CONSORTIUM for BUILDING ENERGY INNOVATION

REPORT

Title: Potential for Various Policies to Impact the Retrofit Market

Report Date: January 2013

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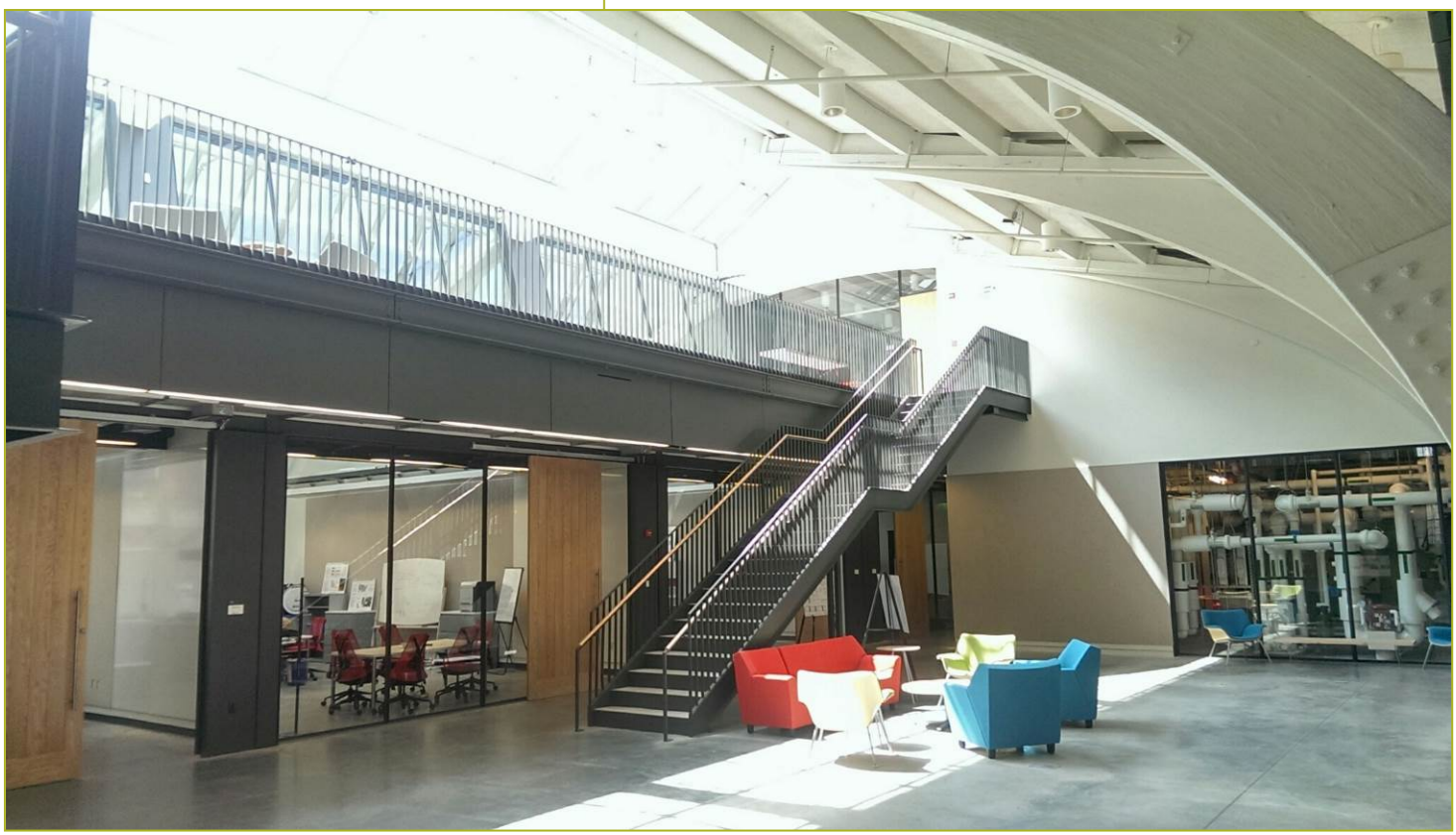

CBEI was referred to as the Energy Efficiency Buildings HUB at the time this report was developed.

Funded by U.S. DOE

Report Abstract

CBEI developed a market model for analyzing the potential for policies to improve the advanced energy retrofit market. This study analyzes the potential for disclosure, on-bill financing, energy service performance contracts, and feebates to influence the retrofit market in the Philadelphia region.

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Acknowledgement

This material is based upon work supported by the Consortium for Building Energy Innovation (CBEI) sponsored by the U.S. Department of Energy under Award Number DE-EE0004261.

Task 6 – Policy, Markets and Behaviors

Subtask 6.3 – Market and Policy Network Models

Deliverable 28, Expanded AER Market Model

January 28, 2013

Executive Summary

The deliverable addressed by this subtask is as follows:

28. Expanded Regional AER Market Model with a capacity to simulate the impact of technologies, incentives, market conditions, and behavioral scenarios on the size and character of the commercial AER market in Greater Philadelphia

In BP1, the AER Market Model (hereafter referred to as the "Market Model") was used to project the effects of policy scenarios likely to be available or implemented in the Philadelphia region on the mid-size commercial office building submarket. To achieve Deliverable 28 of BP2 listed above, UTRC, in conjunction with Drexel University, the University of Pennsylvania, and Carnegie-Mellon University, expanded the regional AER Market Model beyond the mid-size commercial office market segment by incorporating the multi-family housing (MFH) market segment and developing a defined suite of additional policy analysis capability for utilization within the Market Model.

To expand the Market Model to include an additional high priority market segment beyond the BP1 mid-size commercial office capability, the team analyzed the available building data for the Philadelphia region, which included CBECS, RECS, US HUD 2010 Census and the Philadelphia Housing Authority (PHA), and concluded that the segment with the best combination of accessible information and impact on regional building energy use was the MFH market segment. The submarket data suggested that we could accurately characterize the energy consumption profile of the MFH building segment by subdividing it into 1-4 unit attached row-houses and high rise apartment/condominium buildings. These segments were themselves further subdivided into several distinct baselines to account for the distribution of age, envelope performance, level of HVAC service, and HVAC efficiency in the Market Model analysis. Building energy simulations were performed on the baseline cases alone and with multiple combinations of energy conservation measures to provide a broad set of possible energy efficient upgrade options that the Market Model could allow the building stock to migrate into under the appropriate policy, market and behavioral conditions. The energy simulations were performed using EnergyPlus to produce end use energy consumption profiles for each baseline and ECM alternative. The University of Pennsylvania's BPAT building simulation tool was used to check

the results for consistency. In the case of the row-house segment, over 1100 individual EnergyPlus runs were required to fully capture the segment and its potential evolution.

