THERMAL EFFICIENCY STANDARDS AND THE MARKET FOR NEW HOMES

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The incremental market value of higher thermal efficiency standards in new houses and the resulting energy savings are estimated using linear regression techniques. Based on the empirical findings, a home buyer discount rate is calculated. The findings indicate that the real estate market operates efficiently in capitalizing the value of energy savings into sale prices.

INTRODUCTION

The economic implications of a DSM program involving the construction of energy efficient houses are examined in this study through two empirical analyses focusing on the willingness of home buyers to pay for increased energy efficiency and the operating cost savings resulting from the improved thermal performance. Using the findings of these analyses, the study examines the functioning of the housing market with respect to the valuation and capitalization of energy efficiency improvements.

BACKGROUND AND DATA SOURCES

Single-family, detached, electrically-heated houses built between 1983 and 1985 in the Tacoma City Light service territory, which includes all of the city of Tacoma and parts of Pierce County, Washington, are the focus of this study. Prior to June 1984, the Washington building code of 1981 applied to new construction in these areas. However, starting in June 1984 all new electrically-heated houses were required to meet higher energy efficiency standards. This change was due to the City of Tacoma's voluntary adoption of the Model Conservation Standards (MCS) building standards proposed for all future construction in the Pacific Northwest region. The MCS was developed by the Northwest Power Planning Council as part of their first Northwest Conservation and Electric Power Plan (1983).

To comply with the MCS in 1984 and 1985, new houses in Tacoma City Light service territory were required to meet a predicted kWh/sq ft/yr performance goal. The new code allowed this goal to be achieved in any number of ways. For example, compliance could be achieved with a required glass-to-wall ratio and specified levels of insulation in certain building elements. Or the goal could be met with a combination of individual envelope and equipment choices, such as combining a lower level of envelope insulation with an energy efficient heat pump system. To illustrate the difference between the conventional standards and the MCS, a comparison of the thermal criteria used in the 1981 Washington State Code and MCS is presented in Table 1.

Various mechanical requirements were upgraded by MCS as well, in addition to more stringent criteria for infiltration levels, vapor barrier integrity, and other related characteristics. Also, for most non-heat pump MCS houses, an air-to-air heat exchanger was required to assure healthy indoor air quality.

The first part of this study addresses the issues raised with respect to market valuation and the widely held belief that housing market prices do not adequately reflect the benefits of increased energy efficiency. This issue is addressed by estimating the implicit market value of the energy efficiency component of new houses, using a hedonic price model. For this analysis, a search was made of all electrically-heated MCS single family houses built in Tacoma in 1984 and 1985.
Table 1. Thermal Criteria Comparison

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Walls</td>
<td>R-11</td>
<td>R-19</td>
</tr>
<tr>
<td>Floors</td>
<td>R-11</td>
<td>R-30</td>
</tr>
<tr>
<td>Ceilings</td>
<td>R-30</td>
<td>R-38</td>
</tr>
<tr>
<td>Windows</td>
<td>U = .65</td>
<td>U = .37</td>
</tr>
<tr>
<td>Doors</td>
<td>Not specified</td>
<td>D1SL = 2</td>
</tr>
<tr>
<td>Slab on Grade</td>
<td>R-4.25</td>
<td>R-15 with</td>
</tr>
<tr>
<td></td>
<td></td>
<td>moisture barrier</td>
</tr>
</tbody>
</table>

Source: Tacoma Public Utility Board, 1984

The initial prerequisite for including a house in the study database was that it was resold at least once as of the final months of 1988. This requirement is of utmost importance because the original sale price of a new house is often not indicative of the price that will be paid for it over its remaining lifetime. Typically, newly-built houses and their surrounding property are not in final condition at the time of the original sale. For example, a home buyer may purchase a house when the landscaping or driveway is incomplete, or with part of the basement or garage unfinished. Under these circumstances the first sale price would be discounted, and comparing this price with full-priced houses would lead to biased findings.

By studying resold houses—all built around 1985 and resold within a year or two of each other—additional complications beyond the "first price" issue are also avoided. Restricting housing vintages makes it unnecessary to control for changing building codes, construction practices and relative costs. Levels of home repair, maintenance and improvement, and—more critically in the present context—levels of weatherization, insulation and thermal retrofitting also need not be reckoned with.

