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Bounded Decision Making and Analytical Biases in Demand Side Management*

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Demand side management (DSM) programs across the United States commonly approach barriers to energy efficiency through technical/economic means and evaluate their impact through technical/economic analysis. To the extent that non-technical barriers exist and influence decision making, they complicate the expected capture of savings. Two utility DSM projects—Pacific Gas and Electric's Advanced Customer Technology Test for Maximum Energy Efficiency (ACT^2) and Bonneville Power Administration's Energy Edge—serve as case studies to illustrate how non-technical barriers to specific energy-efficiency measures (EEMs) can limit technical conservation potential. An analysis of rejected EEMs suggests that lessons about non-technical barriers may be lost or obscured because of the predominant focus on technical/economic criteria over social, institutional, or cultural constraints. These findings support the need for different evaluation methodologies and further social science research devoted to understanding the non-technical barriers confronted by DSM project participants.

Introduction

Rapid urban development burdens existing power grids with the demands of new buildings and contributes to the need for new electric capacity. Although better building energy standards are improving end-use efficiency, these improvements are being overcome by increasing office equipment use and by additions in the number of buildings. While standards guard against the construction of inefficient buildings, they do little to encourage the development and construction of highly-efficient buildings. Efficiency advocates maintain that it is technically feasible and economically optimal to improve the energy performance of buildings beyond standard practice. The size of the efficiency gap between "what is" and "what could be" varies from one engineering analysis to another, but typical estimates are on the order of 30%. Some engineering analyses suggest that new buildings could be as much as 75% more efficient than they commonly are, but such claims have yet to be proven.

To prove the efficiency potential beyond standards, some electric utilities have developed projects to support the implementation of energy efficiency measures (EEMs) in buildings. Two such demand side management (DSM) projects were designed to demonstrate the feasibility of EEM strategies in the "real world"—Pacific Gas and Electric's Advanced Customer Technology Test for Maximum Energy Efficiency (ACT^2) and Bonneville Power Administration's Energy Edge. They also served as unintentional social experiments. Because there is no exact or universal recipe for optimizing the energy-efficiency of a building, improving the energy performance of any structure above a baseline involves many decisions as to what measures might be most effective. Although EEM decisions were often treated as if they were based exclusively on engineering-economic criteria, analysis of these projects points to the importance of other institutional and cultural factors that selectively influence the acceptance or rejection of certain EEMs.

Both Energy Edge and ACT^2 have contributed valuable technical/economic lessons about the effectiveness of installed EEMs. The participating buildings constructed are more efficient than average, but they were not always as efficient as the utilities expected them to be. The difference between expected and achieved savings follows a trend seen in other DSM programs, where impact evaluation results are often lower than engineering estimates (Nadel and Keating 1991). This difference has many common explanations, one of which is erroneous assumptions in the engineering estimates. For example, estimates may be based on complete implementation of a full range of cost-effective EEMs. In reality, the range of EEMs considered for implementation is limited by more than the engineering/economic criteria scripted in the project plans. Program evaluations of Energy Edge and ACT^2 show that there were unanticipated problems with installation, operation, and maintenance with some EEMs. Others were abandoned or altered along the way from initial design to final construction, and some EEM options were not pursued at all. The reasons for failure and rejection vary, but some decisions made by design teams in both projects, particularly with respect to the building envelope and the heating-ventilation-air-conditioning (HVAC) systems, are not sufficiently explained by technical/economic methods.

The purpose of this paper is not to identify more savings than the engineering analyses suggest, but to promote a path that will help DSM planners understand how best to secure those savings promised by the technical calculations. The efficiency gap exists, even in utility DSM programs designed to bridge it, and its causes need to be better delineated. If they are irreducible, linking expectations more closely to reality by reducing projections of EEM efficacy by some factor would lead to more realistic estimates of cost-effectiveness and programmatic goals. More optimistically, a better understanding of non-technical barriers could lead to more effective efforts to overcome them.