The capability of the Market Model to analyze new scenarios was expanded by the addition of several new policy models. These included:

- Disclosure – this was implemented to understand the potential short- and long-term effects of the recently enacted City of Philadelphia disclosure law which requires building owners to report their buildings' energy consumption. While the law requires no commitment to an energy efficiency measure, it will have the impact of raising awareness and the potential to influence decision making for energy efficient properties in the market. By analyzing landlord-tenant transactions, particularly under lease structures where tenants pay for utilities, the Market Model indicates reductions in energy consumption are likely as the effects of disclosure potentially allow landlords to recoup a portion of their energy efficient upgrades through higher rent, enabled by the disclosure itself and a willingness of tenants to occupy energy efficient properties as preferred spaces and thus pay a premium for these spaces.
- On-bill financing – financing energy efficient improvements through a building owner's or tenants utility bill reduces or eliminates the first cost hurdle to adoption and increases the investment horizon for energy efficiency improvements from the typical 3 years to 15 years or more. Moreover, as tenants will benefit from reduced energy costs over their lease term while at the same time repaying for the properties investment, it secures the likelihood of owner's cooperative agreements among tenants to perform the property improvement as supported by a favorable utility analysis. Further, these structures will extend to current and future tenants and owners. Lease structures allowing such improvements are assumed to enable this transaction. As a result, more extensive ECMs are implemented than occur under business-as-usual, with landlords and tenants both benefiting from the decision.
- Energy Service Companies (ESCOs) – ESCOs have a similar effect as on-bill financing, although at slightly higher costs due to the need for the ESCO itself to cover its costs plus a reasonable profit margin.
- Feebates – Feebates have a similar effect as Disclosure. The difference between them is the mechanism by which energy savings are channeled back to owners. In the case of disclosure the mechanism stems from the choices of market participants and their willingness to pay rent premiums in return for lower anticipated utility bills.. In the case of feebates the mechanism is mandated penalties (fees) or subsidies (rebates) levied directly to owners by public authorities versus an occupier/tenant, which serves as an input for decision making on energy efficiency investments. Similar to disclosure, the net result is an owner is economically penalized for a poorly performing property or economically benefits from a better performing property and at some point in their

economic horizon will choose to invest to either overcome the penalty costs or benefit from the subsidy.

Detailed Narrative

Deliverable 28: Expanded Regional AER Market Model with a capacity to simulate the impact of technologies, incentives, market conditions, and behavioral scenarios on the size and character of the commercial AER market in Greater Philadelphia.

Subtask SOPO Description

In BP2 the EEB Hub Policy and Market Model will be applied to analyze ECM adoption in the multi-family building sector, producing estimates of energy savings, first costs, operating costs and tenant operating benefits under different economic and policy conditions. The analysis will be used to project the regional impact of potential ECMs, policies, efficiency actions, and stakeholder decision-making over time. UTC will coordinate project activities and manages project collaboration. Additionally, UTC investigators are responsible for the creation of the Policy and Market Macro Model based on work of this subtask. CMU will develop studies that demonstrate the economic, environmental and human cost-benefits of investing in energy efficient building components and systems for retrofits and to incorporate these benefits within a multi-media decision support tool. Drexel will conduct a series of whole-building energy simulation results using EnergyPlus to quantify the impacts of various combinations of energy efficiency measures on energy consumption in multi-family buildings. Additionally, investigators are modeling the broad array of decision heuristics that determine ECM uptake, and how those decisions are affected by policies, choice framing and available ECM technologies. Penn is responsible for three areas of research: (1) BPAT+ simulations to generate normative values on consumption for predefined sub-categories of both multi-family and commercial building space; (2) experiments to better understand the demand of cost-effective energy efficient technologies and how to make investing in energy efficient technology more attractive to decision makers; (3) develop strategic energy buying, selling and storage strategies to facilitate the large scale deployment of energy efficient solutions.

Discussion

The sub-task participants pursued two paths to achieving these deliverables:

1. Researching an additional building submarket, and creating the data required to project the effects of policy scenarios using the Market Model.
2. Adding to the suite of policy models incorporated in the Market Model to allow the Hub to study the effect of emergent policies in the Greater Philadelphia region.

Item 1 was addressed by studying the available building market data for the ten-county region, which included CBECS, RECS, and HUD 2010 Census data. In BP1, the subtask studied mid-

sized office buildings, which, as part of the commercial office segment, is one of the largest energy consumers in the region. The team concluded that multifamily housing represents another significant consumer of energy, which must be addressed if regional energy consumption is to be reduced by 20% by 2020 as part of the Hub's overall objectives. The narrative below discusses how the multifamily market was further subdivided and its energy use analyzed.

The sub-task addressed item 2 by adding decision maker response algorithms to the Market Model to assess the impact of

- Energy use disclosure laws
- Direct on-utility bill financing for energy efficient retrofits
- ESCO financing
- "Feebates"

The sub-task used the new market segment data and policy options to run a suite of simulations assessing the relative impact of, and interactions between the possible market-based policies, subsidies/incentives and codes/regulations on the greater Philadelphia commercial building stock

Building submarket expansion: Building Energy Simulation

In order for EEB to achieve its stated goal by 2020, it is important to have a basic understanding of the energy use and consumption characteristics in the region, as well as the potential savings available in the form of energy conservation measures (ECMs). This is being accomplished in part by developing a stock of EnergyPlus commercial building energy models representing buildings that are currently found or may be found in the future in the Greater Philadelphia region. The focus of BP2 was the development of a stock of buildings representing the multifamily housing market segment. Analysis of the market segment (see Figure 0-1 below) from data sources such as the Census Bureau and Department of Housing and Urban Development yielded that 1-4 unit, attached housing represented the greatest density of building unit types in the region as well as the greatest potential to have an impact on the region's energy consumption.

