Built Smart Program Multifamily New Construction Impact Evaluation

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2008

Seattle City Light

Seattle City Light
Built Smart Program
Impact Evaluation

Seattle City Light

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March 2008

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Prepared by the City of Seattle — Seattle City Light Department

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Debra Tachibana (Seattle City Light), Bing Tso and Jeffrey Romberger (SBW Consulting, Inc.).

"Multifamily New Construction: Utility Program Leads the Way

Toward Changing Building Practice and Energy Codes."

In Proceedings of the American Council for an Energy-Efficient Economy

2008 Summer Study on Energy Efficiency in Buildings, Pacific Grove, CA (pp. 2.315–2.326).

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Multifamily New Construction: Utility Program Leads the Way Toward Changing Building Practice and Energy Codes 71

Debra Tachibana, Seattle City Light Bing Tso & Jeffrey Romberger, SBW Consulting, Inc. 71

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Built Smart Program Impact Evaluation

Investigating the Energy Impacts of the Built Smart Program in Multifamily Units

Executive Summary

Introduction

Seattle City Light (SCL), through their Built Smart program, provides financial incentives to encourage multifamily building developers to upgrade the efficiency of their new buildings in SCL's service area through rigorously-inspected building envelopes, efficient lighting fixtures, high-efficiency domestic water heaters, and whole house fans. SCL's current estimates of energy savings from these measures are based on an impact evaluation completed in 1996. These estimates have been adjusted over time to reflect changes in the state energy code and standard practice. Nonetheless, neither SCL nor the Regional Technical Forum feel comfortable with these savings estimates, given the time that has elapsed since the original research was performed. As a result, SCL has conducted a new program impact evaluation to measure the effect directly. This report documents the objectives, methodology, and results of the evaluation.

The evaluation contractor, SBW Consulting, Inc. (SBW), investigated program energy impacts using typical energy program evaluation methods, including the review of program, billing, and characteristics data for a sample of participants, as well as a similar review for a sample of non-participants. These formed the basis for developing separate participant and non-participant energy simulation models, which were calibrated to utility billing records. This process provided the best available estimate of the total program energy impacts. To the extent possible, the total savings were further broken down according to program measures and actions.

Objectives

The primary objectives of this study were as follows.

1. *Determine Program Participant Characteristics. Prepare a calibrated participant prototype using energy simulation software. Use this prototype to determine the as-built energy consumption characteristics of new multifamily buildings that represent the population of recent (2002-2004) program participants.*

2. *Determine Non-participant Characteristics. Prepare a calibrated non-participant prototype using energy simulation software. Use this prototype to determine the as-built energy consumption characteristics of new multifamily buildings that represent the population of non-participants that were built at the same time as the participants. These non-participants are selected from the Puget Sound Energy (PSE) customer base in East King County.*
3. *Establish Baseline Characteristics. Determine the baseline energy consumption characteristics of participants, excluding the provisions of the Built Smart program. Modify the calibrated participant prototype simulation using parameters from the calibrated non-participant prototype.*
4. *Estimate Energy Savings. Determine the energy savings associated with the provisions of the Built Smart program, computed as the difference between participant and baseline models under typical meteorological conditions and full occupancy. Develop savings estimates for specific program measures as well as for building commissioning provisions.*

Methodology

Data Collection and Analysis

Sampled Building Characteristics: SCL compiled customer data on the population of multifamily buildings that participated in the Built Smart program during the period of interest. This included available characteristics data, billing records, and relevant project file information. To limit the scope of the study, townhomes were not included as study candidates, nor were high-rises, gas heated residences, complexes of less than eight units, and buildings lacking a non-residential first floor. From the sample frame, SCL and SBW selected thirteen participant buildings, most of which had laundry facilities in the units. We attempted to find eligible non-participant buildings in the SCL service area. This proved impossible, so SCL and SBW worked with Puget Sound Energy (PSE) to select suitable non-participants outside of the SCL service area. After an extensive screening process, we reduced the non-participant list to ten sites in Bellevue and Kirkland, Washington.

SBW then collected detailed participant and non-participant characteristics data from SCL project files, design documents available from municipal governments, and building site visits or drive-by observations. Key data included number of floors, type of wall construction, type of water heating for each building, as well as average conditioned floor and wall area, and installed wattage for each housing unit and common area zone. We used this information to develop inputs to the participant and non-participant models.

Electric Usage Data: SCL and PSE provided monthly or bimonthly electric billing records for all occupied housing units in the participant and non-participant samples, respectively. We also used supplemental electric load data to help inform the modeling effort. These data included hourly loads for constructing typical infiltration, internal load and thermostat set-point schedules, and for non-participants, daily kWh totals and 15-minute kW interval data. After summarizing and cleaning these data, we obtained useful insights into day-types, and variations in use between weekdays and weekends, and diurnal patterns of non-heat consumption. We also developed average Energy Use Indices (EUIs) for participants and non-participants to serve as calibration targets during modeling.

Weather: SBW obtained TMY (typical meteorological year) and actual weather data for the model calibration period (calendar year 2006) from the National Climatic Data Center weather station at SeaTac. These data were used in the eQUEST energy simulation model.

Building Inspection Practices: SBW conducted telephone interviews to determine how builders install insulation and other related building envelope components, how rigorously they achieve air sealing, and how differences in the level of enforcement of the energy code between jurisdictions affects how builders install insulation and other related building envelope components. We recorded interview responses in a database, and then analyzed the results. We also compared these results with building characteristics data and billing records to develop synthesized findings and recommendations.

Participant and Non-Participant Model Development

SBW developed one fully calibrated participant prototype model using eQUEST hourly simulation software. The prototype reflected the as-built conditions of the predominant participant building type, which included buildings containing primarily one- and two-bedroom housing units that had laundry facilities in the units. We assumed full occupancy throughout. We compared the monthly energy use predicted by the model with actual billing data, and adjusted the simulation until the predicted whole building EUI was within 10% of the monthly target values and 5% of the annual target value. We then modified the as-built model to reflect measure participation levels for optional measures, and reran the model under TMY weather conditions.

We developed the non-participant model in a very similar way, with the additional step of incorporating summaries of daily and 15-minute kW data to adjust the model.

Baseline Model Development

SBW compiled the non-participant model inputs associated with the features of the Built Smart program. We then reran the modified as-built participant model simulation, changing the inputs associated with the Built Smart features to the non-participant values for all envelope components and lighting power densities. This created a baseline model that simulated the performance of the participant model without the influence of the Built Smart program.

Analysis of Program Energy Savings

We computed energy savings as the difference between participant and baseline models under TMY weather and full tenant occupancy conditions. The specific program measures evaluated for energy savings impact included:

- Option I (<12% glazing ratio) & Option II (12-15% glazing ratio) envelopes
- Common area, in-unit, and exterior lighting
- Hot water heaters
- Whole house fans
- Enhanced envelope specification and inspection process

We modeled the two envelope measures by adjusting the participant models to include only the envelope differences. We then estimated savings for the other measures by adjusting the Option I envelope model to include each measure sequentially, in a "rolling baseline" fashion. To estimate the nominal effect of non-envelope measures such as lighting and hot water heaters, we performed hand calculations to inform the models, as necessary.

Findings

Sample Characterization

SCL developed a list of 72 buildings that participated in Built Smart in 2003-2004. Many buildings were eliminated from the study sample because of they were built under previous codes, or because their style or construction was inappropriate for the study. The 13 participant projects selected consisted of seven residences with in-unit laundries and six with common area laundries). Across these projects, 81% of the residence units had in-unit laundries. These included several large complexes with over 160 units each.

To select non-participants, SCL identified 93 buildings constructed outside of Seattle in King County between 2002 and 2004. We eliminated 72 of these because their style or construction was inappropriate for this study. After further review of billing data and available documentation, we selected a final sample of 10 projects, all of which had in-unit laundries.

Nine of the sampled participant buildings had Option I envelopes, while four had Option II envelopes. About a third of the participating buildings also incorporated efficient lighting and whole house fan measures into the Built Smart project. Nearly half of the buildings installed efficient water heaters.

Building Characteristics

The average sizes of participant and non-participant dwelling units were 777 and 825 sq. ft., respectively, based on our assessment of 673 participant units and 834 non-participant units. We also observed that:

- Use of the Option II building envelope was limited within the participant sample.
- Component U-values for participants were uniformly lower (more efficient) than corresponding values for non-participants.
- Attic ceiling construction was not present in Option II and non-participant buildings.
- Participants' domestic hot water heaters were only a slight improvement over baseline.
- Lighting measures reduced interior lighting power densities significantly.

Billed and Modeled Energy Use

Billing data revealed that for sampled participants, the average EUI was 6.65 kWh/sq.ft./year, while for non-participants, it was 7.64 kWh/sq.ft./year. Expressed in percentages, participants used 13% less on average than non-participants in 2006, unadjusted for any mitigating factors.

We successfully calibrated both models within the target values of ±10% of each month and ±5% overall. In fact, simulated annual consumption for both models was within ±0.6% of the annual target. The final estimate of typical annual consumption for the participant and baseline prototypes was 6.68 kWh/sq.ft./year and 7.36 kWh/sq.ft./year, respectively.

Energy Savings

As expected, estimated annual baseline usage is greater in the baseline case than it is for participants. The difference of 0.70 kWh/sq.ft./year represents overall gross savings of nearly 10%. Applied across all participants with in-unit laundries, the absolute average unit savings from the Built Smart program is 621 kWh/year/unit. It is important to keep in mind that because of the sensitivity of energy models outputs to particular input parameters, as well as the small differences between participants and non-participants that produce differences in energy use, a fair amount of uncertainty exists around these point estimates of savings.

By comparison, evaluated savings from the predecessor SuperGoodCents Program for complexes with in-unit laundries were 1.43 and 1.57 kWh/sq.ft./year for Tier 1 shell measures and lighting add-on provisions, respectively, for a total of 3.0 kWh/sq.ft./year. The latter represents 23% of the baseline consumption of 13.26 kWh/sq.ft./year. The current estimate of Built Smart savings represents 23% of the original savings estimates for SuperGoodCents.

Table 1 below disaggregates these savings by individual measures. It is important to realize in this table that the reported results are normalized across all program participants in the sample, not just those affected by the particular measure. So, for example, Option II envelope savings appear much lower than Option I envelope savings, not because Option II envelopes are much less efficient than Option I ones, but because we found Option II among a mere 7% of the sampled participants.

These results indicate that 64% of the gross savings from the Built Smart program comes from lighting measures. This is particularly notable since not all participants implemented lighting measures since they were optional (envelope measures, by contrast, were mandatory under program rules). This also contrasts with the previous SuperGoodCents results, which showed that lighting and envelope measure savings were nearly equal. Most of the savings for the Built Smart lighting measures is found in the common area lighting, since it is operated 24 hours per day.

Table 1: Evaluated Measure Savings

Measure*	Annual EUI (kWh/ft2/year)	Difference in EUI (kWh/ft2/year)	Annual savings (kWh/year)**	% of total savings	% of model represented in sample
[Baseline]	7.36	n/a	n/a	n/a	
Option I envelope	7.13	0.22	200	31%	93%
Option II envelope	7.12	0.01	11	2%	7%
In-unit lighting	7.04	0.08	71	11%	66%
Common area lighting	6.69	0.35	313	51%	59%
Exterior lighting	6.68	0.01	9	2%	91%
Domestic hot water heaters	6.66	0.02	17	3%	67%
Whole-house fans***	6.66	0.00	-	0%	62%
Enhanced inspection***	6.66	0.00	-	0%	100%
ALL		**0.70**	**621**	**100%**	

* Savings from each measure are normalized across floor area for all in-unit laundry program participants, not just for measure-affected floor area.

** Savings per living unit averaged across all in-unit laundry participants.

*** Savings from these measures was assumed to be negligible and/or unquantifiable, and so were not analyzed.

Building Inspection Practices

To aid in study design and interpretation of study results, during the data collection phase SBW conducted telephone interviews with 12 individuals involved in the construction of multifamily buildings not participating in the Built Smart program. These included two general contractors, four insulation subcontractors, and six building inspectors. The subset of insulation contractors we interviewed represented a significant fraction of the pool of contractors in the area for this kind of work. The purpose of the interviews was to determine how builders install insulation and other related building envelope components, how rigorously they achieve air sealing, and how differences in the level of enforcement of the energy code between jurisdictions affects how builders install insulation and other related building envelope components. The consensus was that compliance with the insulation and air sealing requirements in the Washington State Energy Code is generally better in municipal jurisdictions and more lax in the unincorporated areas. It appears many of the municipalities in the Puget Sound region achieve a reasonable level of compliance with the code while a few, e.g., Bellevue and Seattle's Built Smart, appear to achieve a more rigorous standard for code compliance.

The non-participants in the study sample were constructed in either the Bellevue or Kirkland jurisdictions. Based on the interviews, each jurisdiction appears to have different levels of thermal performance based on the integrity of insulation and air sealing practices. This might suggest that two non-participant models might have been appropriate—one for Bellevue, representing installation practices equivalent to Built Smart installation practices, and one for Kirkland representing non-participant Seattle buildings.

Quantitative analysis of the building data, however, did not offer any evidence that such a difference exists. The 2006 electric usage indices (EUI) for sampled buildings in Bellevue is about 9% higher than the Kirkland one, despite the suggestion during the interviews that

Bellevue inspections are more rigorous. Differences, if any, in energy usage because of inspection-related envelope differences are masked by other, more significant differences in building geometry and glazing. In addition, the normal variation between inspectors and contractors, coupled with the relatively small sample sizes, may obscure the effect even further. SBW therefore concluded that developing separate non-participant models to capture the inspection effect would be fruitless.

Conclusions

Based on the findings of this study, we offer these key conclusions:

> *Reduced overall electric usage among multifamily residential tenants, combined with lower percentage savings from Built Smart measures, has significantly reduced program savings, compared to Super Good Cents program of 10 years ago. This reduction very likely indicates the eventual success that multifamily new construction programs have had in transforming the marketplace in the Seattle area which drives energy codes to more conserving levels. This success, ironically, may pose challenges for future SCL programs of this type.*

The evaluated average Built Smart baseline usage is 37% less that the baseline calculated a decade ago for SuperGoodCents. While the overall Built Smart energy savings represents nearly 10% savings over current baseline, this value is much smaller than the SuperGoodCents finding of 23% savings over the previous baseline. The end result is that the Built Smart savings of 0.70 kWh/sq.ft./year (621 kWh/year per unit) only accounts for 23% of the 3.0 kWh/sq.ft./year savings that SuperGoodCents provided.

Both the reduced baseline usage and the smaller difference between participants and non-participants suggest that overall, multifamily new construction projects in the greater Seattle area are becoming much more energy efficient. We surmise that a combination of tighter building codes, improved building designs, and increased public awareness of efficiency may have much to do with this welcome development. It is highly likely that programs such as SuperGoodCents and Built Smart have been instrumental in effecting these improvements to the marketplace over the many years they have been in existence.

Looking forward, SCL might consider additional measures to enhance their portfolio of existing measures. Some possibilities might include efficient appliances beyond clothes washers, such as refrigerators and dishwashers that meet or exceed Energy Star[1] guidelines. Others might include combined water- and energy-saving measures, such as low-flow faucet aerators and showerheads. These fixtures likely would have to be installed after plumbers had installed the stock fixtures, but before tenants moved in.

> *Interior lighting measures yield the preponderance of savings in the program, suggesting a sustained program emphasis on these measures is warranted.*

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[1] Energy Star is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy that promotes energy efficient products and practices. Rated appliances meet strict energy efficiency guidelines set by these agencies.

Using the Washington State Energy Code as the baseline, savings from interior (in-unit and common area) lighting measures comprise nearly two-thirds of the gross savings from the Built Smart program. By comparison, just over half of gross savings came from lighting measures in the SuperGoodCents program a decade earlier. This occurs even though not all participants implemented lighting measures, since they were optional, while envelope measures were mandatory under program rules. Most of the savings for the lighting measures is found in the common area lighting, since it is operated 24 hours per day. Nonetheless, Built Smart lighting savings are only 28% of SuperGoodCents lighting savings, due to more stringent current baseline conditions.

The high percentage of savings from lighting measures, in the current program, as well as the relatively ease with which they can be implemented, suggests that future programs might continue to emphasize straightforward lighting measures. As with the low-rise mixed-use electrically-heated buildings included in this study, Built Smart is spurring on lighting efficiency improvements in other related building types, such as high-rise multifamily buildings with natural gas space heat.

To confirm that lighting measures are cost-effective, however, SCL should consider performing additional work to verify actual baseline interior lighting conditions. Onsite visits of non-participant buildings from this study could determine whether the installed lighting falls short of code, meets code, or exceeds it. Such results could establish credible estimates of savings to expect in the future. These onsite visits could be extended to other non-participants, such as buildings currently under construction, as well as buildings that fell outside the scope of this study, such as high-rise steel-frame residences and townhomes. Assessing baseline conditions is particularly relevant, since the 2007 Seattle Energy Code calls for common-area lighting power densities (LPDs) of 0.8 watts per square foot. This more aggressive target is still higher than program participant LPDs, but will reduce the potential savings that the program will be able to claim.

> *Exterior lighting measures yielded minimal savings, since standard practice appears to be at or near program thresholds.*

With average unit savings of 8 kWh/sq.ft./year, exterior lighting measures make up a negligible 2% of program savings. It appears that standard practice for this lighting—installing compact fluorescent lamps in fixtures with photocell control—is fast approaching program requirements, severely limiting opportunities for the program to achieve savings in this realm.

> *Energy savings from Built Smart's enhanced building inspections and commissioning appear to be negligible overall when compared to other jurisdictions with rigorous building inspections. These savings remain potentially valid in concept, but it will require alternative approaches to ascertain their value.*

Interview research for this study provided anecdotal evidence that different areas of the Puget Sound region may have different levels of envelope thermal performance based on the integrity of insulation and air sealing practices. For example, relevant construction practices may be more rigorous in Seattle and Bellevue because of building inspector influence than in other municipalities. However, the quantitative analysis did not offer any evidence that such a difference exists between Seattle program participant buildings and non-participant buildings in Bellevue and Kirkland. It is possible that more significant differences, such as in

building geometry and glazing, or between inspectors and contractors, are masking the inspection differences.

SCL might consider other options for future study to quantify or frame the question of the value and effects of enhanced inspections. One method might be "inspections of the inspections," in which an impartial third party accompanied Built Smart staff, observed actual deficiencies, and based estimates of energy impacts on these observations. Such an approach, unfortunately, would likely be expensive and intrusive, and yield biased results. Another option might be to prove the hypothesis that enhanced inspections are cost-effective. This might be approached by first estimating the incremental cost to the program of these inspections, then assessing the minimum savings that inspections must provide to make the investment cost-effective. If the minimum savings seems plausible given the evidence at hand, then one could conclude that inspections are cost-effective. A third, and perhaps the most direct and effective approach, would be to repeat this study with nonparticipants drawn from unincorporated areas of King County, where there are no multifamily new construction programs, and building departments that place little emphasis on State energy code enforcement.

Built Smart Program Impact Evaluation

Investigating the Energy Impacts of the Built Smart Program in Multifamily Units

Introduction

The Seattle City Light (SCL) Built Smart program provides financial incentives to encourage multifamily building developers to upgrade the efficiency of their new buildings. The program measures include:

- Rigorously-inspected building envelopes (walls, ceiling, floors, doors, and windows) whose insulating value exceeds code;
- Efficient lighting fixtures in common areas, units, and building exteriors;
- High-efficiency domestic water heaters; and
- Whole house fan controls.

SCL's current estimates of energy savings from these measures are based on an impact evaluation completed in 1996. These estimates have been adjusted over time based on updated modeling of individual measures assuming more current baseline conditions, including changes to the state energy code and standard practice. The estimate of the program's net effect on energy consumption beyond the modeled measures has been halved compared to that identified in the 1996 impact evaluation. However, given the amount of time since the original evaluation was completed, the utility is no longer comfortable with its estimate of the program's net energy savings impacts. The Regional Technical Forum recently refused to endorse SCL's estimates and recommended that a new program impact evaluation be conducted to measure the effect directly. This study was intended to achieve that objective.