This paper begins by describing the efficiency gap and noting that research into non-technical barriers is not new to DSM. Secondly, literature and data from Energy Edge and ACT^2 support the assertion that non-technical barriers confront and affect DSM programs through EEM choices. Taking into account the existing process evaluations already underway or completed in both projects, this project concentrates on the constraints on those measures *not* installed. Where possible, estimates of the lost energy savings from classes of measures not implemented are provided. Finally, recommendations are made for further research into the non-technical, non-economic barriers to energy efficient design.

The Nature of the Efficiency Gap

Efficiency in the US commercial building sector has improved since the 1970s, but these improvements did not arise spontaneously from within the building sector. Energy service companies capitalize on the efficiency gap by using new energy efficient technologies to retrofit existing buildings and pocketing some of the money designated for the utility bill. Utilities have paid for DSM programs to encourage the construction industry and design community to improve building energy performance. Governments and professional organizations support the continued development of standards for building energy-efficiency. Despite the efforts of groups outside the building sector, design trends do not widely reflect the available tools and techniques for limiting energy use.

Perceived Barriers

A central focus of recent research regarding this non-optimal behavior has been on market failures. Koomey develops a typology of these failures which include imperfect competition, imperfect information, economic non-rationality, risk aversion, presence of side effects, public goods problems, cash flow constraints, and regulatory distortions (Koomey 1990). Others blame the market failures on institutional barriers to efficient practice, which include fragmented and commoditized design (Lovins 1992). Organizational models have also been used to explain the low level of energy conservation implementation (Cebon 1990). While this kind of research describes real obstacles in the flows of money and power at a general level, such methods are not commonly applied to explain the efficiency gap in specific DSM projects.

In current practice, DSM program design reflects some subset of the perceived barriers to widespread efficient practice. In response to barriers described in broad economic terms, DSM programs tailor their approach to address tangible economic and technical issues. Concomitant DSM program evaluations may also adopt economics and technology as the basis for appraisal. This orientation persists even though there is an awareness that "human factors" can be a more significant barrier to achieving peak efficiency than hardware (Hirsh and Pruitt 1993).

Energy research from the 70s and early 80s suggested that technical factors alone were "neither sufficient nor adequate" to explain energy use in buildings (Vine 1993). Since the mid 80s, however, research efforts have favored evaluations based on technical/engineering approaches. Earlier papers raised open questions about overcoming social and institutional barriers to energy efficiency, noting problems associated with changing "custom" as well as increasing cost (Blumstein et al. 1980). Recent work attempts to situate such questions within a technologically positive and economics-oriented framework, where perceived risk can be alleviated by financial subsidies (Vine and Harris 1989). While economic and technical barriers pose questions that are appropriately addressed with financial incentives and technology demonstrations, other barriers to efficient practice may better understood through different methods.

Non-Economic, Non-Technical Constraints

To some extent, each new building design can be characterized as the tangible result of negotiation between different "cultures," loosely defined as social/professional groups with disparate goals. For example, developers are interested in profit, architects pursue aesthetic ideals, and engineers want reliable performance, yet members of these groups (and many others) work together in the building process. DSM projects that promote changes in construction practice superimpose another culture—utility administrators seeking to improve energy efficiency—over those pre-existing in the building process (O'Drain et al. 1993). Participants from different cultures determine the form of a building and the way it functions, yet little attempt has been made to specify how cultural differences could affect building design and energy performance or how such differences could constrain EEM decisions.

Typically, DSM program evaluations focus on technological performance, not cultural interactions. Understandably, they also tend to emphasize the cost-effectiveness of measures implemented and exclude caveats about non-implemented measures. Process evaluations may identify the factors that constrain or enable certain measure types, but they commonly do not attempt to do so at an EEM-specific level, nor connect the unchosen EEMs to the lost energy-saving opportunities they represent. To get at the question of how non-economic, non-technological issues affect EEM decisions and conservation potential, this paper analyzes EEMs that were not installed. In other words, the author suggests that it is possible to learn something useful about a doughnut by looking at its hole.