In addition to house age and resale status, other criteria were used to assure data quality and sample homogeneity. These included that the houses selected be located in subdivisions rather than in-filled lots, that the resale date be separated by at least several months from the date of original sale, and that resale price not be greater than double the mean resale price, or $170,000. In total, after screening all of the over 800 MCS houses built in Tacoma in 1984 and 1985, 42 suitable resales were found for this study. This represents all the resales that met the criteria for this study, minus those that had to be dropped due to missing or other data-related problems. The data for the analysis was drawn from the Pierce County Assessor's records.

For the second empirical analysis, energy savings were estimated for an independent larger sample of 157 MCS houses. Resale for this sample was an issue, too, but in quite a different respect. Because the energy savings analysis requires continuous billing histories for a single household within each house for approximately one year, a house was dropped from the sample if resale caused it to remain vacant for more than one month, or caused a change in households during the study period. Houses were also dropped due to missing billing data, long periods of vacancy due to vacations, and other problems associated with the billing histories. In addition to billing data for each house in the sample, household data was collected through a mail survey. The data was used to control for factors other than the energy efficiency standards that may have affected the level of household energy use.

Comparable control groups of non-MCS houses were used in each analysis. The control group for the market value analysis consists of resales of 25 electrically-heated single family houses built shortly before the adoption of MCS in 1983 and early 1984. A larger sample of 183 non-MCS houses of 1983 and 1984 vintage was randomly selected for the energy savings analysis. All the data used in these analyses was collected as part of evaluation projects funded by the Bonneville Power Administration.
THE MARKET VALUE OF MCS

More than most goods, houses are composite products whose prices are determined by the quantity and quality of distinct, identifiable amenities such as square footage, number of rooms and location. To explore the relationship between a house’s sale price and its amenities, many empirical studies employ a hedonic modeling regression technique. This approach estimates the underlying impact of each amenity on the final sale price; in essence, extracting from the full sale price the implicit, individual prices of each amenity.

The present analysis adopts this approach to estimate the implicit price associated with the MCS feature of new houses. Because the available data is limited, a single-equation hedonic model is estimated rather than a system of structural models. The advantage of the reduced-form type of model is that it provides a single point estimate of the market value of a given amenity. This estimate is not circumscribed by the restrictions and ambiguities inherent in theoretical models of underlying supply and demand functions.

The hedonic model for housing considers the price of a house to be a function of its major identifiable amenities or characteristics. The model is succinctly formalized by the expression:

$$P_i = P(X_{i1}, \ldots, X_{in})$$

where $P_i$ is the price of a given house $i$, $P$ is the hedonic or implicit price function, and the $X$ values are variables representing the presence or level of structural, locational or other characteristics of house $i$. The marginal implicit price of a characteristic can be found by differentiating the price function with respect to that characteristic:

$$dP/dX_n = P_{xn}(X_n)$$

This value is the increase in price necessary to purchase a house with one more unit of $X_n$, all other things being equal. Using the reduced-form hedonic model, there is little controversy over interpreting the regression coefficient as the implicit market value or "market-clearing price" for any specific feature. However, a number of conventional assumptions are also required, such as that households have full information and that the price vector adjusts instantaneously to changes in supply and demand.

The model developed for the present analysis is estimated using ordinary least squares. Since location has been largely accounted for by selecting only those houses built within subdivisions in similar areas of the county, no locational variables are present in the specification. The model is represented by the equation:

$$P_i = f(S_{ij}, E_{ij}, e_i)$$

where $P_i$ is the resale price for the $i$th new house; $S_{ij}$ is a vector of structural variables for each house such as total square footage; $E_{ij}$ is a vector of energy-related variables for each house such as whether the house is MCS; and $e_i$ is the error term, assumed to have a mean of zero and a constant variance. Summary statistics for the independent variables in the hedonic model are provided in Table 2.

In the model itself, MCS houses are represented by two variables; first, by a binary variable coded 1 for MCS houses and 0 for non-MCS houses; and second, by an interaction term formed by multiplying floor area by the binary MCS variable. This second variable is added to the model in the prior expectation that the incremental costs of constructing an MCS house and the incremental benefits derived from the feature are not constant, but vary for houses of different sizes.

