# Energy Efficiency and its Relationship to Household Income in Multifamily Rental Housing

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## Introduction and Background

This paper examines the energy efficiency of multifamily rentals in comparison to other housing types and its relationship to household income. It analyzes 2005 and just-released 2009 data from the U.S. Residential Energy Consumption Survey and finds that multifamily rentals were significantly less energy efficient than other types of housing, both nationwide and in every region of the country.[2] Nationwide, in 2009, multifamily rentals averaged 34% fewer energy efficiency features than the number found in other types of housing (7.4 vs. 11.2). Multifamily rentals added efficiency features between 2005 and 2009, but the efficiency gap between them and other housing types shrank only slightly. In addition, lower income multifamily renters lived in less energy efficient units than higher income multifamily renters in 2005 and they fell even further behind from 2005 to 2009.

Multifamily housing, generally defined as residential buildings with 5 or more units, is an important part of America's low income housing supply. It houses about a quarter (27.3%) of all households with incomes below the poverty line (AHS, 2009), 28.4% of all very low income families[3] (ACS, 2010) and nearly half (48.9%) of all very low income renters (ACS, 2010). Although more recent data are unavailable on how many subsidized low income housing units are found in multifamily buildings, a 1998 study (Cummings and DiPasquale 1998) estimated that 80% of all Low Income Housing Tax Credit (LIHTC) housing, the federal program that provides the majority of new low income units (Desai *et al.* 2009), is found in multifamily structures.

A challenge to sustaining affordable multifamily housing is the cost of energy in rental apartments. Nearly all (93%) very low income households who live in multifamily housing units are renters (AHS 2010). And in rented multifamily units, energy expenditures run 37% higher per square foot than in owner-occupied multifamily units (i.e. condos or



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[2] Throughout this paper "multifamily rentals", "rented multifamily housing" or MF rentals (in some tables) includes housing units in apartment buildings with 5 or more units that are rented by the occupant(s). "Other housing" or "other housing types" includes any of the following: a) units in apartment buildings with 5 or more units that are owned or being bought by the occupant(s) (including condos or cooperatives) or are occupied without paying rent, b) units that are rented, owned, being bought or occupied without paying rent in apartment buildings with 2 to 4 units, and c) units that are rented, owned, being bought or occupied without paying rent in detached single family units, attached single family units, or mobile homes. "All types of housing" or "all housing types" include both multifamily rentals and other housing except residences that are part of a public housing authority. Units provided by a public housing authority are excluded from the study and from multifamily rentals, other housing, and all housing, as used in this study.

[3] "Very low income" is defined here and by the federal government as households that earn less than half the national median income.

cooperatives), 41% higher than in renter-occupied single family detached units, and 76% higher than in owner-occupied single family detached units (RECS, 2005, Table US1)[4]. This pattern holds in every region of the country.[5]

There are several explanations for why energy expenditures are higher per square foot in multifamily rentals. Multifamily rentals are less energy efficient, as this paper will show. In addition, multifamily renters live about 20% more densely (per room and per bedroom).[6] And multifamily renters probably conserve less because fewer of them pay their energy bills directly; more of them have some or all of their energy costs included in the rent, which has been tied to less conservation behavior (Munley *et al*. 1990, Levinson and Niemann 2004, Maruejols and Young, 2011).[7] Whatever the causes, higher energy expenditures per square foot in multifamily rentals, compared to other housing types makes it harder for multifamily rentals to house their occupants affordably.

Home energy is a significant component of many household budgets, especially for lower income families (Roberts 2008, Hernandez and Bird 2010). For households that earn less than the national median household income (in any housing type), home energy comprises about 17% of their total housing cost and consumes 9% of their total income (CES, 2010). These percentages take on greater significance considering the median household living below the poverty line pays nearly half (49%) its income for housing (AHS, Table 2-13, 2009), which is well above the 30% standard commonly used for what a family should spend on housing in order to have enough left over to meet its non-housing needs.[8]

Price and spending trends for home energy exceed general inflation rates. Nominal home energy prices grew by 37% from 2000-2010, while the CPI grew by 27%.[9] Meanwhile, *spending* on home energy grew even faster. Nominal spending on home energy by renters jumped 53% from 2000-2010, while their average spending on all goods and services rose by only 22%.[10] This rapid uptick in energy spending is probably linked to several factors including more home electronics, larger homes, weather patterns, and geographic population shifts.[11]

Previous researchers have pointed out special challenges associated with implementing energy efficiency measures in multifamily housing. These challenges include lack of national data on the payback period from retrofits, financial split-incentives, technical unknowns, poorly informed owners and other institutional barriers (Levine *et al.* 1982, Laquatra 1987, DeCicco *et al.* 1994, Katrakis *et al.* 1994, Davis 2010, HUD 2011). As Laquatra put it 25 years ago, with reference to rental housing in general, "…a number of institutional barriers in rental housing markets…are conducive to low levels of

[4] These amounts are estimated regardless of whether energy bills are paid directly by the renter or included in the rent. For households that do not pay their bills directly, expenditures are estimated by the EIA.

[5] For example, energy expenditures per square foot in multifamily rentals are higher than in single family homes in every US Census Division, from 28% higher in the Pacific to 129% higher in New England.

[6] In 2009, the mean number of persons per bedroom in multifamily rentals ranged from 1 to 1.2, depending on household income, compared to 0.9 in all other types of housing. The average per room of any kind was 0.6 in multifamily rentals vs. 0.5 in other housing types (RECS, 2009)

[7] In 2009, only 58% of multifamily renters paid all of their energy bills, rather than having some or all of them included in the rent. This compares to 89% across all types of owned and rented housing (RECS 2009, Table HC9.2). A similar pattern is found regardless of fuel or region. For example, in all US census regions, a smaller percentage of multifamily renters directly pay their electric bill for space heating, their natural gas bill for space heating, or their fuel oil bill, when they receive such bills, compared to occupants of all housing types.

[8] Housing costs in the AHS include the mortgage or rent (excluding any rent subsidies), property taxes, insurance, fees, land rent and utilities. Also note that the AHS also reports a median of 84% when households that pay 100% or more of their current income are included in the calculation of housing costs as a percent of median income. According to the AHS, this higher percentage may reflect a temporary situation, living off savings, or response error.

[9] CPI, 2000 and 2010

[10] CES, 2000 and 2010

[11] EIA, Trends in Heating and Cooling Degree Days: Implications for Energy Demand, *Issues in Focus,* AEO2008. Available at: http://www.eia.gov/oiaf/aeo/otheranalysis/aeo_2008analysispapers/thcdd.html

energy efficiency in a substantial portion of a community's housing stock, which is in many cases inhabited by those who can least afford anticipated energy price increases."

Beyond these affordability issues, other important social and environmental problems are linked to home energy use. Thompson *et al.* (2009) review the evidence showing that improving warmth and energy efficiency can benefit general, respiratory and mental health. They also report socio-economic benefits beyond lower fuel bills, including less time off from work and school. There also can be increased use of the home for studying and leisure, more social visitors, increased privacy, and improved relationships between household members. Home energy use has also been associated with various environmental issues, according to federal sources.[12]

Aside from climate and geography, the amount of home energy used by lower income renters is driven by energy prices, household behavior, and housing unit efficiency. Different parties are responsible for each. Energy suppliers, markets and regulators determine prices, households control their behavior (though their options may be limited by circumstances beyond their control), and property owners and investors make decisions about the efficiency of apartment units. But unit efficiency is certainly a determining factor of home energy use, which is why this paper takes a closer look at the topic.

Concern about energy efficiency in affordable housing is not new. Almost 20 years ago, in a report for HUD and DOE on incorporating energy efficiency into multifamily housing, Katrakis *et al.* (1994) wrote: "Typically, affordable rents or mortgages are achieved by minimizing construction costs. Yet, in an effort to meet this goal, energy efficiency is often excluded. The result is housing that may have affordable rents or mortgages but unaffordable energy costs." The central question addressed in this paper, then, is whether "affordable" multifamily rentals are less efficient than other housing types.