Research Approach

This project uses two of the three most common constraints on utility DSM programs—stage of building design and acceptability of measures—to study the extent to which the efficiency gap in DSM projects results from the differences between utility expectations and project goals on the one hand, and designer/builder culture and the inertial effects of "common practice" on the other.

Background

Energy Edge and ACT^2 serve as effective comparative case studies for several practical reasons. Both are multi-year utility-funded research projects designed to encourage energy efficiency above standard practice through supporting groups of EEMs and providing design assistance. For the 28 new commercial buildings included in Energy Edge, the project goal was to achieve 30% energy savings over the Model Conservation Standards (circa 1985). Energy Edge construction took place between 1986 and 1989; analysis ended in 1993. Work on ACT^2 began in 1990 and will continue through 1997. The nine ACT^2 sites include a broader range of new and existing building types than Energy Edge but a smaller number of cases. The ACT^2 maximum efficiency goal is more ambitious than the Energy Edge project's, emphasizing state-of-the-art technologies in packages designed to optimize building efficiency. Access to data and analytical expertise from both projects was also a consideration, as was the author's previous experience with the cost-effectiveness analysis for Energy Edge.

Research Design

The first part of the research was to survey and summarize both Energy Edge and ACT^2 to establish a baseline of goals and expectations. This was accomplished with a mixture of literature and program review and interviews with those who designed and specified the program goals and objectives. Using this information as a guide, the author reviewed data on actual EEMs to establish a reference database on performance, with particular emphasis on those measures that failed or were rejected. From this process, a typology of unchosen EEMs emerged which reflects the influence of non-technical criteria. Additionally, ways in which the project assessment methodology may mask lessons learned from the rejected EEMs became apparent.

Typology of Failure and Rejection

The Energy Edge data contain 257 individual measures and 108 measure types distributed over the 28 new commercial buildings. The master EEM list for ACT^2 contains approximately 300 options for new and existing residential buildings, offices, restaurants, and warehouses, although less than 100 EEMs are candidates for any one building type. While some measures in both projects worked very well, others did not. Installed measure failure occurs when an EEM does not perform as promised, either as the result of human error (e.g., poor design, improper installation), technical malfunction, or some combination of the two. Installed measure successes and failures are explored in other reports; this paper focuses on non-installed measures and the reasons for their rejection.

Rejected Measures: Analysis Omitted. Many EEMs are rejected for obvious technical or economic reasons that need no detailed analysis. For instance, an EEM may be inappropriate for a particular building type. In some cases, however, EEM analysis may not be pursued for other reasons. A process evaluation of the Energy Edge project suggested that the types of EEMs examined for implementation are constrained by the stage of building design and the acceptability of the measure to the design community (Heidell and Lorberau 1989). Because a utility may perceive architects or clients as unwilling to discuss design options until something exists on paper, the utility might wait until the design concept has passed the schematic stage before getting involved. Also, utility expertise is assumed to be in analyzing specific EEMs, rather than developing generic design guidelines. One possible effect of these primarily social constraints is that participants are likely to evaluate the potential benefits of more efficient HVAC and lighting systems, as well as considering better insulation and glazing. They may less frequently consider building orientation, footprint, or different glazing areas and orientation because these aspects are typically decided before the participant gains EEM assistance.

Rejected Measures: Analyzed and Refused. Not all EEMs considered for inclusion in a building make the cut from analysis to implementation. The rejection can occur on technical or economic grounds, but decisions not to implement EEMs can also be culturally biased. The rejected EEMs at this stage are generally alternative to common architectural or engineering practice. Architectural alternatives include building orientation, window area and orientation, shading strategies, and footprint. Engineering alternatives include downsizing standard equipment, using new types of equipment, or some combination of the two. Architectural efficiency in particular is critical, because it provides the shell which the other building technologies serve.

