When the Straight Line Is Not the Fastest Route: Counterintuitive Approaches to Improving Energy Efficiency in Buildings

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This paper provides a critical assessment of some common assumptions on which energy policy is made. It identifies shortcomings in the typical economic analyses used to promote efficiency investments, and describes the limitations of technology as the focus of an efficiency strategy. Despite repeated setbacks from unintended consequences related to efficiency improvements (e.g. concerns over personal safety, comfort, product reliability, and indoor air quality), efficiency proponents continue to misunderstand the context of basic energy services and the fundamental aims of end users.

Approaches which place more fundamental social goals (such as job creation, environmental protection, and worker and corporate productivity) at the center of attention are proposed as alternative means to an energy-efficient end. These alternative approaches require an integration of technological and behavioral factors, including technology assessment and consideration of transaction costs. To develop this approach and theme, the essay draws on concepts from planning theory, building ecology, and management science. To maximize the benefits of an integrated approach, an appeal is made to efficiency proponents to reconsider a value-based social marketing effort in support of energy conservation. Such an effort may capitalize on the nascent public dissatisfaction with material consumerism.

Introduction

Whither Improvement?

Energy consumption in the U.S. reached an all-time high in 1993. Energy use in the residential and commercial sector (i. e. buildings) also reached a new high that year, exceeding 30 Quads for the first time ever (EIA 1994). The increase in energy use may be attributed to several factors: the economy rebounding from the recession, the stock of buildings is steadily increasing, and real energy prices are at (or below) 1974 levels.

Nonetheless, greater energy savings have been expected over the past decade, due to big efficiency gains in equipment, substantial incentives through utility demand-side management (DSM), and a costly war to defend major oil suppliers. Indeed, if a fundamental motivation behind increasing efficiency is to minimize the potential for global climate change, we must reduce energy consumption, not merely slow its growth rate. What explains the apparent slow rate of improvement in buildings energy performance recently, and how might we spur greater improvements?

This essay explores the prospects for greater efficiency from a systemic perspective, explicitly integrating the technological and behavioral influences on energy use. Rather than taking a linear, reductionist approach to improvements at the component level, this work places energy use in context with other important societal aims and needs. This real world approach suggests there is more than one way to greater efficiency, and that while alternative routes may seem less direct, they may in fact yield substantial results.

For example, most recent strategies to improve efficiency focus on moving directly from (A) inefficient products and buildings, to (B) highly-efficient products and buildings, using a variety of policy carrots and sticks to entice builders and manufacturers to improve system components (see Figure 1). The co-benefits of efficiency (e.g. environmental protection, job creation, worker and corporate productivity) are promoted as further *rewards* upon reaching the target (point B).

POINT A	-->-- the usual path -->--	POINT B	
Inefficient buildings, equipment, and practices	Improved technologies through standards, market incentives, and education programs	More efficient buildings, equipment, & practices	Environmental protection; economic development; productivity; national security

Figure 1. Traditional Approach to Improving Efficiency-Straight from A to B, with Collateral Benefits Touted for Program Marketing Purposes

Of course no one would deny that these co-benefits are essential *targets* in their own right. However, the energy efficiency community often takes these goals for granted as natural consequences of its own success. This paper argues that efficiency advocates should recognize the primacy of these more compelling social objectives, and consider repositioning efficiency is a co-benefit of those goals.

To develop this theme, this paper identifies and discusses a number of shortcomings in the engineering-economic approach most often used by efficiency proponents. Following a brief review of the current strategies used to overcome the purported market imperfections and barriers to the use of efficient products, this paper introduces *transaction costs,* which are additional factors often overlooked or undervalued by many energy analysts. Transaction costs differ from neoclassical barriers in that transaction costs are real, they are valid, and they represent hurdles to agents of change.

One key transaction cost is the risk inherent in the use of new technologies. The importance of technology assessment is discussed with respect to energy-efficient equipment. The rapid pace of technological change in the building industry is particularly relevant given the important role of builders and their associated tradespeople. The building trades must be strongly supported by efficiency proponents, or else much of the gains in equipment efficiency will be lost. Continuing along the subject of personnel, an appeal is made for greater interdisciplinary cooperation between energy researchers in the engineering-economic and social science communities.

