reducing the upfront costs of investing in energy efficiency improvements, increasing customer access to energy use feedback, and expanding the range of utility-lead energy savings programs.

For the past 30 years, Americans have often been told that the solutions to our nation's energy problems lie in the hands of government, utilities, and corporations who are invested in finding new energy resources and developing new, energy-efficient technologies so Americans can continue to demand an ever greater amount of energy services. This kind of approach is consistent with our nation's current energy culture and the values and beliefs that underlie it. However, given the emissions constraints imposed by climate change, the finite nature of most existing energy resources, the limitations in the short or medium-term availability of renewable sources of energy, continued growth in the U.S. population, and the need for continued growth in the economy, there is an urgent need to rethink our assumptions about solutions to both energy and climate constraints. For reasons cited throughout this volume, the most effective solution will likely require that we put people first and that we engage the broader public to be part of the larger set of energy and climate solutions. Such an approach would recognize the need to find the right balance between efforts to increase energy efficiency and efforts to promote fair and equitable reductions in energy consumption. As discussed in Chapters 6, 7, and 15 a failure to address the rapid expansion in energy service demands could well continue to forestall the ability of energy efficiency initiatives to achieve net reductions in the nation's level of energy consumption or make a meaningful contribution toward the needed reduction in climate emissions.

The evidence presented in Chapters 2 though 4 clearly convey three important insights: that addressing the human dimensions of energy consumption can result in large scale energy savings—an estimated savings of 9 quads; that much of these savings can result from changes in everyday habits and practices; and that rapid and lasting energy savings are possible if we put people first. In order to achieve these savings, we need to engage and empower the broader public to become part of America's energy solution. In order to do so, we must first develop new ways of perceiving and understanding America's current energy culture and the diverse attitudes and practices that comprise it. Secondly, we must identify the most effective mechanisms and strategies that will successfully engage and empower Americans to take action. The chapters presented in this volume represent some of the best thinking in this regard and include the insights from scholars and practitioners who have spent years and (in some cases) decades researching the human dimensions of energy consumption and energy savings. We hope they might catalyze new ideas and new ways of thinking about the solutions to America's energy and climate problems and spark the revolutionary change that we need.

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ENERGY STAR® program, the California Energy Commission, PG&E, NRDC, NYSERDA, and Natural Resources Canada. Internationally recognized for his ability to successfully make the technical, economic and political arguments for setting stringent product efficiency specifications for voluntary programs and mandatory government standards, Chris's areas of expertise include external and internal AC-DC power supplies, battery chargers, computers, servers, televisions, set top boxes, monitors, residential lighting (fluorescent and general service incandescent), ceiling fans, swimming pools, heat pump water heaters, and automotive tires. Along with three peers, he was honored by ACEEE as a Champion of Energy Efficiency for his pioneering research and policy efforts in external power supply efficiency. He has served on the editorial board of *OnEarth* since 1995 and on *Home Energy*'s board from 1995 to 2006. Chris holds a Bachelor of Arts in environmental studies from Trinity University and a Masters of Science from the Energy and Resources Group at the University of California at Berkeley.

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Kat A. Donnelly is the Founder and President of EMpower Devices and Associates, an organization providing simple, cost-effective energy management solutions emphasizing the customer/user perspective. Previously, she managed numerous local and regional planning studies, as well as large transit and transportation infrastructure projects at the San Diego Association of Governments in California. Kat is also a Ph.D. Candidate at the Massachusetts Institute of Technology examining the impact of technology and consumer behavior on energy consumption and efficiency. She is particularly interested in using technology systems to deliver social and individual behavior techniques that result in reduced energy waste. She received dual M.S. degrees in Sustainable Energy Technology & Policy, and Civil & Environmental Engineering from MIT. She earned her undergraduate degree in Civil Engineering from San Diego State University.

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Jonathan Gilligan is Associate Professor of Earth and Environmental Sciences at Vanderbilt University and Associate Director for Research at the Vanderbilt Climate Change Research Network. He holds a Ph.D. in Physics from Yale University and a Bachelor of Arts in Physics from Swarthmore College. His research interests focus on transdisciplinary approaches to environmental problems, bringing experts in natural sciences, social and behavioral sciences, and engineering together to explore interactions between human and natural systems. As coordinator of the Transdisciplinary Initiative on Environmental Systems in Vanderbilt's graduate curriculum in environmental sciences, he introduces doctoral students to transdisciplinary approaches to such topics as nuclear waste disposal and water resources in Bangladesh.