This report documents how SBW Consulting, Inc. (SBW) investigated the energy impacts of provisions of the Built Smart Program on new construction multifamily buildings in the SCL service area. This effort used typical energy program evaluation methods, including the review of data from utility program records, analysis of electricity consumption histories, collection of characteristics data, analysis of load data collected from previous research, preparation of weather data, selection of representative participant[2] and non-participant[3]

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[2] *Participants* are defined as multifamily buildings in the Seattle City Light service area constructed during 2002-2004, viz., "vested" projects with permit applications submitted after July 1, 2002 and Built Smart project completed by December 31, 2004, excluding townhome and high-rise projects.

buildings, prototype development, prototype calibration to billing data, calculation of energy impacts from the Built Smart program, and documentation of the study methodology and results. The method included the development of separate participant and non-participant energy simulation models and calibration to utility billing records. This process provided the best available estimate of the total program energy impacts. To the extent possible, the total savings were further broken down into savings associated with the physical program measures and savings associated with the building commissioning / diligent specification-and-inspection process.

Objectives

The following are the primary objectives of this study.

1. *Determine Program Participant Characteristics. Prepare a calibrated participant prototype using energy simulation software. Use this prototype to determine the as-built energy consumption characteristics of new multifamily buildings that represent the population of recent (2002-2004) program participants.*
2. *Determine Non-participant Characteristics. Prepare a calibrated non-participant prototype using energy simulation software. Use this prototype to determine the as-built energy consumption characteristics of new multifamily buildings that represent the population of non-participants that were built at the same time as the participants. These non-participants are selected from the Puget Sound Energy (PSE) customer base in East King County.*
3. *Establish Baseline Characteristics. Determine the baseline energy consumption characteristics of participants, excluding the provisions of the Built Smart program. Modify the calibrated participant prototype simulation using parameters from the calibrated non-participant prototype.*
4. *Estimate Energy Savings. Determine the energy savings associated with the provisions of the Built Smart program, computed as the difference between participant and baseline models under typical meteorological conditions and full occupancy. Develop savings estimates for specific program measures as well as for building commissioning provisions.*

[3] *Non-participants* are defined as multifamily buildings constructed in nearby neighboring utility service areas, such as Puget Sound Energy, during 2002-2004: viz., "vested" projects with permit applications submitted after July 1, 2002 and construction completed by December 31, 2004, excluding townhome and high-rise projects. Projects permitted prior to this period are acceptable, so long as their permitted envelope construction is consistent with 2002-2004 Washington State Energy Code requirements.

Methodology

This section describes the methodology for selecting and analyzing the sample of participant and non-participant multifamily buildings. This methodology first involved screening appropriate buildings, then collecting building characteristics, load, billing, and weather data associated with these buildings. In addition, SBW interviewed key building inspectors and contractors to better define the non-participant/baseline characteristics. Next, we developed two eQUEST prototype building models that represented aggregate participant and non-participant characteristics. These models formed the basis for a simulation-based analysis of energy savings. These various steps are discussed in more detail below.

Data Collection

Sampled Building Characteristics

To prepare for the study, SCL compiled customer data on the population of multifamily buildings that participated in the Built Smart program during the period of interest. This included available characteristics data, billing records, and relevant project file information. To limit the scope of the study, townhomes were not included as study candidates. Additionally, we excluded high-rises, gas heated residences, complexes of less than eight units, and buildings lacking a non-residential first floor from the study. From the sample frame, SCL and SBW concluded that thirteen participant buildings should be included in the sample for the analysis of the program energy savings. Table 9 in the appendix provides further details of the participant selection process.

The participant prototype reflected the as-built conditions of the predominant participant building type, which included buildings containing primarily one- and two-bedroom housing units that had laundry facilities in the units. This included four buildings that participated under the Option I provision of the program and two buildings that participated under Option II[4]. The seven participant buildings with common laundries provided useful data and modeling results that, used in conjunction with results from the 1996 Super Good Cents evaluation, permitted us to estimate savings for the common laundry program participants.

We applied a similar process to determine if eligible non-participant buildings could be found in the SCL service area. SCL queried an extract of permit applications for “R-1” occupancy, obtained from the Seattle Department of Planning and Development for projects receiving permits during the period of interest. The identified buildings were then compared with program participation records. From this analysis, SCL and SBW concluded that eligible non-participants could not be found in the SCL service area because during the period of interest, all but one of the new non-townhome, non-high-rise multifamily buildings participated in the Built Smart program. Table 10 in the appendix provides further details of the screening process for Seattle non-participants.

[4] The program defines the difference between Option I and Option II according to the maximum allowable window-to-floor-area percentage. This percentage is 12% for Option I, and 15% for Option II.

Consequently, SCL and SBW worked with Puget Sound Energy (PSE) to select suitable non-participants outside of the SCL service area. SCL queried a real estate database[5] to obtain listings of projects built during the period of interest in King County localities outside of the SCL service area. SBW reviewed available data for more than 90 multifamily complexes that were non-participant candidates. In some cases, we augmented this review with additional information obtained from web searches, phone calls, and drive-by inspections. SBW then applied a series of screening criteria to develop a short list of 14 buildings from this list that were similar to the participants except for their participation in the program. To simplify data collection, we limited the final non-participant list to the ten sites from Bellevue and Kirkland, reducing the non-participant sample to ten buildings. Table 11 in the appendix provides further details of the selection process for King County non-participants.

Using standardized forms and procedures (provided in Tables 14 and 15 in the appendix), SBW collected detailed participant characteristics data from SCL project files, design documents available from the Seattle Department of Planning and Development (DPD), and building site visits or drive-by observations. Similarly, SBW collected non-participant characteristics data from the public records of the corresponding agencies in Bellevue and Kirkland and from building site visits and drive-by observations. The building summary form was used to collect building level details, such as number of floors, type of wall construction, type of water heating. The zone summary form was used to collect details by space type, such as average conditioned floor and wall area, and installed wattage for each housing unit and common area zone. We used this data to develop inputs to the participant and non-participant models.

Electric Loads

Electric load data relevant to this study consisted of the following three varieties:

1. Hourly load data collected by the Bonneville Power Administration Multifamily Metering Study to construct typical infiltration, internal load (lighting and equipment) and thermostat set-point schedules.

2. For non-participants, PSE provided daily kWh totals for the calibration period. Daily use data provided useful insights into day-types and variations in use between weekdays and weekends.

3. For non-participants, PSE provided 15-minute average kW interval data, at units where it is available, for a one-month period beginning in June 2007. Very little heating was in use during this time period due to warm weather, so operational patterns for the heating system was not observable. However, it did provide useful insight into diurnal patterns of non-heat consumption.

[5] MetroScan™, version 3.7.0, © 1994-2005 First American Real Estate Solutions, L.P. The search criteria selected projects inside King County, outside the Jurisdiction of Seattle, with Land Use of Residential Apartment or Condominium, built in 2002-2004. These criteria identified 93 apartment complexes as candidates for further screening.

..... Billing

SCL and PSE provided monthly or bimonthly electric billing records for all occupied housing units in the participant and non-participant samples, respectively. These records were in electronic form, and generally spanned the calibration period.

..... Weather

SBW obtained TMY (typical meteorological year) and actual weather data for the model calibration period from the National Climatic Data Center weather station at SeaTac. Based on the billing data available, we used the period from January 2006 to December 2006 to calibrate billed electrical use against model output for both participants and non-participants.

..... Building Inspection Practices

SBW conducted telephone interviews to determine how builders install insulation and other related building envelope components, how rigorously they achieve air sealing, and how differences in the level of enforcement of the energy code between jurisdictions affects how builders install insulation and other related building envelope components. We developed a list of general contractors and insulation subcontractors associated with the projects in the participant and non-participant sample frames. In addition, SBW developed a list of building inspectors with Energy Code enforcement responsibilities in the government jurisdictions of the sample frame projects (i.e., Cities of Bellevue, Kirkland, and Seattle). SBW also developed separate telephone interview instruments for building inspectors, general contractors, and insulation contractors. To encourage candid responses from the interview participants, the interview protocol was designed to be conversational in tone, open-ended and confidential. The participants were asked to expand on their responses to generate as much anecdotal information as possible. The interviews were not conducted in a rigidly structured fashion. The three sets of interview questions can be found in the appendix. SBW consulted with SCL on how best to apportion the interviews among inspectors and contractors.

Data Analysis

SBW analyzed five data sources in preparation for model calibration. Building simulation analyses were conducted using eQUEST® Version 3-6 software[6] powered by DOE-2. The

[6] eQUEST® is a sophisticated, yet easy to use, freeware building energy use analysis tool that provides professional-level results with an affordable level of effort. eQUEST was designed to allow detailed comparative analysis of building designs and technologies by applying sophisticated building energy use simulation techniques but without requiring extensive experience in the "art" of building performance modeling. This is accomplished by combining schematic and design development building creation wizards, an energy efficiency measure (EEM) wizard and a graphical results display module with a complete up-to-date DOE-2 (version 2.2) building energy use simulation program. eQUEST is supported as a part of the Energy Design Resources program that is funded by California utility customers and administered by Pacific Gas and Electric, San Diego Gas & Electric, Southern California Edison, Southern California Gas under the auspices of the California Public Utilities Commission as well as the Sacramento Municipal Utilities District. In 2001-2002 Seattle City Light sponsored enhancements to add multifamily building prototypes and construction parameters to the basic eQUEST freeware tool.

latter is the preeminent energy simulation tool in the U.S. These analyses are described in more detail below.

..... Building Characteristics

The envelope component data collected from the plans were used to compute U-values for each type of wall, floor, and ceiling for each participant and non-participant building. Applying these the building square footages, we analyzed unit-level UA data (where UA is the coefficient of heat transmission for a given area) to determine appropriate dwelling unit types for use in the participant and non-participant prototypes.

..... Building Inspection Practices

SBW recorded building inspection interview responses in a database, and then analyzed the results. We also compared these results with building characteristics data and billing records to develop synthesized findings and recommendations. These recommendations included whether or not to incorporate the findings in the non-participant model development.

..... Billing

SBW analyzed SCL- and PSE-supplied billing records for housing units in the participant and non-participant samples. The analysis included “calendarizing” the billing records so usage corresponded to calendar months, as well as examining outliers and periods of high or low usage, then determining their disposition. Vacant units were removed from the analysis. SBW calculated Energy Use Indices (EUIs) for each type of apartment considered during prototype development. The unit-level EUIs were aggregated to whole building EUI values for each of the prototypes. Whole building EUIs were prepared for each month in the calibration period. EUIs were prepared for both the housing units and the common area. We also summarized PSE automated meter read (AMR) data to prepare load profiles and other useful data summaries.

..... Electric Loads

SBW analyzed and applied hourly load data collected by the BPA Multifamily Metering Study to construct typical infiltration, internal load (lighting and equipment) and thermostat set-point schedules for the eQUEST participant and non-participant models. In addition, SBW summarized the PSE-provided daily kWh totals and 15-minute average kW interval data. These summaries helped us better understand typical daily and weekly load shapes for the modeled units. This understanding aided in the modeling and calibration process.

..... Weather

SBW converted the SeaTac TMY weather data into the binary file that the eQUEST energy simulation model required. SBW also adapted this file using actual hourly outdoor air dry bulb temperatures, wind speeds, and wind directions for 2006. This latter file was also converted into a binary file for model calibration.

Participant Model Development

SBW developed one fully calibrated participant prototype model using eQUEST hourly simulation software. The prototype reflected the as-built conditions of the predominant participant building type, which included buildings containing primarily one- and two-bedroom housing units that had laundry facilities in the units. This included four buildings that participated under the Option I provision of the program and two buildings that participated under Option II. The Option I and Option II building characteristic were input into the model and represented by separate thermal zones. This allowed determining savings for the two envelope features using the same model. The common areas were also addressed in the prototype. We also collected data for the buildings with common-area laundries, but because of scope constraints, we did not develop a calibrated model for them.

Inputs to the eQUEST simulation were prepared for the prototype using the characteristics data and load data collected and prepared in the previous steps. We prepared a separate set of inputs for each dwelling unit type.

We assumed full occupancy in preparing the infiltration, internal load, and thermostat set-point profiles for the prototype. After running the eQUEST model for the prototype, we compared the monthly whole building EUI predicted by the model with the monthly EUI target developed from actual billing data. We adjusted the simulation until the predicted whole building EUI was within 10% of the monthly target values and 5% of the annual target value.

We then prepared a modified as-built model for the prototype by rerunning the fully calibrated model under TMY weather conditions. Other modifications included adjusting common area lighting, exterior lighting, and in-unit lighting to reflect the average of the subset of sample participant buildings that participated in these optional program measures. This produced a model that fully represented the inclusion of these measures.

Non-participant Model Development

SBW developed one fully calibrated non-participant prototype model using eQUEST hourly simulation software. The prototype reflected the as-built conditions of the ten non-participant buildings with characteristics similar to the participant model sample buildings. This included buildings containing primarily one- and two-bedroom housing units that had laundry facilities in the units. The 10 sample buildings selected for inclusion in the model included buildings built in the cities of Bellevue and Kirkland. As with the participant model, both the housing units and the common areas were addressed in the prototype. Non-participant model development was similar to the participant model development.

Inputs to the eQUEST simulation were prepared for the prototype using the characteristics data and load data collected and prepared as described earlier in this report. We prepared a separate set of inputs for each dwelling unit type.

We assumed full occupancy in preparing the infiltration, internal load and thermostat set-point profiles for the prototype. After running the eQUEST model for the prototype, we compared the monthly whole building EUI predicted by the model with the monthly EUI target developed from actual billing data. We also examined summaries of the 15-minute billing data from Puget Sound Energy to develop energy use profiles for the non-participant

prototype. We adjusted the simulation until the predicted whole building EUI was within 10 percent of the target value on a monthly basis for the prototype.

Baseline Model Development

SBW compiled the non-participant model inputs associated with the features of the Built Smart program. We then reran the modified as-built participant model simulation, changing the inputs associated with the Built Smart features to the non-participant values for all envelope components and lighting power densities, with one exception.[7] This created a baseline model that simulated the performance of the participant model without the influence of the Built Smart program.

Analysis of Program Energy Savings

We computed energy savings as the difference between participant and baseline models under TMY weather and full tenant occupancy conditions. The total savings were further broken down, as much as was reasonable, into savings associated with the specific physical program measures, as well as the savings associated with the building commissioning / diligent specification-and-inspection process.

The specific program measures evaluated for energy savings impact were as follows:

- Option I Envelope – stipulated envelope requirements for buildings with window to floor area less than or equal to 12%. Details of the requirements, and how they compare to the building code, can be found in Table 2.

1. Option II Envelope – stipulated envelope requirements for buildings with window to floor area between 12% and 15%. Details of the requirements, and how they compare to the building code, can be found in Table 2.
2. Common Area Lighting – lighting power density less than or equal to 0.8 watt per square foot.
3. In-Unit Lighting – up to four fluorescent lighting fixtures per housing unit.
4. Exterior Lighting – fluorescent lighting with photocell controls.
5. Hot Water Heaters – energy efficiency factor of 0.91 or greater.
6. Whole House Fans – if whole house fans are installed, then timers must be installed and initially set to operate for at least 8 hour per day.
7. Enhanced Inspections – includes building component commissioning through a diligent specification and inspection process.

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[7] The sole exception was the window-to-floor area ratio for Option II zones. Because the non-participant projects had used a component performance compliance method instead of a prescriptive one, these buildings had a lower window-to-floor area ratio than corresponding participants. To avoid unwarranted negative savings, we adjusted to ratio to eliminate this effect.

We modeled the two envelope measures by adjusting the participant models (Option I model and Option II model) to include only the envelope differences. The models were run without the lighting, water heater and whole house fan differences, and then were compared to the baseline model. We estimated savings for the other measures by adjusting the "Option I envelope only model" to include each measure sequentially, thus creating additional models with the add-on measures. We compared each model against the previous model in a "rolling baseline" fashion to obtain savings for each measure.

To estimate the nominal effect of non-envelope measures, we performed hand calculations to inform the models, as necessary. These are summarized below.

- Lighting (common area, in-unit, exterior): Calculated lighting power densities (LPD) using information from program files. For common area lighting, we used code LPD baseline assumptions; for others, we assumed comparable incandescent baseline fixtures. For interior lighting, we entered summary results from these calculations into models so we could simulate heating interactions and adjusted savings. For exterior lighting, we estimated comparable fractions of the lighting that was not photocell controlled, based on our observations of non-participant buildings.

- Hot Water Heaters: SCL stopped providing incentives for water heaters in multifamily new construction in January 2004, when federal efficiency standards went into effect. Prior to that, they provided rebates for water heaters with an energy factor of 0.93 for tanks of 59 gallons or less, and 0.91 for tanks of 60 gallons or more. Savings for water heater incentive recipients was computed using the DOE Energy Cost Calculator for Electric and Gas Water Heaters[8].

- Whole house fans: Savings for timers associated with these were assumed negligible, based on engineering judgment and a discussion with another knowledgeable consultant (Ecotope, 2007). The expectation is that the program does not change timer use, since studies have shown timer use is highly unpredictable. The baseline assumes timers are installed as a matter of course. The program effect, then, is not adding timers, but influencing their settings. This influence is deemed negligible, although no additional data exists confirming this.

- Diligent inspection: We assumed that the savings from these were negligible, and any savings that did accrue would fall under the general building envelope savings for Option I/II. Our interviews and analyses yielded no quantifiable data suggesting that inspections had a significant effect on savings. We did note that modifying infiltration rates and R-values was not necessary to calibrate the non-participant model. If the effect were larger, we might have expected to have needed to do so.

Envelope savings for buildings with common laundry facilities were estimated by combining information from this study of in-unit laundry buildings with results from the 1996 Super

[8] http://www1.eere.energy.gov/femp/procurement/eep_waterheaters_calc.html#output

Good Cents evaluation, which estimated savings for both in-unit and common laundry facilities. The ratio of common laundry savings per square foot to in-unit laundry savings per square foot from the Super Good Cents evaluation was multiplied by the Built Smart in-unit laundry saving per square foot to estimate the Built Smart savings per square foot for the common laundry buildings.

Table 2: Code and Program Building Envelope Requirements

Envelope feature	**Units**	**Code***	**Built Smart** (per program literature)
Glazing	U-value, max.	0.35 (for Option I) 0.40 (for Option II)	0.33
Unglazed doors	U-value	0.20	0.19
Attic ceiling	R-value	38	49 (advanced framing**)
Vaulted/flat roof ceiling	R-value	30	38
Wall, above grade	R-value	15 (for Option I) 21 (for Option II)	21 (intermediate framing***)
Wall, below grade	R-value	15-interior or 10-exterior (for Option I) 21-interior or 10-exterior (for Option II)	21 (interior)
Floor, above PT slab	R-value	15	15
Underfloor	R-value	30	30
Slab-on-grad perimeter	R-value	10	15

* Per Washington State Energy Code from 2001 through 2004. Option I refers to buildings with a glazing-to-floor-area percentage of 12% or lower. Option II refers to buildings with a glazing-to-floor-area percentage between 12% and 15%.

** An advanced-frame attic uses special construction so that the insulation thickness decreases to no less than R-38 where the attic tapers down at the roof-wall intersection.

*** Intermediate framing, as specified by the Washington State Energy Code, uses addition framing and insulation to improve thermal performance beyond standard construction.

Findings

This section discusses the results we obtained after applying the methodology described above. First, we explain the results of the sample selection process. This is followed by a summary of salient characteristics of the selected participant and non-participant buildings. Lastly, the section includes a detailed discussion of the results of the energy savings analyses performed on the two prototypes.

Sample Characterization

SCL developed a list of 72 buildings that participated in Built Smart in 2003-2004. Of these, 21 were eliminated because they were permitted prior to July 2002, when new building code requirements came into effect. SCL removed an additional 22 because their style or construction was inappropriate for this study. SCL provided the remaining list of 29 to SBW, who reviewed associated plans and files, and then selected 13 suitable projects. These participant projects were categorized as either Type A (non-student residences with in-unit laundries) or Type C (student residences with common area laundries). We deliberately exceeded the 10-building target, with the knowledge that the student buildings were similar because they were all within the same complex. Across these 13 projects, 81% of the residence units were Type A. These included several large complexes with over 160 units each. The remaining 19% of the residence units were Type C.

Of the 13 sampled participants, all buildings had Option I envelopes with the exception of four with Option II envelopes. About a third of the participating buildings also incorporated efficient lighting and whole house fan measures into the Built Smart project. Nearly half of the buildings installed efficient water heaters.