Total quality management and social marketing issues are examined to illustrate the theme developed here. The energy focus in this paper is part of a broader effort to reconcile post-modem technology with social and environmental ethics to address societal needs (Morrill 1994).

Background: Are We Stuck in a Rut?

Much of the decrease in the energy intensity of the U.S. economy between 1972 and 1983 can be attributed to behavioral changes, such as reduced driving, thermostat changes, and curtailed use of appliances and lighting (DOE 1989). Unfortunately, these behavior modifications were accompanied by negative connotations of sacrifice: reduced mobility, decreased comfort, and diminished perception of safety, respectively. Therefore, in the wake of Jimmy Carter's "moral equivalent of war" phrasing and Ronald Reagan's comparing conservation to "sitting in the cold in the dark," energy conservation proponents embraced "efficiency" as the key operative word.

Today, advanced technology is at the center of most discussions of improved efficiency, with new technologies promising high levels of services at much lower costs. Over the past fifteen years we have seen the emergence of condensing furnaces, compact fluorescent lamps (CFLs), heat pump water heaters, low-e windows, a doubling of air conditioner efficiency and a tripling of refrigerator efficiency. A wide array of emerging technologies promise to continue these advances (Nadel et al. 1993).

But energy end-users have not adopted these improved technologies commensurate with their apparent economic potential. Efficiency proponents therefore use a variety of public policies to overcome "market imperfections" and "barriers" to the use of efficient technologies. The literature on this topic is extensive (Stem 1986; Kempton and Neiman 1986; Hirst and Brown 1990); the usual litany of barriers and market failures include:

- inadequate or distorted price signals (including non-monetarized externalities);
- lack of information about cost-effective technologies;
- lack of availability of high-efficiency products;

- split incentives between those who make construction and purchase decisions and those who pay operating costs;
- limited access to capital;
- the "payback gap" between the expectations of energy consumers and energy suppliers.

Central to these efforts to overcome barriers are the assumptions that 1) end users are rational economic actors, and 2) these end users perform in a slightly-less-than-perfect market, and that once these imperfections are overcome, rationality will prevail. The strategies employed over the past two decades include: regulatory codes and standards; tax credits; market incentives ranging from Golden Carrots‘M to low- and no-interest loans; rebates on efficient products; direct installation (give-aways); and ratings, labeling, and other kinds of educational programs.

However, the inadequacy of the first assumption is exposed simply by recalling the powerful effects of anecdotes and stories in our own decision making (Norman 1993: 128- 130), and more specifically with respect to energy analysis in critical works from the behavioral sciences (Stern 1986; Lutzenhiser 1992). Quite simply, advice from the government or a consumer magazine pales in comparison to what one learns from a neighbor's experience. As for the second assumption, classical economics simply ignores consideration of costs beyond the direct production of goods and services, despite the idiosyncrasies pervasive in the real world (Kahn 1966; Alexander 1992).

Transaction Costs

To present a complete picture of the true costs incurred by energy end users, consideration must be given to *transaction costs* (Laitner and Morrill 1993). In general economics, transaction costs are diverse and wide-ranging, from a generic hassle factor to changeover costs if completion of a transaction (e.g. purchase of new equipment) requires altered behavior or employee retraining (Stokey and Zeckhauser 1977: 298-300). Transaction costs also include opportunity costs, considerations of risk taking, and even political judgments by actors in both the public and private sectors (Alexander 1992).

Transaction costs are different from market barriers or imperfections; they are real but difficult-to-quantify costs. In short, energy efficiency technologies will be adopted if the following equation is satisfied (Laitner, Morrill, and Elliott 1994):

$$C_{TECHNOLOGY} + C_{TRANSACTION} < C_{AVOIDED}$$

where:

$C_{TECHNOLOGY}$ = costs of technologies, including installation
$C_{TRANSACTION}$ = transaction costs
$C_{AVOIDED}$ = avoided costs (end user perspective)

It is beyond the scope of this essay to quantify these costs for many energy efficiency programs, but simple descriptions and examples are provided below.

Information and Paperwork

If a household, small business, or large corporation is to invest in more efficient equipment or participate in a utility DSM program, someone must take the time to learn about the product, decide whether participation is worthwhile, and initiate steps toward participation. Typical efforts to "overcome barriers" include information programs to reduce this cost, but rarely is this opportunity cost actually quantified and included in the cost of the efficiency measures under consideration.