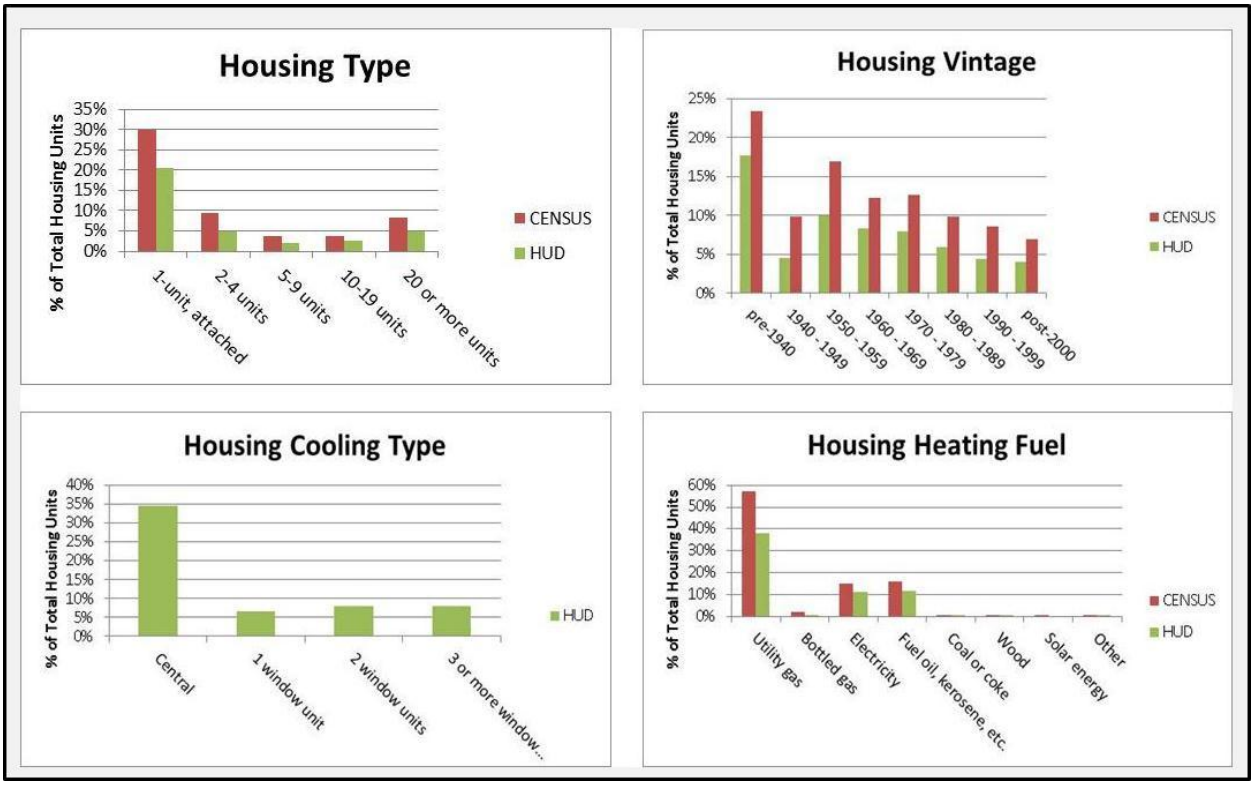

Figure 0-1: Characterization of Housing in Greater Philadelphia

The characteristics found from Census and HUD data were used to develop six baseline EnergyPlus models (representing market subsegments of varying vintages and construction types), and from those six baselines over 1,100 EnergyPlus models were developed representing upgrades and ECMs applied to each of the baselines. The upgrades and ECMs model range technologies related to lighting, fenestration, envelope, occupant comfort, occupant behavior, and HVAC. While this database of buildings in itself is very valuable, its real value derives from its use in the advanced energy retrofit (AER) Market Model developed by UTC. Drexel simulated each of the EnergyPlus models under typical meteorological conditions for the period of a year and reported the annual energy end-use data in a format which is understood by the AER Market Model. Baseline energy consumption results were verified using data from the 2009 Residential Energy Consumption Survey and compared to results derived with TC Chan's BPAT simulations of models with the same characteristics.

Policy Scenario Expansion

As the EEB Hub develops new policy and technology solutions, it is important to develop quantitative methods to evaluate their effect on short and long term energy consumption and emissions trends. This, in turn, will allow policy makers, utility companies, and building decision makers to understand, in concrete terms, their effectiveness in comparison to the status quo and the other available options. Our investigations during the development of the Market Model have shown that such analysis capability is mostly lacking and that new policies and incentive

programs tend to be designed and analyzed using ad hoc tools that cannot account for the multitude of interactions that take place in the marketplace. In Sub-task 6.3 we have developed and employed a system of analytical models (hereafter referred to as the Market Model) initially developed by the World Business Council for Sustainable Development (WBCSD) Energy Efficiency in Buildings (EEB) project and extended for the EEB-Hub to quantify how the building stock in a submarket will change over time as retrofits of the energy related systems occur. During BP2 UTRC continued to enhance and expand the virtual decision maker algorithms in the Market Model to support analysis of policies under consideration by the EEB Hub. Table 0-1 below summarizes the policy extensions completed during BP2.

	Policy/Case Description	Purpose	Key Inputs, Coefficients	Status/Comments
1	Building Rating and Disclosure Policy	Indicates market response to disclosure of Energy Use Intensity and its impact on building rent differentials	Sensitivity of building rent to energy consumption relative to market average	Algorithm developed in BP2. Used for CLIMA paper and commercial building stock analysis
2	Feebates	Indicates market response to incentives to achieve EUI better than market average	Incentive rate for energy savings relative to market average	Same algorithm as #7 Disclosure
3	On-bill financing (in tax or utility bill)	Indicates market response to financing mechanisms that allow adopters to amortize costs over life of equipment	Financing terms for amortized cost (interest rate, duration, first cost mark-up)	Two versions coded in BP2. Used for CLIMA paper and commercial building stock analysis
4	ESCO	Indicates market response to implementation of ECMs through ESCO contracts	Typical structure of ESCO deals	Same algorithm as #9 on-bill financning

Table 0-1: Summary of new policy models implemented in the Market Model during BP2

Results of Submarket and Policy Analyses

This narrative focuses primarily on 1) disclosure laws and 2) on-bill financing, as these policies are seen having significant potential impact by a consensus of hub policy makers. In addition, these policies start to behave like the other policy scenarios under certain limiting assumptions, for example: ESCOs behave like on-bill financing as the cost of financing is reduced; disclosure looks like owner-occupier when there is 100% transparency to the reduction in energy cost from retrofits; etc.

New Policy Algorithms Applied to Commercial Office Segment

After developing the extended algorithm set, UTRC performed simulations of the greater Philadelphia commercial office buildings in support of a paper written (and accepted) for the upcoming CLIMA conference in Prague, the results of which are summarized below.

In an attempt to understand the impact and dynamics of the two market-based policies described above (disclosure and on-bill financing), we start by establishing a "business as usual" (BAU) case wherein policies remain as they have been up to until the recent past. In the BAU case we assume that building codes are neither strict enough to significantly influence energy consumption, nor uniformly enforced. This leaves decision makers to define and apply their own decision criteria. Based on recent, and as yet unpublished, research performed by Drexel University and the University of Pennsylvania, the dominant criteria in retrofit decision making is break-even time (BET). The survey results indicate that, for private sector decision makers, the cut-off for adoption of ECMs occurs when the break even time based on simple payback exceeds about 3.25 years. But, survey respondents indicate that they do consider hard-to-quantify parameters such as environmental impact and employee productivity, so we have assumed a cut-off BET of 4 years in the BAU case to acknowledge that these other drivers are at play in the market. Our model assumes that ECM alternatives that clear the breakeven hurdle are ranked according to the present value of total costs, with the largest share of market adoption going to alternatives with the lowest lifetime costs.

In addition to establishing baseline decision criteria we need to recognize that there are multiple stakeholders (owners or their agents and the building occupants). Situations where the owner and occupant are one and the same are referred to as owner-occupied scenarios. Alternatively, the split incentive (also known as "principal-agent") case occurs when the owner rents to third party occupants who pay rent and are responsible for the utility bills.

The Market Model assumes that owner-occupiers will, over time, tend to adopt ECMs that meet their break-even criteria. These ECMs typically include efficient lighting upgrades, either exclusively or in combination with other ECMs such as double pane windows, better envelope insulation or high efficiency boilers.

The result, as shown in Figure 0-2, is a 25% reduction in energy consumption over the planning horizon.

