REDUCING ENERGY CONSUMPTION IN PUBLIC HOUSING: AN IMPACT ASSESSMENT OF BOULDER HOUSING PARTNERS' FY 2010 ENERGY PERFORMANCE CONTRACT AND ANALYSIS OF OPTIONS TO ENGAGE RESIDENTS IN CONSERVATION

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EXECUTIVE SUMMARY

POLICY QUESTION

PART I

How have recent energy efficiency measures undertaken by Boulder Housing Partners affected electricity consumption at properties where the landlord (Boulder Housing Partners) pays for residents' utilities?

PART II

What should Boulder Housing Partners do in the future to solve the problem of misaligned incentives between the public housing authority and residents of public housing?

PROBLEM STATEMENT

In an attempt to further its goals of environmental stewardship, Boulder Housing Partners has made a public commitment to reduce the electricity consumption of its public housing portfolio enough to attain net-zero electricity consumption, or have all consumption offset by the on-site generation of renewable power. Furthermore, Boulder Housing Partners strives to surpass the City of Boulder's stringent energy efficiency standards, which far exceed state and federal efficiency requirements for rental housing. As a result, Boulder Housing Partners recently decided to invest heavily in energy efficiency measures via an Energy Performance Contract (EPC) executed by Johnson Controls, Inc. in fiscal year (FY) 2010.

To date, Boulder Housing Partners has been unable to assess the EPC's impact on actual energy consumption. The concurrent installation of numerous photovoltaic (PV) panels led to uncertainty over consumption changes as a direct response to the EPC, and the utility company only bills Boulder Housing Partners for net, and not gross, consumption. Since their public housing properties possess varying amounts of PV generation capacity, gross consumption is masked by the solar offsets incorporated into net billed consumption. The two different types of data have historically been managed by different divisions within the organization, causing internal impact assessments to be time and labor intensive. These factors make it difficult for Boulder Housing Partners to assess consumption trends across time, and develop an effective strategy to attain net-zero status in their public housing portfolio.

RESULTS: POLICY QUESTION I

Initial results suggest that properties in the treatment group— those which received the EPC work—experienced an overall decline in electricity consumption. Average monthly electricity consumption for the treatment group declined by 17.44% from FY 2009 to FY 2011, while average monthly electricity consumption increased by 7.96% for the control group. However, a series of simple t-tests suggests the absence of any statistically significant change. This is confirmed by a difference-in-difference analysis.

The EPC had an effect on the treatment group to the magnitude of -2701.865 kWh and was not statistically significant. In order to verify that outliers in the treatment group did not substantially affect these results, the difference-in-difference analysis was repeated after dropping the outliers from the dataset. This resulted in an increase in the effect of the EPC on the treatment group to -4284.125 kWh and an increase in statistical significance from 0.88 to 0.122. Although this is a substantial change, 0.122 remains well past the standard 0.05 threshold for statistical significance. Consequently, it does not change the conclusions or interpretation of the results.

CRITERIA: POLICY QUESTION II

- **Maximize reduction in electricity consumption.**
- **Advance Boulder Housing Partners' organization mission and vision.**
- **Minimize implementation and management costs.**
- **Provide consideration for population demographics**.
- **Work within the regulatory and legal confines faced by Boulder Housing Partners.**

ALTERNATIVES: POLICY QUESTION II

An array of potential policy interventions were selected from the relevant body of literature based upon resident, property, and organizational characteristics. These include:

1. **Install sub-meters in all public housing units.** Most of the public housing properties under the purview of Boulder Housing Partners are currently master-metered, or not metered down to the individual unit. This limits BHP's ability to identify units with atypically high consumption and ascertain and address the reasons for such over-consumption.

2. **Provide residents with a monthly notice detailing their previous month's usage and performance compared to other property residents.** Residents currently receive neither a bill nor any kind of statement discussing the cost or volume of their electricity consumption. This makes it very difficult to convince residents that 1) there are connections between their behaviors and monthly electricity consumption, 2) that changing their behavior makes a difference to the overall bottom line, and 3) that their electricity consumption behavior is something they should actively consider even when they do not face the price signals incorporated into a monthly bill. The literature suggests that addressing this information asymmetry may yield changes in resident consumption behavior.

3. **Institute a monthly or annual savings sharing program.** A monthly or annual savings sharing program would incorporate information feedback in the form of a

periodic notice regarding resident electricity consumption, a housing authority directed savings target for the residents, and a promise of cash payments or resident directed property improvements for any savings achieved past the target. This would require periodic information regarding individual resident and total property progress towards a specified goal, and would need to be implemented and managed by BHP staff.

4. **Conduct energy conservation information sessions.** Individuals from BHP staff or outside firms and/or agencies could conduct energy conservation information sessions at BHP public housing sites. These informational sessions would incorporate a discussion of how to conserve energy; provide an explanation of its relevance to the organization, the tenants, and the world as a whole; and disseminate flyers or pamphlets that discuss various ways to save energy.

5. **Distribute written material on the cost of electricity and how to reduce consumption.** This alternative would require BHP to draft written recommendations and tip sheets designed to encourage public housing residents to conserve energy. The ultimate outcome would rest on the ability of tenants to understand the written material, their perception that the information is relevant, and their individual estimations of the costs and benefits of behavior change.

6. **Solicit written commitment to achieving conservation goals.** Evidence suggests that written commitment to conservation goals, especially when the commitment is made to peers or with the full knowledge of peers, can increase pro-conservation behavior. This largely occurs through social norms and a feeling of accountability to other individuals or peer groups.

RECOMMENDATION: POLICY QUESTION II

It is recommended that BHP pursue a combination of alternatives 1, 2, 3, and 6. If the organization so chose and resources permitted, they also could pursue information sessions and the dissemination of written materials.

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OVERVIEW

The Housing Authority of the City of Boulder d/b/a Boulder Housing Partners was established by a resolution passed by the Boulder City Council on June 21, 1966. The organization currently manages almost 2,000 rental units, including 456 federally assisted units at eleven sites throughout the City of Boulder. Boulder Housing Partners maintains a public commitment to long-term fiscal, social, and environmental responsibility while carrying out its mission of providing quality, affordable housing, which is developed and managed in a way that creates a sense of community strength and spirit and facilitates the efforts of residents to realize success in their lives.

In an attempt to further its goals of environmental stewardship, Boulder Housing Partners has made a public commitment to attain net-zero status in the electricity consumption of its public housing portfolio through the on-site generation of solar power and the implementation of energy efficiency technologies as they become available. Furthermore, Boulder Housing Partners strives to surpass the City of Boulder's stringent energy efficiency standards, which far exceed state and federal efficiency requirements for rental housing. As a result, Boulder Housing Partners recently decided to invest heavily in energy efficiency measures via an EPC executed by Johnson Controls, Inc. in fiscal year (FY) 2010.