For example, the EPA's Green Lights program has been, by most accounts, a roaring success. In fact, according to participants' own reporting, remarkably little in-house staff time is used to plan, develop, and administer Green Lights participation (see Table 1).

Table 1. Average Project Costs for Green Lights Partners (through March 1994)

	Cost per square foot
Survey	$0.07
Materials	0.30
Installation	0.14
Administration	0.01
Total	**$0.52**

Source: Robert Kwartin, U.S. EPA (personal communication)

In this case the survey and administration costs may be considered transaction costs, and they appear to be a small fraction of the hardware costs. However, lighting experts and Green Lights staff agree that respondents probably underestimate their own staff costs (Neal Elliott, ACEEE, personal communication; Robert Kwartin, EPA Green Lights, personal communication).

Accurate estimation of these transaction costs has two important consequences on corporate participation in the Green Lights program: 1) companies that underestimate staff time devoted to their lighting program are erroneously accelerating the project's payback period, 2) companies that properly assess the transaction costs may determine participation is too costly and therefore not enroll.

Social and Behavioral Factors

It is well known that social and behavioral factors influence consumer decisions far beyond the boundaries of economic rationality; Kahn called this the "tyranny of small decisions" (Kahn 1966). In particular, there are tremendous social, cultural, and class implications associated with many energy-consuming items (Lutzenhiser 1993). These factors are inescapable at home and at work, and apply to everything from clotheslines to automobiles to who has the most powerful computer in the office. This should not be surprising because, as Lutzenhiser notes, "the whole point of *marketing,* after all, is to induce purchase through appeals to *non-economic* motives" (Lutzenhiser 1992: 52).

Time Frames and Windows of Opportunity

For a corporation, upgrading to more energy-efficient processes or system components does not make sense if the corporation plans to overhaul the entire process within the expected payback period on efficiency upgrades. As for the residential sector, American society is quite mobile. Homeowners should not have to apologize for requiring a two-year payback on an uncertain investment if they think they might move within three.

Considering much narrower time frames, there is the issue of how individuals value and make trade-offs between energy and time (Spreng 1993; Schipper et al. 1989). The title of this paper was suggested by a fact of driving that we are all familiar with, namely, avoiding congestion by taking a longer route (but at a faster speed), thereby shortening the length of time required to arrive at the destination, but not the distance travelled. The time-saving route may consume as much or more fuel as the more direct route, but energy is substituted for time. Furthermore, in some cases people may elect to drive the longer route at a faster speed much more than the shorter, congested route even if they expect no time savings, if they value the sense of moving much more than sitting in traffic. In this way the quality of the experience overshadows both energy and time considerations.

Changeover and Indirect Costs

Changeover costs may include employee retraining, investments in related supplies, and adjustments to other processes that may be related to the use of a new technology (Porter 1980: 114). For example, improving the thermal integrity of a centrally-heated multifamily building by installing new windows and/or insulation must be accompanied by adjustments to the heating plant and resident education, or else the expected savings simply will not be achieved (DeCicco and Kempton 1987; Judd 1993).

Indirect costs include occupant comfort and amenities, which can far outweigh energy costs. For example, ACEEE occupies a suite in a downtown Washington DC office building. Our annual payroll costs are about $\$200/ft^2$, in sharp contrast to our proportionate share of the building's annual energy use of about $\$1.50/ft^2$. If we reduced our energy use to zero, but suffered a 1% decline in productivity for accomplishing this feat, we would lose money. [1] This is a critical aspect of energy services, still underappreciated by many efficiency proponents.

Risks Inherent with New Technologies

The public's wariness of new technologies and practices should not be ignored or dismissed quickly, after all, the efficiency business is not without its duds. Much as we might like to, we should not forget the noise problems with early pulse-combustion furnaces, "instant-on" compact fluorescent lamps which are not, poor dehumidification from the early high-efficiency air conditioners, and office buildings designed with inoperable windows and poor ventilation. In some cases the customer pays a stiff price for remediation, while in others the cost is mostly inconvenience. The stakes are particularly high in the commercial and industrial sectors, where *the cost of product failure can be much larger than the cost of the product itself* (Porter 1980: 115).

