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Low hanging fruit? Energy Efficiency and the Split Incentive in Subsidized Multifamily Housing

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Please note that this paper is a work in progress.
The authors are receptive to any feedback on the content of this paper.

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Introduction

Cities across the U.S. are contemplating ways to reduce greenhouse gases, and often cite the retrofitting of multifamily housing as one means to achieve this goal. For cities like New York, where the largest source of its greenhouse gas emissions is its building stock (2014b) and multi-family housing accounts for more than 40% of the 3.25 residential units across the City (Furman Center 2010), the retrofitting of multifamily housing could be a highly effective way to reduce greenhouse gases. It is projected that multifamily properties across the country can be almost 30 percent more energy efficient (Benningfield Group 2009). The federal government has invested in multifamily housing through an array of subsidized housing programs. In theory, these subsidized properties are "low hanging fruit" for increasing efficiency in multifamily housing because the government has regulatory levers to require certain efficiency levels and can create new energy efficiency financing programs targeting these properties. In reality, these programs present an important venue for understanding how regulations governing multifamily units can dampen an owner's incentive to make energy efficiently investments, and a tenant's desire to reduce energy consumption levels.

Market failures that lead to a socially sub-optimal investment in energy efficiency have been well-studied (Jaffe and Stavin 1994; Gillingham et al 2009). These market failures include information asymmetries, ineffective pricing signals, environmental externalities, and the split-incentive problem. The split-incentive problem is of particular importance in the multifamily housing context, as it emerges between tenants and owners with respect to who bears the cost of energy efficiency improvement and who realizes the benefits of new savings.

In this paper, we explore whether and how the rules governing utility billing arrangements of subsidized housing programs impact energy consumption and exacerbate market failures that create incentives for both tenants and owners to be indifferent about their consumption levels. We then test whether these incentives, or dis-incentives, result in higher energy consumption in subsidized properties than in comparable non-subsidized properties. We focus on three subsidized housing portfolios: Public Housing, Project-based Section 8, and the Low Income Housing Tax Credit (LIHTC). Through these programs, owners enter a contract with the federal government that can be as long as 20 years, such as in the Project-based section 8 program, or in perpetuity, as is the case with Public Housing. The rules governing these subsidies, therefore, are likely to affect owner and tenant utility consumption behavior. These three programs have major and minor differences, which we expect to result in varying levels of energy efficiency across programs. Two studies that examine how the regulatory framework might influence consumption behavior in subsidized housing and both find that the Public Housing program offers few incentives to reduce utility consumption, while the LIHTC program offers the best incentives (Dastrup et al 2012; Pazuniak et al 2015). However, these studies lack the data to test whether these incentives result in higher or lower consumption levels.

In this paper, we establish a framework for why the regulations governing subsidy program affect investment and consumption incentives. We then combine several unique datasets to establish utility consumption levels across all large (greater than 50,000 sq. ft.) subsidized and market-rate multifamily properties in New York City, which allows us to analyze the variation in energy consumption within and across subsidy programs as compared to market-rate properties for the first time. Using several multivariate regression models, we find that subsidized properties are associated with higher utility consumption than market-rate properties and, of the subsidized housing programs, Public Housing tends to consume the most energy. The findings in this paper suggest that despite the seeming opportunities to retrofit multifamily properties, there are often other regulatory factors that affect investment and consumption decisions in multifamily housing as in the case of subsidized properties.

<u>Theoretical Framework</u>

We motivate our empirical analysis by developing a theoretical framework for the drivers of energy use in subsidized housing. Energy use in subsidized housing is given by

$$\hat{y}_{it} = f\ (H\ \ , O\ \ , M\ \ , S\ , W\ \ , P\ )$$

Where y is the expected annual energy use intensity of building *i* at time t, H is the housing quality of building *i* at time t, O is the occupant characteristics of building *i* at time t, M is the metering arrangement of building *i* at time t, S is the subsidized housing program that building *i* is a part of in year t, W is the weather at time t, and P is the price of energy for building *i* at time t. The price of energy is a function of the types of fuels consumed (e.g. natural gas, fuel oil, electric, etc.).

In all rental properties, owners have control over housing quality, *H,* and metering configuration, *M*. When tenants are not directly metered (*M*), and the cost of utilities is included in rent, an owner has an incentive to increase the energy efficiency of the building (*H*). A building's net operating income is a product of the revenue, which is derived from rent minus costs, which are a function of several factors including utility costs: $R_t - C_t = NOI_t$. Improved energy efficiency will reduce the building's operating costs (*C*) and thus increase net operating income (*NOI*), holding gross revenue (*R*) constant. The decision to invest (I) in energy efficiency upgrades will be determined by the net present value of future energy cost savings (CF_n), less the first or up-front, cost (CF_0) of installing energy efficiency improvements, given by:

$$I = \sum_{n=1}^{N} \frac{CF_n}{(1+r)^n} - CF_0$$

Thus, if the expected future increase in savings exceeds the initial capital cost, then a building owner should be willing to invest in energy efficiency improvements because it will increase their NOI (holding R constant). This assumes, however, that a tenant will not alter their energy use behavior in such a way as to consume more energy and offset the energy savings associated with energy efficiency investments. This behavior has been described as the "rebound effect" (Gillingham, Newell, and Palmer 2009; Greening, Greene, and Difiglio 2000). Given this uncertainty, the discount rate, *r*, in the owner's decision analysis will be higher than alternative investments to account for the anticipated risk of the realized energy savings from the technologies over time and the likelihood in a shift in the tenants' energy consumption behavior.

