Impact Evaluation of the Long-Term Super Good Cents Multifamily Program

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CONTENTS

Contents, Continued

Contents, Continued

TABLES

1.0 EXECUTIVE SUMMARY

This report describes an impact evaluation of the Long Term Super Good Cents (LTSGC) program, which has been operated since 1992 by Seattle City Light, a municipal electric utility. The Bonneville Power Administration is withdrawing financial support for customer incentives from regional implementation of this program. Current licensing agreements with the national Good Cents program are also coming to an end. Seattle City Light is now redesigning products and services for multifamily new construction, to operate a new program under revised specifications and terms beginning in 1997.

Long Term Super Good Cents (LTSGC) is a "beat the code" program designed to encourage builders of new residential dwellings with electric space heat to exceed provisions of the Washington State Energy Code in their building design and construction. The policy goal is to move the market toward more efficient construction practices.

Seattle City Light planned to bring the LTSGC program to at least 50% of the new multifamily units constructed in the utility's service area in each year from 1992 through 2003. With multifamily construction projected to decline over time, this was expected to mean as many as 1,500 units participating in the early years, falling to as few as 500 units in the later years. By the year 2003, the program was expected to provide 1.2 average megawatts (aMW) of load reduction. Savings were expected at about 12% of baseline energy usage.

ORGANIZATION & METHODS

About the Program, Evaluation Objectives, Study Organization, and Report

Section 2 introduces the program and study. This evaluation estimates energy savings from LTSGC measures, as implemented in a sample of new Seattle multifamily building projects completing construction in 1993-1994. The study uses engineering simulation models calibrated to utility billing data. Separate estimates of net savings are made for shell measures (windows and insulation) and for lighting measures. One insulation specification is examined for cost-effectiveness. Energy savings are translated into typical bill savings for tenants and building owners.

The findings are then projected to performance of the 1995-1996 LTSGC program. This report continues with detailed discussion about each program feature. It concludes with a series of recommendations for future improvements to products and services for the target market. Seattle City Light is using the findings from this study to develop the *Built Smart* program for energy and resource efficiency in multifamily new construction projects.

About the Study Methods and Prototypes

Section 3 describes the methodology that was used to select and analyze the sample of participant and non-participant apartment building projects. Data were collected from program records, filed permits, and on-site surveys. The methodology was applied to two prototype buildings that represented the two distinct categories of buildings found within the participant sample. The methodology included a simulation based analysis of energy savings with the DOE-2 model. The simulations were calibrated to the actual construction methods and energy use of the participant buildings. They were run a second time based on the construction methods of a nonparticipant group of buildings. This model predicted the space heat consumption of each prototype based upon inputs that characterized the weather conditions and respective space heating loads. The methodology also included a cost-effectiveness analysis of the R-26 wall insulation provision.

About the Major Research Findings on Building Characteristics, Prototype Energy Savings, and Cost-Effectiveness of R-26 Wall Insulation

Section 4 presents the results that were achieved from the application of the methodology described in Section 3. The presentation begins with the results of the sample selection process. This is followed by a summary of salient characteristics of the selected participant building projects. Actual billing records for 19 projects completed in 1993-1994 supplied targets for calibrating engineering simulations. Nonparticipant characteristics are derived from 20 nonparticipant projects. Two prototypes are compared under as-built (actual) and baseline (comparison) conditions to estimate energy savings attributable to the Long-Term Super Good Cents Program. Energy savings are estimated for the sampled projects under conditions of full occupancy and typical weather. Customer bill savings are estimated for the 19 projects, and the incremental cost of R-26 wall insulation is evaluated.

About Current Program Impacts, Process Issues, Product & Service Improvements, and Recommendations for Action

Section 5 continues the impact evaluation to make projections about Long Term Super Good Cents program performance in 1995-1996. The discussion portion is organized by program feature and intended uses of the evaluation findings. Process evaluation information that surfaced in the course of this impact evaluation is discussed, and conclusions are drawn about the LTSGC program. Section 5 concludes with a series of detailed recommendations for product and service improvements in the revised multifamily new construction program at Seattle City Light.

PROGRAM RESULTS

Attainment of Goals

- *Seattle City Light planned to bring the LTSGC program to at least 50% of the new multifamily units constructed in the utility's service area in each year from 1992 through 2003.*

The LTSGC program penetrated about 72% of the new multifamily construction in Seattle City Light's services area during 1993-1994, or about 80% of the electric space-heat buildings. This compares with the experience of PacifiCorp, which found penetration of 63% from their Oregon LTSGC program in 1992-1994, peaking in at 78% in 1993.

- *With multifamily construction projected to decline over time, this was expected to mean as many as 1,500 units participating in the early years, falling to as few as 500 units in the later years.*

The LTSGC program completed shell insulation work with buildings containing 1,015 units in 1993, 614 units in 1994, 666 units in 1995, and 289 units in 1996. In 1993 an additional 660 units received appliance measures only. The higher level of completions in 1993 reflects projects contracted after construction had begun. The apparent decline in 1996 completions corresponds to a program shift toward contracting projects at an earlier point in development, closer to the date of permit, to maximize opportunities to intervene at the design stage. Contracts signed in 1996 remain high at over 1,600 units.

- *By the year 2003, the program was expected to provide 1.2 average megawatts (aMW) of load reduction.*

New construction projects completed during 1993-1996 (cumulative) have reduced Seattle City Light's load by 0.735 aMW direct energy savings, amounting to 0.773 aMW including a credit for 5.2% transmission and distribution savings. The program has already attained nearly two-thirds of the LTSGC ten-year goal, half-way through its intended duration. This success may be attributed to higher savings per project than expected, and a higher program penetration rate than planned. In 1996, new construction permits have dramatically increased over previous years, portending rising opportunities to intervene in multifamily new construction efficiency.

- *Savings were expected at about 12% of baseline (residential unit) energy usage.*

Savings from shell measures averaged 12.5% across prototypes, while savings from lighting measures were 15.5% of baseline energy use (2.0% from kitchen/bath lighting, and 13.5% from common-area measures). Total savings per building were 28% of the projected baseline (total building including common area) energy use—more than double the savings expected when this program was planned. This result excludes additional savings realized from add-on appliances.

The success of Seattle's LTSGC program at achieving the expected savings from thermal shell measures may be attributed to two factors. First, Seattle's program established a firm foundation with a careful plan for implementing the primary compliance path, which draws its strength from the prescriptive requirements. Second, the program staff were diligent in negotiating measures with builders, and repeatedly inspecting work in progress to ensure that measures perform up to potential. The staff also kept careful records of the original building design and measures actually installed as a result of the program intervention, which facilitated the accountability process. The planners for Seattle's LTSGC program must also be applauded for their foresight in emphasizing the lighting component, which has led to the program's marked success in acquiring significant savings from the building common areas.

Major Findings: Energy Savings from Shell and Lighting Measures

Annual energy savings to tenants from the Shell measures (Tier I insulation, windows, and thermostats) were 1.43 kWh per square foot in the In-Unit Laundry prototype (12% of preperiod consumption) and 1.25 kWh in the Common Laundry Prototype (13%). These findings may generalized to weighted annual energy savings of *1.40 kWh per square foot of floor are*a, where floor area includes all enveloped enclosed spaces, both rentable and common area. In addition, energy savings to tenants from Kitchen and Bath Lighting measures averaged *0.15 kWh per square foot of floor area,* in buildings where this measure was installed.

Annual energy savings from Common Area Lighting measures were 1.50 kWh per square foot in the In-Unit Laundry prototype (13% of preperiod consumption) and 1.71 kWh in the Common Laundry Prototype (17%). These findings may generalized to weighted annual energy savings of *1.53 kWh per square foot of floor area,* where floor area includes all enveloped enclosed spaces, both rentable and common-area. Another way of describing these results is in terms of the square footage directly affected by the measures. Normalized for the square footage of interior common areas plus parking garage spaces, the annual energy savings were 2.89 kWh per square foot in the In-Unit Laundry prototype and 2.95 kWh in the Common Laundry Prototype, generalized to weighted energy savings of 2.90 kWh annually.

Overall, weighted energy savings were over 3 kWh per square foot of envelope-enclosed floor area, or 2,500 kWh per residential unit. This includes savings from shell and lighting measures, but excludes savings from refrigerator and hot water appliances. These savings are *more than double* what was expected based on BPA projections at the time of initial program design (in estimates that did include appliances). The space heat savings were acquired mainly (60%) during the winter-peak months of November through February, and during the "shoulder months" of October and March-April (33%). Lighting savings were acquired throughout the year.

Program participants with buildings completed in 1993-1994 received 1995 bill savings of about $75 per unit to tenants and $50 per unit to building owners. The typical 60-unit building from this group thus saves about $7,500 on energy bills each year ($4,500 shared by tenants and $3,000 to the owner). Buildings participating in 1995-1996 averaged 36 units, so while savings per unit remain similar, savings per building will be proportionately lower.

Based on the findings of this study, the LTSGC 1992-1994 program acquired energy savings in 1995 at the cost of 14 mills per kWh to the Utility. If one assumes that the program incentive has covered 80% of the incremental cost of prescribed measures, then the cost to Participants was 3 mills per kWh and the Service Area cost was 17 mills per kWh. A sensitivity analysis of this service area levelized cost ranges from 15 mills (at a 90% incentive coverage rate) to 23 mills (at 70% coverage). These costs are very competitive with the costs of energy alternatives, whether internally (Seattle City Light generation) or from external markets.

RECOMMENDATIONS

Shell and Lighting Measures

The major recommendations emerging from this evaluation concern the shell measure incentive structure and specifications, and common-area lighting products and services.

- **Shell Measure Incentive Structure Recommendation.** Revise the multifamily new construction program to improve the incentive structure for shell measures. Calculate incentives based upon the envelope-enclosed square footage, rather than upon number of residential units.
- **Shell Measure Specification Recommendations.** Implement revised Tier II specifications in the multifamily new construction program to capture space-heat efficiency opportunities in buildings with R-21 wall insulation. Allow R-21 wall insulation in some projects; or, encourage measure trade-offs on a Wattsun (or equivalent) simulation model of building heat loss.

  Continue to have a staff engineer monitor changes in insulation technology and the market availability of new products.

  Discuss with the Department of Construction and Land Use a potential revision to the Seattle Energy Code regarding insulation above post-tension slabs in multifamily new construction, to establish a specification of R-15.
- **Lighting Measure Recommendations.** The excellent performance of LTSGC common-area lighting measures is noteworthy, and future opportunities to build on the strength of this measure should be captured wherever possible.

  Capture lighting-efficiency opportunities in buildings with gas space heat as well as those with electric space heat.

Establish congruency between the Multifamily Common Area Lighting retrofit program and the multifamily new construction efficiency program. Establish common record-keeping systems, and file a printout of the analysis worksheet in the program building project file. Revise the kitchen lighting specification from T-12 to T-8. Provide the builder or owner with a lighting operations and maintenance (O&M) tip sheet including information on acquiring replacement lamps. Continue to have a staff engineer monitor changes in lighting technology and the market availability of new products.

Coordinate lighting programs for existing and new-construction multifamily buildings, with initiatives by the Seattle Department of Housing and Human Services (DHHS low-income rehabilitation projects) and the Northwest Energy Efficiency Alliance (NEEA regional lighting fixture rebates).

Require upgrades to lighting in all common areas, including outside exterior-lighting. Raise or eliminate limits on the number of fixtures that may be rebated. Monitor the outside/exterior lighting power density in future projects. Re-evaluate the impact of this program provision in one year and determine whether to continue the provision, change the measure specifications to assure savings, or discontinue to offer incentives for outside fixtures.

Discontinue incentives for lighting fixtures in parking garages, and join with the Department of Construction and Land Use (DCLU) in inspection-based enforcement of the 1994 Non-Residential Energy Code lighting power allowance (0.20 watts per square foot). Encourage the DCLU to provide technical assistance and training to builders regarding the application in parking garages of fluorescent lighting for low-temperature environments. Discourage application of high-pressure sodium lighting in garages and halogen lighting on building exteriors.

Discuss with the Department of Construction and Land Use a potential new provision in the Seattle Residential Energy Code regarding a lighting power allowance (watts per square foot) in common areas of multifamily new construction. Recommend a lighting power allowance in common areas (hallways, stairwells, lobbies, etc.) of 1.00 watts per square foot.

Appliances and Information Uses

Other recommendations emerging from this evaluation concern accountability and load forecasting, other measure provisions and specifications, and customer information services.

- **Accountability Reports and Load Forecast Recommendations.** Revise estimates of annual energy savings in the EMSD Energy Conservation Accomplishments report, and adopt revised estimates in the Seattle City Light Load Forecast. (Detailed forecast inputs are provided in Section 5.) Ensure that the Energy Load Forecast does not double-count participation and savings from water heaters between the EEWHRP and LTSGC programs.
- **Space Heat Thermostats Recommendation.** Continue to implement electronic line voltage thermostats in the multifamily new construction program. Continue to have a staff engineer monitor changes in thermostat technology and the market availability of new products, and keep program specifications abreast of these improvements. Monitor improvements in wall heater and baseboard heater technology (e.g., low density baseboards), and assess the potential of these measures for the multifamily new construction program.
- **Window Glazing Recommendations.** Require a lower solar heat-gain coefficient on west and south glazing than on east and north glazing in the multifamily new construction program specifications. Continue to have a staff engineer monitor changes in window technology and the market availability of new products. Revise the required glazing heat-transfer coefficient from $U<0.35$ to $U<0.33$ by the

year 1999. Consider options for measure trade-offs that include reduced glazing square footage and determine the feasibility, within building code limitations, for future revised program provisions.

- **Refrigerators, Laundry Appliances, and Hot Water Measures Recommendations.** Continue to have a staff engineer monitor changes in appliance technology and the market availability of new products, and keep program specifications abreast of these improvement. Reinstate the upgrade provision for high-efficiency refrigerators in the multifamily new construction program with new efficiency targets. Add an upgrade provision to the program for high-efficiency laundry appliances. Continue to promote high-efficiency appliances through early adoption incentives, with rebates calculated on a per-appliance basis.

  Coordinate with federal appliance code officials on increased efficiency standards, and be available to the U.S. Department of Energy to provide a test site for new appliance technologies.

  Pay high-efficiency water heater rebates through the multifamily new construction program and attribute savings to this program in future. Monitor the performance of heat-pump water heaters in the 1995 program and explore a program or rebate option for this measure. Encourage builders to install water sub-metering devices, in coordination with the Seattle Water Department.

  Record inspections of showerhead and aerator installations in program building project file. Install showerheads that perform at 2.0 gpm and faucet aerators that perform at 1.5 gpm, to ensure program savings.

- **Customer Information Recommendations.** Inform multifamily builders, owners, managers, and tenants about the energy savings, bill savings, and cost effectiveness of participation in the multifamily new construction program. In the typical weather year, and at 1996 electric rates, Seattle City Light customers may expect to save the following amounts on bills from the shell, lighting, and refrigerator measures combined: Tenants, $75 per unit (plus $3 per water heater); and Owner, $50 per unit

  Since the average building receiving shell measures has 36 units, these customers in the aggregate may expect to save the following amounts on total bills from the shell, lighting, and refrigerator: Tenants, $2,700 per building (plus $108 from water heaters); Owner, $1,800 per building; and Total Savings, $4,500 per building. Other, more specific information for customers may be derived from the tables and analysis found in this report.

  Develop ways to underscore the value of improved energy efficiency in multifamily new construction buildings through follow-on services to program participants and through marketing activities. Use the Conservation Tracking System (research capabilities) to assist in providing follow-on services. Follow-on services may include assistance with lighting operations and maintenance (O&M), and ongoing tracking of savings performance via bill comparisons for participating buildings.

2.0 INTRODUCTION

This report describes an impact evaluation of the Long Term Super Good Cents (LTSGC) program, which has been operated since 1992 by Seattle City Light, a municipal electric utility. The Bonneville Power Administration is withdrawing financial support for customer incentives from regional implementation of this program. Current licensing agreements with the national Good Cents program are also coming to an end. Seattle City Light is now redesigning products and services for multifamily new construction, to operate a new program under revised specifications and terms beginning in 1997.

This evaluation estimates energy savings from LTSGC measures, as implemented in a sample of new Seattle multifamily building projects completing construction in 1993-1994. The study uses engineering simulation models calibrated to utility billing data. Separate estimates of net savings are made for shell measures (windows and insulation) and for lighting measures. One insulation specification is examined for cost-effectiveness. Energy savings are translated into typical bill savings for tenants and building owners.

The findings are then projected to performance of the 1995-1996 LTSGC program. This report continues with detailed discussion about each program feature. It concludes with a series of recommendations for future improvements to products and services for the target market. Seattle City Light is using the findings from this study to develop the *Built Smart* program for energy and resource efficiency in multifamily new construction projects.

2.1 ABOUT THE PROGRAM

Long Term Super Good Cents (LTSGC) is a “beat the code” program designed to encourage builders of new residential dwellings with electric space heat to exceed provisions of the Washington State Energy Code in their building design and construction. The policy goal is to move the market toward more efficient construction practices. It was initiated by Bonneville Power Administration under the Residential Conservation Agreement with Seattle City Light and other regional utilities. Funding provided by the BPA via the Third Party Financing Agreement with Seattle began in June 1994 and ceases at the end of 1996.

At Seattle City Light, the Long Term Super Good Cents program provides financial incentives to the owners of new multifamily buildings that install efficiency measures prescribed by the program. These measures exceed the efficiency requirements of the current Seattle Energy Code. The program began in October 1992 after a year of development. Partial funding for program development and promotion was provided by the BPA. Seattle does not implement the Super Good Cents program for single-family or small multifamily (under five units) new construction. This is because the utility has determined that, given current gas prices, it is not in the best interest of Seattle customers to heat smaller new homes with electricity, and the utility does not wish to encourage fuel switching through builder incentives. Fuel switching is not an issue for larger multifamily buildings of five or more units, because almost all new units (about 90%) are electrically heated.

Program Measures

Seattle City Light pays incentives to builders to install measures that upgrade the building shell (added insulation and high-efficiency windows and doors). Incentives are paid for high-efficiency common-area lighting measures (in building interiors, garages, and outside spaces), as well as fluorescent lighting within the residential units (in the bathroom and kitchen areas). The program has also paid for certain appliances that exceed federal efficiency standards (the "add-ons"), such as refrigerators, water heaters, heat pump water heaters, and showerheads (that exceed the state plumbing code standard). In addition to incentives, City Light also offers program marketing and technical assistance to builders and developers.

The building shell must comply with the pre-defined prescriptive requirements or a component performance analysis. Thermal envelope upgrades are based upon a computer analysis of heat loss and estimated savings per dwelling unit. If a specific measure is found to be below the prescriptive requirement, then the proposed measures are entered into the computer analysis program (currently Wattsun thermal performance analysis) to ensure that the overall building still meets or exceeds LTSGC requirements for watts per square foot. The component performance analysis offers options for selecting and combining measures to meet the needs and specifications of the project.

Appliance upgrades are based upon efficiency ratings. Optional items selected from the available list have pre-defined incentive amounts. If the building has both commercial and residential spaces, the LTSGC program works with the residential portion only. (A commercial efficiency program would work with the small commercial portion, but Seattle City Light does not currently have such a program.)

Participants placed under contract in 1992 to 1993 were defined as Tier I (all feasible space-heat measures) or Tier II (a proportion of feasible space-heat measures), with or without Add-Ons (appliance measures). Beginning in the BPA's fiscal year 1994, reporting of participation was redefined as Option 1 ("flat rate single-family", applied as a flat rate per multifamily residential unit) or Option 2 (square-footage based), with added Optional Measures.

Population Served

The Seattle program serves new construction multifamily buildings having five or more units. They must have electric heat, be wood framed (stick construction), with building plans approved under the 1991 Washington State Energy Code, which is equivalent to the 1994 Seattle Energy Code. The LTSGC program addresses the residential and common portions of these buildings. Commercial portions may use steel and concrete construction, which falls under the 1994 Non-Residential Energy Code. Electric space heat construction within Seattle City Light's service area in the mid-1990s amounts to about 1,500 new units per year.

Program participants are mainly apartment buildings and condominiums, but have also included a few motels and retirement complexes (and one single-family demonstration site).

Program Process

Owners of eligible buildings must sign a contract before proceeding, and detail measures to be installed in a Builder's Agreement. They must agree to inspections throughout the building process. Seattle City Light provides technical support throughout design and construction. Energy efficient lighting design assistance is available from the Lighting Design Lab operated by Seattle City Light.

Multifamily new construction projects may take about two years on average to move from the contract stage, marking Seattle City Light's initial intervention, to project completion, when the building is ready for occupancy. There may also be an earlier period sandwiched between issuance of building permits by the Seattle Department of Construction and Land Use (DCLU), and negotiation of a contract by Long Term Super Good Cents staff. The contract may be negotiated before or after construction starts. The program intervention ends with the final inspection phase. After the final inspections marking project completion, additional time is required for the building to reach full occupancy. Thus a building permitted in 1991 and contracted by the program in 1992 might not be completed and fully occupied until sometime in 1994.