## Data

To answer this question it is necessary to have data on the efficiency of the nation's housing stock. The only available national dataset on the topic is the US Department of Energy Residential Energy Consumption Survey (RECS). The Energy Information Administration (EIA) administers the RECS every 4 years to a nationally representative sample of housing units. The survey is collected from households in housing units statistically selected to represent all US housing occupied as a primary residence. Interviewers collect energy characteristics on each housing unit surveyed, usage patterns, and household demographics. The information is combined with data from energy suppliers to estimate energy costs and usage for heating, cooling, appliances and other end uses. For renters, household energy cost figures do not depend on whether they pay their bill directly or have it included in their rent. For households that do not pay directly, expenditures are estimated by DOE. First conducted in 1978, the thirteenth survey was conducted in 2009. The following analysis was based on information from the 2005 and just-released 2009 results.

The RECS contains data on household income but not on housing cost or county location. This makes it is impossible to determine whether units in the survey meet the common definition for affordable using the traditional ratio standard of housing cost to county area median income. It is possible, however, to use the survey to analyze the energy efficiency of units occupied by moderate, low, and very low income households, which often depend on below market rate housing. That is the approach taken for this project. It is safe to assume that some of the households in the survey occupy

[12] The residential sector was responsible for about 18% of all US greenhouse gas emissions in 2010 (EPA 2012). Atmospheric deposition of pollutants due to air pollution from power plants, motor vehicles, pesticide applications, and other industrial sources is the largest source of water quality impairment in lakes, ponds and reservoirs in the USA and a top ten source in rivers and streams (EPA 2009). Thermoelectric power accounts for about half of total water withdrawals (USGS, 2009).

affordable units and others do not. But regardless of whether their housing is affordable, this analysis allows us to better understand whether the housing occupied by low and moderate income households is more or less energy efficient than the housing occupied by higher income families.

## Methods and Results

### Energy Efficiency Features

"Energy efficiency" refers to the amount of energy used for a given level of energy service. In housing, these services include space heating and cooling, water heating, lighting, operating appliances and electronics, and so on. The services used to support a housing unit depend on the climate where it is located, and a variety of occupant-related factors, such as their number and ages, how often they're home, how they set their thermostats, and how often they shower. But the amount of energy required to provide these services (i.e. the energy efficiency of the unit) depends on the physical features of the unit such as insulation, building orientation, shading, windows, HVAC systems, lighting systems, appliance efficiency and so on. These, in turn, are sensitive to how each system is managed and maintained by owners, building staff, and occupants. The total efficiency of a unit, therefore, depends on the type, management, and maintenance of various physical features found in and around the home.

In this paper, physical attributes that reduce the amount or cost of energy required for a given level of energy service are referred to as Energy Efficiency Features (EEFs). Taking an inventory of EEFs is one way to determine the efficiency of a unit. This approach was used in this study and is similar to the approach used by DOE in its own recent analysis of home energy efficiency trends (Energy Information Administration 2009).

Two dozen questions in the RECS ask about EEFs. The features addressed by the survey are listed in Table 1, grouped into 3 basic types: those pertaining to the HVAC system, those pertaining to household appliances, and those pertaining to the building envelope. Several EEFs address whether a unit has HVAC equipment and appliances produced after 2000, because after that date more stringent federal energy efficiency standards took effect (Energy Information Administration 2005). Natural gas appliances and HVAC equipment are also included as EEFs because natural gas is typically less expensive than other fuels.[13]

Cross-tabulations were used to compare the prevalence of EEFs in different housing groups. A summary of the results is given in Table 1. More detailed results are given in Table 2 (in the appendix).

The first comparison was made between multifamily rentals and other housing types (see Table 2, columns 8 and 9). Significance was determined by Pearson's chi-squared test (Table 2, column 10), which is the appropriate test when dependent variables are binary (i.e. whether a given EEF is present or absent). Overall, 87.5 percent of the EEFs (21 out of 24) were significantly less common in multifamily rentals than in other housing in 2005 (at the .10 significance level or better). By 2009 this difference had been reduced to 75 percent, though clearly the deficiency in multifamily housing remained.

In the 2005 sample, every HVAC EEF, all but 1 building envelope EEF, and 9 of the 11 appliance EEFs were significantly less common in multifamily rentals. Only 1 feature was more common in multifamily rentals (2000+ vintage clothes dryers) and only 1 was equally common (natural gas cook top). In the 2009 sample, all but one HVAC EEF (2000+ vintage AC), every building envelope EEF, and 6 of the 11 appliance EEFs were significantly less common in multifamily rentals,

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[13] For space heating see: Heating Fuel Comparison Calculator at www.eia.gov/neic/experts/heatcalc.xls. For water heating and ovens see: California Energy Commission, Consumer Energy Center, http://www.consumerenergycenter.org/home/appliances/

compared to other housing. Six features were equally or more common in multifamily rentals, all but one related to appliances.

These findings show that multifamily rentals were less energy efficient than other housing in 2005 and that the gap persisted into 2009. Some improvement occurred, but it was modest. And, as will be shown below, more of these improvements were in units with higher income occupants.

**TABLE 1:** Relative prevalence of Energy Efficiency Features (EEFs) in multifamily rentals vs. other housing types and significant effects of household income on EEFs in MF units

| Energy Efficiency Features (EEFs) | Less | | Same | | More | |
|---|---|---|---|---|---|---|
| | 2005 | 2009 | 2005 | 2009 | 2005 | 2009 |
| *HVAC* | | | | | | |
| Programmable heat thermostat | X | X | | | | |
| Programmable AC thermostat | X | X | | | | |
| 2000+ vintage AC | X | | | X | | |
| AC by heat pump | X | X | | | | |
| 2000+ vintage heat | X | X | | | | |
| Heat by heat pump | X | X | | | | |
| Ceiling fans | X | X | | | | |
| Natural gas main heat | X | X (-) | | | | |
| *APPLIANCES* | | | | | | |
| 2000+ vintage clothes washer | X (-) | | | | | X |
| ESTAR clothes washer | X | X | | | | |
| 2000+ vintage clothes dryer | | | | | X | X |
| Natural gas clothes dryer | X (-) | X | | | | |
| 2000+ vintage dishwasher | X (-) | | | X (-) | | |
| ESTAR dishwasher | X | X | | | | |
| 2000+ vintage refrigerator | X (-) | | | | | X (-) |
| ESTAR refrigerator | X | X | | | | |
| 2000+ vintage water heater | X (-) | X (-) | | | | |
| Natural gas cook top | | | X | X | | |
| Natural gas water heater | X | X (-) | | | | |
| *BUILDING ENVELOPE* | | | | | | |
| Some or all new window glass | X | X (+) | | | | |
| Double pane window glass or better | X | X (-) | | | | |
| Insulation adequate | | X | X | | | |
| Not too drafty | X | X | | | | |
| Trees give summer PM shade | X | X | | | | |
| (-/+) indicates frequency of EEF declines (-) or increases (+) significantly (at .10 level of better) with falling income in multifamily units | | | | | | |

A notable case where the gap disappeared was for 2000 and later vintage central AC units. Given that AC is one of the largest energy expenses in multifamily rentals (14.4% nationwide in 2005), that is a notable achievement (RECS 2005). The gap also disappeared for 2000 and later vintage dishwashers, though they are less important for energy spending.

To get a better idea of which EEFs became more and less common in multifamily rentals, a second comparison was made between the percentage of multifamily rentals with each EEF in 2005 and 2009 (see Δs in Table 2, column 8). It showed that two-thirds of the EEFs were more common in 2009 than in 2005 and one-third were less common. It is unclear what net effect this had on energy use and expenditures because the relative importance of the different EEFs was not measured for this study. All but one of the HVAC EEFs was more common in 2009 than in 2005 while all the building envelope features were less common, though only slightly. It is hard to say what the net effect of these changes in HVAC and building envelope features was for heating and cooling efficiency since both HVAC and building envelope features affect heating and cooling performance. That is important given that heating and cooling is the most costly part of energy budgets in multifamily rentals (about 43% in 2005). In general, though, we can say that even though the gap in EEFs that existed between multifamily rentals and other housing in 2005 persisted into 2009, two-thirds of the EEFs did become more common in multifamily rentals over the 4 year period.