An EPC is a method of financing energy and water efficiency and conservation measures in public housing. It provides the customer (in this case Boulder Housing Partners) with a comprehensive set of building upgrades, which are accompanied by guarantees that the savings they produce will be sufficient to finance their full cost. It is on this basis that loans are procured. Such a project is performed by an Energy Service Company (ESC) like Johnson Controls, Inc., and includes all services necessary to design and implement the project, and ensure the client is receiving projected cost savings. The chosen endeavors are tailored specifically to the needs of the client and the condition of the relevant buildings.[1]

To date, Boulder Housing Partners has been unable to assess the EPC's impact on actual energy consumption. The concurrent installation of numerous photovoltaic (PV) panels led to uncertainty over consumption changes as a direct response to the EPC, and the utility company only bills Boulder Housing Partners for net consumption, not gross consumption. Since their public housing properties possess varying amounts of PV generation capacity, gross consumption is masked by the solar offsets incorporated into net billed consumption. The two different types of data have historically been managed by different divisions within the organization, causing internal impact assessments to be time and labor intensive.

These factors make it difficult for Boulder Housing Partners to easily assess consumption trends across time and develop an effective strategy to attain net-zero status in their public housing portfolio. This Masters Project will combine utility and PV data to extrapolate gross consumption, thus providing Boulder Housing Partners with an accurate understanding of tenant utility consumption trends, as well as an understanding of the true impact of the FY 2010 EPC. Additionally, it will evaluate and recommend potential policy options to encourage increased resident energy conservation through a comprehensive literature review and assessment of organizational goals, constraints, and demographics.

[1] See Table 1 for a list of Energy Conservation Measures (ECMs) by property.

Table 1. List of Energy Conservation Measures (ECMs) by Property

Property	Measures
Arapahoe	
	Lighting Retrofit/Control
	Programmable Thermostats
	High Efficiency Condensing Unit
	Pipe Insulation
	Envelope Infiltration
	Spray Foam Roof
	Water Conservation
Diagonal	
	Lighting Retrofit/Control
	Ranges
	High Efficiency DHW Boiler
	Duct Insulation
	Envelope Infiltration
	Water Conservation
Iris/Hawthorne	
	Lighting Retrofit
	Safe-T Elements
	Duct Insulation
	Envelope Infiltration
	Water Conservation
Kalmia	
	Lighting Retrofit/Control
	Ranges
	Envelope Infiltration
	Water Conservation
Madison	
	Lighting Retrofit/Control
	Ranges
	Envelope Infiltration
	Water Conservation
Manhattan	
	Lighting Retrofit/Control
	Ranges
	High Efficiency Furnaces
	Envelope Infiltration
	Water Conservation
Northport	
	Lighting Retrofit/Control
	Control Limiting Thermostat
	Programmable Thermostats
	Vending Misers
	Ranges
	High Efficiency Boiler (DHW Side Arm)
	Pipe Insulation
	Envelope Infiltration
	Water Conservation
Walnut	
	Lighting Retrofit/Control
	Vending Misers
	High Efficiency Motors
	High Efficiency Condensing Unit
	High Efficiency Air Conditioners
	Safe-T Elements
	High Efficiency Boiler (DHW Side Arm)
	Evaporative Cooling
	Pipe Insulation
	Envelope Infiltration
	Window Caulking
	Water Conservation

LITERATURE REVIEW

As of 2010, the US residential sector was responsible for approximately 22% of the nation's energy consumption and 17% of total greenhouse gas (GHG) emissions. Given the current level of consumption, rate of growth, and energy policy, GHG emissions from the residential sector will amount to 21% of total US emissions by 2020 (Langevin, Gurian, & Wen, 2012). In light of rising and unstable fuel prices, geopolitical concerns, uncertainty over the long-term viability of the energy supply, and questions relating to climate change, there has been an increased interest in encouraging efficiency and conservation in the residential electricity sector (Gonzales, Aronson & Costanzo, 1988).

Holding demographics and housing stock variables constant, households can exhibit variations in energy use to the magnitude of 200-300% (Lutzenhiser, 1993). Data indicate that although unobserved differences may account for some of this variation, household energy consumption behavior is heterogeneous and non-normally distributed (Lutzenhiser, 1993). Heterogeneity in consumption can be even more pronounced in public housing. Due to U.S. Department of Housing and Urban Development regulations, many residents of public housing do not pay for the utilities they consume. Without the price signals provided by utility bills, tenants have little reason to conserve energy, and tenants and landlords become locked into a principal-agent problem (Small & Van Dender, 2007; Greening et al., 2000; Winett & Ester, 1983).

A principal-agent problem is a market failure that emerges when one person, the agent, acts on behalf of another individual, the principal, but makes decisions contrary to the principal's best interests. In the context of the tenant-landlord relationship in public housing, the tenant acts as the agent and the public housing authority, or landlord, serves as the principal (Levinson & Niemann, 2004; Gillingham, Hading & Rapson, 2012). The landlord seeks to minimize operating costs through conservation and efficiency, but the tenants, who consume the resources, see a flat marginal cost curve with a value of zero, and have little reason to concern themselves with the financial consequences of their consumption decisions. As a result, tenants often engage in inefficient heating and cooling behavior, make little effort to change heating or cooling settings to conserve resources, leave unnecessary lights and appliances on, and purchase less efficient household appliances (Gillingham et al., 2012; Maruejols & Young, 2011).

Decreased use of electricity can be achieved through 1) efficiency improvement, and 2) reduced consumption. While energy efficiency efforts require the substitution of capital for energy, reduced consumption relies on an overall decrease in the use of existing capital. Because these two mechanisms rely upon substantively different behaviors, they are likely influenced by different things (Black et al., 1985). Since, in large part, energy efficiency in public housing units is determined by the housing authority itself, appreciable reductions in energy use will likely be achieved by convincing tenants to use less. The magnitude of potential savings is quite large; a 2010 report produced by the National Consumer Law Center suggests that reducing energy consumption in low-income housing by 20% could potentially save the federal government a minimum of $1 billion per year (Harak, 2010).

It is often argued that price and elasticity of demand and supply are the true determinants of consumption. However, estimates for elasticity are only useful in attempts to calculate the effects of pricing policies on the aggregate, and they provide little information regarding the behavior of individual groups and responses to non-price policies or situational factors (Black, Stern, & Elworth, 1985; Heslop, Moran, & Cousineau, 1981). In fact, various studies estimate that behavioral factors account for approximately 30% and 50% of heating and cooling consumption respectively (Langevin et al., 2013). The disproportionate number of "extremely low income,"[2] elderly,[3] and disabled[4] individuals in public housing may further confound expected consumption patterns. This can occur in part due to the presence of "folk theory," or beliefs—such as raising the thermostat to the highest possible setting will speed up the rate at which a room increases in temperature—as well as varying levels of understanding and acceptance of the need for pro-environment behavior (Langevin et al., 2013; McMakin, Malone, & Lundgren, 2002; Marcell, Agyeman, & Rappaport, 2004).

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[2] Less than 30% of national median. This population is estimated to account for approximately 67% of public housing residents in the United States (Langevin et al., 2013).
[3] 31% of the population of public housing residents in the United States (Langevin et al., 2013).
[4] 35% of the population of public housing residents in the United States (Langevin et al., 2013).