Program Goal

According to the Endorsement Package submitted to the City Council in May 1992, City Light proposed to bring the LTSGC program to at least 50% of the new multifamily units constructed in the utility's service area in each year from 1992 through 2003. With multifamily construction projected to decline over time, this was expected to mean as many as 1,500 units participating in the early years, falling to as few as 500 units in the later years. By the year 2003, the program was expected to provide 1.2 average megawatts (aMW) of load reduction. Savings were expected at about 12% of baseline energy use.

The program proposal states that ideally it would be desirable to have as many as possible of the new construction projects participate in each year, since they otherwise represent "lost opportunities." The shell measure in particular must be included in the design and build phase, because a later retrofit would be prohibitively expensive. For this reason the 50% program goal was not established as a "lid," only a planning estimate of likely program achievement.

Seattle Ordinance 116267 authorizing the LTSGC program was passed by the City Council and endorsed by the Mayor in July 1992. This ordinance stated that, further, in the LTSGC program, Seattle City Light would place special emphasis on targeting low income projects.

Expected Impacts

The original program budget was split between a base budget, intended to serve the first 700 units per year, and a pending budget, containing ramp-up increases for another 400 units per year, necessary to achieve the projected participation at 50% of new construction. (Projected program activity levels were based on the utility's short-range and long-range load forecasts for multifamily unit completions during 1994-1996.) The program proposal acknowledged that exact annual forecasts of program activity would be impossible due to the cyclic nature of construction activity and the large variations in project sizes.

The primary source of information on space heat energy savings was a calculation prepared by the Bonneville Power Administration for a multifamily building of 12 units with 850 square feet per unit, receiving measures at the Tier I level. The values were derived from the Northwest Power Planning Council's regional plan (1991 Model Conservation Standards), and prototype simulation models calibrated for the Seattle area by the NWPPC. Expected energy savings in kilowatt-hours per residential unit are shown below, along with the expected lifetime, capital cost, and customer rebate. The lifetime of measures averaged 33 years in the actual LTSGC program (weighted across the mix of measures installed). Lighting measures were also expected to reduce the customers' costs to replace bulbs during the life of the fixture.

Table 1. LTSGC Planning Projections

Measure Type	Energy Savings kWh	Expected Lifetime years	Capital Cost $	Customer Rebate $
Space Heat (shell)	510	50	664	500
Lighting	463	20	0	76
Refrigerator	120	20	79	60
Showerhead	239	15	13	20
Water Heater	171	12	63	60

The planning analysis for this program expected participating customers to receive benefits in the form of reduced electricity consumption, amounting to about 12% per year. About 90% of the economic benefits were associated with the utility's electrical system. Additional benefits were expected for participating customers (10%) due to the lower life-cycle cost of replacing energy efficient lamps (light bulbs). Program participants experience other economic impacts that are not captured in the electricity bill impacts. For example, apartment owners were expected to directly bear some of the capital costs, because the program incentives were designed to reimburse only about 88% of the installation costs.

For purposes of program accounting, Seattle City Light has estimated that the average unit in a new construction multifamily building that participated in the LTSGC program saved about 1,380 kilowatt-hours (kWh) per year. This figure was based on the savings estimates above for building shell measures, plus an average weighted mix of add-on appliances, as projected by Seattle City Light planners. The current study will provide more accurate estimates of energy savings from the majority of buildings participating in the first few program years.

2.2 About This Study

The primary purpose of this study is to evaluate the thermal performance of the Tier I shell and lighting (interior and exterior) features of the Long-Term Super Good Cents program on a sample of 1992-1994 program participants. The basis of comparison is non-participant building projects, located within the jurisdiction of the Seattle Energy Code, that were completed and occupied by February 1995. A secondary purpose of the study is an incremental cost-effectiveness analysis of the R-26 wall insulation LTSGC provision within the Tier I shell package. This study does *not* address the impacts of add-on appliances.

The scope of the study was established to meet the following specific objectives.

1. **Participants.** Determine the as-built energy consumption characteristics of two classifications of new multifamily buildings that represent the populations of current and future program participants.
2. **Baseline.** Determine the baseline energy consumption characteristics of two classifications of new multifamily buildings that represent the corresponding non-participant population.
3. **Energy Savings.** Determine the energy savings associated with Tier I shell measures and the lighting add-on measures (interior and exterior) for each of the two building classifications.
4. **Wall Insulation.** Determine the incremental cost-effectiveness of the R-26 wall insulation measure with respect to an R-21 baseline to see if the additional insulation required by LTSGC is economically justified.

This evaluation project was managed by Debra Tachibana of the Evaluation Unit, Seattle City Light, who developed the scope of work. An internal team provided guidance throughout the project. It included field manager Ken Katayama; LTSGC program staff members John Forde (lead), John Flynn, and Leslie Wagoner; program planner Maxine Fischer; and policy planners Vern Wong and Mike Little. The work described in Sections 3 and 4 of this report was performed by an engineering consultant firm, SBW Consulting, Inc. (Marc Schuldt and Jeff Romberger, leads). Additional analyses of the samples (Sections 4.1-4.2) were performed by Debra Tachibana, who also did the analysis for and wrote Sections 1, 2, and 5. Seattle City Light supplied SBW Consulting with data from program files and the customer billing system. SBW acquired additional data from the Department of Construction and Land Use and through limited on-site surveys, as described in the methodology section.

This evaluation will help the Seattle City Light program staff to improve the efficacy of program delivery, and to provide information on energy savings to customers who are considering the adoption of one or more of the LTSGC rebate options. The models established by this study will also enable Seattle City Light planners to estimate the effects of proposed changes in the program. A revised multifamily new construction program will be implemented in 1997.

This study used a simulation based approach to estimate energy savings for both the Tier I shell and lighting measures. Two prototypes were developed with the DOE-2 hourly simulation model to represent the consumption characteristics of the two categories of buildings found within the participant sample. This model is the industry standard for applications that require the simulation of hourly energy consumption. Separate estimates of savings were produced for the Tier I shell and lighting measures within each prototype.

The *as-built* configuration of each prototype was calibrated to the annual billing records of the Tier I participants represented by the prototype. The *baseline* configuration of each prototype was established using characteristics data from appropriate non-participants. Energy savings for the measures within each prototype were computed as the difference between the as-built and baseline conditions under typical weather conditions.

This report documents the methodology used and results obtained from the selected LTSGC provisions in a sample of new multifamily buildings.

- Section 3 of the report provides a detailed description of the procedures that were used for sample selection, data collection and analysis; estimation of energy savings; and an assessment of cost-effectiveness for one program measure.
- Section 4 presents the major research findings, including a summary of the participant building and prototype characteristics, the energy savings estimates for the selected measures, and the cost-effectiveness of the R-26 wall insulation provision.
- Section 5 provides projections of findings to the current program, discussion of process issues not addressed in the simulation analysis, conclusions about product and service improvements, and recommendations for action.
- Section 6 cites a few references for lighting and other load schedules. The report concludes with two Appendices that contains more detailed documentation of the data collection procedures and analyses.

3.0 METHODOLOGY

This section describes the methodology that was used to select and analyze the sample of participant and non-participant apartment building projects. Data were collected from program records, filed permits, and on-site surveys. The methodology was applied to two prototype buildings that represented the two distinct categories of buildings found within the participant sample. The methodology included a simulation based analysis of energy savings with the DOE-2 model. The simulations were calibrated to the actual construction methods and energy use of the participant buildings. They were run a second time based on the construction methods of a nonparticipant group of buildings. This model predicted the space heat consumption of each prototype based upon inputs that characterized the weather conditions and respective space heating loads. The methodology also included a cost-effectiveness analysis of the R-26 wall insulation provision. A discussion of the seven tasks that were followed in conducting this research is provided below.

3.1 SELECTION OF SAMPLE BUILDINGS

Seattle City Light selected samples of participant and non-participant building projects that were used as the basis for the evaluation. For the Tier I shell sample an attempt was made to select 20 qualified participants and 20 qualified non-participants. Each building in the sample was a newly constructed apartment complex located within the Seattle City Light service area. The participants were required to be electric space-heat buildings and have installed one or more of the LTSGC provisions listed in Table 2.

Table 2 compares the LTSGC program requirements to those of the Seattle Energy Code. The LTSGC program requirements differ from the Washington State and Seattle Energy Codes in two areas not dealt with in this study, besides the measures described in Table 2. These include: exterior doors (U-0.19 in the state code versus U-0.20 in the city code), and water heater efficiency (0.91/0.93 state versus 0.86/0.88 city, for tanks over/under 60 gallons). The impact evaluation described in Section 3 and Section 4 of this report addressed only the Table 2 measures.

Table 2. Long-Term Super Good Cents Provisions

Provision		Washington State & Seattle Energy Code Requirement	SGC Prescriptive Requirement
Thermal Shell	**Tier I Measures**		
Ceilings:	Attics	R-38	R-49
	Vaulted	R-30	R-38
Walls:	Above-Grade	R-19	R-26
	Below-Grade (R-5 thermal break)	R-19	R-21
Floors:	Crawl Space	R-30	R-30
	Unheated Areas	R-30	R-30
	Slab-on-Grade Perimeter	R-10	R-15
	Above PT Slab	—	R-15
	Pinned Under PT Slab	R-30	R-30
Glazing		U-0.40	U-0.35
Infiltration:	Assumed Rate	0.35 ACH	0.35 ACH
Thermostats		—	Heat Anticipator
Lighting	**Add-on Measures**		
	Kitchen/Bath	—	Fluorescent
	Unconditioned Common Area	—	Fluorescent
	Outside Exterior	—	Fluorescent or HPS

Provisions are explained in the SGC Program Handbook[1]

PT Slab = Post Tension Slab
ACH = Air Changes per Hour
HPS = High Pressure Sodium Luminaire
— = Not applicable or no code requirements

Separate sub-samples were selected for three measure types to properly define as-built and baseline conditions. They included:

1. Tier I Shell Measures
2. Interior Lighting
   - Bathroom Lighting
   - Kitchen Lighting
3. Exterior Lighting
   - Common Area Lighting (unconditioned area including parking garage)
   - Outside Lighting

In selecting the non-participant building projects for each measure type, an attempt was made to choose reference sites that were as identical as possible to the participants, except for the implementation of the respective LTSGC measure. Buildings that were participants for one measure type were allowed to be non-participants for one of the other measure types, if it was not installed in the building. The Tier I shell non-participants were required to have electric space heat.

Characteristics data available from a Seattle City Light spreadsheet on the participant building projects was examined for similarities and differences among the sampled sites. From this review it was determined that the participant sample could be classified into two basic categories. Each of these categories became the basis for the development of a prototype building.

Prototype 1: Buildings with in-unit laundries. They included primarily one- and two-bedroom housing units.

Prototype 2: Buildings with common-area laundries. They contained primarily studio and one-bedroom housing units.

Both of the prototypes were fictitious buildings that were assembled to depict the average end use energy consumption characteristics of the group of buildings that they represent. Although they were not real buildings, the characteristics of the energy system components incorporated into the prototype models were derived from data observed about real buildings in the respective building groups. Energy savings for Tier I shell measures and lighting measures (interior and exterior) were estimated for each of these prototypes.

3.2 DATA COLLECTION

To support the calculation of energy savings for each of the measure types, SBW collected a variety of data to characterize the energy consumption of both prototypes during the selected one year calibration period of November 1994 to October 1995. Data were also collected to support the cost-effectiveness analysis of the R-26 wall insulation. The methods used to collect these data are described below.

3.2.1 Building Characteristics Data

The forms and procedures described in Appendix A were used to collect data on building characteristics necessary to determine LTSGC measure performance and satisfy the inputs to the DOE-2 model prepared for each prototype.

For the Tier I shell measures, the primary sources of participant characteristics data were the project files and construction drawings provided by Seattle City Light for each site. For the lighting measures, the primary sources of participant data were the Seattle City Light project files and an on-site survey performed by SBW Consulting. Construction drawings available on microfiche from the Department of Construction and Land Use (DCLU) were the primary source of non-participant baseline data relevant to the Tier I shell measures. A combination of on-site survey data and other data available from Seattle City Light were used to establish a non-participant baseline for the lighting measures. The on-site survey was also used to verify questionable data from the construction drawings and project files.

3.2.2 Weather and Billing Data

SBW obtained hourly weather data for the Sea-Tac airport from the National Oceanographic and Aeronautic Administration (NOAA) for the calibration period of November 1994 through October 1995. The data were prepared for use with the DOE-2 model. Sea-Tac Typical Meteorological Year (TMY) weather data were also prepared for use in the simulation to estimate savings under long term weather conditions.

Seattle City Light staff compiled the electric billing records for each housing unit and the common area at the participant sites and checked for major vacancy problems during the calibration period. SBW then screened the billing data for reasonableness and completeness. Problematic consumption data were removed from the data set. The data were then prepared for the computation of the Energy Use Index (EUI) targets that served as a reference for the consumption estimates from the participant models. The EUI normalizes annual billed electric consumption to conditioned floor area.

3.2.3 Lighting Data

SBW performed a literature search of recent residential lighting program evaluations and other load research to determine an appropriate time-of-day internal (bath and kitchen) lighting utilization profile for new multifamily buildings, expressed as a fraction of total internal (bath and kitchen) lighting capacity.

The data sources consulted included the Seattle Lighting Design Lab[2], the Washington State Energy Office (WSEO) Electric Ideas Clearinghouse[3,] and program evaluations from Puget Power[4] and Pacific Gas & Electric (PG&E)[5].

3.3 Data Analysis

Three data sets were analyzed in preparation for model calibration. These analyses include:

1. **Characteristics Data.** Unit level UA data were analyzed to determine appropriate apartment types for use in the prototypes. Apartment types were distinguished by significant differences in heat loss, which was best determined by the UA. The UA expresses heat loss as Btu per hour per degree F of temperature difference.
2. **Load Data.** Hourly load data collected by the BPA Multifamily Metering Study[6] were analyzed to construct typical infiltration, hot water, internal load (lighting and equipment) and thermostat setpoint schedules. These schedules are documented in the software inputs supplied to Seattle City Light.
3. **Billing Data.** Billing records provided by Seattle City Light were analyzed to produce EUIs for each type of apartment that was considered in the prototype development. A cubic spline fit routine was used to estimate consumption by calendar month from bi-monthly billing records. Only occupied units were included in this analysis. The unit level EUIs were aggregated to whole building EUI values for each of the two prototypes. Whole building EUI targets were prepared for each month in the calibration period.

3.4 Participant Model Development

Inputs to the DOE-2 simulation were prepared for each prototype using the characteristics data and load data collected and prepared in the previous steps. Full occupancy was assumed in preparing the infiltration, internal load and thermostat setpoint profiles for each prototype. The DOE-2 model for each prototype was run and the monthly whole building Energy Use Index (EUI) predicted by the model was compared to the monthly EUI target prepared in Task 3.3. This comparison was performed to calibrate the model to actual energy use and ensure accurate estimates of energy savings. Adjustments were made to the simulation until the predicted whole building EUI was within 10% of the target value on a monthly basis for both prototypes. The adjustments were made to the parameters with the highest degree of uncertainty, such as thermostat setpoints and equipment capacities.

A modified as-built model was then prepared for both prototypes by rerunning the fully calibrated model under TMY weather conditions.

3.5 NON-PARTICIPANT MODEL DEVELOPMENT

A non-participant model was developed for each prototype by changing the parameters in the modified as-built model relevant to the energy performance of the Tier I shell and lighting measures. The parameters were modified to reflect the baseline characteristics compiled in Task 3.2 for the non-participant sample within each prototype. That is, for example, the LTSGC prescribed R-value for attic insulation was substituted with a baseline R-value reflecting the Seattle Energy Code or common building practice. The DOE-2 models were then rerun under these baseline conditions and TMY weather conditions. The results were compared to the respective as-built models for reasonableness.

3.6 ENERGY SAVINGS

Energy savings were computed for both prototypes as the difference between participant and non-participant consumption for each prototype under TMY weather conditions. Separate savings estimates were prepared for the Tier I shell and lighting measures (interior and exterior) within each prototype. The savings reflected full occupancy and typical long-term weather conditions. Dollar savings were also computed by applying the appropriate Seattle City Light rate schedules to the energy savings values. The Seattle City Light 1995 Rate Schedule 20 (residential second block) was used to compute bill savings for the Tier I shell plus kitchen/bath lighting measures, and Rate Schedule 31 (small general service) for the common-area and outside lighting add-on measures[7].

3.7 COST-EFFECTIVENESS OF R-26 WALL INSULATION

The value of the R-26 wall insulation feature of the LTSGC program was evaluated by assessing the costs and benefits of R-26 wall insulation for both prototypes incrementally against an R-21 baseline. The R-26 construction consists of a standard-framed 2 x 6 wall with R-21 batt insulation installed in all framing cavities and an R-5 foam-board under the siding. The R-21 construction is the same except for elimination of the R-5 foam-board.

Energy savings were computed through a series of sensitivity runs with the DOE-2 simulation. For both prototypes the as-built model, under TMY weather conditions, was rerun at the R-21 wall insulation level. Annual energy savings were computed as the difference between these levels.

The incremental cost of R-26 wall insulation against an R-21 baseline was estimated using the recent WSEO contractor cost report[8]. An estimate of service (i.e., economic) lifetime was taken from the Seattle City Light Custom Incentive Project documentation[1]. The incremental costs and savings were input to a calculation of levelized cost and simple payback, that assessed cost-effectiveness from the utility and customer perspectives, respectively.

4.0 RESULTS

This section presents the results that were achieved from the application of the methodology described in Section 3. The presentation begins with the results of the sample selection process. This is followed by a summary of salient characteristics of the selected participant building projects. Actual billing records for 19 projects completed in 1993-1994 supplied targets for calibrating engineering simulations. Nonparticipant characteristics are derived from 20 nonparticipant projects. Two prototypes are compared under as-built (actual) and baseline (comparison) conditions to estimate energy savings attributable to the Long-Term Super Good Cents Program. Energy savings are estimated for the sampled projects under conditions of full occupancy and typical weather. Customer bill savings are estimated for the 19 projects, and the incremental cost of R-26 wall insulation is evaluated.

4.1 SAMPLE SELECTION

4.1.1 Sampling Frame & Study Sample

Between mid-1992 and the end of 1994, the Super Good Cents Program signed contracts with 58 multifamily construction projects containing 68 buildings (3,178 residential units). By the end of 1994, construction was completed at 35 of these sites on 40 buildings (2,312 residential units). This group constituted the study sampling frame.

Nine participant projects (11 buildings) were disqualified from this study based on their atypical construction, occupancy, and metering characteristics. The building types and reasons for exclusion were:

- Single-family demonstration site, Model Conservation Standards
- Multiplex (3-unit) building, refrigerator appliance Add-Ons only
- Motor inn, no kitchens, no in-unit or common laundry, commercial metered
- Retirement village, master metered
- Multifamily building, gas space heat
- Multifamily building, refrigerator appliance Add-Ons only
- Multifamily building, atypical construction, advanced air seal
- Multifamily building, Tier II shell measures only, atypical construction
- Multifamily building, Tier II shell measures only, not fully occupied during post-period

The remaining building projects constituting the participant sample studied have 26 sites containing 29 buildings (1,557 residential units).

The study sample comprises 67% of the residential units in the sampling frame. The average building size, in terms of units per building, is 46.7 among contracted projects, 57.8 in the sampling frame of completed projects, 53.7 in the selected sample of program participants, and 60.2 among the subset of Tier I shell participants studied.

The contracted incentive dollars per unit (including shell measures, refrigerators, lighting, and water heater rebates) were $573 among contracted projects, $520 in the sampling frame, $609 in the selected sample, and $695 among the subset of Tier I shell participants studied. Contracts for the program participants not receiving shell measures averaged $120.

The non-participant sample frame consisted of building projects constructed during the same time period that did not participate in any SGC program provisions. The total number of buildings in this frame is not known precisely. One may estimate that about 2,880 units in all-electric buildings (eligible for LTSGC Tier I shell measures) were built during 1993-1994, based on new service connections established by SCL in those two years. During the same time period, another 320 new units heated by gas were probably constructed, since about 90% of this sector heats with electricity. This yields about 3,200 new multifamily units potentially eligible for appliance and lighting measures, if not for shell insulation.

Penetration of the LTSGC program was approximately 80% of the all-electric buildings, or about 72% of new construction. (This penetration may be overstated, as some condominiums may be listed on utility reports as single-family dwellings, and others, in high-rises, as commercial construction.) The sampling frame for non-participating buildings was thus about 910 units. Access to lighting plans at the City Department of Construction and Land Use (DCLU) was limited for many of these non-participants. Fortunately, some had been screened by the Multifamily Common-Area Lighting retrofit program and lighting analyses were available from these records.

