ENERGY CONSERVATION IN BUILDINGS: PROBLEMS AND SOLUTIONS FROM THE CONTRACTOR'S VIEWPOINT

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ABSTRACT

The paper gives a mechanical contractor's perspective on the issues involved in energy conservation. Since the mechanical contractor works with all the actors in the design and construction process, we have experience with the way people think and make decisions regarding energy use. The paper is divided into three sections. The first discusses perceived barriers to the adoption of energy-conservation measures in both new and existing buildings. The second discusses potential policy solutions to the problem and makes recommendations. The third section discusses some particular recommendations regarding future HVAC technology.

INTRODUCTION

Our perspective on the problem of encouraging energy conservation in buildings is based on the experience of a mechanical contracting firm. R.M. Thornton, Inc. installs systems in commercial, industrial, and institutional buildings. These systems include heating, ventilation, and air conditioning (HVAC), plumbing, sprinklers, process piping, control wiring, and site utilities. All these systems involve the use of energy and together constitute the major energy consumption in most buildings.

The mechanical contractor is accustomed to dealing with dynamic systems, with cost and performance considerations, and with changing technologies. The mechanical contractor works with owners, architects, consulting engineers, operating engineers, other contractors, building inspectors, manufacturers, and occupants, as well as the personnel in the field. The mechanical contractor has a practical overview of the total design-construction-operation sequence.

In addition, as a business involved in the construction sector, the mechanical contractor must be familiar with the problems of other businesses connected with the building trade--financing, management, competition, profitability, etc.--and with their networks, such as the professional and trade associations.

R.M. Thornton, Inc., in particular, has an interest in energy conservation both as a direction for national policy and as a source of profitable business. The company built its own headquarters as a research and demonstration building, incorporating energy storage, active and passive solar systems, storm water utilization, and composting toilets. Our contribution to the study, based on this experience and interest, can be divided into three parts. The first, and probably most important in policy terms, consists of perceived barriers to the exploitation of economically viable energy saving opportunities in the buildings sector. These barriers are primarily psychological, organizational, and regulatory, as well as economic. The second part consists of perceptions and recommendations regarding various potential solutions. The third consists of recommended directions for energy saving technologies in mechanical systems based on our experience with the Thornton Building and other systems.

BARRIERS TO ENERGY EFFICIENCY

There are hundreds of practical opportunities to save energy in the operation of commercial, industrial, and institutional buildings, involving all aspects of environmental control as well as energy-consuming processes. At this point the focus for policymakers who want to encourage greater energy-saving efforts in the buildings sector should be that decisionmaking process which determines the specifics of design, construction, maintenance, and operation of real buildings in the real world. The technical problems are being solved; at the moment, the organizational, motivational, and financial problems seem to be more intractable.

Reaching the Decisionmaker: Who makes the decisions that affect present and future energy use in these buildings? Basically, it's the person who spends the money--the owner, president, chief financial officer, or administrator. A significant energy conservation effort may require changes in operating procedures, personnel, investment in energy audits and new equipment, or in the case of new buildings, changes in design which may result in increased first costs. It's crucial to reach the person with the authority to make the proper decision.

The person who ordinarily handles construction or maintenance decisions may not have the authority to take extraordinary measures, and therefore business proceeds as usual. Often the operating engineer or other individual in charge of maintenance and operation has a stake in maintaining "business as usual." That person will seem negligent to a superior if an outside expert can point out energy savings opportunities that have been overlooked. It is important to both educate and enlist the support of the people in charge of day-to-day operation. Some organizations provide incentives for energy savings. In-service training may be helpful.

Since it is so important to influence the building owners, we need to understand their motivation. Their behavior regarding the exploitation of energy conservation opportunities is based on a number of factors.

Return On Investment: The most obvious factor, if not always the most important, is payback. Basically, the payback on an energy saving investment must be greater than on other investments--those perceived as less risky or more central to the owner's primary business. This usually means a payback period of less than 3 years.

Building owners must have confidence in their investments. This depends on many things. If recommended by someone who they know is reputable and experienced, if they can get an objective disinterested opinion, if the equipment supplier is big and well-advertised, or if they or their advisers are familiar with the products and procedures involved, then they are more likely to invest.