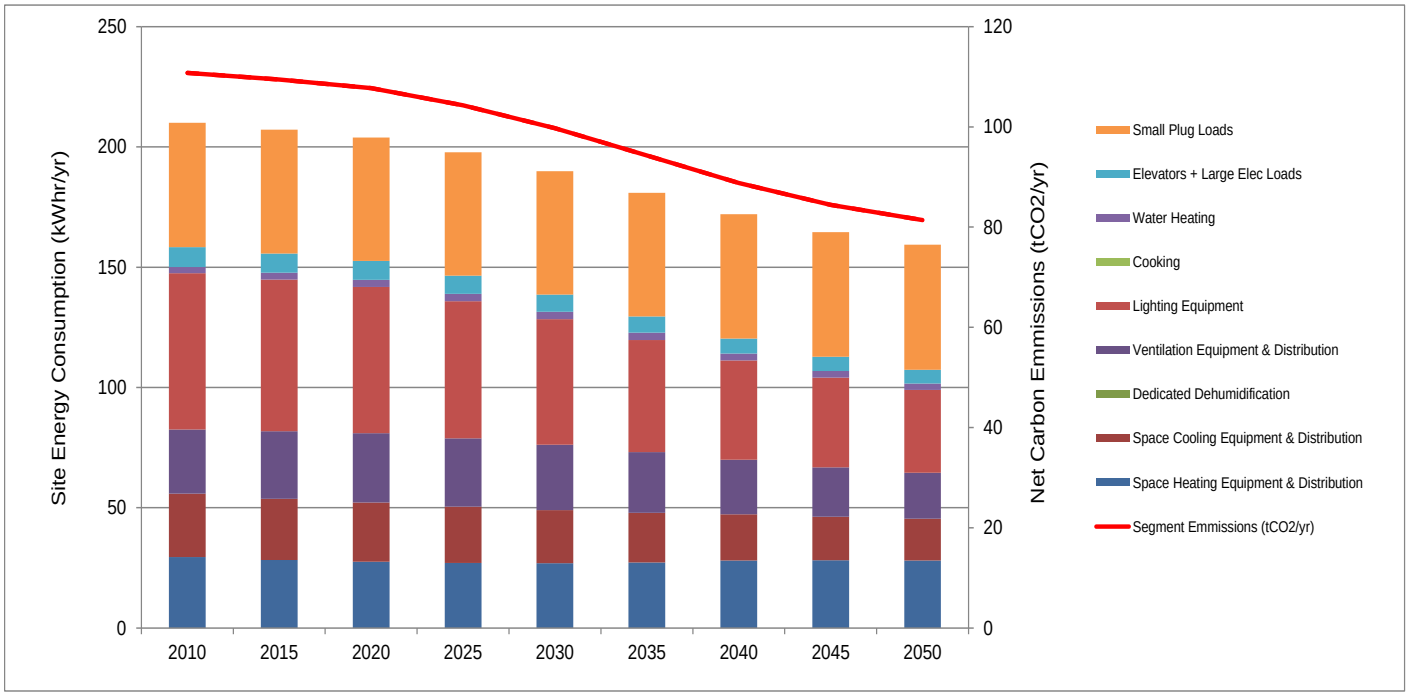

Figure 0-2: Business as Usual: Owner-Occupier

In the split-incentive case, the building owner does not realize any of the energy savings resulting from investment in energy conservation and every ECM fails to meet the break-even criteria. As result the model indicates that decision makers would stay with, or revert to, the baseline configuration if the entire market was indeed characterized by the split-incentive scenario. This results in an 8% increase in energy consumption over the 40-year time horizon simulated by the Market Model as shown in Figure 0-3.

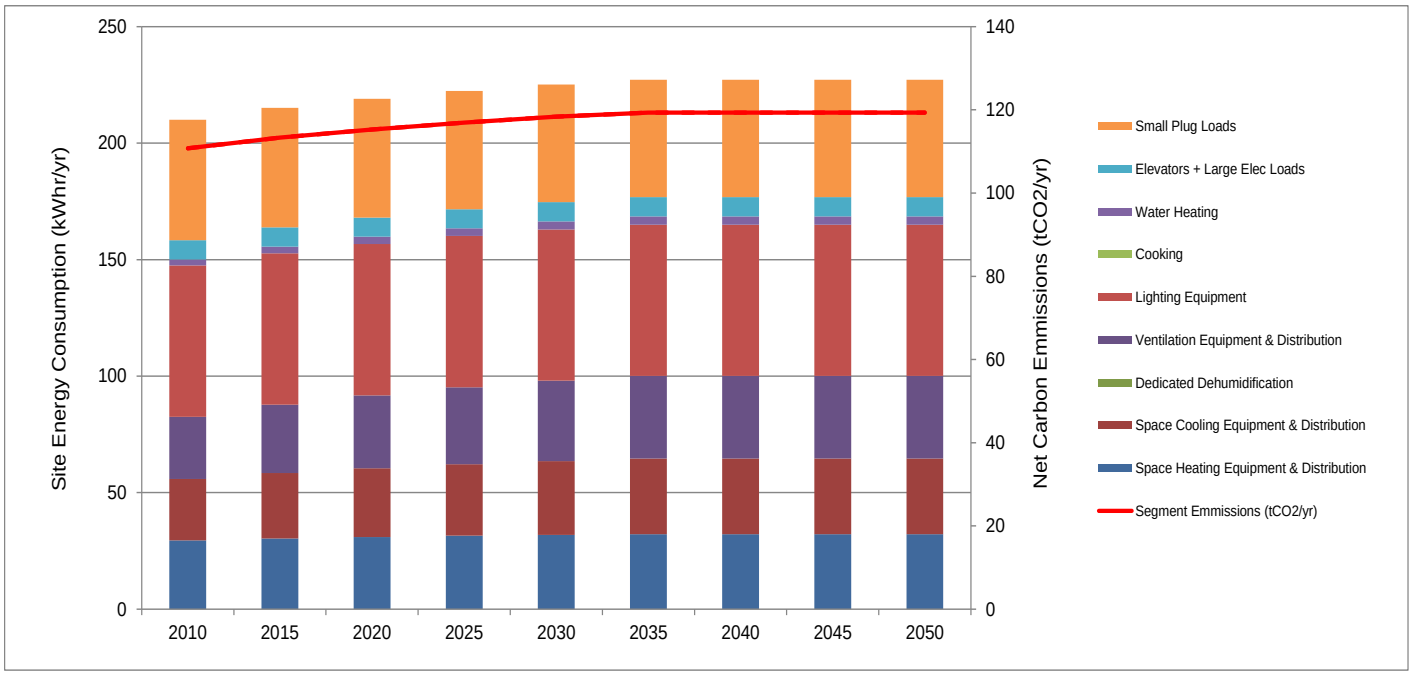

Figure 0-3: Business-as-Usual: Split-Incentive

Our modeling work indicates that in the limit of a perfectly transparent disclosure policy (i.e. one that provided the market with 100% accurate and actionable information regarding the prospective energy consumption of a building), the rent differentials between improved and unimproved buildings would create the same economic incentives for the building owner to upgrade as the owner-occupier scenario and the results are identical. However, and even in the absence of empirical data on the impact of energy disclosure on building owner cash flow due to the newness of these disclosure policies, it is reasonable to assume that this level of impact will not be achieved due to the following factors:

- Aggregation of disclosed consumption across multiple tenants
- Uncertainty about the behavior underlying reported energy consumption
- Uncertainty about the stock of plug and process loads that underlie reported energy consumption
- Misinterpretation of energy data by prospective tenants
- Propensity of prospective tenants to discount energy cost savings while fully accounting for rent increases

To reflect these realities we considered a disclosure case where tenants effectively discount by 50% the energy cost differential between rental choices. In this case, the reduction in energy consumption was modest relative to the split incentive case because break-even times are lengthened for all ECM alternatives. These results are shown in Figure 0-4.