Table 3. Sampling Frame of LTSGC Projects Contracted and Completed 1992-1994

	1992		1993		1994		Total	
Sampling Frame	**Bldgs**	**Units**	**Bldgs**	**Units**	**Bldgs**	**Units**	**Bldgs**	**Units**
Contracted								
Tier I w/ or w/o Add-Ons	4	428	16	963	34	1056	54	2447
Tier II w/ or w/o Add-Ons	0	0	4	71	0	0	4	71
Add-Ons Only	1	6	9	654	0	0	10	660
Total	5	434	29	1688	35	1056	68	3178
Completed								
Tier I w/ or w/o Add-Ons *	0	0	11	944	13	614	24	1558
Tier II w/ or w/o Add-Ons	0	0	4	71	0	0	4	71
Add-Ons Only	0	0	10	660	0	0	10	660
Total	0	0	25	1675	15	637	40	2312

* One of these building was certified completed by SGC in January 1995, but construction ended in 1994.

The building projects included in each of the measure samples are summarized in Table 4. This table shows that many of the buildings served as a participant and/or non-participant in more than one of the samples. Twenty-six of the building projects were to some degree LTSGC participants. Many of these buildings served as non-participants for aspects of the LTSGC program in which they did not participate. Thirteen of the building projects were pure non-participants because they did not participate in the program in any way.

The Tier I shell sample contained 19 participants and 15 non-participants. The kitchen lighting sample contained 12 participants and 16 non-participants. The bathroom lighting sample contained 5 participants and 22 non-participants. The low number of participants in this sample was due to the lack of available candidates.

The common-area lighting sample contained 24 participants and 4 non-participants. The outside lighting sample contained 19 participants and 5 non-participants. The 4 non-participants in the common-area lighting sample were relatively-new construction participants in the Seattle City Light Multifamily Common Area Lighting Program that had documentation of the pre-retrofit lighting capacities. This information was used in this study to establish the baseline conditions. The 5 non-participants in the outside lighting sample consisted of sites that received exterior lighting rebates under LTSGC for the common-area measures but whose outside lighting fixtures did not qualify for a rebate.

4.1.2 Sample Selection by Measure

The 19 participants in the Tier I shell sample contained 1,314 units. Electricity bill histories were examined for these building projects (commercial house meters) and their dwelling units (residential tenant meters). Meters were located for 1,413 premises. From this total, 50 meters were dropped from the analysis for various reasons: 29 were commercial accounts (temporary construction meters, or for retail businesses located on ground floors); 11 had missing data during apparent tenant changes; and 10 appeared to be vacant for more than half of the study period.

During the period from November 1, 1994 through October 31, 1995, there were 44 residential premises that had some missing data at the beginning or end of that year. For the 10 mentioned, billing records covered less than half of the study period; the final meter read date falling before May 1, 1995. These were the 10 premises deleted from the study analysis due to excessive vacancy. The other 34 meters with fewer than 365 days of occupancy were retained in the study.

As a result of these adjustments to the meter list, 1,363 premises were included in the analysis of Tier I shell participants. This group of premises comprises one tenant meter per unit plus an average of 2.6 house meters per building. These units represent about half of all electric space-heat units newly constructed in the Seattle City Light service area during 1993-1994.

The 20 nonparticipant projects (28 buildings) in the LTSGC Tier I shell sample contained 779 units. Of these, 7 projects (7 buildings, 232 units) received LTSGC common-area lighting measures, along with some add-on appliance measures, but no bath or kitchen lighting provisions. The other 13 projects (21 buildings, 547 units) received no LTSGC measures of any kind. These units represent more than half of the sampling frame, which consisted of multifamily new construction unserved by the LTSGC program or ineligible for its Tier I shell provisions.

4.2 Summary of Building Characteristics

Salient physical characteristics of the 19 participant projects in the Tier I shell sample are summarized in Table 5. The primary sources of data for the parameters in this table were the project files and the construction drawings. This table also provides a comparison with the building characteristics among the 20 nonparticipant projects.

Table 4. Participation Status of Sample Buildings

Case Number	SGC Participant	Thermal Shell Participant	Kitchen Lighting Participant	Bathroom Lighting Participant	Common Area Lighting Participant	Outside Lighting Participant
1	P	P	NP	NP	P	NP
2	P	P	P	P	P	P
3	P	P	NP	NP	P	P
4	P	P	P	P	P	P
5	P	P	NP	NP	P	NP
6	P	P	P	P	P	NP
7	P	P	—	—	P	P
8	P	P	NP	NP	P	P
9	P	P	P	NP	P	P
10	P	P	P	NP	P	P
11	P	P	NP	NP	P	P
12	P	P	P	P	P	P
13	P	P	P	NP	P	P
14	P	P	P	P	P	NP
15	P	P	NP	NP	P	P
16	P	P	P	NP	P	P
17	P	P	P	NP	P	NP
18	P	P	P	NP	P	P
19	P	P	P	NP	P	P
20	P	NP	NP	NP	P	P
21	P	NP	NP	NP	P	P
22	P	NP*	—	—	—	—
23	P	NP	NP	NP	P	P
24	P	NP	NP	NP	P	P
25	P	NP	NP	NP	P	P
26	P	NP*	—	—	—	—
27	NP	NP	—	—	—	—
28	NP	NP	—	—	—	—
29	NP	NP	—	—	—	—
30	NP	NP	—	—	—	—
31	NP	NP	—	—	—	—
32	NP	NP	—	—	—	—
33	NP	NP	—	—	—	—
34	NP	NP	—	—	—	—
35	NP	—	NP	—	NP	—
36	NP	—	NP	NP	—	—
37	NP	—	NP	NP	NP	—
38	NP	—	NP	NP	NP	—
39	NP	—	NP	NP	NP	—
P Projects	26	19	12	5	24	19
P Units	1,546	1,314	786	444	1,470	1,058
NP Projects	13	15	16	22	4	5
NP Units	547	463	993	1,239	214	412

P = Participant (as-built data source)
NP = Nonparticipant (baseline data source)
* = Participated in appliance add-ons only
— = No data available or used

Table 5. LTSGC Tier I Shell Building Characteristics

Case No.	Number of Housing Units							Gross Floor Area (SqFt)			
	Laundry Type		Number of Bedrooms					Project Total	Common Area +Parking	Resident Area Units	Avg Unit Size
	In Unit	Common	0	1	2	3	Total				
1*	245	0	27	115	103	0	245	287,783	105,011	182,772	746
2	12	88	33	41	14	12	100	110,771	50,146	60,625	606
3	20	0	5	10	5	0	20	40,180	26,365	13,815	691
4	0	200	170	30	0	0	200	118,862	36,442	82,420	412
5	25	0	0	12	13	0	25	44,549	23,512	21,037	841
6	64	0	5	30	29	0	64	92,452	39,378	53,074	829
7*	7	0	0	0	7	0	7	10,776	2,628	8,148	1,164
8	147	0	31	82	34	0	147	166,708	58,913	115,838	733
9	183	0	0	119	46	18	183	192,573	64,079	152,734	702
10	26	0	1	9	16	0	26	40,987	17,831	26,332	891
11	44	0	0	28	8	8	44	53,748	22,036	35,868	721
12	14	0	0	7	7	0	14	18,486	7,670	11,716	773
13	33	0	0	28	5	0	33	38,045	16,590	24,395	650
14	66	0	6	46	14	0	66	74,158	25,403	52,985	739
15	40	0	1	28	11	0	40	48,766	19,330	33,501	736
16*	22	0	0	16	6	0	22	17,829	1,105	17,829	760
17	12	0	0	0	12	0	12	19,286	6,116	14,877	1,098
18	16	0	0	8	8	0	16	20,655	6,301	15,415	897
19	50	0	0	35	15	0	50	54,425	18,455	40,535	719
P Total	1,026	288	279	644	353	38	1,314	1,451,039	547,311	903,728	—
Avg	—	—	—	—	—	—	69	76,370	28,806	47,565	688
NP 20-39	—	—	—	—	—	—	779	856,861	292,849	564,012	—
Avg	—	—	—	—	—	—	39	42,843	14,642	28,201	724

Participants: 19 projects (22 buildings)
Non-participants: 20 projects (28 buildings)
* = Cases with two buildings on site
Avg = Average per project
— = No information available or not applicable

Examination of the data in Table 5 shows that 17 of the 19 Tier I shell participants had in-unit laundries and therefore were used to define the first prototype. These building projects ranged in size from 7 to 245 housing units. They had predominantly one and two bedroom housing units, whose average size ranged from 650 to 1,164 rentable square feet (excluding common area).

The remaining two buildings in the sample, cases 2 and 4, had exclusively or primarily common-area laundries and therefore were used to define the second prototype. These two buildings ranged in size from 100 to 200 housing units that were predominantly studio apartments. The average unit size for these sites ranged from 412 to 606 rentable square feet (excluding common area), which was significantly smaller than the first prototype. These two buildings had income guidelines for tenants, and therefore represent the program's influence on low-income (although not subsidized) projects.

While the average rentable square footage per unit was the same between participants and nonparticipants, the number of housing units was far lower among the nonparticipant projects. On a unit per building basis, nonparticipants averaged half the size (28 units) of participant buildings (60 units). Both types of buildings had the same proportion of rentable to common- and parking-area square footage.

4.2.1 As-Built and Baseline Conditions for LTSGC Provisions

The LTSGC efficiency measures analyzed for each prototype were defined as the difference between the as-built and baseline conditions that were established through the analysis of data collected from the participant and non-participant samples, respectively. Table 6 provides a comparison of the observed as-built average and baseline conditions that resulted from this analysis. The table also provides the corresponding LTSGC prescriptive requirements as a reference for the as-built conditions. The U-factor (coefficient of heat transmission) is given for each insulating R-value (space heat insulation value, the inverse of U). The following assumptions were made in computing the as-built and baseline U-factors for this table:

1. **Attic Construction.** Advanced framing was assumed for the as-built condition and standard framing, derated for reduced perimeter insulation, was assumed as the baseline condition. Standard framing assumes tapering of insulation depth around the perimeter with resultant decrease in thermal resistance. An increased R-value is assumed in the center of the ceiling due to the effect of piling leftover insulation. Advanced framing assumes full and even depth of insulation extending to the outside edge of exterior walls.
2. **Vaulted Ceiling Construction.** A vented ceiling was assumed for the as-built condition and a vented ceiling, derated for 7 square feet per apartment of uninsulated space around fans and recessed can lighting, was assumed for the baseline condition. Vaulted ceiling insulation was assumed to be fiberglass batts installed in roof joist cavities. At least 1.5 inches in left open between the top of the batts and the underside of the roof sheathing for ventilation in each cavity.
3. **Wall Construction.** A standard-framed 2x6 wall with R-21 batts between the studs and an R-5 insulation board under the siding was assumed for the as-built condition. Standard 2x6 framing with R-19 batts (no board) was assumed for the baseline condition.
4. **PT Slab Construction.** When insulation was pinned under the slab, the R-value installed was derated by 50% to account for uninsulated beams and perimeter surface, for both the as-built and baseline conditions.
5. **Glazing Construction.** Double pane, low-emissivity (e), air filled, vinyl framed windows were assumed for the baseline condition; argon fill was assumed for the as-built case.
6. **Thermostats.** Hysteresis, or temperature control dead-band differential, is expressed in degrees Fahrenheit plus or minus from the thermostat setpoint. This band was assumed to be 2°F in the as-built condition and 5°F in the baseline condition (for a 3°F differential).
7. **Lighting.** The weighted average lighting power density is expressed in Watts per square foot. This value was greater under the baseline condition than under the as-built condition in all areas excepting outside lighting, where they were found equivalent.

Table 6 shows that, on average, the participants met or exceeded the prescriptive requirements of all LTSGC provisions. Based on the information in this table, significant energy savings would be expected for both the Tier I shell package and lighting provisions.

Table 6. LTSGC Provisions and Baseline Values

Provision		SGC Prescriptive Requirement	SGC As-Built Condition	non-SGC Baseline Condition
Thermal Shell	**Tier I Measures**			
Ceilings:	Attics	R-49	R-49, U-0.020	R-37, U-0.028
	Vaulted	R-38	R-38, U-0.027	R-36, U-0.030
Walls:	Above-Grade	R-26	R-26, U-0.041	R-19, U-0.062
	Below-Grade	R-21	—	—
Floors:	Crawl Space	R-30	—	—
	Unheated Areas	R-30	—	—
	Slab-on-Grade Perimeter	R-15	—	—
	Above PT Slab	R-15	R-17, U-0.045	R-17, U-0.045
	Pinned Under PT Slab	R-30	R-30, U-0.049	R-21, U-0.064
Glazing		U-0.35	U-0.35	U-0.45
Infiltration	Assumed Rate	0.35 ACH	0.30 ACH	0.40 ACH
Thermostats		Heat Anticipator	Dead Band: 2°F	Dead Band: 5°F
Lighting	**Add-on Measures**			
	Kitchen	Fluorescent	1.95 W/SqFt	2.53 W/SqFt
	Bathroom	Fluorescent	3.37 W/SqFt	4.74 W/SqFt
	Unconditioned Common Area	Fluorescent	0.28 W/SqFt	0.64 W/SqFt
	Outside Exterior	Fluorescent or HPS	0.02 W/SqFt	0.02 W/SqFt

Provisions are explained in the SGC Program Handbook[1].
PT Slab = Post Tension Slab
ACH = Air Changes per Hour
HPS = High Pressure Sodium Luminaire
— = Insignificant quantities or none found; provision not included in prototype

Table 6 also shows that the baseline conditions established by the non-participants were less efficient than the corresponding participant as-built conditions except for the insulation above PT slab provision. For this provision, the as-built and baseline conditions were the same. Regarding infiltration, LTSGC program operators test all fans to ensure compliance with the 0.35 air changes per hour (ACH) required by Washington State Ventilation and Indoor Air Quality Codes for mechanical ventilation systems. The value of 0.30 ACH in the as-built condition reflects a weighted average between mechanicals and gains from improved sealing, estimated to perform at 0.25 ACH.

Table 7 provides as-built characteristics data relevant to major provisions of the LTSGC program for the individual Tier I shell participants. The table shows that the participant building projects were constructed to meet the minimum LTSGC requirements, with the single exception of the average window U-factor for three sites. For cases 4, 11, and 15, the as-built glazing U-factor was slightly greater than the 0.35 maximum value required by the LTSGC program. For the PT slab provision, note that the R-30 insulation pinned under the slab option was installed in about half of the buildings. Also note that in three of the five cases where the R-15 above slab option was installed, the installed insulation level was significantly greater than the LTSGC minimum requirement.

Table 7. LTSGC Tier I Shell As-Built Provisions

Case No.	Wall	Ceiling		Floor		Window	Lighting Power Density W/SqFt			
	R-Value	Type	R-Value	Type	R-Value	Avg. U-factor	Kitchen LPD	Bath LPD	Uncond LPD	Outside LPD
1	R-26	vaulted	R-38	PT slab	R-30	0.35	4.69	4.53	0.33	0.007
2	R-26	attic	R-49	PT slab*	R-19	0.35	1.12	0.96	0.21	0.026
3	R-28	vaulted	R-38	PT slab	R-30	0.33	3.13	8.85	0.19	0.037
4	R-26	vaulted	R-38	PT slab	R-30	0.40	0.89	1.00	0.46	0.006
5	R-26	vaulted	R-38	PT slab	R-30	0.35	1.63	2.46	0.20	0.029
6	R-26	vaulted	R-38	PT slab*	R-19	0.35	1.25	0.59	0.32	0.018
7	R-26	attic	R-49	wood frame	R-30	0.32	—	—	0.13	0.126
8	R-28	vaulted	R-38	PT slab*	R-15	0.34	1.32	5.00	0.21	0.011
9	R-26	vaulted	R-38	PT slab	R-30	0.35	1.32	4.62	0.29	0.010
10	R-26	vaulted	R-38	PT slab	R-30	0.33	0.87	4.90	0.19	0.008
11	R-26	vaulted	R-38	PT slab	R-30	0.36	2.81	5.61	0.22	0.036
12	R-26	vaulted	R-38	none	—	0.34	1.23	0.89	0.25	0.234
13	R-26	vaulted	R-38	PT slab	R-30	0.33	1.48	5.33	0.21	0.008
14	R-26	vaulted	R-38	PT slab*	R-15	0.35	1.23	0.96	0.28	0.030
15	R-26	vaulted	R-38	PT slab	R-30	0.38	2.81	5.45	0.16	0.044
16	R-26	attic	R-49	slab on-grade	R-15	0.35	1.19	1.19	0.73	0.105
17	R-26	vaulted	R-38	wood frame	R-30	0.35	1.06	0.64	0.48	0.142
18	R-26	vaulted	R-38	PT slab*	R-16.7	0.32	1.12	10.67	0.25	0.022
19	R-26	vaulted	R-38	PT slab	R-30	0.35	1.25	1.79	0.37	0.008

* = Insulation installed above post-tension slab in 5 cases
— = No information available
Uncond = Unconditioned common space including parking garage
Outside = Exterior to the building and excluding parking garage

4.3 PARTICIPANT ENERGY CONSUMPTION

A calibrated simulation was prepared for each prototype using the procedures described in Section 2. The In-unit Laundry Prototype (prototype 1) required seven thermal zones to adequately represent the spaces in the building with unique thermal performance. The Common Laundry Prototype (prototype 2) required six thermal zones to represent these spaces. Thermal zones are areas that exhibit unique thermal behavior. Table 8 provides a summary of important characteristics for each of the thermal zones in both prototypes.

The table shows that thermal zones were distinguished by the presence of unconditioned space (parking and common area) and the location of the conditioned housing units in the building. Conditioned common areas represent only 9% of all common-area square footage (3% of common area plus parking), and have been combined with unconditioned common areas for this study. Most buildings have no conditioned common areas. These buildings have primarily unconditioned, double-loaded corridors. Ground floors are often commercial space with a different construction method; wood framing in these cases starts on the residential first floor.

Table 8. LTSGC Prototype Envelope Characteristics

DOE-2 Zone Description by Prototype	No. Apt Units	Floor: Zone Total SqFt	Floor: Unit Avg	PT Slab Insulation: Pinned Under	PT Slab Insulation: Above Slab	Ceiling: Vaulted SqFt	Ceiling: Attic SqFt	Wall: Exterior Net SqFt	Window: Glazing SqFt
In Unit Laundry									
Unconditioned Parking Garage	0	347,612	—	0	0	0	0	0	0
Unconditioned Common Area	0	113,111	—	19,476	5,653	16,820	552	30,993	3,729
Apt. Type 1 (UA/SqFt <0.06)	237	157,609	665	0	0	675	0	41,948	17,586
Apt. Type 2 (0.06<UA/SqFt <0.08)	266	194,347	731	488	1,034	35,030	680	59,881	29,241
Apt. Type 3 (0.08<UA/SqFt <0.10)	233	182,056	781	25,212	14,709	47,990	5,859	73,846	28,893
Apt. Type 4 (0.10<UA/SqFt <0.12)	166	135,965	819	29,095	15,501	44,538	6,918	61,338	24,880
Apt. Type 5 (UA/SqFt> 0.12)	124	105,818	853	36,348	20,138	43,988	1,292	58,505	23,967
Prototype Total	1,026	1,236,518	—	110,619	57,035	189,040	15,301	326,511	128,296
Prototype Average	—	—	756	—	—	—	—	—	—
Common Laundry									
Unconditioned Parking Garage	0	65,328	—	0	0	0	0	0	0
Unconditioned Common Area	0	21,260	—	1,420	1,409	4,108	0	5,154	637
Apt. Type 1 (UA/SqFt <0.06)	140	57,858	413	0	0	0	0	12,658	6,161
Apt. Type 2 (0.06<UA/SqFt <0.08)	51	22,335	438	402	0	14,154	0	5,727	2,665
Apt. Type 3 (0.08<UA/SqFt <0.10)	48	21,082	439	5,916	854	4,099	0	9,971	2,816
Apt. Type 4 (UA/SqFt >0.10)	49	26,658	544	2,570	7,728	7,538	0	16,999	5,160
Prototype Total	288	214,521	—	10,308	9,991	29,899	0	50,508	17,440
Prototype Average	—	—	444	—	—	—	—	—	—

Net Exterior Wall is the opaque insulated exterior wall excluding windows.

Apartments were assigned to an appropriate apartment type based upon their calculated UA per square foot, which was computed by dividing the exterior UA of the unit by its floor area. (UA, or U x Area, represents the magnitude of heat transmission through the unit's exterior surfaces.). Interior housing units had relatively low values for UA per square foot, while corner apartments had relatively high values for UA per square foot. The zone floor area values in the table show that the various apartment types were fairly evenly distributed across both prototypes.

Table 8 also shows that the zone floor areas represented by the In-unit Laundry Prototype are much larger than the Common Laundry Prototype, since many more In-unit Laundry buildings were included in the sample. For both prototypes, 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. Pinned under slab insulation was predominant in the In-unit Laundry Prototype, but covered the same area as above floor insulation in the

Common Laundry Prototype. Both prototypes have significant window area, accounting for about one-quarter of the gross exterior wall area.