Since public housing tenants are largely, if not completely, insulated from the cost of their consumption, we must look to the non-price factors of their energy consumption decisions. Although evidence suggests a positive correlation between education level and some energy conservation measures, and a positive or curvilinear relationship between income and energy conservation measures, it is likely that socio-demographic effects on energy conservation behavior are driven primarily by beliefs and attitudes or by the perception of personal benefit and social sanctions via social norms (Black et al., 1985).

Conservation behavior can be encouraged by promoting pro-conservation attitudes through persuasive communication, eliciting behavior from those predisposed to conservation-focused actions, persuading individuals to conserve based upon material or social incentives, using community leaders or admired individuals as models of behavior, eliminating barriers to conservation behaviors that would otherwise be adopted, or providing information and feedback (Cook & Berrenberg, 1981). Unfortunately, this process is complicated by the fact that research suggests pro-conservation attitudes have little bearing on consistent pro-conservation behavior (Cook & Berrenberg, 1981; Costanzo, Archer, Aronson & Pettigrew, 1986; Dennis, Soderstrom, Koncinski & Cavanaugh, 1990; Heslop et al., 1981; Macey & Brown 1983; McMakin et al., 2002; Marcell et al., 2004; Neuman 1986).

Furthermore, individuals may lack access to alternative paths to resource conservation, anticipate strong negative consequences, receive insufficient informational feedback regarding their efforts, or experience insufficiently strong consequences to a change in behavior. They also may fail to connect decisions to pro-conservation attitudes, be unable to identify which alternative actions are pro-conservation, not experience pro-conservation attitudes as salient in a specific context, or find themselves biased against information that contradicts existing beliefs (Cook & Berrenberg, 1981; Dennis et al., 1990).

In order to address this problem, the applied psychology and behavioral economics literature suggest the use of incentives and information feedback to encourage decreased consumption of scarce resources through alterations of routinized and habitual behavior (Bittle, Valesano & Thaler, 1979; Fischer, 2008; Hayes & Cone, 1977 Lutzenhiser, 1993). Incentives and disincentives can be material or social in nature, and they rest upon the assumption that rewarded behavior is repeated and punished behavior is avoided. The rewards for desired behavior, or punishments for undesired behavior, must be perceived as more salient than the benefits of continuing existing behavior patterns (Cook & Berrenberg, 1981). Even if this is the case, human behavior is inherently complex and unpredictable. The effects of punishments may be transitory or mitigated by avoidance of the source of the punishment, or they may be undermined if positive enforcement isn't also provided for the desired behavior (Cook & Berrenberg, 1981).

Material incentives can be financial or based upon increased convenience and comfort. Financial incentives typically occur in the form of rebates for energy efficient purchases, prizes for changing behavior, various tax rebates, and favorable loan terms, while disincentives typically include either fines or higher prices (Cook & Berrenberg, 1981). Convenience and comfort incentives involve things such as close or reduced/free parking for those who carpool, advanced thermostats, showers and covered parking for those who bicycle to work, and increased availability of public transportation, while convenience and comfort disincentives could be such things as more expensive parking and increased time spent in traffic. Social incentives and disincentives could include recognition for pro-conservation actions, a public commitment to others to engage in certain conservation behaviors, and the use of a group decision-making process to participate in conservation activities (Cook & Berrenberg, 1981). These strategies rest upon the assumptions that 1) individuals value the opinions others hold of their behavior, and 2) that social norms are sufficiently strong to provide a meaningful consequence for failure or defection.

The use of information to encourage pro-conservation behavior is based upon the belief that individuals often do not make the decision to conserve simply because they do not connect their behavior to the rate at which they consume resources or the changes are too small to be noticeable in the short run using traditional sources of information (Cook & Berrenberg, 1981; Fischer, 2008). Information may be categorized as antecedent, contingent, feedback, or social feedback. Antecedent information is provided to the individual prior to the behavior in question, contingent information is a punishment or reward for a behavior, feedback information is given after an individual has the chance to try a behavior, and social feedback information is derived from peer group behavior (Dennis et al., 1990). Evidence suggests antecedent information is successful at encouraging energy conservation, while contingent information appears unsuccessful when applied in real-world scenarios. Feedback information yields mixed results depending upon the cost of interpreting the provided information, and peer influence through social feedback information appears to have an impact both on program compliance and overall results (Dennis et al., 1990).

Some incentives and information feedback mechanisms target patterns of consumption through decreasing demand during peak periods, while others aim to decrease overall levels of consumption (Hayes & Cone, 1977). To further focus selection of policy interventions, Bernard, McBride, Desmond and Collins (1988) classifies consumption into three categories. These include: (1) “structural consumption” which occurs during times that units are unoccupied, (2) “habitual consumption” which results from routine behavior, and (3) “daily variation consumption” which is determined by unusual events (Bernard et al., 1988; Lutzenhiser, 1993). These delineations facilitate the development of clear and targeted interventions through a well-defined understanding of the problem to be addressed. Structural and habitual consumption are the most problematic and are easily modified by incentive or information feedback programs.

The success of any information-based intervention can be highly dependent upon the means with which the information is disseminated (Costanzo et al., 1986;

Gonzales et al., 1988). Since consumers typically think about energy consumption in terms of its cost in dollars, providing information in terms of kilowatt hours (kWh) may lead to confusion about the success of their behaviors both immediately and over time as energy prices change (Costanzo et al., 1986; Dennis et al., 1990; Fischer, 2008; Yates & Aronson, 1983). The information must also be perceived as credible and framed in such a way that it is easily applied to relevant circumstances (Cook, 1981; Dennis et al., 1990; Fischer, 2008). Evidence suggests individuals will value salient information more highly than non-salient information, even when presented reliable and contradictory statistical evidence. Concrete, vivid and personal information simply is perceived as more relevant (Costanzo et al., 1986; Gonzales et al., 1988; McMakin et al., 2002; Yates & Aronson, 1983). As such, the framing and presentation of information is critical (Costanzo et al., 1986; Dennis et al., 1990; Fischer, 2008).

Further complicating the issue is motivation. Research suggests consumers are highly loss-averse (Yates & Aronson, 1983). That is, they will work harder to avoid their bills increasing than they will to make their bills decrease (Costanzo et al., 1986; Dennis et al., 1990; Gonzales et al., 1988; Yates & Aronson, 1983). Given that most energy conservation programs focus on savings rather than avoiding an increase in costs or averting losses due to inaction, participants may in fact be discouraged from participating (Gonzales et al., 1988; Yates & Aronson, 1983). Consumers are also highly sensitive to even the slightest perception of a change in their comfort level; in many cases, especially when the consumer does not pay for the electricity they use, individual comfort receives substantially more weight in the decision-making process than energy savings (Langevin et al., 2013). Ultimately, individuals are more likely to follow through on energy conservation behaviors when they perceive the action as relevant, when they have the skill and resources required to change their behavior, when other members of their community are also making similar changes, when the action and outcome is correctly explained, and when then they have made a public commitment to complete the action(s) (Gonzales et al., 1988; McMakin et al., 2002; Yates & Aronson, 1983).