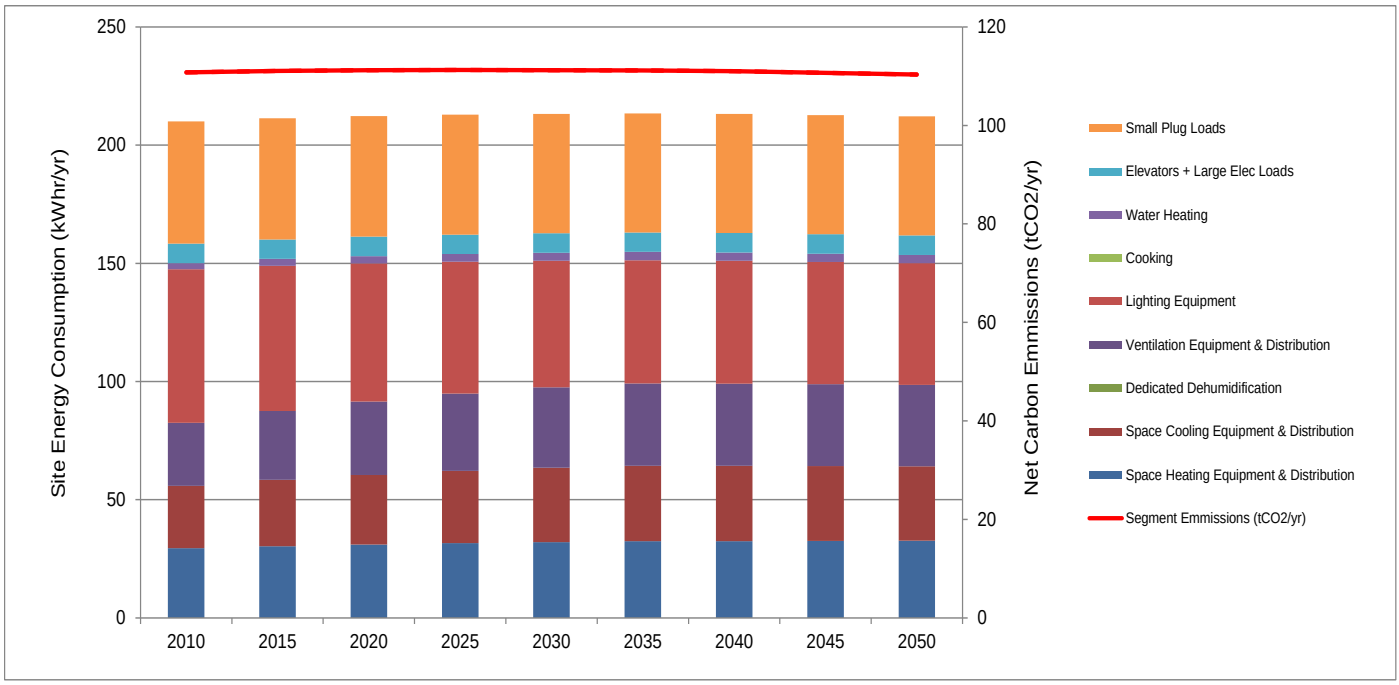

Figure 0-4: 50% Effective Disclosure

We evaluated on-bill financing both as an independent policy and in conjunction with disclosure. For the purposes of the model we assumed on-bill financing at 5% for 15 years would be available for the difference in first cost between the ECM alternative and the baseline configuration for any ECM alternative for which the cost of capital repayment plus the financing cost is exceeded by energy savings. We evaluated this policy for owner-occupier (or 100% effective disclosure policy) and 50% effective disclosure scenarios.

The assumption that the incremental first cost of any ECM alternative can be financed on-bill means that qualifying alternatives have the same first cost, resulting in a BET of zero from the perspective of the building owner, who is left to prioritize alternatives base on discounted total cost of ownership. For the owner-occupier scenario (100% disclosure) energy consumption is 29% lower than BAU by 2050 with on-bill financing and 25% lower without it as additional more aggressive (and costly) ECMs clear the owner's economic hurdles. For the 50% effective disclosure scenario, on-bill financing reduces stock energy consumption by 16% in 2050, as compared to a 1% increase in energy use without it, as a large number of ECM alternatives now offer energy savings which exceed financing cost, even when only 50% of those savings are considered by the building owner. The results of these scenarios are shown in Figure 0-5 and Figure 0-6 below.