The number of bathrooms for each house is represented in the model by adding the number of full baths to one-half the number of partial baths, and the variable representing fireplaces is simply the number of fireplaces present (the minimum number was 0 and the maximum was 3). The type of heating system, i.e., zonal or furnace versus heat pump, is represented by a binary variable. Finally, to represent non-functional, cosmetic features of a new house that can add significantly to its cost, an interaction term was used to signify houses with roofs constructed from composite shingles versus those constructed from more aesthetic wood shingles or tiles. The variable takes on a value equal to floor area for houses with wood shingle or tile.
Table 2. Sample Characteristics

<table>
<thead>
<tr>
<th>Variable</th>
<th>MCS (N=42)</th>
<th>Non-MCS (N=25)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Floor Area (sq ft)</td>
<td>1537</td>
<td>1601</td>
</tr>
<tr>
<td>Houses with Heat Pumps</td>
<td>13 (31%)</td>
<td>3 (12%)</td>
</tr>
<tr>
<td>Houses with Wood or Tile Roof</td>
<td>18 (43%)</td>
<td>12 (48%)</td>
</tr>
<tr>
<td>Houses with no Fireplace</td>
<td>11 (26%)</td>
<td>0 (00%)</td>
</tr>
<tr>
<td>Mean Baths</td>
<td>1.55</td>
<td>1.78</td>
</tr>
<tr>
<td>Most Recent Resale Price</td>
<td>$82,079</td>
<td>$83,330</td>
</tr>
</tbody>
</table>

roofs, and a value of 0 otherwise. The estimation results are shown in Table 3.

The first noteworthy finding of this model is its high $R^2$. Given the small number of explanatory variables in the model, and the much lower $R^2$ typically found in more extensive housing studies, this finding suggests that one of the original goals of the study--to ensure the validity of the analysis by selecting a relatively homogeneous sample of MCS and control houses--was successful.

The specific estimates for the coefficients indicate that the characteristic of primary interest, MCS, is related in a statistically significant manner to sale price. Further, the significance of the MCS interaction term indicates that the implicit price of MCS is not a constant, but varies with floor area square footage. Based on the model specification, the marginal implicit price of MCS calculated as:

$$dP/dMCS = b_1 + b_2(Floor\ Area) \tag{4}$$

where $b_1$ is the coefficient for the binary MCS variable and $b_2$ is the coefficient for the MCS interaction term. Evaluated at the mean floor area of MCS houses, the market-clearing implicit price ($P_{mcs}$) associated with the MCS feature is:

$$P_{mcs} = -2933.22 + 19.94(1537) = 1315 \tag{5}$$

From an investment perspective, the price of $1,315 represents the capitalized value of the energy efficiency measures present in an average size MCS house.

It is important to note that the implicit price of the MCS feature is not indicative of the full incremental value of houses with heat pump systems--this feature’s distinct contribution to the total sale price is estimated with a separate variable to be $4,384.

Heat pumps systems require a separate variable because they are substantially more expensive to install than zonal or furnace systems and have different benefits and costs. If heat pumps were not treated as distinct from other heating systems, interpretation of the model coefficients would be confounded by the fact that: (1) heat pump systems are generally in larger, luxury houses; (2) they often provide central air conditioning in addition to heating; (3) they are mechanically more complex, often requiring an additional heating back-up system; and (4) they contain more moving parts, require more repair and maintenance, and have shorter lifetimes than shell measures. The complex nature of these systems, and the upward biases in the MCS coefficients that they are likely to cause, are avoided by differentiating between those MCS houses achieving the kWh/sq ft/yr goal through the choice of a heat pump system versus those meeting the goal with increased building shell efficiency.

The model’s coefficient for the implicit price of a heat pump system, although not statistically significant, is of realistic magnitude. The same is true for the marginal implicit prices of fireplaces and bathrooms. It seems likely that with a larger sample of houses these coefficients would have had relatively smaller standard errors. The other two coefficients in the model represent house size and roof type, or exterior cosmetic features. The former is undoubtedly the single most important variable in a hedonic housing model; here it is highly statistically significant and takes a value of $23.50 per square foot of floor area. As expected, this value declines as more amenities are added to the specification. The last coefficient indicates a joint impact.
Table 3. Parameter Estimates for Hedonic Price Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>t-Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor Area (sq ft)</td>
<td>23.50</td>
<td>3.4*</td>
</tr>
<tr>
<td>MCS</td>
<td>-29333.22</td>
<td>-2.9*</td>
</tr>
<tr>
<td>MCS * Floor Area (sq ft)</td>
<td>19.94</td>
<td>3.1*</td>
</tr>
<tr>
<td>Heat Pump</td>
<td>4383.70</td>
<td>0.9</td>
</tr>
<tr>
<td>Baths</td>
<td>2868.48</td>
<td>0.7</td>
</tr>
<tr>
<td>Fireplaces</td>
<td>2765.30</td>
<td>1.0</td>
</tr>
<tr>
<td>Roof * Floor Area (sq ft)</td>
<td>6.19</td>
<td>2.3*</td>
</tr>
<tr>
<td>(Constant)</td>
<td>31040.14</td>
<td>3.5*</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.86</td>
<td></td>
</tr>
<tr>
<td>Standard Error</td>
<td>10846.58</td>
<td></td>
</tr>
</tbody>
</table>