Research indicates that monetary payments to individual consumers who achieve set conservation goals—although expensive and difficult to implement—are the most successful mechanism for reducing peak demand and overall resource consumption, regardless of type (Hayes & Cone, 1977; Hayes & Cone, 1981; Bittle et al., 1979; Meter, Weenig & Zieverink, 1982). Winett and Nietzel found that a group of households that received cash payments contingent on achieving conservation goals consumed less energy than a matched group of households that only received educational information on how to reduce electricity consumption (Winett & Nietzel, 1975).

Although information feedback programs are not quite as effective as monetary payments at reducing consumption, they provide a viable, and more financially sustainable, alternative to monetary payments by immediately connecting consumption decisions to actual usage and cost information (Bittle et al., 1979;

Hayes & Cone, 1981; Meter et al., 1982; Petersen, Shunturov, Janda, Platt & Weinberger, 2007; Seligman & Darley, 1977; Winett, Neale & Grier, 1979).

Such information feedback mechanisms are most successful when policy interventions are combined with sub-metering by unit for the purposes of increased accuracy in estimates of individual consumption (Lutzenhiser, 1993). In fact, research suggests that individually metered buildings may use 35% less electricity than master-metered buildings, and information feedback interventions at individually metered multi-family properties appear to result in effects that persist over time (Lutzenhiser, 1993; Walker, 1979).

This outcome is likely because utility bills in sub-metered buildings are based on unit specific consumption, while utility bills in master-metered buildings are typically split across all residents irrespective of the individual resident's consumption. Examples of feedback mechanisms include periodic information on electricity consumption and its associated cost, and percent above or below a selected baseline value or previous period (Hayes & Cone, 1977). Current technology can also provide instantaneous consumption information and makes remote control of consumption possible via wireless capable smart outlets.

Meta-analysis suggests that information feedback mechanisms can reduce consumption from 0 to 20%, with a substantial portion of studies producing an effect ranging from 5% to 14% reductions (Faruqui, Sergici & Sharif, 2010). Successful feedback policies involve prompts that are specific, proximal to the relevant behavior, convenient, non-demanding, and obtrusive or employ well designed consequence strategies that adhere to reinforcement principles (Winett & Ester, 1983). Feedback mechanisms that incorporate computerized feedback, include an interactive component, offer appliance specific energy consumption breakdowns, and provide information at least one time per day appear to encourage maximum savings (Fischer, 2008). Policies that meet these criteria, and are designed based upon demographic and contextual information, could potentially impact resource consumption in public housing and decrease the utility burden on public housing authorities.

This Masters Project will contribute to 1) an enhanced understanding of the relationship between energy efficiency interventions and consumption outcomes within the context of public housing, and 2) attempt to address the principal-agent problem that is created by landlord-paid utilities. Ideally, it will inform future energy efficiency investment decisions for public housing authorities and provide the necessary evidence to support further investigation into the initiation of an information feedback or incentive program to decrease energy consumption in Boulder Housing Partners' public housing properties. The decision will ultimately be dependent upon organization resource constraints and net-benefit calculations that will ideally occur on a property-by-property basis to maximize efficiency. Depending upon external validity concerns, this information may also support the development of similar programs in other geographic areas.

DATA: POLICY QUESTION I

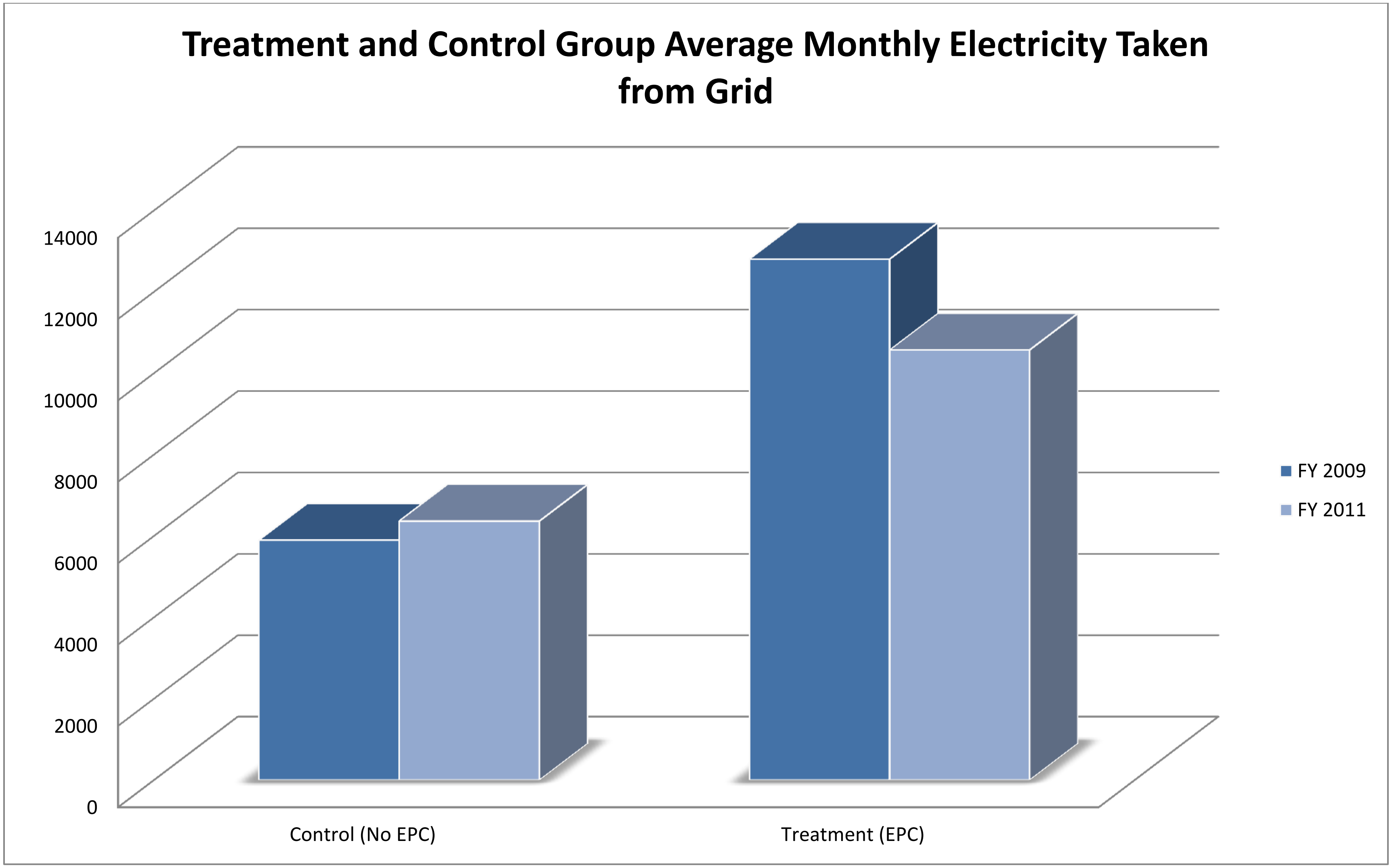
Boulder Housing Partners maintains a database of utility data for all units with landlord-paid utilities. These data is collected for financial purposes, and includes utility provider, utility account number, meter number, physical address, a unique property identifier, month, year, net consumption, solar offsets, and cost. This report analyzes aggregate monthly electricity consumption for the eight public housing sites that received energy efficiency upgrades during the FY 2010 EPC with Johnson Controls, Inc. (designated the treatment group), and two public housing sites that received no efficiency upgrades (referred to as the control group).