In the case where the building is sub-metered, meaning that tenant energy consumption is directly measured and the tenant pays for some or all of their utilities, an owner only has an interest in making investment (*I*) if: 1) it allows them to increase rents and the value of that increase over time exceeds the cost of investment (*I*) or 2) building inefficiency decreases asking rent such that the value of that decrease is greater than the cost of investment.

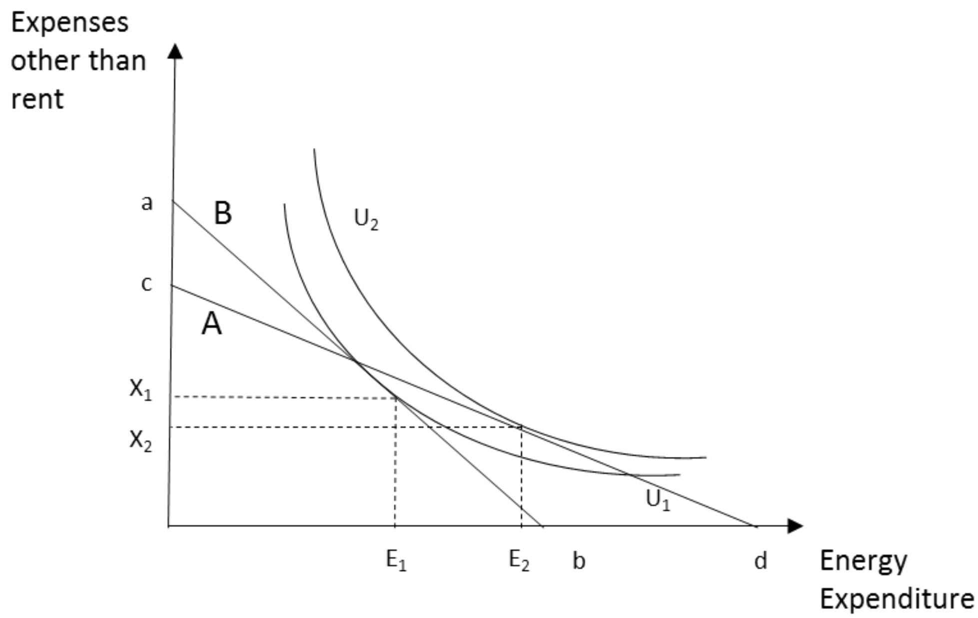
An owner's investment calculation is different for subsidized versus unsubsidized rental housing, and varies based on the subsidy program (*S*). First, in the public housing program where quasi-government entities called Public Housing Authorities (PHAs) are the owners, rent levels are approved by HUD, thus placing a limit on revenue. In addition, all of the operating costs for a property in the Public Housing program are reimbursed through a HUD operating subsidy that is based on the average operating costs over the prior three years. Historically, if a PHA's costs are lower than the budgeted amount, the PHA keeps 75 percent of cost savings in that year, but the operating budget is then decreased by that 25 percent and then further decreased by being calculated going forward on a three year average. This means that a PHAs investment return from any energy efficient investment also needs to be discounted by the fact that HUD keeps a portion of those savings and reduces its operating subsidy. One the other end, if costs increase, the PHAs' budget is increased through a similar formula, which consequently does not allow the PHA to recoup all of its loses in that year.

The project-based Section 8 program finances private owners of subsidized housing. Through this program HUD also approves rents, but the rent levels are capped by local marker rents. In addition, HUD reimburses the owner directly for operating costs through a series of cost adjustment mechanisms, and owners often only receive approval for rent increases to cover operating cost increases. In essence, HUD covers some or all of the cost of inefficient systems through cost adjustments, and in some cases incentivizes higher costs through its rent calculation system. As a result, an owner in this program would only make energy efficient investments if the value of the cost savings from the investment exceeded the value of future rent increases that would have been justified by higher costs.

The LIHTC regulations offer the strongest incentives for efficient utility investments of all of the subsidy programs. The simplified structure of this program is that property developers apply for tax credits. If a developer is awarded these credits, they then sell the credits to raise capital that is used to lower construction and permanent loan levels. Reduced debt service payments allow developers to charge lower rents that are affordable to low-income households. Through this program, the total revenue is fixed. If the owner pays for utilities, they must pay all utility costs from the property's rental income and cannot adjust rents higher in response to higher costs. As a result, owners of these properties have an interest in minimizing costs (*C*) to increase NOI.

For sub-metered subsidized buildings, where tenants pay utility costs directly, the building owner has little incentive to invest in energy efficiency improvements because (1) the tenant disproportionately benefits through lower energy expenditures and (2) the owner is unable to increase rent to reflect the lower operating costs. Given that demand for subsidized housing exceeds available supply, owners are further dis-incentivized from energy efficiency investments because differentiating their building to attract tenants is unnecessary.

Next, we look at this structure from the perspective of tenant behavior. As the graph below shows, a tenant will attempt to maximize their utility U by adjusting their consumption level through either changing their energy use behavior or selecting a more energy efficient unit until their energy expenditure is reduced to fall along the indifference curve between expenses other than rent and energy cost. Line *cd* indicates the tenant's budget constraints for unit A, and their willingness to pay for rent is given by a-x1. A market-rate unit tenant can choose to rent a more efficient unit, assuming the efficiency of the unit is observable. The more efficient unit is shown by line B, with associated tenant budget constraint *ab* and marginal cost of energy given by *a/b*. Selecting the more efficient unit results in a decrease in energy expenditures from e2 to e1. Correspondingly, the tenant should be willing to pay up to x1-x2 in additional rent to compensate for the improved efficiency.