Non-technical, non-economic barriers to alternative architectural and engineering strategies may be aesthetic, cultural, or legal. One famous example of a building where aesthetics were selected over efficiency is the United Nations Secretariat, which was oriented to obtain the best views for its occupants as well as to present its own form more strikingly to observers. This orientation was selected explicitly over one that would have required lower initial and operating costs (Ellis 1950). This example illustrates two points: 1) orientation alone can have a measurable impact on energy use; 2) precedents such as these in the architectural community send a strong signal to architects that differs from the energy-saving bias of DSM planners.

Measure Analysis

Architectural Strategies and Barriers

The distribution of EEM types considered and installed in the Energy Edge buildings versus the rejected EEMs reflects the inclination outlined above. Of the 28 Energy Edge buildings, participants in 25 buildings installed more efficient (but not necessarily down-sized or alternative) HVAC components; participants in 23 buildings installed more efficient lights; participants in 23 buildings improved the insulation; and window measures were installed in 25 buildings. In contrast, orientation was considered as an EEM for only one building. This measure was not sponsored by the project, and it was not implemented. A footprint measure was considered for one building, but it was not sponsored by the project and not implemented. A range of daylighting and shading strategies (including clerestories, light shelves, skylights, overhangs, trellises, and sunscreens) were considered in this building and five others. The daylighting and shading strategies under consideration were sponsored in only three of the six buildings, and they were not implemented in one.

Many of the architectural strategies rejected by Energy Edge participants were accepted by ACT^2 participants. Changes to site and form were considered for all four of the new ACT^2 buildings, with positive results. ACT^2 analyses expect the architectural EEMs of orientation, footprint, and daylighting to yield energy savings of 40% over standard practice in a new commercial building (1992). In residential construction, perimeter reduction measures offer 10-17% annual site energy use savings, with changes in glazing areas and orientation contributing another 5-10% savings over the base case (Davis Energy Group 1992).

While the ACT^2 project emphasizes the pursuit of maximum efficiency, the real world dictates that the efficiency gained cannot come at the expense of marketability or reliability. Although the ACT^2 residential studies suggest that as much as 27% savings are possible from site and form EEMs, the most efficient perimeter and glazing package was deemed the least marketable by the developer. The most efficient plan proposed angled corners which resulted in four non-rectangular rooms, and it reduced glazing on the north, east, and west sides to half of the base case window area. It also presented a "challenge" in creating a "pleasing roofline and facade." Although the analysis showed that cutting two corners was cheaper and more energy-efficient than leaving them square, the prevailing assumption was that no one (except perhaps members of the utility project steering committee) would want to live in a house with obtuse angles. As a result, this package was rejected in favor of a less efficient and less architecturally radical alternative which kept conventional corners but followed the same glazing strategy. The lost opportunity in energy savings from the rejected to the selected package was on the order of 5%, and the initial incremental cost of construction increased by about $700.

Two lessons can be drawn from this example. First, although developers are notorious for pinching pennies, avoiding aesthetic risk was worth more than capturing an estimated $727 of initial cost and energy savings benefits. Secondly, this aesthetic risk was perceived by the developer, not demonstrated by consumers. Although the housing market is conservative, architectural styles and personal tastes do change. Should increasing resource scarcity influence the social, political, and economic forces of the future, it is possible to envision the next generation of homeowners parking their fuel-efficient cars in the carports of their cut-corner houses. A more aggressive projection of changes in socioeconomic factors might trade the cars in this scene for access to public transportation, and an extreme view might call for higher-density housing and challenge the single-family suburban home itself.

Engineering Strategies and Barriers

In addition to finding some resistance at the edge of the architectural envelope, the ACT^2 project has also confronted non-technical barriers to implementing engineering alternatives. For a new commercial building project's HVAC package, the utility project steering committee favored an innovative rooftop ponding system which would have taken advantage of nighttime temperature differentials, radiant exchange with the night sky, and rooftop thermal mass. The builder and owner were concerned about leaks and reliability, so a more conventional HVAC system was installed.