RESULTS: POLICY QUESTION I

Initial results suggest that properties in the treatment group, or those which received the EPC work experienced an overall decline in electricity consumption.[5]

[5] See Table 2 for comparison of average monthly electricity taken from grid and percentage change from FY 2009 (pre-EPC) to FY 2011 (post-EPC).

Figure 1. Comparison of Treatment and Control Group Average Monthly Electricity Taken from Grid Pre- and Post-EPC



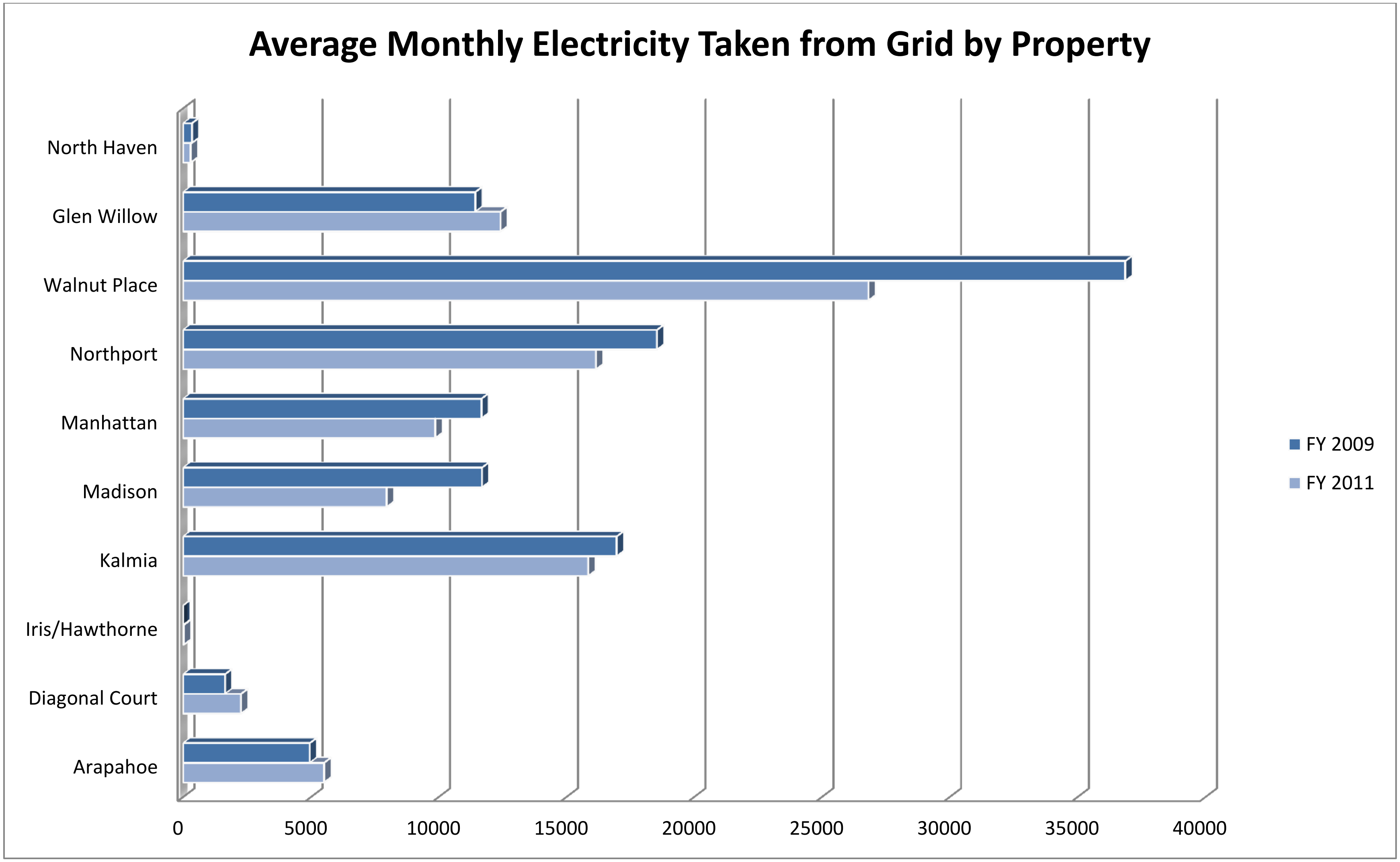
Average monthly electricity consumption declined by 17.44% from FY 2009 to FY 2011 for the treatment group, while average monthly electricity consumption increased by 7.96% for the control group. However, there are some points of concern. The Arapahoe, Diagonal Court and Iris/Hawthorne treatment properties saw an increase ranging from 11.25% to 883.78%, and the North Haven property in the control group experienced a 15.01% decrease in electricity consumption. These results directly contradict the expected outcome for their member groups or are the opposite sign than what was expected.

Table 2. Average Monthly Electricity Taken from Grid and Percentage Change Pre- and Post-EPC by Property

Average Monthly Electricity Taken From Grid			
	FY 2009	**FY 2011**	**% Δ**
Treatment Group			
Arapahoe	4966.42	5524.92	11.25%
Diagonal Court	1647.33	2275.17	38.11%
Iris/Hawthorne	3.08[6]	30.33	883.78%
Kalmia	16981.33	15872.42	-6.53%
Madison	11706.67	7976.67	-31.86%
Manhattan	11682.83	9874.25	-15.48%
Northport	18560.00	16173.33	-12.86%
Walnut Place	36880.00	26840.00	-27.22%
TOTAL	**12803.46**	**10570.89**	**-17.44%**
Control Group			
Glen Willow	11440.67	12431.83	8.66%
North Haven	350.33	297.75	-15.01%
TOTAL	**5895.50**	**6364.79**	**7.96%**

[6] This value appears atypically low and raises the concern of a data entry error or a confounding factor which has biased the results. Currently available data does not provide an explanation, but it may warrant additional investigation prior to undergoing a valuation of interventions at the Iris/Hawthorne property.

