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

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ABSTRACT

A recent book by Horace Herring and Steven Sorrell (Energy Efficiency and Sustainable Consumption: The Rebound Effect) suggests that energy efficiency will not be successful in reducing energy consumption and that a reliance on energy efficiency to reduce carbon emissions may be misguided. Such claims are rooted in concerns over the rebound effect and raise important policy issues. Do improvements in energy efficiency cause people to use *more* energy? Do energy service demands increase when appliances and technologies become more efficient? In other words, is rebound best understood as a social and behavioral response to technology-based solutions? Alternatively, how might a shift from technology-focused policies to people-centered policies offset the tendency toward increased energy service demands and promote energy resource management? This paper summarizes the evidence regarding the prevalence and characteristics of the rebound effect, documents its historical contribution to U.S. energy consumption, and considers the causal relationships which both result in rebound and suggest potential mitigation strategies. The second section explores the impact of different types of program strategies on energy efficiency, energy conservation, and rebound. The paper concludes with a discussion of the strengths and weaknesses of people-centered versus technology-focused approaches to reduce energy consumption and accelerate carbon savings.

Introduction

In the United States, and around the globe, there is a clear need for immediate large scale, affordable alternatives that can reduce our inefficient use of energy resources (Laitner et al. 2009b). More productive and cost-effective investments in greater levels of energy efficiency can reduce the upward pressures on and the volatility of energy prices as well as reduce the GHG emissions burden (American Physical Society 2008; Committee on America's Energy Future 2009; and Laitner 2009b). Furthermore, energy efficiency investments can do all this while maintaining the production of the many goods and services demanded by our economy, and according to many analyses, actually increase net employment opportunities (Laitner and McKinney 2008, McKinsey 2009, Laitner 2009b; and Roland-Holst et al. 2009).

Despite the promise of significant cost-effective energy efficiency improvements, recent studies highlight evidence suggesting that energy efficiency improvements, at whatever scale, are likely to consistently fall short in delivering the expected energy savings potential (Herring and Sorrell 2009). One oft cited explanation is that improvements in energy efficiency may actually encourage greater demand for energy services than expected (for example, warmer homes or greater travel) which reclaim a portion of the anticipated energy savings (Calwell 2010). These social and behavioral responses to energy-efficiency improvements have come to be known as the energy efficiency "rebound effect" (Sorrell 2007). This paper summarizes the evidence regarding the prevalence and characteristics of the rebound effect, documents its historical contribution to U.S. energy consumption, considers the causal relationships which result in rebound, and suggests potential mitigation strategies that counter the rebound effect. The second section explores the impact of different types of behavior-based approaches on energy efficiency and energy conservation. The paper concludes with a discussion of the strengths and weaknesses of people-centered versus technology-focused approaches for reducing energy use and accelerating carbon savings.

Defining the Rebound Effect

As we define it here, the rebound effect refers to the social and behavioral responses to the introduction of more energy efficiency technologies and processes by which there is a corresponding increase in energy service demands. This phenomenon is also sometimes referred to as the take-back effect. Such responses are assumed to offset some or possibly all of the energy saving benefits of the new technology or improvements.[1]

In general, rebound is thought of as a ratio of the lost energy savings as it might compare 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 'missing' five percent might have been consumed by household residents increasing their thermostat setting because their more efficient furnace allows them to be warmer without using more natural gas and without spending more on their fuel bill..

The existence of the rebound effect is not at all controversial. Within the public policy arena the debate is over the expected size of the rebound effect and the remaining energy savings benefit. Within the literature there are three expected outcomes as the rebound or take-back effect might impact net energy savings:

- **Negative rebound** - actual energy savings are higher than expected. This is relatively unusual but can occur in some situations. 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.
- **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. Studies of rebound suggest that it usually falls in the range of zero to 100 percent.
- **Back-fire** – actual energy savings are negative. (In other words, the rebound effect is greater than 100 percent.) This effect is also known as the Jevons paradox. Some economists argue that efficiency gains stimulate a set of effects in the economy – whether resource substitution, cost-reductions, or more general productivity benefits – that paradoxically increase overall energy use (Sorrell 2007).[2]

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[1] While most of the attention on the rebound tends to focus on the impact of energy efficiency improvements, the same idea can hold for any use of natural resources.