They must have confidence in the future. If they foresee death, disaster, recession, or a change in the regulations, they are less likely to invest in the future in the form of energy conservation. They may prefer to keep any excess cash liquid to cover the payroll, taxes, creditors, bank payments, or sales costs. In times of bad business conditions, immediate problems of survival will take precedence over the comparatively long-range problem of energy conservation.

Owners may consider prestige more important, for either emotional or rational reasons. That little extra in terms of first cost may go for marble in the lobby or chandeliers over the staircase.

Owners, of course, are subject to the normal human conservatism and lethargy. If this lack of active concern is also characteristic of local architects, engineers, and contractors, then inertia may prevail over economics.

Financing: Financing is another serious problem. The financial community is not yet educated to the intricacies of energy conservation and may be skeptical or unresponsive. Without their support to leverage money, energy conservation will lose out to building investment. The bankers and their accountants need education.

Investment in mechanical equipment may be unattractive because the equipment has a shorter life than the buildings. Owners may worry about the obsolescence of technology, particularly in such fields as computers.

Many owners are postponing action until the government acts. They have been led to expect a national energy policy, tax credits, grants, new regulations, etc. Why should they act too early and miss out?

For owners of rental property, the terms of leases or rent control provisions relating to utility costs may prevent investments. In many cases, although a tenant is not individually metered and does not pay utilities directly, the cost of utilities (as well as the saving), is passed on automatically whereas capital improvement costs cannot be passed on. There is then little or no incentive for building owners to invest in energy saving.

Design: Even if the building owners are ready and willing to make enlightened decisions, the results will only be as good as their technical advisers. There are barriers to the achievement of energy-efficient design. Energy efficiency as a consideration in building design is new. Although the technology may be available, engineers are also being conservative. They must stake their reputation on a relatively untested design, system, or piece of equipment, while their training may not have prepared them to make such decisions. They are paid a relatively limited fee; they are not paid to be innovative or to educate themselves in the new technology.

There is a bewildering variety of energy-conserving procedures, modifications, designs, and hardware. Cost optimization is complex and interactive. There is no incentive in the fee structure, usually based on a percentage of the total cost, for the engineer to make an effort to save on either energy or first costs, or both (which is preferable).

There is a tendency to depend on free help from equipment manufacturers. A large supplier such as Honeywell or Johnson will help get a particular product into plans and specifications. This is a tempting offer.

The converse of this phenomenon is that no one is out there selling the simple and inexpensive solutions. Nobody's pushing something they can't make a profit from. So energy saving techniques are overlooked.

There is a tendency to "play it safe." If a 40-horsepower motor would be sufficient, the "safe" thing to do is to specify a 50-horsepower motor. HVAC has practically no safety factor in its design; an owner may add more people, lights, or computers; or the building envelope may not be as tight as is anticipated. Thus, there is a great incentive to overdesign systems which leads to inefficiency.

There is a tendency to use the packaged systems. These are easier to design and often cheaper to install, but not necessarily the most energy-efficient choices. Again, the manufacturer may help in design and troubleshooting, and advertising by manufacturers influences both engineers and owners. The attractiveness of such modular systems may conflict with energy considerations.

To be effective in achieving an energy-efficient end product, the building design process has to be informed, unbiased, and comprehensive. Energy has to be a concern from the beginning. Often the design-construction timetable is squeezed, and energy optimization is forgotten. To do a good job, architects and engineers need support for education and information sharing, and they need adequate fees and fee incentives for achieving energy savings.

Construction: Contractors also have a role to play in building energy-efficient buildings. There is a certain amount of frustration inherent in the present system. The contractor is usually not expected or encouraged to contribute to the design process, in spite of extensive installation, start up, and performance experience. A contractor's criticism of designs may be resented.

If a contract is won in competitive bidding there is no incentive for the contractor to make an extra effort to save the customer energy or money, particularly where competition is stiff. However, the design team concept pools the knowledge and efforts of contractor and designer; this may be an especially valuable institutional innovation in the context of encouraging energy conservation.

SOLUTIONS

Some possible solutions have been mentioned in reference to a specific problem. We now discuss these suggestions in general and add the next level of complexity--some of the problems with the solutions.

