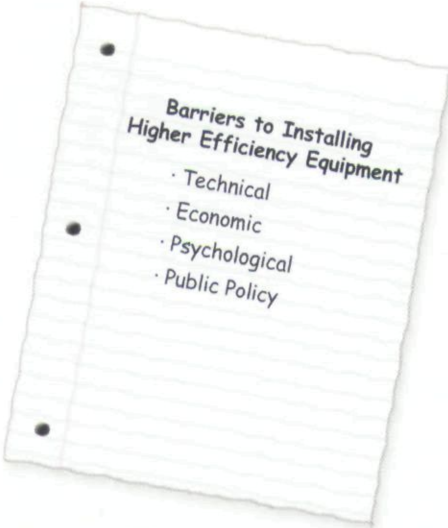

Overcoming Barriers to Efficiency

By **Thomas M. Lawrence,** Member ASHRAE, **Jeffrey D. Mullen, Douglas S. Noonan,** and **Jay Enck,** Member ASHRAE

Commercial and residential buildings consumed approximately 39% of the total energy used in the United States in 2002[1] with the remaining used in the industrial (33%) and transportation (28%) sectors. Approximately 4.6 million commercial buildings exist in the United States.[2] Of these, 68% of the non-governmental buildings are owner-occupied, and the rest are leased or vacant. More than 90% of buildings owned by the U.S. federal government are owner-occupied.[3]

The majority of energy use is devoted to space conditioning, lighting and other equipment. *Figure 1* shows energy consumption in commercial buildings.

Barriers to Installation of High-Performance HVAC Equipment

Many factors influence a decision on whether additional expense is allocated to higher performance HVAC equipment. The following section discusses barriers we have identified. These also are summarized in *Table 1*.

Building Ownership

While all situations can be summarized in terms of justifying a cost expenditure compared to other options for the capital, the viewpoint is different depending on whether the particular building is occupied by the owning entity or is leased.

For owner-occupied buildings, the utility and capital expenses are ultimately included in one corporate budget. Thus, decision processes become a justification of any additional expense for higher performing equipment relative to the expected returns via lower energy costs. In an existing building, business management principles determine the evaluation process. The decision is influenced by whether modifications are necessary

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(servicing or replacement) or purely for improved performance. More flexibility exists in new construction because necessary energy-consuming equipment must be installed anyway. Equipment performance selected depends on the business model and external factors such as building codes or standards.

The option being considered will be evaluated against other competing projects for capital resources. When only tangible or more easily measured cost savings are considered, energy cost saving projects often perform poorly compared to other core business activity alternatives.

For buildings not owner-occupied, two separate entities must be considered: the owner and the lessee. This situation becomes a dilemma when neither party has a strong incentive to make the investment in higher efficiency equipment. If the building owner purchases or builds with the intent to later sell or lease, then alternatives that increase the attractiveness of the building to future owners or lessees (in property values or potential leasing prices) warrant further consideration.

Current market conditions also play a significant role. The commercial real estate market is cyclical. In good economic times, the market for leased space will be tight and owners can obtain attractive prices regardless of the HVAC efficiency. In economic downturns, attracting a quality lessee is imperative and the owner may want to offer a building that operates efficiently and provides a quality indoor environment. However, in economic downturns, the owner needs to conserve cash, decreasing likelihood of an investment in higher efficiency equipment.

Leased buildings also face principal-agent problems in contracting, where it is difficult for one party, the principal (lessee), to control the behavior of the agent (owner). Lessees responsible for energy costs may struggle to get their landlord, who may own and maintain the equipment, to invest in efficient systems.

Technical

Technical factors generally are well understood by ASHRAE members and are not addressed in much detail here. Key related issues include:

- Equipment compatibility;
- Analysis cost of a proposed system upgrade;
- Impact on maintenance cost; and
- Lack of management understanding of the technology involved.