Our search for suitable non-participant candidates began by identifying 93 buildings constructed outside of Seattle in King County between 2002 and 2004. We eliminated 72 of these because their style or construction was inappropriate for this study. After further review of billing data and available documentation, we selected a final sample of 10 projects. Details of the participant and non-participant sample screening process can be found in Tables 9-11 in the appendix.

Ultimately, we limited projects to those in the cities of Bellevue and Kirkland to simplify data collection. All non-participants were classified as Type B (non-student residences with in-unit laundries), which corresponds to participant Type A. The buildings included in the participant and non-participant samples are summarized in Table 3. Note that one of the non-participants was eliminated late during the data collection process, after the construction drawings revealed the presence of gas heat and air conditioning units in some of the units.

It is worth noting that while program participants qualified their designs using the prescriptive approach that the table implies, the non-participant buildings that we examined used a component performance path approach. In such a scheme, the designer can trade off performance among components, e.g., specifying bigger windows, but offsetting the reduced thermal performance by adding more insulation in other areas. These tradeoffs are permitted within prescribed overall limits.

Building Characteristics

We used envelope component data from the plans to compute U-values for each type of wall, floor, and ceiling for each participant and non-participant building. We then aggregated and summarized these data to develop unit-level UA per square foot estimates (where UA is the coefficient of heat transmission for a given area). Based on these UA/sq.ft. values, we grouped the units into three classifications, less than or equal to 0.07, greater than 0.11, or in between. Table 4 summarizes the aggregate building envelope characteristics for the Option I and Option II participants, as well as the non-participants. The Built Smart program defines the difference between Option I and Option II according to the maximum allowable window-to-floor-area percentage. This percentage is 12% for Option I, and 15% for Option II. Other envelope requirements are the same among the options.

The average sizes of participant and non-participant dwelling units were 777 and 825 sq. ft., respectively, based on our assessment of 673 participant units and 834 non-participant units. Other key points from this table include:

1. Use of the Option II building envelope was limited within the participant sample. Only about 7% of the units were in buildings with Option II envelopes.

2. Component U-values for participants were uniformly lower (more efficient) than corresponding values for non-participants. This occurred even though the non-participants used the component performance compliance path.

3. Attic ceiling construction was not present in Option II and non-participant buildings.

Table 5 describes important lighting and domestic hot water heater characteristics for participants and non-participants that we found during the plan review. Key points include:

4. Participants' domestic hot water heaters were only a slight improvement over baseline. The average efficiency factor among participants in this measure was only 1% higher than for those buildings that did not participate.

5. Lighting measures reduced power densities significantly. In-unit and common area lighting power densities (watts per square foot) in measure-affected areas dropped by 75% and 34%, respectively.

6. Exterior lighting measures reduced lighting hours of operation somewhat. Exterior lighting for the non-participants consisted of fluorescent and HID fixtures, the same as the Built Smart program requirement. Program-sponsored lighting controls reduced operating hours by an estimated 17%.

Table 3: Characteristics of Sampled Participant and Non-Participant Buildings

							BuiltSmart measures					
P/NP count	**SBW #**	**Suggested model type***	**City**	**Units**	**Stories**	**Year Built****	Envelope option	Lighting: common-area	Lighting: exterior	Lighting: in-unit	Water heaters	Whole house fans
				PARTICIPANTS								
1	P3	(A) Participant, in-unit laundry	Seattle	237	6	2004	I		1	1		
2	P1	(A) Participant, in-unit laundry	Seattle	201	10	2003	I	1	1	1	1	1
3	P2	(A) Participant, in-unit laundry	Seattle	162	8	2004	I	1	1		1	1
4	P5	(A) Participant, in-unit laundry	Seattle	32	4	2003	II	1			1	1
5	P8	(C) Participant, common-area laundry	Seattle	39	6	2003	II					
6	P13	(C) Participant, common-area laundry	Seattle	32	5	2003	II					
7	P4	(C) Participant, common-area laundry	Seattle	31	5	2003	1	1	1	1	1	1
8	P6	(A) Participant, in-unit laundry	Seattle	25	3	2002	I				1	
9	P10	(C) Participant, common-area laundry	Seattle	16	3	2003	I					
10	P7	(A) Participant, in-unit laundry	Seattle	16	4	2003	II		1		1	1
11	P9	(C) Participant, common-area laundry	Seattle	15	4	2003	I					
12	P12	(C) Participant, common-area laundry	Seattle	14	3	2003	I					
13	P11	(C) Participant, common-area laundry	Seattle	15	5	2003	I					
		Total with In-Unit Laundry	**81%**	**673**								
		Total with Common Area Laundry	**19%**	**162**								
				NON-PARTICIPANTS								
1	NP1	(B) Non-participant, in-unit laundry	Bellevue	210	8	2001						
2	NP2	(B) Non-participant, in-unit laundry	Kirkland	196	6	2001						
3	NP3	(B) Non-participant, in-unit laundry	Kirkland	108	7	2002						
4	NP4	(B) Non-participant, in-unit laundry	Kirkland	80	6	2002						
5	NP5	(B) Non-participant, in-unit laundry	Kirkland	64	6	2000						
6	NP6	(B) Non-participant, in-unit laundry	Bellevue	51	5	2003						
7	NP7	(B) Non-participant, in-unit laundry	Bellevue	48	5	2001						
8	NP8	(B) Non-participant, in-unit laundry	Kirkland	43	4	2002						
9	NP9	(B) Non-participant, in-unit laundry	Kirkland	43	4	2002						
10	NP10	(B) Non-participant, in-unit laundry	Kirkland	42	4	2002						
		Total Participant Units		**835**								
		Total Non-Participant Units		**885**								

*Zone level details will be collected for the projects with In-unit laundry to create the participant and non-participant prototypes.

** Energy code requirements for the component performance path have not changed significantly from the 1996 energy code to the 2002 energy code, so non-participants permitted prior to 7/1/2002 should be comparable to those permitted afterwards.

Table 4: Envelope Characteristics for Sampled Buildings

		% units by UA classification			Apt floor		PT Slab	Ceiling		Wall		Window	Door
	No. of units	UA/sf <= 0.07	UA/sf <= 0.11	UA/sf > 0.11	Total (ft2)	Unit avg. (ft2)	(avg. U-value)	Attic (avg. U-value)	Vaulted (avg. U-value)	Above grade (avg U-value)	Below grade (f-value)	(avg. U-value)	(avg. U-value)
PARTICIPANTS													
Option I	625	52%	39%	8%	485,461	777	0.033	0.043	0.047	0.059	0.348	0.309	0.193
Option II	48	0%	69%	31%	37,350	778	0.032	-	0.049	0.057	-	0.321	0.200
Totals	**673**	**49%**	**41%**	**10%**	**522,811**	**777**	**0.033**	**0.043**	**0.047**	**0.058**	**0.348**	**0.310**	**0.193**
NON PARTICIPANTS	**834**	**43%**	**23%**	**34%**	**688,073**	**825**	**0.055**	n/a	**0.050**	**0.068**	**1.150**	**0.365**	**0.463**
Participant values as % of NP values	**-19%**	**14%**	**79%**	**-70%**	**-24%**	**-6%**	**-41%**	n/a	**-5%**	**-14%**	**-70%**	**-15%**	**-58%**

Table 5: Lighting and Water Heater Characteristics for Sampled Buildings

	Baseline	Participants	% improvement
Domestic hot water heater (efficiency factor[1])	0.911	0.922	1%
In-unit lighting (LPD watts/sq.ft.)[2]	0.306	0.076	75%
Common area lighting (LPD watts/sq.ft.)[3]	1.000	0.656	34%
Exterior lighting (on hours/year)[4]	5,256	4,380	17%

1 DHW effifiency was not available for non-participants. Baseline energy factor was computed using energy factor of water heaters in participant buildings that did not receive a DHW incentive.
2 Non-participant lighting information not available, baseline was computed by assuming four fixtures per unit with 60 watts per incandescent fixture.
3 Non-participant lighting information not available, so code maximum used for baseline.
4 Baseline lighting assumed 20% of exterior lighting not photocell controlled and on all hours.

Building Inspection Practices

SBW conducted telephone interviews with 12 individuals involved in the construction of multifamily buildings not participating in the Built Smart program. These included two general contractors, four insulation subcontractors, and six building inspectors from the cities of Bellevue, Kirkland and Seattle. The subset of insulation contractors we interviewed represented, in our judgment, a significant fraction of the pool of contractors in the area for this kind of work.[9] The purpose of these discussions was to determine how builders install insulation and other related building envelope components, how rigorously they achieve air sealing, and how differences in the level of enforcement of the energy code between jurisdictions affects how builders install insulation and other related building envelope components.

The consensus from the interviews suggests compliance with the insulation and air sealing requirements in the Washington State Energy Code is generally better in municipal jurisdictions and more lax in the unincorporated areas. All of the subcontractors and general contractors we interviewed had construction experience with participant and non-participant projects and one of the Bellevue building inspectors was familiar with the Built Smart program due to previous private sector work on Seattle construction projects. As a result, most of the interviewees had an informed understanding of the distinction between Built Smart projects and non-participant projects.

[9] When SBW interviewed Built Smart staff, building inspectors, and general contractors, the same three insulation contractor names kept recurring. A fourth contractor name surfaced late in the interview process and they were interviewed as well. No other insulation contractor names came up in any of the interviews. While it is difficult to infer a precise fraction, it seems likely that we reached most, if not all, relevant contractors.

The appendix contains details from the interviews, including subject responses concerning estimated callback rates and common problem areas. Air sealing is most frequently singled out as a problem with both caulking and vapor barriers mentioned. The second nearly equal problem area is insulation batt compression around utility boxes in walls or batts cut too narrowly to fill the space in off-width cavities. The third problem area is insulation voids in less accessible places, such as corners and rim joists. Comments from specific subgroups of interviews are provided below.

..... Insulation Subcontractors

Most of the insulation subcontractors were forthcoming with details on geographical areas where the code was enforced more stringently. None singled out Seattle (either with or without Built Smart) as a singularly strict jurisdiction for code enforcement, but Seattle was always grouped with a few other municipal jurisdictions with, on average, higher enforcement standards. Two of the three subs with a lot of Built Smart experience said they do not bid Built Smart projects higher. A different mix of two of the three most familiar with Built Smart put their best crews on Built Smart and projects in municipalities known for strict enforcement. The fourth sub had only participated in one Built Smart project and did not have a positive experience.

..... General Contractors

General contractors valued Built Smart (which they characterized as having one less thing to worry about) but were somewhat ambivalent toward insulation and air sealing in general as it represents a small part of the construction process and is considered to be relatively straightforward. One general contractor said Bellevue and Kirkland jurisdictions are as stringent as Seattle but not always on the same things.

..... Building Inspectors

The Seattle building inspectors said they rely on Built Smart staff to do a detailed inspection for insulation and air sealing. One of the inspectors first expressed total reliance on Built Smart staff, and then later allowed that he focuses on insulation inspection with potential fire code issues such as recessed fixtures in ceilings. The other Seattle inspector said there's a big difference between meeting the letter of the code and 'best practice' installation of insulation and air sealing - the implication being that Built Smart projects achieve a higher standard than meeting code minimums. The Bellevue inspector familiar with Built Smart had worked in construction in Seattle prior to becoming a building inspector. He said Built Smart staff has the time to talk with the insulation subs and coach them on best practices, something building inspectors seldom have the time and/or inclination to do. All three inspectors were unanimous in their praise for Built Smart staff and highly value having a second set of eyes in the field.

The building inspectors fell into two camps with differing perceptions on the installation quality of insulation and air sealing by the sub contractors:

> Group 1: Three of the six building inspectors (from Seattle and Bellevue) interviewed said lack of quality control is a frequent problem in multifamily new construction.

Group 2: The other three building inspectors (Kirkland and Seattle) said categorically that insulation and air sealing practices usually comply with the code and quality control problems are infrequent.

Below are additional factors that may explain the diversity of inspector opinions of subcontractor quality control:

- Past and present Built Smart staff cited frequent quality control problems, similar to the first group of building inspectors.
- It seems unlikely the second group of building inspectors--those generally content with installation quality--is, on average, seeing a significantly different set of construction projects.
- Most people interviewed, including the building inspectors, said there is always a range of variation in compliance emphasis between inspectors in every jurisdiction.

Taking all of the above into account, it is probable that quality control issues with insulation and air sealing are common in all municipal jurisdictions but some building inspectors, Group 2, are not as focused on insulation and air sealing enforcement as the others represented by Group 1.

It appears many of the municipalities in the Puget Sound region achieve a reasonable level of compliance with the code while a few, e.g., Bellevue and Seattle's Built Smart, appear to achieve a more rigorous standard for code compliance. Given the comments by most of the insulation subcontractors on the unincorporated areas' lack of enforcement, quality control there is probably at an overall lower level.

The input from all interview groups collectively indicates there are three tiers of energy code enforcement for multifamily buildings with respect to insulation and air sealing:

1. The first tier or most stringent level of compliance with the Energy Code is the Built Smart program participants and the City of Bellevue. These projects are presumed to be in full compliance with the Code for participant sample building modeling.
2. The second tier of performance (less stringent compliance) is the City of Seattle's non-Built Smart projects, and other regional municipal jurisdictions, excluding Bellevue. Based on the interviews, deficiencies in air sealing and insulation occur with similar frequency.
3. The third tier and lowest level of performance is found in the unincorporated areas of King County. It was even reported that King County does not inspect insulation, but only inspects framing and then again after sheetrock installation.

.....Ramifications of interview findings

The non-participants in the study sample were constructed in either the Bellevue or Kirkland jurisdictions. Based on the interviews, each jurisdiction appears to have

different levels of thermal performance based on the integrity of insulation and air sealing practices. This might suggest that two non-participant models are appropriate—one for Bellevue, representing installation practices equivalent to Built Smart installation practices, and one for Kirkland representing non-participant Seattle buildings, and presumably accounting for increased infiltration and reduced effective thermal resistance due to compressed insulation and/or voids.

Quantitative analysis of the building data, however, did not offer any evidence that such a difference exists. The 2006 electric usage indices (EUI) for the aggregate Bellevue and Kirkland sample buildings were 7.94 and 7.21 kWh/sq.ft./year, respectively. The Bellevue EUI is about 10% higher than the Kirkland one, despite the suggestion during the interviews that Bellevue inspections are more rigorous. Differences, if any, in energy usage because of inspection-related envelope differences are likely masked by other, more significant differences. For instance, the window-to-wall ratios for the Bellevue and Kirkland buildings are 0.27 and 0.39 respectively, a difference of 44%. Additionally, the wall-to-floor ratios for the Bellevue and Kirkland buildings are 0.39 and 0.30 respectively, a difference of 23%. These numbers seem to indicate that significant differences in building geometry and glazing probably overshadow differences in envelope inspection practices. In addition, the normal variation between inspectors and contractors, coupled with the relatively small sample sizes, may obscure the effect even further. We therefore concluded that developing separate non-participant models to capture the inspection effect would not be worthwhile for this study.

Model Descriptions

We developed participant and non-participant building simulation models using eQUEST software. The participant model contained different zones to represent the mix of Option I and II buildings. The non-participant model contained three zones, representing (1) sampled projects in Bellevue, (2) sampled projects in Kirkland excepting an atypical complex, and (3) sampled projects in Kirkland from the atypical complex[10]. Both models contained zones representing dwelling units with different levels of calculated UA/sq. ft. This quantity represents the magnitude of heat transmission through the dwelling unit's exterior surfaces. Consequently, interior units had relatively low values, while corner apartments had higher values.

Although common areas—both unconditioned and conditioned–were included in the models, we did not include these during the calibration process. We excluded them because the common areas often contained commercial spaces and garages, making it difficult to match billing data to them. In some cases, common/commercial area usage was very high, and would have dwarfed programmatic measure effects.

For both prototype buildings, the slab and ceiling floor areas are much smaller than the total building floor area, indicating the presence of a parking garage and multiple floor buildings. Both prototypes were dominated by vaulted ceiling construction. All construction was pinned under slab insulation.

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[10] The latter was atypical in that portions of a previous building had been salvaged, so that many of the walls did not meet current code requirements. Nonetheless, we incorporated data from the code-compliant portions of the building, and adjusted the non-compliant components to their code equivalents.

Building level infiltration and thermostat setpoint profiles were developed from previous work developing models for the predecessor SuperGoodCents program. These in turn were based on measurements made in the BPA Multifamily Metering Study. The BPA data were also used to develop building-level average seasonal consumption profiles by day type (weekday and weekend) for the hot water, lighting and equipment end uses.

Operating profiles for the lighting end use were derived from data gathered during a previously-performed literature review of prior research at Puget Power (Gilmore Research Group, 1992) and Pacific Gas and Electric (Kelsey, 1992). Based on this previous work, the bathroom lighting system was assumed to be on 2.0 hours per day throughout the year. Kitchen lighting was assumed to be on 2.9 hours per day during the summer months and 5.5 hours per day during the winter months. These values were also applied to non-bathroom/kitchen rebated lighting fixtures. The lighting system was assumed to be on a schedule that was the same profile shape as the equipment load.

Tables 12 and 13 in the appendix show key characteristics of the participant and non-participant models, respectively.

.....Billed and Modeled Energy Use

We aggregated 2006 billing data from tenants of participant and non-participant sampled buildings, and then adjusted these data to account for apparent vacancies. The resultant summaries provided EUI targets for both prototypes. For participants, the average EUI was 6.65 kWh/sq.ft./year. For non-participants, it was 7.64 kWh/sq.ft./year (expressed in percentages, participants used 13% less on average than non-participants in 2006, unadjusted for any mitigating factors). Figure 1 shows these EUI targets broken into their monthly components.

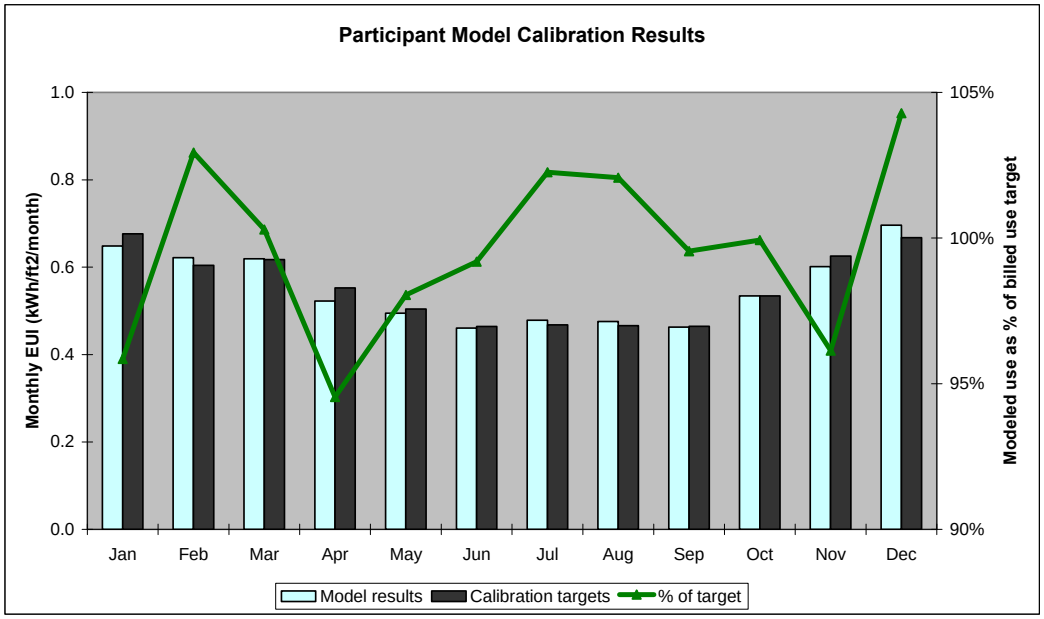
We successfully calibrated both models within the target values of ±10% of each month and ±5% overall. A separate calibration of monthly and total annual consumption was successfully performed for each of the prototypes. Several iterations of the model were required for each prototype to produce a set of simulation inputs that accurately reflected actual consumption characteristics. Figure 1 provides a comparison of simulated monthly consumption to the monthly EUI targets for both models. For both prototypes, simulated annual consumption was within ±0.4% of the annual target, a reasonable calibration result. Summer and winter[11] usage predictions were within ±2.0% and ±1.5% of actual usage, respectively. Therefore, we concluded that these fully calibrated models represented an accurate depiction of predicted end use consumption under full occupancy, and with the weather conditions that existed during the calibration year.