To better understand whether EEFs in multifamily rentals differed in relation to occupant income, a third comparison was made among the units occupied by different income groups, again using the chi-squared test to identify significant differences. Four income groups were evaluated based on whether total household income was less than 50%, 50-80%, 80-100%, or greater than 100% of the median household income in the census region where the household was located for both the 2005 and 2009 samples. County level benchmarks could not be used because the RECS does not report the county location of the units surveyed. The results are given in Table 2, columns 3-7. Overall, the prevalence of efficiency features in rented multifamily housing increased with income for 5 (21%) of the EEFs in 2005 and for 6 (25%) of the EEFs in 2009. One feature (some or all new window glass) decreased with income in the 2009 sample. In general, these results show that income (and rent to the extent that income is a proxy for rent) is positively related to whether an efficiency feature occurs in multifamily rentals for some but not most EEFs and that this income effect was slightly more common in 2009 than 2005.

Further analysis of the changes from 2005 to 2009 among the various income groups (see Δs in Table 2, columns 3-6) indicated that multifamily rentals occupied by higher income households improved more than those occupied by lower income families. This observation is based on the statistic reported in the bottom line of Table 2, which gives the median gain that occurred in the percentage of units with each type of EEF for each housing group studied. The median gain was 7.6 percent for high income renters compared to 3.5 percent for low income renters. This difference indicates that the efficiency improvements that did occur in multifamily rentals were more common in units occupied by higher income renters, causing the difference in dwelling unit energy efficiency to grow larger, both between lower and upper income renters and between lower income renters and all other households. Both of these findings are consistent with the idea that the positive relationship between income and energy efficiency in multifamily rentals grew stronger from 2005 to 2009.

Overall, then, in both 2005 and 2009, rented multifamily units had fewer EEFs compared to other housing types and several of the EEFs were less common in multifamily rentals as household income declined. Also, the percentage of multifamily rentals with EEFs increased faster in units occupied by higher income households than units occupied by lower income families, increasing the difference between the efficiency of units occupied by low-income multifamily renters and other types of households. These findings support the hypothesis that energy efficiency is related to both housing type (both building type and tenure) and household income; although housing type appears to have a stronger effect than household income (or rent by proxy).

## Total Efficiency Index

To investigate whether the aggregate number of EEFs may have been affected by housing type, tenure and household income, a Total Efficiency Index (TEI) was created by counting the total number of EEFs in each housing unit. No items were weighted as more important than others in the TEI. A weighted index is evaluated in the next section. For the entire 2005 sample (including all housing types), TEI scores ranged from 0 to 21 and averaged 8.4. For the 2009 sample, scores ranged from 0 to 22 and averaged 10.7. Most of the change in the average TEI over the four years was due to an increase in the number of 2000 and later vintage appliances. That is unsurprising given that over time a larger share of older appliances would naturally be replaced.

TEI scores for multifamily rentals and other housing types are compared in Table 3 by region and nationwide for the 2009 sample. It shows that in 2009, in every region, other housing had more EEFs than multifamily rentals, ranging from 18 percent more in the Mountain South to 68 percent more in the East North Central. Nationwide, in 2009, multifamily rentals averaged 34% fewer energy efficiency features than the number found in other types of housing (7.4 vs. 11.2).

Analysis of Variance (ANOVA) was used to identify any significant differences in the average TEI score for multifamily rentals occupied by the four income groups examined in the previous section (Tables 4-7). ANOVA was substituted for the chi-squared test at this stage of the study because the dependent variable (TEI) was now continuous (i.e. the mean number of EEFs) compared to being binary in the prior analysis.

The result show that multifamily rentals had an average of 5.2 to 6.3 EEFs in 2005 (Table 5), and 6.9 to 8.1 EEFs in 2009 (Table 7), depending on occupant income. In both samples this was roughly 30-40% fewer EEFs than the number found in other housing types. The analysis also shows that multifamily rentals occupied by lower income families had lower TEI scores than multifamily rentals occupied by moderate and higher income households, strengthening the case that there is an income or price related effect separate from housing type and tenure. Finally, the data indicate that the difference in the mean number of EEFs found in multifamily rentals occupied by the lowest income households and other housing was 3.6 in 2005 versus 4.3 in 2009, indicating that units occupied by low income multifamily renters fell further behind over time. In fact, the largest gap between groups in absolute terms occurred in 2009, where other housing had 4.3 (63 percent) more EEFs than multifamily rentals occupied by the lowest income households.

To separate the effects of housing type, tenure, and income from one another, and to control for other factors that might also explain the TEI, two linear regression models were developed, one for each sample year. In both models the response variable was the TEI. Three predictor variables included a dummy for whether or not the unit was a rental (RENTAL), a dummy for whether or not it was in a 5+ unit multifamily building (APTBLDG5), and an ordinal variable that indicated household income range in $5,000 increments (INCOME). Controls included dummies for each Census Division, a dummy for whether the unit was in a rural area, the unit square footage, and the year the unit was built.[14] Descriptive statistics for both samples are given in Table 8 and did not suggest normalcy problems for any of the variables. Tables 9 and 10 give correlations for the independent variables, which were weak, indicating an absence of collinearity issues.

The results are given in Table 11 and reinforce the prior findings. All else being equal, multifamily building type, rentals, and income were all inversely related to the number of EEFs at significant levels. Based on the unstandardized coefficients in the model, units in multifamily buildings had an average of 1.7 fewer efficiency features in 2005 and 1.6 fewer in 2009, while rental units had an average of 1.8 fewer EEFs in 2005 and 2.2 fewer in 2009. Together, the models predict that multifamily rentals (regardless of occupant income) had about 3.5 fewer features in 2005, compared to a norm of 8.5 for all housing[15] (from Table 8), and 3.8 fewer in 2009, compared to a norm of 10.7 for all housing (from Table 8), regardless of when the unit was built, whether it was urban or rural, or its regional location.

The models also predict a modest but growing income effect on the prevalence of EEFs from 2005-2009. For every $5,000 decrease in occupant household income, units had about 0.13 fewer features in 2005 and 0.17 fewer in 2009. In 2005, the national median household income was $46,242 and the difference between households that earned 100% vs. 50% of that amount was about $23,121. So, according to the model, households earning 50% of the median would have had 0.60[16] fewer EEFs than those earning 100%, *ceteris paribus*. Similarly, for 2009, households earning half the national median income would have had 0.85 fewer EEFs than those earning 100%. So, income had a larger inverse effect on the number of EEFs in 2009 than it did in 2005.

Combining these findings, the models predict that multifamily units occupied by renters who earned 50% of the median income in 2005 had 4.1 fewer EEFs in 2005 and 4.7 fewer EEFs in 2009 compared to houses occupied by owners with income not less than 50 percent of the median.

## Alternative Indices

A Reduced TEI was created for the 2009 survey by eliminating the 2000 and later appliance items where an ENERGY STAR labeled variable was available in the RECS. This affected dishwashers, refrigerators and clothes washers. All appliances listed as ENERGY STAR in the RECS surveys were made in 2000 or later (even though some less stringent ENERGY STAR labels were available earlier), so in about two-thirds of the cases, 2000 and later vintage appliances also were ENERGY STAR labeled, adding two points to the full TEI. There was some concern that this "double counting" could make it harder to interpret the TEI scores, even though, in general, having an ENERGY STAR and newer appliance is more efficient than either alone. To address this concern, a Reduced TEI was produced to see if using just one indicator for

[14] The energy efficiency of both single and multifamily is increasing. Housing built in the 90s, for example, was 23% more efficient than housing built before 1960 ( Brown and Wolfe 2007).

[15] Data in the models were for all housing except units owned by public housing authorities. "All housing" refers to all housing analyzed in the model.

[16] (23,121 ÷ 5,000) x 0.13

these 3 appliances would alter the basic findings.

For the 2009 sample, the Reduced TEI scores ranged from 0 to 19 with an average of 9.2 (compared to 10.7 for the TEI). As with the TEI, income, tenure, and building type were all significantly related to the Reduced TEI score, *ceteris paribus*. These relationships are demonstrated in the third regression model presented in Table 11. It predicts that multifamily units occupied by renters who earned 50% of the median income in 2005 had 4.2 fewer EEFs in 2009. This compares to 4.7 fewer in the full TEI model. However, when these differences are expressed in percentage terms, the two models predict virtually identical results. The full TEI model predicted that non-multifamily renters earning their regional median income had 56% more EEFs than multifamily renters earning half as much, while the Reduced TEI model predicted they had 55% more EEFs. These consistent results confirm that whether or not appliance age is included along with ENERGY STAR status in the efficiency index, the basic findings are the same: holding regional location, building age, and urban/rural status constant, multifamily renters of all kinds have less energy efficient homes, and the efficiency of housing units declines with falling family income.