Economic Factors

Certain economic factors apply regardless of building ownership. For example, a cost is associated with the information gathering process for new technology or obtaining information relevant to current resource use. This is primarily a direct expense in the form of employee salaries or consultant fees.

Other major issues/barriers may exist in the tax and finance system. Whether the owner intends to occupy or later lease a building under construction, a decision on the equipment efficiency may depend on external factors such as local or state building codes and the degree to which these codes are enforced. HVAC upgrades can be financed through means ranging from outright cash payment to borrowed capital. If a building owner invests cash to upgrade the HVAC efficiency, the property value is (potentially) raised. The owner then should be able to leverage that increased value to obtain additional cash today for a possible net gain if this, is in fact, an efficient investment.

The decision maker functions within several other constraints in the decision process. One is the availability of capital for any type of business improvement. This is particularly significant for small- to medium-sized companies that generally face higher interest rates. Higher interest rates, whether caused by market conditions or the type of business, pose a bigger hurdle for profitability when justifying capital investments. Also, uncertainty about rates can be a barrier.

A somewhat different form of capital constraint exists for public sector entities. These organizations have low risk, and, hence, do not face a high interest rate barrier. However, legal restrictions often exist to borrowing, on investment of additional capital for energy-efficiency improved projects, or on selecting single-source vendors with unique technologies.

Decision makers tend to focus on the core aspect of their business, the bounded rationality of economic theory. In economics, bounded rationality refers to the inability of decision makers to consider every relevant aspect in the decision. This is a barrier particularly when the energy costs are a small percentage of the total operational budget. The decision maker may fail to realize that energy efficiency actually helps stabilize cost variability for the business as a whole by decreasing the percentage of total costs due to energy.

New equipment is generally considered a capital expense, which must be amortized over time, compared to an operating expense, which is treated differently on the company's tax report.

Private firms are unlikely to be able to finance their activities by issuing notes with a return equal to that of 30-year treasury bonds, which is considered the risk-free cost of capital. Rather, they generally borrow from commercial lenders. The interest rate commercial lenders offer is comprised of four components: the risk-free cost of capital, a risk premium, expected inflation, and a margin to cover transaction costs (these may be levied as up front fees instead). In analyzing a project, firms generally consider the interest rate for borrowing their most appropriate discount rate, which is higher than the social discount rate since it includes inflation and transaction costs. The end result is a project that may be attractive from the perspective of society in general is not considered so by the firm.

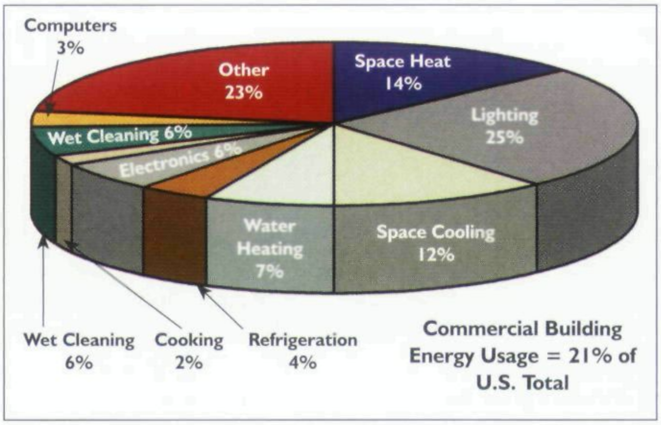

Figure 1: Energy use in U.S. commercial buildings.

Inherent in choosing a discount rate is the subjective decision of how to weigh the value of future generations relative to today. Higher discount rates negate costs incurred and benefits gained in the future. For public projects, government agencies are obliged (in principle) to consider intergenerational impacts. This can lead to fairly long planning horizons and a selection of low discount rates in the analysis. Private companies are under no obligation to consider intergenerational impacts. They have shorter planning horizons, consistent with higher discount rates.