Tax Incentives: Next to deregulation, tax incentives are probably most often mentioned as solutions. Existing tax credits for energy-related equipment are not widely known and are even less understood. In a recent example with which we were involved, an energy conserving water source heat pump was installed in a new addition which filled in a courtyard area. Was this or was this not a "rehab" job under the regulations? Could the HVAC system be defined as a recuperator hooked to a heat pipe under the regulations, or was it excluded as a heat pipe on any of a number of different considerations specified under the regulations? Our Association, which had done a study of the regulations for the tax credit, couldn't tell us. We couldn't find out. Getting a decision on these questions is complex and time consuming.

Tax credits may distort rational decisionmaking. Is it rational to add solar collectors to an office building when the internal load generates more than enough heat? A practical system might combine storage, heat distribution, and a heat pump. But the solar collectors get a tax credit. Is it possible to specify tax credits in anticipation of the correct design decision when every situation is different?

A simpler approach might be to reward the building owner through a tax credit or subsidy based on actual dollars saved the first year. (This would be preferred over a system based on Btu's saved, because it takes into account savings on the utility's demand charge). In essence this rewards the owner for the actual energy savings, which is what is important for national policy, rather than for the cost of such savings, which includes energy consumed in the change. A procedure for certifying that savings were permanent and not based a milder winter or low occupancy would be relatively simple to institute. This could be a one-time credit or payment and would have the desired effect of shortening the payback period and increasing the attractiveness of energy conservation measures.

A tax credit based on the cost of energy conservation might more appropriately be confined to analysis and design. Energy conservation requires, first, an energy audit or budget; second, an overall energy conservation plan; and third, a system design which includes practical energy conservation measures. Expenditures for such studies might be covered by a tax credit. They are front-end costs, with no guarantee of return on investment, and ideally they are not biased toward any particular procedure, technology, or set of hardware. Auditors and engineers might have to be certified.

Grants: We do not feel that competitive grants for energy conservation or solar technologies as presently administered are useful in influencing the buildings sector. For a commercial organization, or for any independent organization, it is very expensive to prepare a proposal. The chances of success are not very good. Often the successful companies are those, such as the many aerospace firms, who know the workings of government and have personal contacts on which they can draw. They are accustomed to getting money from the government, but they may know relatively little about building design or construction.

Grants also tend to be based on incremental costs. The government will give money to cover the extra cost of installing an energy-efficient system. But if you design a system that costs no more than a conventional system, that has zero incremental cost, then you get nothing. This biases the development of systems toward the expensive and therefore impractical. If anything, grants should be given for design. Good design is more practical than expensive hardware.

In addition, a grant will tend to lock the grantee into the proposed technology. A system being monitored by NASA because it was supported by a grant cannot be modified along the way, whereas good engineering sense might dictate constant refinements and modifications to take advantage of operating experience. The need for the grantor to monitor and regulate the grantee represents additional overhead for the commercial company.

Regulations: There are also problems with regulations, of course. They are notoriously difficult to enforce, particularly where the operations being covered are complex. Building owners may use regulations such as Building Energy Performance Standards (BEPS) to justify withholding payment on contracts, and some types of regulations may restrict the choice of designers.

Those who are regulated are often not happy about the fact, since regulations cost time and paperwork, as well as often driving up the price of construction and affecting the market. There are technical problems with the regulations. The emergency temperature regulations do not work well with existing thermostats. In some seasons a building may cycle from heating in the morning to cooling in the afternoon; existing thermostats have to be reset each time this happens, since allowed temperature in the cooling mode is not the same as that in the heating mode. Proof of performance is a difficult technical problem. Under grandfather clauses, many of the most inefficient buildings escape regulation.

Nevertheless, regulations are already a part of everyday life for the construction trade. They serve the purpose of increasing awareness and motivating the unpersuadable, superseding regulatory and administrative barriers to the contrary. There may be a place for regulations in resolving barriers related to lease provisions. To be successful, they must be simple to understand and to enforce, flexible, well-accepted by the business community, and effective in achieving their stated goals. The emergency temperature regulations are widely perceived by operators and others as difficult or impossible to put into practice and ineffective in actually saving energy. Such a situation lowers the credibility of the regulatory agencies and the energy conservation effort. If building standards are to be promulgated, we recommend a flexible standard allowing a choice of compliance based either on design performance or a menu of prescriptive standards. The design process must be, as far as possible, unbiased regarding specific technologies or design choices. It is possible that such standards should not be based on an energy measure such as Btu per square foot but on dollar savings or marginal cost calculations for energy sources in the area. Pure energy measures ignore the variation in regional availability of different sources of energy, including renewable sources, and may not accurately represent rational design choice.