A second alternative index was created also using the 2009 survey to consider whether using an "expenditure weighted" index might affect the results. This was done by weighting the contributions of the various types of EEFs to the TEI score according to the degree to which they affect average household energy expenditures. According to the 2005 RECS (Table US15), households spend about 30% on space heating, 15% on air conditioning, 16% on water heating, 8% on refrigerators, and 36% on other appliances and lighting. Each of the EEFs in Table 1 was assigned to 1 or more of these categories, depending on which they would likely affect. Then, the number of EEFs in each category was counted for each dwelling unit and a weighted total computed by summing the product of each category total multiplied by the appropriate percentage of total energy spending that the average household spent on the category in 2005. These values were then normalized to a 0-100 scale by dividing the raw score by the range of all scores. The mean normalized score for each of the subgroups being studied is given in Table 12. It shows a pattern very similar to the prior analyses. This index was also used as the dependent variable in a regression model with the same independent variables given in Table 11, and again, the same findings emerged.

In sum using alternative indices does not change the conclusions drawn in the prior sections.

## Discussion

How much would multifamily renters save if their homes had 4 or 5 more EEFs? Consider this evidence on the savings linked to some of the EEFs:

- According to Lawrence Berkeley Labs, programmable thermostats installed in 2004 could have saved a household $235 per year on their heating and cooling bills (Webber *et al.* 2006), or 27% of what the average household spent that year for heating and cooling.[17] Currently, the US DOE estimates the savings would be closer to 16% per year, which is consistent with emerging evidence that occupants do not always use programmable thermostats to their full potential.[18] If the average multifamily renters in 2005 could have saved 21.5% on their heating and cooling bills,[19] the average of these two savings estimates, they would have saved $126 annually from this one measure alone, or 11.7% of their total annual home energy expenditure.[20]

[17] The average household spent $532 for home heating using any fuel and $335 for central AC, according to the 2005 RECS, Tables SH9 and AC7, respectively.

[18] http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=TH, accessed on 11/14/11.

[19] The average multifamily renters spent $324 for home heating using any fuel and $262 for central AC, according to the 2005 RECS, Tables SH9 and AC7, respectively.

[20] $1,080 per year, according to the 2005 RECS, Table US1

- According to the US EPA, a comprehensive package of ENERGY STAR qualified appliances today can save up to $80 per year on energy costs. A similar package in 2005 would have saved the typical multifamily household about 7.4% on their total yearly energy bill (in 2005 dollars).[21]
- The US Department of Energy reports that converting an older furnace or boiler heating system to a modern conventional system saves $25 or more per $100 of fuel costs.[22] For multifamily renters in 2005, this conversion would have saved $81 per year, or another 7.5% on their total home energy bill.[23]
- Simpson and McPherson (1996) reviewed several studies on how tree shading affects energy use. Air conditioning savings ranged from 25-80%. Applying the midpoint (52.5%) of these to the average expenditure on air conditioning in multifamily buildings in 2005[24] would yield an estimated savings of $132 per year or 12.2% of the annual home energy expenditure.

Now, recall the findings that multifamily units occupied by renters who earned 50% of the median income in 2009 had 4.7 fewer EEFs than other types of homes. If this gap were closed by installing 5 more EEFs (rounding up from 4.7), and if the savings for each additional EEF equaled the average savings produced by the features just reviewed (9.7%), the total savings would come to 48.5% of the annual home energy bill. And since the average multifamily renting household spent $1,080 per year in 2005 on home energy for all uses,[25] they would have saved $524 per year in 2005 ($608 in 2011 dollars).

That may be an overestimate of what is actually feasible because it may not be cost effective for owners to install 5 more EEFs in lower income units. The achievable efficiency potential in multifamily housing (i.e. economically reasonable projects that building owners would accept and take on) has recently been estimated to be 30% (Benningfield Group 2009). If 30% were the maximum achievable with 5 additional EEFs, the savings would have come to $376 per year in 2011 dollars.

Another recent estimate of potential cost-effective savings was made by Oak Ridge National Laboratory for the DOE Weatherization Assistance Program (Eisenberg 2010). That estimate was that annual energy savings for 2010 from cost-effective heating, cooling, lighting and appliance measures in low income dwellings would average from $541 to $611 per year.

So, using a range of $376-$611 for the yearly savings that might be achieved, for a lower income household that earns $15,000-$20,000 per year, the energy efficiency gap consumes a dollar amount equal to 10-16% of what they spent on food in 2010, 18-30% of what they spent on healthcare and 36-58% of what they received from public assistance, supplemental security income, and food stamps.[26]

Are efficiency retrofits sufficiently profitable to attract private debt and equity investments? At least two issues complicate the question. The first is that 58% of all multifamily renters pay their energy bills directly, rather than having them partially or fully included in the rent (RECS 2009, Table HC9.2). This creates the well-known split incentive problem. If owners make improvements, they would have to recover the savings from their tenants thru some kind of mechanism allowed for by the lease. The second problem, however, is that even if an owner could recover costs thru lease terms, if most or all the savings from added efficiency flowed to the owner to pay for the improvements, then the tenants would

[21] It is necessary to use the 2005 household as the benchmark in these examples because that is the year of the most recent data on energy expenditures by multifamily renters.
[22] See Furnaces and Boilers, US Department of Energy, http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12530, accessed on 11/14/11
[23] Based on 2005 RECS, Table SH9
[24] $195 from 2005 RECS, Table AC7
[25] From 2005 RECS, Table US1
[26] BLS CES, Table 2. Income before taxes: Average annual expenditures and characteristics, Consumer Expenditure Survey, 2010.

not see lower energy bills, at least not unless the improvements generated surplus savings that could flow to the tenants after the owner earned a market rate of return on the original efficiency investment.

These problems might be solved, however, because there are multiple pathways by which an owner could profit from energy efficiency investments. The first is from the energy cost savings produced by the project. This is how such projects are normally evaluated (e.g. by payback time, savings-to-investment ratios, etc.). But as noted, this pathway is complicated by the split incentive problem, which even if solved could still divert much or all the savings from making the units more energy efficiency for the tenants.

A second source of returns, however, could resolve these issues. That would be via the effect that greater energy efficiency could have on variables that directly affect the owner's cash flow. These benefits could include reduced common area energy bills, vacancy rates, turnover rates and repair expenses. If benefits from efficiency investments to these items were sufficient to justify the investment, the split incentive and tenant benefit issues could be reduced, and the owners could earn returns on their investments in ways that could leave the housing unit-level energy savings to benefit the tenants. In some cases, it might also be possible to earn higher rents from mid to upper market rate units in a building that also included below market rentals.

A third source of potential return could come from the capital markets. Equity investors may be willing to pay more for each dollar of income from buildings that are "future proofed" against market shocks caused by energy spikes. This phenomenon has been observed in commercial office buildings, where ENERGY STAR properties sold at a lower cap rate in the 1999-2008 period (Pivo and Fisher 2010). Lenders might also find that these improvements reduce default risk, allowing them to offer more favorable loan terms when improved buildings are refinanced.

Thus, there are several ways that investors might earn returns from making energy retrofit investments, including several that could reduce or avoid the split incentive problem and allow energy savings to benefit the tenants.

Unfortunately, there are few facts available at this time to test these hypotheses. The only national double-blind peer reviewed research on the economics of energy retrofits in multifamily housing was published nearly 25 years ago by Goldman *et al.* (1988). They examined data from 191 projects, representing more than 25,000 units, which focused on measures to reduce space heating and domestic hot water energy use. The economics varied greatly, depending on whether a building was heated by electricity or other fuel (natural gas and fuel oil)[27]. In fuel heated buildings, projects had median simple payback times of 4 years.[28] For electric heated buildings, however, the returns were unattractive as far as private investors would be concerned: a 23 year median payback time. Another study of fewer properties conducted 9 years later reached the same conclusion – high savings at low cost could be found in buildings heated with fuels other than electricity but buildings heated with electricity often required higher-cost building shell (e.g. windows and insulation) measures to achieve significant savings (Kinney *et al.* 1997).[29]

[27] Gas was the most common space heat fuel in the study (55%) followed by electricity (22%). Almost all fuel-heat buildings had central boilers and master meters, while electric-heat buildings typically had baseboard resistance heating in apartments that were individually metered. The fuel-heat buildings spanned all climate zones, although most of the buildings were located in five urban areas: Minneapolis-St. Paul, New York City-New Jersey, Philadelphia, Chicago, and San Francisco.