Other Barriers

Other barriers to implementing higher efficiency equipment are difficult to classify. One of these can arise if an outside party is contracted to evaluate and implement energy savings projects, which is one alternative to internal funding of a system improvement. The outside party is motivated to find and select items that provide the most immediate and greatest economic payback with the lowest risk. Therefore, projects that could still provide significant long-term energy savings may be bypassed if they cannot provide the rapid payback, which benefits the outside party. This can result in only the "low-hanging fruit" options being selected.

After implementing this series of energy-efficiency improvements, the building owner may place an even lower priority on considering any further system improvements because they may (wrongly) believe that all viable options have been performed.

The distinction between "internal" and "external" costs and benefits factors significantly in the analysis. Internal costs and benefits are the only areas that a business traditionally considers in a decision process. Other factors that benefit or cost others or society as a whole are not considered.

A barrier to implementation may exist, even for internal costs and benefits if a business has difficulty readily identifying or quantifying them. The result is a major barrier to installing high-performance HVAC technologies today. The full costs of not doing so (or the full benefits of doing so) are not accounted for or borne (internally) by the decision maker.

In the first instance, where the decision maker does not account for the costs, barriers to implementation might be primarily informational or organizational. In the second instance, where external costs are not borne by the decision maker, barriers to implementation may involve the economic and legal systems.

Regardless of their process, decision makers are discouraged from installing HVAC upgrades because the costs of not adapting are artificially low. Examples include external environmental and climate impacts, politically made decisions (government buildings, codes and zoning ordinances), dependence on unstable foreign energy sources and (potentially) economic discount rates.

Costs & Benefits Generally Not Included in Decision Process

Several examples of additional internal and external cost or benefit items that should be considered when selecting energy consuming equipment are offered here.

Employee Productivity

One source estimates that companies can spend an average of 70 times as much annually on employee salaries per unit floor area compared to energy costs.[4] Another source estimates that only 2% of the total life-cycle owning costs for a commercial building are in design and construction. The other 98% is attributed to operation, maintenance, employee cost and financing charges.[5,6] A wide range of physical environment

Barrier	General Description	Potential Remedies
Ownership Structure	Those who make decisions about energy equipment may not pay operating costs.	Need for increased education, awareness and communication by and between owner and lessee. Encourage alternative lease structures.
Technical	For example: Will the equipment work as promised? Is it compatible with other (existing) systems?	Encourage public and private R&D programs. Encourage technology compatibility and standardization.
Baseline Information Costs	Answering a question like "How much do I spend on energy?" can be expensive.	Annual Cost-to-Date Billing from energy providers.
Technology Information Costs	Accessing relevant information to analyze energy efficient equipment can be expensive. Information regarding compatibility with existing technology and estimation of benefits are important.	Include charts/calculators to convert energy savings to dollars in marketing materials for energy efficient technologies or provide savings calculation software. Cooperative advertising of energy efficient concepts.
Capital Constraints	Private sector borrowing constraints. Public sector legal restrictions on borrowing.	Subsidize borrowing through low interest loans for adoption of energy-saving equipment.
Interest Rate Uncertainty	Rising interest rates decrease attractiveness of future cost savings.	Encourage no- or low-interest loans for new equipment through tax breaks, etc.
Bounded Rationality	Reluctance/inability of business leaders to assess impacts of non-core business activities on overall performance.	Education to encourage business leaders to recognize their energy expenditures. Provide incentives for lowering energy consumption.
Energy Price Volatility	As energy prices fall, rate of return for energy efficient equipment also falls. Risk adverse firms may not want to "bet" on future energy costs, since past performance has been very volatile.	Education to focus on the ability of energy-saving equipment to reduce cost variability even if energy prices are low.
Cost Amortization	Equipment is a capital expense that current tax policy requires amortization over time.	Modify tax code to allow more rapid (current year) depreciation.
Discounting/Planning Horizon	Business leaders heavily discount the future, have short planning horizons, thus preventing adoption of technologies where the benefits occur in the future but the costs are incurred today. Society in general would prefer long term horizons for discounting and planning purposes.	Subsidize borrowing to lower the effective discount rate business leaders use. Provide information on returns to technology for various interest rates and various energy prices. Policy changes such that entities take into account the full life-cycle cost effects of system selection, and encourage longer-term planning horizons.
Negative Externalities	Negative externalities arise when the user of a resource does not bear the full costs of its use. For example, the price of gasoline does not include environmental and human health damages from burning the gasoline.	Incorporate as much as practical all costs into energy prices; for example tie the funding of governmental environmental programs into a tax on fossil fuels. Cap-and-trade programs for certain pollutants. Tax for energy security on oil?