*Probability less than 0.05

of house size and roof material on total sale price. This impact, equal to an increase in total price of $9,662 for an average size house with a wood shingle or tile roof, is clearly too high an estimated price for the roof feature alone. One possible interpretation of this finding is that it lends support to the initial assumption that expensive roofs are collinear with other high-priced, largely cosmetic amenities that are not explicitly accounted for in the model, such as the design and building materials used for the siding, landscape, driveway and garage.

ENERGY SAVINGS IN MCS HOUSES

The energy savings analysis involves estimating a cross-sectional regression model of household energy use based on second, unrelated random sample of 157 MCS and 183 non-MCS houses. Its goal was to compare energy use in the MCS and non-MCS houses while controlling for factors other than the program that may systematically affect levels of energy consumption. This analysis provides a direct estimate of the net benefits of the MCS. However, it should be noted that because of the complications associated with heat pump houses and the unique difficulties in estimating their contribution to energy savings, no heat pump houses are present in the samples. Thus, the results only apply to those houses meeting the MCS criteria through increased shell efficiency.

Information on household characteristics was obtained through two occupant surveys of MCS and non-MCS houses in the Tacoma area conducted in 1986 and 1987. For these surveys, no distinction was made between new and resold houses. Selected survey results are summarized in Table 4.

For the energy savings model, the dependent variable is annual electricity consumption derived from the utility billing records of each house. Since most annual billing cycles either fall short of a full year or extend beyond a year, a specialized program known as PRIISM (Fels 1983) was used to "annualize" this variable for each household. Derived in this way, total electricity use for MCS households averaged 18,398 kWh/year; for non-MCS households, total electricity consumption averaged 25,295 kWh/year. Weather adjustment was not necessary because the analysis covers but one year. Moreover, the weather pattern for this year was fairly typical for the Tacoma area.

The choice of explanatory variables for the model was guided by two considerations: first and foremost, the need to control for factors that influence household electricity use other than the level of thermal efficiency; and second, to control for interactions between baseload and heating load. Ultimately, the presence of multicollinearity precluded the use of many variables, particularly structural characteristics and appliance holdings. Thus, the final specification represents a compromise drawn from many different variables. The model was given a linear functional form and estimated by ordinary least squares. The findings are shown in Table 5.

The variable of primary interest for this analysis is again MCS, a binary variable taking a value of 1 if the house was MCS and 0 otherwise. As the variable...
Table 4. Occupant Characteristics (Means)*

<table>
<thead>
<tr>
<th>Variable</th>
<th>MCS  (N=157)</th>
<th>Non-MCS (N=183)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Household Members</td>
<td>3.2</td>
<td>3.3</td>
</tr>
<tr>
<td>Households With Members Under 6 or Over 65 Years Old</td>
<td>45%</td>
<td>37%</td>
</tr>
<tr>
<td>Number of Children Under 11</td>
<td>0.87</td>
<td>0.83</td>
</tr>
<tr>
<td>Education of Head of Household</td>
<td></td>
<td></td>
</tr>
<tr>
<td>At Least High School</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Some College</td>
<td>66%</td>
<td>83%</td>
</tr>
<tr>
<td>Presence of Electric Appliances</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Heater</td>
<td>96%</td>
<td>98%</td>
</tr>
<tr>
<td>Air Conditioner</td>
<td>15%</td>
<td>26%</td>
</tr>
<tr>
<td>Dishwasher</td>
<td>87%</td>
<td>95%</td>
</tr>
<tr>
<td>Washing Machine</td>
<td>89%</td>
<td>91%</td>
</tr>
<tr>
<td>Clothes Dryer</td>
<td>88%</td>
<td>91%</td>
</tr>
<tr>
<td>Freezer</td>
<td>40%</td>
<td>46%</td>
</tr>
<tr>
<td>Refrigerator</td>
<td>94%</td>
<td>96%</td>
</tr>
<tr>
<td>More Than One Refrigerator</td>
<td>7%</td>
<td>9%</td>
</tr>
<tr>
<td>Waterbed Heater or Electric Blanket</td>
<td>52%</td>
<td>54%</td>
</tr>
</tbody>
</table>

*These samples do not contain houses with heat pumps.