[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, nor does the real world analysis support that large-

Prevalence and Characteristics of the Rebound Effect

Great strides have been made in increasing the energy efficiency of products and services throughout the U.S. economy and elsewhere. In fact, energy efficiency has been credited with meeting three-quarters of the growth in energy service demands in the United States during the 40 years between 1970 and 2010 (Ehrhardt-Martinez and Laitner 2008). Nevertheless, total energy demand has continued to rise. During the same 40 year period, U.S. energy consumption grew from 68 quads to just over 100 quads. 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. A number of important studies (Herring and Sorrell 2009, Geller and Attali 2005, Schipper 2000) have indicated that investments in energy efficiency often result in both increased energy productivity and energy savings but also in the subsequent growth in demand for energy services. By increasing energy productivity, less energy is used to meet the existing energy needs of consumers and producers, resulting in a hypothetical decline in energy use and 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.

The rebound effect can be studied at different scales (from national-level effects to household level effects) and includes both direct and indirect measures. A comprehensive measure of rebound includes both direct and indirect effects which can occur at both the micro level (within households, businesses and organizations) and at the macro level (economy-wide effects). 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 (ch 1)). 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

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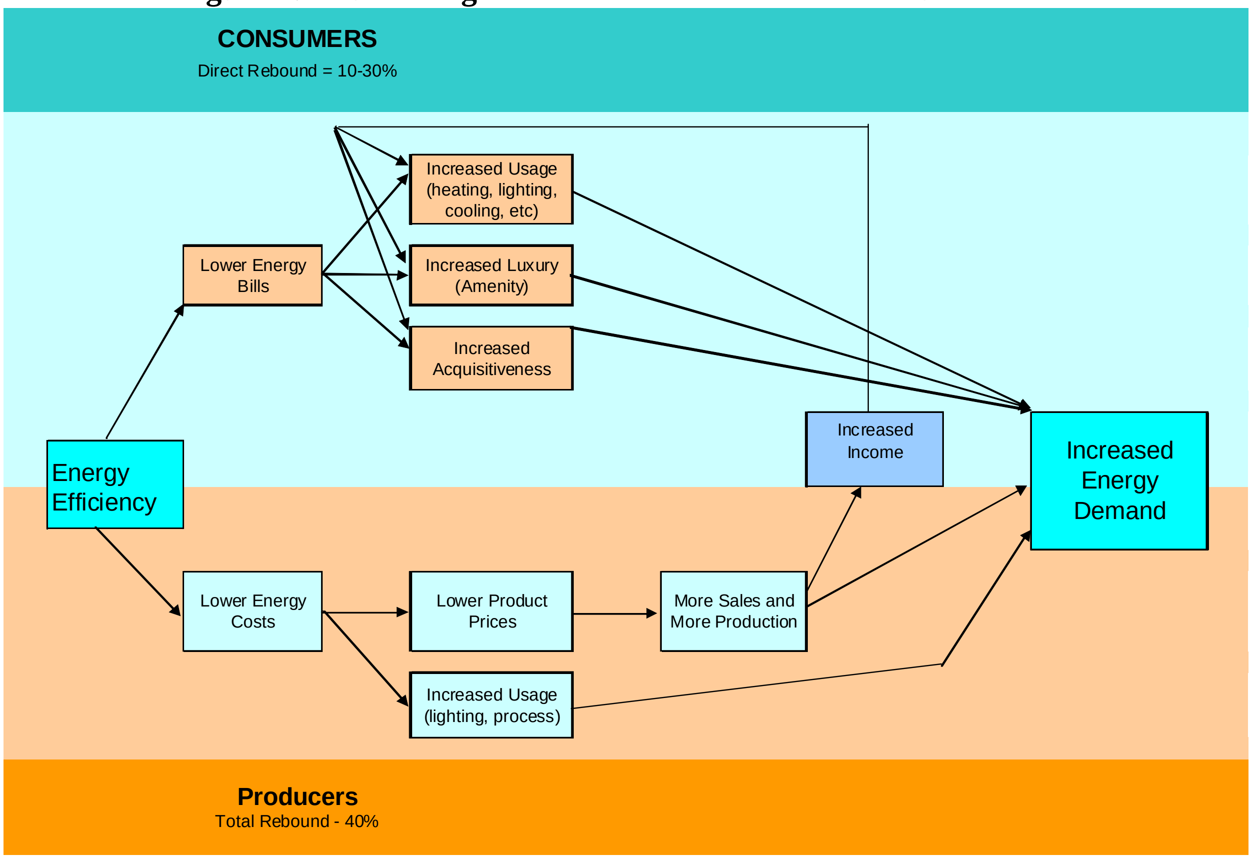
scale productivity impact. Hence, our paper here focuses on the more common impact of rebound as somewhere within the lower range of zero to 100 percent.