Figure 2. Comparison of Pre- and Post-EPC Average Monthly Electricity Taken from Grid by Property

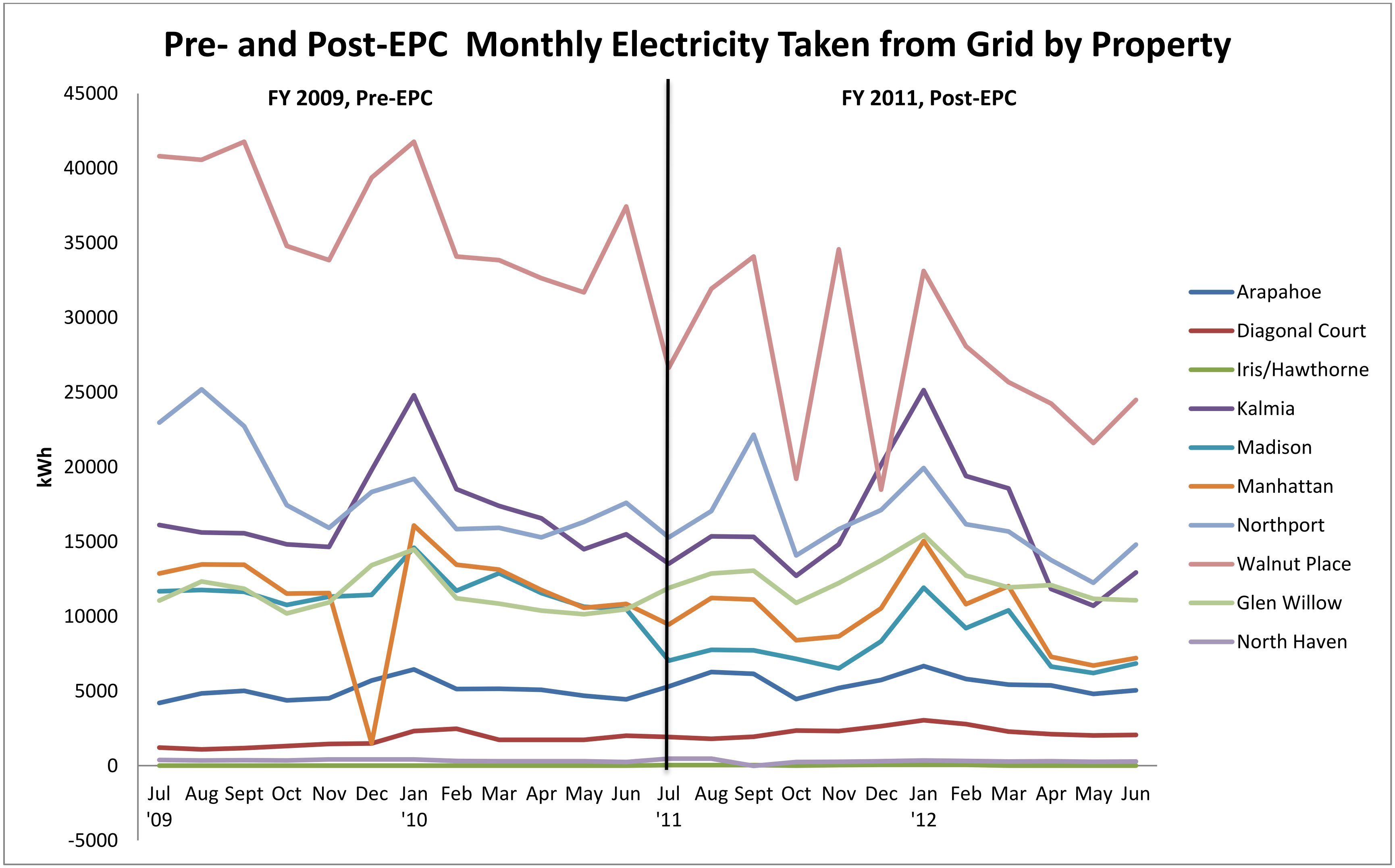


This implies problems with the data, especially given the 883.78% increase seen at the Iris/Hawthorne treatment property. It is rather surprising that one of the two non-EPC properties, or controls, experienced a decrease in consumption of such magnitude over the same time period. This could potentially be due to changes in resident composition or to other unobserved variation in behavior or occupancy patterns. Although Figure 3, or a graphical representation of the pre- and post-EPC monthly electricity taken from grid by property, illustrates rather substantial variation for each property over time, the general trends for FY 2009 and FY 2011 seem to be relatively similar.

These data suggest that although there is a seasonal component to residential electricity consumption patterns, the changes appear to be relatively similar across time and are mostly netted out in the analysis. There are, however, several points of concern. In December of FY 2009, Manhattan, a treatment property, experienced a sudden and unexplained drop in electricity consumption from over 10,936 kWh in November, to 1508 kWh in December. Consumption at this property rebounded immediately, and reached 16,075 kWh in January before returning to the general trend of the remaining properties. It is possible this is due to property maintenance that required residents to temporarily vacate, but this cannot be ascertained from currently available data.

The trends in electricity taken from the power grid explain, in part, the existence of the three outlying treatment observations: Diagonal Court, Arapahoe, and Iris/Hawthorne. It is likely that some of the substantial variation in Diagonal Court's

Figure 3. Pre- and Post- EPC Monthly Electricity Taken from Grid for Treatment and Control Properties



post-EPC consumption accounts for the observed increase in post-EPC average monthly electricity taken from the grid. Consumption at the Arapahoe property remains flat on either side of the pre- and post-EPC dividing line, thus suggesting the EPC was ineffective at curbing consumption, it failed to address the major source of electricity consumption at the property, or the EPC was confounded by resident behavior. The Iris/Hawthorne property experienced a rather strange phenomenon pre- and post-EPC. The average monthly electricity consumption for the property went from approximately 3 kWh per month pre-EPC, to 30 kWh per month post-EPC. Although the absolute magnitude of the consumption is quite low, this change represents an increase in consumption in excess of 800% and serves as a major point of concern regarding data integrity.

A series of simple t-tests to ascertain the presence of a statistically significant difference between pre- and post-EPC average monthly electricity taken from the power grid suggests the absence of any statistically significant change. This is not unexpected given the limited number of observations and the heterogeneity of the age and design of the buildings involved. The EPC decreased total consumption, but not to the extent that the pre- and post-EPC average monthly consumption values warrant the rejection of the null hypothesis that the EPC yielded no change in monthly total electricity taken from the grid for Boulder Housing Partners' treatment group properties.

These results are further supported by a difference-in-difference analysis that was conducted for the purposes of examining the impact of receiving the treatment (in this case the EPC), and an observation falling in a post-treatment year (FY 2011). EPC is a dummy variable scored 1 for an observation that belongs to the treatment group and 0 for an observation that belongs in the control group. Similarly, POST is a dummy that has a value of 1 for all FY 2011 observations, and a value of 0 for all FY 2009 observations. The interaction variable, or EPC*POST signifies the effect of being in the treatment group post-EPC.

The results shown in table 3 indicate that the EPC had an effect on the treatment group to the magnitude of -2701.865 kWh and was not at all statistically significant. The EPC dummy variable was the only statistically significant result; it was significant to the 0.05 level.