[28] This payback period is the equivalent of a 25% return on equity for equity financed projects and a nearly 65% return on equity for a project debt financed with a .7 loan-to-value ratio at 7% amortized over 30 years.

[29] Deutsche Bank recently released a relevant study on energy retrofit projects in New York City (Steven Winter & Associates and HR&A Advisors, 2012). The study included an analysis of 100 projects to determine whether a lender could have used the savings from the energy retrofits to increase the loan size on the first lien mortgage at the point of refinancing. The analysis found that about half the projects produced savings that could have been enough to justify debt financing for the full cost of the project (assuming a 30 year term, at an interest rate of 7% and debt service coverage ratio of 1.30). High retrofit costs would have prevented the use of this approach in many of the other projects; however many of those projects were still necessary upgrades to

As of 2009, 44% of all multifamily buildings in the nation were mainly fuel heated (with natural gas or oil) and 47% mainly heated by electricity (RECS, Table HC6.1, 2009). Among those heated with fuel, 2.3 million apartments (18.4% of all multifamily rentals) were heated with equipment that was at least 15 years old, including 1.4 million units occupied by families earning less than 80% of the regional median income (see Table 13). If previous findings remain valid (that buildings with older fuel heating systems are an excellent economic opportunity for upgrades), then these figures suggest that many such opportunities are currently available to investors.

As to the other potential pathways, there are no studies on multifamily buildings that look at how energy efficiency affects vacancies, turnover, rents, maintenance, valuations or mortgage risk. Studies of commercial office buildings (Miller *et al.* 2008, Fuerst and McAllister, 2009, Eichholtz *et al.* 2010, Pivo and Fisher 2010, Wiley *et al.* 2010, Fuerst and McAllister, 2011) and single family homes (Corgel *et al*. 1982, Johnson and Kaserman 1983, Longstreth *et al.* 1984, Laquatra 1986, Dinan and Miranowski, 1989, Horowitz and Haeri 1990, Bloom *et al*. 2011) have found such effects on vacancies, rents and values in ENERGY STAR labeled or weatherized properties. These studies indirectly support the hypothesis that similar benefits would be found in the multifamily market. Thus, similar analysis of multifamily properties should be a high priority area for future research.

The frustration with the lack of data on this question is captured rather well in a recent report by HUD (2011). It emphasized how "the sluggish pace of energy-efficiency improvements in the multifamily rental housing sector continues to vex advocates of sustainability" and places much of the blame on market failures caused in large part by a "lack of sufficient data about multifamily retrofits and their advantages".

## Summary and Conclusion

This paper compared trends in the energy efficiency of multifamily rentals to other housing types. Energy efficiency in multifamily rentals is important because home energy is a significant component of lower income family budgets, multifamily rentals are an important part of the affordable housing supply, many lower income families already pay a large share of their income for housing and utilities, and both energy prices and spending have been growing quickly over the past decade.

Data were analyzed from the 2005 and 2009 RECS. Cross-tabulations were used to compare the prevalence of energy efficiency features (EEFs) in different housing groups. In both 2005 and 2009, multifamily rentals had fewer EEFs compared to other housing types. And for some of the features, they were less common as household incomes declined. A positive finding was that most EEFs became more prevalent in multifamily rentals over the 4 year period.

An unweighted Total Efficiency Index (TEI) was created to see if the aggregate number of EEFs is affected by housing type, tenure and household income. This analysis reinforced the conclusion that multifamily rentals had fewer EEFs than other housing types and that multifamily rentals occupied by lower income families were less efficient than those occupied by moderate and higher income households. Nationwide, in 2009, multifamily rentals averaged 34% fewer energy efficiency features than the number found in other types of housing (7.4 vs. 11.2). Alternative indices were also tested, giving the same results.

Finally, a linear regression model for each sample year was used to separate the effects of building type, tenure and income, while holding other factors constant. These models also confirmed the initial findings. All else being equal, multifamily building type, rentals, and income were all inversely related to the number of EEFs at significant levels.

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replace existing systems that were at the end of their useful lives. The study did not determine whether returns were sufficient to justify private equity investment.

Overall, the models predicted that multifamily units occupied by renters who earned 50% of the median income in 2005 had 4.1 fewer EEFs in 2005 and 4.7 fewer in 2009 than houses occupied by owners with at least 50 percent of median income.

If multifamily rentals had 5 more EEFs, putting them on par with other types of housing, the savings could range anywhere from $376 to $611 per year. For lower income households, these improvements would be a substantial benefit. The cost-effectiveness to investors, however, as well as any effects on rents that might follow from the improvements, require further study before practical predications can be made about the results that would come from addressing this issue.[30]

# Acronyms

ACS – American Community Survey, US Census Bureau
AHS – American Housing Survey, US Census Bureau
BLS- Bureau of Labor Statistics, US Department of Commerce
CES – Consumer Expenditure Survey, Bureau of Labor Statistics
CPI – Consumer Price Index, Bureau of Labor Statistics
DOE – US Department of Energy
EIA – Energy Information Administration, US Department of Energy
HUD – US Department of Housing and Urban Development
HVAC – Heating, ventilation and cooling
LIHTC – Low Income Housing Tax Credit
RECS – Residential Energy Consumption Survey, US Energy Information Administration

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[30] It is worth emphasizing that energy improvements could allow owners to charge more rent, which could reduce or eliminate savings for tenants from lower energy bills and work against the preservation of affordable rental housing. It would be unfortunate if energy efficiency were achieved at the expense of affordable housing preservation. The potential for this problem and possible solutions need to be explored.