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).

Figure 1: Causal Diagram of Direct and Indirect Rebound Effects



Note: The degree to which efficiency and lower energy bills result in increased energy demand can vary significantly depending on how people choose to spend or invest their savings. Programs and policies can reduce the effect through the application of choice architecture and other types of initiatives.

Estimates of direct rebound effects: rebound by sector and end use. Most primary studies of direct rebound effects have been focused on understanding the energy implications of rebound as it occurs in relation to a limited number of household energy end uses (primarily space heating and cooling) and personal transportation in the United States. While the methodologies employed vary considerably, Herring and Sorrell's meta-review (2009) suggests that direct rebound is 30 percent of the energy savings or less. Table 1 summarizes the findings from the meta-review. The two most well studied end uses are transportation and home heating. Findings from these studies suggest that increased efficiency in personal transportation is likely to result in a direct rebound effect of 10 to 30 percent in the long run. In other words, for every 10 percent efficiency gain in personal transportation, 1 to 3 percent of the energy savings are likely to be spent toward increasing the number of vehicle miles traveled. However, a note of caution is in order since most of these studies did not really study the effect of efficiency gains on travel. Instead they studied the effect of changing fuel prices on efficiency and assumed that household response to fuel prices was equal in size (but opposite in sign) to the variable of interest: the response to a change in fuel efficiency. Given that the elasticity of fuel efficiency is likely to be less than the elasticity 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.

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

End Use	Range of values In evidence base	"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

Studies of residential space heating suggest that the rebound effect for this end use is also likely to fall somewhere in the 10 to 30 percent range. Overall the studies estimate that increased efficiency in household heating results in somewhat higher household temperatures. Actual temperature increases were found to range from 1.6˚F to 2.7˚F which may increase energy consumption for space heating by 10 percent or more (Sorrell 2009). Importantly, direct rebound effects tend to be higher for low income groups and households with low indoor household temperatures because they are likely to exchange some energy savings for increased thermal comfort. Higher income groups and others who have already achieved comfortable indoor temperatures are much less likely to increase indoor temperatures as a result of increased efficiency because their energy service demands have been met (Sorrell 2009).

An earlier literature review of econometric studies by Greening, Greene and Difiglio (2000) resulted in similar conclusions. Their findings suggest a small to moderate rebound effect (<10-40%) for residential space heating, water heating and automotive transport and a small effect (<10%) for residential appliances and lighting. In terms of residential space cooling, studies estimated effects of 0-50 percent. Their study also estimates some rebound effects in businesses including lighting (0-2%) and process uses (0-20%). More detailed estimates are presented in Table 2.

Table 2: Summary of Empirical Evidence of the Rebound Effect in the United States

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)

Finally, evidence suggests that the rebound effect is sensitive to the time costs associated with the particular end use in question. For example, lower fuel costs may encourage individuals to drive more, however, driving more also requires more time. So while lower fuel costs might encourage people to purchase a house in the suburbs, the additional time required to commute is likely to mitigate the effect such that fewer people move and those who do seek to limit their commute time. Similarly time costs are likely to limit the size of rebound effects associated with the use of televisions, stereos, computers and even clothes washers. In general, when energy technologies are more efficient, people appear to feel less constrained to limit their use of devices, however time costs serve as an alternative constraint for some devices.

It is important to note that the evidence of direct rebound effects does not indicate that energy efficiency is a failure. As stated by Geller and Attali (2005) "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." It is equally important to recognize that rebound is not inevitable. A more thorough understanding of the causes of rebound is the best means of formulating strategies for mitigating its effects.