Table 5. Parameter Estimates for Energy Consumption Model (N=293)

Dependent Variable: Annual Electricity Consumption

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>t-Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCS</td>
<td>-3475.0</td>
<td>-3.6*</td>
</tr>
<tr>
<td>Floor Area (sq ft)</td>
<td>3.8</td>
<td>6.3*</td>
</tr>
<tr>
<td>Household Size</td>
<td>1028.0</td>
<td>4.9*</td>
</tr>
<tr>
<td>Household Income</td>
<td>619.5</td>
<td>2.6*</td>
</tr>
<tr>
<td>Wood Stove</td>
<td>-1385.2</td>
<td>-2.0*</td>
</tr>
<tr>
<td>Electric Blankets/Waterbed Heaters</td>
<td>710.3</td>
<td>3.7*</td>
</tr>
<tr>
<td>Central Thermostat</td>
<td>2144.7</td>
<td>4.2*</td>
</tr>
<tr>
<td>Dishwasher</td>
<td>1335.7</td>
<td>1.1</td>
</tr>
<tr>
<td>Electric Dryer</td>
<td>1225.8</td>
<td>1.2</td>
</tr>
<tr>
<td>Number of Televisions and Computers</td>
<td>974.3</td>
<td>3.4*</td>
</tr>
<tr>
<td>Electric Water Heater for Hot Tub/Seua</td>
<td>3000.0</td>
<td>2.9*</td>
</tr>
<tr>
<td>(Constant)</td>
<td>4110.0</td>
<td>2.3*</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.59</td>
<td></td>
</tr>
<tr>
<td>Standard Error</td>
<td>3201.0</td>
<td></td>
</tr>
</tbody>
</table>

*Probability less than 0.05

is binary, the coefficient represents the net difference in annual energy consumption between MCS and non-MCS houses, or energy savings due to increased thermal efficiency. The coefficient indicates that, on average, the difference in energy use between MCS and non-MCS houses is approximately 3,500 kWh per year. This difference is interpretable as "net savings due to MCS," since the model is specified such that it controls for the other major factors that may differentially affect household space heating energy use.

All the remaining influences in the model are also in the expected direction, and all of the estimated parameters for variables that affect space heating energy use are statistically significant. These include floor area, household size, household income (a categorical variable with a range of 1 to 7, representing approximately $10,000 intervals), and the presence of a wood stove, electric blankets or waterbed heaters, and a central thermostat. Variables associated with baseload energy use include the number of televisions and computers; and the
THE HOME BUYER DISCOUNT RATE AND REAL ESTATE MARKET EFFICIENCY

The findings of the hedonic price analysis and the energy savings analysis provide answers to the two most fundamental questions about residential programs raised by energy policy-makers and planners. These findings are useful for understanding household behavior and projecting energy demand, but they may also be used for addressing broader program and policy questions.

An issue of much interest involves the "household discount rate." This rate is no more than the investment yield or rate of return households seemingly require for making a capital expenditure. There are several good reasons why the household discount rate is important to planners. For one, it is a crucial parameter for projecting household energy conservation or efficiency investment levels, which are in turn used to forecast energy demand and conservation impacts. The more confidence that can be placed in this parameter, the more optimal the resulting programs and policies will be.

On another level, the household discount rate serves as an indicator of real estate market efficiency. In a perfectly competitive market where houses are built to match buyer preferences, home buyers should be willing to invest in conservation measures until the marginal value of the benefits of the measures, i.e., the operating cost savings resulting from using less fuel, equals the marginal costs of the measures. According to financial theory, the appropriate rate of return for these investments would be the household's opportunity cost of capital. In the case of riskless thermal measures in new houses such as glazing and insulation--whose lifetimes match those of the house and whose benefits are net of taxes--this rate should be equal to the after-tax mortgage interest rate.

Comparing the discount rate to the relevant opportunity cost can yield important insights. If the household discount rate were found to be substantially higher than the mortgage rate, this would provide evidence of uncertainty, insufficient information, income effects or other imperfections in the real estate market, and would help justify intervention by public agencies. However, if the household discount rate were found to be lower, this might suggest that home buyers were overestimating the value of savings. Conversely, it might indicate that home buyers were viewing the added expenditure as consumers as well as investors, finding additional, non-quantifiable benefits in the efficiency measures, such as decreased draftiness or nosiness.