Once calibrated, we then added in zones for common area heating/lighting/exterior lighting to capture impacts of exterior/common area lighting measures, as well as the minor impact of the common area envelope. We also created the baseline model by applying the calibrated characteristics of the non-participant model to the calibrated participant model.

[11] Using the SCL definition of Summer (May-Oct) and Winter (Nov-Apr).

The fully calibrated participant model and the baseline model were run under Sea-Tac Typical Meteorological Year (TMY) weather conditions to remove the effect of unusual weather conditions during the calibration year. Running the participant model with TMY weather instead of 2006 weather resulted in a difference of less than 1%, suggesting that the 2006 calibration year was very similar to a typical weather year. The final estimates of annual consumption for the participant and baseline prototypes were 6.68 kWh/sq.ft./year and 7.36 kWh/sq.ft./year, respectively. Note that the evaluated baseline usage is considerably lower than that from the previous SuperGoodCents study, which calculated baseline usage of 11.69 kWh/sq.ft./year. The current baseline is 37% less than the previous baseline, indicating that average usage has dropped dramatically over the last decade.

Figure 1: Simulated vs. Actual Electric Use



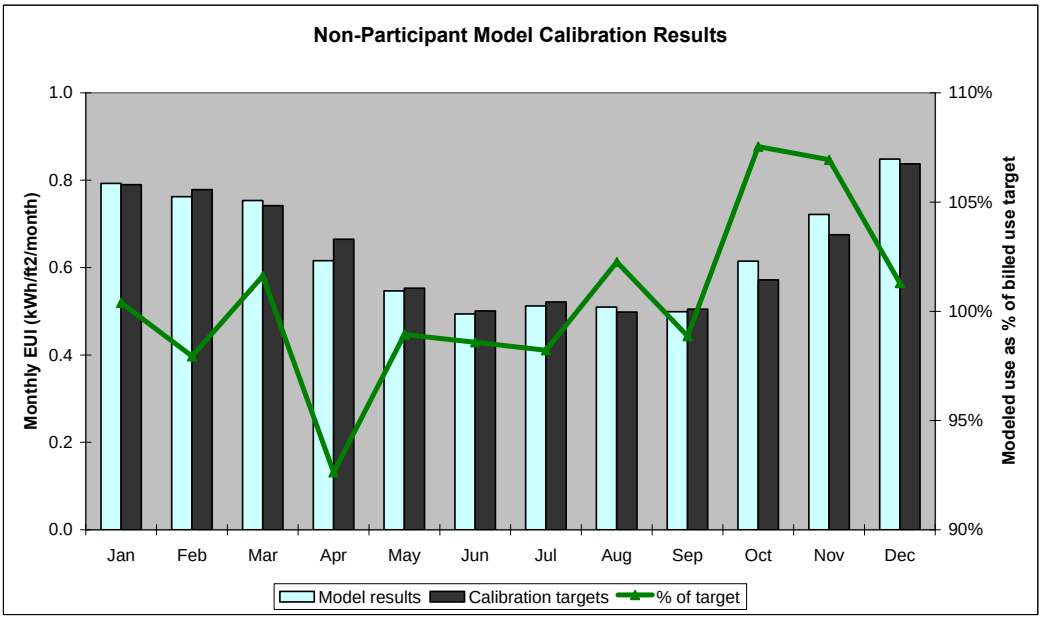


Table 6: Evaluated Energy Savings

	Annual EUI (kWh/ft2/year)	Difference in electric use (kWh/ft2/year)	% difference
Targets from 2006 billing data			
Participant model	6.65	0.99	13.0%
Non-participant model	7.64		
Simulated 2006 usage			
Participant model	6.62	1.05	13.8%
Non-participant model	7.67		
Usage based on typical weather			
Participant model	6.68	0.68	9.2%
Baseline model	7.36		
EVALUATED SAVINGS*			
Winter (Oct-Mar)	0.42	62% of annual	
Summer (Apr-Sep)	0.28	41% of annual	
Total annual	**0.70**	**kWh/ft2/year**	
	9.5%	**reduction**	

* Includes savings from domestic hot water heater measure, which was not modeled.

Energy Savings

.....Unit Savings

After estimating typical energy usage for the participant and baseline models, we took the difference to calculate savings, as shown in Table 6. We then added in the effect of the efficient domestic hot water heater measure, which was calculated outside of the simulation. Overall, the gross reduction in EUI was 0.70 kWh/sq.ft./year, or 9.5% of typical baseline usage. It is important to keep in mind that because of the sensitivity of energy models outputs to particular input parameters, as well as the small differences between participants and non-participants that produce differences in energy use, a fair amount of uncertainty exists around these point estimates of savings.

As expected, estimated annual baseline usage is greater in the baseline case than it is for participants. The difference of 0.70 kWh/sq.ft./year represents overall gross savings of nearly 10%. Applied to the average in-unit laundry participant, the absolute average unit savings from the Built Smart program is 621 kWh/year/unit. By comparison, evaluated savings from the predecessor SuperGoodCents Program for complexes with in-unit laundries were 1.43 and 1.57 kWh/sq.ft./year for Tier 1 shell measures and lighting add-on provisions, respectively, for a total of 3.0 kWh/ sq.ft./year (23% of the baseline consumption of 13.26 kWh/sq.ft./year). The current estimate of Built Smart savings represents 23% of the original savings estimates for SuperGoodCents.

..... End Use Splits

Examining EUIs by end use provides another basis for comparing SuperGoodCents impacts with Built Smart ones. Table 7 and Figure 2 show, in tabular and graphical form respectively, the EUI reductions attributable to each program. The SuperGoodCents program yielded significant reductions in space heat and miscellaneous equipment (which includes interior lighting), reducing the average EUI from 13.26 to 10.26 kWh/ft2/year. The Built Smart program also reduced space heat and miscellaneous equipment consumption, but the magnitude of these changes is relatively small. The fact that the Built Smart baseline EUI is well below the SuperGoodCents efficient EUI likely illustrates how much more efficient current multifamily buildings have become compared to their predecessors a decade ago. Interestingly, the end use proportions for efficient SuperGoodCents and Built Smart buildings remained nearly the same, although their overall magnitude has dropped. In both cases, space heating is about 12% of total usage, domestic hot water about 32%, miscellaneous equipment about 55%, and exterior lighting less than 1% of total usage.

The significant decrease in baseline EUI can be explained by several factors. The building envelope thermal integrity has improved because code changes and market transformation have altered standard practices. Specifically, the following items helped reduce baseline energy use over the ten-year period.

- Window U-value: In 1994-5, the baseline window U-value was observed to be 0.47, which did not even meet the code value of 0.45. In 2002-4, baseline windows had a U-value of 0.36, which was better than the code requirement of 0.40. It is difficult to even find windows in today's market with a U-value as high as 0.40.

- Air sealing: Since the 1994-5 study, builders have significantly improved moisture and air sealing practices, primarily due to liability problems associated with moisture damage.

- Domestic hot water: Hot water tank efficiency standards have increased over time also. Previously required energy efficiency factors were 0.86, instead of the more recent requirement of 0.91. Also, general improvements in the efficiency of dishwashers, clothes washers, and showerheads have reduced hot water demand.

- Miscellaneous equipment: The efficiency of refrigerators has improved over the ten-year period, as well as for other equipment, such as computers. Use of efficient lighting, such as compact fluorescent lamps, has also increased during this time.

- Exterior lighting: Common practice for exterior lighting fixture types and controls has improved to near the Built Smart program level over the ten-year period.

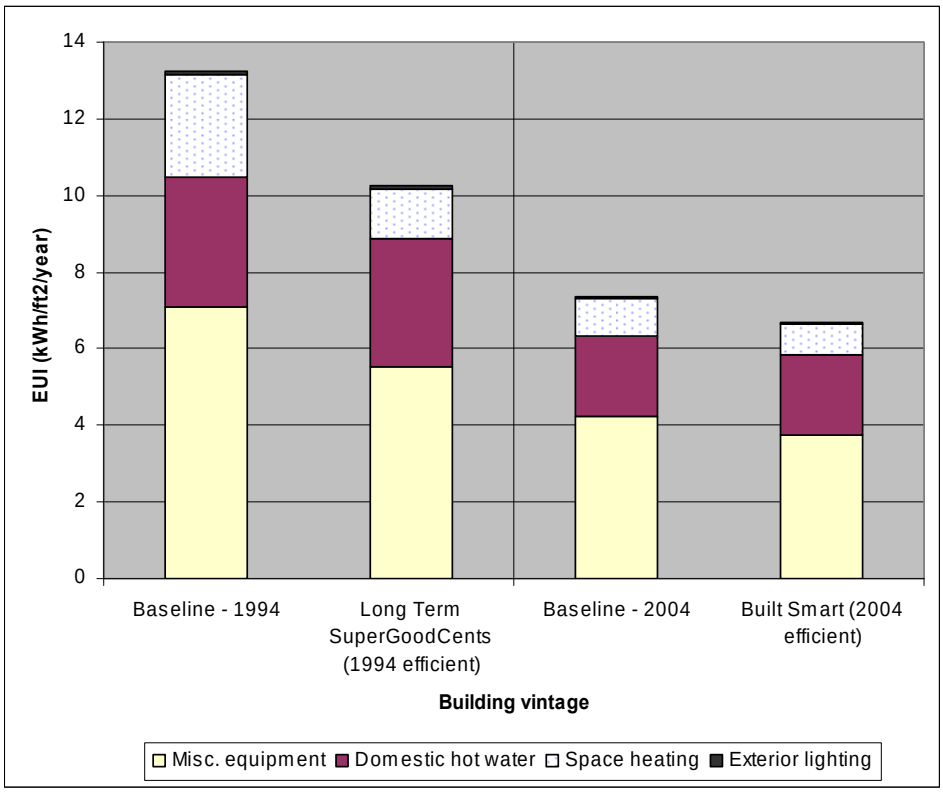
Other differences, such as in occupant behavior, may also be affecting EUIs, although it was not possible to discern these effects in the data collected for this evaluation study.

Table 7: EUI Breakdown by End Use

End Use	Long Term Super Good Cents (1996 Evaluation) Baseline Annual EUI (kWh/ft2 /year)	Baseline % of total	Efficient Annual EUI (kWh/ft2 /year)	Efficient % of total	Built Smart (2007 Evaluation) Baseline Annual EUI (kWh/ft2 /year)	Baseline % of total	Efficient Annual EUI (kWh/ft2 /year)	Efficient % of total
Space Heat	2.71	20.4%	1.28	12.5%	0.94	12.8%	0.78	11.7%
Domestic Hot Water	3.38	25.5%	3.38	32.9%	2.11	28.7%	2.11	31.6%
Miscellaneous Equipment*	7.08	53.4%	5.51	53.7%	4.24	57.7%	3.74	55.9%
Exterior lighting	0.09	0.7%	0.09	0.9%	0.06	0.8%	0.05	0.7%
ALL	**13.26**	**100.0%**	**10.26**	**100.0%**	**7.36**	**100.0%**	**6.68**	**100.0%**

* Includes conditioned and unconditioned common area.

Figure 2: EUI Breakdown by End Use



..... Measure Savings

We performed further analyses to disaggregate these savings by individual measures. Table 8 shows the results of this effort. It is important to realize in this table that the reported results are normalized across all program participants in the sample, not just those affected by the particular measure. So, for example, Option II envelope savings appear much lower than Option I envelope savings, not because Option II envelopes are much less efficient than Option I ones, but because we found Option II among a mere 7% of the sampled participants.

The annual savings and percent of total savings in Table 8 reflect a model that is representative of the buildings in the evaluation sample. The last column in Table 8 shows, the percentage of model for each measure, on a square foot basis, as was represented in the participant sample. Not all buildings in the sample participated each of the measures, except for the mandatory enhanced inspections.

As Table 8 illustrates, 64% of the gross savings from the Built Smart program comes from lighting measures. This is particularly notable since not all participants implemented lighting measures since they were optional (envelope measures, by contrast, were mandatory under program rules). This also contrasts with the previous SuperGoodCents results, which showed that lighting and envelope measure savings were nearly equal. Most of the savings for the Built Smart lighting measures is found in the common area lighting, since it is operated 24 hours per day. The effect of heat/light interactions is included in the lighting savings estimates for the kitchen/bath measures, since these were in conditioned spaces. The interactive effect degraded the lighting savings to account for an increase in space heat consumption necessary to meet the higher space heat load caused by the reduced lighting capacity. However, the heat/light interaction for common areas is not significant because the majority of common area is unconditioned space.

Table 8: Evaluated Measure Savings

Measure*	Annual EUI (kWh/ft2/year)	Difference in EUI (kWh/ft2/year)	Annual savings (kWh/year)**	% of total savings	% of model represented in sample
[Baseline]	7.36	n/a	n/a	n/a	
Option I envelope	7.13	0.22	200	31%	93%
Option II envelope	7.12	0.01	11	2%	7%
In-unit lighting	7.04	0.08	71	11%	66%
Common area lighting	6.69	0.35	313	51%	59%
Exterior lighting	6.68	0.01	9	2%	91%
Domestic hot water heaters	6.66	0.02	17	3%	67%
Whole-house fans***	6.66	0.00	-	0%	62%
Enhanced inspection***	6.66	0.00	-	0%	100%
ALL		**0.70**	**621**	**100%**	

* Savings from each measure are normalized across floor area for all in-unit laundry program participants, not just for measure-affected floor area.

** Savings per living unit averaged across all in-unit laundry participants.

*** Savings from these measures was assumed to be negligible and/or unquantifiable, and so were not analyzed.

The sample also included buildings that had common area laundry facilities instead of washers and dryers in the units. These buildings were not included in the eQUEST model because they tend to have different infiltration characteristics (because of clothes-dryer-induced airflow) and equipment fraction of heat gain to the space (because most of the dryer heat is vented outside). Option I envelope energy savings was estimated for the common area laundry buildings using the results of the Super Good Cents evaluation, which separately modeled in-unit and common area laundry buildings. The ratio of common area laundry savings per square foot to in-unit laundry savings was determined to be 0.87, and was multiplied by the Built Smart envelope savings. This resulted in common area laundry Option I annual savings of 0.19 kWh/sq.ft./year and 0.009 kWh/sq.ft./year for Option II. Note that these values are also based on the same percent of model participation values presented in Table 8 above and are similar to in-unit laundry facilities.

Conclusions

Based on the findings of this study, we offer these key conclusions:

> *Reduced overall electric usage among multifamily residential tenants, combined with lower percentage savings from Built Smart measures, has significantly reduced program savings, compared to Super Good Cents program of 10 years ago. This reduction very likely indicates the eventual success that multifamily new construction programs have had in transforming the marketplace in the Seattle area which drives energy codes to more conserving levels. This success, ironically, may pose challenges for future SCL programs of this type.*

The evaluated average Built Smart baseline usage is 37% less that the baseline calculated a decade ago for SuperGoodCents. While the overall Built Smart energy savings represents nearly 10% savings over current baseline, this value is much smaller than the SuperGoodCents finding of 23% savings over the previous baseline. The end result is that the Built Smart savings of 0.70 kWh/sq.ft./year (621 kWh/year per unit) only accounts for 23% of the 3.0 kWh/sq.ft./year savings that SuperGoodCents provided.

Both the reduced baseline usage and the smaller difference between participants and non-participants suggest that overall, multifamily new construction projects in the greater Seattle area are becoming much more energy efficient. We surmise that a combination of tighter building codes, improved building designs, and increased public awareness of efficiency may have much to do with this welcome development. It is highly likely that programs such as SuperGoodCents and Built Smart have been instrumental in effecting these improvements to the marketplace over the many years they have been in existence.

Looking forward, SCL might consider additional measures to enhance their portfolio of existing measures. Some possibilities might include efficient appliances beyond clothes washers, such as refrigerators and dishwashers that meet or exceed Energy Star[12] guidelines. Others might include combined water- and energy-saving measures, such as low-flow faucet aerators and showerheads. These fixtures likely would have to be installed after plumbers had installed the stock fixtures, but before tenants moved in.

> *Interior lighting measures yield the preponderance of savings in the program, suggesting a sustained program emphasis on these measures is warranted.*

Using the Washington State Energy Code as the baseline, savings from interior (in-unit and common area) lighting measures comprise nearly two-thirds of the gross savings from the Built Smart program. By comparison, just over half of gross savings came from lighting measures in the SuperGoodCents program a decade earlier. This occurs even though not all participants implemented lighting measures, since they were optional, while envelope measures were mandatory under program rules. Most of the savings for

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[12] Energy Star is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy that promotes energy efficient products and practices. Rated appliances meet strict energy efficiency guidelines set by these agencies.

the lighting measures is found in the common area lighting, since it is operated 24 hours per day. Nonetheless, Built Smart lighting savings are only 28% of SuperGoodCents lighting savings, due to more stringent current baseline conditions.

The high percentage of savings from lighting measures, in the current program, as well as the relatively ease with which they can be implemented, suggests that future programs might continue to emphasize straightforward lighting measures. As with the low-rise mixed-use electrically-heated buildings included in this study, Built Smart is spurring on lighting efficiency improvements in other related building types, such as high-rise multifamily buildings with natural gas space heat.

To confirm that lighting measures are cost-effective, however, SCL should consider performing additional work to verify actual baseline interior lighting conditions. Onsite visits of non-participant buildings from this study could determine whether the installed lighting falls short of code, meets code, or exceeds it. Such results could establish credible estimates of savings to expect in the future. These onsite visits could be extended to other non-participants, such as buildings currently under construction, as well as buildings that fell outside the scope of this study, such as high-rise steel-frame residences and townhomes. Assessing baseline conditions is particularly relevant, since the 2007 Seattle Energy Code calls for common-area lighting power densities (LPDs) of 0.8 watts per square foot. This more aggressive target is still higher than program participant LPDs, but will reduce the potential savings that the program will be able to claim.

> *Exterior lighting measures yielded minimal savings, since standard practice appears to be at or near program thresholds.*

With average unit savings of 8 kWh/sq.ft./year, exterior lighting measures make up a negligible 2% of program savings. It appears that standard practice for this lighting—installing compact fluorescent lamps in fixtures with photocell control—is fast approaching program requirements, severely limiting opportunities for the program to achieve savings in this realm.

> *Energy savings from Built Smart's enhanced building inspections and commissioning appear to be negligible overall when compared to other jurisdictions with rigorous building inspections. These savings remain potentially valid in concept, but it will require alternative approaches to ascertain their value.*

Interview research for this study provided anecdotal evidence that different areas of the Puget Sound region may have different levels of envelope thermal performance based on the integrity of insulation and air sealing practices. For example, relevant construction practices may be more rigorous in Seattle and Bellevue because of building inspector influence than in other municipalities. However, the quantitative analysis did not offer any evidence that such a difference exists between Seattle program participant buildings and non-participant buildings in Bellevue and Kirkland. It is possible that more significant differences, such as in building geometry and glazing, or between inspectors and contractors, are masking the inspection differences.

SCL might consider other options for future study to quantify or frame the question of the value and effects of enhanced inspections. One method might be "inspections of the

inspections," in which an impartial third party accompanied Built Smart staff, observed actual deficiencies, and based estimates of energy impacts on these observations. Such an approach, unfortunately, would likely be expensive and intrusive, and yield biased results. Another option might be to prove the hypothesis that enhanced inspections are cost-effective. This might be approached by first estimating the incremental cost to the program of these inspections, then assessing the minimum savings that inspections must provide to make the investment cost-effective. If the minimum savings seems plausible given the evidence at hand, then one could conclude that inspections are cost-effective. A third, and perhaps the most direct and effective approach, would be to repeat this study with nonparticipants drawn from unincorporated areas of King County, where there are no multifamily new construction programs, and building departments that place little emphasis on State energy code enforcement.