Estimates of indirect and economy-wide rebound effects. Some energy analysts and energy efficiency critics argue that large-scale energy efficiency improvements can lead to broader macroeconomic impacts that in turn result in an increase in energy consumption. These secondary effects are listed in Figure 2 (shown earlier in this paper). Generally, improvements in energy efficiency gains can result in increased energy consumption in two ways: by reducing the cost of energy relative to other inputs, and by stimulating economic growth and the energy inputs required to drive it. For example, Brooks (1992) and Inhaber (1997) argue that in the short-term energy efficiency reduces energy demand and lowers energy prices, but in the longer term, low energy prices stimulate energy demand in other sectors or by means of increased product demand. In addition, increased economic productivity can also result in the reinvestment of energy cost savings into the production process sparking a demand for new production equipment and services. Sorrell and Herring (2009 Ch 12) echo these conclusions in their review of the topic stating:

…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 any general conclusions. Nevertheless, Sorrell and Herring (ibid.) do suggest the following:

- 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) seem to agree that rebound effects do 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 discuss the ways in which distinct program strategies may impact the scale of the rebound effect..

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. 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 to energy efficiency that focus on ensuring that new devices consume less energy than their predecessors, people-oriented approaches are focused on understanding changes in energy service demands and the many factors that shape those changes (as illustrated in Figure 2 above). As such, people-oriented initiatives offer a viable opportunity for mitigating rebound-induced losses from investments in energy efficiency technologies.

A variety of studies suggest that a better understanding and application of social and behavioral insights may offer the opportunity to catalyze and amplify technology-based energy savings or close the gap between the expected and the actual energy savings from traditional efficiency programs (Ehrhardt-Martinez et al 2009, Lutzenhiser 2009). Of equal importance, people-oriented initiatives can also provide the means of unlocking new sources of energy savings while ensuring the persistence of energy savings into the future (Ehrhardt-Martinez et al. 2010, Meier 2009). Notably, several recent studies suggest that the potential energy savings from people-oriented initiatives are sizable (Laitner et al. 2009a, Dietz et al. 2009, Leighty and Meier

2010) – on the order of 9 or 10 quads of energy annually. These studies suggest that people-oriented strategies could reduce energy consumption in both personal transportation and residential buildings by a total of 25 percent and contribute significantly to climate change goals (Laitner *et al.* 2009a, Dietz et al. 2009).

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.

Because not all behaviors are the same, efforts have also been made to distinguish and classify different types of energy-related behaviors. In one recent publication, the authors create a typology using frequency of action and economic cost to define three categories of household behaviors associated with energy consumption, efficiency and conservation (Laitner *et al.* 2009a). As shown in Figure *3*, among the low-cost and no-cost behaviors, the authors distinguish between *infrequent energy stocktaking behaviors* (such as installing compact fluorescent lightbulbs (CFLs) 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). The third category, *consumer (or investment) behavior*, includes infrequent and higher-cost investments in more energy efficient appliances, devices and products.

Notably, of the behavior-related energy savings estimates calculated by Laitner et al. (2009a), 57 percent were found to be associated with either energy stocktaking or changes in routines and habits. Laitner et al. estimate that, total potential energy savings are on the order of 9 quads with approximately 5.2 quads generated from low-cost and no-cost behavior changes.

Both Laitner et al. (2009a) and Dietz et al (2009) suggest that a more comprehensive understanding of the social and behavioral dimensions of energy consumption is likely to result in more effective policies and programs that can accelerate and deepen potential energy savings. These estimates are further supported by studies of countries and communities around the world that have faced temporary shortfalls in electricity supplies and that were subsequently able to dramatically reduce electricity consumption to avoid blackouts (Meier 2005). From Alaska to Brazil, a variety of examples provide proof that populations can rapidly reduced electricity consumption in dramatically short periods of time. Brazil, for example, was able to cut electricity demand by 20% when faced with a severe drought in 2001. And a more recent crisis in Juneau, Alaska provided the impetus for electricity savings of 30% in just six weeks (Meier 2009, Leighy and Meier 2010). These examples clearly show that significant energy savings can be achieved quickly given the right set of programs and policies.

Social and behavioral approaches employ a variety of insights from sociology, psychology, anthropology and other social science fields. Many of these interventions address behavior change at the individual or household level, while others are more focused on city-wide or even nation-wide policy changes. For example, efforts to reduce household energy consumption frequently focus on informing and motivating residential energy consumers to use less energy rather than focusing exclusively on economic incentives. Information strategies have included the use of energy labels and in-home energy feedback devices that make energy more visible to energy consumers and empower consumers to become more engaged and effective energy managers (IEA 2010). In addition, motivational interventions are increasingly using well-researched principles from psychology and behavioral economics to encourage new consumer preferences, decisions, and practices (ibid). Moreover, these approaches to behavior change are also beginning to be recognized as a means of addressing energy rebound. As stated by Levett (2009), smart energy policies need to anticipate rebound and "start from the behavior changes desired." He argues that "'getting the prices right' is less important than understanding when people make the decisions that affect their energy behavior and what will make them adopt more sustainable options."