There are several factors that alter this calculation in subsidized housing (Bird and Hernandez 2012). First, the demand for subsidized housing often exceeds the supply, which means tenants cannot shop for a more efficient unit. This reality reduces the pressure on owners to make energy efficient investments to attract tenants. In addition, in the case of public housing and project-based Section 8, when tenants pay for their utilities a portion of the rent payment is reduced by a utility allowance and HUD increases its portion of the rent payment by that allowance amount. These utility allowances are often set at the building level and are calculated based on the average consumption levels for tenants in that building in the previous year and are adjusted based on the number of bedrooms in a unit. As a result, if tenants increase their consumption, their allowance subsequently increases and rent payment decreases in the following period to ensure they spend no more than 30 percent of their income on rent and utilities. HUD does not provide a benchmark for determining what a reasonable utility allowance is, and there is no feedback mechanism for what ones utility consumption "should" be.[1] In aggregate, this

[1] PHAs must set the allowance to "approximate a reasonable consumption of utilities by an energy-conservative household of modest circumstances consistent with the requirements of a safe, sanitary, and healthful living environment." 24 C.F.R. § 965.505(a)

utility allowance adjustment system shields households from the repercussions of overconsumption, and in doing so reduces their desire to reduce energy consumption or shop for a more efficient unit (if they could). The owner receives the same overall amount for rent plus utilities, regardless of the utility allowance amount, which also makes them indifferent about making energy efficient investments. In the case of the LIHTC program, tenants have a similar utility allowance, but owners have an incentive to make sure that allowance amount is small because there is no ongoing operating subsidy to the owner that increases if the utility allowance increases. As a result, any utility allowance reduces an owners' net operating income. Tenants in these properties have an incentive to consume less than their utility allowance because they keep any savings accrued from being below that allowance amount. Combined, these factors mean that in the public housing and Project-based Section 8 programs there is no pricing incentive for the landlord to increase the efficiency of the unit from A to B, or for tenants to reduce consumption levels, but there is some incentive for owners to make property investments in LIHTC properties.

Finally, an important factor to note that weather (W) and pricing (P) generally are out of the control of both tenants and owners, although pricing is influenced by the type of fuel used for heating and hot water. Household characteristics (0) could be influenced by the subsidized housing programs because each program targets households within a certain income band, and variations in consumption behavior can be tied to household characteristics.

Energy Use Behavior in Subsidized Housing

We currently know little about energy consumption in subsidized properties and how it compares to market rate properties. One study finds that HUD utility costs increased by 35 percent between 2004 and 2010, from $6.3 to $8.5 billion (White, 2012). However, that study used HUD data and does not analyze whether these increases are due to the incentives in these programs, changes in utility pricing, the characteristics of the buildings that are being subsidized, or owner or tenant behavior. Nor does it look at how these costs increases compare to similar market-rate properties. There is only one study that compares utility costs across subsidized an unsubsidized properties, and that study finds that on the whole, subsidized properties have higher costs than similar market rate properties, but these difference largely disappear when controlling for household characteristics (Dastrup et al. 2012). That study uses American Housing Survey data, which has limited information on the type of rental subsidy; therefore it merges all subsidized units into one larger "subsidized" category. In addition, that study is a national analysis and therefore has limited statistical power when all of the building, household, and location controls are included. As a result, the lack of differentiation across subsidy programs, combined with a limited sample size, reduces the scope of that study.

We expect that building quality, on average, in subsidized housing is inferior to market-rate properties, and that these deficiencies will negatively impact energy consumption. Building quality is affected by both building systems (age and efficiency of boiler, for instance) and construction materials, such as the R-value of wall assemblies and glazing efficiency (Perez-Lombard, Ortiz, and Pout 2008). We anticipate that the variation in building quality will be a function of the subsidy program category of a particular building. In particular, we expect that housing quality should be on par with market-rate housing in LIHTC properties because they are newer and the program leverage private capital, whereas Public Housing and Section 8 properties may exhibit lower levels of building quality due to development budget constraints, inferior or deferred maintenance, among other factors.

Occupant behavior has been shown to have a significant impact on energy consumption in residential buildings (Lutzenhiser 1993). Studies have found that factors such as occupant density (Kontokosta 2015); occupant behavior (McMakin et al. 2002; Santin et al. 2009), and socioeconomic and cultural differences (Kontokosta and Jain 2015) affect consumption behavior. With the exceptions of the citations listed, many of the studies of the impact of occupants on consumption behavior are derived from models, simulations, or surveys rather than actual energy use data (Langevin, Gurian, and Wen 2013). While these methods are useful for cross-validation and estimating potential impacts, the empirical analysis of actual use data provides an opportunity for new insights into the effects of these factors on building energy efficiency. Accounting for occupant characteristics has been shown to be an important, although challenging, component of understanding relative energy efficiency.