To summarize, transaction costs add a large degree of complexity to individual decision making, and efficiency programs which focus on overcoming the conventional barriers in strict economic terms only address part of the picture. The extraordinary implicit discount rates required by end users for high-efficiency products may not be an imperfection after all-they may simply reflect the customer's markup on efficiency due to transaction costs (Plunkett and Chernick 1988; Sutherland 1991). With these factors in mind, energy analysts would be wise to revisit the topic of technology assessment.

Technology Assessment

> "Technologies are not neutral. They affect the course of society, aiding some actions, impeding others, independent of the morality or necessity of those actions." (Norman 1993: 250)

Meeting Expectations

If consumers and businesses are to find persistent savings through efficient technologies, several key conditions must be met. First, the improved products and processes must perform as expected. In the case of products such as compact fluorescent lightbulbs (CFLs) and high-efficiency refrigerators, this simply means providing the user with the same (or better) level of service expected from older, less efficient models. More complicated applications, such as HVAC equipment or motor systems, need proper installation, operation, and maintenance to match their rated performance and provide the expected benefits to users.

In fact, CFL programs are showing lower-than-predicted savings due to 1) overestimated lighting hours of operation, 2) customer dissatisfaction with CFL light quality, leading to discontinued use of CFLs, and 3) overstated light output of CFLs, leading to discontinued use and/or use in place of lower-wattage lamps (e.g. using a 23 watt CFL in place of 40 or 60 watt lamps, rather than replacing a 75 watt lamp). This latter problem may be due in part to reason (2). When the product is heavily subsidized, as is often the case with CFLs, consumers may not appreciate the full value of the item, and if the product fails to meet expectations, the public will understandably become more skeptical of subsequent technical advances in efficiency (Tempchin and LeBlanc 1992).

Efficiency ratings are only part of the story with space conditioning equipment. There are many complex interactions in buildings not always addressed in engineering estimates, especially when incentive programs focus on individual components rather than complete systems. High-efficiency commercial HVAC chillers–specified by well-meaning utility DSM programs-are too frequently mismatched with other building components and thereby defeating the expected improvement in performance, resulting in systems consuming more energy than (nominally) "less efficient" but properly-matched systems (T. Mikulina, The Trane Company, personal communication). Residential HVAC equipment must likewise be properly sized and installed; this topic is revisited below.

Minimizing Side Effects

Well-meaning innovations should not have detrimental side effects. These side effects may be real, such as the fire hazard posed by kerosene heaters, or they may stem from lay misunderstandings and perceptions of negative consequences, as has been the case with safety concerns with high-efficiency automobiles. The effect of perceptions on market performance can be as harmful as actual failures or shortcomings.

Energy efficiency has not been without side effects, real and perceived. Indoor air pollution was a wake-up call to the conservation community in the 1970s. First, formaldehyde off-gassing from poorly-installed urea-formaldehyde foam insulation (UFFI) emerged as a legitimate health issue when its rapid commercial growth eclipsed the number of qualified installers. Indoor air quality remained in the news throughout the 1980s as the media linked weatherization efforts with a growing awareness of indoor pollution problems. Most of the concern related to energy conservation was misdirected, but it has taken years of research to demonstrate that fact (duPont and Morrill 1989).

Secondary (Indirect) Consequences of Technology

Finally, researchers should be mindful of the potential indirect effects of innovations, and evaluate the desirability of those effects. A classic example of unintended consequences is that of flood control darns and levees. The presence of such control structures leads to the perception of safety, resulting in a floodplain much more heavily settled than without any control structure. Floods occur less frequently, but with more catastrophic losses due to the increased density of settlement (Hohenemser et al. 1982: 127). Of more direct relevance to energy, the social ramifications of air conditioning have been substantial. It hastened the demise of the front porch, isolating families and fragmenting communities, and altered social values and institutions (Prins 1992).

Despite the repeated exhortations from engineers that new devices will relieve us from mundane tasks, the public continues to embrace a low-tech lifestyle: witness the millions of VCRs across America blinking 12:00 at their owners. More directly related to energy is the fact that many people do not understand how thermostats work (Kempton and Neiman 1986). We are increasingly dependent on others to help us make decisions regarding the machines around us, including those in our homes.

