Energy Performance Standards: A Look At The Economic Issues

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Abstract

To determine the best level at which to set designed energy consumption standards for buildings, economic efficiency based on prior determination of energy efficiency has been chosen as the decision criterion.

Life cycle cost minimization has been identified as the best method of assessing tradeoffs between capital investment and fuel consumption in buildings, but there are several important parameters whose effect on the results must be carefully considered. The discount rate used to calculate the net present value of expense streams should represent the cost of capital for the entity from whose perspective the tradeoffs are being analyzed. For the purpose of setting an energy performance standard, the discount period used should approximate the expected life of the building.

Ideally, the fuel price projections used should represent the marginal social costs of supply for a small region. Such estimates are simply unavailable at present. The next best alternative may be a relatively highly aggregated estimate of average or perhaps marginal market costs.

Key Words: Building code, economics, energy

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ENERGY PERFORMANCE STANDARDS: A LOOK AT THE ECONOMIC ISSUES

INTRODUCTION

The Energy Conservation Standards for New Buildings Act of 1976 is resulting in the promulgation of standards limiting the designed energy consumption of new buildings. To determine the best level at which to set designed energy consumption, DOE is sponsoring research to identify the most efficient Btu consumption levels for a wide range of building types with diverse use patterns and exposed to the full range of typical climatic conditions. There are two concepts of efficiency which are relevant in optimizing the space conditioning of buildings: energy or thermal efficiency and economic efficiency. A widely used definition of thermal efficiency is:

\[
\text{Thermal efficiency} = \frac{\text{useful work done}}{\text{energy input}}
\]

Unfortunately, if thermal efficiency is the only criterion used to determine energy system investments, the results will conflict with other desirable goals. A major problem with using energy efficiency ratios to select the best energy system design is that such ratios fail to account for the relative values of the resources used. This problem was specifically addressed by Robert Jones in his discussion of Resource Impact Factors in the ASHRAE Journal.\(^1\) While the RUF concept and the development of RUF values provides a measure of energy efficiency for use in decision making, the lack of comparable development of RIF's severely limits the usefulness of RUF's.
The concept of efficiency used in economic analysis directly addresses the problem of valuing alternative resource uses. Economic efficiency may be defined as:

\[
\text{Economic efficiency} = \frac{\text{Value of output}}{\text{Value of input}}
\]

The economic concept of efficiency, however, depends on prior determination of energy efficiency in space conditioning systems. This means that in order for economic analysis to identify the "best" level of energy consumption for a building, the systems analyzed must be well designed and well constructed so that they deliver the maximum in energy efficiency for the investment required. Given information as to possible building and equipment design trade-offs against energy consumption and maintenance requirements, economic efficiency is a useful criteria for selection of the "best" system. The life cycle cost method of economic analysis and the issues surrounding the choice of prices for use in that analysis are discussed in the following sections.

Life Cycle Cost Minimization

If two alternative methods produce exactly the same space conditioning results, we can compare their relative economic efficiency on the basis of the value of the inputs required for each method. The method that produces the desired output at the lowest input cost is the most efficient. Thus, the economic efficiency criterion allocates resources in a manner which maximizes the difference between benefits and costs. To set standards which do just this, we must take into account both the value of all of the energy
used to provide adequate comfort levels in buildings and the value of the other resources (such as insulation) that may be substituted for energy in the provision of those comfort levels.

A life cycle cost model should include all the relevant costs of space conditioning such as initial structural and equipment costs, maintenance costs, and fuel costs expressed on a present value basis. The major elements of a life cycle cost model are illustrated in Figure 1. Description of a simplified life cycle cost methodology can be found in William Coad's article on Investment Optimization in the ASHRAE Journal. The capital and fuel utilization trade-offs resulting from application of a life cycle cost model to building energy performance are sensitive to the parameters used in the calculation of the net present value of the various expense streams. These critical parameters include the discount rate, the discount period and projections of fuel prices.