The proposed system may or may not have been unreliable, but it certainly was unfamiliar and to some extent counter-cultural. By depending on natural rather than mechanical processes, the rejected HVAC system represents a significant departure from conventional practice. It offers operational reliability (i.e., thermal mass will not "break"), but it does not provide the same degree of control as a mechanical system (i.e., radiant exchange cannot be turned "on" or "off"). Mechanical HVAC systems are designed to provide a controlled internal environment, free from variable external weather conditions. In contrast, the rooftop ponding system is inextricably linked to changes in the outdoor environment. The principles employed by the rooftop system are some of the oldest known and most common elements of climate-responsive design in vernacular buildings, but they are not a part of modern commercial construction practice. Although other new and unfamiliar technologies (efficient lights, spectrally selective windows) were acceptable to the builder and owner, this "new" method of partially passive cooling was not. Even the possibility of having the system's performance guaranteed was not sufficient to convince the builder and owner of its reliability and persuade them to take the risk of installing it.

The lost conservation potential from the proposed to the installed system were again on the order of a few percent, at a comparable cost. The lesson learned is similar to that of pushing the architectural envelope: even in a project designed to achieve maximum efficiency, non-technical barriers can prevent the complete pursuit of a technological goal. The ACT^2 project could pay the builder and owner to install an efficient HVAC system but could not persuade them to install the *most* efficient one which also challenged common practice.

In the above examples, cultural biases between groups participating in the project form the basis for non-technical barriers to specific EEMs. The next case shows that such barriers can develop between project participants and groups outside the project. Such a situation may turn the reputation of the project participants into the most influential factor in determining the "acceptability" of a measure. Hydronic radiant floor heating was recommended as an EEM in both the ACT^2 new residential sites, one in Davis, the other at Stanford Ranch. Because it uses a different type of tubing than standard, this EEM challenged current practice and building codes in both locations. The Davis design received a variance from code officials for this measure; the Stanford Ranch design did not. In the opinion of an ACT^2 project staff member, the Davis dispensation was due to special social circumstances. The Davis design/build team had a positive preexisting relationship with the Davis code officials, who were also progressive in their outlook. This extant connection between a group inside the project and one outside it made the difference between getting the measure approved and having it rejected. The code officials responsible for the Stanford Ranch site were less familiar with the work of the design/build team, and they decided the measure was unacceptable.

Methodology Analysis

The above examples sketch a picture of resistance to selected EEMs, especially those that challenge conventional architectural or engineering practice. DSM projects tend to characterize the technical/economic attributes of EEMs but do not systematically address their social/institutional/cultural acceptability. For the EEMs falling further and further outside from the realm of conventional practice, there seems to be a line where social, legal, and cultural barriers eclipse technological or economic opportunity. Learning where this line has been drawn previously and what it looks like constitutes an important step toward anticipating its occurrence and overcoming the obstacles it may present.

Existing measure analyses in either Energy Edge or ACT^2 do not actively seek this kind of information, and currently neither project provides consistent methods for incorporating such information when it arises. Basic EEM information for both Energy Edge and ACT^2 consist initially of alphabetical lists of individual measures, sorted by general categories such as HVAC, shell, lighting, and "other." As the projects progress, measure costs and energy savings are added to the lists, and cost-effectiveness analysis proceeds with these figures. This kind of analysis is designed to answer technical/economic questions about installed measures but does not specifically address social/cultural questions about them or provide non-technical/non-economic insight into the measures that fail or are rejected.

To address issues not included in current analyses, the problem "frame" commonly used by DSM program evaluations could be reshaped. There are many possible ways the evaluation methodology could evolve, but two dimensions in particular should be considered: (1) integrating social science research methods, and (2) broadening the basis of cost-effectiveness inquiries. Because the dominant barriers to some of the failed or rejected EEMs may be cultural/sociological, a social science approach to measure analysis could yield valuable clues to utilities seeking to optimize their DSM programs (see Recommendations for Further Research). In its current configuration, cost-effectiveness analysis may actually obscure useful information by focusing too closely on some data and paying less attention to others. There is some evidence that costs and benefits which do not fit into established categories of EEM costs and energy savings may be excluded or ignored. Examples of this kind of information include design costs, energy savings from passive EEMs, and non-energy benefits of some EEMs.