Table 1: Summary of barriers to implementation and potential solutions.

factors can contribute to overall worker productivity such as lighting, temperature control, indoor air quality, etc. These factors can be difficult to quantify, yet should factor in the overall design. Kumar and Fisk give an example approach for a simple cost-benefit analysis of balancing employee health benefits from improved ventilation with energy costs.[7] A related issue is the performance of students in the classroom. The sidebar discusses one related issue in schools.

Corporate Societal Goodwill

Corporations gain favorable public perception by working to reduce their negative impact on the environment such as through improving the operation's energy efficiency. Empirical evidence of this is difficult to discern, but one recent study indicates that corporate investment in environmental protection can have long-term positive impacts on shareholder value.[8]

Reduced Reliance on Foreign Energy Resources and Reduced Overall Energy Demand

Instability in the world and increasing demand in developing nations can cause a sudden suspension of supplies or a run-up in oil prices. Therefore, a benefit exists from increasing the overall energy efficiency of all systems, building operations included.

Reduced Impact On The Environment

Society pays a penalty for degradation of the environment through increased health-care costs, damage to natural resources or man-made structures from phenomena such as acid rain, and a general decrease in quality of life. Energy production and consumption is a significant contributor to environmental pollution, so improving energy efficiency will reduce the overall environmental impact. This is the basis for environmental policy and regulation adopted in recent decades.

Potential Public Policy Approaches

Our hypothesis is that a major impetus to removing these barriers only can come from public policy measures, with some measures discussed here. The approach to public policy varies across the U.S. and is influenced by factors such as energy cost and stability, general public attitudes, and utility structure. For these to be a success, they must balance out the rights of individuals, cost effectiveness and the overall benefits to society.

Regulatory Measures

One method is the use of regulatory authority at the federal, state and local levels. On the federal level, the U.S. Department of Energy (DOE) is the primary agency that influences direction in the industry. One well-known example is the recent increase in minimum efficiency required for air conditioners and heat pumps, which was a contentious issue for some time. The Energy Information Administration estimates that this change in Seasonal Energy Efficiency Rating (SEER) ratings will result in a net savings of $5.2 billion (2001 dollars), assuming a 3% discount rate for the 30-year-period after the rules take effect.[9]

At the state level, California has been a leader in setting higher energy efficiency standards. The regulations are contained in California Code of Regulations, Title 24 Building Energy Efficiency Standards,[10] which covers a wide range of equipment and systems.

Incentive Programs

Incentives can originate from state or public agencies or via local utility-administered programs, and a summary is maintained by the Pacific Northwest National Laboratory.[11]

These programs involve approaches such as load management through rate structuring, renewable energy generation and 'tagging,' or building energy-efficiency rebates and technical assistance. Carbon taxes offer another high-profile example of incentive-based policies to induce adoption of more energy-efficient technologies.

Subsidizing the cost of borrowing through low-interest loans is another common tool used to encourage firms to undertake socially desirable projects. In addition, alternative lease structures giving incentives for installing and maintaining efficient HVAC equipment that avoid the principal-agent issues with leased buildings are needed.

Research and Development

Federal programs, through the DOE and national laboratories, support energy-efficiency R&D. On the state level, California also is involved in research to improve overall energy efficiency in buildings, for example, through their Public Interest Energy Research program, which supports research, development and demonstration projects for energy efficiency or environment-friendly energy generation technologies.