The selection of an appropriate discount rate involves determining the rate at which people are willing and able to trade current income for future gains. Indications of this rate may be found in private capital markets such as the mortgage market. However, imperfections in capital markets (e.g., inability of all households to invest and borrow at the same interest rate, imperfect information and the effects of taxes and transaction costs) generate a complex interest rate structure within which rates vary based on risk and other factors. In making investment decision that involve annual cash inflows or outflows, the discount rate used is usually the
LIFE CYCLE COST MODEL

MINIMIZE 

\[
\left[ \text{CAPITAL COSTS} + \text{MAINTENANCE COSTS} + \text{FUEL COSTS} - \text{SALVAGE VALUE} \right]
\]

WHERE:

- **CAPITAL COSTS** include costs of insulation, windows, heating + cooling systems, etc. and the net present value of related interest expense.
- **MAINTENANCE COSTS** are the net present value of expected annual energy system operation and maintenance costs.
- **FUEL COSTS** are the net present value of expected annual Btu consumption.
- **SALVAGE VALUE** is the present value of the capital equipment at the end of its life cycle.

FIGURE 1. Life Cycle Cost Model
interest rate at which the individual or firm is able to borrow or the rate of return at which they can invest funds. Whatever discount rate is used, care must be taken to treat inflation consistently throughout the calculation of net present value. That is, if constant dollars are used, the discount rate must be adjusted for inflation.

The appropriate discount period for minimizing life cycle costs from an individual's point of view is the expected length of building ownership. From society's point of view, the appropriate discount period is the expected life span of the building. If the discount period used in minimizing life cycle costs is less than the life span of the building, the effect is to neglect the value of fuel savings in the future that would be associated with greater capital investment in the present. For this reason, the life cycle costs used in determining optimal levels of energy consumption generally should assume at least a 20 year building life.

Fuel Prices

The third critical parameter in life cycle cost minimization is the set of fuel prices used. The expected changes in fuel prices over the discount period affect both the optimal level of capital investment and the relative merits of substitute fuels. In order to determine the Btu consumption levels that minimize the total costs over time of attaining requisite comfort levels in buildings, information on the true cost of energy and capital inputs is needed.
Behind the ASHRAE proposal that RIF's and RUF's be used in determining the choice of fuel in new buildings, there lies an assumption that for some reason or reasons, the present market system does not promote optimal choices of energy resources. Prices in fuel markets are assumed to be such poor indicators of fuel's value to society that price alone should not be allowed to determine fuel consumption choice.

The costs incurred by firms in producing and distributing fuels are "market costs". In addition to these costs, the public incurs other production costs (called nonmarket costs) in the form of federally subsidized research, costs of industry regulation, and health and environmental damages resulting from pollution, to name a few. These external costs together with the market costs compose the total social cost of fuel production. The main components of total social cost for fuels are shown in Figure 2. In order to discover whether current fuel prices are indeed a poor indicator of the total social cost of fuels, an examination of fuel markets, prices and nonmarket costs was undertaken. Evidence was found of market failure resulting in fuel prices that do not reflect the total social costs of the resources consumed. However, the difference between fuel values and prices has been decreasing since the mid-1960's.

In estimating the full social cost of fuel use, the nonmarket costs and the market prices were summed to account for both public and private costs. In other words, costs of social, economic and environmental effects
FIGURE 2. Social Costs of Energy Sources
were added to get the total net cost per Btu of producing a fuel. Thus, the calculation of total social cost applies to end use Btu, but is otherwise a concept that is similar to the RIF.

Since the purpose of these estimates of the real cost of fuels is to determine the life cycle cost minimizing levels of fuel consumption in new buildings, the market cost component should be an estimate of the marginal cost of fuel supplies. Marginal rather than average cost is appropriate because it measures the cost to society of expanding fuel supplies to serve buildings that represent new energy demand. Both fuel production costs and sources of new supply will vary from region to region. The cost of LNG is the relevant marginal cost of gas in some regions; SNG represents the marginal cost source in others. For oil, the marginal cost is the world oil price. The marginal cost of electricity is most difficult to estimate since the marginal source of supply for building space conditioning may not only vary from region to region, but also may vary seasonally within regions.