The building characteristics data and derived profiles were integrated into the simulation. Building level infiltration and thermostat setpoint profiles were developed from measurements made in the BPA Multifamily Metering Study[6]. The BPA data were also used to develop building level average seasonal consumption profiles (24 hour) by day type (weekday and weekend) for the hot water, lighting and equipment end uses in the In-unit Laundry Prototype. Adjustments were made to the profiles for the equipment and hot water end uses in the Common Laundry Prototype. The consumption profiles for both prototypes were integrated directly into the simulation input stream.

Operating profiles for the lighting end use were derived from data gathered during the literature review of previous research at Puget Power[4] and Pacific Gas and Electric[5]. 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. The lighting system was assumed to be on a schedule that was the same profile shape as the equipment load.

The billing data compiled for the participant sites was used to establish EUI targets for both prototypes. For the Common Laundry Prototype the EUI target was computed to be 7.99 kWh/sq.ft./year. This target was slightly lower than the target of 10.05 kWh/sq.ft./year developed for the In-unit Laundry Prototype. This magnitude of difference was expected because of the reduced laundry usage associated with the smaller apartment size in the Common Laundry sample. These targets were checked for reasonableness and found to be realistic targets for use in calibrating the adequacy of the prototype models.

A separate calibration of 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. Table 9 provides a comparison of simulated consumption to the EUI targets for the In-unit Laundry Prototype. The comparison is provided for each month in the calibration period. The table shows that simulated monthly consumption met the 10% acceptability criteria for each month in the calibration period. Similar results were achieved for the Common Laundry Prototype, as shown in Table 10. For both prototypes, simulated annual consumption was within about 1% of the annual target, indicating that a reasonable calibration of both models was achieved. The fully calibrated models represented the most accurate depiction of predicted end use consumption under full occupancy and weather conditions that existed during the calibration year.

The fully calibrated models were rerun under Sea-Tac Typical Meteorological Year (TMY) weather conditions to remove the effect of unusual weather conditions during the calibration year. The energy savings could then be calculated under long term average weather conditions. Table 9 and Table 10 also provide the results of the re-simulation of annual consumption under typical weather conditions. Examination of the consumption data in the table reveals that consumption increased slightly under long term weather conditions, indicating that the calibration heating season was warmer than normal. The final estimate of annual consumption for the In-unit Laundry and Common Laundry Prototypes was 10.26 kWh/sq.ft. and 8.32 kWh/sq.ft., respectively. For both prototypes, monthly energy consumption during the peak winter months is observed to be about twice the consumption in the summer months.

Table 9. In-Unit Laundry Prototype: Simulation Comparison

	Calibration Year			TMY Weather Year
Month	Target kWh/SqFt	Simulated kWh/SqFt	Percent Difference	Simulated kWh/SqFt
Jan	1.12	1.04	-6.96%	1.20
Feb	0.95	0.93	-1.34	1.00
Mar	0.91	0.86	-5.50	0.94
Apr	0.79	0.77	-2.85	0.81
May	0.72	0.77	6.31	0.78
June	0.65	0.63	-3.32	0.63
July	0.66	0.65	-2.13	0.65
Aug	0.65	0.65	-0.27	0.65
Sept	0.70	0.75	6.40	0.75
Oct	0.76	0.80	5.13	0.81
Nov	0.95	0.97	2.56	0.88
Dec	1.18	1.14	-3.44	1.18
Annual	10.05	9.96	-0.87%	10.26

Consumption kWh/SqFt based on envelope-enclosed Common and Apartment floor area of 888,906 square feet

TMY = Typical Meteorological Year

Table 10. Common Laundry Prototype: Simulation Comparison

	Calibration Year			TMY Weather Year
Month	Target kWh/SqFt	Simulated kWh/SqFt	Percent Difference	Simulated kWh/SqFt
Jan	0.85	0.83	-1.87%	0.97
Feb	0.69	0.75	8.94	0.80
Mar	0.72	0.70	-3.14	0.77
Apr	0.61	0.63	2.74	0.65
May	0.59	0.63	7.66	0.64
June	0.48	0.50	4.80	0.50
July	0.53	0.52	-2.00	0.52
Aug	0.49	0.52	5.68	0.52
Sept	0.57	0.61	7.37	0.61
Oct	0.67	0.65	-3.06	0.66
Nov	0.77	0.79	2.91	0.71
Dec	1.02	0.92	-9.28	0.96
Annual	7.99	8.07	0.93%	8.32

Consumption kWh/SqFt based on envelope-enclosed Common and Apartment floor area of 149,193 square feet

TMY = Typical Meteorological Year

4.4 Baseline (Non-Participant) Energy Consumption

A baseline (non-participant) model was created for each prototype by rerunning the TMY participant model with the Tier I thermal shell and lighting LTSGC provisions removed. Baseline energy system performance relative to the LTSGC program was assumed to be the values shown in Table 6. Separate baseline models were created for each measure type (i.e., thermal shell and lighting measures) in both prototypes. The monthly estimates of energy consumption produced by the baseline models are provided in Table 11 and Table 12 for the In-unit and Common Laundry Prototypes, respectively.

As expected, estimated annual baseline consumption for both measure types in each prototype is greater than as-built consumption. For the In-unit Laundry Prototype, baseline energy consumption increased to 11.69 kWh/sq.ft. for the thermal shell measure package, 10.34 kWh/sq.ft. for the kitchen/bath lighting measure and 11.77 kWh/sq.ft. for the exterior lighting measure. For the Common Laundry Prototype, similar increases were found. Baseline energy consumption increased to 9.57 kWh/sq.ft. for the thermal shell package, 8.45 kWh/sq.ft. for the kitchen/bath lighting measure and 10.03 kWh/sq.ft. for the exterior lighting measure.

4.5 Energy Savings from LTSGC Provisions

Energy savings were computed for both prototypes as the difference between participant and baseline (non-participant) consumption for each prototype under full occupancy and TMY weather conditions. Bill savings were computed by applying the appropriate Seattle City Light rate schedules. The monthly and annual energy and bill savings values for the In-unit and Common Laundry Prototypes are given in Table 11 and Table 12, respectively.

The tables show significant energy savings were achieved by the LTSGC provisions in both prototypes. Annual energy savings of 1.43 kWh/sq.ft. (1,239 kWh/apartment) were estimated for the thermal shell package in the In-Unit Laundry prototype. Energy savings of 1.57 kWh/sq.ft. (1,361 kWh/apartment) were estimated for the lighting measures. These values represent 12% and 13% of baseline consumption, respectively.

The lighting saving may be broken out by location: within unit or in common areas. Energy savings of 0.07 kWh/sq.ft. (61 kWh/apartment) were estimated for the kitchen/bath lighting measure and 1.50 kWh/sq.ft. (1,300 kWh/apartment) were estimated for the unconditioned common-area lighting measure. These savings values represent 1% and 13% of baseline consumption, respectively.

The energy savings from shell insulation and high-efficiency windows occurred mainly during the winter-peak months. From November through February (when winter rates apply), 60% of Thermal Shell savings were realized in the In-Unit Laundry Prototype. The majority of remaining space heat savings (33%) occurred during the “shoulder” months of March-April and October.

Table 11. In-Unit Laundry Prototype: Energy & Bill Savings

Month	As-Built Electric kWh/SqFt	Thermal Shell Provisions: Baseline Electric kWh/SqFt	Thermal Shell Provisions: Energy Savings kWh/SqFt	Thermal Shell Provisions: Bill * Savings $/SqFt	Kitchen and Bath Lighting: Baseline Electric kWh/SqFt	Kitchen and Bath Lighting: Energy Savings kWh/SqFt	Kitchen and Bath Lighting: Bill * Savings $/SqFt	Unconditioned Common Ltg: Baseline Electric kWh/SqFt	Unconditioned Common Ltg: Energy Savings kWh/SqFt	Unconditioned Common Ltg: Bill ** Savings $/SqFt
Jan	1.20	1.44	0.24	$ 0.014	1.20	0.00	$ 0.000	1.31	0.12	$0.006
Feb	1.00	1.20	0.20	0.012	1.00	0.00	0.000	1.10	0.10	0.005
Mar	0.94	1.14	0.20	0.008	0.94	0.00	0.000	1.06	0.12	0.004
Apr	0.81	0.96	0.16	0.006	0.81	0.01	0.000	0.93	0.12	0.004
May	0.78	0.86	0.07	0.003	0.79	0.01	0.000	0.92	0.13	0.004
June	0.63	0.65	0.02	0.001	0.64	0.01	0.000	0.76	0.13	0.004
July	0.65	0.65	0.01	0.000	0.66	0.01	0.000	0.79	0.14	0.005
Aug	0.65	0.65	0.00	0.000	0.66	0.01	0.000	0.79	0.14	0.005
Sept	0.75	0.75	0.01	0.000	0.76	0.01	0.000	0.88	0.13	0.004
Oct	0.81	0.92	0.11	0.004	0.81	0.01	0.000	0.94	0.13	0.004
Nov	0.88	1.06	0.18	0.010	0.88	0.00	0.000	0.99	0.11	0.005
Dec	1.18	1.41	0.23	0.013	1.18	0.00	0.000	1.30	0.12	0.006
Annual	10.26	11.69	1.43	$ 0.072	10.34	0.07	$ 0.003	11.77	1.50	$ 0.056

* Tier I Shell and Kitchen/Bath Lighting bill savings based on 1995 Residential Rate 20, second block
** Common Area lighting bill savings based on 1995 Small General Service Rate 31

kWh/SqFt consumption and energy savings based on envelope-enclosed Common and Apartment floor area of 888,906 square feet (excludes parking garage)

Table 12. Common Laundry Prototype: Energy & Bill Savings

Month	As-Built Electric kWh/SqFt	Thermal Shell Provisions: Baseline Electric kWh/SqFt	Thermal Shell Provisions: Energy Savings kWh/SqFt	Thermal Shell Provisions: Bill * Savings $/SqFt	Kitchen and Bath Lighting: Baseline Electric kWh/SqFt	Kitchen and Bath Lighting: Energy Savings kWh/SqFt	Kitchen and Bath Lighting: Bill * Savings $/SqFt	Unconditioned Common Ltg: Baseline Electric kWh/SqFt	Unconditioned Common Ltg: Energy Savings kWh/SqFt	Unconditioned Common Ltg: Bill ** Savings $/SqFt
Jan	0.97	1.18	0.21	$ 0.012	0.97	0.00	$ 0.000	1.10	0.13	$0.006
Feb	0.80	0.98	0.18	0.010	0.81	0.00	0.000	0.92	0.12	0.006
Mar	0.77	0.94	0.18	0.007	0.77	0.01	0.000	0.91	0.14	0.005
Apr	0.65	0.79	0.13	0.005	0.67	0.01	0.000	0.80	0.14	0.005
May	0.64	0.70	0.06	0.002	0.66	0.02	0.001	0.79	0.15	0.005
June	0.50	0.52	0.02	0.001	0.52	0.02	0.001	0.66	0.15	0.005
July	0.52	0.53	0.00	0.000	0.54	0.02	0.001	0.68	0.16	0.005
Aug	0.52	0.52	0.00	0.000	0.54	0.02	0.001	0.68	0.16	0.005
Sept	0.61	0.62	0.00	0.000	0.63	0.02	0.001	0.76	0.15	0.005
Oct	0.66	0.75	0.09	0.004	0.67	0.02	0.001	0.81	0.15	0.005
Nov	0.76	0.87	0.16	0.009	0.72	0.00	0.000	0.84	0.13	0.006
Dec	0.96	1.16	0.21	0.012	0.96	0.00	0.000	1.09	0.13	0.006
Annual	8.32	9.57	1.25	$ 0.063	8.45	0.13	$ 0.005	10.03	1.71	$ 0.064

* Tier I Shell and Kitchen/Bath Lighting bill savings based on 1995 Residential Rate 20, second block
** Common Area lighting bill savings based on 1995 Small General Service Rate 31

kWh/SqFt consumption and energy savings based on envelope-enclosed Common and Apartment floor area of 149,193 square feet (excludes parking garage)

Most of the savings for the 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. No savings were found from the outside lighting component of the exterior lighting measure because the baseline and as-built conditions were determined to be the same.

Annual energy savings of 1.25 kWh/sq.ft. (648 kWh/apartment) were estimated for the thermal shell package in the Common Laundry prototype. Energy savings of 1.84 kWh/sq.ft. (953 kWh/apartment) were estimated for the lighting measures. These values represent 13% and 19% of baseline consumption, respectively.

Broken out by location (within unit or in common areas), the lighting savings are as follows. Energy savings of 0.13 kWh/sq.ft. (67 kWh/apartment) were estimated for the kitchen/bath lighting measure and 1.71 kWh/sq.ft. (886 kWh/apartment) were estimated for the unconditioned common-area lighting measure. These savings values represent 2% and 17% of baseline consumption, respectively. Again, most of the lighting savings are found in the common-area lighting system, which is run continuously.

The energy savings from shell insulation and high-efficiency windows occurred mainly during the winter-peak months. From November through February (when winter rates apply), 61% of Thermal Shell savings were realized in the Common Laundry Prototype. The majority of remaining space heat savings (32%) occurred during the “shoulder” months of March-April and October.

In both prototypes there is a slight summer/winter differential in the savings from common-area lighting. This is due to the common wall with conditioned apartments within the building envelope, and some heat takeback during the months from November through April. The savings from kitchen and bathroom lighting in both prototypes were zero from November through April, also reflecting a heat takeback interaction within the apartment conditioned space. Meanwhile, the Tier I shell space-heat savings show the typical seasonal pattern of space heat usage.

The Common Laundry Prototype has a smaller proportion of envelope surface area to floor area than the In-unit Laundry Prototype. As a result, the shell savings in the Common Laundry Prototype are less than the In-unit Laundry Prototype on a square foot basis. The Common Laundry Prototype also has kitchen and bathrooms that represent a larger fraction of the floor area of the average housing unit. Thus the kitchen and bath lighting energy savings in the Common Laundry Prototype, on a square foot basis, are greater than in the In-unit Laundry Prototype.

For convenience, the unconditioned common lighting values in Table 11 and Table 12 are normalized to the envelope-enclosed floor area (common and apartment). In fact, however, the lighting add-on measure for the unconditioned common area also encompasses the parking garage in both prototypes. If the parking garage floor area were included in the normalization, the unconditioned common lighting savings would change to 1.19 and 1.08 kWh/sq.ft. for the Common Laundry and In-unit Laundry Prototypes, respectively. Expressed in these terms, the lighting savings in the Common Laundry Prototype are somewhat greater than the In-unit Laundry Prototype, because the fraction of affected floor area is greater in the Common Laundry Prototype.

4.6 BILL SAVINGS FROM LTSGC PROVISIONS

Bill savings were realized for both measure categories in each prototype. The annual bill savings were about $0.14 per square foot of floor area, based on the 1995 rate schedules and the complete package of measures. These bill savings in the Common Laundry Prototype are equivalent to $33 per apartment annually from the Tier I thermal shell measure package and $42 per apartment from the lighting measures. Bill savings were significantly higher for In-unit Laundry Prototype, with customers annually saving about $62 per apartment from the thermal shell measures and $60 per apartment from the lighting measures.

The higher per apartment bill savings for the In-unit Laundry Prototype are due to the larger size housing units. The amount of the LTSGC rebate did not vary with apartment size. Bill savings from thermal shell measures accrued to the tenants. Bill savings from the bath and kitchen lighting measures (about $4 of the lighting savings per unit) accrued to the tenants, while bill savings from the remaining lighting measures accrued to the owner. For the entire 19 project sample receiving Tier I thermal shell measures, the annual bill savings under typical weather conditions amounted to $73,300 from the thermal shell measures and $73,700 from the lighting measures in 1995 (totaling $147,000 per year).

4.7 COST-EFFECTIVENESS OF R-26 WALL INSULATION

A series of sensitivity runs were made with the participant and baseline models to compute the incremental energy savings of R-26 wall insulation against an R-21 baseline, under full occupancy and typical weather conditions. The results of this analysis are provided in Table 13 and Table 14 for the In-unit and Common Laundry Prototypes, respectively. These tables show an energy savings of 0.40 kWh/sq.ft. wall for both prototypes. The monthly distribution of savings shown in the tables is as expected, with all of the savings occurring in the heating months.

The incremental cost-effectiveness analysis includes the calculation of levelized cost and simple payback, to reflect both the utility and customer perspectives. The analysis assumed an incremental insulation cost of $0.42/sq.ft. of wall area (or $0.15/sq.ft. of floor area), and a service life of 50 years. Based on these data, Seattle City Light rate schedules, and the savings values in Table 13 and Table 14, the R-26 insulation had an incremental payback of 20 years and a levelized cost of 41 mills per kWh saved.

Table 13. In-Unit Laundry Prototype: Wall Insulation Savings

	R-26 Wall	R-21 Wall			
Month	As-Built Electric kWh/SqFt Floor	Baseline Electric kWh/SqFt Floor	Energy Savings kWh/SqFt Floor	Energy Savings kWh/SqFt Wall	* Bill Savings $/SqFt Wall
Jan	1.20	1.23	0.03	0.08	$ 0.005
Feb	1.00	1.02	0.02	0.06	0.004
Mar	0.94	0.96	0.02	0.05	0.002
Apr	0.81	0.82	0.01	0.03	0.001
May	0.78	0.79	0.01	0.03	0.000
June	0.63	0.63	0.00	0.00	0.000
July	0.65	0.65	0.00	0.00	0.000
Aug	0.65	0.65	0.00	0.00	0.000
Sept	0.75	0.75	0.00	0.00	0.000
Oct	0.81	0.81	0.00	0.02	0.001
Nov	0.88	0.90	0.02	0.05	0.003
Dec	1.18	1.21	0.03	0.08	0.005
Annual	10.26	10.41	0.15	0.40	$ 0.021

* Tier I shell bill savings based on 1995 Residential Rate 20, second block

kWh/SqFt Floor consumption and energy savings based on envelope-enclosed Common and Apartment floor area of 888,906 square feet (excludes parking garage)

kWh/SqFt Wall energy and bill savings based on Common and Apartment net exterior wall area of 326,511 square feet

Table 14. Common Laundry Prototype: Wall Insulation Savings

	R-26 Wall	R-21 Wall			
Month	As-Built Electric kWh/SqFt Floor	Baseline Electric kWh/SqFt Floor	Energy Savings kWh/SqFt Floor	Energy Savings kWh/SqFt Wall	* Bill Savings $/SqFt Wall
Jan	0.97	1.00	0.03	0.08	$ 0.005
Feb	0.80	0.83	0.03	0.06	0.004
Mar	0.77	0.79	0.02	0.05	0.002
Apr	0.65	0.66	0.01	0.03	0.001
May	0.64	0.65	0.01	0.03	0.000
June	0.50	0.50	0.00	0.00	0.000
July	0.52	0.52	0.00	0.00	0.000
Aug	0.52	0.52	0.00	0.00	0.000
Sept	0.61	0.61	0.00	0.00	0.000
Oct	0.66	0.66	0.00	0.02	0.001
Nov	0.71	0.73	0.02	0.05	0.003
Dec	0.96	0.98	0.02	0.08	0.005
Annual	8.32	8.45	0.14	0.40	$ 0.021

* Tier I shell bill savings based on 1995 Residential Rate 20, second block

kWh/SqFt Floor consumption and energy savings based on envelope-enclosed Common and Apartment floor area of 149,193 square feet (excludes parking garage)

kWh/SqFt Wall energy and bill savings based on Common and Apartment net exterior wall area of 50,508 square feet

4.8 SUMMARY

This section presented findings about the building projects sampled and analyses of their salient characteristics. Actual billing records for 19 projects supplied targets for calibrating engineering simulations. Two prototypes were compared under as-built and baseline conditions to estimate energy savings attributable to the Long-Term Super Good Cents Program. These savings were estimated for the 1993-1994 projects sampled, under conditions of full occupancy and typical weather. Customer bill savings were estimated for the 19 projects, and the incremental cost of R-26 wall insulation was evaluated.

5.0 DISCUSSION, CONCLUSIONS & RECOMMENDATIONS

This section continues the impact evaluation to make projections about Long Term Super Good Cents program performance in 1995-1996 and beyond. The discussion is organized by program feature and intended uses of the evaluation findings. Process evaluation information that surfaced in the course of the impact evaluation is discussed. Conclusions are drawn about the LTSGC program. Section 5 concludes with a series of detailed recommendations for product and service improvements in the revised multifamily new construction program at Seattle City Light.

5.1 SUMMARY OF FINDINGS

Table 15 presents a summary of the findings from this study regarding baseline and as-built energy use, energy savings, and utility bill savings. The findings appear for the two prototypes, broken out by measure category and totaled for the hypothetical building receiving all measures. Also broken out is a detail on the wall insulation specification (R-26 vs. R-21) that has been a barrier to program participation for some builders. Lighting measures are divided between in-unit (kitchen and bath) versus common-area (within envelope plus garage), based on the customer type, tenant versus owner, benefiting from bill savings.

While baseline and as-built annual energy use varies between the two prototypes by about 2 kWh per square foot of floor area, annual energy savings are nearly identical for the hypothetical building receiving all measures, at about 3 kWh per square foot. The floor area used to normalize these findings includes the entire building envelope, encompassing tenant spaces and internal common areas, but excluding any residential parking garage square footage.