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Appendices

Gathering Data on Participant Building Characteristics and Building Inspection Standard Practice for Seattle-area Multifamily New Construction

Appendix A. Summaries of Participant and Non-participant Sample Selection

Table 9: Seattle Program Participant Sample Selection

	Participant Buildings	Buildings	Units
Population	Program Completed 2003–2004	72	2,419
Permit Screen	Old Code: Pre-July 2002 (not eligible for study)	–21	–982
	New Code: Post-July 2002	51	1,437
Type Screen	Style, Construction, Metering (inappropriate types)	–22	–219
	Mixed-Use & Occupied	29	1,218
Data Screen	Building Characteristics (inadequate data)	–16	–383
	Suitable for Study Sample	***13***	***835***
Sample	***Percent of 2003–2004 New Code Jobs***	***26%***	***58%***
Sub-samples	Common Laundry	7	162
	In-Unit Laundry (modeled)	6	673
	Percent of 2003–2004 New Code Jobs	*12%*	*47%*

Table 10: Potential Seattle Non-participants

	R-1 Building Permits*	Projects**	Units
Population	Permitted July 2002–2004	45	1,754
Program Screen	In Built Smart Program (not eligible for study)	–21	– 1,430
	Not in Program	24	324
Heat Screen	Gas Space Heat (not eligible for study)	–9	–92
	Electric or Unknown Space Heat	15	232
Type Screen	Style, Construction, Metering (inappropriate types)	–15	–232
	Suitable for Study Sample	***0***	***0***
Sample	***Percent of 2003-2004 New Code Jobs***	***0%***	***0%***

* Residential permits where UsePerZoningCode includes keywords such as apartment, apt, multifamily, townhouse, mixed use.

** Number of buildings in these projects was not available from permit records.

Table 11: King County Non-participants Sample Selection

	Non-participant Buildings*		Buildings	Units
Population	Built Outside Seattle 2002–2004		93	5,775
All Projects	Year Built:	2002	26	1,904
		2003	45**	2,674
		2004	22	1,197
Apartments	Year Built:	2002	10	1,175
		2003	11	1,296
		2004	8	690
Condominiums	Year Built:	2002	16	729
		2003	31	1,378
		2004	14	507
Type Screen	Style, Construction, Metering (inappropriate types)		–72	– 4,214
	Mixed-Use & Occupied		21	1,561
Data Screen	Building Characteristics, Location (inadequate data)		–11	–676
	Suitable for Study Sample (modeled)		***10***	***885***
Sample	***Percent of 2002–2004 Jobs***		***11%***	***15%***

* Residential projects where LandUse code begins with keywords such as RES,APT or RES,CONDO, and Site City/Zip begins with other than 981– (Seattle zip codes).

** Number of units for three buildings was not available from tax assessor records.

Appendix B. Building Inspection Practices Interview Guide

Non-participant Questions

The overall objective of these interviews to evaluate the level of compliance with the Washington State Energy Code's insulation and air sealing requirements for comparable multifamily buildings not participating in the Built Smart program. The type of Built Smart building investigated in this study has five or more units, on six or fewer residential floors of the building, has a wood frame, is electrically heated, and excludes townhouse style construction. The non-participant group will be defined by recent multifamily projects located outside of the Built Smart program's service area in nearby jurisdictions such as the Cities of Bellevue and Kirkland.

Below are the proposed questions for a qualitative interviewing protocol to thoroughly explore how insulation contractors, general contractors and building code officials perceive compliance in the non-participant group. This protocol will be used to guide the interviewer in a discussion rather than a structured interview. It is fully anticipated that additional questions/topics will be raised during the interview and will be explored by the interviewer.

The Building Inspector interviews should also be conducted with City of Seattle inspection staff from the Department of Planning and Development.

Insulation Contractors

Verify name of interviewee and position.

SBW is a research firm working for Seattle City Light to evaluate the Built Smart program. Built Smart is the energy efficiency improvement program for multifamily new construction in Seattle City Light's service area. We are trying to determine what would probably have happened in the multifamily construction process *without* the Built Smart program.

Your responses will be confidential and nothing in this conversation will be attributed to you or your company.

1. First a background question: Has your company worked on multifamily construction projects in the City of Seattle? Did you participate in Built Smart /or not, with any of your insulation jobs?

    a. (If the response to 1 is they **have** participated in Built Smart) Do the Built Smart projects generally require more time and effort for your crews to meet their standards? (if yes) Can you give us an example of how things are different with non-Built Smart projects?

    b. (If the response to 1 is they have done projects **both with and without** Built Smart in the City of Seattle) Ask (a) above and follow up with prompts for additional participant/non-participant comparison in questions 5 and 6.

2. Can you please describe you company's installer training process? Is it a challenge to maintain quality standards and, if so, what's the best approach you've found to maintaining reasonable standards?

3. Could you please describe your quality control process?

4. Do you pay your crews by the hour or by piecework?

5. How much does code enforcement for insulation and air sealing vary between building inspectors within a particular jurisdiction? And between jurisdictions? (Prompt if necessary: "None, some, a lot?")

6. Approximately, what percentage of projects gets correction orders from the building inspector for insulation and air sealing? (Prompt if necessary: "None, some, a lot?")

    a. What types of corrections are typical?

    b. Are re-inspections always required if a correction order is issued?

7. Do you have anything else to say on this topic you think would be good for us to know?

This concludes our survey. Your responses have been very helpful. Thank you for taking the time to speak with me.

General Contractors

Verify name of interviewee and position.

SBW is a research firm working for Seattle City Light to evaluate the Built Smart program. Built Smart is the energy efficiency improvement program for multifamily new construction in Seattle City Light's service area. We are trying to determine what would probably have happened in the multifamily construction process *without* the Built Smart program.

Your responses will be confidential and nothing in this conversation will be attributed to you or your company.

1. First a background question, has your company worked on multifamily construction projects in the City of Seattle and participated in City Light's Built Smart program?

    a. (If response to 1. is affirmative) Do your insulation subs have to do extra work to meet the Built Smart program requirements? And, if yes, please explain.

2. How often do you or your subs have corrections cited by building inspectors on installation of insulation and air sealing? Are there particular areas where inspectors typically require corrections? (Prompt if necessary: "Never, some, a lot?")

3. In your opinion, what are the significant differences in the level of enforcement of the energy code between jurisdictions with respect to insulation and air sealing?

4. Which insulation subs do you work with frequently?

5. Do you have anything else to say on this topic you think would be good for us to know?

This concludes our survey. Your responses have been very helpful. Thank you for taking the time to speak with me.

Building Inspectors

Name of interviewee and title.

SBW is a research firm working for Seattle City Light to evaluate the Built Smart program. Built Smart is the energy efficiency improvement program for multifamily new construction in Seattle City Light's service area. We are trying to determine what would probably have happened in the multifamily construction process *without* the Built Smart program.

Your responses will be confidential and nothing in this conversation will be attributed to you or the City of (Kirkland or Bellevue *or Seattle*).

1. In general, how well do the multifamily project contractors comply with the insulation and air-sealing provisions in the State energy code?

2. When you encounter problems with the insulation and air-sealing components of the code, are there particular areas that frequently require correction?

    a. (If yes) What are the most common areas requiring correction?

3. Are there other inspectors in your jurisdiction who frequently check this type of work? If so, could you please give me their names?

4. Do you have anything else to say on this topic you think would be good for us to know?

This concludes our survey. Your responses have been very helpful. Thank you for taking the time to speak with me.

Appendix C. Building Inspection Practices Interview Comments

General Contractors

Both subjects were site superintendents and had experience on Built Smart and non-Built Smart projects. Below are statements of interest.

GC-1

The insulation crews generally do a good job. If quality control is and issue at the start, they get it straightened out quickly when expectations are explained. Insulation and air sealing are a pretty cut and dried affair (either it's done right or it isn't).

Built Smart influences a more thorough inspection process.

The County inspectors are more lax than the City inspectors.

Correction callbacks are <10%.

GC-2

Built Smart projects are definitely higher quality for insulation and air sealing. When he has a non-Built Smart project they deliberately do a less diligent job to save money.

On Built Smart projects, building inspector correction orders are rare.

The Cities of Bellevue and Kirkland inspectors are strict. The Seattle building inspectors seem to rely on Built Smart inspectors for the caulking and insulation inspection. On non-participating buildings in Seattle, the Seattle building inspectors are somewhat more diligent when they know Built Smart isn't involved.

Insulation Contractors

All three subjects were either principals or managers in three of the larger insulation firms covering Western Washington. All companies have a similar system for training new workers; the rookies are teamed with experienced workers until they can work more independently. All companies employ roving quality control inspectors. All acknowledged high worker churn rates. All installer pay is a combination of an hourly wage combined with incentive bonuses for production. All reported a constant source of quality control problems lie with other trades removing insulation and not replacing when done.

Insulation Contractor-1

Bids for Built Smart projects are higher, anticipating the need for a more thorough job.

For Built Smart and certain city jurisdictions, he will send his 'A and B' crews (on a scale of A to D). Built Smart inspectors have been known to check every bay. Individual

building inspectors have a lot of variability in what they check. On the whole, Bellevue and some other cities' inspectors are pretty strict and comparable to Built Smart.

Correction callback rate is about 5%. Air sealing problems are rare, either it's done or it isn't.

Insulation Contractor-2

There's no difference in bidding for Built Smart or non-Built Smart projects. The same standard applies regardless of jurisdiction.

Their pay is weighted toward piecework.

Correction orders run about 5%.

Insulation Contractor-3

They used to bid Built Smart projects higher but now usually bid projects without regard to Built Smart participation.

In addition to the roving QC inspector, he'll assign a site foreman for larger projects to maintain more rigorous quality control.

Many of the cities are stricter than the unincorporated areas. They assign the better crews to these project areas, includes Built Smart.

Callbacks are <20%.

Insulation Contractor–4

Did only one Built Smart project and it was a nightmare. GC didn't communicate Built Smart requirements and they got into hassles with the Built Smart inspector. Sub ended up charging GC for difference.

Built Smart requires R38 in cathedral ceilings, code is R30.

Municipal jurisdictions have many quirks and they try to keep track of them so they don't get caught more than once. Renton and Issaquah are notable in this regard.

Callbacks are <5%. Most frequent is FSK is missing.

King County doesn't inspect insulation, literally. They inspect the framing and the structure once the sheetrock is installed. They don't care about insulation.

Employee turnover isn't a problem.

Building Inspectors

A building inspector was interviewed for each of the cities of Bellevue, Seattle and Kirkland. Also, a building inspector supervisor at the City of Bellevue provided background on their system.

Seattle Inspector-1

There is a clear difference in installation quality between Built Smart participants and non-participants with Built Smart's quality being superior. When he sees the paperwork that a Built Smart inspector has approved the project for cover, he knows that part of the work is up to standard.

He said there is a big difference between just meeting the letter of the code and having a quality installation. (When asked to elaborate) Built Smart ensures a quality installation above just meeting the code. He noted there might be an additional 'hassle factor' for the contractors in working with Built Smart.

Seattle Inspector-2

Built Smart is a big help. When they've been there, he hardly ever looks at the insulation. He occasionally sees non-Built Smart participant buildings but doesn't see a clear pattern of distinction between the two. The big insulation subs generally do a decent job although quality can vary some between crews. Said that quality control with the insulation subs is a 'lot better than it used to be.'

Insulation installation quality is usually ok. More frequently he finds sealing problems and said that's usually handled as a 'working correction' where he'll tell them what he wants done and that he will peel back insulation to check when he returns for the final inspection before the 'ok to cover.'

His most frequent insulation problem is insulation around heat-producing devices, also a fire code issue.

Thinks there is quite a bit of variation between Seattle inspectors and other jurisdictions.

Kirkland Inspector-1

Compliance with the air sealing and insulation requirements of the code is not much of a problem. Failure rates are <10%. Contractors not meeting the code are usually quick to respond to the pressure created by a correction notice and fall into line without further problems.

Kirkland Inspector-2

Kirkland is known as a tough jurisdiction and the insulation contractors usually do a good job.

If there are problems requiring a correction, the insulation guys work on a piecework basis and callbacks hit them in the wallet.

If there are problems, it's usually air sealing (responding to interviewer's prompt).

Bellevue Inspector-1

This individual is familiar with Built Smart as he worked fairly recently in multifamily new construction in Seattle.

There's a lot of variability in installation quality even within a single subcontractor. The range is from decent to terrible, zero consistency. (He went on to elaborate at length about the nature of installation problems, which left the impression that he's very thorough).

Referring to his Built Smart experience, it really helps the building inspectors out if the Built Smart staff is out there talking and providing training to the insulation contractors and their crews.

As an inspector, you're looking for a million things and it really helps to have a second set of eyes for part of it, it's kind of a teaming thing.

Bellevue Inspector-2

Issues correction orders (especially for air sealing), on almost every job.

Insulation installation problems are often aggravated by the other trades coming back to make changes or additions to their work and wreak havoc on completed insulation work.

Wasn't familiar with Built Smart but thought it would be nice to have someone from the utility coming in to provide oversight on these items.

Said inspectors in his jurisdiction are fairly consistent. A few of the guys who've been around a long time are less concerned with insulation than the newer guys.

Bellevue Supervisor

He wasn't given the survey but provided background on Bellevue's approach to code enforcement with the inspectors. He said Bellevue is somewhat unique in that they send their inspectors to a lot of formal training on the code. And, to increase the consistency between inspectors, they have a lot of structured discussions among themselves to increase consistency in code enforcement in their jurisdiction.

This was interesting to hear because the City of Bellevue is the municipality most frequently singled out by the other interview groups for having strict and somewhat consistent enforcement.

Energy Code Trainer

This individual travels around the State conducting Energy Code training seminars for code officials. He teaches groups of inspectors and generally gets a lot of exposure to people who enforce the codes. He very seldom gets into the field so his observations are more inferred in nature. Although he's heard the Build Smart name, he didn't know anything about the program.

Municipalities generally (there are some exceptions) do a good job of energy code enforcement. Enforcement by the counties is uneven (he gave examples of each). He wasn't sure about King County until teaching a class there recently and was impressed by the questions and knowledge of the inspectors attending the class. At least at the plan review level, his guess is they're doing a good job.

Overall, the level of compliance with the code is good. One hears more about the bad apples in the enforcement field but feels they're very much the exception to the rule.

Summary of Quality Control Problems by Interview Subject

		Problem Areas		
Interview Subject	% Projects w/ Correction Orders	Air sealing & vapor barriers	Batts too narrow or overly compressed	Other voids (e.g., rim joists, corners)
IC-1	5%	X		
IC-2	5%			
IC-3	<20%	X		
IC-4	<5%	X		
GC-1	<10%	X	X	
GC-2	'Very rare with Built Smart'			
Seattle-1	Not discussed		X	
Seattle-2	Not discussed			
Bellevue-1	10%			X
Bellevue-2	Not Discussed	X		
Kirkland-1	<10%		X	X
Kirkland-2	Not Discussed	X		

Appendix D. Detailed Building Characteristics Summaries for Modeling

Table 12: Participant Building Characteristics Summary

		Floor			PT Slab	Ceiling		Wall		Window	Door
	No. Apt Units	Zone Total (sf)	Volume at 8' Ceilings	Unit Avg (sf)	Zone Total (sf)	Attic Zone Total (sf)	Vaulted Zone Total (sf)	Above Grade Zone Total (Net sf)	Below Grade Zone Total (linear ft)	Zone Total (sf)	Zone Total (sf)
Option I											
Apartments											
UA/sf <= 0.07	328	242,695	1,941,556	740	4,942	-	3,822	67,275	77	25,813	53
UA/sf <= 0.11	244	198,211	1,585,691	812	30,834	25,667	46,673	66,109	-	26,269	125
UA/sf > 0.11	53	44,555	356,441	841	11,457	6,753	21,272	19,260	-	8,621	171
Unconditioned Common Area	-	51,546	412,368	-	4,430	1,668	4,946	24,826	130	756	996
Conditioned Common Area	-	20,841	166,724	-	7,721	585	2,163	5,098	-	530	84
Prototype Total	625	557,847			59,384	34,673	78,875	182,568	206	61,989	1,428
Prototype Average				777							
Prototype Average U-Value					0.033	0.043	0.047	0.059	0.348	0.309	0.193
Option II											
Apartments											
UA/sf <= 0.11	33	23,120	184,960	701	-	-	1,114	10,340	-	4,244	-
UA/sf > 0.11	15	14,230	113,840	949	7,056	-	7,980	6,162	-	2,119	-
Unconditioned Common Area	-	4,274	34,195	-	343	-	659	1,345	-	113	62
Conditioned Common Area	-	-		-	-	-	-	-	-	-	-
Prototype Total	48	41,624			7,399	-	9,752	17,847	-	6,475	62
Prototype Average				778							
Prototype Average U-Value					0.032		0.049	0.057		0.321	0.200
Option I and II											
Prototype Average U-Value					0.033	0.043	0.047	0.058	0.348	0.310	0.193

Table 13: Non-Participant Building Characteristics Summary

		Floor		PT Slab	Ceiling		Wall		Window	Door
	No. Apt Units	Zone Total (sf)	Unit Avg (sf)	Zone Total (sf)	Attic Zone Total (sf)	Vaulted Zone Total (sf)	Above Grade Zone Total (Net sf)	Below Grade Zone Total (linear ft)	Zone Total (sf)	Zone Total (sf)
Bellevue										
Apartments										
UA/sf <= 0.07	118	58,891	499	-	-	-	14,542	-	5,890	-
UA/sf <= 0.11	14	11,959	854	-	-	-	6,306	-	1,734	-
UA/sf > 0.11	126	64,015	508	20,451	-	33,779	24,728	-	7,504	-
Unconditioned Common Area	-	19,956	-	-	-	3,585	13,126	-	674	166
Conditioned Common Area	-	8,316	-	3,823	-	2,086	4,476	-	1,403	40
Prototype Total	258	163,138		24,274	-	39,450	63,178	-	17,204	206
Prototype Average Area			523							
Prototype Average U-Value				0.092		0.060	0.062		0.431	0.200
Kirkland 1										
Apartments										
UA/sf <= 0.07	240	221,334	924	-	-	1,438	53,634	-	23,884	-
UA/sf <= 0.11	134	124,725	934	12,427	-	54,745	41,372	-	17,578	-
UA/sf > 0.11	75	76,635	1,022	15,895	-	43,340	32,179	-	12,967	-
Unconditioned Common Area	-	33,840	-	2,577	-	5,369	10,393	-	-	404
Conditioned Common Area	-	22,972	-	14,761	-	1,974	6,949	-	2,516	301
Prototype Total	448	479,506		45,659	-	106,866	144,527	-	56,944	706
Prototype Average Area			944							
Prototype Average U-Value				0.039		0.048	0.064		0.333	0.540
Kirkland 2										
Apartments										
UA/sf <= 0.07	-	-	-	-	-	-	-	-	-	-
UA/sf <= 0.11	45	48,015	1,075	-	-	-	15,521	-	6,867	-
UA/sf > 0.11	83	82,497	990	23,790	-	41,871	29,602	-	11,389	-
Unconditioned Common Area	-	8,168	-	-	-	-	-	404	-	-
Conditioned Common Area	-	15,143	-	3,992	-	3,992	521	-	229	-
Prototype Total	128	153,823		27,782	-	45,863	45,644	404	18,486	-
Prototype Average Area			1,020							
Prototype Average U-Value				0.051		0.044	0.089	1.150	0.400	

Appendix E. Data Collection Forms and Procedures

The data collection form consists of two sheets. The building summary sheet will be used to collect building level information. The zones summary sheet will be used to collect information by zone, which will be defined by gross external surface area and total conditioned area. Each dwelling unit will be categorized under one of the predefined zones. Table 8 below provides a description of the fields in the building summary sheet. Table 9 below provides a description of the fields in the zone summary sheet. Some fields are not included in the non-participant forms. An explanation is provided in the notes after the tables.