Data Sources and Descriptive Statistics

One of the challenges facing the study of utility consumption in subsidized properties is sufficient data that link subsidized properties, utility consumption, and the tenants who live in these properties. In this paper, we combine several rich databases that allow us to analyze utility costs across subsidy programs, as compared to market properties, for the first time. First, we use Local Law 84 (LL84) data, which provides detailed building-level energy consumption data for all multifamily properties in New York City larger than 50,000 square feet (Kontokosta 2013). We combine these data with detailed information on all subsidized properties in New York City, including every subsidy layer on a property, from the Subsidized Housing Information Project (SHIP) at the NYU Furman Center for Real Estate and Urban Policy. Finally, we combine both of these data with detailed building data, including whether and when a building was last altered, from the Real Property Assessment Database, and neighborhood demographics from the census. Combined, this integrated dataset allows us to develop a detailed picture of energy consumption in multifamily properties in New York City, and explore whether there is variation in consumption between subsidized and unsubsidized properties and across subsidy programs.

There are two primary sources of data that we use in this study. First, we used New York City's LL84 energy benchmarking data for detailed annual energy use by fuel type and energy source (Kontokosta 2012, 2015). These data come from a mandate in New York City that all buildings that exceed 50,000 square feet, or two buildings on the same lot that exceed 100,000 square feet, disclose their energy consumption by energy source each year (City of New York 2014a). The data used here represent consumption across 15,000 properties for the year 2013, representing 2.9 billion square feet of space. The LL84 data were cleaned to account for data entry errors, duplicates, and outliers, and then merged with New York City's Primary Land Use Tax Lot Output database, which includes information on building and tax lot characteristics (Kontokosta 2012). This results in an integrated database of large multifamily properties in New York City, their energy use, billing arrangements, and a host of building and lot-level characteristics.

Second, we used the SHIP database. The SHIP database is a publicly accessible database that was developed by the NYU Furman Center for Real Estate and Urban Policy to track all privately owned subsidized properties in New York City. The SHIP database catalogues the nearly 235,000 units of privately owned, publicly subsidized affordable rental properties ever developed in New York City. This database combines more than 50 government databases and account for all public subsidy layers on every rental property in New York City. (Reina and Williams, 2012) These data allows us to develop a more robust understanding of what regulatory frameworks are governing the utility costs in a building, and whether there are regulations from multiple subsidy programs influencing decisions on utility consumption.

We then merge these two datasets and identify 783 properties that have a subsidy through the Public Housing, LIHTC, or HUD's Project-based Section 8 programs. We used the SHIP dataset to determine all of the subsidy layers on each property and find that 259 properties had more than one form of subsidy. Therefore, we include a binary flag for whether a property received a subsidy from any program, and then a flag for each subsidy that it received.

As seen in Figure 1 and Table 1, there is observed variation in the characteristics of market versus subsidized properties, and across individual subsidy programs. Properties that do not receive a rental subsidy comprise approximately 80 percent of the rental properties in our sample. On average, market-rate properties tend to be older and have the smallest total unit count of the portfolios in our sample. Market-rate properties average 1.3 bedrooms per unit, which is the lowest of the portfolios, but have a larger than average square footage per unit. Public Housing tends to be the largest in square footage, unit counts, and average number of bedrooms and is the second oldest portfolio on average in our sample. As previously stated, metering arrangements likely affect utility consumption. In our data, we find that over 90 percent of properties with no subsidy are submetered, 84 percent of LIHTC properties are submetered, 77 percent of Section 8 properties are submetered, and only 36 percent of Public Housing properties are submetered.

We use two metrics for energy consumption: site energy use, which is the energy consumed by the building as given by meter readings and oil deliveries, and source energy use, which accounts for the energy consumed by the building as well as the energy used in the generation and transmission of the energy that the building used (Kontokosta 2015). Source energy use is often used in the analysis of energy benchmarking data when the primary consideration is the carbon emissions associated with building energy use (City of New York 2014a). Market-rate properties have the lowest mean site and source energy use per square foot (referred to as the source energy use intensity) and Public Housing has the highest in both categories (see Table 1). LIHTC properties tend to perform better than the other subsidized housing portfolios, but worse than market-rate properties. This purely descriptive analysis provides some preliminary support for our hypothesis that subsidized properties consume more energy than market rate properties, and that within the subsidy programs, buildings in the LIHTC program consume the least amount of energy and Public Housing the most. Below, we develop a series of models to test for statistically significant differences across portfolios and control for property and household characteristics that impact energy consumption in order to understand whether higher consumption is due to program structure or other factors.

One limitation of the data available for this study is that we do not have demographic and socioeconomic characteristics of the tenants living in these properties. We use two variables as proxies for these factors. First, we include the average number of bedrooms per unit as a proxy for the number of people in a unit given the relationship between household size and number of bedrooms. Second, we include the tract-level unemployment rate because a higher rate could mean that households are home for a larger share of the day and therefore likely to consume more utilities.