Figure 3: Household Behaviors – Energy Consumption, Efficiency and Conservation

		Frequency of Action	
		Infrequent	***Frequent***
Cost	***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 and Other Devices
	Higher cost / Investment	CONSUMER BEHAVIOR New EE Windows New EE Appliances Additional Insulation New EE Car New EE AC or Furnace	

Source: Laitner *et al.* (2009a).

Additional evidence of the potential energy savings associated with people-centered programs and policies is found in a series of recent reviews of feedback-induced energy savings in the residential sector (Darby 2006, EPRI 2009, Ehrhardt-Martinez et al. 2010). These studies explore a variety of different means by which energy can be made more visible to, and meaningful for, household energy consumers and how efforts to provide information and context can result in significant energy savings (4 to 12 percent historically but potentially even higher). According to one recent meta-review of 57 feedback studies (Ehrhardt-Martinez et al. 2010) most of the energy savings achieved through feedback programs has come from changes in behaviors (not investments)[3]. Regardless of the action taken, the study found that feedback-induced behaviors were also motivated by a variety of factors including self-interest (energy bill savings) as well as civic concerns and altruistic motives. These findings suggest that the practices of traditional energy efficiency programs – aimed at the installation of new, more energy-efficient technologies alone – are likely to result in 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.

[3] Although people who invest tend to save the most energy.

Notably, this same study found that feedback-induced energy savings were persistent over time.

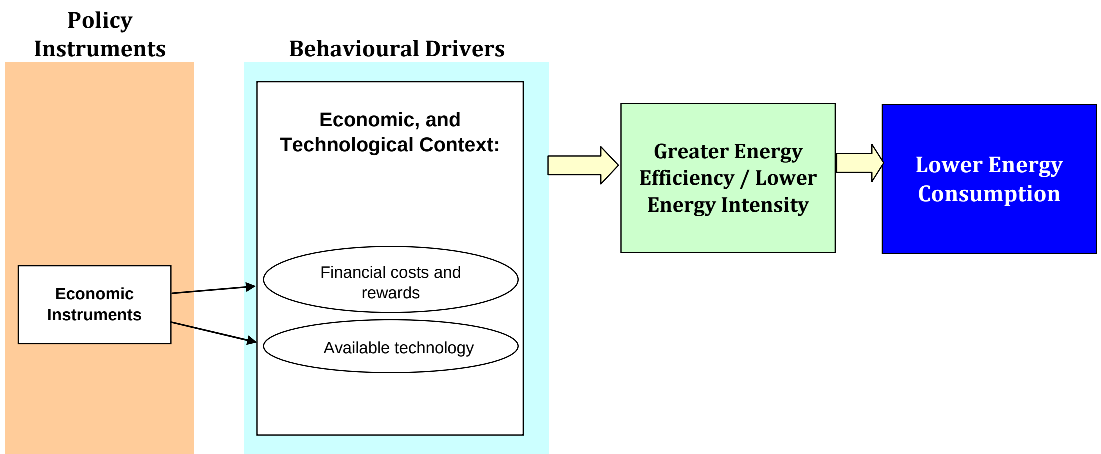
The evidence presented here clearly suggests that while technology-oriented interventions are likely to result in important energy savings, they are also likely to trigger some level of rebound in energy consumption. On the other hand, people-oriented programs and policies that focus on a range of strategies (including no-cost and low-cost energy savings) offer the opportunity to both mitigate the effects of rebound and significantly reduce energy consumption in ways that don't induce additional rebound effects.