Table 14: Building Summary Form

FIELD NAME	FIELD DESCRIPTION	NOTES
	PAGE HEADER	
Building Number	Enter the building number for which this data applies. P=Participants; NP=Non-participants	
Building Name	Enter the name of the building from the study candidate list.	
Date	Enter the date when the plan take-off is started.	
Initials	Enter your initials.	
Number of apartments in building	Enter the total number of apartments in the building. Do not include apartments that are excluded from the Built Smart agreement (participants) or have gas heating (non-participants).	
Compliance Method	Identify the compliance method used as defined in the Built Smart notebook - Option I, Option II, Calculated.	
Total # of floors	Enter the total number of floors in the building. Include all residential, commercial and parking areas.	
Total Non-residential # of floors	Enter the number of floors used for parking or commercial use. Use fractions if part of the floor is used for residential and part for commercial or parking.	
	BUILDING ENVELOPE	
Framed External Wall	Provide wall characteristics for each wall type that has distinct thermal performance. Thermal performance may change with stud spacing, insulation value and framing	

FIELD NAME	FIELD DESCRIPTION	NOTES
	material.	
Wood / steel / other	Enter type of framing.	
U-value	Enter the wall U-value as provided in the Built Smart application (participants).	A, B
Gross Area	Enter gross wall area as provided in the Built Smart application (participants). Do not deduct window and door areas.	A, C
Description of component layers	Enter a description of the wall components. Stud spacing and material should be included.	
Nominal Insulation R-value	Enter the nominal insulation R-value for the framed wall.	
Exterior Wall Below Grade	Provide wall characteristics for each wall type that has distinct thermal performance. Required only if there is conditioned common/residential area below the ground line. Thermal performance may change with stud spacing, insulation value and framing material.	
U-value	Enter the wall U-value as provided in the Built Smart application (participants).	A, B
Gross Area	Enter gross wall area as provided in the Built Smart application (participants). Do not deduct window and door areas.	A, C
Description of component layers	Enter a description of the wall components.	
Nominal Insulation R-value	Enter the nominal insulation R-value for the wall.	
Windows	Include glazing in doors, if less than 50% of the door area. Doors with more than 50% glass area should be considered windows.	
Average U-value	Enter the average window U-value from the Built Smart application (participants) or from the plans (non-participants). If average U-value is not available on the plans, compute average U-value, using the window schedule in the zone summary sheet.	
% glazing	Enter the percentage of window area from the Built Smart application (participants).	A, C
Total glazing area	Enter total window area for the building from the Built Smart application. Window area	A, C

FIELD NAME	FIELD DESCRIPTION	NOTES
	includes frame area.	
Skylights	Do not include skylight areas with windows.	
Average U-value	Enter the average skylight U-value from the Built Smart application (participants) or from the plans (non-participants).	
Total glazing area	Enter total skylight area for the building from the Built Smart application (participants) or from the plans (non-participants).	
Doors	Consider doors on exterior walls only. Doors with more than 50% glass area should be considered windows.	
Average U-value	Enter the average door U-value from the Built Smart application (participants) or from the plans (non-participants). If average U-value is not available on the plans, compute average U-value, using the door schedule in the zone summary sheet.	
Total building exterior door area	Enter total exterior door area for the building from the Built Smart application.	A, C
Ceiling (attic)		
U-value	Enter the attic ceiling U-value from the Built Smart application (participants).	A, B
Gross Area	Enter gross attic ceiling area as provided in the Built Smart application. Do not deduct skylight area.	A, C
Description of component layers	Enter a description of the attic ceiling components.	
Nominal Insulation R-value	Enter the nominal insulation R-value for the attic ceiling.	
Ceiling (vaulted/flat)		
U-value	Enter the vaulted or flat ceiling U-value from the Built Smart application (participants).	A, B
Gross Area	Enter gross vaulted or flat area as provided in the Built Smart application. Do not deduct skylight area.	A, C

FIELD NAME	FIELD DESCRIPTION	NOTES
Description of component layers	Enter a description of the vaulted or flat ceiling components.	
Nominal Insulation R-value	Enter the nominal insulation R-value for the vaulted or flat ceiling.	
Slab Type	Provide details for a slab type only if it is provided in a conditioned common/residential area of the building.	
Type	Enter S for slab-on-grade, PT for post tension concrete slab with space below or F for wood framed floor.	A, D
S>> F-value	Enter the floor F-value for floor slab-on-grade - insulation measured per lineal foot of slab perimeter.	
Description of component layers	Enter a description of slab-on-grade construction.	
PT>> Nominal R-value	Enter the nominal insulation R-value for the PT slab below conditioned common/residential area.	
Description of insulation location	Enter a description of PT slab construction.	
F>> U-value	Enter the floor U-value for wood famed floor.	
Description of component layers	Enter a description of wood framed floor construction.	
	SPACE HEATING	
Primary Heat Source - Residential		
Type	Select from baseboard; heat pump - split system; heat pump - ducted, hydronic radiators, hydronic wall fan coils, forced air wall units, forced air furnace, other.	
Heat source efficiency	Enter energy efficiency if the heat pump is the primary source of space heating.	

FIELD NAME	FIELD DESCRIPTION	NOTES
Primary Heat Source - Common Area	Identify the main source of heat, if the common areas have multiple heat sources.	
Type	Select from baseboard; heat pump - split system; heat pump - ducted, hydroninc radiators, hydronic wall fan coils, forced air wall units, forced air furnace, other.	
Heat source efficiency	Enter energy efficiency if the heat pump is the primary source of space heating.	
Fireplace		
Yes/No	Enter yes if some or all the dwelling units in the building have a fireplace.	
Fuel Type	Select from electric, gas, wood or other.	
	WATER HEATING	
Heater type	Enter electric or gas, and individual or central.	
Model #	Enter water heater model number if available.	
Efficiency (if available)	Enter water heater efficiency if available.	
	LIGHTING	
Common Area - Exterior Lighting	Provide location, fixture type and description, installed watts and controls for each type of fixture installed on the exterior of the buildings. Enter data only if the project received rebates for exterior lighting (participants). For non-participants, always enter data, if it is available.	
Total Exterior Installed watts	Enter the total exterior lighting watts for the building.	
Location	Enter the location of the light fixtures, e.g. wall, courtyard, rooftop.	
# Fixture1	Enter the number of fixtures installed.	
Fixture1 description	Enter type, make and model of the fixture, as available.	

FIELD NAME	FIELD DESCRIPTION	NOTES
Total installed watts	Enter total wattage of the above fixtures.	
Controls	Enter type of control used to switch off the fixture. Generally photocells are provided with outdoor fixtures.	
Rebated Common Area Interior Lighting	This is an optional measure in the Built Smart Program. Leave blank if not listed in the application (participants).	A, E
Total Rebated Watts	Enter the total rebated common area interior lighting watts for the building.	A, E
Hours of operation	Enter the hours of operation for the common area fixtures from the Built Smart application. If some fixtures are controlled by sensors and others are not, provide hours of operation, prorated by total fixture wattage.	A, E
Rebated In-unit Lighting	This is an optional measure in the Built Smart Program. Leave blank if not listed in the application (participants).	A, E
Total Rebated Watts	Enter the total rebated in-unit lighting watts for the building.	A, E
	FANS	
Whole House Fan	This measure will be in the Built Smart application only if the building has whole house fans. Leave blank if not listed in the application (participants) or not shown on plans (non-participants).	
Fan Model #	Enter whole house fan model number.	
Fan Watts	Enter a range for the installed whole house fan wattage, if available.	
Fan CFM	Enter a range for the installed whole house fan CFM, if available. Use the CFM measured by the inspector (participants) - this will be found in the inspector's handwritten notes.	
Additional Fans		

FIELD NAME	FIELD DESCRIPTION	NOTES
Present/Absent	Enter present if other fans are installed in the dwelling unit. This includes bathroom, kitchen, laundry and fireplace exhausts.	
	BUILDING AREAS	
Total Floor Area: common + residential	Enter total residential and common area square footage as provided in the Built Smart application, if available.	A, C
Total Residential Floor Area	Enter total residential area square footage as provided in the Built Smart application, if available.	A, C

Table 15: Zone Summary Form

FIELD NAME	FIELD DESCRIPTION	NOTES
	PAGE HEADER	
Building Number	Enter the building number for which this page applies. P=Participants; NP=Non-participants	
Building Name	Enter the name of the building from the study candidate list.	
Initials	Enter your initials.	
	ZONE DETAILS	
Zone #	Enter a zone number for the zone defined below. R = dwelling units; C = common area serving residences; P = parking. Do not record commercial (retail) areas. Only lighting information should be collected for the parking zone. Do not distinguish between floors, ceilings, and walls, when determining number of exterior surfaces for the zone.	
Space Multiplier	Enter the number of times this zone used. For residential zones this equals to the number of dwelling units that fit into this zone description. For common areas the zone multiplier is always 1.	F
Space type description	Enter the number of bedrooms and the number of exterior surfaces.	
Conditioned space	Enter No for common space that is unconditioned. Enter Yes for conditioned (heated) common space and all apartments.	
Number of bedrooms	Enter the number of bedrooms in the apartment. Enter zero for common space.	

FIELD NAME	FIELD DESCRIPTION	NOTES
Floor Area (sq.ft.)	Enter the floor area, in square feet, of the space.	F
U-A Value For Zone	Enter the sum of the U-value multiplied by the area for each envelope component. (U-value Net Framed Wall x Area Net Framed Wall + U-value Underground Wall + Area Underground Wall + U-value Window x Area Window...).	G, H
# of exterior surfaces	Enter the number of exterior surfaces (1 to 5). An exterior surface is defined as an entire facing direction of the space, which includes 3 possible side walls, 1 ceiling, and 1 floor. If a surface is only partially exterior, round up if exterior space is more than or equal to half, round down if exterior space is less than half.	
Washer/dryer present	Enter Yes if there is a clothes washer/dryer set inside the space, No if not.	
	ENVELOPE	
Framed External Wall	**Provide wall characteristics. If two identical dwelling units have walls with distinctly different thermal performance, the dwelling units should be assigned separate zones. If the same dwelling unit has more than one thermally distinct wall type, use the wall type with the larger area. Thermal performance may change with stud spacing, insulation value and framing material.**	
Gross Area (ft2)	Enter the average exterior insulated *gross* opaque wall area from plans. Do not deduct window and door areas.	F
Net Area (ft2)	Enter the average exterior insulated *net* opaque wall area for the space. Subtract window and door area from gross wall area.	H
Average Wall Height (ft)	Enter the average wall height.	
U-value	Enter the U-value from the building summary sheet.	A, B

FIELD NAME	FIELD DESCRIPTION	NOTES
U-value Calculated	Enter the U-value using the description of component layers in the building summary sheet and ASHRAE recommended formulae. This will be computed after plans take-off.	G, H
U-A Value	Enter the product of the calculated U-value and the net area.	H
Exterior Wall Below Grade	**Provide wall characteristics if a conditioned part of the common/residential area is below the ground line. Thermal performance may change with stud spacing, insulation value and framing material.**	
Area (ft2)	Enter the below grade exterior wall area, in square feet, for the space.	
U-value	Enter the U-value from the building summary sheet.	A, B
U-A Value	Enter the product of the calculated U-value and the net area.	H
Windows	**Includes glazing in doors. Doors with more than 50% glass area should be considered windows.**	
Area (ft2)	Enter the total exterior window area, in square feet.	
Window U-value	Enter the U-value from the building summary sheet. If not available (non-participants), and individual U-value for each window type is available, then use the window schedule to compute average U-value.	
U-A Value	Enter the product of the U-value and the area.	H
Doors	**Consider doors on exterior walls only. Doors with more than 50% glass area should be considered windows.**	

FIELD NAME	FIELD DESCRIPTION	NOTES
Area (ft2), exterior only	Enter the exterior door area in square feet.	
Door U-value	Enter the U-value from the building summary sheet. If not available (non-participants), and individual U-value for each door type is available, then use the window schedule to compute average U-value.	
U-A Value	Enter the product of the U-value and the area.	H
Ceiling		
Type	Enter A or V for zones that do not completely have a conditioned space above. A = insulated attic; V = insulated vaulted (cathedral) or flat roof.	
Area (ft2)	Enter the insulated ceiling/roof area exposed to the exterior for the space.	F
Ceiling U-value	Enter the U-value from the building summary sheet.	A, B
U-value Calculated	Enter U-value using the description of component layers in the building summary sheet and ASHRAE recommended formulae.	H
U-A Value	Enter the product of the calculated U-value and the area.	H
Floor		
Type:	Enter S, PT or F for zones that do not completely have a conditioned space below. S=slab-on-grade; PT=post-tension concrete slab with space below; F=wood-framed with space below.	
Insulated floor area	Enter the average exterior surface area in square feet for wood framed and post tension slabs. Enter the average exterior perimeter floor length in feet for slab-on-grade.	F

FIELD NAME	FIELD DESCRIPTION	NOTES
Floor U-value	Enter the U-value from the building summary sheet.	A, B
U-value Calculated	Enter U-value using the description of component layers in the building summary sheet and ASHRAE recommended formulae.	H
U-A Value	Enter the product of the calculated U-value and the area.	H
	SPACE HEATING	
Fireplace		
Yes/No	Enter yes if the dwelling units have a fireplace.	
Fuel Type	Select from electric, gas, wood or other.	A, I
	LIGHTING	
Lighting Interior		
Total watts	Enter the total installed interior lighting fixture wattage from plans, if available.	
Total # of fixtures	Enter the number of interior fixtures installed from plans, if available.	

FIELD NAME	FIELD DESCRIPTION	NOTES
Lighting Exterior		
Total watts	Enter the total installed exterior lighting fixture wattage from plans, if available.	
Total # of fixtures	Enter the number of exterior fixtures installed from plans, if available. Patio fixtures in dwelling units qualify as exterior fixtures.	

DWELLING UNIT SCHEDULE

This schedule is used to collect dwelling unit information and compute averages that feed into the zone summary.

Wing/Bldg #	Enter information that will help identify the dwelling unit described, such as building number, wing name or building floor.
Apt #	Enter a description of the space for which the data is collected. Common areas can be described by the utility of the space, e.g. corridor, stairway and elevator, lobby. Enter apartment number for dwelling units.
Zone Type	Enter the zone to which the common area or apartment can be assigned. (Zones are defined by conditioned floor area and number of exterior surfaces).
Space multiplier	Enter a count of the number of spaces listed under apartment number.
Floor Area	Enter the conditioned floor area of the common area or apartment in square feet.
Exterior Wall Area	Enter the gross exterior wall area in square feet.
Window Area	Enter the gross window area in square feet.

FIELD NAME	FIELD DESCRIPTION	NOTES
Door Area	Enter the gross door area in square feet.	
Exterior Roof Area	Enter the gross exterior roof area in square feet.	
Exterior Floor Area / Perimeter	Enter the gross exterior floor area in square feet for PT slab and wood framed floors or floor perimeter in feet for slab on grade.	J
Win U-value x Area	Enter sum of product of window U-value and area from window schedule for all windows present in common area or apartment.	J
	WINDOW AND DOOR SCHEDULE	
	The schedule is used to collect door and window area and U-value to feed into the dwelling unit schedule.	
Windows		
Win #	Enter the window ID from the window schedule in the plans.	
Length	Enter the length of the window in feet.	
Width	Enter the width of the window in feet.	
Area	Enter product of window length and width.	
U-value	Enter U-value from plans if average U-value for all windows is not available and U-value for each window type is provided.	J
Doors		
Door #	Enter the door ID from the door schedule in the plans.	
Length	Enter the length of the door in feet.	

FIELD NAME	FIELD DESCRIPTION	NOTES
Width	Enter the width of the door in feet.	
Area	Enter product of door length and width.	
U-value	Enter U-value from plans if average U-value for all doors is not available and U-value for each door type is provided.	J

Notes:

A - Fields not included in the non-participant form.

B - Envelope U-values are not easily available for non-participants. Final U-values used for both participants and non-participants will be computed from component layers using ASHRAE recommended formulae.

C - Data not easily available for non-participants – will be computed from the zone summary sheet.

D - Collected in zone summary sheet.

E - No rebates for non-participants. Data for installed fixtures will be computed from zone summary sheet.

F - This value will be automatically computed from the dwelling unit schedule.

G - Final U-values used for both participants and non-participants will be computed from component layers using ASHRAE recommended formulae.

H - This will be computed after plans take-off.

I - Collected in building summary sheet.

J - Not included in participant form. Data directly entered in the zone summary instead.

Appendix F. ACEEE 2008 Conference Paper

Multifamily New Construction: Utility Program Leads the Way Toward Changing Building Practice and Energy Codes

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..... ABSTRACT

New construction of multifamily buildings in the Seattle area is becoming much more energy efficient. Two studies a decade apart reveal a 35% decline in energy use indexes (EUIs) among Built Smart program participants and a 45% decline among local-area baseline buildings. The findings point to ongoing transformation of the market place, led by a utility efficiency program that has touched most new projects in the past 15 years. Changes in standard practice have likely also been influenced by increased public awareness of energy efficiency, improved building designs and construction practices, and tighter building codes.

This paper describes the methods employed and empirical findings from two studies evaluating an evolving program that provides financial incentives to building developers to upgrade efficiency through building envelope specifications, efficient lighting fixtures, other equipment, and rigorous in-progress inspections. Evaluation methods included a review of billing and characteristics data for samples of participants and nonparticipants to form the basis for developing separate energy simulation models calibrated to utility billing records. Parameters from the nonparticipant model were substituted into the participant model to generate a baseline model.

Key findings show that, between 1994 and 2004, annual baseline EUIs declined from 13.26 to 7.36 kWh per square foot, while participant EUIs dropped from 10.26 to 6.66. This decline was demonstrated in all end uses: space heat, domestic hot water, lighting, and miscellaneous loads. While a welcome development, it also presents future challenges for the program to continue “pushing the envelope” of energy efficiency in multifamily new construction.

Introduction

This study arose out of uncertainty about the changing baseline for efficiency of multifamily new construction in the Puget Sound Area. Seattle City Light, through the Built Smart program, provides financial incentives to encourage multifamily building developers to upgrade the efficiency of their new buildings in the utility service area through “beat the code” specifications for design, construction, and equipment, as well as rigorous in-progress inspections that go beyond normal oversight by City building and energy code inspectors. Current estimates of energy savings from these measures are based on an impact evaluation completed in 1996 (Tachibana 1996). These estimates have been adjusted over time to reflect changes in the state energy code and

standard practice. Nonetheless, Seattle City Light did not feel comfortable with these estimates, given the time that has elapsed since the original research was performed. As a result, a new program impact evaluation (Tachibana 2008) was conducted to measure the effect directly.

The purpose of this study was to update the baseline for estimating Building Smart energy savings, taking into consideration the effects of state energy code and standard practice since the period investigated in the 1996 impact evaluation. The study was also intended to discern energy savings associated specifically with rigorous in-progress inspections. This paper describes the methods employed and empirical findings from this impact study, and compares the results to those of the prior study, to evaluate an evolving program.

The Built Smart program (1997-present) and its predecessor, Long-term Super Good Cents (LTSGC, 1992-1997) have been "beat the code" programs designed to encourage builders of new multifamily residential dwellings with electric space heat to exceed provisions of the Washington State and Seattle Energy Codes (WSBCC 2002). The utility goal is to move the market toward more efficient construction practices.

LTSGC paid incentives to builders for specifications and measures that upgrade the efficiency of the building shell, thermostats, lighting, equipment and appliances such as fans, water heaters, refrigerators, and showerheads. Thermal envelope upgrades were based upon a prescriptive path of measures, or a computer analysis of heat loss and estimated savings per dwelling unit. Appliance upgrades were based upon efficiency ratings.

Built Smart has gone further to also incorporate referrals for water conservation and waste recycling measures, during both the construction and occupancy stages of each project. Built Smart provides builders with a simpler prescriptive path for energy efficiency compliance (SCL 2003). In 2001 a new Seattle Energy Code requirement for common-area lighting secured improvements in standard practice which the program previously acquired through incentives. In 2002 the Energy Code was again revised; the most significant and relevant change was an increase in wall insulation requirements. Once again, former program measures were secured in code requirements.

New program components implemented in 1999 include Built Smart–Affordable Housing and Built Smart–Lighting & Appliance Options. Affordable Housing provides specialized new-construction and rehabilitation incentives to builders/developers of low-income multifamily housing with electric space heat. Lighting & Appliance Options provide incentives for installing energy efficient lighting fixtures in common areas of multifamily buildings that are ineligible for Built Smart envelope measures; these include buildings with gas space heat or steel framing. High-rise steel-framed buildings are also offered incentives for qualifying models of appliances such as dishwashers and refrigerators, and for efficient ventilation fan systems.

Methodology

The study team investigated program energy impacts using typical energy program evaluation methods, including the review of program, billing, and characteristics data

for a sample of participants, as well as a similar review for a sample of non-participants. These formed the basis for developing separate participant and non-participant energy simulation models, which were calibrated to utility billing records. First a calibrated prototype was developed for low-rise mixed-use multifamily Seattle City Light program participants (2002-2004), using energy simulation software. This prototype was used to determine the as-built energy consumption characteristics of new multifamily buildings that represent the majority of the population of recent program participants. Next a calibrated prototype was developed for non-participants, drawn from comparable buildings in the service are of an adjacent utility. This prototype was used to determine the as-built energy consumption characteristics of new multifamily buildings that represent the population of non-participants that were built at the same time as the participants. These non-participants are selected from the Puget Sound Energy (PSE) customer base in urbanized east King County (Seattle is located in the west of this county), where there is no multifamily new construction conservation program.