Costs Excluded

Determining the real "cost" of each EEM is a complicated and subjective process that includes much more than recording its purchase price. Selecting which measures to install generates administrative, design, and modeling costs; installing the selected measures incurs additional design and construction expenses; and gathering information about the measures' installation, implementation, and operation requires further expenditures. Comparing these costs for each measure to "what might have been" if the hypothetical baseline building had been constructed adds another level of uncertainty. Finally, there are the externalities that affect the price of material costs, and the difficulty in attaching dollar values to non-material expenses, such as estimating engineering effort.

To account for some of these difficulties, both Energy Edge and ACT^2 developed methods of estimating the standard or mature market cost of the EEMs. Because many of the EEMs were relatively new at the time the projects began, the standard or mature market costs were intended to correct for immature market pricing policies, such as higher production costs and limited production runs. The resulting estimates were meant to reflect the typical cost of a measure after it has become "familiar." These estimates are generally lower than current cost estimates, and both projects use them in their cost-effectiveness analyses.

While this reasoning is appropriately applied to material expenses, the Energy Edge project experienced difficulties in collecting and standardizing non-material costs. Predicted and reported design costs were supposed to accurately reflect engineering effort, but for some EEMs they were thought to indicate "hassles" with new technology more than the absolute difficulty of a design task (e.g., specifying efficient lights or windows should take no more time than specifying standard ones, but installing an energy management systems requires more engineering effort than not installing one) (Gilbertson 1990). The Energy Edge project also found that it was unfeasible to obtain realistic design costs from contractors surrounding items and systems for a hypothetical project. Contractors contacted for this purpose pointed out that they spend time preparing bids and costs in hope of doing the work, and they would not provide system costs for conceptual analysis. Similarly, there is no incentive for manufacturers' representatives to prepare possible design budgets, unless they feel it likely that their products may be specified on future projects. As a result, Energy Edge standardized costs do not include estimates of engineering effort.

For valid reasons within the technical/economic problem frame, the Energy Edge cost-effectiveness analysis does not include design costs. They could not be standardized, they represented on average a small fraction of the construction costs (about 10%), they were highly variable, and they were potentially unreliable. Although design costs did not serve their intended function of indicating "familiarity," they might have been useful indicators of "unfamiliarity." As a percentage of construction costs, predicted incremental design costs varied from 0 to 80% of construction costs. There are 13 individual measures where predicted design costs were estimated at a third of the construction cost. One of these measures is a daylighting strategy for which design costs are estimated at 40% of construction costs. If the design costs gathered are indeed "hassle" costs, they could have served to screen for EEMs that cause more than average difficulties.

Passive Savings and Non-Energy Benefits

Identifying the impact of installed EEMs is a complicated process, but one to which a lot of effort has been devoted. In new buildings, this process requires a kind of "crystal ball gazing" to determine baseline usage, and it faces abundant analytical difficulties which complicate accurate measurement (Fels and Keating 1993). End-use submetering, used extensively by ACT^2, seems to be the most satisfying method of evaluation because it produces actual data on energy use instead of inferences from models.

One drawback of this method is that it cannot be applied equally to all EEMs. Its use biases evaluation toward the actively electronic or mechanical EEMs but does little to explain the effectiveness of the passive or architectural measures such as footprint, orientation, shading, insulation, or glazing. It does even less to provide information to future programs about the efficacy of EEMs that exist on the theoretical plate of options but are rarely implemented through DSM programs. Because a positive feedback loop forms between evaluation methods and the available engineering evidence for choosing EEMs, architectural EEMs may receive even shorter shrift in the future. A recent assessment of the technical potential of electricity efficiency improvements in the U.S. residential sector analyzed the conservation potential of 214 EEMs, but due to lack of data it did not include perimeter reduction, window orientation, or passive solar features (Koomey et al. 1991).