Pricing: Of course, basing tax incentives or regulations on the dollar as the common denominator between various energy sources and efficiency improvements makes it very important for the pricing mechanism to be unbiased. It seems clear that energy efficiency will not be efficiently implemented until the price of energy reflects the true costs. However this is achieved, it is a necessary prerequisite for rational decisionmaking by energy consumers. In comparison, other incentives such as tax credits or regulations are clumsy and inequitable.

Education: Each time we have listed an institutional barrier to implementation of energy conservation, education has been one of the first solutions to come to mind. By education we mean a combination of information sharing and motivation. There are many separate individuals and roles involved in design, construction, and operation, and each is crucial in achieving greater energy efficiency. If you attempt to convince a building owner that a conservation investment is worthwhile, the owner may say, "Tell it to my bank! They don't understand it and they won't approve it." The bank will say its accountants don't understand it, and the operating engineer will say that the building owner doesn't care. All actors in this drama must understand why energy conservation is necessary and how it works.

The primary source of information for practicing professionals and business people is the professional association. Association meetings and conventions reach a significant proportion of each group. They provide a channel for information that is respected and validated by peers. They also represent a democratic mechanism for such groups to provide input into the policy-making process. Federal agencies ignore them only at their own peril; they are poor enemies and could be good friends. What is needed is increased Federal support for educational programs through such associations, including both funding and technical help, which should be made available over a number of years.

This cannot be a haphazard, one-shot program and still reach a significant number of people.

In particular, there are professional associations for architects, consulting engineers, building owners and managers, contractors, operating engineers, accountants, building inspectors and code officials, and, last but not least, the financial community. All of these groups must be more knowledgeable about energy considerations and must recognize the need for extra effort. Investing in educational programs for these crucial groups may be a more cost-effective approach to the problem than Federal government regulations, grants, or subsidies.

The educational strategy should stress practical measures and cost considerations. It should not be biased toward particular technologies. It should emphasize the examples set by successful peers. Information must be perceived as accurate, up-to-date, and objective.

The educational approach is more difficult to evaluate than the hardware approach, but the effects are more lasting. Such a program should not be put together one year and dropped the next; a sustained and thoughtful effort is necessary. The Cooperative Extension Service of the U.S. Department of Agriculture in its early years is a possible model. Although the Energy Extension Service is a step in the right direction, funding through state energy offices has not always led to high quality program design. More coordinated and sustained effort by the Department of Energy is necessary, working through an extension service, the professional associations, or both.

Many practitioners in the energy conservation field, even though they are knowledgeable and highly motivated, admit they need help in keeping up with the rapidly changing technology. A data system providing information to professionals in the design and construction industry might help speed technology transfer. The system should accumulate, index, abstract, and disseminate information on energy conservation technologies and procedures, including costs and savings where possible. No single firm can afford to accumulate and analyze all the available information. The industry can best use information that is correctly abstracted and aimed at the most probable users. This information may include computer programs and other software. An existing institution, such as the National Institute of Building Sciences, might be funded to fulfill this function.

Alternate Practices: The consulting engineer is a key figure in selecting and designing the correct system from the available choices. Present fee structures, based on a percentage of the building cost, do not allow an engineer to put in the necessary time to produce an energy-efficient design that fits the individual circumstance of the building to be constructed, nor is there enough incentive for the engineer to design practically and efficiently. A change in the fee structure is one way to encourage energy efficiency. Either we should separate fees for an energy analysis and an energy-conscious start-up and check out, or establish a "fee bonus" for energy savings as compared to a mean based on building area.

Another approach to the design problem is the concept of the design team. A team, consisting of the architect, consulting engineers, and contractors, designs, estimates, and writes specifications for the desired building at the desired price. They pool their expertise to create a cost-effective and energy-efficient design. They may be able to prepurchase energy-efficient equipment, and save time and money in the construction sequence.