Other Approaches

Federal facilities in the U.S. are required to follow the DOE Federal Energy Management Program for evaluating the life cycle cost effectiveness of energy and water conservation projects in buildings,[12] and this approach should be adapted at all public agencies. Life-cycle costing was addressed in another recent *ASHRAE Journal* article.[13] Energy audits and publications of energy efficiency ratings can help overcome information barriers, for example EPA's Energy Star performance rating system is used in more than 21,000 commercial buildings nationwide. The growing adaptation of the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED®), while not a perfect process, is encouraging energy efficiency and tax credits or other incentives could be given that would help offset the administrative costs of obtaining LEED certification.

Summary

Hopefully, this article has helped increase awareness of the existing barriers to energy efficiency. Recognizing them is the first step toward overcoming the problem. The barriers can be overcome but will require individual, corporate and societal efforts.

Professionals working in the industry should continue to encourage our companies and clients to select higher efficiency equipment and systems. Organizations such as ASHRAE should continue providing educational opportunities and open forums

Sustainable HVAC for Modular Classrooms

To keep up with booming enrollment, schools increasingly resort to portable, modular classroom facilities. More than their traditional counterparts, modular classrooms can suffer from energy inefficiency and additional maintenance costs, plus poor indoor air quality and ventilation.

Modular classrooms, often leased or purchased to keep initial costs low, typically have higher energy costs due to their all-electric, inexpensive HVAC systems. With 385,000 such classrooms in 36% of schools nationwide, modular classrooms pose major challenges and opportunities for greener technologies.[14]

Students are particularly vulnerable to health hazards created by inadequate systems and evidence suggests that a poor indoor environmental quality has a detrimental effect on overall student performance.[15] This alone should warrant improving current HVAC systems. Low-cost HVAC systems common to modular classrooms may fail to meet ASHRAE ventilation standards by a large margin if facilities are overcrowded or HVAC systems are poorly operated and maintained.

Implementation of greener or more effective HVAC technology in these classrooms faces several barriers, including its cost, lack of awareness, and school politics. Better systems and technologies exist but with higher upfront costs. One study[16] showed a 1,000 kWh savings in annual electricity use by adding a modulating outdoor air damper and economizer cooling controller to a modular classroom in Sacramento, Calif., with an initial cost of $600. For this particular site, the modified system also would allow for adequate fresh air ventilation that meets ASHRAE standards, which was not possible with the existing equipment. At $0.10 per kWh, the energy cost savings alone warrant greener HVAC systems—unless decision makers have strikingly high discount rates (14% in this case) and neglect the additional benefits to student health and performance.

Higher initial cost may deter some investment, especially among administrators and school boards concerned with year-to-year enrollment and budgetary crises. Widespread lack of knowledge about energy efficiency issues also limits adoption. Untrained and unaware instructional and maintenance staff further compounds inefficiencies by operating existing systems improperly.

Overcoming these barriers requires addressing root causes. First, decision makers (school administrators and boards) should be made accountable for future costs at reasonable discount rates. Second, encourage behavior (by instructors and maintenance) to improve efficiency and environments with existing equipment. Promoting awareness and furthering research on gains from greener HVAC systems can help. Third, stricter standards and enforcement—combined with threat of litigation— can induce even apathetic decision-makers to enhance HVAC systems.

for disseminating information necessary to make informed decisions, and we encourage continued discussion on this topic in *ASHRAE Journal*.

To continue this discussion, the authors are organizing a symposium (or symposia) to be held at a future ASHRAE meeting(s). These will be sponsored by ASHRAE Technical Committee 2.8, Building Environmental Impacts and Sustainability, with other committees hopefully participating. We encourage those with a professional interest in the broad range of subjects discussed in this article to contact the authors (lawrence@hoth.engr.uga.edu).

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