Building Ecology and the Unsung Building Trades

Buildings are complex systems. Two decades of research on building energy use and indoor environments has revealed a number of surprising conditions and relationships, ranging from the pressure-driven flow of radon into homes to the substantial energy losses through duct leakage. The energy performance of a building and the comfort, health, and safety it provides to occupants are tightly interrelated (duPont and Morrill 1989). Recognition of this complexity is critical because as systems become more complex it becomes more difficult to maximize any one attribute, such as energy efficiency.

The engineering-economic approach taken by efficiency advocates is often referred to as a "bottom-up" method, since the performance of individual end-uses comprising energy demand are the starting point for analyses of cost-effective energy savings. This is in contrast to the top-down macroeconomic, energy supply-oriented approach usually favored by neoclassical economists.

But *within* each end-use industry, the typical approaches taken to advance efficiency have a decided top-down flavor due to their heavy reliance on improvements to technical components through equipment standards, building codes, and market incentives to accelerate the development of these advanced products. Figure 2 illustrates this process for the residential sector, showing the gap between the focus of attention on technical improvements and the level at which consumption is measured—and success is actually determined. Some describe approaches emphasizing technological innovations as *market transformation* (Geller and Nadel 1994); others reserve that term for more comprehensive approaches including trade allies in the process (Prahl and Schlegel 1993).

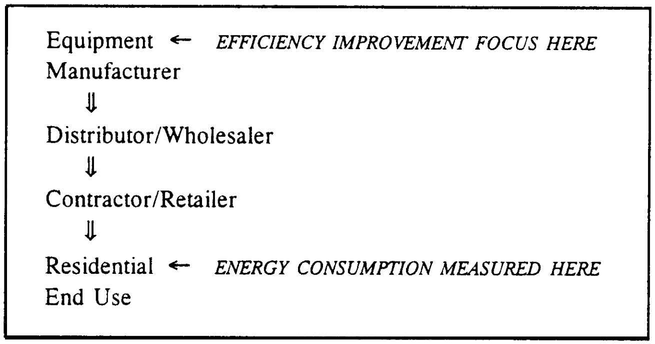

Figure 2. A Troubling Gap Between the Focus on Equipment Improvements and the Point at Which Energy Use Is Measured

Efficiency proponents need to appreciate two simple facts regarding trade allies: 1) Buildings are entangled systems with resource distribution systems interwoven throughout, requiring skilled, creative tradespeople to make efficiency improvements actually *work.* We cannot overlook the significance of these trades, or else continued improvements in technology will be simply wasted; 2) At present there are not enough skilled technicians to do the increasingly-demanding tasks required of them, and while demand for these technicians is sure to grow, their future supply is by no means assured. These points are described in greater detail below, along with appropriate roles for the energy efficiency community.

Modern Buildings Are Entangled Systems

Homes today consist of wood or metal framing with a remarkable array of installed pipes for supplying and carrying away fluids, air ducts for moving air, and thousands of feet of wires for electric power and communications. Trade sequencing is often irregular, and the spaces between framing members are filled by the first to get there (Kendall 1993). Accordingly, "each work gang finds its workplace defined by the previous gang and, in turn, defines that of its successor" (Groak 1992, 43). Hence there should be little surprise at the difference between plans "as designed" and "as built", but most retrofitters would certainly love to have access to the latter (Hayes 1992).

The entanglement in housing is due in part to the number of subcontractors required by the increasing complexity of building systems (Kendall 1994), This complexity has been accompanied by a sharp decline in the technical precedent, that is, on-the-job experience. Builders can no longer use the reliable tried-and-true methods, as innovations have accelerated the pace of change in construction (Groak 1992). Over the past 20 years builders have witnessed a revolution, with new building codes, new technologies, and new materials, plus a heightened appreciation among their clients for the quality of indoor environments in terms of comfort, health, and safety. Add the strong undercurrent of rapidly evolving design and demographic forces on the construction industry, and it is somewhat remarkable that new buildings perform as well as they do.

Meanwhile, only recently have researchers identified the significance of leakage in residential ductwork on building HVAC performance and energy consumption. One estimate is that 0.5- 1.2 Quads are lost each year through inefficient ducts (Obst 1993), or about 3%-8% of primary energy use in the residential sector (roughly 15 Quads). Additional energy losses and strains on HVAC equipment are due to improper maintenance, faulty ductwork design, location, and integrity, over- and undercharging of heat pumps and air conditioners, and gross oversizing of space conditioning equipment (Neal 1992; Jenkins 1991).