Table 3. Difference-in-Difference Model Results Including Treatment Outliers

Variable	Coefficient	t	P>t	[95% Confidence Interval]	
EPC*POST	(2701.865)	-0.880	0.377	-8720.635	3316.906
	(3055.110)				
EPC	6907.958	3.200	0.002	2652.045	11163.87
	(2160.289)				
POST	469.292	0.170	0.864	-4914.061	5852.644
	(2732.573)				
_cons	5895.500	3.050	0.003	2088.895	9702.105
	(1932.221)				
Number of obs	240			R-squared	0.0632
F(3, 236)	5.31			Adj R-squared	0.0513
Prob > F	0.0015				

In order to verify that the outliers in the treatment group (the Arapahoe, Diagonal Court and Iris/Hawthorne properties) did not substantially affect the results shown in Table 3, the difference-in-difference analysis was repeated after dropping the outliers from the dataset. This results in an increase in the effect of the EPC on the treatment group to -4284.125 kWh, and an increase in statistical significance from 0.88 to 0.122. Although this is a substantial change, 0.122 remains well past the standard 0.05 threshold for statistical significance. Consequently, it does not change the conclusions or interpretation of the results. The EPC variable remained statistically significant, but changed from statistically significant to the 0.05 level to statistically significant to the 0.001 level.

Table 4. Difference-in-Difference Model Results Excluding Treatment Outliers

Variable	Coefficient	t	P>t	[95% Confidence Interval]	
EPC*POST	-4284.125	-1.550	0.122	-9726.061	1157.811
	(2756.060)				
EPC	13266.670	6.810	0.000	9418.637	17114.7
	(1948.829)				
POST	469.292	0.200	0.841	-4129.984	5068.567
	(2329.296)				
Constant	5895.500	3.580	0.000	2643.321	9147.679
	(1647.061)				
Number of obs	168			R-squared	0.305
F(3, 164)	23.97			Adj R-squared	0.292
Prob > F	0				

ANALYSIS: POLICY QUESTION I

Although the analysis failed to find any statistically significant results, it still provided sufficient evidence to conclude that the FY 2010 EPC performed by Johnson Controls, Inc. did yield an overall reduction in kWh consumed at the affected properties. More robust results might be possible with additional years of data on either side of the intervention and by using a more complex regression model that considers weather and building and demographic characteristics in its analysis. However, due to concerns over degrees of freedom and limited validity, such models were not possible with the existing dataset. It is recommended that Boulder Housing Partners investigate the increase in consumption at the Diagonal Court, Arapahoe, and Iris/Hawthorne properties in order to ascertain the cause of the observed phenomenon and determine if the trend continues into FY 2012.

CRITERIA: POLICY QUESTION II

A selection of decision criteria was developed based upon discussions with Boulder Housing Partners staff and a review of the relevant literature for the purposes of facilitating the evaluation and ranking of the policy alternatives proposed as solutions to Policy Question II.

- **Maximize reduction in electricity consumption.**

  Alternative should provide a method of consumption reduction that conforms to the literature with respect to its projected efficacy within the low-income population served by Boulder Housing Partners.

- **Advance Boulder Housing Partners' organization mission and vision.** Accomplish electricity reduction goal in a manner that conforms to Boulder Housing Partners' emphasis on sustainability and resident quality of life.

- **Minimize implementation and management costs.**

  Achieve maximum savings for minimum implementation cost within budgetary constraints and minimize long-term management costs and usage of valuable staff time.

- **Provide consideration for population demographics**.

  Alternative must consider and address the characteristics and information-processing styles of the resident population in order to avoid intrusiveness and confusion.

- **Work within the regulatory and legal confines faced by Boulder Housing Partners.**

  Boulder Housing Partners is subject to legal and regulatory requirements from the federal, state, and local level. Any alternative the organization chooses to undergo must work within the confines of relevant laws and regulations in order to function effectively and protect Boulder Housing Partners from legal challenge.

ALTERNATIVES: POLICY QUESTION II

1. **Install sub-meters in all public housing units.**

   Most of the public housing properties under the purview of Boulder Housing Partners are currently master-metered, or not metered down to the individual unit. This limits BHP's ability to identify those with atypically high consumption and ascertain and address the reasons for such over-consumption. Furthermore, without sub-metering, BHP is extremely limited in its ability to deploy information feedback interventions in order to decrease resident consumption. However, the installation of sub-meters is both costly and labor intensive. Such a substantial upgrade is likely only possible when funding availability coincides with planned building renovation.

2. **Provide residents with a monthly notice detailing their previous month's usage and performance compared to other property residents.** Residents currently receive neither a bill, nor any kind of statement discussing the cost or volume of their electricity consumption. This makes it very difficult to convince residents that 1) there are connections between their behaviors and monthly electricity consumption, 2) changing their behavior makes a difference to the overall bottom line, and 3) their electricity consumption behavior is something they should actively consider even when they do not face the price signals incorporated into a monthly bill. The literature suggests that addressing this information asymmetry may yield changes in resident consumption behavior.

3. **Institute a monthly or annual savings sharing program.**
   Residents must understand the connection between behavior and electricity consumption, and they must also perceive the issue as relevant and worth their time and attention. Research indicates that financial incentives can encourage changes in resource consumption behavior, as long as the incentives are contingent on outcome and viewed as something of value to the target population.

   A monthly or annual savings sharing program would incorporate information feedback in the form of a periodic notice regarding resident electricity consumption, a housing authority directed savings target for the residents, and a promise of cash payments or resident directed property improvements with any savings achieved past the target. This would require periodic information regarding individual resident and total property progress towards a specified goal, and would need to be implemented and managed by BHP staff.

4. **Conduct energy conservation information sessions.**

   Individuals from BHP staff or outside firms and/or agencies could conduct energy conservation information sessions at BHP public housing sites. These informational sessions would incorporate a discussion of how to conserve energy, emphasize its relevance to the organization, the tenants, and the world as a whole, and disseminate flyers or pamphlets that discuss various ways to save energy.

5. **Distribute written material on the cost of electricity and how to reduce consumption.**

   This alternative would require BHP to draft written recommendations and tip sheets designed to encourage public housing residents to conserve energy. The ultimate outcome would rest solely on the ability of tenants to understand the written material, their perception that the information is relevant, and their individual estimations of the costs and benefits of behavior change.

6. **Solicit written commitment to achieving conservation goals.**

   Evidence suggests that written commitment to conservation goals, especially when the commitment is made to peers or with the full knowledge of peers, can increase pro-conservation behavior. This largely occurs through social norms and a feeling of accountability to other individuals or peer groups.

ANALYSIS: POLICY QUESTION II

The policy alternatives have been scored from one to five on each decision criteria as a method to rank the potential projects based upon information obtained from Boulder Housing Partners staff, the literature review, and observation of Boulder Housing Partners' operating environment.

Alternative 1: Install sub-meters in all public housing units.

Table 5. Alternative 1 Decision Analysis

	Decision Criteria				
Alternative	Maximize Reduction in Electricity Consumption	Advance BHP Mission and Vision	Minimize Costs	Consider Population Demographics	Work Within Relevant Regulatory and Legal Confines
Sub-meters	5	5	1	5	5

Scale 1-5; high score best meets criterion

The installation of sub-meters would maximize the reduction in electricity consumption through a substantial increase in available electricity consumption information. This information would then permit property managers to discuss consumption with abnormally high users, allow for the dissemination of monthly electricity consumption reports to residents, and enable BHP to engage in a savings sharing program to provide residents with financial incentives to conserve more. The savings sharing program could provide residents with cash bonuses, or be used to fund resident directed property improvements. The latter would potentially serve dual purposes: enhancing the value of BHP's housing stock and providing residents with desired amenities and services. As such, this alternative excels at furthering BHP's mission and vision, as well as considering population demographics. Furthermore, this alternative should not raise any major legal or regulatory concerns. However, the installation of sub-meters on all BHP public housing units would be quite expensive, potentially even prohibitively so, and would likely only occur in the immediate future if BHP converts all public housing to low-income tax credit financed housing and initiates a major renovation.