5.1.1 Within-Unit Energy Savings

Energy savings from the Tier I Shell measures (insulation, windows, and thermostats) were 1.43 kWh per square foot in the In-Unit Laundry Prototype and 1.25 kWh per square foot in the Common Laundry Prototype. As Table 5 showed, the majority of the In-Unit Laundry units has one to two bedrooms and a 70% larger square floor area (756 square feet) than the average Common-Laundry unit (444 square feet), which are primarily studio apartments. These results may be generalized across prototypes to a weighted finding of 1.40 kWh per square foot of floor area saved annually from Tier I Shell measures.

As remarked in the Table 15 notes, only half of In-Unit Laundry Prototype cases (465 units) received kitchen and bath lighting measures through the program. These building projects had an envelope-enclosed floor area of 411,768 square feet, including common areas and apartments. Normalized to the floor area of these treated cases only, annual energy savings in the In-Unit Laundry prototype were 0.15 kWh per square foot (with annual tenant bill savings of $8). All Common Laundry Prototype cases received the program measures for kitchen and bath lighting, and saved 0.13 kWh per square foot. These results may be generalized across prototypes to a weighted finding of 0.15 kWh per square foot of floor area saved annually from Kitchen and Bathroom Lighting measures, in buildings receiving the measure.

5.1.2 Common Area Energy Savings

Energy savings from the Common Area Lighting measures (conditioned and unconditioned common areas plus parking garage) were 1.50 kWh per square foot in the In-Unit Laundry Prototype and 1.71 kWh per square foot in the Common Laundry Prototype. These results may be generalized across prototypes to a weighted finding of 1.53 kWh per square foot of floor area saved annually from Common Area Lighting measures.

The Common Area Lighting results have been normalized to the envelope-enclosed Common and Apartment floor area of 1,308,099 square feet. Another way of describing these results is in terms of the square footage directly affected by the measures. Normalized for the Common Area and Parking Garage square footage of 547,311, the annual energy savings were 2.89 kWh per square foot in the In-Unit Laundry Prototype (460,723 SqFt) and 2.95 kWh per square foot in the Common Laundry Prototype (86,588 SqFt). These results may be generalized across prototypes to a weighted finding of 2.90 kWh per square foot of common and garage floor area saved annually from Common Area Lighting measures.

5.1.3 Total Building Energy Savings

In summation, the typical building receiving all Tier I Shell and Lighting measures saved a total of 3.08 kWh per square foot of envelope-enclosed floor area, deriving 1.40 from the shell measures, 0.15 from within-unit lighting and 1.53 from the common-area lighting. These measure-level savings are tolerably additive because space heat, laundry heat, and lighting interactions have been compensated by the study design. Any remaining interaction effects, such as water heater or refrigerator waste heat (especially low with high-efficiency appliances), would be lost in the noise of the error band due to weather year adjustments and variations in tenant vacancy. The shell savings on space heat occur primarily in winter-peak months.

Per residential unit, these weighted average savings are 2,380 kWh per unit, comprising 1,109 from the shell measures, 62 from within-unit lighting and 1,209 from the common-area lighting. These savings translate into $53 per unit on the owner's annual electric bill and $61 per annual tenant bill in 1995. These amounts exclude additional bill savings from high-efficiency refrigerators and water heaters installed due to the program.

A comparison may be drawn from an evaluation of PacifiCorp's Oregon LTSGC 1992-1993 program[9]. Their study found savings in multifamily new construction of 1.70 kWh per square foot of rentable space (where units average 890 square feet). PacifiCorp measures included ceiling, floor, and wall insulation, windows, some water heaters (one-third of units) and some heat exchangers (also in one-third or units). The Seattle finding of 1.40 kWh per square foot is normalized to a total building square footage that includes common areas. Normalized to rentable space, this is equivalent to 1.61 kWh per square foot (where units average 690 square feet). This result is within 5% of the PacifiCorp finding, although the Seattle finding excludes water heaters, as well as heat exchangers (not a Seattle measure).

Table 15. Summary of LTSGC Consumption & Savings

Prototype & Measure Provisions	Annual Energy Use		Annual Energy Savings			Annual Bill Savings
	As-Built under SGC kWh / SqFt	Baseline Condition kWh / SqFt	per Bldg Shell kWh / SqFt	per Tenant Unit Unit	Pct of Baseline %	per Tenant Unit 1995$
In-Unit Laundry						
(R-26 vs. R-21 Wall)	*10.26*	*10.41*	*0.15*	*130*	*1%*	*$ 7*
Thermal Shell Total	10.26	11.69	1.43	1,239	12%	$ 62
Kitchen & Bath Lighting*	10.26	10.34	0.07*	61	1%	$ 4*
Common Area & Garage Lighting**	10.26	11.77	1.50**	1,300	13%	$ 56
Whole Building	—	—	3.00	2,600	26%	$ 122
Common Laundry						
(R-26 vs. R-21 Wall)	*8.32*	*8.45*	*0.13*	*67*	*2%*	*$ 3*
Thermal Shell Total	8.32	9.57	1.25	647	13%	$ 33
Kitchen & Bath Lighting	8.32	8.48	0.13	67	2%	$ 4
Common Area & Garage Lighting**	8.32	10.03	1.71**	885	17%	$ 38
Whole Building	—	—	3.09	1,599	32%	$ 75

Bill savings from Tier I Shell and Kitchen/Bath Lighting measures accrue to tenants, while bill savings from Common Area, Garage & Exterior lighting accrue to the building owner. Bill savings are based on the average envelope-enclosed floor area per unit for each prototype.

* Only half of In-Unit Laundry Prototype cases (465 units) received Kitchen/Bath Lighting measures; these buildings had an envelope-enclosed Common and Apartment floor area of 411,768 square feet. Normalized for treated cases only, annual energy savings were 0.15 kWh/SqFt and annual tenant bill savings were $8. All Common Laundry Prototype cases added on Kitchen/Bath Lighting.

** Common Area & Garage Lighting has been normalized to the envelope-enclosed Common and Apartment floor area of 1,308,099 square feet. Normalized to the Common Area and Parking Garage square footage of 547,311, annual energy savings were 2.89 kWh/SqFt for the In-Unit Laundry Prototype (460,723 SqFt) and 2.95 kWh/SqFt for the Common Laundry Prototype (86,588 SqFt). No savings were found from exterior/outside lighting.

5.2 DISCUSSION & CONCLUSIONS

In terms of the program goals stated in the proposal to the City Council in 1992, the findings of this LTSGC program evaluation may be summarized as follows. Supporting details follow in sections 5.2.1 through 5.2.10.

- *Seattle City Light planned to bring the LTSGC program to at least 50% of the new multifamily units constructed in the utility's service area in each year from 1992 through 2003.*

The LTSGC program penetrated about 72% of the new multifamily construction in Seattle City Light's services area during 1993-1994, or about 80% of the electric space-heat buildings. This compares with the experience of PacifiCorp, which found penetration of 63% from their Oregon LTSGC program in 1992-1994, peaking in at 78% in 1993.

- *With multifamily construction projected to decline over time, this was expected to mean as many as 1,500 units participating in the early years, falling to as few as 500 units in the later years.*

The LTSGC program completed shell insulation work with buildings containing 1,015 units in 1993, 614 units in 1994, 666 units in 1995, and 289 units in 1996. In 1993 an additional 660 units received appliance measures only. The higher level of completions in 1993 reflects projects contracted after construction had begun. The apparent decline in 1996 completions corresponds to a program shift toward contracting projects at an earlier point in development, closer to the date of permit, to maximize opportunities to intervene at the design stage. Contracts signed in 1996 remain high at over 1,600 units.

- *By the year 2003, the program was expected to provide 1.2 average megawatts (aMW) of load reduction.*

New construction projects completed during 1993-1996 (cumulative) have reduced Seattle City Light's load by 0.735 aMW direct energy savings, amounting to 0.773 aMW including a credit for 5.2% transmission and distribution savings. The program has already attained nearly two-thirds of the LTSGC ten-year goal, half-way through its intended duration. This success may be attributed to higher savings per project than expected, and a higher program penetration rate than planned. In 1996, new construction permits have dramatically increased over previous years, portending rising opportunities to intervene in multifamily new construction efficiency during the current cycle of higher building activity.

- *Savings were expected at about 12% of baseline (residential unit) energy usage.*

Savings from shell measures averaged 12.5% across prototypes, while savings from lighting measures were 15.5% of baseline energy use (2.0% from kitchen/bath lighting, and 13.5% from common-area measures). Total savings per building were 28% of the projected baseline (total building including common area) energy use—more than double the savings expected when this program was planned. This result excludes additional savings realized from add-on appliances.

The success of Seattle's LTSGC program at achieving the expected savings from thermal shell measures may be attributed to two factors. First, Seattle's program established a firm foundation with a careful plan for implementing the primary compliance path, which draws its strength from the prescriptive requirements. The planning team included John Forde (implementation), Linda Lockwood (economic analysis), and John Baniago (legal issues). Second, the program staff were diligent in negotiating measures with builders, and repeatedly inspecting work in progress to ensure that measures perform up to potential. The staff also kept careful records of the original building design and measures actually installed as a result of the program intervention, which facilitated the accountability process. The planners for Seattle's LTSGC program must also be applauded for their foresight in emphasizing the lighting component, which has led to the program's marked success in acquiring significant savings from the building common areas.

Discussions and conclusions follow, organized by program feature and intended uses of the evaluation findings. Process evaluation information that surfaced in the course of this impact evaluation is discussed, and conclusions are drawn about the LTSGC program.

5.2.1 Accountability Reports and Load Forecast

Prior Assumptions. In May 1992, Seattle City Light formally proposed before the City Council to offer the Bonneville Power Administration's Long Term Super Good Cents Program for new multifamily units constructed in the utility's service area. The proposal was adopted in July, and the first program contract was signed in August 1992. Quoted in the program proposal were estimates for energy savings from space heat and lighting efficiencies. The estimates were made by the BPA, based on the NWPPC's regional plan and 1991 Model Conservation Standards. These estimates projected annual savings of 510 kWh per residential unit from thermal shell measures and 463 kWh from lighting measures.

When combined with projected savings from refrigerator add-on measures (120 kWh), energy savings were estimated as 1,380 kWh per residential unit in the ENERGY CONSERVATION ACCOMPLISHMENTS REPORT: 1977-1995. An additional 145 kWh per water heater has not been reported with the Long Term Super Good Cents program because, while coordinated by SGC field staff, the rebates have actually been processed through the Energy Efficient Water Heater Rebate program (EEWHRP).

Study Findings. Regarding market penetration, during 1993-1994 the LTSGC program completed interventions with 2,312 units while Seattle City Light connected new service panels for about 3,200 new units (in apartment buildings with four or more units). This number of new connections is in line with projections in the utility's short-range load forecast. The program penetration during these two years was thus about 72% of the new multifamily construction in Seattle City Light's service area, or 80% of the buildings with electric space heat. This penetration may be overstated, as some condominiums may be listed on utility connection reports as single-family dwellings, and others (in high-rises) as commercial construction; the comparison also excludes service connections for new extended-stay hotels. The program has served a few projects in each of these categories. For comparison on market penetration, an evaluation of PacifiCorp's Oregon LTSGC 1992-1994 program[9] found their multifamily new construction market penetration to be 63% on average, peaking in 1993 at 78%.

Two of the participant buildings had income guidelines for tenants, and therefore represent the program's influence on low-income (although not subsidized) projects. These were the two buildings with common laundry facilities, containing 288 units (about one-fourth of the units served). Energy savings in these two buildings were quite comparable with other buildings, as a percentage of baseline energy use. Readers interested in impacts on low-income housing may wish to review the Common Laundry Prototype.

This impact study of the Long Term Super Good Cents program has found significantly greater savings that more than double the BPA estimates. Compared to 510 kWh per unit originally projected for space heat savings, the Tier I shell measures as implemented by Seattle City Light in 1993-1994 saved 1,109 kWh (217%) on 1995 bills. And compared to 463 kWh per unit originally projected for lighting savings, the lighting measures implemented by Seattle City Light in 1993-1994 saved 1,271 kWh (275%) on 1995 bills.

The implication of this impact study is that actual savings during 1995, including refrigerator measures, are 2,500 kWh per residential unit where all measures are installed (Tier I shell, lighting, and refrigerators). From the perspective of building owners and tenants, 145 kWh per unit for water heater savings may be added to represent total savings on electric utility bills, yielding energy savings of 2,645 kWh per unit. These findings pertain to the 19 new construction projects studied, which were completed in 1993-1994.

Projections from Sample to Program. In point of fact, not all buildings receive the full array of measures. Appendix B contains four tables which project these findings for buildings where construction was completed in each year from 1993 through 1996. The assumption has been made that the study findings may be projected to the buildings disqualified from this study based upon atypical construction, occupancy, and metering characteristics. Units in motor inns and other buildings lacking in-unit laundries have been classified with common laundry buildings, due to the smaller average unit size and absence of appliance/space-heat interactions.

Four caveats apply to the following projections from the study findings.

First, extrapolation from the group studied to the full sampling frame of projects completed before 1995 incorporates some bias which has not been estimated. The buildings disqualified from the study do differ in occupancy patterns and some construction features.

Second, projects started (contracted) in 1994 through 1996 were not required to comply with provisions for bathroom lighting and refrigerator upgrades, due to changes in program specifications. (Federal standards for refrigerators were raised in 1994 to the level formerly required by the LTSGC program.) Adjustment for this mix has been made in the projects below.

Third, projects started (contracted) in 1995 and 1996 responded to new specifications requiring electronic line voltage (ELV) thermostats in the living room. Heat anticipator (2-3°F dead band) bimetal thermostats were previously specified throughout the residential unit. After 1994 the program continued to allow them in bedrooms. Under the baseline condition, non-participating builders typically installed less sensitive bimetal thermostats (4-7°F dead band) that are not heat anticipating.

Requiring ELV thermostats throughout the unit would be expected to boost tenant energy savings by another 250 kWh per unit over the heat anticipator thermostats implemented in 1992-1994 contracts. This adjustment has not been made in the following projections because it is not known by the evaluator what mix of thermostats was installed in projects completed from 1993 through 1996. Projects started in 1995-1996 also included a small amount of slab insulation and heat-pump water heaters.

Fourth, the savings are slightly overstated because they were estimated under conditions of full occupancy (an adjustment of about ±3%) and typical weather (another ±3% adjustment from 1995 actual weather). These adjustments would affect both the as-built and baseline conditions equally, however, so they may have little or no influence on the difference estimates of energy savings.

Energy Savings. Keeping these caveats in mind, what follow are simple projections from the study findings to buildings where construction was completed in each year from 1993 through 1996. (See Appendix B, Tables B-7 through B-10, for details.) The following calculations were made for energy savings from the program measures studied; excluded are savings from water heaters and from appliances installed as add-on measures (1993 completions) in buildings not receiving insulation. The unadjusted average of energy savings per residential unit, weighted across the prototypes, was: 2,472 kWh per unit in 1993 (99% of potential); 2,238 kWh in 1994 (90%); 2,313 kWh in 1995 (93%); and 2,500 kWh in 1996 (100%). The percent of potential savings indicates variations by year in the mix of measures installed. This percent was highest in 1993 and 1996 project starts, when all program measures were installed. (Appendix B also shows water heaters, in order to calculate complete electric bill savings from the perspective of tenants and owners.)

These average energy savings may be suitable for use in the Utility Load Forecast. However, in discussion with LTSGC program staff and re-design planners, it was observed that the Load Forecast may be double-counting participation and savings between the Energy Efficient Water Heater Program (EEWHRP) and the LTSGC program. This possibility should be investigated and any necessary corrective actions taken.

Bill Savings. According to the tables in Appendix B, the following calculations may be made of customer bill savings from all program measures installed, including water heaters and add-on only appliances. The tenants of buildings completed in each year saved the following amounts on 1996 electric bills: $50 per tenant unit from 1993 project completions; $69 from 1994 projects; $71 from 1995 projects; and $78 (in 1997) from 1996 projects. Meanwhile, owners of buildings completed in each year saved the following amounts on 1996 electric bills: $34 per unit from 1993 project completions; $45 from 1994 projects; $46 from 1995 projects; and $50 (in 1997) from 1996 projects. Since the energy savings per unit and 1996 rates have been held constant, these changes over time reflect variations in the mix of unit types between the two prototypes (in-unit appliances versus common laundry facility or no laundry facility at all).

A hypothetical mix of units with 75% In-unit laundries and 25% common laundries, where all measures were installed, would yield program savings to tenants of $75 per unit and to building owners of $47 per unit. Rounding this last amount to $50 for the sake of simplicity, the yield per average building of 60 units (as in the 1993-1994 program) would be $4,500 to tenants in the aggregate and $3,000 to the owner, for total building savings of $7,500 annually on electricity bills. This amount excludes bill savings from high-efficiency water heaters, which would be about $3 per tenant unit, or another $180 per building each year.

5.2.2 Shell Measure Incentive Structure

A key finding from this study is that the incentive structure should be revised in the multifamily new construction program.

Currently the SGC incentive structure for Tier I and Tier II shell measures is based on a flat rebate per residential unit. As this study has shown, units vary considerably in size while the savings are better normalized on the basis of envelope-enclosed floor area. If the incentive basis were revised to envelope-enclosed square footage, the result would a more equitable compensation to builders for energy savings acquired. Estimation of savings at the level of individual buildings would also improve (rather than relying on group averages). This would make it more feasible in future to follow on with projects to verify energy savings after some period of occupancy. This change would also position the utility well for any future shift to an energy service charge incentive structure, whereby building owners would be compensated for energy savings based on comparison of actual energy use to a building-specific baseline.

5.2.3 Shell Measure Specifications

According to program staff, a small but significant number of projects have dropped out of the program because the Tier I wall insulation requirements present a barrier to participation. Some of these projects have been designed for low-income tenancy. Builder concerns centered on the R-26 wall insulation requirement, which in practice calls for application of an R-5 exterior foam board, which is not always feasible. As this impact study demonstrated, actual energy savings from the shell measures were more than twice the savings estimated at program start-up. Since the program was determined to be cost-effective at the lower savings level, it would be reasonable to redesign program specifications to allow some projects to proceed with R-21 wall insulation. This could be done by recreating a Tier II level of participation in shell measures; or by allowing other trade-offs on a Wattsun simulation model of building heat loss. This added program flexibility may be helpful to builders of low-income projects as a cost-containment option. The goal would be to retain projects in the program and still gain significant insulation savings without foregoing the opportunity for savings from the windows, thermostat, lighting, and appliance measures.

While the LTSGC measure specifications from the Bonneville Power Administration allowed for air-to-air heat exchangers, Seattle's program did not implement this measure. A metering study[6] by the BPA and Tacoma City Light of the Model Conservation Standards found heat exchangers to be ineffective conservation measures. As operated by system controllers, the heat exchangers actually produced significant negative savings (i.e., energy use went up instead of down). The Seattle multifamily new construction program should continue to exclude this measure from its program specifications.

Another issue raised within the context of this study is the insulation requirement for floors. The R-value required for Insulation Above Post-Tension Slab is a Washington State and Seattle Energy Code issue not now addressed in the codes. Program staff and builders feel that R-30, required for Insulation Pinned Under Post-Tension Slab, is not an appropriate above-slab value for typical multifamily new construction in the City of Seattle. The under-slab specification of R-30 was originally written for structures designed with standard wood-framed flooring, which is more typical of single-family construction. The first story of multifamily building projects more commonly has a slab suspended on pillars above a parking garage or commercial ground floor. A value for Above PT Slab Insulation that is feasible, according to the findings of this study, would be R-15 or R-19, which SGC builders for the five participants in this category managed to achieve. As a matter of informal policy, it appears that the Department of Construction and Land Use has in practice been approving R-15 in this above-slab application (none of the non-participant buildings met the under-slab R-30 code in above-slab applications.) It may well be that these buildings meet code by a calculation of component performance. However, in terms of measure prescriptions, this is an area where the State and Seattle Codes might be revised to require new specifications.

5.2.4 Lighting Measures

Another key finding from this study is that common-area lighting measures have proved a major strength of the Seattle LTSGC program. Seattle City Light should build upon this strength to capture other lost opportunities, by addressing building codes, non-electric space heat construction, and alignment of products and procedures.

A specification for lighting watts per square foot is not now in the building code for residential multifamily new construction. This study of the SGC program has shown that significant improvements are possible from the current baseline lighting installed in non-participant buildings. This should become a Seattle Residential Energy Code issue. As shown in Table 6, the SGC projects demonstrated average lighting power densities of 0.28 watts per square foot in the common areas including residential parking garages (based on the total floor area of these spaces), and 0.02 watts for outside lighting (based on the total envelope-enclosed floor area). In the baseline condition, represented by nonparticipant buildings, the densities were 0.64 watts per square foot in the common areas and 0.02 outside.