The pricing of energy at less than its marginal social cost leads to choices of building energy systems which result in higher annual levels of fuel consumption than would occur if all of the relevant resources were accurately or proportionally inaccurately priced. To ascertain whether it is feasible to use marginal social costs of fuels in developing an energy performance standard, more detailed research on social cost estimation was carried out.4
This study sought to determine the importance of the nonmarket components of social cost such as environmental relative damages. In addition, we assessed the feasibility of developing long-term (20 year) estimates of marginal market and nonmarket fuel costs for use in the life cycle cost framework. This analysis dealt with several important tradeoffs among aspects of available fuel cost estimates such as their uncertainty, the costs of developing better information, and the cost variation between regions.

The use of estimated total social cost per Btu of fuel in minimizing life cycle costs is responsive to both the intent of the BEPS legislation and the spirit of the ASHRAE RIF concept. Because social cost goes beyond the market costs of fuels to incorporate environmental and national costs, it promotes efficient use of energy resources. Information on the market cost component of total fuel supply cost is relatively easy to obtain. Of the nonmarket costs of fuels, the amounts of direct subsidies and administrative costs of regulation are the most clearly documentable. Some other nonmarket cost components such as effects of airborne emissions on the environmental and human health and costs to society of nonoptimal taxation require sophisticated statistical estimation. In many cases, data on physical impacts which is a prerequisite for economic analysis, is not currently available. Thus, while it is relatively easy to set a lower bound on estimates of the nonmarket costs of fuel production, more accurate estimates will be extremely costly to develop.
The fact that currently documentable nonmarket costs are small relative to marginal market costs and that much better estimates would be quite costly points to the conclusion that, at present, development of total social cost estimates for use in setting building energy performance standards is not justified.

Another issue area involves determination of an appropriate level of regional fuel cost data aggregation. The prices used in the LCC minimization framework may be derived from the prices occurring over an area as small as a single utility district or as large as the entire U. S. and its possessions. In general, as the size of the region considered increases, the range of fuel costs found in the region increases. Thus, in moving from a unit consisting of a utility service area to the whole nation, we move from a region where all consumers face the same prices to one where fuel prices vary by a factor of as much as seven.

Since both high and low fuel price extremes sometimes occur within similar climatic regions, an energy standard based on a national average of fuel prices could require different changes from current building practice in areas whose only difference is in local fuel prices. That is, in areas with high fuel prices, the standard could require fewer fuel conserving practices than are currently used. In areas with low prices, the required capital investment would not be offset, from the consumer's point of view, by the value of the resulting fuel savings. The variations in regional prices appear to be the result for the most part, of real differences in the cost
of fuel supply, so that use of national average price estimates may create inequities.

Unfortunately, avoiding this problem is not easy. There are enough uncertainties regarding both fuel sources and costs that the reliability of fuel cost projections diminishes as the size of the region considered decreases. Thus, utility district costs may be highly variable over time as well as differing greatly at any one time within a relatively small region. Even for state level data, it is difficult to identify a consistent set of price projections though there are numerous state price projections available, based on a wide range of assumptions. In response to this situation, we are currently assessing all available price data to determine the smallest regions for which a relatively reliable set of price projections exists.

The third major issue area involves the choice between use of marginal and average fuel supply costs in minimizing life cycle costs. The marginal cost of a delivered unit of fuel is the cost of production, processing, and transportation of the marginal unit of fuel when the total quantity produced is increased slightly. Average cost, on the other hand, is the total cost of production, processing, and delivery of the fuel divided by a measure of the total quantity. Currently, fuel pricing strategies are based on an average cost approach. This has led to the cost situation for interstate natural gas in some regions which is illustrated in Figure 3. The cost supply of supply from marginal sources such as imported
FIGURE 3. Comparison of Marginal and Average Cost for Natural Gas
LNG may be up to two times the average price charged consumers. Hence, decisions which expand consumption do not take actual costs into account, and allocation of supply has been required to manage excess demand.

As the divergence between marginal and average cost increases, differences between the life cycle costs and fuel budgets which result from use of these two alternative cost measures also increase. When marginal costs exceed average costs, the use of marginal cost produces a more efficient allocation of resources from a national perspective. Thus, use of marginal cost has the advantage of leading to minimization of the total cost to society of building space conditioning and to less fuel consumption at the same time.