The message here is that while equipment performance standards are necessary, they alone are not sufficient to improve building energy use. Trade allies are absolutely critical to further improvements, and they can literally make or break a DSM program (Hammerlund 1993). Some utilities and other organizations recognize this fact, but the sentiment is by no means universal; there may even be a subtle bias unfolding among analysts, as horror stories from the field invite trade-bashing (Groak 1992; Hammerlund 1993).

We Need More Skilled Tradespeople

Despite the horror stories, it is foolish to attempt to draw moral or intellectual distinctions between those who work principally with their minds and those who work principally with their hands; the building industry is well served by many people who mostly work with both. This point is belabored because the HVAC trades are in acute need of additional skilled workers. According to industry surveys since 1988, the "single biggest problem contractors face" has been "finding qualified people" (ACH&R News 1988-1994); this response consistently ranked ahead of changing CFC regulations, industry competition, employee moonlighting, and the health of the economy. Contractors complain that help wanted ads go unanswered, and industry leaders fear the problem will only get worse "as the comfort industry technology grows more and more complex" (Service Reporter 1994). Such trade concerns are for the first time finding their voice in DOE deliberations over future equipment efficiency standards (Barlas 1994).

Moreover, the U.S. Department of Labor projects a shortage of skilled technicians well into the future. It estimates that only one quarter of the job openings in the construction trades (including electricians, sheet metal workers, HVAC and insulation technicians) between 1990-2005 will be filled by workers completing certification programs or education beyond high school (Eck 1993). These are jobs for which training is becoming more important and valuable-for efficiency proponents and the workers themselves—but recruitment and training is lagging.

The Need for Interdisciplinary Unity

Continuing on the topic of occupations, it is time to restore balance in energy efficiency research between the behavioral social science crowd and the engineering-economic analysts who have dominated the field of late. Science and technology rely on precise and accurate measurements which can be replicated and then predicted. Things that cannot be measured, replicated and predicted with confidence are ignored or judged to be of little importance. In this way science and technology are somewhat divorced from the real world when humans are present; reliance on technology may produce wonderful results in a narrow sense, but what is left out is of equal or greater importance (Norman 1993: 15). In the words of a British sociologist, "although it would be easier to promote scientifically proven energy technologies if there were no building designers or building users to get in the way, the snag is that then there would be no buildings either" (Shove 1992: 8).

Of course the efficiency community is not the only profession facing this problem, but many of these divisions occur in environmental circles. It is a division worth mending. In an essay on reconciling ecology with human activity, a professor of physics and philosophy that "two centers of knowledge are very definitely one center too many, and the dichotomy between the natural sciences and social sciences proves to be a disaster lying very much at the root of today's environmental problems" (Meyer-Abich 1979, 303).

In his seminal *Foreign Affairs* article, Amory Lovins wrote:

> Any demanding high technology tends to develop influential and dedicated constituencies of those who link its commercial success with both the public welfare and their own. Such sincerely held beliefs.. tend to discourage such people from acquiring a similarly thorough knowledge of alternative policies and the need to discuss them. (Lovins 1976)

He used this language to warn us about the continued reliance on large, centralized energy suppliers. Might we soon speak these same words about energy efficiency analysts intent on delivering the biggest bang for the energy buck at the point of end use?

Applications

Figure 1 presented the linear, reductionist approach to greater energy efficiency. This section takes cues from the preceding discussion and offers alternative approaches to achieving energy efficiency. Mapping these routes takes nothing away from the tremendous efficiency gains brought by the technologies and programs over the past 20 years. But rather than beginning with the goal of increased efficiency as the focal point, these approaches pursue the more fundamental goals of society and then seek opportunities for efficiency along the way. Approaches from this perspective are shown in Figure 3 and outlined below.