Based on the data from which Table 7 was constructed, the average lighting power densities may be calculated separately for common areas and parking garages under the as-built condition. The common areas contained 25% of the affected space (134,700 square feet) but 61% of the lighting (93,500 watts). The parking garages associated with the tenant units contained 75% of the affected space (411,900 square feet) but 39% of the lighting (59,900 watts). Based only on the floor area affected by each lighting type, the power densities for participant buildings were 0.70 watts per square foot in the common areas and 0.15 watts per square foot in the parking garages. For comparison, in the baseline condition, nonparticipant buildings had densities of 2.31 watts per square foot in the common areas and 0.19 in the garages.

The impact of the SGC lighting provisions has thus been most marked in the common areas, reducing the lighting power density by two-thirds, from 2.31 down to 0.70 watts per square foot. It is in the common areas of multifamily buildings where the Seattle Energy Code could most profitably be revised. Seattle City Light should work with the city Department of Construction and Land Use (DCLU) to develop a lighting density level (in the ballpark of 1.0 watt per square foot), along with provisions for technical assistance to lighting designers of multifamily new construction projects.

The impact of the SGC provisions has been less profound in the parking garages, where the lighting power density was reduced from 0.19 in the baseline condition down to 0.15 watts per square foot in the as-built condition. It is reassuring to note that the LTSGC program concentrated primarily on the common areas rather than garages, because this minimized the potential free-ridership problem when the Non-Residential Energy Code (NREC) was revised in 1994. The 1994 NREC limits the lighting power allowance in covered parking, open parking, and outdoor areas of commercial buildings. Building codes consider the common areas of multifamily buildings as having residential use, along with outside lighting; however, the tenant parking garage is regarded as a commercial use.

The 1991 NREC allowed up to a maximum of 0.30 watts per square foot. The new 1994 NREC allowance of 0.20 watts per square foot (Section 1532) became effective April 1994. The LTSGC program has influenced lighting levels downward in parking garages compared to the baseline condition. One may argue that, to a small extent, the program has in effect been paying incentives to enforce the energy code. In the observation of LTSGC staff, however, the building community has yet to adapt design practices to the new code, which has not to date been strictly enforced. As it happens, the four nonparticipant buildings selected to establish the baseline for this SGC study had lighting power densities averaging 0.19 watts per square foot, which is within the NREC requirements. However, staff still see individual buildings with higher densities, and two of them were in fact included in the SGC participant group (the year of permit is not known and may have been before the 1991 revision).

The policy question revolves around whether this is a code adoption issue or a case of program free-ridership (receiving incentives to take actions that the customers would have done anyway). For comparison, Seattle City Light's Northwest Energy Code Program (implementing the Washington State Energy Code) paid incentives for four years to encourage builders to comply with the 1991 revision to the Seattle and State Energy Codes. Nonetheless, it is possible that some proportion between 0% and 21% of LTSGC participant buildings during 1994-1996 could be considered garage-lighting "free riders," based on the 1993-1994 proportion of lighting watts in unconditioned areas that were located in the parking garages associated with the tenant units [(0.19-0.15)/0.19 watts/sq.ft.]. The potential free-riders would represent between 0% and 8% of the total lighting wattage installed in LTSGC participant buildings (0%-5% of lighting in the non-participant buildings). This level of potential free-ridership does not significantly threaten projections of energy savings made from the 1993-1994 sample to the current and future program.

It would be best for Seattle's redesigned multifamily new construction program to discontinue incentives for lighting fixtures in parking garages, and join with the Department of Construction and Land Use in inspection-based enforcement of the new code. Since most participant and non-participant buildings in the 1993-1994 completion samples did meet the code, detailed surveys might be concentrated on buildings with high-pressure sodium (HPS) fixtures in the parking garage. Meanwhile, technical assistance for all builders should be concentrated on choosing the appropriate type of fluorescent lighting for low temperature environments. This is recommended because dissatisfaction with low-performing fluorescent lighting sometimes impels builders to select HPS for parking garages, leading to problems with excessive glare. High pressure sodium remains a suitable choice for some exterior applications when mounted properly and with automated controls.

This study found no savings from exterior outside lighting, because the watts per square foot were found to be identical in the baseline and as-built conditions. This argues for either discontinuing to offer incentives for outside fixtures, or changing the measure specifications to assure savings. A mitigating factor is that the Seattle SGC program was limited by the BPA on the number of fixtures that could be rebated per building. This limit was usually reached before exterior lighting was considered, so not all potential improvements were made. A third alternative for the program, then, would be to raise or eliminate the limit on number of fixtures that might be rebated, and revisit the As-Built watts per square foot at a later date to see if there has been an improvement over the 0.21 LPD baseline found in this study. High pressure sodium or compact fluorescent fixtures should be used wherever feasible for exterior lighting, including as replacements for exterior halogen lighting. Program staff should be encouraged to seek lighting savings in all common areas, as this is a very cost-effective measure (especially when life-cycle costs are included).

Significant opportunities are also being lost at present in new construction multifamily buildings that are heated with gas. The LTSGC program has demonstrated lighting measure that alone are responsible for acquiring energy savings of a magnitude that the BPA program was designed to capture from space heating in combination with lighting. Meanwhile, the Multifamily Common-Area Lighting program at Seattle City Light is offering retrofit measures to existing multifamily buildings, both gas and electric. The retrofit and new construction programs ought to be brought into alignment, offering common-area lighting measures to all multifamily buildings in Seattle, new and old, regardless of space heat fuel.

In addition, the Seattle City Light programs should coordinate lighting offerings with the Department of Housing and Human Services (DHHS), which conducts rehabilitation projects in existing multifamily buildings. The lighting requirements of these programs should also be coordinated with planning activities for the regional lighting fixture rebate program, to be sponsored by the Northwest Energy Efficiency Alliance (NEEA).

When collecting data for this impact study from program records, it became apparent that discrepancies exist in specifications and record keeping between the Multifamily Common-Area Lighting retrofit and the SGC new construction program, as well. Discussions with program staff led to consensus that the MF-CAL specifications and analysis worksheets provide more savings potential and a better basis of information for accountability and follow-on. For example, there is an opportunity to revise the kitchen lighting specification from T-12 to T-8. Staff in the multifamily new construction program should be encouraged to use the MF-CAL worksheets and place a printout in the building project file. A lighting operations and maintenance (O&M) tip sheet should be left with the building owner or developer, including information on how to get replacement lamps. Program specifications should be revised to be congruent across all multifamily programs.

5.2.5 Space Heat Thermostats

The program specifications were revised for new contracts written in 1995 and 1996, to require electronic line voltage (ELV) thermostats in the living room (bimetal heat anticipater thermostats still being allowed in bedrooms). This is an area where the equipment technology continues to improve. ELV thermostats are estimated to add another 250 kWh per year to energy savings from each tenant unit, beyond the savings from heat-anticipating bimetal thermostats, at a very low cost. The multifamily new construction program should move to requiring ELVTs throughout the residential units.

Program operators would be well advised to continue keeping abreast of changes in this technology with the help of a staff engineer, and increase specification levels to encourage early adoption of improved equipment. The staff engineer should also monitor improvements in the technology for in-unit wall heaters and baseboard heaters, which might lead to the introduction through this program of low-density baseboard heaters (that have three-fourths the wattage and added fire safety features). Program designers should consider creative alternatives to making improved thermostat equipment available to builders, such as bulk purchases that would improve access to the latest technology and minimize costs. Peninsula Power has taken a lead in this area by starting a bulk purchase program for 1997.

5.2.6 Window Glazing

High efficiency windows have clearly performed well for the SGC program, which could not have achieved such excellent space-heat results otherwise. However, insulated wall areas still reduce heat loss more than insulated windows, on a foot for foot basis. As a measure trade-off, program designers should consider the option for measures that “go beyond” the requirements, such as reduced glazing square footage to increase the insulated wall area, within building code limitations.

Windows are another measure where the technology continues to improve, with lower U-values becoming feasible every few years. It may be feasible soon to reduce the specification for the glazing heat-transfer coefficient from U-0.35 to U-0.33. The multifamily new construction program designers should continue to monitor technology improvements and move program targets to encourage early adoption.

The SGC program operators have attended to the issue of low solar heat-gain (SHG) glazing on south and west facing windows. This often recommended measure improves comfort and reduces air conditioning, sometimes making rooms with these exposures habitable during the summer when they otherwise would not be. Program designers should consider strengthening this recommendation to make low-SHG coefficient windows mandatory on west and south exposures.

5.2.7 Refrigerators, Laundry Appliances, and Hot Water Measures

The program discontinued requiring upgrades to high-efficiency refrigerators in 1994, when the Federal efficiency standards were raised to match LTSGC specifications. This measure, however, has the potential to save twice the amount of energy per unit than upgrades to kitchen and bathroom lighting. Designers for the multifamily new construction program should consider reinstating this measure with a more stringent efficiency target. One development to keep an eye on (especially for single occupancy, smaller units) is the design of new high-efficiency 14 cubic foot models by American manufacturers. One of these models is currently being purchased by a national consortium in bulk for public housing authority complexes. Future availability of high performing refrigerators in this class, at the same or lower cost than competing models, should encourage program designers to set a new refrigerator efficiency target for multifamily builders.

At the same time, program designers should look toward the new regional WashWise program and plan to implement provisions for upgrades to new higher-efficiency laundry appliances, such as the tumble-action (horizontal axis) washer and microwave dryer. The tumble action washer tested by the national THELMA research project had the special advantage of being very quiet, which would provide added benefits to residents of apartment units with in-unit laundries. Tumble action washers should also be considered for buildings with common laundries, because they provide other benefits as well, including reduced water and sewer flows.

While the incentive structure for shell measures may come to be calculated on a floor area basis, rebates for appliance add-on measures should continue to be calculated on a per appliance basis. With the discontinuation of the BPA's Energy Efficient Water Heater Rebate Program, rebates should be paid directly by the multifamily new construction program. Energy savings from water heaters should be attributed to this program in future, as well. A related issue is the installation of heat pump water heaters by some 1995 LTSGC program participants. These heat pumps should be monitored for performance and customer satisfaction. The multifamily new construction program designers should explore appropriate program or rebate options for heat pump water heaters in the future.

Another possible development for multifamily new construction is encouraging builders to install water sub-metering devices. This would encourage tenant conservation of water and reduce hot water usage. Here is an opportunity to bridge programs with the Seattle Water Department. Another development is the installation of heat pump water heaters in some buildings through the 1995 LTSGC program. The performance of this measure should be monitored, and a rebate option explored for the multifamily new construction program.

When collecting data for this impact study from program records, it became apparent that no records were being kept on high-efficiency showerheads and aerators installed in participating units. Program staff confirmed that they are not inspecting this measure. As a result, no credit may be assigned to the LTSGC program for energy or water savings from showerhead or aerator measures. Staff have been advised to begin conducting and recording these inspections in future. The program should ensure that these measures exceed the present Washington State Plumbing Code, by installing showerheads that perform at

2.0 gpm and faucet aerators that perform at 1.5 gpm. (fixtures may be stamped or rated at a higher level; selection should be based on laboratory or field performance).

5.2.8 Customer Information

The policy goal for the LTSGC program is to move the market toward more efficient construction practices. Market transformation of this nature was facilitated in two ways, by encouraging early adoption of new building practices and technologies (as did the Model Conservation Standards), and by creating market demand for energy-efficient apartments and condominiums. Early adoption incentives are offered to builders, while recognition and demand is promoted with building owners and tenants.

At present, SGC program operators promote recognition of SGC participation by presenting the owner with a certificate and plaque suitable for installation in the building's common area. Each tenant-unit thermostat is labeled with the SGC logo, and the building electric panel with information about construction efficiencies. The SGC program promotes recognition with brochures for the first new tenants, as well. However, as units change tenants over time and buildings are sold, recognition of building efficiencies may easily diminish.

This study provides program designers with information which can be shared with multifamily builders, owners, managers, and tenants: about program energy savings, bill savings, and the cost effectiveness of program measures. This information can be used to ensure interest and participation in the multifamily new construction program, in future. It can also be used to provide information on an ongoing basis to current residents and customers seeking energy-efficient housing.

Program designers should develop ways to underscore the value of improved energy efficiency in participating buildings through follow-on services. This type of service can provide building owners and tenants with ongoing information about energy bills and savings. Assistance with operations and maintenance (O&M) can ensure that the proper lamps are replaced in high-efficiency lighting fixtures. The Conservation Tracking System (CTS) can assist staff in providing follow-on services, through use of the Research and Targeting modules. This may become an important component of the program in future, as an opportunity to provide non-energy services to customers.

5.2.9 Cost Effectiveness

As shown in Table 2, the sampling frame for this study contains 2,289 residential units in 38 buildings averaging 60 units each. The study group likewise averaged 60 units per building. Incentives paid in 1992-1994 totaled $1,117,271; adjusted for inflation, incentives equaled $1,176,684 in 1995 dollars. The average incentive paid per unit, therefore, was $514 for lighting, shell, and refrigerator measures.

The buildings studied contained 1,308,099 square feet of floor area within the building envelope, of which about 87% is rentable within tenant units; the remainder consists of conditioned and unconditioned common areas. Extrapolating to all buildings completing the LTSGC program in 1992-1994, the program served 1,808,378 square feet of multifamily new construction. Dividing total incentives in those years by the floor area served yields an average cost of $0.65 per square foot of envelope-enclosed space, in 1995 dollars.

The administrative cost of the LTSGC program (staff salaries and expenses) during 1992-1994 was $367,991, which would be $386,025 in 1995 dollars. The average administrative cost per unit was $169.

To calculate the levelized cost of the 1992-1994 program, the following assumptions were made. The total utility cost per unit is $743, comprised of $514 for installed lighting, shell, and refrigerator measures plus $60 for a water heater rebate and $169 for LTSGC program administration. The cost to customers of LTSGC efficiency projects (costs beyond the baseline but not covered by the program incentive) are not known but are assumed to be about 20% of the incremental cost. The annual energy savings per unit are

2,645 kWh from lighting, shell, refrigerator, and water heater measures combined. The weighted lifetime of these measures is 33 years (see Section 5.3.1).

The Utility's levelized cost is calculated as program costs (incentive plus administration) divided by the present value of lifetime energy savings (which are discounted by three percent per year at the utility's borrowing rate). The Participant's cost is based on efficiency project incremental expenses that exceed the expense of the baseline plan and are not covered by the program incentive. The Service Area cost includes both Utility and Participant costs.

To judge cost-effectiveness, the levelized costs are compared to the avoided cost of buying energy in other markets. During 1996, spot market and power prices have been in the neighborhood of $0.015 to $0.020 per kWh (or 15 to 20 mills). In the longer term, low-cost gas and combined-cycle combustion turbines will likely drive the average avoided costs to below $0.032 (32 mills) per kWh, in 1996 dollars.

The energy savings in 1995, from the 1992-1994 LTSGC program as a whole, were 6,054 mWh, providing 0.7 megawatts of average load reduction. The present value of these savings was nearly 55,000 kWh per residential unit over the life of the measures, or 125,725 megawatt-hours (mWh) for the program overall.

Based on the findings of this study, the LTSGC 1992-1994 program acquired energy savings in 1995 at the cost of 14 mills per kWh to the Utility. If one assumes that the program incentive has covered 80% of the incremental cost of prescribed measures, then the cost to Participants was 3 mills per kWh and the Service Area cost was 17 mills per kWh. A sensitivity analysis of this service area levelized cost ranges from 15 mills (at a 90% incentive coverage rate) to 23 mills (at 70% coverage). These costs are very competitive with the costs of energy alternatives, whether internally (Seattle City Light generation) or from external markets.

5.2.10 Study Methodology

In the first run at calibrating the DOE2.1 simulation model to 1995 energy use, the model came within ±5% of actual annual energy use. With minor adjustments to input parameters, the model matched actual annual energy consumption within ±1%. This degree of accuracy in projecting energy use by means of an engineering model is phenomenal. The credit for this excellent performance of the model goes to three sources.

First, the Seattle LTSGC program operators deserve credit for keeping accurate records of measures installed, and diligently inspecting work in progress to ensure that measures perform up to potential.

Second, the study project team (at Seattle City Light and SBW Consulting) monitored every detail of the measure specifications and definition of the as-built and baseline conditions. Seattle staff worked closely with the consultant team, and provided clean and accurate energy consumption records. This ensured that the best data were used to build and calibrate the model.

And third, the MCS new construction Multifamily Metering Study[6] proved a gold mine of reliable parameters for typical infiltration, internal loads, thermostat setpoints, and hourly load curves. This SGC study demonstrates the value of the MCS evaluation work sponsored by the BPA and Tacoma City Light. The Seattle SGC project team has no qualms about recommending this study methodology using DOE-2 simulations, and the multifamily MCS study as a source of parameters, to any northwest regional utility seeking to measure loads or impacts in multifamily new construction buildings.

5.3 RECOMMENDATIONS

Based upon the consultant study, discussions with program staff and management, and subsequent analysis, eight categories of recommendations for product and service management are stated below. These recommendations are intended to lead to improvements in *Built Smart,* the redesigned program for multifamily new construction.

5.3.1 Accountability Reports and Load Forecast

Revise estimates of annual energy savings in the EMSD Energy Conservation Accomplishments report, and adopt revised estimates in the Seattle City Light Load Forecast. For LTSGC projects completed in 1992-1996, use the following figures for unit energy savings and measure lifetimes (where SqFt is envelope-enclosed floor area).

Provision	kWh per SqFt	kWh per unit	Lifetime in years	
Tier I Shell	1.40	1,110	50	
Lighting: In Unit	0.15	60	20	
Lighting: Common Area	1.53	1,210	20	
Thermostats*	—	—	15	*(250 kWh for ELVT)
Refrigerators	—	120	20	
Water Heaters**	—	145	12	**(beginning 1997)
Showerheads	—	—	15	

Use the following assumptions about participant building characteristics in 1993-1994.

Percent of Units with In-Unit Laundry	75	%
Percent of Units with Common Laundry	25	%
Average Size of Building	60	units
Average Rentable Size of Unit	688	square feet
Average Envelope-Enclosed Floor Area per Unit	790	square feet
Average Conditioned Floor Area per Building	47,200	square feet
Weighted Lifetime of Measures	33	years

Assume that estimation errors are due mainly to occupancy rate (about ±3% per year); to actual weather year versus typical meteorological year (about ±3% per year); and to calibration of the model itself with actual energy use (about ±1%).

Ensure that the Energy Load Forecast does not double-count participation and savings from water heaters between the EEWHRP and LTSGC programs.

5.3.2 Shell Measure Incentive Structure

The most important of recommendations from this study regards the incentive structure:

Revise the multifamily new construction program to improve the incentive structure for shell measures. Calculate incentives based upon the envelope-enclosed square footage, rather than upon number of residential units.

5.3.3 Shell Measure Specifications

Implement revised Tier II shell specifications in the multifamily new construction program to capture space-heat efficiency opportunities in buildings with R-21 wall insulation.

- Allow R-21 wall insulation in some projects; or,
- Encourage measure trade-offs on a Wattsun (or equivalent) simulation model of building heat loss.

Continue to have a staff engineer monitor changes in insulation technology and the market availability of new products.

Discuss with the Department of Construction and Land Use a potential revision to the Seattle Energy Code regarding insulation above post-tension slabs in multifamily new construction, to establish a specification of R-15.

5.3.4 Lighting Measure

Second in importance among recommendations from this study is the excellent performance of common-area lighting measures, and future opportunities to build on the strength of this measure:

Revise the multifamily new construction program to capture lighting-efficiency opportunities in buildings with gas space heat as well as those with electric space heat.

Revise lighting specifications to establish congruency between the Multifamily Common Area Lighting retrofit program and the multifamily new construction efficiency program.

Establish common record-keeping systems, and file a printout of the analysis worksheet in the program building project file.

Revise the kitchen lighting specification from T-12 to T-8.

Provide the builder or owner with a lighting operations and maintenance (O&M) tip sheet including information on acquiring replacement lamps.

Coordinate lighting programs for existing and new construction multifamily buildings with initiatives by the Seattle Department of Housing and Human Services (DHHS low-income rehabilitation projects) and the Northwest Energy Efficiency Alliance (NEEA regional lighting fixture rebates).

Require upgrades to lighting in all common areas, including outside exterior-lighting. Raise or eliminate limits on the number of fixtures that may be rebated. Monitor the outside/exterior lighting power density in future projects. Re-evaluate the impact of this program provision in one year and determine whether to continue the provision, change the measure specifications to assure savings, or discontinue to offer incentives for outside fixtures.

Continue to have a staff engineer monitor changes in lighting technology and the market availability of new products.

Discontinue incentives for lighting fixtures in parking garages, and join with the Seattle Department of Construction and Land Use (DCLU) in inspection-based enforcement of the 1994 Non-Residential Energy Code lighting power allowance (0.20 watts per square foot maximum for parking garages). Encourage the DCLU to provide technical assistance and training to builders regarding the application in parking garages of fluorescent lighting for low-temperature environments. Discourage application of high-pressure sodium lighting in garages and halogen lighting on building exteriors.