After this, parameters from the nonparticipant model were substituted into the participant model to generate a baseline model, to determine the baseline energy consumption characteristics of participants excluding the provisions of the Built Smart program. Finally, energy savings associated with the provisions of the Built Smart program were determined, computed as the difference between participant and baseline models under typical meteorological conditions and full occupancy. This process provided the best available estimate of the total program energy impacts. To the extent possible, the total savings were further broken down according to physical program measures and actions, including the rigorous inspection (building commissioning) provisions. Selected market actors were interviewed to inform the analysis, as well.

The Built Smart methodology was very similar to that used for the previous LTSGC study. Both studies created a baseline model by removing program features from a calibrated participant model. The Built Smart study also created a calibrated non-participant model. This was used to specify parameters to manipulate in the participant model to generate the baseline model. It also was examined in the attempt to identify building inspection impacts.

..... Sample Selection and Building Characteristics

The majority of electric-heat multifamily buildings newly constructed in Seattle today are mixed-use construction, having one or two concrete (retail or garage) lower floors, topped by three to five stories of stick-framed residences. To limit the scope of the study to the most prevalent type, town-homes and complexes of fewer than eight units, and buildings lacking a non-residential first floor, were not included as study candidates. These types are less common among electric-heat buildings and have different construction and energy-use characteristics. The sample frame also excluded high-rises and gas heated residences. From the sample frame, 13 participant buildings were selected, most of which had laundry facilities in the units.

It proved impossible to find eligible non-participant buildings in the City of Seattle, after extensive screening of building permits and cross-matching with program records; there were no program nonparticipants. Puget Sound Energy assisted with selecting mixed-use construction non-participants outside of Seattle. After an

extensive screening process, 10 non-participant sites were located in the Cities of Bellevue and Kirkland, Washington.

Data collection included detailed participant and non-participant characteristics from program project files, design documents and blueprints available from municipal governments and, when necessary, drive-by observations or site visits at selected buildings. Key data included number of floors, type of wall construction and water heating for each building, as well as average conditioned floor and wall area and installed wattage for each housing-unit and common-area zone.

..... Electric Loads and Weather Data

Seattle City Light and Puget Sound Energy provided monthly or bimonthly electric billing records for all occupied housing units in the participant and non-participant samples, respectively. Supplemental electric load data was used to help inform the modeling effort, including hourly loads from similar buildings for constructing typical infiltration, internal load and thermostat set-point schedules (Tachibana 1996; SBW 1994). For non-participants, electric load data also included utility-supplied daily kWh totals and 15-minute kW interval data. After summarizing and cleaning these data, useful insights were obtained into day-types, variations in use between weekdays and weekends, and diurnal patterns of non-heat consumption. Also developed were average Energy Use Indices (EUIs) for participants and non-participants to serve as calibration targets during modeling.

Typical meteorological year (TMY) and actual weather data were assembled for the model calibration period (calendar year 2006) from the National Climatic Data Center weather station at SeaTac. These data were used in the energy simulation models.

..... Standard Practice and Energy Code Enforcement

An innovation in this study was to conduct telephone interviews to determine how builders install insulation and other related building envelope components, and how rigorously they achieve air sealing. A special emphasis was placed on whether differences in the level of enforcement of the energy code between jurisdictions affects how builders install insulation and other related building envelope components. Market actors interviewed included general contractors, insulation subcontractors, and city building inspectors. Responses were compiled in a database, analyzed, and compared with building characteristics data and billing records to develop synthesized findings and recommendations regarding the impacts of program in-progress inspections.

..... Model Development and Analysis of Energy Savings

One fully calibrated participant prototype model was developed using eQUEST (DOE2) hourly energy simulation software. The prototype reflected the as-built conditions of the predominant participant building type, which included buildings containing primarily one- and two-bedroom housing units that had laundry facilities in the units. The prototype model characteristics were derived from program documentation that included as-built plan take-off data about floor and envelope areas, and construction and program participation features. Appliance, lighting, infiltration,

and thermostat set-point schedules from prior research (SBW 1994) and the LTSGC prototype model (Tachibana 1996) were used as the starting point for model calibration.

Monthly energy use predicted by the model was compared to target values developed by aggregating actual 2006 billing data. The simulation was adjusted until the predicted whole building EUI was within 10% of the monthly target values and 5% of the annual target value. The as-built model was then modified to reflect measure participation levels for optional measures, and rerun under TMY weather conditions and full occupancy. The non-participant model was developed in a very similar way, with the additional step of incorporating summaries of daily and 15-minute kW data to adjust the model.

From the non-participant model, a list of inputs was compiled that are associated with the features of the Built Smart program. The modified as-built participant model simulation was then rerun, changing the inputs associated with the Built Smart features to the non-participant values for all envelope components and lighting power densities. This created a baseline model that simulated the performance of the participant model without the influence of the Built Smart program.

Energy savings were computed as the difference between participant and baseline models under TMY weather and full tenant occupancy conditions. The specific program measures evaluated for energy savings impact included: Option I (<12% glazing ratio) and Option II (12-15% glazing ratio) envelopes; common area, in-unit, and exterior lighting; hot water heaters; whole house fans; and the Built Smart program's enhanced envelope specification and inspection process

The two envelope measures were modeled by adjusting the participant models to include only the envelope differences. Energy savings were then estimated for the other measures by adjusting the Option I envelope model to include each measure sequentially, in a "rolling baseline" fashion. To estimate the nominal effect of non-envelope measures such as lighting and hot water heaters, hand calculations were performed to inform the models, as necessary.

Findings

..... Sample Characterization and Building Characteristics

Out of a list of 72 buildings that participated in the Built Smart umbrella of programs during 2003-2004, many were eliminated from the study sample because they were built under previous codes (21 buildings), they were not mixed-use construction, or insufficient metered billing data were available (22 buildings). The 13 participant projects selected from the pool of 29 mixed-use buildings consisted of seven residences with in-unit laundries and six with common area laundries. Across these projects, 81% of the residence units had in-unit laundries. These included several large complexes with over 160 units each.

To select non-participants, 93 buildings were identified that were constructed outside of Seattle in King County between 2002 and 2004; only part of this area is urban. Of these 72 were eliminated because they were not mixed-use construction. After further

review of billing data and available documentation, a final sample of 10 projects was selected from the pool of 21 mixed-use buildings, all of which had in-unit laundries.

Nine of the sampled participant buildings had Option I envelopes (<12% glazing ratio) while four had Option II envelopes (12-15% glazing ratio). About a third of the participating buildings also incorporated efficient lighting and whole house fan measures into the Built Smart project. Nearly half of the participant buildings installed efficient water heaters.

The average sizes of participant and non-participant dwelling units were 777 and 825 square feet, respectively, based on an assessment of 673 participant units and 834 non-participant units. Component U-values for participants were uniformly lower (more efficient) than corresponding values for non-participants. Participant domestic hot water heaters were only slightly more efficient than non-participant heaters. Lighting measures among participants reduced interior lighting power densities significantly for participants, compared to energy code.

..... Energy Use Index and Program Energy Savings

Billing data revealed that for sampled participants the average energy use index (EUI) was 6.65 kWh per square foot annually, while for non-participants it was 7.64 kWh. Expressed in percentages, participants used 13% less energy on average than non-participants in 2006, unadjusted for any mitigating factors. After calibration of all models, the final estimate of typical annual consumption for the participant and baseline prototypes was 6.66 kWh and 7.36 kWh per square foot, respectively.

As expected, estimated annual energy usage is greater in the baseline case than it is for participants. The difference of 0.70 kWh per square foot represents overall annual gross savings of nearly 10% for program participants. Applied across all participants with in-unit laundries, the absolute average unit savings from the Built Smart program is 621 kWh per residential unit.

Table 1 below disaggregates these savings by individual measures. It is important to realize in this table that the reported results are normalized across all program participants in the sample, not just those affected by the particular measure. So, for example, Option II envelope savings appear much lower than Option I envelope savings, not because Option II envelopes are much less efficient than in Option I, but because Option II was found among a mere 7% of the sampled participants.

Table 1. Evaluated Measure Savings

Measure*	Annual EUI	Difference in EUI	Annual kWh Savings per Unit ***	% of Total Savings	% of Model Represented in Sample
Baseline	7.36				
Option I Envelope	7.13	0.22	200	31%	93%
Option II Envelope	7.12	0.01	11	2	7
In-unit Lighting	7.04	0.08	71	11	66
Common Area Lighting	6.69	0.35	313	51	59
Exterior Lighting	6.68	0.01	9	2	91
Domestic Hot Water Heaters	6.66	0.02	17	3	67
Whole House Fans **	6.66	0.00	0	0	62
Enhanced Inspections **	6.66	0.00	0	0	100%
ALL		0.70	621	100%	

EUI: Energy Use Index, in annual kWh per square foot.
* Savings from each measure are normalized across floor area for all in-unit laundry program participants, not just for measure-affected floor area
**Savings from these measures were found to be negligible and/or unquantifiable.
*** Savings per living unit are averaged across all in-unit laundry participants.

These results indicate that 64% of the gross savings from the Built Smart sample come from lighting measures. This is particularly notable since not all participants implemented lighting measures, as they were optional (envelope measures, by contrast, were mandatory under program rules). This also contrasts with the previous LTSCG results, which showed that lighting and envelope measure savings were nearly equal. Most of the savings for the Built Smart lighting measures are found in the common area lighting, since it is operated 24 hours per day.

..... Building Inspection Practices

To aid in study design and interpretation of study results, during the data collection phase telephone interviews were conducted with 12 individuals involved in the construction of multifamily buildings not participating in the Built Smart program. These market actors included two general contractors, four insulation subcontractors, and six building inspectors. The subset of insulation contractors interviewed represented a significant fraction of the pool of contractors in the area for this kind of work. The purpose of the interviews was to determine how builders install insulation and other related building envelope components, how rigorously they achieve air sealing, and how differences in the level of enforcement of the energy code between jurisdictions affects how builders install insulation and other related building envelope components. The consensus was that compliance with the insulation and air sealing requirements in the Washington State Energy Code is generally better in municipal jurisdictions and more lax in the unincorporated areas. It appears many of the municipalities in the Puget Sound area achieve a reasonable level of compliance with the code while a few, e.g., Bellevue and Seattle's Built Smart, appear to achieve a more rigorous standard for code compliance.

The non-participant buildings in the study sample were constructed in either the Bellevue or Kirkland jurisdictions. Based on the interviews, each jurisdiction appears to have different levels of thermal performance based on the integrity of insulation and

air sealing practices. This might suggest that two non-participant models might have been appropriate—one for Bellevue, representing installation practices equivalent to Built Smart installation practices, and one for Kirkland representing non-participant Seattle buildings.

Quantitative analysis of the building data, however, did not offer any evidence that such a difference exists. The 2006 electric usage indexes (EUIs) for sampled buildings in Bellevue are about 9% higher than for Kirkland buildings, despite the suggestion during the interviews that Bellevue inspections are more rigorous. Differences, if any, in energy usage because of inspection-related envelope differences are masked by other, more significant differences in building geometry and glazing. In addition, the normal variation among inspectors and contractors, coupled with the relatively small sample sizes, may obscure the effect even further. The study team therefore concluded that developing separate non-participant models to capture the inspection effect would be fruitless.

..... Comparison Across the Decade: 1994 to 2004

Examining EUIs by end use provides another basis for comparing LTSGC impacts with those of Built Smart. Table 2 and Figure 1 show, in tabular and graphical form respectively, the EUI reductions attributable to each program. The LTSGC program yielded significant reductions in energy use of space heat and miscellaneous equipment (which includes interior lighting), reducing the average total EUI from 13.26 to 10.26 kWh per square foot annually, a 23% reduction. Evaluated annual savings from the LTSGC program for complexes with in-unit laundries were 1.43 and 1.57 kWh per square foot for Tier 1 shell measures and lighting add-on provisions, respectively, producing a total of 3.0 kWh per square foot in energy savings. The Built Smart program also reduced space heat and miscellaneous equipment consumption, but the magnitude of these changes is relatively small (annual savings of 0.68 kWh per square foot). The current estimate of Built Smart savings represents one-fourth (23%) of the savings estimate for LTSGC.

The fact that the Built Smart baseline EUI is well below the LTSGC efficient EUI likely illustrates how much more efficient current multifamily buildings have become compared to their predecessors a decade ago. Interestingly, the end use proportions for efficient LTSGC and Built Smart buildings remained nearly the same, although their overall magnitude has dropped. In both cases, space heating is about 12% of total usage, domestic hot water about 32%, miscellaneous equipment about 55%, and exterior lighting less than 1% of total usage. Built Smart lighting savings are 28% of LTSGC lighting savings.

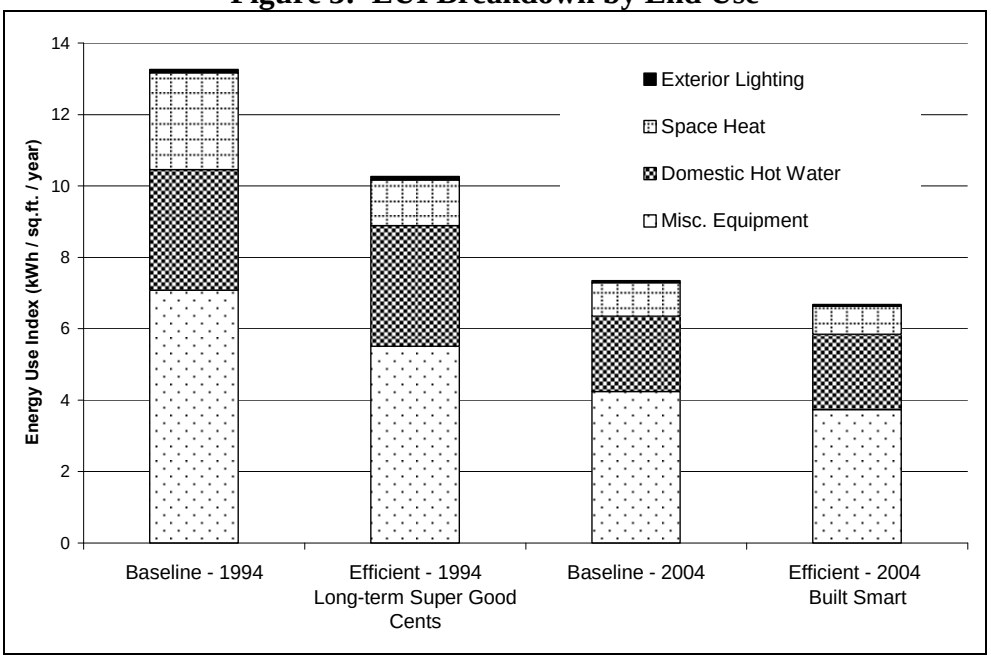
The significant decrease in baseline EUI over the decade can be explained by several factors. The building envelope thermal integrity has improved because code changes and market transformation have altered standard practices in design and construction. Specifically, the following items helped reduce baseline energy use over the ten-year period.

Table 2. EUI Breakdown by End Use

End Use	Long-term Super Good Cents (1996 Evaluation)				Built Smart (2007 Evaluation)			
	Baseline		Efficient		Baseline		Efficient	
	Annual EUI	% of Total	Annual EUI	% of Total	Annual EUI	% of Total	Annual EUI	% of Total
Space Heat	2.71	20.4	1.28	12.5	0.94	12.8	0.78	11.7
Domestic Hot Water	3.38	25.5	3.38	32.9	2.11	28.7	2.11	31.6
Misc. Equipment / Interior Ltg.*	7.08	53.4	5.51	53.7	4.24	57.7	3.74	55.9
Exterior Lighting	0.09	0.7	0.09	0.9	0.06	0.8	0.05	0.7
ALL	13.26	100.0	10.26	100.0	7.36	100.0	6.66	100.0

EUI: Energy Use Index, in annual kWh per square foot.
* Includes in-unit lighting as well as lighting in conditioned and unconditioned common areas.

Figure 3: EUI Breakdown by End Use



Window U-Value. In 1994-1995, the baseline window U-value was observed to be 0.47, which did not even meet the code value of 0.45. In 2002-2004, baseline windows had a U-value of 0.36, which was better than the code requirement of 0.40. It is difficult to even find windows in today's Northwest regional market with a U-value as high as 0.40.

Air Sealing. Since the 1994-1995 study, builders have significantly improved moisture and air sealing practices, primarily due to liability problems associated with moisture damage.

Domestic Hot Water. Hot water tank efficiency standards have increased over time also. Previously required energy efficiency factors were 0.86, instead of the more

recent requirement of 0.91. Also, general improvements in the efficiency of dishwashers, clothes washers, and showerheads have reduced hot water demand.

Miscellaneous Equipment. The efficiency of refrigerators has improved over the ten-year period, as well as for other equipment, such as computers. Use of efficient lighting, such as compact fluorescent lamps, has also increased during this time.

Exterior Lighting. Common practice for exterior lighting fixture types and controls has improved to near the Built Smart program level over the ten-year period.

Other differences, such as in occupant behavior, may also be affecting EUIs, although it was not possible to discern these effects in the data collected for this evaluation study.

Discussion and Conclusions

New construction of multifamily buildings in the Seattle municipal area is becoming much more energy efficient. Between 1994 and 2004, energy use indexes (EUIs) declined significantly among both program participant and local area baseline buildings. The findings point to a large success in the ongoing transformation of the market place, led by a utility efficiency program that has touched most new Seattle projects in the past 15 years. Changes in standard practice have likely also been influenced by increased public awareness of energy efficiency, improved building designs and construction, and tighter energy codes.

Key findings show that, between 1994 (LTSCG) and 2004 (Built Smart), baseline EUIs declined from 13.26 to 7.36 kWh per square foot per year, while participant EUIs dropped from 10.26 to 6.66. This decline was demonstrated in all end uses: space heat, domestic hot water, lighting and miscellaneous loads. While a welcome development, it also presents future challenges for the program to continue “pushing the envelope” of energy efficiency in multifamily new construction. Seattle City Light plans to use the study findings to better estimate program impacts and make program revisions.

Based on the findings of this study, five key conclusions are offered.

> *1. Energy savings from the 2004 Built Smart Program were lower than from the 1994 Long-Term Super Good Cents Program.*

Reduced electric usage of newer multifamily buildings, combined with program measures with less scope that yield smaller savings, led to Built Smart program impacts being much lower than those of its predecessor program. This reduction very likely indicates the success that Seattle City Light new construction programs have had in transforming the multifamily marketplace in the Seattle area, driving energy codes to more conserving levels. This success, ironically, may pose challenges for future Seattle programs of this type.

The evaluated average Built Smart baseline usage is 37% less that the baseline calculated a decade ago for the LTSGC program. While the overall Built Smart energy savings represents nearly 10% savings over current baseline, this value is much smaller than the LTSGC finding of 23% savings over the previous baseline. The end result is

that the Built Smart annual savings of 0.70 kWh per square foot (621 kWh per unit) only is only 23% of the 3.0 kWh per square foot savings that LTSGC provided.

Both the reduced baseline usage and the smaller difference between participants and non-participants suggest that overall, multifamily new construction projects in the greater Seattle area are becoming much more energy efficient. We surmise that a combination of tighter building codes, improved building designs and construction practices, and increased public awareness of efficiency may have much to do with this welcome development. It is highly likely that programs such as LTSGC and Built Smart have been instrumental in effecting these improvements to the marketplace over the many years they have been in existence. Looking forward, Seattle City Light may consider additional measures to enhance the program portfolio of existing measures for multifamily new construction.

> *2. Interior lighting measures yielded most of the program savings for the 2004 Built Smart Program.*

Interior lighting measures yielded the preponderance of savings in the Built Smart sample, suggesting that a sustained program emphasis on these measures is warranted. Using the Washington State Energy Code as the baseline, savings from interior (in-unit and common area) lighting measures comprise nearly two-thirds of the gross savings from the Built Smart program. By comparison, just over half of gross savings came from lighting measures in the LTSGC program a decade earlier. This occurs even though not all Built Smart participants implemented lighting measures, since they were optional, while envelope measures were mandatory under program rules. Most of the savings for the lighting measures is found in the common area lighting, since it is operated 24 hours per day. Nonetheless, Built Smart lighting savings are only 28% of LTSGC lighting savings, due to more stringent current baseline conditions.