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# Additional Tables

## Cross Tabulations

**TABLE 2:** Percentage of housing units with energy efficiency features (excluding public authority housing)

| | | Multifamily Rentals by Percent of Regional Median Income | | | | | Multifamily Rentals vs. Other Housing Types | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| *Features* | *Survey* | *< 50%* | *50-80%* | *80-100%* | *>100%* | *$\chi^2$ sig* | *All MF Rentals* | *Other Housing* | *$\chi^2$ sig.* |
| HVAC | | | | | | | | | |
| Prog. heat thermostat | 2005 | 16.3 | 13.3 | 8.6 | 16.7 | .653 | 15.2 | 34.7 | .000 |
| | 2009 | 20.3 | 21.6 | 22.4 | 25.6 | .469 | 22.3 | 49.3 | .000 |
| | Δ | 4 | 8.3 | 13.8 | 8.9 | | 7.1 | 14.6 | |
| Prog. AC thermostat | 2005 | 18.8 | 19.4 | 8.7 | 21.8 | .597 | 18.6 | 41.0 | .000 |
| | 2009 | 25.8 | 23.5 | 28.9 | 31.1 | .399 | 27.2 | 53.2 | .000 |
| | Δ | 7.0 | 4.1 | 20.2 | 9.3 | | 8.6 | 12.2 | |
| 2000+ vintage central AC | 2005 | 6.4 | 7.9 | 11.1 | 7.8 | .724 | 7.4 | 17.8 | .000 |
| | 2009 | 48.7 | 58.5 | 53.2 | 55.7 | .199 | 53.5 | 56.3 | .147 |
| | Δ | 42.3 | 50.6 | 42.1 | 47.9 | | 46.1 | 38.5 | |
| AC by heat pump† | 2005 | 5.4 | 12.5 | 0.0 | 12.1 | .164 | 7.8 | 18.8 | .000 |
| | 2009 | 17.6 | 10.8 | 10.4 | 19.6 | .343 | 12.1 | 29.6 | .000 |
| | Δ | 12.2 | -1.7 | 10.4 | 7.5 | | 4.3 | 10.8 | |
| 2000+ vintage heat equip | 2005 | 20.4 | 19.41 | 28.1 | 19.5 | .759 | 20.9 | 26.8 | .027 |
| | 2009 | 40.9 | 41.9 | 46.6 | 42.1 | .638 | 42.1 | 48.9 | .000 |
| | Δ | 20.5 | 22.49 | 18.5 | 22.6 | | 21.2 | 22.1 | |
| Space heated by heat pump† | 2005 | 2.9 | 0.0 | 0.0 | 5.1 | .340 | 2.3 | 7.9 | .000 |
| | 2009 | 5.9 | 4.0 | 2.4 | 4.8 | .278 | 4.7 | 19.9 | .000 |
| | Δ | 3.0 | 4.0 | 2.4 | -0.3 | | 2.4 | 12 | |
| Ceiling fans | 2005 | 36.8 | 52.4 | 33.3 | 52.6 | .164 | 42.4 | 72.9 | .000 |
| | 2009 | 45.6 | 50.2 | 55.5 | 50.1 | .139 | 49.1 | 77.5 | .000 |
| | Δ | 8.8 | -2.2 | 22.2 | -2.5 | | 6.7 | 4.6 | |
| Natural gas main space heat | 2005 | 40.5 | 44.3 | 48.8 | 38.9 | .671 | 41.4 | 54.4 | .000 |
| | 2009 | 34.6 | 33.7 | 31.3 | 41.3 | .088 | 35.8 | 52.7 | .000 |
| | Δ | -5.9 | -10.6 | -17.5 | 2.4 | | -5.6 | -1.7 | |
| APPLIANCES | | | | | | | | | |
| 2000+ vintage clothes washer | 2005 | 8.8 | 14.3 | 20.0 | 19.8 | .015 | 13.3 | 36.6 | .000 |
| | 2009 | 80.7 | 83.9 | 87.5 | 81.1 | .580 | 82.6 | 73.0 | .000 |
| | Δ | 71.9 | 69.6 | 67.5 | 61.3 | | 69.3 | 36.4 | |
| ESTAR clothes washer | 2005 | 47.1 | 33.3 | 50 | 27.8 | .583 | 38.5 | 69.7 | .000 |
| | 2009 | 46.3 | 40.2 | 43.6 | 33.7 | .290 | 40.7 | 69.0 | .000 |
| | Δ | -0.8 | 6.9 | -6.4 | 5.9 | | 2.2 | -0.7 | |
| 2000+ vintage clothes dryer | 2005 | 52.8 | 50.0 | 72.7 | 48.8 | .556 | 52.8 | 37.9 | .002 |
| | 2009 | 79.4 | 78.7 | 83.8 | 83.7 | .657 | 81.2 | 70.1 | .000 |
| | Δ | 26.6 | 28.7 | 11.1 | 34.9 | | 28.4 | 32.2 | |
| Natural gas clothes dryer | 2005 | 1.6 | 1.6 | 4.4 | 8.6 | .007 | 3.6 | 18.8 | .000 |
| | 2009 | 8.5 | 6.5 | 11.8 | 7.1 | .607 | 8.1 | 20.1 | .000 |
| | Δ | 6.9 | 4.9 | 7.4 | -1.5 | | 4.5 | 1.3 | |
| 2000+ vintage dishwasher | 2005 | 10.0 | 12.7 | 17.8 | 20.7 | .039 | 13.7 | 24.5 | .000 |
| | 2009 | 66.8 | 75.6 | 75.3 | 76.6 | .088 | 73.1 | 71.8 | .469 |
| | Δ | 56.8 | 62.9 | 57.5 | 55.9 | | 59.4 | 47.3 | |
| ESTAR dishwasher | 2005 | 68.4 | 50.0 | 57.1 | 56.5 | .794 | 59.6 | 73.3 | .026 |
| | 2009 | 25.0 | 24.8 | 13.8 | 27.1 | .251 | 24.1 | 69.4 | .000 |
| | Δ | -43.4 | -25.2 | -43.3 | -29.4 | | -35.5 | -3.9 | |
| 2000+ vintage refrigerator | 2005 | 28.4 | 31.7 | 51.1 | 38.8 | .013 | 33.5 | 37.7 | .076 |
| | 2009 | 70.6 | 76.8 | 78.7 | 79.3 | .014 | 75.3 | 70.7 | .058 |
| | Δ | 42.2 | 45.1 | 27.6 | 40.5 | | 42 | 69.4 | |
| ESTAR refrigerator | 2005 | 38.3 | 46.7 | 59.1 | 36.6 | .309 | 42.0 | 69.4 | .000 |
| | 2009 | 31.7 | 29.7 | 27.5 | 34.8 | .516 | 31.5 | 65.7 | .000 |
| | Δ | -6.6 | -17.0 | -31.6 | -1.8 | | -10.5 | -3.7 | |

**TABLE 2 (cont.):** Percentage of housing units with energy efficiency features (excluding public authority housing)

| | | Multifamily Rentals by Percent of Regional Median Income | | | | | Multifamily Rentals vs. Other Housing Types | | |
|---|---|---|---|---|---|---|---|---|---|
| *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *10* |
| *Features* | *Sample* | *< 50%* | *50-80%* | *80-100%* | *>100%* | *$\chi^2$ Sig.** | *All MF Rentals* | *Other Housing* | *$\chi^2$ Sig.** |
| 2000+ vintage water heater | 2005 | 30.3 | 18.5 | 55.0 | 34.6 | .061 | 32.3 | 38.1 | .101 |
| | 2009 | 56.9 | 62.5 | 68.9 | 60.4 | .041 | 60.6 | 63.2 | .058 |
| | Δ | 26.6 | 44.0 | 13.9 | 25.8 | | 28.3 | 25.1 | |
| Natural gas cook top | 2005 | 32.0 | 34.9 | 33.3 | 31.9 | .986 | 33.0 | 34.6 | .491 |
| | 2009 | 32.0 | 45.5 | 25.0 | 50.0 | .558 | 37.9 | 38.4 | .939 |
| | Δ | -1.0 | 10.6 | -8.3 | 18.1 | | 4.9 | 3.8 | |
| Natural gas water heater | 2005 | 45.8 | 50.0 | 46.7 | 37.2 | .327 | 44.3 | 53.4 | .000 |
| | 2009 | 42.6 | 47.7 | 43.3 | 52.7 | .023 | 46.5 | 53.7 | .000 |
| | Δ | -3.2 | -2.3 | -3.4 | 15.5 | | 2.2 | 0.3 | |
| BUILDING ENVELOPE | | | | | | | | | |
| Some or all new glass | 2005 | 24.4 | 20.8 | 31.0 | 22.9 | .688 | 24.3 | 44.6 | .000 |
| | 2009 | 10.8 | 8.0 | 5.5 | 7.1 | .097 | 8.5 | 34.5 | .000 |
| | Δ | -13.6 | -12.8 | -25.5 | -15.8 | | -15.8 | -10.1 | |
| Double pane glass or better | 2005 | 45 | 43.5 | 47.7 | 41.4 | .881 | 44.1 | 55.9 | .000 |
| | 2009 | 38.8 | 39.7 | 45.7 | 49.1 | .012 | 42.5 | 60.4 | .000 |
| | Δ | -6.2 | -3.8 | -2.0 | 7.7 | | -1.6 | 4.5 | |
| Insulation adequate | 2005 | 77.0 | 70.5 | 74.4 | 84.2 | .175 | 77.7 | 80.3 | .184 |
| | 2009 | 75.0 | 77.1 | 76.8 | 78.5 | .685 | 76.6 | 80.2 | .002 |
| | Δ | -2 | 6.6 | 2.4 | -5.7 | | -1.1 | -0.1 | |
| Not too drafty | 2005 | 82.7 | 76.8 | 80.5 | 90.4 | .121 | 83.6 | 87.8 | .013 |
| | 2009 | 81.3 | 82.9 | 81.1 | 83.3 | .839 | 82.1 | 85.5 | .001 |
| | Δ | -1.4 | 6.1 | 0.6 | -7.1 | | -1.5 | -2.3 | |
| Trees give summer PM shade | 2005 | 27.6 | 25.4 | 24.4 | 30.2 | .859 | 27.6 | 49.7 | .000 |
| | 2009 | 22.2 | 25.7 | 27.4 | 27.8 | .231 | 25.1 | 48.4 | .000 |
| | Δ | -5.4 | 0.3 | 3.0 | -2.4 | | -2.5 | -1.3 | |
| Median percent for all EEFs, 2005 | | 29.4 | 28.6 | 33.3 | 31.1 | | 32.7 | 39.6 | |
| Median percent for all EEFs, 2009 | | 39.9 | 41.1 | 43.5 | 45.6 | | 41.4 | 58.4 | |
| Median change for all EEFs, 2005-2009 | | 3.5 | 5.5 | 5.2 | 7.6 | | 4.4 | 4.6 | |