Methods

Using a multivariate regression approach with robust standard errors, we develop a base model to understand the variation in energy consumption between subsidized and unsubsidized properties, and across different subsidy programs, and then re-specify the model in several ways. The base model is as follows:

$$y = \alpha + \beta_1 \chi + \beta_2 \gamma + \beta_3 \phi + \varepsilon \quad (1)$$

The outcome *y* is the log of the site energy use intensity for a particular building. We use a natural log transform of the dependent variable to account for the observed right-skewed distribution. The *Portfolio* variable is series of binaries for the building's subsidized portfolio. In the first model, we created a binary variable where 1 signifies that the property receives some form of rental subsidy and 0 indicates that property has no subsidy, otherwise known as being "market rate." γ is a vector of building characteristics that could affect consumption levels, including the percent non-residential floor area in the building, the log of the dwelling unit count, whether the building is on a corner lot, the number of stories in the building, the log of the gross floor area of the building, the decade the building was constructed, the primary fuel type (defined as the fuel accounting for more than 50 percent of total site energy consumption), whether there is laundry in the unit, and whether there is a dishwasher in the unit. Φ is a vector of variables that we use to proxy for the households characteristics that could affect consumption levels, which includes the number of bedrooms per unit, and the log of the unemployment rate of the census tract. We then re-specify this model to include whether the units in the property are submetered. Finally, we run both of these models with the log of the source energy use as the dependent variable, replacing site energy use intensity.

Next, we use these same four model specifications, but transform the *Portfolio* variable into a series of binary variables designating whether the property is market-rate or has a subsidy from the Public Housing, Project-based section 8, or LIHTC programs. This specification allows us to look at the variation between market-rate properties and specific subsidy programs, and account for the fact that some properties receive subsidies from multiple programs.

Results & Analysis

The results from the model including sub-metering and subsidized housing binary variables are shown in Table 2. As the results indicate, after controlling for a host of building and household characteristics, subsidized properties are found to have statistically significant higher energy consumption than market-rate buildings. However, this relationship is not significant when we control for the metering arrangement of the property. This result suggests that submetered properties tend to have lower energy consumption than those that are master-metered, which is consistent with expectations.

The results from the model specification testing the significance of each subsidized housing program independently are shown in Table 3. When we look across subsidy programs we find that all subsidized properties are associated with higher utility consumption than market-rate properties, and that Public Housing has the highest level of consumption of the three subsidized portfolios. Theoretically we expected LIHTC properties to perform similarly to market rate properties. In our model, we see that LIHTC properties perform slightly better than Section 8 properties at the site level, and much better than Public Housing properties, but that these properties are associated with higher utility consumption than those that are market-rate. Again, when we control for the metering arrangement the significance of all of these relationships disappear, suggesting that the metering arrangement is what is driving any differences in utility consumption. Interestingly, Public Housing is still marginally associated with higher utility consumption at the site level, even when controlling for metering arrangement, which reinforces the theory that this portfolio generally performs the worst.

Next, we re-specify the model to only include subsidized properties so that we can explore variation between subsidy programs. As we see in table 4, LIHTC and Section 8 properties do not perform better than Public Housing properties. This is particularly interesting because we expected the LIHTC program to perform much better than the other subsidy programs due to the incentives offered in the program.

One finding consistent across all of the models is that metering arrangements appear to impact energy consumption levels. The incentives in the Public Housing and Section 8 programs often make owners indifferent about metering arrangements because they allow owners to recoup costs associated with higher consumption levels, which reduces the financial benefits of submetering despite its effect on consumption behavior. As a result, we use a logistic regression model that controls for building and tenant characteristics and test the incidence that a property is submetered based on: 1) whether it is subsidized and 2) by the type of subsidy. In table 5, we can see that subsidized properties are associated with lower odds of being submetered than market rate properties. When we then disaggregate the variable by program, we see that all three subsidy programs have a lower likelihood of being submetered than market-rate properties, and that Public Housing buildings have the lowest probability of being submetered. Finally, we look at how subsidized and market-rate properties with the same metering arrangement compare to each other. To do this, we first restrict our sample to only properties that are master-metered (table 6) and then to only submetered properties (table 7). We find no statistically significant difference in utility consumption between market rate and subsidized properties that are master-metered, although the lack of significance could be due to a small sample size. We do find that subsidized properties that are submetered, particularly those in the Public Housing program, are associated with higher utility consumption than market-rate properties with a similar metering arrangement.

Discussion and Policy Implications

There are several key takeaways from our analysis. First, subsidized properties on the whole tend to consume more energy than market-rate properties, even when controlling for a range of factors that have been found to influence building energy consumption, except for metering arrangement. Specifically, properties in the Public Housing program tend to consume the most energy of the subsidy programs. However, across all models, when we control for the metering arrangement, we find that whether tenants pay for at least some of their utilities is a significant factor in energy use across programs. Not surprisingly, we find that subsidized properties tend to have a lower probability of being submetered, with properties in the Public Housing program most often configured with whole-building meters. When we focus solely on submetered properties, we find that subsidized properties on the whole, and Public Housing in particular, are associated with higher energy consumption than market-rate properties with similar billing arrangements. Although we find that government subsidy programs tend to not promote submetering, which is an important part of the solution to the split incentive problem, submetered subsidized housing still under-performs as compared to similar market-rate housing. Combined, this reinforces the theory that regulations governing subsidized housing programs are not resolving the split-incentive problem, which may be contributing to higher utility consumption levels in subsidized properties.

Interestingly, properties in the LIHTC program do not perform much better than properties in the other subsidy programs, either in consumption levels or in the likelihood of being submetered. We suspect that this could be due to disconnect between the rules governing the LIHTC program and its implementation. For example, while obtaining these data, we spoke to housing officials in New York City who said it is uncommon for LIHTC owners to receive a utility allowance adjustment that is determined at the building-level, even if they make improvements to their property that warrants such adjustments, due to staffing limitations that prohibit such reviews. If owners cannot adjust their utility allowance level they cannot realize the cost savings of energy efficient investments, which dampens their desire to make such investments. As a result, the regulatory structures for the Public Housing and Section 8 programs could be leading to higher consumption levels, whereas in the LIHTC program the implementation of regulations may be driving higher consumption. Overall, this suggests that while subsidized housing may seem like low hanging fruit in terms of energy efficiency opportunities, these properties still tend to consumer higher amounts of energy due to the design and implementation of the subsidy programs themselves.