Discuss with the Department of Construction and Land Use a potential new provision in the Seattle Residential Energy Code regarding an lighting power allowance (watts per square foot) in common areas of multifamily new construction. Work the the DCLU to develop a lighting density level for commons areas (hallways, stairwells, lobbies, etc.) in the range of 1.0 watts per square foot, along with provisions for technical assistance to lighting designers of multifamily new construction projects.

5.3.5 Space Heat Thermostats

Implement electronic line voltage thermostats throughout the residential unit, in the multifamily new construction program. Continue to have a staff engineer monitor changes in thermostat technology and the market availability of new products, and keep program specifications abreast of these improvements.

Monitor improvements in wall heater and baseboard heater technologies (e.g., low-density baseboards), and assess the potential of these measures for the multifamily new construction program.

5.3.6 Window Glazing

Require a lower solar heat-gain coefficient on west and south glazing than on east and north glazing in the multifamily new construction program specifications.

Continue to have a staff engineer monitor changes in lighting technology and the market availability of new products. Revise the required glazing heat-transfer coefficient from $U<0.35$ to $U<0.33$ by the year 1999.

Consider options for measure trade-offs that include reduced glazing square footage and determine the feasibility, within building code limitations, for future revised program provisions.

5.3.7 Refrigerators, Laundry Appliances, and Hot Water Measures

Continue to have a staff engineer monitor changes in appliance technology and the market availability of new products, and keep program specifications abreast of these improvements.

Reinstate the upgrade provision for high-efficiency refrigerators in the multifamily new construction program with new efficiency targets.

Add an upgrade provision to the program for high-efficiency laundry appliances.

Continue to promote high-efficiency appliances through early adoption incentives, with rebates calculated on a per-appliance basis.

Coordinate with federal appliance code officials on increased efficiency standards for appliances, and be available to the U.S. Department of Energy to provide a test site for new appliance technologies.

Pay high-efficiency water heater rebates through the multifamily new construction program and attribute savings to this program in future.

Monitor the performance of heat-pump water heaters in the 1995 program and explore a program or rebate option for this measure.

Encourage builders to install water sub-metering devices, in coordination with the Seattle Water Department.

Record inspections of showerhead and aerator installations in program building project file. Install showerheads that perform at 2.0 gpm and faucet aerators that perform at 1.5 gpm, to ensure program savings.

5.3.8 Customer Information

Inform multifamily builders, owners, managers, and tenants about the energy savings, bill savings, and cost effectiveness of participation in the multifamily new construction program. In the typical weather year, and at 1996 electric rates, Seattle City Light customers may expect to save the following amounts on bills from the shell, lighting, and refrigerator measures combined.

- Tenants $75 per unit (plus $3 per water heater)
- Owner $50 per unit

Since the average building receiving Tier I shell measures in 1995-1996 has 36 units, current customers in the aggregate may expect to save the following amounts on total bills from the shell, lighting, and refrigerator (1993-1994 program participants, averaging 60 units, saved a total of $7,500 per building).

- Tenants $2,700 per building (plus $108 from water heaters)
- Owner $1,800 per building
- Total $4,500 per building

Other, more specific marketing information for customers may be derived from the tables and analysis found in this report.

Develop ways to underscore the value of improved energy efficiency in multifamily new construction buildings through follow-on services to program participants, and through marketing activities.

Use the Conservation Tracking System (research capabilities) to assist in providing follow-on services. Follow-on services may include assistance with lighting operations and maintenance (O&M), and ongoing tracking of savings performance via bill comparisons for participating buildings.

6.0 REFERENCES

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3. Personal communication, Washington State Energy Office Energy Ideas Clearinghouse, Olympia, Washington, May, 1995.

4. Gilmore Research Group, "Survey of Participants In Puget Power's Retail Compact Fluorescent Lighting Program," Seattle, Washington, September, 1992.

5 Kelsey, K. and Richardson, V., "1991 Residential Appliance Saturation Survey- A Profile of the Residential Lighting Load in Northern California," PROCEEDINGS OF THE 1992 SUMMER STUDY ON ENERGY EFFICIENCY IN BUILDINGS, American Council for an Energy Efficient Economy (ACEEE), August 1992.

6. SBW Consulting, Inc., MULTIFAMILY METERING STUDY- IMPACT EVALUATION OF THE MODEL CONSERVATION STANDARDS, for the Bonneville Power Administration and Tacoma Public Utilities, Bellevue, Washington, April, 1994.

7. Seattle City Light, "Electrical Rates & Provisions, Ordinance 117490," Seattle, Washington, January 1995.

8. Cost Regional Advisory Group, "Costs of New Residential Conservation Measures in the Pacific Northwest," Washington State Energy Office, Olympia, Washington, September, 1995.

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APPENDIX A:

DATA COLLECTION FORMS & PROCEDURES

SGC MULTIFAMILY BUILDING DATA

A.1 CHARACTERISTICS SUMMARY FORM

This form was used to summarize building characteristics pertinent to Super Good Cents Tier I and Add-on Lighting features. Both LTSGC participant and non-participant baseline characteristics are summarized on the form. One form is was completed for each building in the study.

A.1.1 Page Header Information

First, complete the page header information as follows:

Building Number. Enter the building number for which this page of data applies.

Building Name. Enter the name of the building. This information can be obtained from the characteristics data spreadsheet.

Date. Enter the date.

Initials. Enter your initials.

A.1.2 Characteristics Information

Next, complete the remaining items as follows:

Building Address. Enter the building address from the characteristics data spreadsheet.

Number of Apartments. Enter the number of apartments in the building(s).

Tier I Rebate. Circle yes if the building received a Tier I rebate, no if it did not.

Net Framed Wall U-value/Components. Enter the wall U-value and a description of the component wall layers. Obtain U-values from Table 5-1 in the LTSGC program notebook.

Net Wall Nominal Insulation R-value. Enter the Nominal insulation R-value for the framed wall.

Underground Wall U-value/Components. Enter the underground wall U-value and a description of the component wall layers. Obtain U-values from Table 2-1 in the LTSGC program notebook.

Underground Nominal Insulation R-value. Enter the Nominal insulation R-value for the underground wall.

Average Window U-value. Enter the average window U-value from the project file for Tier I participants. Calculate for non-participants or obtain from the plans, if available. Default window U-values can be obtained from Table 7-1 in the LTSGC program notebook.

Total Building Window Area. Enter the total window area for the building. For Tier I participants, this information can be obtained from the LTSGC project file.

Attic Ceiling U-value/Components. Enter the attic ceiling U-value and a description of the component ceiling layers. Obtain U-values from Table 8-1 in the LTSGC program notebook.

Attic Ceiling Nominal R-value. Enter the Nominal insulation R-value for the attic ceiling.

Vaulted Ceiling U-value/Components. Enter the vaulted ceiling U-value and a description of the component ceiling layers. Obtain U-values from Table 8-1 in the LTSGC program notebook.

Vaulted Ceiling Nominal R-value. Enter the Nominal insulation R-value for the vaulted ceiling.

Floor Type (S/PT/F/PTP). Enter **S** for slab-on-grade, **PT** for post tension concrete slab, (insulated above slab), **F** for wood framed floor or **PTP** for post tension concrete slab, (insulation pinned below slab).

Slab Floor F-value/Description. Enter the floor F-value for floor type **S** and a description of floor construction. Obtain F-values from Table 3-1 in the LTSGC notebook.

Slab Floor Nominal R-value. Enter the Nominal insulation R-value for floor type **S**.

Floor U-value/Components. Enter the floor U-value and a description of the component floor layers for floor types **PT**, F and **PTP**. Obtain U-values from Tables 4-1 or 4-2 in the LTSGC program notebook. For floor type **PTP** calculate the u-value with a 50% degrade of the insulation R-value.

Floor Nominal R-value. Enter the Nominal insulation R-value for floor types **PT**, F and **PTP**.

Common Space (Conditioned):

> **Floor Area (ft^2).** Enter the total conditioned common space floor area in square feet.
>
> **Lighting Power Density.** Calculate and enter the conditioned common space LPD.
>
> **Rebated LPD.** Calculate and enter the conditioned common space LPD that was rebated.

Common Space (Unconditioned):

> **Floor Area (ft^2).** Enter the total unconditioned common space floor area.
>
> **Lighting Power Density.** Calculate and enter the unconditioned common space LPD.
>
> **Rebated LPD.** Calculate and enter the unconditioned common space LPD that was rebated.

Kitchen/Bathroom: (List both separately)

> **Floor Area (ft^2).** Enter the average apartment kitchen and bathroom floor area.
>
> **Lighting Power Density.** Calculate and enter the average kitchen/bathroom LPD.
>
> **Rebated LPD.** Circle yes if the building received an interior lighting rebate, no if it did not.

Total Exterior Lighting Watts. Enter the total exterior lighting watts for the building.

Rebated Watts. Enter the total exterior lighting fixture wattage that was rebated for the building. Do not include common space lighting accounted for above.

Total Building Floor Area. Enter the total building floor area to include all apartments and common area.

Window to Floor Area Ratio. Calculate and enter the ratio of total window area to floor area.

Figure A-1

SGC Multifamily Building Characteristics Summary

Bldg Number	Building Name	Date:	Initials:

Building Address		
Number of Apartments		Tier I Rebate: Yes No
Net framed wall U-value / components		
Net wall nominal insulation R-value		
Underground wall U-value / components		
Underground wall nominal R-value		
Average Window U-value		
Total Building Window Area (ft²)		
Attic Ceiling U-value / components		
Attic Ceiling nominal R-value		
Vaulted Ceiling U-value / components		
Vaulted Ceiling nominal R-value		
Floor Type (S/PT/F/PTP)		
Slab Floor F-value / description		
Slab Floor nominal R-value		
Floor U-value / components		
Floor nominal R-value		
Common space (conditioned):		
Floor Area (ft²)		
Lighting power density		Rebated LPD:
Common space (unconditioned):		
Floor Area (ft²)		
Lighting power density		Rebated LPD:
Kitchen / Bathroom:		
Floor Area (ft²)		
Lighting power density		Rebated: Yes No
Total Exterior Lighting Watts		Rebated Watts:
Total Building Floor Area (ft²)		
Window to Floor Area Ratio		

Comments: ______________________________

____

____

A.2 ZONE DESCRIPTION FORM

This form is used to document building characteristics at the apartment or thermal zone level. This data will be summarized to define the DOE2 model prototype zones necessary to simulate building energy consumption.

A.2.1 Page Header Information

First, complete the page header information as follows:

Building Number. Enter the building number for which this page of data applies.

Building Name. Enter the name of the building. This information can be obtained from the characteristics data spreadsheet.

Initials. Enter your initials.

Date. Enter the date.

Page ___ of ___. Enter the page sequence for this building.

A.2.2 Zone Type Information

Next, complete a column for each space type in the building as follows:

Apartment Number(s) or Common Space. Enter the apartment numbers or common space that the data represents. If there are more apartment numbers than will fit in the space provided, make a footnote and continue the list in the comments section below.

IMPORTANT NOTE: The following items must be entered for EACH apartment or common space. If multiple apartments are listed, DO NOT enter to total of all apartments.

Conditioned Space (Y/N). Enter **N** for common space that is unconditioned. Enter **Y** for conditioned (heated) common space and all apartments.

Number of Bedrooms. Enter the number of bedrooms in the apartment. Enter zero for common space.

Floor Area (ft^2). Enter the floor area, in square feet, of the space.

Number 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 include 4 possible side walls, 1 ceiling, and 1 floor. If a surface is only partially exterior, fractional values may be entered.

Washer/Dryer (Y/N). Enter **Y** if there is a clothes washer/dryer set inside the space, **N** if not.

Window Area (ft^2). Enter the total exterior window area, in square feet. Include sliding glass doors and skylights.

Window U-value. Enter the window U-value from the LTSGC Multifamily Building Characteristics Summary form.

Net Wall Area (ft^2). Enter the exterior insulated net opaque wall area for the space.

Net Wall U-Value. Enter the net wall U-value from the LTSGC Multifamily Building Characteristics Summary form.

Below Grade Wall Area (ft^2). Enter the below grade exterior wall area, in square feet for the space.

Below Grade Wall U-Value. Enter the below grade wall U-value from the LTSGC Multifamily Building Characteristics Summary form.

Ceiling Type (A/V/N). Enter **A** if there is an insulated attic or a **V** if there is an insulated vaulted or flat roof ceiling above the space. Enter **N** if there is conditioned space above.

Ceiling Area (ft^2). Enter the insulated ceiling/roof area exposed to the exterior for the space.

Ceiling U-Value. Enter the ceiling U-value from the LTSGC Multifamily Building Characteristics Summary form.

Floor Type (S/PT/F/N/PTP). Enter **S** for slab-on-grade, **PT** for post tension concrete slab insulated above, **F** for wood framed, **N** where there is conditioned space below such as another apartment and **PTP** for post tension concrete slab insulated below.

Insulated Floor Area. Enter the insulated floor area, in square feet, for Floor Types **PT**, **F** or **PTP**. Enter the exterior perimeter floor length in feet for Floor Type **S**. Enter zero for Floor Type **N**.

Insulated Floor U-value. Enter the floor U-value from the LTSGC Multifamily Building Characteristics Summary form.

Interior Wall Area. Enter the wall area between the conditioned space and adjacent unconditioned common space.

Interior wall U-Value. Enter the interior wall U-value from the LTSGC Multifamily Building Characteristics Summary form.

Door Area (ft^2). Enter the exterior door area in square feet.

Door U-value. Enter the door U-value from the LTSGC Multifamily Building Characteristics Summary form.

Lighting Add-on (Y/N). Enter **Y** if lighting add-on fixtures were rebated or enter **N** if not.

Lighting Add-on Floor area. Enter the floor area associated with the lighting add-on. For apartments, this is the floor area of the kitchen and bathroom. For common area, the entire floor area would be included.

Lighting Add-on Watts. Enter the total lighting fixture wattage associated with the lighting add-on floor area.

Comments. Enter any additional information as needed.

Figure A-2

SGC Multifamily Zone Description

Building Number	Building Name	Date	Initials	Page of
Common Space or Apartment Number(s):				
Conditioned Space (Y/N)				
# of Bedrooms				
Floor Area (ft²)				
# of Exterior Surfaces				
Washer/Dryer (Y/N)				
Window Area (ft²)				
Window U-value				
Net Wall Area (ft²)				
Net Wall U-value				
Below Grade Wall Area (ft²)				
Below Grade U-value				
Ceiling Type (A/V/N)				
Ceiling Area (ft²)				
Ceiling U-value				
Floor Type (S/PT/F/N/PTP)				
Insulated Floor Area (ft²)				
Insulated Floor U-value				
Interior Wall Area (ft²)				
Interior Wall U-value				
Door Area (ft²)				
Door U-value				
Lighting Add-on (Y/N)				
Lighting Add-on Floor Area (ft²)				
Lighting Add-on Watts				

Comments:

APPENDIX B:

ESTIMATION OF ANNUALIZED ENERGY & BILL SAVINGS

Table B.1. Units by Participation Status of Sample Building

Case Number	Tenant Units	SGC Program		Tier I Shell		Kitchen Lighting		Bathroom Lighting		Common Area		Outside Lighting	
		P	NP	P	NP	P	NP	P	NP	P	NP	P	NP
1*	245	245	—	245	—	—	245	—	245	245	—	—	245
2	100	100	—	100	—	100	—	100	—	100	—	100	—
3	20	20	—	20	—	—	20	—	20	20	—	20	—
4	200	200	—	200	—	200	—	200	—	200	—	200	—
5	25	25	—	25	—	—	25	—	25	25	—	—	25
6	64	64	—	64	—	64	—	64	—	64	—	—	64
7*	7	7	—	7	—	—	—	—	—	7	—	7	—
8	147	147	—	147	—	—	147	—	147	147	—	147	—
9	183	183	—	183	—	183	—	—	183	183	—	183	—
10	26	26	—	26	—	26	—	—	26	26	—	26	—
11	44	44	—	44	—	—	44	—	44	44	—	44	—
12	14	14	—	14	—	14	—	14	—	14	—	14	—
13	33	33	—	33	—	33	—	—	33	33	—	33	—
14	66	66	—	66	—	66	—	66	—	66	—	—	66
15	40	40	—	40	—	—	40	—	40	40	—	40	—
16*	22	22	—	22	—	22	—	—	22	22	—	22	—
17	12	12	—	12	—	12	—	—	12	12	—	—	12
18	16	16	—	16	—	16	—	—	16	16	—	16	—
19	50	50	—	50	—	50	—	—	50	50	—	50	—
20	6	6	—	—	6	—	6	—	6	6	—	6	—
21	76	76	—	—	76	—	76	—	76	76	—	76	—
22	16	16	—	—	16	—	—	—	—	—	—	—	—
23	18	18	—	—	18	—	18	—	18	18	—	18	—
24	15	15	—	—	15	—	15	—	15	15	—	15	—
25	41	41	—	—	41	—	41	—	41	41	—	41	—
26	60	60	—	—	60	—	—	—	—	—	—	—	—
27	14	—	14	—	14	—	—	—	—	—	—	—	—
28	33	—	33	—	33	—	—	—	—	—	—	—	—
29	51	—	51	—	51	—	—	—	—	—	—	—	—
30*	21	—	21	—	21	—	—	—	—	—	—	—	—
31	9	—	9	—	9	—	—	—	—	—	—	—	—
32	24	—	24	—	24	—	—	—	—	—	—	—	—
33	70	—	70	—	70	—	—	—	—	—	—	—	—
34	9	—	9	—	9	—	—	—	—	—	—	—	—
35	96	—	96	—	—	—	96	—	—	—	96	—	—
36**	102	—	102	—	—	—	102	—	102	—	—	—	—
37	16	—	16	—	—	—	16	—	16	—	16	—	—
38	82	—	82	—	—	—	82	—	82	—	82	—	—
39	20	—	20	—	—	—	20	—	20	—	20	—	—
Total													
Projects	39	26	13	19	15	12	16	5	22	24	4	19	5
Buildings	50	29	21	22	16	12	24	5	31	27	4	21	6
Units	2,093	1,546	547	1,314	463	786	993	444	1,239	1,470	214	1,058	412

* Notes. Projects with 2 buildings: Cases 1, 7, 16, 30. Project with 8 buildings: Case 36.

— = No data available or used

Table B.2. Participant Building Characteristics

Case Number	Tenant Units	Parking Space	Common Area	Lighting Measure Space	Rentable Tenant Area	Envelope Enclosed Area	Total Project Space	Rentable Area per Unit
		SqFt	SqFt	Pkg+ CA SqFt	SqFt	CA+Rent SqFt	Pkg+CA+ Rent SqFt	Rent SqFt / Unit
1*	245	70,478	34,533	105,011	182,772	217,305	287,783	746
2**	100	41,896	8,250	50,146	60,625	68,875	110,771	606
3	20	23,206	3,159	26,365	13,815	16,974	40,180	691
4	200	23,432	13,010	36,442	82,420	95,430	118,862	412
5	25	19,440	4,072	23,512	21,037	25,109	44,549	841
6	64	28,219	11,159	39,378	53,074	64,233	92,452	829
7*	7	2,628	0	2,628	8,148	8,148	10,776	1,164
8	147	50,870	8,043	58,913	107,795	115,838	166,708	733
9	183	39,839	24,240	64,079	128,494	152,734	192,573	702
10	26	14,655	3,176	17,831	23,156	26,332	40,987	891
11	44	17,880	4,156	22,036	31,712	35,868	53,748	721
12	14	6,770	900	7,670	10,816	11,716	18,486	773
13	33	13,650	2,940	16,590	21,455	24,395	38,045	650
14	66	21,173	4,230	25,403	48,755	52,985	74,158	739
15	40	15,265	4,065	19,330	29,436	33,501	48,766	736
16*	22	0	1,105	1,105	16,724	17,829	17,829	760
17	12	4,409	1,707	6,116	13,170	14,877	19,286	1,098
18	16	5,240	1,061	6,301	14,354	15,415	20,655	897
19	50	13,890	4,565	18,455	35,970	40,535	54,425	719
P Total	1,314	412,940	134,371	547,311	903,728	1,038,099	1,451,039	
Project Avg	69	21,734	7,072	28,806	47,565	54,637	76,370	
Building Avg	60	18,770	6,108	24,878	41,079	47,186	65,956	
Unit Avg		314	102	417	688	790	1,104	
Total In-Unit Laundry	**1,026**	347,612	113,111	460,723	775,795	**888,906**	**1,236,518**	
Project Avg	60	20,448	6,654	27,101	45,635	52,289	72,736	
Building Avg	51	17,381	5,656	23,036	38,790	44,445	61,826	
Unit Avg		339	110	449	**756**	866	1,205	
Total Comn Laundry	**288**	65,328	21,260	86,588	127,933	**149,193**	**214,521**	
Project Avg	144	32,664	10,630	43,294	63,967	74,597	107,261	
Building Avg	144	32,664	10,630	43,294	63,967	74,597	107,261	
Unit Avg		227	74	301	**444**	518	745	

* Notes. Projects with 2 buildings: Cases 1, 7 and 16.

Participants with common laundries: Cases 2 (split) and 4.