**TABLE 3:** TEI by region, 2009

| Region | Type | Mean |
|---|---|---|
| New England | Other | 10.2 |
| | MFR | 6.5 |
| | Pct | 56.9 |
| Middle Atlantic | Other | 10.8 |
| | MFR | 6.9 |
| | Pct | 56.5 |
| East North Central | Other | 11.6 |
| | MFR | 6.9 |
| | Pct | 68.1 |
| West North Central | Other | 11.4 |
| | MFR | 7.4 |
| | Pct | 54.1 |
| South Atlantic | Other | 11.2 |
| | MFR | 8.2 |
| | Pct | 36.5 |
| East South Atlantic | Other | 10.9 |
| | MFR | 6.6 |
| | Pct | 65.1 |

**TABLE 3:** TEI by region, 2009 (cont.)

| Census Division | Multifamily Rental | Mean |
|---|---|---|
| West South Central | Other | 11.3 |
| | MFR | 7.6 |
| | Pct | 48.7 |
| Mountain North | Other | 11.7 |
| | MFR | 8.8 |
| | Pct | 33.0 |
| Mountain South | Other | 11.8 |
| | MFR | 10.0 |
| | Pct | 18.0 |
| Pacific | Other | 11.1 |
| | MFR | 7.0 |
| | Pct | 58.6 |
| Total | Other | 11.2 |
| | MFR | 7.4 |
| | Pct | 51.4 |

**Analysis of Variance**

**Table 4:** TEI ANOVA, 2005 sample

| | Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 4343.214 | 4 | 1085.804 | 81.163 | .000 |
| Within Groups | 58555.955 | 4377 | 13.378 | | |
| Total | 62899.169 | 4381 | | | |

**Table 5:** TEI ANOVA descriptive statistics, 2005 sample

| | | | | | 95% Confidence Interval for Mean | | | |
|---|---|---|---|---|---|---|---|---|
| | N | Mean | Std. Deviation | Std. Error | Lower Bound | Upper Bound | Minimum | Maximum |
| <50 MF Rental | 250 | 5.1960 | 2.28791 | .14470 | 4.9110 | 5.4810 | .00 | 15.00 |
| 50-80 MF Rental | 63 | 5.5079 | 2.92857 | .36897 | 4.7704 | 6.2455 | .00 | 14.00 |
| 80-100 MF Rental | 45 | 6.2889 | 3.42864 | .51111 | 5.2588 | 7.3190 | 1.00 | 16.00 |
| 100+ MF Rental | 116 | 6.1897 | 3.35679 | .31167 | 5.5723 | 6.8070 | 1.00 | 17.00 |
| Other housing | 3908 | 8.7515 | 3.74882 | .05997 | 8.6340 | 8.8691 | .00 | 21.00 |
| Total | 4382 | 8.4089 | 3.78910 | .05724 | 8.2967 | 8.5212 | .00 | 21.00 |
| <50 MF Rental v. Other housing | | -3.5555 | | | | | | |
| <50 MF Rental v 100+ MF Rental | | -0.9937 | | | | | | |

**Table 6:** TEI ANOVA, 2009 sample

| | Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 17435.357 | 4 | 4358.839 | 292.751 | .000 |
| Within Groups | 172462.124 | 11583 | 14.889 | | |
| Total | 189897.480 | 11587 | | | |

**Table 7:** TEI ANOVA descriptive statistics, 2009 Sample

| | | | | | 95% Confidence Interval for Mean | | | |
|---|---|---|---|---|---|---|---|---|
| | N | Mean | Std. Deviation | Std. Error | Lower Bound | Upper Bound | Minimum | Maximum |
| <50 MF Rentals | 528 | 6.8636 | 2.96603 | .12908 | 6.6101 | 7.1172 | .00 | 18.00 |
| 50-80 MF Rentals | 327 | 7.3639 | 3.20166 | .17705 | 7.0156 | 7.7122 | 1.00 | 17.00 |
| 80-100 MF Rentals | 164 | 7.8171 | 3.10799 | .24269 | 7.3378 | 8.2963 | 1.00 | 16.00 |
| >100 MF Rentals | 353 | 8.1190 | 3.20555 | .17061 | 7.7834 | 8.4545 | 1.00 | 20.00 |
| Other housing | 10216 | 11.1768 | 3.94892 | .03907 | 11.1002 | 11.2534 | .00 | 22.00 |
| Total | 11588 | 10.7320 | 4.04831 | .03761 | 10.6582 | 10.8057 | .00 | 22.00 |
| <50 MF Rental v. Other housing | | -4.3132 | | | | | | |
| <50 MF Rental v 100+ MF Rental | | -1.2554 | | | | | | |

## Regression Analysis

**Table 8:** Descriptive statistics for the samples

| | | *2005 Sample* | | *2009 Sample* | |
|---|---|---|---|---|---|
| | | *(N=4,382)* | | *(N=11,587)* | |
| *Label* | *Description* | *Mean* | *Std. Dev.* | *Mean* | *Std. Dev.* |
| TEI | Count of energy efficiency features (EEFs) | 8.500 | 3.795 | 10.732 | 4.048 |
| TEI REDUCED | TEI excluding vintage items with ENERGY STAR option | | | 9.202 | 3.444 |
| APTBLDG5 | Dummy variable for unit in multifamily building with 5+ units. | 0.130 | 0.337 | 0.138 | 0.345 |
| RENTAL | Dummy variable for unit was rented | 0.277 | 0.447 | 0.287 | 0.452 |
| INCOME | Ordinal variable for total household income | 11.970 | 6.483 | 13.350 | 6.721 |
| YEARMADE | Ordinal variable for year structure was built | 5.100 | 2.930 | | |
| YEARMADE | Year structure was built | | | 1971.130 | 24.927 |
| RURAL | Dummy variable for in rural location | 0.206 | 0.404 | 0.206 | 0.405 |
| DIVENC | Dummy variable for in East North Central census division | 0.143 | 0.350 | 0.095 | 0.293 |
| DIVESOUTHCENT | Dummy variable for in East South Central census division | 0.080 | 0.271 | 0.106 | 0.308 |
| DIVMIDATLANTIC | Dummy variable for in Mid Atlantic census division | 0.089 | 0.285 | 0.106 | .30793 |
| DIVMOUNTAIN | Dummy variable for in Mountain census division | 0.081 | 0.273 | | |
| DIVMOUNTAINSO | Dummy variable for in Mountain South subdivision | | | 0.031 | 0.173 |
| DIVMOUNTAINNO | Dummy variable for in Mountain North subdivision | | | 0.038 | 0.191 |
| DIVNENGLAND | Dummy variable for in New England census division | 0.089 | 0.285 | 0.076 | 0.264 |
| DIVPACIFIC | Dummy variable for in Pacific census division | 0.160 | 0.367 | 0.173 | 0.379 |
| DIVSOATLANTIC | Dummy variable for in South Atlantic census division | 0.154 | 0.362 | 0.189 | 0.391 |
| DIVWNC | Dummy variable for in Western North Central census division | 0.076 | 0.264 | 0.141 | 0.348 |
| DIVWSOUTHCENT | Dummy variable for in Western South Central census division | 0.091 | 0.287 | 0.100 | 0.300 |