No matter how the energy savings are measured or modeled, there are non-energy benefits to some EEMs that are not captured by standard cost-effectiveness analysis. Benefits described in terms of kilowatt-hours or British thermal units cannot account for the amenity value of daylighting measures or the fire and security benefits of an energy management and control system.

Recommendations for Further Research

Future investigations of social and cultural factors should be based on interviews with program participants, with special attention to identifying negotiations between and among those drawn from different professional "cultures" and/or different analytic perspectives or problem "frames." The term "organizational culture" has generally been used to examine beliefs and behavior that pertain to the relationship between individuals or groups and the organization as a whole (Schein 1985). A "professional" culture spans the more general class- or education-based culture and the more specific definitions used in the organizational literature. In this context, the definition also includes aspects that could be characterized in social, institutional, and/or psychological terms. A professional culture approach could address a variety of issues inaccessible to an analysis based on the project literature and technical data, such as experiential knowledge gained with traditional technologies, cognitive representations of buildings as technical and engineering systems, and professional history, tradition, and purpose. The methods used could follow the general outline of those used with success in previous studies (Rochlin 1993; Rochlin and von Meier 1994)

Such interviews could help identify those social and cultural factors that affect choices among EEMs and pinpoint those places where misunderstandings and conflict arise from cultural incompatibilities. Questions should include subjects' perception of the "others" involved in building design and construction as well as their views of their own profession and its goals and methods.

Previous work has addressed the relative intractability of the relationships between technical and non-technical professionals (von Meier 1992); the work recommended could extend that analysis to relationships between technical cadres trained in different traditions and possessed of different approaches to and understandings of the enterprise in which they are mutually engaged. Understanding these relationships is a necessary prerequisite for attempting to identify the underlying reasons for the current shortcomings of building designs when compared to the large savings that have already been identified as technically and economically achievable.

Conclusions

Analysis of EEMs rejected by Energy Edge and ACT^2 shows that a variety of social, aesthetic, and cultural barriers exist and can constrain EEM decisions. By restricting EEM choice, these non-economic, non-technical barriers can reduce the conservation potential of buildings and contribute to the efficiency gap between expected and achievable savings in DSM projects. Although no single panacea can dissolve these barriers, some of them can be overcome if project participants can devote the necessary time and effort to this pursuit. Fortunately, the magnitude of the barrier and the potential benefits of overcoming it may not be directly related. In Energy Edge, one reason given for the low implementation level of architectural EEMs was the utility's own perception that its role was not to give design advice. As the ACT^2 experience shows, architectural EEMs can be responsible for a sizable portion of energy savings, estimated at 27% in one residence and 40% in a new commercial building. Providing good design advice may not be "easy" or cheap, but it is possible and potentially very effective. In comparison, consider the ACT^2 case of the builder's and owner's resistance to a partially passive HVAC system. The efficiency gains from the system would have been marginal, and the effort necessary to overcome expressed resistance was significant, possibly infinite.

Even the seemingly insurmountable barriers may soften over time. Although cut-corner houses and rooftop ponding systems are currently unacceptable for some combination of aesthetic, social, or cultural reasons, they could gain acceptance in the future. For example, about a decade ago white or light-colored roofs were considered unacceptable, but they were recently written into the U.S. government's Office of Management and Budget guidelines for the acquisition and use of energy efficient products (Kelman 1994). Although cultural change with respect to energy efficiency strategies occurs slowly and incrementally compared to technological development, it can be brought about through communication, education, and experience.

DSM research projects have a major role to play in supporting cultural change as well as technological development. The current focus on proving technical and economic efficacy, however, does not encourage the practice of gathering social and cultural information that could help map and promote such change. Cost-effectiveness analysis of installed EEMs currently provides only part of the picture that DSM projects could conceivably paint. Using social science methods and broader definitions of costs and benefits, the DSM evaluation framework could be reshaped to include analysis about EEM rejection as well as acceptance. The resulting information could help subsequent DSM project participants negotiate the non-technical, non-economic barriers that contribute to the efficiency gap between technical potential and achievable savings. Ultimately, this practice could pay off in more successful DSM projects and better building design.

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