>----->----->----- Direction of Travel ----->----->----->

POINT A Current Situation	Route and vehicle(s)	POINT B Societal Goal	Co-Benefit(s)
Unemployment, worker dissatisfaction	Encourage and fund expanded HVAC technician and builder training	Job creation; worker satisfaction	Improved energy efficiency in the field
Environmental degradation	Increase awareness, experience, and appreciation for outdoors to reduce reliance on over-conditioned buildings	Environmental protection	Reduced over-conditioning of buildings = reduced energy intensity
Uncomfortable, unaffordable housing	Programs focusing on basic, quality construction; renovations using systemic approach; disentangling	Simple, affordable, and comfortable housing	Improved energy efficiency and comfort
Corporate restructuring (all sectors)	Follow principles of TQM, that is, do it right the first time	Productivity, competitiveness	Improved energy efficiency in industrial processes and services

Figure 3. When More Compelling Social Goals Become the Target, Energy Efficiency Becomes the Collateral Benefit

Total Quality Management

The concept of Total Quality Management (TQM) suggests tremendous opportunities for energy efficiency. A few key tenets of TQM are directly related to achieving our goals, specifically 1) designing for and serving the customer's interest; 2) in process work, doing it right the first time; 3) waste of any kind—labor, time, material, energy—is anathema to TQM.

For example, achieving efficiency as a collateral benefit of meeting the customer's interest is shown in IBM's approach to developing its Energy Star computer:

> Fundamentally, the consumer could care less about energy efficiency.. personal computers are really sold to customers on some well-established parameters and metrics—such as warranty and performance-and we were looking to try to enhance those . . . The PS2E is silent-operating because there is no fan, and customers like that. The only way I could eliminate the fan was to reduce the amount of power it used, so that it produces very little heat.. that lower temperature might yield longer lifetime for its components and subsystems, and produce a better warranty for our customers.. getting rid of the fan also makes the machine very small, which the customer also likes. (Jim Davis, IBM computer designer, quoted in ECD 1994)

Getting it right the first time in new housing means not only installing HVAC systems properly, but also ensuring that the distribution system—pipes, ducts, and wires—are installed correctly and not "entangled". Quality construction is "the main prerequisite for building an energy-efficient house" (Uniacke 1994, 37). In commercial buildings, doing it right the first time may require involving building operators in the selection and design of building HVAC systems (ACH&R News 1994), or at least providing adequate system documentation for the new building's operating staff (Schliesing et al. 1993).

Environmental Protection

One of the unintended effects of inexpensive air conditioning has been the proliferation of its use to the point where many otherwise-healthy Americans have difficulty coping in hot weather (Prins 1992). Commercial buildings with inoperable windows exacerbate the dependence on compressor cooling. The awareness of sunlight, subtle air movement, and clouds is important to human perception and well-being (Groak 1992; Gallagher 1993). I suggest that a decreased reliance on conditioned indoor space, including an increase in daylighting, may help reestablish a human connection to the outdoor environment. Breaking this dependence on technology for comfort offers the greatest potential savings, which is: equipment with the switch in the "OFF" position.

Job Creation

As shown in the discussion of entangled buildings and faulty ductwork, there is a substantial amount of meaningful work available for skilled energy auditors, retrofitters, and HVAC technicians. To replenish the supply of technicians, the Air Conditioning Contractors of America (ACCA) is directing a new recruitment effort at vocational high schools. The HVAC industry has begun referring to itself as the "comfort industry" in part to reflect a friendlier service orientation.

Unfortunately, overall enrollment at vocational schools is down, due in part to the stigma associated with vocational training (Swoboda 1994). Recruitment, training, and certification efforts in these areas should be given a priority in energy, economic development and labor-related agencies. Energy efficiency program managers, policymakers, and advocates can help this situation by informing educators in secondary schools about the importance of these skilled trades and the rewards they convey. These are key jobs in their own right as proper operation and preventive maintenance of buildings is a vital aspect of maintaining the existing capital infrastructure. The substantial energy efficiency benefits to follow are an added bonus.

A recent review of DOE's Office of Building Technologies recognized these needs and recommended DOE and utility funding of training and certification programs (ACEEE and ASE 1992). Utilities in at least ten states presently operate duct repair programs (Penn 1993), and DOE is among a consortium known as Residential Energy-Efficient Distribution Systems (REEDS) working to establish uniform duct ratings and performance specifications (Obst 1993),

Social Marketing: the Time Is Ripe to Address Values

Due to the bygone public distaste for curtailment, it has become nearly taboo to discuss whether we really *need* all the gadgets and amenities provided by these technologies. "The fear of energy efficiency advocates, in particular, is that just when energy efficiency is entering the mainstream, we risk Cauterizing the efficiency enterprise and tarring it all." (Kempton 1993, 221)

Fortunately, several veteran analysts have begun to question the lack of discussion of values, ethics, and "energy consciousness" in efficiency programs. Some question the moral virtue of the reliance on technological fixes, with their implicit message that "it's appropriate to use electricity whenever we want, as long as we use it efficiently" (Rudin 1992). Others are concerned that large subsidies offered for efficient technologies are creating an artificial market without promoting the intrinsic social value of efficient energy use (Tempchin and LeBlanc 1992).