There are several changes that can help reduce consumption levels in subsidized housing. Each suggestion is not mutually exclusive because it is important to ensure that both owners and tenants realize the costs and benefits of lower energy consumption levels. First, HUD should mandate that all properties be sub or check-metered to ensure tenants understand their consumption patterns and realize the benefits of consuming less. Second, HUD should require upgrades for older and less efficient properties, and offer financing programs that make it feasible to make these improvements. HUD should also calculate utility allowances on a household-level based on an analytics benchmarking model, rather than the current method of estimating allowances based on consumption levels on a building or regional basis. Finally, HUD should improve access to tenant utility cost information so they can account for energy efficiency when selecting a unit, and provide a clear feedback mechanism for tenants to contest allowance calculations. As noted in Pazuniak et al. (2015), the majority of such changes can be made to the Project-based Section 8 program through modifications to HUD Guidance, but more substantial changes to the Public Housing program will likely need to occur through adjusting existing regulations. In the case of the LIHTC program, the issue is not with the regulations, but rather with the implementation of the program. In this case, the federal government should provide additional support and guidance to local administering agencies to ensure the incentives in the LIHTC program are effectively implemented.

Overall, this paper uses a unique dataset to look at energy use in multifamily housing and highlights that regulations, as in the case of subsidized housing, can create incentives that promote inefficient energy consumption. As a result, policymakers and planners interested in reducing energy consumption levels and greenhouse gas emissions from the multifamily housing stock should consider the modification of existing regulations as the low hanging fruit for achieving these goals.

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Figure 1: Mean Site Energy use by program

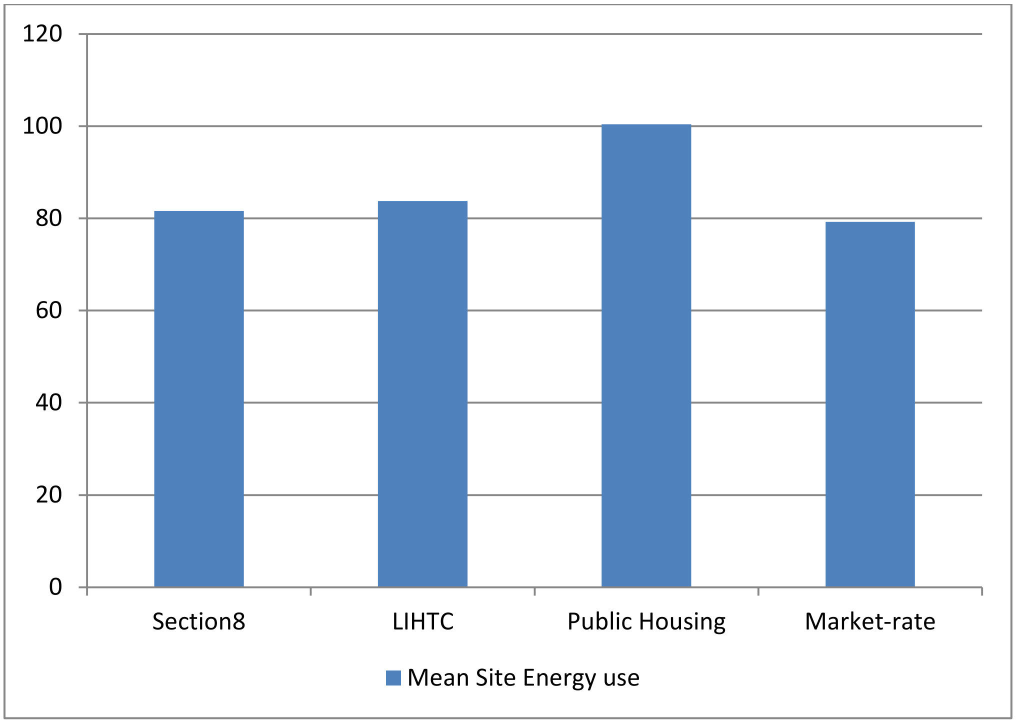

Table 1: Summary Statistics

Program	Number of Properties	Mean Year Built	Mean Unit Count	Mean Bedrooms Per Unit
Section8	407	1964	197	1.5
LIHTC	254	1979	142	1.7
HUD	339	1965	157	1.4
Public Housing	149	1957	467	1.9
Market-rate	3,512	1940	99	1.3
Total	4,415	1946	129	1.3

Program	Mean Residential Area	Mean Area Per Unit
Section8	166,031	843
LIHTC	137,919	972
HUD	153,299	973
Public Housing	494,381	1,059
Market-rate	100,433	1,013
Total	126,725	984

Program	Mean Site Energy use	Standard Deviation	Mean Source Energy use	Standard Deviation
Section8	81.62	31.91	131.86	58.66
LIHTC	83.72	23.24	138.55	40.82
HUD	81.62	31.28	131.00	45.94
Public Housing	100.41	39.31	151.10	51.45
Market-rate	79.20	30.96	118.66	43.97
Total	80.45	31.18	121.63	46.59