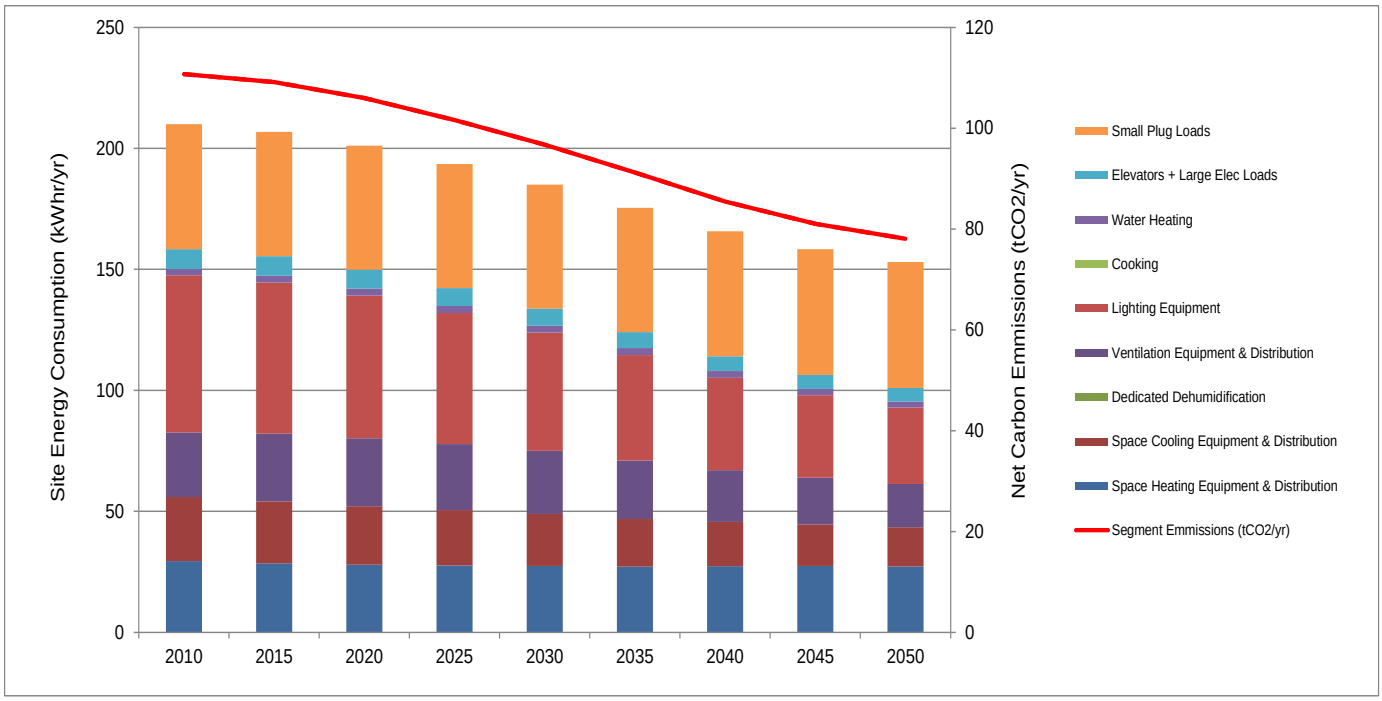

Figure 0-5: On-Bill Financing with 100% effective Disclosure (or Owner-Occupier)

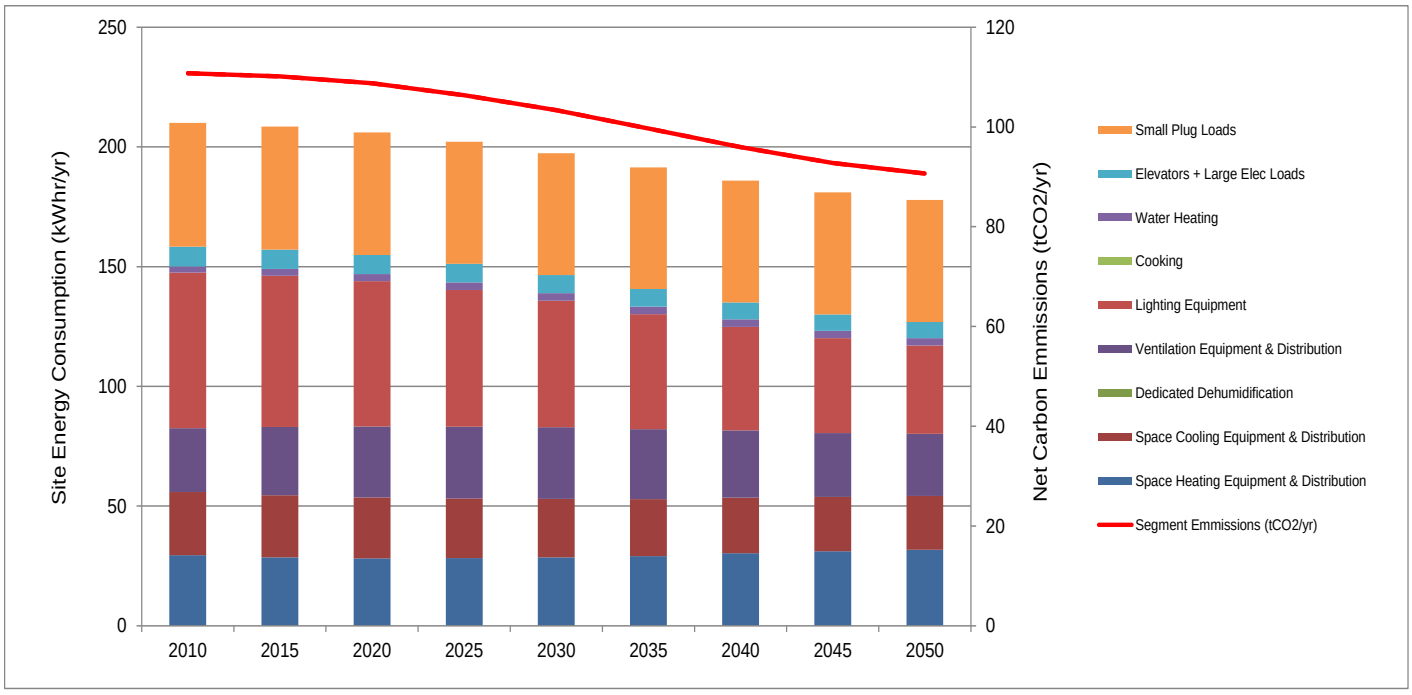

Figure 0-6: On-Bill Financing with 50% Effective Disclosure

Integration of Multifamily Attached Housing Model

UTRC integrated data related to building stock, potential ECM combination, ECM cost, and potential ECM energy consumption impact into a model of the great Philadelphia multi-family housing market.

An analysis of potential policies, similar to that for commercial office, was conducted using the multi-family housing attached market model. For the purpose of these simulations we assumed that building owners had a breakeven time hurdle of four years and would not be allowed to build new homes or retrofit existing homes with single pane windows or wall insulation below a value of R11. Results from the largest multifamily attached housing sub-segment are summarized below. This sub-segment is characterized by:

- Heating with a 70% AFUE natural gas boiler (performance degraded due to age and duty cycle)
- Cooling with COP 2.5 window air conditioners
- Widespread use of incandescent lighting
- Significant penetration (63%) of double pane windows
- Use of standard (i.e. non Energy Star) appliances

The Market Model indicates that owner-occupiers will find a number of ECMs that meet their breakeven hurdle under the BAU scenario. This will lead to widespread adoption of efficient boilers and appliances, as well as automated controls, over the modeled time horizon of 2010-2055. This will lead to a 30% reduction in average building energy consumption as shown in Figure 0-7.