The high percentage of savings from lighting measures in the study sample, as well as the relatively ease with which they can be implemented, suggests that the program should continue to emphasize straightforward lighting measures. As with the low-rise mixed-use electrically-heated buildings included in this study, Built Smart is spurring on lighting efficiency improvements in other related building types, such as high-rise multifamily buildings with natural gas space heat.

The question remains, is the State Energy Code a good baseline for common areas? To confirm that lighting measures are cost-effective, Seattle City Light plans in future to perform additional work to verify actual baseline interior lighting conditions. Onsite visits of non-participant buildings from this study could determine whether the installed lighting falls short of code, meets code, or exceeds it. Such results would establish credible estimates of savings to expect in the future. These onsite visits could be extended to other non-participants, such as buildings currently under construction, as well as buildings that fell outside the scope of this study, such as high-rise steel-frame residences and town-homes. Assessing baseline conditions is particularly relevant, since the 2007 Seattle Energy Code calls for common-area lighting power densities of 0.8 watts per square foot. This more aggressive target is still higher than program participant densities, but will reduce the potential savings that the program will be able to acquire.

> *3. Exterior lighting measures yielded minimal savings for the 2004 Built Smart Program.*

Exterior lighting measures yielded minimal savings, since standard practice appears to be at or near program thresholds. With average annual unit savings of 8 kWh per square foot, exterior lighting measures made up a negligible 2% of program savings. It appears that standard practice for this lighting—installing compact fluorescent lamps in fixtures with photocell control—is fast approaching program requirements, severely limiting opportunities for the program to achieve savings in this realm.

Since the 2002-2004 period from which the study sample was drawn, the Built Smart program has in fact been installing more common-area (as well as in-unit) lighting measures. As a result, estimates of current lighting impacts will need to be updated proportionately to obtain an estimate of current overall program impacts.

> *4. Energy savings from the Built Smart Program's inspection process were negligible compared to this control group.*

Energy savings from Built Smart's enhanced in-progress building inspections and commissioning appear to be negligible overall when compared to other jurisdictions with rigorous building department inspections. These savings remain potentially valid in concept, but it will require alternative approaches to ascertain their value.

Interview research for this study provided anecdotal evidence that different areas of the Puget Sound area may have different levels of envelope thermal performance based on the integrity of insulation and air sealing practices. For example, relevant construction practices may be more rigorous in Seattle and Bellevue, because of program and building inspector influences, respectively, than is the case in other municipalities. However, the quantitative analysis did not offer any evidence that such a difference exists between Seattle program participant buildings and non-participant buildings in Bellevue or Kirkland. It is possible that more significant differences, such as in building geometry and glazing, or between inspectors and contractors, are masking any inspection differences.

> *5. Alternative approaches to detect program inspection impacts are needed.*

As it turns out, the major drawback of this study is that it did not settle the question of what impact is made by diligent beyond-code measure specification and inspection. The control group selected for this study happened to be drawn from a geographic area where, contrary to expectations at study design, the building departments take on more responsibility for energy code inspections than was anticipated based on experience in the City of Seattle. This fact did not become apparent until well into study execution. To truly settle the question, it will be necessary to range further afield to locate similar building types in jurisdictions where this is not the case. The issue remains important to the utility, because this feature has been a hallmark of the program, and a center-point of its value to participants. It is also of concern if the utility were to cease rigorous on-site inspections, and the building department did not take up the slack.

Seattle City Light has considered other options for future study to quantify or frame the question of the value and effects of enhanced inspections. One method might be an

"inspect the inspector" approach, in which an impartial third party accompanied Built Smart staff, observed actual deficiencies, and based estimates of energy impacts on these observations. Such an approach, unfortunately, would likely be expensive and intrusive, and yield biased results. Another option might be to prove the hypothesis that enhanced inspections are cost-effective. This could be approached by first estimating the incremental cost to the program of these inspections, then assessing the minimum savings that inspections must provide to make the investment cost-effective. If the minimum savings seemed plausible given the evidence at hand, then one could conclude that inspections are cost-effective. A third, and perhaps the most direct and effective approach, would be to repeat this study with nonparticipants drawn from unincorporated areas of King County or Pierce County, where there are no multifamily new construction programs, and building departments that place little emphasis on State energy code enforcement. The difficulty would be to locate mixed-use construction in these localities. Discussions have ensued with other utilities in the Puget Sound area to collaborate on an investigation such as this, to determine the true baseline in the absence of any diligent measure specification and inspection process.

In order to project findings from this study for the current and future 2008 Built Smart program, several steps will be taken. Today's program generates project-specific savings calculations based on prior research and project characteristics. This method can be applied to the impact evaluation projects and comparisons drawn, to determine whether adjustments in the calculation methods are required. Today's program also provides increased levels of lighting measures, compared to the 2002-2004 study cohort, also requiring upward revisions to estimates. Also, the energy code has been updated for glazing and window U-values. With adjustments for these factors, study findings can be adjusted to estimate current program impacts and guide program revision. Analysis can also follow to optimize program cost-effectiveness.

It is hoped that, by addressing the conclusions from this evaluation, Seattle City Light can make appropriate program revisions to the evolving Built Smart program and continue "pushing the envelope" of energy efficiency in multifamily new construction.

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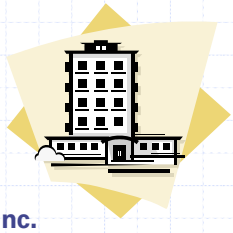
Appendix G. Presentation Slides

Multifamily New Construction

Utility Program Leads the Way Toward Changing Building Practice and Energy Codes



Debra Tachibana, Seattle City Light
Bing Tso & Jeffrey Romberger, SBW Consulting, Inc.

2008 Summer Study on Energy Efficiency in Buildings, Panel 2
American Council for an Energy Efficient Economy

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Context of Current Study

- Uncertainty about current baseline
  - Long-term Super Good Cents, 1992-1997
    - Evaluation 1996 > program redesign
  - Built Smart, 1997-2008
    - Financial incentives
    - Beat-the-code specifications
    - Rigorous in-progress inspections
  - Upgrades to standard practice
  - Updates to State & Seattle energy codes

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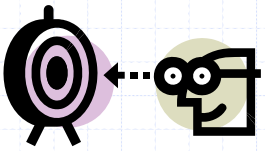
Study Objectives



- Characterize Participants, as-built
  - Low-rise mixed-use multifamily
    - Concrete lower floors (1-2 stories, retail or garage)
    - Stick-framed upper floors (3-5 stories, residences)
- Characterize Nonparticipants, as-built
- Establish Baseline Model
  - Use NP characteristics to adjust P model
- Estimate Changes in Energy Use

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Methodology

- Review program specs, bill histories, design & construction data
- Develop models: P, NP & Baseline
  - Separate energy simulations in eQUEST (DOE2)
    - Calibrated to actual energy use
    - Normalized to full occupancy, typical weather
- Analyze Program Energy Savings
- Compare to 1996 Study

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Study Groups

- Program Participants
  - Seattle City Light [SCL]: Built Smart (2002-2004)
    - City building inspectors defer to program inspectors
- Nonparticipants
  - None in City of Seattle
  - Seek comparable buildings in East King County
  - Served by Puget Sound Energy [PSE]
    - No multifamily new construction program
    - Independent Bellevue & Kirkland building inspectors

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Data Collection

- Select Samples
  - Extensive screening of building permits, property assessment files
  - 13 SCL Parts., 10 PSE Non-Parts.
- Identify Building Characteristics
  - Project files, drive-by observations or site visits, design docs, blueprints, plan take-offs
- Capture Electric Loads
  - SCL/PSE billing + PSE daily/interval data

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Preparation for Modeling

- Calculate Energy Use Indices (EUIs)
  - Set calibration targets
    - ± 1% annual, ±10% monthly
- Weather Data
  - Actuals and typical meteorological year (TMY2)
- Supplement with Prior Hourly Load Research
  - Typical schedules for infiltration, internal load, thermostat set-point

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Analysis of Energy Savings

- Building Inspection Practices
  - Telephone interviews with market actors
    - General Contractors
    - Insulation Subcontractors
    - City Building Inspectors (Seattle, Bellevue, Kirkland)

- Calibrate Models to EUIs
- Hand-calculate Lighting, Hot Water
- Model Envelope, LPD on Rolling Baseline

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Findings: Building Samples

- Mixed-Use Sample Characterization
  - 13 of 29 Participants (673 units)
  - 10 of 21 Nonparticipants (834 units)
  - Wide size range, mostly in-unit laundries
- Building Characteristics
  - Square footage: 777 Part., 825 Nonpart.
  - Typically 1 to 2-bedrooms
  - Mostly Option I, ≤12% glass/floor area
  - Ps have lower U-values, LPDs than NPs

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Findings: Energy Use

- Energy Use Indexes (kWh/square foot/year)
  - Participants: 6.66
  - Baseline: 7.36
  - Savings: 0.70
- Program Energy Savings
  - 621 kWh / unit, 10% over Baseline Use
  - ¼ of LT-SGC savings 10 years earlier

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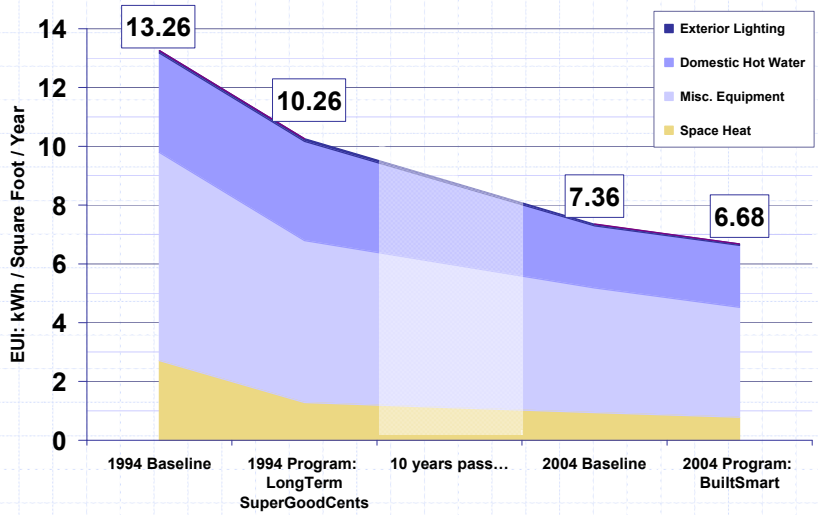
Declining EUIs, 1994-2004



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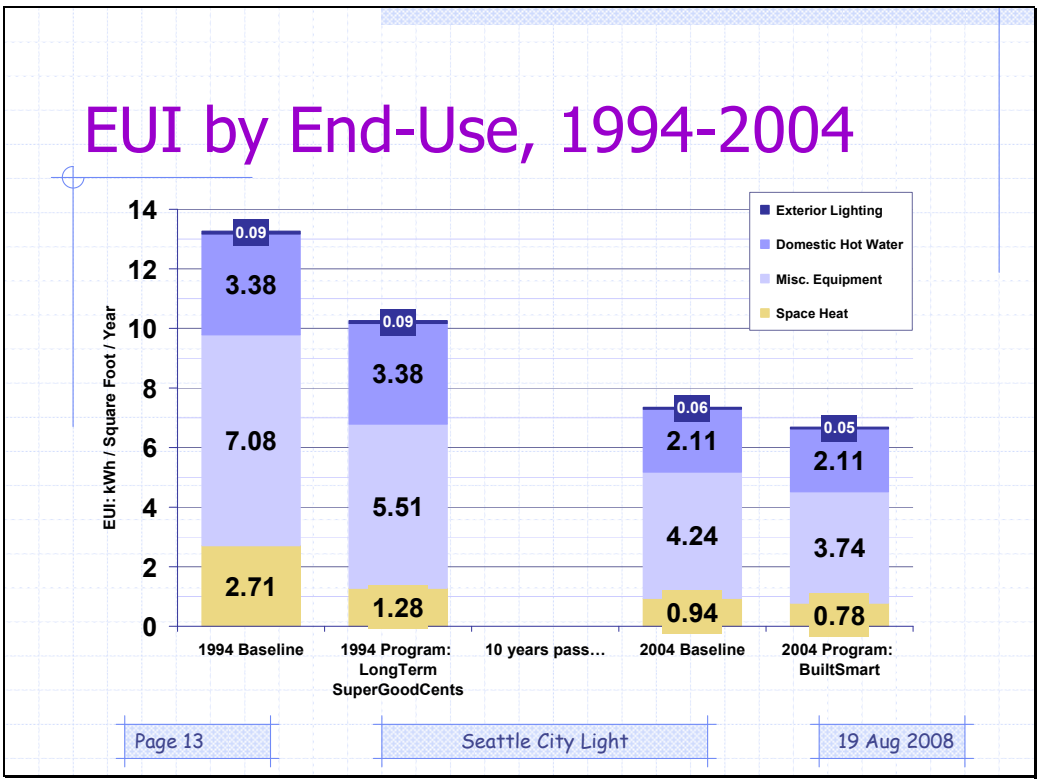
EUI by End-Use, 1994-2004
EUI: kWh / Square Foot / Year
14
12
10
8
6
4
2
0
Exterior Lighting
Domestic Hot Water
Misc. Equipment
Space Heat
0.09
3.38
7.08
2.71
0.09
3.38
5.51
1.28
0.06
2.11
4.24
0.94
0.05
2.11
3.74
0.78
1994 Baseline
1994 Program: LongTerm SuperGoodCents
10 years pass...
2004 Baseline
2004 Program: BuiltSmart
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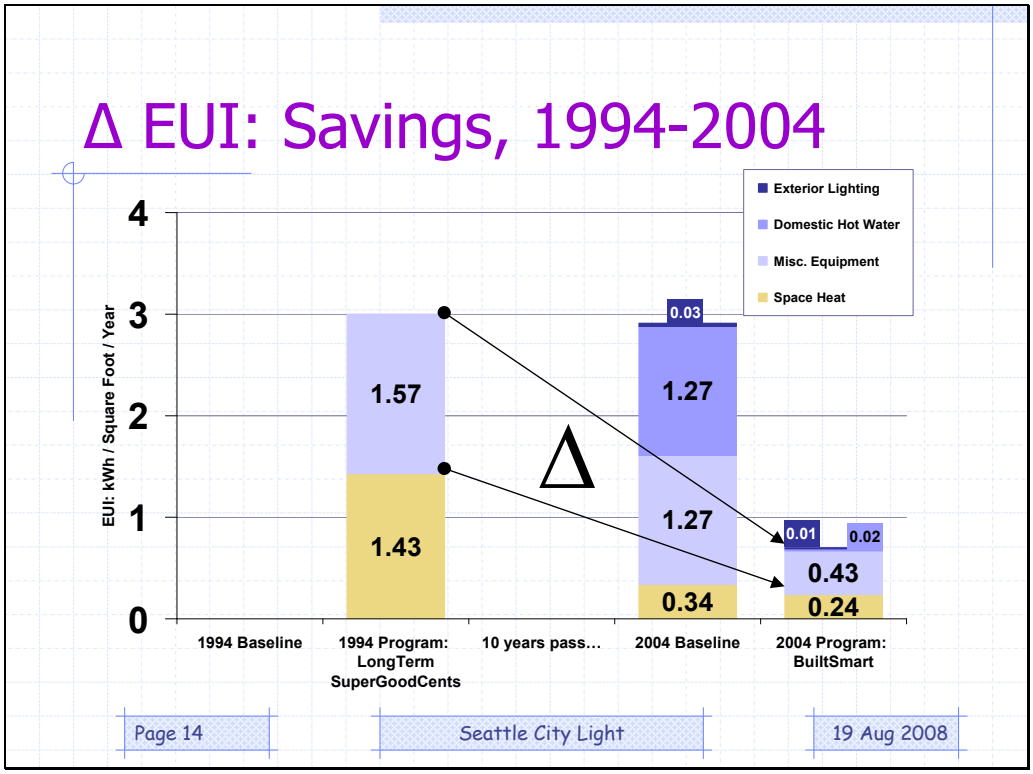
Δ EUI: Savings, 1994-2004
EUI: kWh / Square Foot / Year
4
3
2
1
0
Exterior Lighting
Domestic Hot Water
Misc. Equipment
Space Heat
1.57
1.43
Δ
0.03
1.27
1.27
0.34
0.01
0.02
0.43
0.24
1994 Baseline
1994 Program: LongTerm SuperGoodCents
10 years pass...
2004 Baseline
2004 Program: BuiltSmart
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Findings: Code Enforcement

- Building Inspection Practices
  - 12 interviews with market actors
    - 4 insulation (most), 2 general contractors
    - 6 building inspectors
  - Bellevue City inspection process apparently similar to Built Smart Program process, less so Kirkland
  - Anecdotal evidence of inspection effects
    - Consensus on better compliance in municipal areas than in unincorporated areas
  - However, effects masked in data by other factors
    - Differences in building geometry, glazing

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Conclusions

- Built Smart Program energy savings are significantly reduced compared to Long-term Super Good Cents
  - Reduced absolute energy use
  - Reduced absolute energy savings
  - Minimal space heat fraction
  - Lower percentage measure savings
  - ***Indicates success in transforming market***

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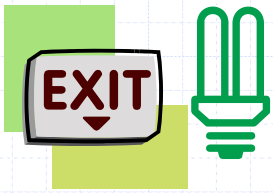
Conclusions



- Interior lighting measures yield preponderance of program savings
  - Emphasize going forward, in all BS projects
  - Is Energy Code a good baseline for common areas?
  - Suggest future on-site audits to establish standard practice
- Exterior lighting measures yield minimal savings
  - Standard practice appears near program thresholds
  - Note: More interior & exterior lighting measures installed in 2006-08 than in 2002-04
  - Need to update estimates proportionately

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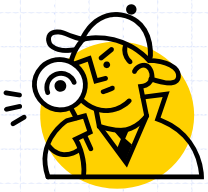
Conclusions



- Negligible energy savings from Program's enhanced specification, inspection, and commissioning
  - Potentially valid, anecdotal support in concept, however . . .
  - Nonparticipants received City energy inspections
  - Difference of P from this NP control group is too small to detect
- Alternative approaches needed to detect inspection impacts
  - Repeat study with second NP group drawn from unincorporated areas of nearby King or Pierce County

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Next Steps

- Update 2002-04 findings to fit current program & future opportunities
  - Compare to project-calc method for same projects
  - Increase level of lighting measures
  - Assess recent change in Energy Code for glazing & window U-values
- Conduct on-site lighting audits
  - Goal: to develop standard-practice baseline
- Process Evaluation (shadow inspectors?)

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Questions?

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Utility Program Leads the Way Toward Changing
Building Practice and Energy Codes

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Comparison to Prior Study

BASELINE	Long-Term Super Good Cents (1996 Evaluation)		Built Smart (2007 Evaluation)	
End Use	Annual EUI	% of Total	Annual EUI	% of Total
Space Heat	2.71	20.4%	0.94	12.8%
Domestic Hot Water	3.38	25.5%	2.11	28.7%
Miscellaneous Equipment *	7.08	53.4%	4.24	57.7%
Exterior Lighting	0.09	0.7%	0.06	0.8%
ALL	13.26	100.0%	7.36	100.0%

** Includes plug loads, appliances, in-unit and common-area lighting*

Comparison to Prior Study

PROGRAM	Long-Term Super Good Cents (1996 Evaluation)		Built Smart (2007 Evaluation)	
End Use	Annual EUI	% of Total	Annual EUI	% of Total
Space Heat	1.28	12.5%	0.78	11.7%
Domestic Hot Water	3.38	32.9%	2.11	31.6%
Miscellaneous Equipment *	5.51	53.7%	3.74	55.9%
Exterior Lighting	0.09	0.9%	0.05	0.7%
ALL	10.26	100.0%	6.66	100.0%

** Includes plug loads, appliances, in-unit and common-area lighting*

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Rolling Baseline Runs

Measure	Annual EUI	Δ EUI	Annualized Unit Savings	Pct of Total Savings	Pct of Model Represented in Sample
BASELINE	7.36				
Option I Envelope	7.13	0.22	200	31%	93%
Option II Envelope	7.12	0.01	11	2%	7%
In-unit Lighting	7.04	0.08	71	11%	66%
Common Area Ltg.	6.69	0.35	313	51%	59%
Exterior Lighting	6.68	0.01	9	2%	91%
Domestic Hot Water	6.66	0.02	17	3%	67%
Whole-house Fans	6.66	0.00	0	0%	62%
Enhanced Inspection	6.66	0.00	0	0%	100%
ALL COMBINED		0.70	621	100%	

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