Table 2: Energy use of subsidized properties

	Site EUI		Site EUI		Source EUI		Source EUI	
Subsidized (Y/N)	0.095	***	0.092		0.110	***	0.072	
Percent residential	0.142	***	-1.262	**	0.010	**	-1.054	*
Square feet in building	-0.069	***	-0.138	***	-0.066	***	-0.134	***
Square feet per unit	-0.188	***	-0.131	***	-0.186	***	-0.124	***
Laundry hookup in each unit (Y/N)	0.005		0.016		0.006		0.070	
Dishwasher in unit (Y/N)	0.053	**	0.107		0.081	***	0.178	**
Building is on a corner lot (Y/N)	0.012		0.003		0.022	*	0.016	
Number of stories	0.013	***	0.011	***	0.015	***	0.013	***
Building 20-39 years old	0.090	***	0.118		0.026		0.054	
Building 40-59 years old	0.176	***	0.186	***	0.086	***	0.117	
Building 60-79 years old	0.066	**	-0.050		-0.060	**	-0.215	*
Building 80-99 years old	0.082	***	0.131	**	-0.022		0.042	
Building 100+ year old	0.107	***	0.213	**	0.004		0.093	
Primary fuel gas	1.020	***	0.855	***	0.377	***	0.259	***
Primary fuel oil	1.086	***	0.891	***	0.410	***	0.273	***
Primary fuel other	0.849	***	0.668	***	0.327	***	0.114	
Number of bedrooms per unit	0.047	***	0.059	**	0.047	***	0.045	*
Unemployment rate of tract	0.048	***	0.013		0.044	***	0.020	
Submetered (Y/N)			-0.223	***			-0.227	***
Observations	4,372		620		4,372		620	
R-squared	0.416		0.354		0.178		0.167	
*** p<0.01, ** p<0.05, * p<0.1								

Table 3: Energy use by subsidy program as compared to market-rate properties

	Site EUI		Site EUI		Source EUI		Source EU	
Public Housing (Y/N)	0.146	***	0.154	*	0.140	***	0.121	
LIHTC (Y/N)	0.073	**	0.084		0.110	***	0.083	
Section 8 (Y/N)	0.087	***	0.081		0.089	***	0.053	
Percent residential	0.140	***	-1.296	**	0.010	**	-1.065	*
Square feet in building	-0.074	***	-0.146	***	-0.069	***	-0.142	***
Square feet per unit	-0.187	***	-0.126	***	-0.185	***	-0.119	***
Laundry hookup in each unit (Y/N)	0.006		0.035		0.006		0.087	
Dishwasher in unit (Y/N)	0.054	**	0.119		0.081	***	0.186	
Building is on a corner lot (Y/N)	0.012		0.006		0.022	*	0.018	
Number of stories	0.013	***	0.012	***	0.015	***	0.014	***
Building 20-39 years old	0.079	**	0.107	*	0.027		0.050	
Building 40-59 years old	0.165	***	0.172	**	0.084	***	0.111	
Building 60-79 years old	0.056	*	-0.083		-0.064	**	-0.239	**
Building 80-99 years old	0.072	***	0.118	*	-0.024		0.035	
Building 100+ year old	0.098	***	0.206	**	0.002		0.089	
Primary fuel gas	1.021	***	0.846	***	0.377	***	0.250	***
Primary fuel oil	1.088	***	0.901	***	0.410	***	0.282	***
Primary fuel other	0.841	***	0.634	***	0.320	***	0.081	
Number of bedrooms per unit	0.047	***	0.056	**	0.047	***	0.042	
Unemployment rate of tract	0.047	***	0.011		0.043	***	0.018	
Submetered (Y/N)			-0.208	***			-0.213	***
Observations	4,372		620		4,372		620	
R-squared	0.416		0.357		0.179		0.171	
*** p<0.01, ** p<0.05, * p<0.1								

Table 4: Energy use by subsidy program as compared to Public Housing

	Site EUI		Site EUI		Source EUI		Source EUI	
LIHTC (Y/N)	-0.024		0.005		0.001		0.016	
Section 8 (Y/N)	-0.041		-0.041		-0.049		-0.043	
Percent residential	-0.240	*	-1.362	**	-0.225	*	-1.083	*
Square feet in building	-0.110	***	-0.147	***	-0.109	***	-0.145	***
Square feet per unit	-0.095	***	-0.126	***	-0.085	***	-0.118	**
Laundry hookup in each unit (Y/N)	-0.024		-0.000		0.022		0.051	
Dishwasher in unit (Y/N)	0.096		0.127		0.139	**	0.209	
Building is on a corner lot (Y/N)	0.005		-0.000		0.026		0.016	
Number of stories	0.011	***	0.010	***	0.013	***	0.013	
Building 20-39 years old	0.102	**	0.102		0.049		0.039	
Building 40-59 years old	0.279	***	0.142	*	0.216	***	0.072	
Building 60-79 years old	0.011		-0.093		-0.146		-0.255	
Building 80-99 years old	0.105	**	0.113	*	0.031		0.024	
Building 100+ year old	0.194	***	0.164	*	0.081		0.045	
Primary fuel gas	0.781	***	0.851	***	0.186	***	0.255	***
Primary fuel oil	0.803	***	0.911	***	0.188	***	0.289	***
Primary fuel other	0.562	***	0.689	***	0.060		0.167	
Number of bedrooms per unit	0.031	**	0.057	**	0.023		0.043	*
Unemployment rate of tract	0.010		0.019		0.025		0.039	
Submetered (Y/N)			-0.250	***			-0.251	***
Observations	781		587		781		587	
R-squared	0.316		0.356		0.138		0.171	