Alternative 2: Provide residents with a monthly notice detailing their previous month's usage and performance compared to other property residents.

Table 6. Alternative 2 Decision Analysis

Alternative	Decision Criteria				
	Maximize Reduction in Consumption	Advance BHP Mission and Vision	Minimize Costs	Consider Population Demographics	Work Within Regulatory and Legal Confines
Usage Report	4	5	3	3	5

Scale 1-5; high score best meets criterion

Providing residents with periodic reports on electricity consumption should have an appreciable impact on consumption without creating legal or regulatory issues. This alternative will further BHP's mission and vision through its' emphasis on sustainability, but has the potential to be somewhat costly in terms of staff time and the resources required to print and disseminate such reports. It may only partially consider population demographics as many residents may not easily understand the information they are given without substantial prior explanation. Furthermore, people are often quite quick to throw out anything they perceive to be extraneous pieces of paper. Residents may simply not look at the reports after a while, as there is no real incentive for them to do so.

Alternative 3: Institute a monthly or annual savings sharing program.

Table 7. Alternative 3 Decision Analysis

	Decision Criteria				
Alternative	Maximize Reduction in Electricity Consumption	Advance BHP Mission and Vision	Minimize Costs	Consider Population Demographics	Work Within Relevant Regulatory and Legal Confines
Savings Sharing Program	5	4	5	4	3

Scale 1-5; high score best meets criterion

A savings sharing program has the potential to maximize reduction in electricity consumption in a way that both furthers BHP's mission and vision, and offsets most, if not all, of the implementation and management costs via electricity savings. This alternative places a strong emphasis on resident demographics and interests, and has the greatest potential to achieve buy-in. However, depending upon changes in the ownership and management of BHP's public housing properties, such cost sharing programs may or may not fall within relevant regulatory and legal confines. This alternative will likely be applicable only if BHP completes its' disposal of all public housing assets, if at all. However, it should be considered given the substantial potential for savings and the mutual benefits for residents and BHP.

Alternative 4: Conduct energy conservation information sessions.

Table 8. Alternative 4 Decision Analysis

	Decision Criteria				
Alternative	Maximize Reduction in Electricity Consumption	Advance BHP Mission and Vision	Minimize Costs	Consider Population Demographics	Work Within Relevant Regulatory and Legal Confines
Information Sessions	2	3	4	4	5

Scale 1-5; high score best meets criterion

The use of information sessions to encourage electricity conservation scores fairly low on the maximizing the reduction in electricity consumption and furthering BHP's mission and vision parameters, but scores high with respect to minimizing cost, considering population dynamics, and working within the confines of the legal and regulatory environment. This alternative includes the most one-on-one interaction with residents and will likely cost BHP little aside from the staff time required to prepare and conduct the information sessions. However, it is not particularly innovative, and the literature suggests it will have limited, if any, effect on either short-term or long-term changes in resident consumption behavior. As such, it fails to maximize a reduction in electricity consumption, and consequently, it is only partially successful at furthering BHP's mission and vision.

Alternative 5: Distribute written material on the cost of electricity and how to reduce consumption.

Table 9. Alternative 5 Decision Analysis

	Decision Criteria				
Alternative	Maximize Reduction in Electricity Consumption	Advance BHP Mission and Vision	Minimize Costs	Consider Population Demographics	Work Within Relevant Regulatory and Legal Confines
Disseminate written material	1	1	5	3	5

Scale 1-5; high score best meets criterion

Similar to alternative 4, alternative 5 is anticipated to have a limited effect on reducing resident electricity consumption, and as a result, fails to further BHP's mission and vision in a meaningful way. However, the dissemination of written material is fairly low cost and easily falls within legal and regulatory limitations. It does not consider residents' skepticism of written information, especially since BHP has a vested interest in the outcome, and it assumes that the residents will both read and understand the material presented to them without any discussion or assistance.

Alternative 6: Solicit written commitment to achieving conservation goals.

Table 10. Alternative 6 Decision Analysis

	Decision Criteria				
Alternative	Maximize Reduction in Electricity Consumption	Further BHP Mission and Vision	Minimize Costs	Consider Population Demographics	Work Within Relevant Regulatory and Legal Confines
Solicit commitment to achieving goals	3	5	3	4	5

Scale 1-5; high score best meets criterion

The literature suggests that the solicitation of commitments to achieving conservation goals has some success at reducing overall consumption. This alternative successfully furthers BHP's mission and vision both by reducing electricity consumption and by engaging residents in sustainability, a core tenant of the organization. This alternative will require staff time and materials, leading to a moderate cost, but should successfully consider, and account for, population dynamics. Finally, it works well within the regulatory and legal framework that binds BHP's activities.

Table 11. Comparison of Alternative Decision Analyses

	Decision Criteria					
Alternative	Maximize Reduction in Electricity Consumption	Advance BHP Mission and Vision	Minimize Costs	Consider Population Demographics	Work Within Relevant Regulatory and Legal Confines	**TOTAL**
Sub-meters	5	5	1	5	5	**21**
Usage Report	4	5	3	3	5	**20**
Savings Sharing Program	5	4	5	4	3	**21**
Information Sessions	2	3	4	4	5	**18**
Disseminate written material	1	1	5	3	5	**15**
Solicit commitment to achieving goals	3	5	3	4	5	**20**

Scale 1-5; high score best meets criterion

RECOMMENDATION: POLICY QUESTION II

It is recommended that BHP pursue a combination of alternatives 1, 2, 3, and 6. If the organization so chose and resources permitted, they also could pursue information sessions and the dissemination of written materials.

CONCLUSION

Boulder Housing Partners has made measurable progress towards its goal of becoming a public housing authority with net-zero electricity consumption in its public housing portfolio. Those properties that received EPC work saw a 17.44% reduction in average monthly electricity consumption from FY 2009 to FY 2010, with property level consumption falling by as much as 31.86%. However, there remains substantial room for improvement. In order to maximize the effectiveness of existing efficiency upgrades and capitalize on additional potential for reductions in consumption through resident behavior change, the organization should develop and institute a series of short- and long-term goals and strategies over the coming year.

With the upcoming potential disposal of public housing assets via low-income tax credit financing, Boulder Housing Partners has an opportunity to pursue substantial property upgrades, including the installation of sub-meters across all public housing properties. These meters would allow the organization to further target consumption reduction approaches to a unit-by-unit basis rather than a property-by-property level, and will enable regular reporting of consumption data to residents. Combined with the recommended incentive- and information-based interventions, as well as additional building upgrades, this should allow Boulder Housing Partners to capture substantive additional increases in energy savings, while decreasing greenhouse gas emissions.

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