Allen Greenberg has 20 years of experience in analyzing and advocating for sustainable U.S. transportation policy at the national and regional levels from both inside and outside of government. For the last ten years, Allen has been employed as a senior policy analyst at the Federal Highway Administration (FHWA), where he plays a leadership role with the Value Pricing Pilot Program and the Urban Partnership Program, including soliciting and managing transportation pricing pilot initiatives. Prior to joining FHWA, Allen spent two years at the U.S. Environmental Protection Agency Office of Policy, where he directed the Transportation Partners Program, which provided grants and technical assistance to national nonprofit organizations promoting local sustainable transportation initiatives. Allen has authored seven peer-reviewed research papers covering a very broad array of issues related to pay-as-you-drive insurance. Allen holds a Masters in Urban and Regional Planning from the University of Virginia and a Bachelor of Science in Public Policy and Management from Carnegie Mellon University.

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John A. "Skip" Laitner is Director of Economic and Social Analysis for the American Council for an Energy-Efficient Economy (ACEEE) in Washington, D.C. He previously served as a Senior Economist for Technology Policy for the U.S. Environmental Protection Agency (EPA). In 1998 he was awarded EPA's Gold Medal for his evaluation of the impact of different greenhouse gas emissions reduction policies and his 2004 paper, *How Far Energy Efficiency?,* catalyzed new research in the proper characterization and scale of energy efficiency as a long-term resource. Author of more than 260 papers, book chapters, and journal articles, Laitner has four decades of involvement in the environmental and energy policy arenas. He has also served as an adjunct faculty at the Virginia Polytechnic Institute and State University and the University of Oregon. Laitner's current research focus is to integrate people-centered insights and new mechanisms of governance as a means to double or even triple the historic rate of energy efficiency improvement as a critical step toward maintaining a robust and environmentally friendly economy. He has a master's degree in Resource Economics from Antioch University in Yellow Springs, Ohio.

Melissa Lapsa leads Oak Ridge National Laboratory's (ORNL's) Sustainable Campus Initiative and is Group Leader of the Whole-Building and Community Integration (WBCI) research group for the Building Technologies Research and Integration Center at ORNL. The WBCI Group is committed to developing partnerships that accelerate the integration of renewable resources, energy-efficient technologies, and advanced energy management into thriving buildings and communities. The WBCI supports the U.S. Department of Energy. Ms. Lapsa has established many cost-share partnerships with industry and utilities including Wal-Mart, Aurora Ballast, LSI Industries, Long Island Power Authority, the Tennessee Valley Authority, and the Sacramento Municipal Utility District. From 1996-1998, Melissa Lapsa was on assignment from ORNL to the Netherlands Agency for Energy and the Environment (NOVEM). Ms. Lapsa presented International Energy Agency (IEA) Energy and Environmental Technologies Information Center (EETIC) programs in eight different countries while on assignment to NOVEM, including at the United Nations Framework Convention on Climate Change (UN FCCC) third Conference of Parties (COP-3) Summit in Kyoto, Japan. Ms. Lapsa received her M.B.A. from Western Illinois University and her B.A. from St. Mary's University.

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Edward Vine is a Research Coordinator at CIEE where he leads the Environmental Program. Dr. Vine has provided technical and management assistance to CIEE since its inception. He is currently providing technical assistance to the California Public Utility Commission (CPUC) and the U.S. Department of Energy on evaluation and program-related issues on energy efficiency, demand response, renewable energy, behavior, and climate change. Dr. Vine is also a Staff Scientist at the Lawrence Berkeley National Laboratory (LBNL), where he has been involved in the evaluation of energy efficiency programs and technology performance measurement for over 30 years. He contributed to the development of the California Public Utility Commission's Energy Efficiency Evaluation Protocols, the U.S. Department of Energy's Impact Evaluation Framework for Technology Deployment Programs, and the National Action Plan on Energy Efficiency's Evaluation, Measurement and Verification Guidelines. He is currently on the Board and the Planning Committee of the International Energy Program Evaluation Conference (IEPEC) and on the Board of the Association of Energy Services Professionals Foundation. He has received the following awards related to his work on evaluation: the Lifetime Achievement Award from the IEPEC, Outstanding Achievement in Marketing Research and Evaluation Award from the Association of Energy Service Professionals, and Certificates of Appreciation from the IEPEC and from the International Performance Measurement and Verification Protocol organization. In 2007, as a member of the Intergovernmental Panel on Climate Change, he received the Nobel Peace Prize. Dr. Vine has a B.S. in Environmental Studies from Middlebury College, and a M.S. and Ph.D. in Ecology from UC Davis.