The findings of the two empirical analyses in this study provide average energy savings and price estimates based on recorded household behavior. To determine the household discount rate for the MCS feature implied by purchases of resold electrically-heated single family houses, a relatively simple investment yield calculation, such as that used to compute the return on an annuity, is employed. The formula for this method is a derivation of the basic present value equation:

\[ P = \frac{A}{1+r} + \frac{A}{(1+r)^2} + \ldots + \frac{A}{(1+r)^n} \]  

where \( P \) is the present value of an investment, \( A \) is the annual income from the investment, \( r \) is the opportunity cost or discount rate per period, and \( 1 \) through \( n \) are the periods constituting the life of the investment. For this analysis the goal is to solve for \( r \), which is interpretable as the home buyer rate of return. With some algebraic rearranging, \( r \) is estimated as

\[ r = \frac{A}{P} \]  

In the present context, \( A \) is the annual income or benefits received from the MCS features, defined as the product of annual kWh savings and the local price per kWh, and \( P \) is the implicit price of the MCS investment at the time of the house sale.

Several assumptions are embodied in this approach. First, the lifetime of the investment is assumed to be the same as that of the structure itself, estimated as 30 years. In effect, this means that the investment is assumed to have an "infinite" lifetime. Second, the investment is assumed to be risk-free in the
sense that there is no physical deterioration and no maintenance or replacement costs over its lifetime. Third, it is assumed that the net energy savings per year are constant. Last, it is assumed that energy prices remain constant, in real terms, over the life of the investment.

These assumptions are hardly unreasonable. The MCS features focused on in this study are passive shell improvements that are virtually inseparable from the structure itself. There is no evidence that these measure deteriorate or that the energy savings resulting from these improvements increase or decrease over time. The assumption that energy prices will remain constant in real terms is quite conventional. It should be noted that there is strong evidence that the real cost of exhaustible resources in the U.S. has, on average, remained constant over the past century.

Based on these assumptions, the empirical findings above, and a fixed winter residential energy rate in 1987 and 1988 for Tacoma Power and Light customers of approximately 3 cents per kWh, the average household discount rate is:

\[ r = \frac{(3475 \text{ kWh}) \times (0.03)}{1315} \]  
\[ = 0.079 \]  

In other words, home buyers who purchased an MCS house were willing, on average, to receive a real return on their investment of 7.9%. This must be considered an after-tax return because the effect of the annual benefits is to decrease household expenses and consequently increase household net spendable income.

Comparing this rate with the average after-tax mortgage rate in the Tacoma, Washington area lends support to the hypothesis that the real estate market operated efficiently in fully capitalizing the energy savings benefit in the sale price of a house. Nominal residential mortgage rates in this area, as in the rest of the country, ranged between 9% and 13% in the period from 1986 through 1988, and inflation ranged between 2% and 4%. At a marginal income tax rate of 25% for the typical household, the real after-tax opportunity cost of capital for the MCS investment was roughly between 5% and 10%. The home buyer discount rate found in the present analysis falls squarely in this range.

CONCLUSION

This study offers several insights into the economics of a residential building standards program. Based on the observed behavior of households, the empirical analyses in this study suggests that home buyer willingness to pay for the MCS features of a new house is consistent with economic expectations, and that doubts about the efficient functioning of the real estate market are unfounded.

Using estimates of the energy savings and market value of single-family houses (i.e., electrically-heated, high thermal efficiency) an average, nominal discount rate for home buyers of approximately 8% is calculated, revealing that purchasing an MCS house is, on average, a cost-effective investment for the home buyer. This conclusion is based on the finding that home buyers discount the MCS investment at an interest rate that is equal to their opportunity cost of capital, i.e., the real, after-tax mortgage rate. Put another way, if the cost of purchasing the MCS feature and the stream of MCS-related energy savings were transformed--using the actual, inflation-adjusted, after-tax mortgage rate (i.e., the true opportunity cost for home buyers)--into an estimate of the "present value per kWh saved," this estimate would equal 3 cents per kWh. This is akin to finding that home buyers have revealed a willingness to invest up to 3 cents per kWh in thermal efficiency measures to avoid using kWhs that would cost them 3 cents.

REFERENCES