In addition to affecting fuel consumption and conversation investment, the marginal versus average cost decision affects fuel choice. The use of average costs in the life cycle cost framework may incorrectly indicate that use of the fuel with the greatest price distortion (whether due to subsidization or regulation) minimizes costs. Figure 4 illustrates a situation in which they may occur. While fuel$_2$ has the lowest marginal costs, fuel$_1$ has the lowest average cost and will be considered the life cycle cost minimizing fuel if capital costs related to fuel use are about equal. At quantity Q, the average cost of fuel$_1$ is lower than the average cost of fuel$_2$, though the marginal costs of fuel$_1$ are higher. Prices based on average cost will encourage use of fuel$_1$ over fuel$_2$, even though the additional quantity of fuel$_1$ is more expensive.
FIGURE 4: Relative Marginal and Average Costs for Two Fuels
Since average costs reflect the fuel market prices which consumers face, use of average costs will do less to stimulate the use of renewable resources than use of marginal fuel costs. The prices of renewable resources reflect the costs of developing new energy sources. Marginal costs of conventional fuels reflect comparable costs of expanding energy supplies. Thus, use of marginal costs will provide consistent information for choices between conventional and renewable energy sources. There are also some advantages to use of average cost projections. Because average cost more nearly approximates fuel prices in the retail market, use of average cost should lead to tradeoffs of capital investment and fuel consumption resulting in life cycle costs that do not differ greatly from the current choices of well-informed consumers. This may minimize objections to BEPS since the merits of reducing the costs of building conditioning which they actually pay can more easily be seen by consumers. Use of marginal cost will lead to higher capital investment and lower energy consumption than consumers would choose in response to actual fuel market prices.

The greatest advantage of using average cost projections is in the reliability of the currently available data. Information on the average cost of fuels is readily available from both industry and government sources. In addition, variation between estimates produced by various agencies is relatively small. Estimates of marginal cost, on the other hand, are less reliable and the assumptions used are sometimes controversial.
The fact is often overlooked, however, that the projection of average costs into the future depends upon estimates of future marginal costs. Thus, average cost estimates are subject to the uncertainties of the marginal cost estimates upon which they depend. Estimates of future average cost values may seem more valid than marginal cost estimates mainly because they are more common and familiar. Research currently underway should shed more light on the availability of acceptable marginal cost projections and the effects on energy consumption levels of using them rather than average costs.

CONCLUSIONS

The Energy Conservation Standards for New Buildings Act of 1976 is leading to promulgation of standards limiting the designed energy consumption of new buildings. To determine the best level at which to set designed energy consumption standards for buildings economic efficiency based on prior determination of energy efficiency has been chosen as the decision criterion. This approach, while differing from that used in ASHRAE Standard 90-75R, addresses the same issues as RUFs and RIFs were intended to.

Life cycle cost minimization has been identified as the best method of assessing tradeoffs between capital investment and fuel consumption in buildings, but there are several important parameters whose effect on the results must be carefully considered. The discount rate used to calculate the net present value of expense streams should represent the cost of capital for the entity from whose perspective the tradeoffs are being
analyzed. For the purposes of setting an energy performance standard, the discount period used should approximate the expected life of the building.

The other critical area in the use of a life cycle cost methodology is the set of price projections used. Because there is evidence that fuels are underpriced, the use of estimated total market and nonmarket or social costs of supply is attractive. Such estimates are not readily available, however, and would be costly to develop. The choice of level of data aggregation is also problematic. Tradeoffs between the reliability of the price projection series and the imposition of inequities on regions with widely varying supply costs, appear unavoidable. There is also a choice required between average and marginal fuel costs. Marginal costs are clearly more appropriate for use in setting a standard that affects new energy demand but the availability of relatively reliable and disaggregated estimates is doubtful. Ideally, the fuel price projections used should represent the marginal social costs of supply for a small region. Such estimates are simply unavailable at present. The next best alternative may be a relatively highly aggregated estimate of average or perhaps marginal market costs.
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