Both approaches might be encouraged by the federal government through its own building program. The federal government is the largest consumer of energy, a gigantic landlord, and the benefactor through loans and grants of an incredible amount of public and private construction. The promotion of alternate approaches to the design process through experiment and example is an appropriate use of this leverage. Of course, the federal government should also use its leverage, directly or indirectly, to ensure that buildings constructed with its support are energy efficient.

The energy service company is a concept that is beginning to gain attention. It is a largely untried but potentially viable enterprise. The energy service company, with its own expertise and capital, would contract with a building owner to make energy conserving improvements on the building. It would invest its own capital and be paid back out of energy savings. There are problems with this concept. The savings must be validated and separated from savings that arise from the behavior of the occupants or routine maintenance.

With this concept, there is a similar separation of incentives as that between renter and landlord. If the individual tenants pay the utilities, they have an incentive to behave in an energy-efficient way but little incentive to make capital investments in the building. If the landlord pays the utilities, the landlord has an incentive to make capital improvements (unless the costs and savings are passed through automatically, as in some leases) but the tenants as individuals have no incentive not to waste energy. Similarly, if the energy service company has assumed the energy costs, and charges the building owner a set fee from which the company makes its profit based on conservation improvements, the building owner and/or occupants lose their incentive to care about energy-efficient operation. The company might have to become, in effect, a part-property manager, with control over maintenance and thermostats and energy-consuming equipment. However, there may be solutions to these and other accounting problems, and the energy service company could be an attractive option for a building owner short on expertise or capital, particularly if a portion of the savings or tax credits are passed on to the owner.

RECOMMENDED TECHNOLOGIES

Energy consumption in buildings does not stop with HVAC and lighting. More attention must be given to the total energy consumption--including garbage and sewage disposal, storm runoff, land-use planning and transportation, overall efficiency of building and facility use, and the savings potential of coordinated design, siting, and construction.

We feel strongly that water use will be a growing problem in the years to come. Excessive water and sewer flows also involve energy use in pumping and treatment. We are experimenting with waterless composting toilets, which cut water use by about 50 percent, in our demonstration office building. We are also experimenting with grey water treatment and hope to cut our sewer output to zero. We have a stormwater retention system including storage and use of water for energy storage, sprinklers, and heating and cooling. We are experimenting with filtration of water for drinking purposes, so that the building may be self-sufficient in terms of water and sewers. We recommend this as a direction for further research and development. It makes sense as an energy strategy as well as from a general environmental perspective.

We also recommend HVAC technologies for commercial, industrial, and institutional buildings that use water source heat pumps. Although the Thornton demonstration building uses both active and passive solar systems, for the wide range of buildings, storage may be more important. The combination of a chiller and water storage allows the building system to take heat generated by people, lights, equipment, and solar gain, and store it overnight for use in warming the building the next morning. The system allows night "push back" (an improvement on night setback) in which the interior space is cooled to 50° overnight and the heat is stored for the next morning. A variable air volume system allows efficient control of temperatures as well as balancing temperature. The concept was developed by Mr. A. I. McFarlan.

Energy consumption for office space in our building is approximately 30,000 Btu per square foot per year, including all energy for all purposes. The concept of a water source heat pump to provide efficient heating and cooling for office buildings can be expanded to include district heating. Water in ductile iron pipe, buried without insulation, would circulate from building to building. The ground temperature would act as a moderating influence on the system, which could heat or cool efficiently with proper water temperatures and depths. A large number of heat sources or heat sinks could be linked by the ductile iron pipe, which can last for centuries underground--much longer than with conventional heating and cooling mains, which are much more expensive and less durable. Waste heat from utility power plants, trash incinerators, solar collectors, or water chillers could be used.

The water-source heat pump in combination with heat storage is an HVAC concept characterized by versatility and efficiency. It uses off-the-shelf components and enables building operators to control the environment in novel ways, such as night pushback and flywheel heating and cooling. It can utilize a wide variety of heat sources and heat sinks to adapt to the local situation. We recommend it for further research and demonstration projects.

We see further energy conservation opportunities in coordinated planning, siting, design, and construction of commercial-industrial-institutional buildings,. The grouping of related businesses or institutions near a single site would reduce time and transportation costs, and therefore energy costs. Businesses and institutions can save by collectively purchasing energy audit, design, or construction expertise. Such arrangements should be sanctioned and encouraged wherever possible.