**Table 9:** Correlations for independent variables, 2005 sample

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | RENTAL | 1.00 | | | | | | | | | | | | | |
| 2 | APTBLDG5 | 0.52 | 1.00 | | | | | | | | | | | | |
| 3 | DIVENC | -0.04 | -0.03 | 1.00 | | | | | | | | | | | |
| 4 | DIVSOUTHCENT | -0.02 | -0.04 | -0.12 | 1.00 | | | | | | | | | | |
| 5 | DIVMIDATLANTC | -0.01 | 0.02 | -0.13 | -0.09 | 1.00 | | | | | | | | | |
| 6 | DIVMOUNTAIN | -0.04 | -0.05 | -0.12 | -0.09 | -0.09 | 1.00 | | | | | | | | |
| 7 | DIVNENGLAND | -0.01 | 0.02 | -0.13 | -0.09 | 1.00 | -0.09 | 1.00 | | | | | | | |
| 8 | DIVPACIFIC | 0.05 | 0.04 | -0.18 | -0.13 | -0.14 | -0.13 | -0.14 | 1.00 | | | | | | |
| 9 | DIVSOATLANTIC | -0.01 | 0.02 | -0.17 | -0.12 | -0.13 | -0.12 | -0.13 | -0.18 | 1.00 | | | | | |
| 10 | DIVWNC | -0.02 | -0.01 | -0.12 | -0.08 | -0.09 | -0.08 | -0.09 | -0.13 | -0.12 | 1.00 | | | | |
| 11 | DIVWSOUTH | 0.00 | -0.01 | -0.13 | -0.09 | -0.10 | -0.09 | -0.10 | -0.14 | -0.13 | -0.09 | 1.00 | | | |
| 12 | RURAL | -0.19 | -0.19 | -0.02 | 0.15 | -0.01 | 0.00 | -0.01 | -0.10 | 0.04 | 0.02 | 0.01 | 1.00 | | |
| 13 | INCOME | -0.31 | -0.20 | -0.02 | -0.07 | 0.01 | 0.03 | 0.01 | 0.10 | 0.00 | -0.02 | -0.03 | -0.01 | 1.00 | |
| 14 | YEARMADE | -0.07 | 0.04 | -0.06 | 0.06 | -0.14 | 0.09 | -0.14 | -0.01 | 0.14 | 0.01 | 0.08 | 0.12 | 0.18 | 1.00 |

**Table 10:** Correlations for independent variables, 2009 sample

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | RENTAL | 1.00 | | | | | | | | | | | | | | |
| 2 | APTBLDG5 | 0.50 | 1.00 | | | | | | | | | | | | | |
| 3 | DIVENC | -0.05 | -0.04 | 1.00 | | | | | | | | | | | | |
| 4 | DIVESOUTHCENT | 0.03 | 0.05 | -0.11 | 1.00 | | | | | | | | | | | |
| 5 | DIVMIDATLANTIC | 0.03 | 0.05 | -0.11 | 1.00 | 1.00 | | | | | | | | | | |
| 6 | DIVMOUNTAINSO | 0.00 | 0.00 | -0.06 | -0.06 | -0.06 | 1.00 | | | | | | | | | |
| 7 | DIVMOUNTAINNO | -0.02 | -0.02 | -0.06 | -0.07 | -0.07 | -0.04 | 1.00 | | | | | | | | |
| 8 | DIVNENGLAND | 0.01 | -0.01 | -0.09 | -0.10 | -0.10 | -0.05 | -0.06 | 1.00 | | | | | | | |
| 9 | DIVPACIFIC | 0.09 | 0.06 | -0.15 | -0.16 | -0.16 | -0.08 | -0.09 | -0.13 | 1.00 | | | | | | |
| 10 | DIVSOATLANTIC | -0.01 | 0.01 | -0.16 | -0.17 | -0.17 | -0.09 | -0.10 | -0.14 | -0.22 | 1.00 | | | | | |
| 11 | DIVWNC | -0.05 | -0.05 | -0.13 | -0.14 | -0.14 | -0.07 | -0.08 | -0.12 | -0.19 | -0.20 | 1.00 | | | | |
| 12 | DIVWSOUTHCENT | 0.01 | 0.00 | -0.11 | -0.12 | -0.12 | -0.06 | -0.07 | -0.10 | -0.15 | -0.16 | -0.14 | 1.00 | | | |
| 13 | RURAL | -0.19 | -0.17 | -0.02 | -0.09 | -0.09 | -0.02 | -0.01 | -0.01 | -0.13 | 0.07 | 0.09 | -0.01 | 1.00 | | |
| 14 | INCOME | -0.30 | -0.17 | -0.02 | 0.04 | 0.04 | 0.00 | 0.01 | 0.06 | 0.05 | -0.05 | -0.01 | -0.03 | 0.01 | 1.00 | |
| 15 | YEARMADE | -0.09 | 0.03 | -0.11 | -0.18 | -0.18 | 0.10 | 0.06 | -0.16 | -0.01 | 0.18 | -0.02 | 0.08 | 0.18 | 0.13 | 1.00 |

| **Table 11:** OLS Parameter Estimates | *2005 Model – Full TEI* | | | *2009 Model – Full TEI* | | | *2009 Model – Reduced TEI* | | |
|---|---|---|---|---|---|---|---|---|---|
| | B | Std. Error | Sig. | B | Std. Error | Sig. | B | Std. Error | Sig. |
| (Constant) | 7.254 | .188 | .000 | -49.830 | 2.725 | .000 | -31.104 | 2.334 | .000 |
| RENTAL | -1.777 | .131 | .000 | -2.208 | .084 | .000 | -2.068 | .072 | .000 |
| APTBLDG5 | -1.690 | .165 | .000 | -1.580 | .107 | .000 | -1.429 | .091 | .000 |
| INCOME | .134 | .008 | .000 | .172 | .005 | .000 | .134 | .004 | .000 |
| DIVENC | .117 | .191 | .540 | .720 | .175 | .000 | 1.015 | .150 | .000 |
| DIVESOUTHCENT | -.887 | .228 | .000 | | excluded | | .483 | .149 | .001 |
| DIVMOUNTAIN | -.318 | .227 | .161 | | | | | | |
| DIVMOUNTAINSO | | | | .585 | .228 | .010 | .751 | .196 | .000 |
| DIVMOUNTAINNO | | | | .449 | .214 | .036 | .483 | .184 | .008 |
| DIVNENGLAND | -1.123 | .214 | .000 | -.541 | .185 | .003 | -.400 | .158 | .011 |
| DIVPACIFIC | -.248 | .186 | .182 | -.008 | .162 | .962 | .256 | .139 | .066 |
| DIVMIDATLANTIC | | excluded | | .038 | .175 | .830 | | excluded | |
| DIVSOATLANTIC | -.879 | .191 | .000 | .191 | .158 | .227 | .167 | .135 | .216 |
| DIVWNC | -.218 | .227 | .336 | .455 | .164 | .005 | .587 | .140 | .000 |
| DIVWSOUTHCENT | -.437 | .217 | .044 | .242 | .173 | .162 | .330 | .148 | .025 |
| RURAL | -1.351 | .130 | .000 | -.737 | .083 | .000 | -.902 | .071 | .000 |
| YEARMADE | .210 | .019 | .000 | .030 | .001 | .000 | .020 | .001 | .000 |
| *Summary Statistics* | Observations = 4,382<br>F-Statistic =115.6<br>$R^2$ = .256<br>Adj. $R^2$ = .254 | | | Observations = 11,587<br>F-Statistic =359.6<br>$R^2$ =.303<br>Adj. $R^2$ =.302 | | | Observations = 11,587<br>F-Statistic =343.909<br>$R^2$ =.294<br>Adj. $R^2$ =.293 | | |

**Table12:** Descriptive statistics for expense weighted tei by regional median income (RMI) multifamily rental group and other types of housing

| Housing Group | Mean | N | Std. Deviation |
|---|---|---|---|
| MF Rentals, <50% RMI | 32.7400 | 782 | 13.56148 |
| MF Rentals, 50-80% RMI | 34.9834 | 352 | 14.41915 |
| MF Rentals, 80-100% RMI | 37.0270 | 175 | 14.72071 |
| MF Rentals, >100% RMI | 38.1395 | 372 | 14.96738 |
| Other Types of Housing | 53.0597 | 10402 | 18.03124 |
| Total | 50.5265 | 12083 | 18.66070 |

**Table 13:** Age of main space heating equipment in multifamily rentals with gas or oil heat by regional median income group

| | | Household Income | | | | |
|---|---|---|---|---|---|---|
| | | <50% RMI | 50-80% RMI | 80-100% RMI | >100% RMI | Total |
| Age of main space heating equipment | < 2 yrs | 137,789 | 67,286 | 59,574 | 78,460 | 343,109 |
| | 2-4 yrs | 222,612 | 95,047 | 66,072 | 272,332 | 656,063 |
| | 5-9 yrs | 436,427 | 203,492 | 162,980 | 288,118 | 1,091,017 |
| | 10-14 yrs | 429,334 | 158,007 | 94,864 | 235,079 | 917,284 |
| | 15-19 yrs | 148,394 | 126,249 | 77,289 | 88,658 | 440,590 |
| | 20+ yrs | 679,533 | 449,430 | 144,815 | 549,027 | 1,822,805 |
| Total | | 2,054,089 | 1,099,511 | 605,594 | 1,511,674 | 5,270,868 |