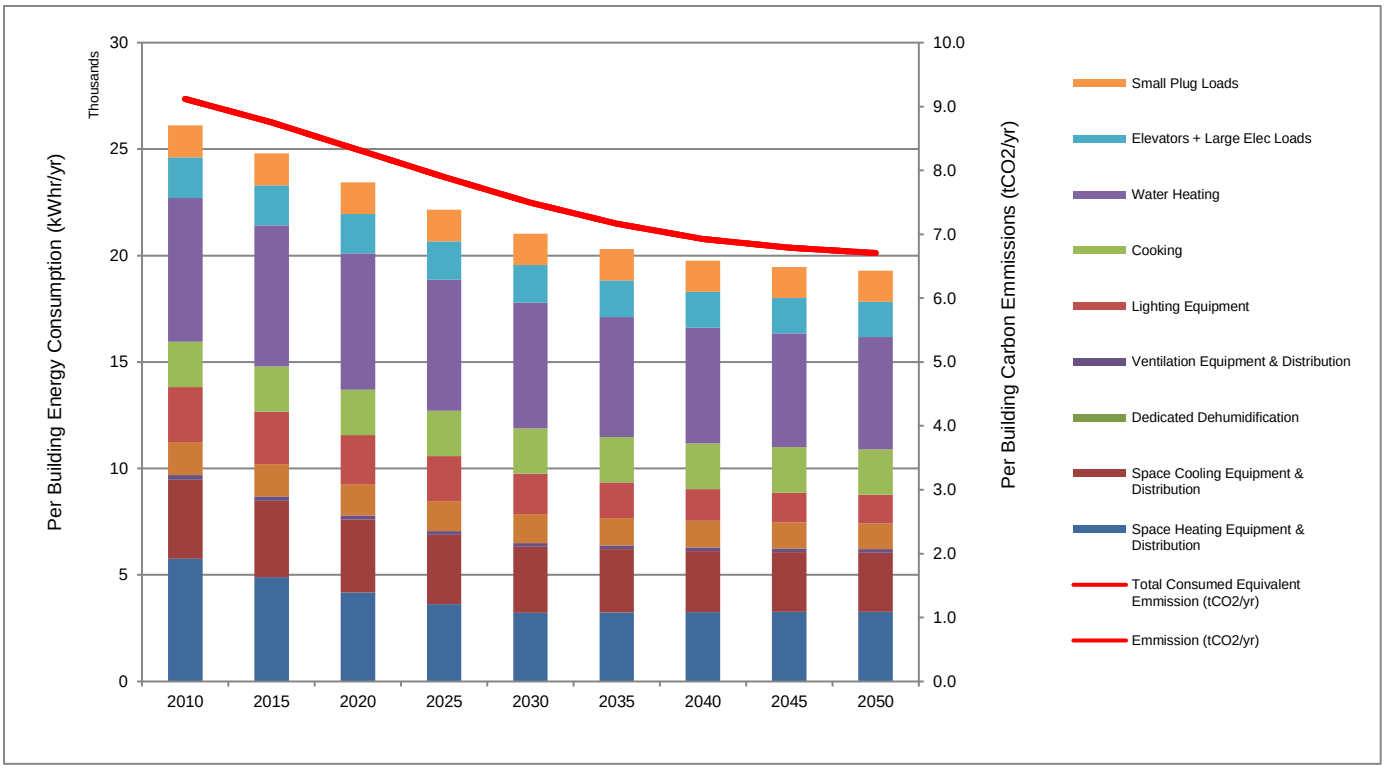

Figure 0-7: Multi-Family Attached Business as Usual: Owner-Occupier

Owners faced with the split incentive (a.k.a. principal-agent) case will find no energy efficiency investment opportunities that meet the 4 year BET hurdle. The model indicates that these owners will choose the lowest cost building configuration with allowable components. In this case, shown in Figure 0-8, the entire projected reduction in per building energy consumption of 14% is attributable to elimination of disallowed single pane windows and low R insulation from the building stock.

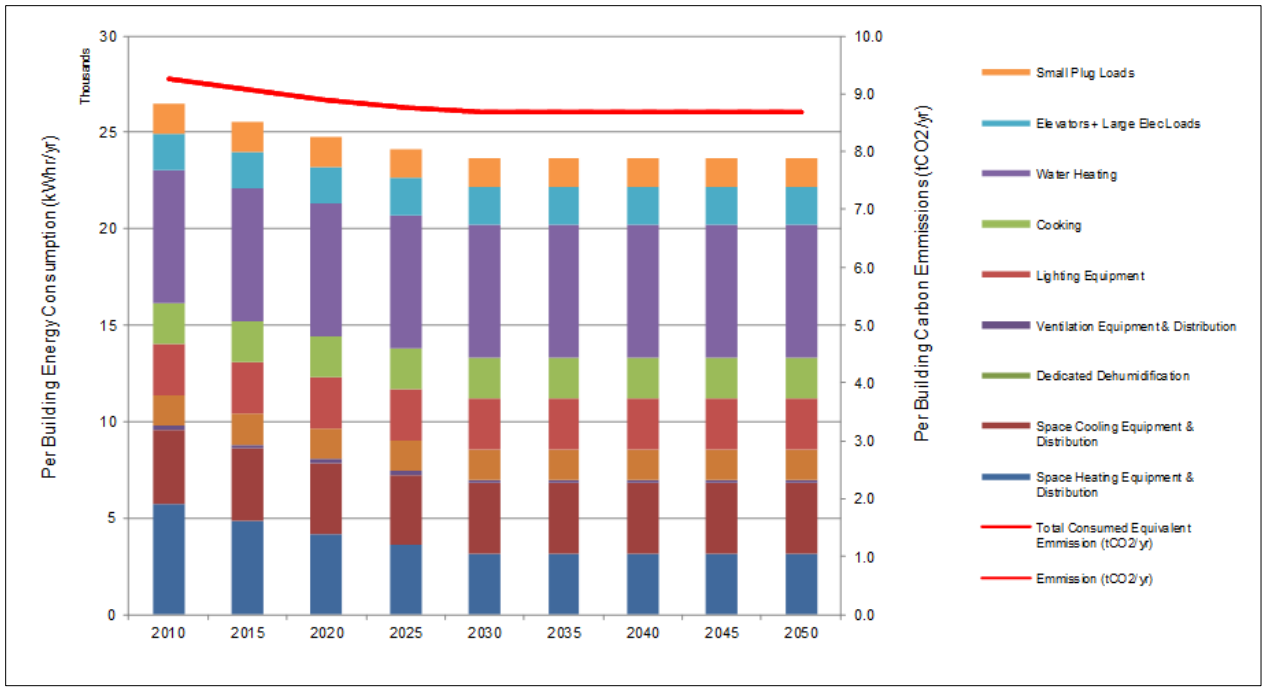

Figure 0-8: Multi-Family Attached Business as Usual: Split Incentive Case

A disclosure policy that is 50% effective in translating energy costs into rent differentials is projected to induce a significant improvement in energy efficiency relative to the split incentive case (25% vs. 14%) as shown in Figure 0-9. With this level of market feedback a number of ECMs, including more efficient boilers, more efficient AC window units, Energy Star appliances and LED lighting, clear the four year breakeven hurdle. Since their cost advantage is not as great, we see lower share for these ECMs than in the owner-occupier case.