Furthermore, exclusive reliance on technological improvements appears insufficient to solve the stated problems (e.g. global warming), and therefore consideration of non-technology options, including value-laden strategies, is only prudent (Kempton 1993). Blumstein (1992) has identified the crux of the matter—that realizing the vision of efficiency will require considerable structural changes, and that these changes will require society to internalize the *values* of the efficiency movement—but he stops short of actually proposing how this internalization might be achieved.

In a thoughtful essay on the substantial social, environmental, and economic consequences of our society's dependence on the automobile—and our persistent inclination to rely on technological solutions—a former vice president of General Motors calls for leadership in devising behavioral, normative (i.e. value-based) solutions to these problems (Johnson 1992). Leadership would be provided by members of a broad mix of industries and interests, all willing to set aside their parochial interests for the larger goals at stake. Similarly, Tempchin and LeBlanc (1992) suggested leadership by opinion leaders in an orchestrated social marketing campaign aimed at spreading the social idea that "energy should be used wisely."

At this point it may be useful to draw a very important distinction between elitism and leadership. Elitists presume to know the correct direction for society and set about activity to that end. Leadership emerges from the investigation and recognition–not presumption–of the fundamental needs, aspirations, and values of constituents (Bums 1978). In this way leadership has the power to bring about changes to satisfy authentic needs of society. The result of such transformational leadership is a relationship of mutual stimulation and elevation of society as a whole.

The changing mix of personal activities—which are largely a function of time—and the location of those activities will drive future energy demand in most industrialized countries (Schipper et al. 1989). A nontrivial issue for consideration is then how society chooses to spend its leisure time: the primary choices are 1) to consume, and 2) pursue cultural development. To produce and consume is energy intensive. To set time aside for cultural development is less energy intensive but requires a change in the aspirations of society (Spreng 1993).

The public is embracing environmentalism as a mainstream value (Farhar 1993). There are numerous small but thriving communities of individuals committed to sustainability, simplicity, and human-centered development (Stisser 1994). These principled lifestyle decisions are ripe for diffusion. It would be ironic and truly unfortunate if energy efficiency proponents fell behind the curve of social change in this area, losing an opportunity for true leadership.

Conclusions

There is a very real danger in accelerating the use of advanced technologies before sufficient numbers of technicians and end users are prepared to deal with them. Recalling themes from technology assessment, market transformation, and societal values:

> Change agents who rush the adoption of a technology without benefiting from the value of the introduction and growth stages of product life-cycle risk hitting the market too early. As we witnessed in the solar industry in the late 1970s/early 1980s, large subsidies can lead to inadequate technology development, a weak support and maintenance infrastructure, and a consumer base which does not fully value the products once subsidies disappear. (Tempchin and LeBlanc 1992, 246)

The advances in technologies established through incentives and regulatory schemes are impressive and should lead to substantial energy savings as they penetrate the market. Market saturation will take decades, however, due to the lifetimes of the equipment to be replaced.

During this time we have the opportunity to magnify these savings by developing programs to ensure that the efficient equipment is installed correctly, and that our buildings and equipment are operated in a safe and efficient manner. More importantly, we have the opportunity-if not the duty—to encourage the public to understand and value the services these technologies provide so that consumers can choose if and when they wish to use the technologies.

Acknowledgments

The author thanks Skip Laitner and Neal Elliott for their encouragement and insights on the topics discussed here. Thanks also to Lee Schipper and two anonymous reviewers for their helpful comments. The views expressed here are those of the author and not necessarily those of the American Council for an Energy-Efficient Economy.

Endnote

1. In fact, ACEEE uses less than a proportionate share of the building's energy, because our offices are equipped with very efficient lighting and laptop computers, and staff take full advantage of our excellent daylighting and passive solar gain. Nonetheless, some decrease in productivity is inevitable in the zero-energy case, since then we would be without computers, fax machines, and our telephone system.

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