*** p<0.01, ** p<0.05, * p<0.1

Table 5: Odds of a property being submetered

	Submetered (Y/N)		Submetered (Y/N)	
Subsidized (Y/N)	-2.662	***		
Public Housing (Y/N)			-2.713	***
LIHTC (Y/N)			-1.140	**
Section 8 (Y/N)			-1.313	**
Percent residential	2.671		2.184	
Square feet in building	-0.814	***	-0.719	***
Square feet per unit	-0.065		-0.271	
Laundry hookup in each unit (Y/N)	-0.839		-1.219	
Dishwasher in unit (Y/N)	1.189		0.835	
Building is on a corner lot (Y/N)	0.533	**	0.446	
Number of stories	-0.065	***	-0.069	***
Building 20-39 years old	-2.170	**	-1.807	*
Building 40-59 years old	-4.824	***	-4.322	***
Building 60-79 years old	-4.641	***	-3.727	***
Building 80-99 years old	-1.914	*	-1.496	
Building 100+ year old	-2.648	**	-2.447	**
Primary fuel gas	1.102	***	1.396	***
Primary fuel oil	1.647	***	1.465	***
Primary fuel other	1.258		1.863	**
Number of bedrooms per unit	0.251		0.386	*
Unemployment rate of tract	-0.394		-0.282	
Observations	620		620	
*** p<0.01, ** p<0.05, * p<0.1				

Table 6: Energy use of subsidized properties (master-metered)

	Master-metered							
	Site EUI		Site EUI		Source EUI		Source EUI	
Subsidized (Y/N)	0.403				0.252			
Public Housing (Y/N)			0.094				0.022	
LIHTC (Y/N)			0.026				-0.015	
Section 8 (Y/N)			0.196				0.112	
Percent residential	-1.794	*	-1.420		-1.178		-0.909	
Square feet in building	-0.159	***	-0.146	***	-0.158	***	-0.148	***
Square feet per unit	-0.093		-0.099		-0.067		-0.072	
Laundry hookup in each unit (Y/N)	-0.079		-0.119		-0.025		-0.064	
Dishwasher in unit (Y/N)	0.227		0.179		0.223		0.179	
Building is on a corner lot (Y/N)	0.038		0.035		0.032		0.032	
Number of stories	0.010		0.010		0.012	*	0.012	*
Building 20-39 years old	-0.063		-0.235		-0.228		-0.350	
Building 40-59 years old	-0.283		-0.416		-0.453		-0.546	
Building 60-79 years old	-0.503		-0.612		-0.782		-0.854	
Building 80-99 years old	-0.230		-0.377		-0.438		-0.539	
Building 100+ year old	-0.256		-0.356		-0.446		-0.520	
Primary fuel gas	0.686	***	0.697	***	0.086		0.095	
Primary fuel oil	0.378	*	0.346	*	-0.254		-0.285	
Primary fuel other	0.600	***	0.637	***	0.010		0.134	
Number of bedrooms per unit	0.056		0.056		0.048		0.048	
Unemployment rate of tract	0.030		0.040		0.030		0.038	
Observations	190		190		190		190	
R-squared	0.347		0.346		0.194		0.196	
*** p<0.01, ** p<0.05, * p<0.1								

Table 7: Energy use of subsidized properties (submetered)

	Submetered							
	Site EUI		Site EUI		Source EUI		Source EUI	
Subsidized (Y/N)	0.115	*			0.118	*		
Public Housing (Y/N)			0.327	***			0.292	***
LIHTC (Y/N)			0.097	*			0.105	**
Section 8 (Y/N)			0.083				0.079	
Percent residential	-0.611		-0.557		-0.853		-0.773	
Square feet in building	-0.122	***	-0.157	***	-0.116	***	-0.147	***
Square feet per unit	-0.174	***	-0.137	***	-0.187	***	-0.156	***
Laundry hookup in each unit (Y/N)	0.110		0.131		0.168	*	0.187	**
Dishwasher in unit (Y/N)	0.132	*	0.140	*	0.223	***	0.228	***
Building is on a corner lot (Y/N)	-0.002		0.027		0.016		0.041	
Number of stories	0.005		0.009	**	0.009	**	0.012	***
Building 20-39 years old	0.094	*	0.063		0.030		0.006	
Building 40-59 years old	0.397	***	0.386	***	0.321	***	0.31	***
Building 60-79 years old	0.115		0.025		0.007		-0.070	
Building 80-99 years old	0.154	***	0.116	**	0.070		0.0392	
Building 100+ year old	0.246	***	0.202	***	0.129	**	0.093	
Primary fuel gas	1.171	***	1.128	***	0.581	***	0.541	***
Primary fuel oil	1.225	***	1.222	***	0.602	***	0.599	***
Primary fuel other	0.821	***	0.737	***	0.202		0.123	
Number of bedrooms per unit	0.069	***	0.048	*	0.064	***	0.045	*
Unemployment rate of tract	0.007		-0.004		0.019		0.010	
Observations	430		430		430		430	
R-squared	0.480		0.506		0.271		0.302	
*** p<0.01, ** p<0.05, * p<0.1								