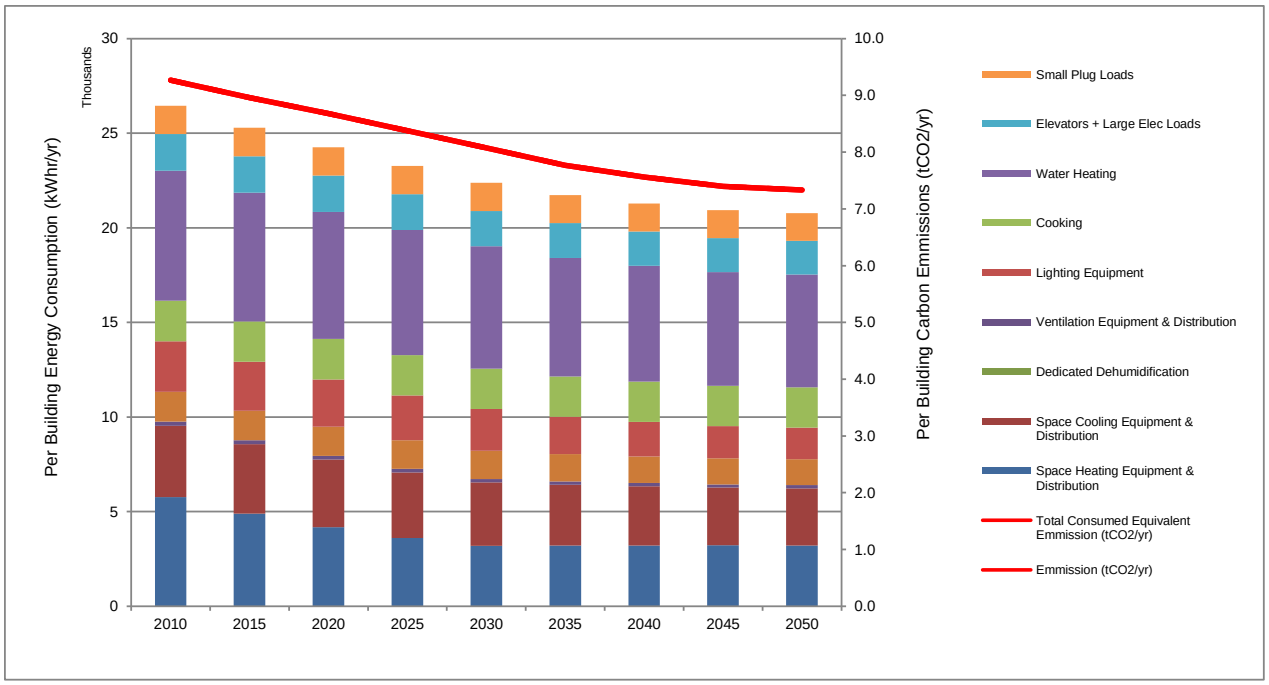

Figure 0-9 Multi-Family Attached 50% Effective Disclosure

When a 50% effective disclosure policy is combined with on-bill financing, the average building energy reduction is slightly superior to the owner-occupier case (31% vs. 30%) as shown in Figure 0-10. It should be noted that the annual savings for some of the configurations indicated for selection by the model yield relatively modest annual savings for the building owner. Actual results would probably be less favorable than indicated if the on-bill financing process entailed non-trivial transaction costs.

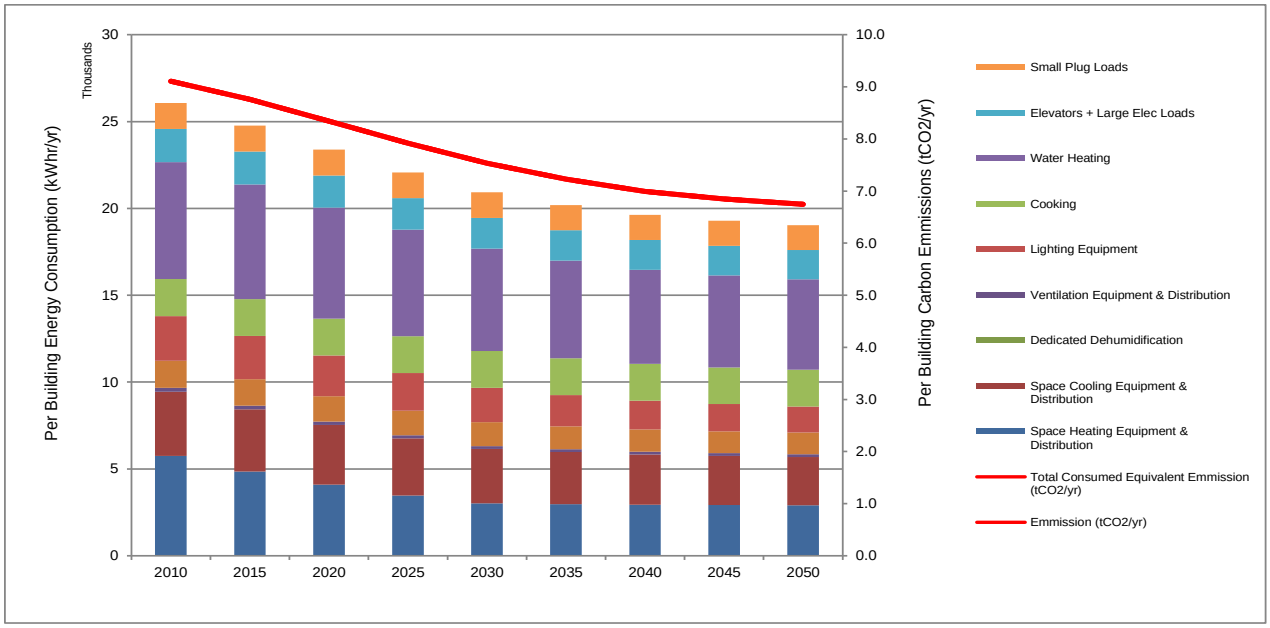

Figure 0-10 Multi-Family Attached On-Bill Financing with 50% Effective Disclosure

External Publications

The additions of disclosure and on-bill financing to the Market Model was submitted and accepted to CLIMA 2013, Prague, Czech Republic, under the title Taylor et al., *The Simulation of Long Term Trends in Building Energy Consumption Due to the Impact of Market-Based Policies to Encourage Adoption of Energy Conservation Measures*. Three abstracts have been prepared for FutureBuild 2013, University of Bath, UK, documenting the analysis of the multifamily housing segment and the application of new policy scenarios to this segment using the Market Model. Additional abstract submissions are likely to the ACEEE Behavior, Energy, and Climate Conference to be held in Sacramento in November, as well as presentations on the Market Model within the context of the Hub's participation at GreenBuild 2013 to be held in Philadelphia in late November.

Planned Work for BP3

In BP3, the UTRC team plans to expand the Market Model to cover at least one more building submarket and additional policy scenarios as defined in consultation with other Hub subtasks and external policy making bodies. The next building segment will be defined based on the availability of data, the relative contribution to regional energy consumption, in addition to the requirements of the Hub. The team will work with the Metrics and Policy subtasks to select the submarket with the largest marginal impact in relation to Hub performance and policy objectives.

Table 0-2 below shows the policy measures that will be implemented in the Market Model in BP3. This list will be supplemented by additional policies that will be identified during the year through interactions with the policy subtasks in addition to other external entities.

1	Tax Abatement	Indicates market response to tax abatement on building improvements	Proposed PHL tax abatement policy	First pass coded BP2 – need to validate approach
2	Energy Price Feedback	Indicates market response to lower energy costs (potentially as the result of previous ECM adoption)	Energy prices/elasticities for natural gas, electricity, coal, etc.	Planned for BP3
3	Environmental impact	Indicates market response to stakeholder value placed on environmental impact (i.e. emissions and water impact)	Price/tax on emissions and/or decision maker value on environmental impact	Coordinated research with other 6.3 collaborators in BP2. Implementation planned effort for BP3
4	Accounting for Productivity	Indicates market response to improvements n productivity resulting from use of certain ECMs (e.g. lighting)	Employee compensation and revenue generation; productivity gains from ECM adoption	Coordinated research with other 6.3 collaborators in BP2. Implementation planned effort for BP3

Table 0-2: BP3 Market Model Planned Policy Measures