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

Traditional technology-focused programs. In the United States, traditional efforts to reduce energy consumption have predominantly focused on increasing the energy efficiency of technologies and then ensuring that the adoption of those new technologies are cost effective for potential consumers. The traditional approach—commonly referred to as the "techno-economic model"— is a framework for understanding and managing the growth of society's energy demand. This approach predominantly relies on technological and economic means of management, either through the development and application of new technologies or by establishing economic incentives and/or disincentives geared toward encouraging the adoption of desirable technologies or impeding the adoption of undesirable technologies (Stern 1986). As shown in Figure *4*, the techno-economic model indicates that energy efficiency and overall reductions in energy consumption are achieved only through the development of new technologies, by making these technologies available at the right price, and then by promoting them to consumers by emphasizing their "rational" economic benefits. Underlying the techno-economic model are the assumptions that growth in energy consumption is best solved through the application of new technologies and that energy consumption and technology adoption behaviors are best understood in terms of a set of rational economic calculations involving the price of energy, the cost of technologies, and the level of disposable income. In this context, consumers are portrayed as logical decision makers who will alter their behavior in predictable ways when confronted with rising energy prices or more resource-efficient products. Moreover, the model suggests that energy-efficient behaviors and choices may be enhanced through the introduction of carefully crafted economic incentives and disincentives (Archer et al. 1987). Finally, consumers are simplistically portrayed as actors pursuing the means to increase their net benefit when presented with information about the economic-desirability of a particular product or service. Unfortunately these assumptions have not been proven in practice (Parnell and Popovic Larsen 2005).

The weakest aspect of this model is the assumption that individuals are economically rational actors. For example, a study of solar technology adoption, found that even when the information is available, most people do not consider information that is essential to cost calculations (Archer *et al.* 1987). Similarly, a study of vehicle purchase decisions, found that even the most financially skilled consumers do not use payback calculations as part of their vehicle purchase decision-making (Turrentine and Kurani 2007). Some of these studies also conclude that observed behaviors appear to contradict a central tenet of the rational model - namely, the rationality of the decision-making process. And there are many additional examples of studies (NRC 2002, Feldman 1987, Stern and Aronson 1984) that indicate that consumers do not consider energy and energy-using equipment only as 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.

Figure 4: Techno-Economic Model of Energy Efficiency



Source: Adapted from Stern 2002

In terms of rebound, the use of traditional, technology-focused programs results in an exclusive focus on efficiency investments 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 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 have been concerned with understanding technology diffusion patterns, and the ways in which social science can be used to increase the adoption of energy efficient technologies. Traditional behavior programs are often focused on overcoming information costs and other barriers that consumers encounter when faced with a decision to adopt more-efficient or less-efficient technologies. According to this perspective, a variety of factors influence household decisions to adopt standard or new technologies including measures of time and inconvenience associated with searching for a better product, collecting and assessing information, and completing the transaction. In addition, consumer perceptions of the potential risks associated with the shift to more efficient technologies may also impede adoption. In general, policies are focused on making energy efficient technologies more attractive to would-be adopters.

While traditional behavior programs integrate a recognition of some behavioral elements into their interventions, they continue to focus exclusively on the adoption of energy-efficient technologies. In this sense they don't differ significantly from traditional, technology-focused programs. As such these programs do nothing to offset both direct and indirect rebound effects associated with initiatives that are exclusively focused on energy efficiency.

Integrated, people-centered programs. People-centered programs are different from traditional programs in several important ways. One of the most important differences is that people-centered programs start with a focus on the needs of people and society. What are the characteristics of existing energy service demands, and what are the social and behavioral factors that shape them? Moreover, people-centered approaches seek to empower consumers to become better energy managers, and they view energy-efficient technologies as simply one set of tools in a larger toolbox that can help people and communities to achieve sustainable levels of energy consumption. In this scenario, people are not just perceived as energy consumers but also as potential energy producers via distributed energy systems and small-scale renewable technologies. Notably, people are seen 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 stand in the way of efforts to reshape the choice sets and 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

Climate change and energy strategies that are focused exclusively on reducing energy demand through the use of traditional interventions that rely on the expanded adoption and use of energy-efficient technologies are likely to suffer from the largest rebound effects. Alternatively, people-centered energy strategies that combine efficiency, conservation, curtailment and management strategies are likely to achieve even greater levels of energy savings with less dramatic levels of rebound in energy consumption. People-centered strategies may include the adoption and use of energy-efficient technologies but also include tools, support, and motivational elements that encourage energy stocktaking behaviors as well as new routines, habits, and lifestyles. As opposed to strategies focused on the dissemination of technologies, strategies that are focused on empowering people think of technologies as tools that can be employed by households and businesses as one of several means to manage their overall levels of energy consumption. Recent studies indicate that potential energy savings from no-cost and low-cost behaviors actually exceed those of programs focus on consumer investment in energy-efficient technologies. Moreover, these same programs are likely to result in a smaller rebound effect.

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