** Case 2:

** Common L.	88	41,896	8,250	50,146	45,513	53,763	95,659	517
** In-unit L.	12	0	0	0	15,112	15,112	15,112	1,259

Table B.3. Non-participant Building Characteristics

Case Number	Tenant Units	Parking Space	Common Area	Lighting Measure Space	Rentable Tenant Area	Envelope Enclosed Area	Total Project Space	Rentable Area per Unit
		SqFt	SqFt	Pkg+ CA SqFt	SqFt	CA+Rent SqFt	Pkg+CA+ Rent SqFt	Rent SqFt / Unit
20	6	3,290	735	4,025	5,616	6,351	9,641	936
21	76	36,809	7,728	44,537	57,837	65,565	102,374	761
22	16	8,336	1,218	9,554	14,620	15,838	24,174	914
23	18	7,368	3,188	10,556	14,413	17,601	24,969	801
24	15	0	900	900	13,654	14,554	14,554	910
25	41	15,265	4,065	19,330	29,436	33,501	48,766	718
26	60	26,568	6,350	32,918	32,695	39,045	65,613	545
27	14	5,625	2,485	8,110	11,179	13,664	19,289	799
28	33	12,265	0	12,265	25,851	25,851	38,116	783
29	51	690	8,985	9,675	26,148	35,133	35,823	513
30*	21	2,418	1,189	3,607	15,640	16,829	19,247	745
31	9	2,294	1,392	3,686	6,208	7,600	9,894	690
32	24	2,550	6,032	8,582	12,432	18,464	21,014	518
33	70	22,192	4,034	26,226	52,230	56,264	78,456	746
34	9	1,563	863	2,426	7,332	8,195	9,758	815
35	96	33,250	6,053	39,303	61,282	67,335	100,585	638
36*	102	0	0	0	89,760	89,760	89,760	880
37	16	5,625	1,386	7,011	24,600	25,986	31,611	1,538
38	82	31,864	8,059	39,923	41,941	50,000	81,864	511
39	20	7,820	2,395	10,215	21,138	23,533	31,353	1,057
NP Total	779	225,792	67,057	292,849	564,012	631,069	856,861	
Project Avg	39	11,290	3,353	14,642	28,201	31,553	42,843	
Building Avg	28	8,064	2,395	10,459	20,143	22,538	30,602	
Unit Avg		290	86	376	724	810	1,100	

* Notes. Project with 2 buildings: 30. Project with 8 buildings: Case 36.

Table B.4. Calculation of Energy Savings by Rate Period

			Shell kWh Savings		Kit/Bath Ltg Savings*		Common Ltg Savings		Total
Case No.	Units	Total Building Floor Area SqFt	Summer @ kWh/SqFt 0.58 In-Unit L 0.49 Comn L	Winter @ kWh/SqFt 0.85 In-Unit L 0.76 Comn L	Summer @ kWh/SqFt 0.00 In-Unit L 0.00 Comn L	Winter @ kWh/SqFt 0.15 In-Unit L 0.13 Comn L	Summer @ kWh/SqFt 0.45 In-Unit L 0.51 Comn L	Winter @ kWh/SqFt 1.05 In-Unit L 1.20 Comn L	Tier I + Kit/Bath+ Comn Ltg kWh Saved
2**	88	53,763	26,344	40,860	0	6,989	27,419	64,516	166,128
4**	200	95,430	46,761	72,527	0	12,406	48,669	114,516	294,879
1	245	217,305	126,037	184,709	0	0	97,787	228,170	636,704
2	12	15,112	8,765	12,845	0	2,284	6,800	15,868	46,562
3	20	16,974	9,845	14,428	0	0	7,638	17,823	49,734
5	25	25,109	14,563	21,343	0	0	11,299	26,364	73,569
6	64	64,233	37,255	54,598	0	9,708	28,905	67,445	197,911
7	7	8,148	4,726	6,926	0	0	3,667	8,555	23,874
8	147	115,838	67,186	98,462	0	0	52,127	121,630	339,405
9	183	152,734	88,586	129,824	0	23,084	68,730	160,371	470,595
10	26	26,332	15,273	22,382	0	3,980	11,849	27,649	81,133
11	44	35,868	20,803	30,488	0	0	16,141	37,661	105,093
12	14	11,716	6,795	9,959	0	1,771	5,272	12,302	36,099
13	33	24,395	14,149	20,736	0	0	10,978	25,615	71,477
14	66	52,985	30,731	45,037	0	8,008	23,843	55,634	163,254
15	40	33,501	19,431	28,476	0	0	15,075	35,176	98,158
16	22	17,829	10,341	15,155	0	2,695	8,023	18,720	54,934
17	12	14,877	8,629	12,645	0	2,249	6,695	15,621	45,838
18	16	15,415	8,941	13,103	0	2,330	6,937	16,186	47,496
19	50	40,535	23,510	34,455	0	6,126	18,241	42,562	124,894
	Total	Total	Subtotal	Subtotal	Subtotal	Subtotal	Subtotal	Subtotal	Total
****Common Laundry**	288	149,193	73,105	113,387	0	19,395	76,088	179,032	461,006
Unit Avg			254	394	0	67	264	622	1,601
In-Unit Laundry	1,026	888,906	515,565	755,570	0	62,235	400,008	933,351	2,666,729
Unit Avg			503	736	0	61	390	910	2,599
Total	1,314	1,038,099	588,670	868,957	0	81,630	476,096	1,112,383	3,127,736
Project Avg	69	54,637	30,983	45,735	0	4,296	25,058	58,546	164,618
Building Avg	60	47,186	26,758	39,498	0	3,710	21,641	50,563	142,170
Wtd Unit Avg			448	661	0	62	362	847	2,380

** Participants with common laundries: Cases 2 (split) and 4.

** In-Unit K/B Ltg saves 0.15 if receiving measures; averages 0.07 across all units.*

Table B.5. Weighted Average Energy Savings per Unit

Case No.	Units	Total Building Floor Area SqFt	Weighted Average Savings per Unit: Thermal Shell 1.43 In-Unit L 1.25 Comn L	KB Ltg 0.07 In-Unit L 0.13 Comn L	Tenant Svg: Tier I + KB Ltg	Owner Svg: Common Ltg 1.50 In-Unit L 1.71 Comn L
2**	88	53,763	764	79	843	1,045
4**	200	95,430	596	62	658	816
1	245	217,305	1,268	0	1,268	1,330
2	12	15,112	1,801	190	1,991	1,889
3	20	16,974	1,214	0	1,214	1,273
5	25	25,109	1,436	0	1,436	1,507
6	64	64,233	1,435	152	1,587	1,505
7	7	8,148	1,665	0	1,665	1,746
8	147	115,838	1,127	0	1,127	1,182
9	183	152,734	1,193	126	1,320	1,252
10	26	26,332	1,448	153	1,601	1,519
11	44	35,868	1,166	0	1,166	1,223
12	14	11,716	1,197	126	1,323	1,255
13	33	24,395	1,057	0	1,057	1,109
14	66	52,985	1,148	121	1,269	1,204
15	40	33,501	1,198	0	1,198	1,256
16	22	17,829	1,159	122	1,281	1,216
17	12	14,877	1,773	187	1,960	1,860
18	16	15,415	1,378	146	1,523	1,445
19	50	40,535	1,159	123	1,282	1,216
	Total	Total	Avg	Avg	Avg	Avg
****Common Laundry** Unit Avg	288	149,193	648	67	715	886
In-Unit Laundry Unit Avg	1,026	888,906	1,239	61	1,300	1,300
Total	1,314	1,038,099	1,109	62	1,171	1,209
Project Avg	69	54,637				
Building Avg	60	47,186				

Table B.6. Calculation of Bill Savings by Rate Period

			Shell kWh Savings		Kit/Bath Ltg Savings*		Common Ltg Savings		Total
Case No.	**Units**	**Total Building Floor Area SqFt**	Summer @ kWh/SqFt 0.0389 Res Rt 20	Winter @ kWh/SqFt 0.0580 Res Rt 20	Summer @ kWh/SqFt 0.0389 Res Rt 20	Winter @ kWh/SqFt 0.0580 Res Rt 20	Summer @ kWh/SqFt 0.0330 Cmcl Rt 31	Winter @ kWh/SqFt 0.0479 Cmcl Rt 31	Tier I + Kit/Bath+ Comn Ltg kWh Saved
2**	88	53,763	$ 1,025	$ 2,370	$ -	$ 405	$ 905	$ 3,090	$ 7,795
4**	200	95,430	1,819	4,207	-	720	1,606	5,485	13,836
1	245	217,305	4,903	10,713	-	0	3,227	10,929	29,772
2	12	15,112	341	745	-	132	224	760	2,203
3	20	16,974	383	837	-	0	252	854	2,326
5	25	25,109	567	1,238	-	0	373	1,263	3,440
6	64	64,233	1,449	3,167	-	563	954	3,231	9,363
7	7	8,148	184	402	-	0	121	410	1,116
8	147	115,838	2,614	5,711	-	0	1,720	5,826	15,871
9	183	152,734	3,446	7,530	-	1,339	2,268	7,682	22,265
10	26	26,332	594	1,298	-	231	391	1,324	3,838
11	44	35,868	809	1,768	-	0	533	1,804	4,914
12	14	11,716	264	578	-	103	174	589	1,708
13	33	24,395	550	1,203	-	0	362	1,227	3,342
14	66	52,985	1,195	2,612	-	464	787	2,665	7,724
15	40	33,501	756	1,652	-	0	497	1,685	4,590
16	22	17,829	402	879	-	156	265	897	2,599
17	12	14,877	336	733	-	130	221	748	2,169
18	16	15,415	348	760	-	135	229	775	2,247
19	50	40,535	915	1,998	-	355	602	2,039	5,909
	Total	Total	Subtotal	Subtotal	Subtotal	Subtotal	Subtotal	Subtotal	Total
****Common Laundry**	288	149,193	$ 2,844	$ 6,576	$ -	$ 1,125	$ 2,511	$ 8,576	$ 21,632
Unit Avg			9.87	22.83	0.00	3.91	8.72	29.78	75.11
In-Unit Laundry	1,026	888,906	$ 20,055	$ 43,823	$ -	$ 3,610	$ 13,200	$ 44,708	$ 125,396
Unit Avg			19.55	42.71	0.00	3.52	12.87	43.57	122.22
Total	1,314	1,038,099	$ 22,899	$ 50,399	$ -	$ 4,735	$ 15,711	$ 53,283	$ 147,028
Project Avg	69	54,637	1,205	2,653	0	249	827	2,804	7,738
Building Avg	60	47,186	1,041	2,291	0	215	714	2,422	6,683
Wtd Unit Avg			17.43	38.36	0.00	3.60	11.96	40.55	111.89

** Participants with common laundries:
Cases 2 (split) and 4.

Table B.7. Calculation of Energy & Bill Savings from 1993 Completions

25 Buildings	**Thermal Shell**	**Kit/Bath Lighting**	**Common Lighting**	**Refri-gerators**	**Water Heaters**	**Total Savings**
Add-on Appliances Only		*CmnL*	*InL*			
Units	0	177	157	656	81	**660**
@ Kwh/Unit	0	*67*	*1300*	120	145	
Kwh Savings	0	11,859	204,100	78,720	11,745	**306,424**
Avg Kwh/Unit	0.0	18.0	309.2	119.3	17.8	**464.3**
	0	**329**		**138**		Wtd Avg
Common Laundry						
Units	200	200	200	200	0	**200**
@ Kwh/Unit	647	*67*	885	120	145	
Kwh Savings	129,400	13,400	177,000	24,000	-	**343,800**
Avg Kwh/Unit	647.0	67.0	885.0	120.0	-	**1,719.0**
In-Unit Laundry	71	48	71	71	71	**71**
Tier II / Tier I Units*	744	287	744	742	493	**744**
@ Kwh/Unit	1239	61	*1300*	120	145	
Kwh Savings	987,793	20,435	1,059,500	97,560	81,780	**2,247,068**
Avg Kwh/Unit	1,327.7	27.5	1,424.1	131.1	109.9	**3,020.3**
** Tier II Shell @ 75%Tier I*						
Tier I&II Summary						
Units	1015	535	1015	1013	564	**1,015**
Kwh Savings	1,117,193	33,835	1,236,500	121,560	81,780	**2,590,868**
Avg Kwh/Unit	1,100.7	33.3	1,218.2	119.8	80.6	**2,552.6**
	1101	**1252**		**200**		Wtd Avg
Total 1993 Program						
Units	1,015	712	1,172	1,669	645	**1,675**
Kwh Savings	1,117,193	45,694	1,440,600	200,280	93,525	**2,897,292**
Avg Kwh/Unit	667.0	27.3	860.1	119.6	55.8	**1,729.7**
Annual Bill Savings	*RS Rt 20*	*RS Rt 20*	*CM Rt 31*	*RS Rt 20*	*RS Rt 20*	
Summer 1996	-	*0.0405*	*0.0345*	*0.0405*	*0.0405*	
Winter 1996-1997	*0.0604*	*0.0604*	*0.0500*	*0.0604*	*0.0604*	
Summer Savings/Unit	$ -	$ 0.74	$ 19.78	$ 3.23	$ 1.51	**$ 25.25**
Winter Savings/Unit	$ 40.29	$ 0.55	$ 14.33	$ 2.41	$ 1.12	**$ 58.70**
Tenant Savings/Unit	$ 40.29	$ 1.29	$ -	$ 5.64	$ 2.63	**$ 49.84**
Owner Savings/Unit	$ -	$ -	$ 34.12	$ -	$ -	**$ 34.12**

Table B.8. Calculation of Energy & Bill Savings from 1994 Completions

13 Buildings	Thermal Shell	Kit/Bath Lighting	Common Lighting	Refri-gerators	Water Heaters	Total Savings
Add-on Appliances Only		*CmnL*	*InL*			
Units	0	0	0	0	0	**-**
@ Kwh/Unit	0	*67*	*1300*	120	145	
Kwh Savings	0	-	-	-	-	**-**
Avg Kwh/Unit	0.0	0.0	0.0	0.0	0.0	**0.0**
	0	**0**		**0**		Wtd Avg
Common Laundry						
Units	258	258	258	85	0	**258**
@ Kwh/Unit	647	*67*	885	120	145	
Kwh Savings	166,926	17,286	228,330	10,200	-	**422,742**
Avg Kwh/Unit	647.0	67.0	885.0	39.5	-	**1,638.5**
In-Unit Laundry						
Units	350	356	356	277	296	**356**
@ Kwh/Unit	1239	61	*1300*	120	145	
Kwh Savings	433,650	21,716	462,800	33,240	42,920	**994,326**
Avg Kwh/Unit	1,218.1	61.0	1,300.0	93.4	120.6	**2,793.1**
Tier I Summary						
Units	608	614	614	362	296	**614**
Kwh Savings	600,576	39,002	691,130	43,440	42,920	**1,417,068**
Avg Kwh/Unit	978.1	63.5	1,125.6	70.7	69.9	**2,307.9**
	988	**1201**		**142**		Wtd Avg
Total 1994 Program						
Units	608	614	614	362	296	**614**
Kwh Savings	600,576	39,002	691,130	43,440	42,920	**1,417,068**
Avg Kwh/Unit	978.1	63.5	1,125.6	70.7	69.9	**2,307.9**
Annual Bill Savings	*RS Rt 20*	*RS Rt 20*	*CM Rt 31*	*RS Rt 20*	*RS Rt 20*	
Summer 1996	-	*0.0405*	*0.0345*	*0.0405*	*0.0405*	
Winter 1996-1997	*0.0604*	*0.0604*	*0.0500*	*0.0604*	*0.0604*	
Summer Savings/Unit	$ -	$ 1.72	$ 25.89	$ 1.91	$ 1.89	**$ 31.40**
Winter Savings/Unit	$ 59.08	$ 1.28	$ 18.76	$ 1.42	$ 1.41	**$ 81.95**
Tenant Savings/Unit	$ 59.08	$ 2.99	$ -	$ 3.33	$ 3.29	**$ 68.70**
Owner Savings/Unit	$ -	$ -	$ 44.65	$ -	$ -	**$ 44.65**

Table B.9. Calculation of Energy & Bill Savings from 1995 Completions

24 Buildings	Thermal Shell	Kit/Bath Lighting	Common Lighting	Refri-gerators	Water Heaters	Total Savings
Add-on Appliances Only		*CmnL*	*InL*			
Units	0	0	0	0	0	**-**
@ Kwh/Unit	0	*67*	*1300*	120	145	
Kwh Savings	0	-	-	-	-	**-**
Avg Kwh/Unit	0.0	0.0	0.0	0.0	0.0	**0.0**
	0	**0**		**0**		Wtd Avg
Common Laundry						
Units	206	206	206	158	0	**206**
@ Kwh/Unit	647	*67*	885	120	145	
Kwh Savings	133,282	13,802	182,310	18,960	-	**348,354**
Avg Kwh/Unit	647.0	67.0	885.0	92.0	-	**1,691.0**
In-Unit Laundry						
Units	460	325	460	35	278	**460**
@ Kwh/Unit	1239	61	*1300*	120	145	
Kwh Savings	569,940	19,825	598,000	4,200	40,310	**1,232,275**
Avg Kwh/Unit	1,239.0	43.1	1,300.0	9.1	87.6	**2,678.9**
Tier I Summary						
Units	666	531	666	193	278	**666**
Kwh Savings	703,222	33,627	780,310	23,160	40,310	**1,580,629**
Avg Kwh/Unit	1,055.9	50.5	1,171.6	34.8	60.5	**2,373.3**
	1056	**1222**		**95**		Wtd Avg
Total 1995 Program						
Units	666	531	666	193	278	**666**
Kwh Savings	703,222	33,627	780,310	23,160	40,310	**1,580,629**
Avg Kwh/Unit	1,055.9	50.5	1,171.6	34.8	60.5	**2,373.3**
Annual Bill Savings	*RS Rt 20*	*RS Rt 20*	*CM Rt 31*	*RS Rt 20*	*RS Rt 20*	
Summer 1996	*-*	*0.0405*	*0.0345*	*0.0405*	*0.0405*	
Winter 1996-1997	*0.0604*	*0.0604*	*0.0500*	*0.0604*	*0.0604*	
Summer Savings/Unit	$ -	$ 1.36	$ 26.95	$ 0.94	$ 1.63	**$ 30.88**
Winter Savings/Unit	$ 63.78	$ 1.02	$ 19.53	$ 0.70	$ 1.22	**$ 86.24**
Tenant Savings/Unit	$ 63.78	$ 2.38	$ -	$ 1.64	$ 2.85	**$ 70.65**
Owner Savings/Unit	$ -	$ -	$ 46.47	$ -	$ -	**$ 46.47**

Table B.10. Calculation of Energy & Bill Savings from 1996 Completions

9 Buildings	Thermal Shell	Kit/Bath Lighting	Common Lighting	Refri-gerators	Water Heaters	Total Savings
Add-on Appliances Only		*CmnL*	*InL*			
Units	0	0	0	0	0	**-**
@ Kwh/Unit	0	*67*	*1300*	120	145	
Kwh Savings	0	-	-	-	-	**-**
Avg Kwh/Unit	0.0	0.0	0.0	0.0	0.0	**0.0**
	0	**0**		**0**		Wtd Avg
Common Laundry						
Units	24	24	24	0	0	**24**
@ Kwh/Unit	647	*67*	885	120	145	
Kwh Savings	15,528	1,608	21,240	-	-	**38,376**
Avg Kwh/Unit	647.0	67.0	885.0	-	-	**1,599.0**
In-Unit Laundry						
Units	265	187	265	0	167	**265**
@ Kwh/Unit	1239	61	*1300*	120	145	
Kwh Savings	328,335	11,407	344,500	-	24,215	**708,457**
Avg Kwh/Unit	1,239.0	43.0	1,300.0	-	91.4	**2,673.4**
Tier I Summary						
Units	289	211	289	0	167	**289**
Kwh Savings	343,863	13,015	365,740	-	24,215	**746,833**
Avg Kwh/Unit	1,189.8	45.0	1,265.5	-	83.8	**2,584.2**
	1235	**1311**		**84**		Wtd Avg
Total 1996 Program						
Units	289	211	289	-	167	**289**
Kwh Savings	343,863	13,015	365,740	-	24,215	**746,833**
Avg Kwh/Unit	1,189.8	45.0	1,265.5	-	83.8	**2,584.2**
Annual Bill Savings	*RS Rt 20*	*RS Rt 20*	*CM Rt 31*	*RS Rt 20*	*RS Rt 20*	
Summer 1996	-	*0.0405*	*0.0345*	*0.0405*	*0.0405*	
Winter 1996-1997	*0.0604*	*0.0604*	*0.0500*	*0.0604*	*0.0604*	
Summer Savings/Unit	$ -	$ 1.22	$ 29.11	$ -	$ 2.26	**$ 32.59**
Winter Savings/Unit	$ 71.87	$ 0.91	$ 21.09	$ -	$ 1.69	**$ 95.55**
Tenant Savings/Unit	$ 71.87	$ 2.12	$ -	$ -	$ 3.95	**$ 77.94**
Owner Savings/Unit	$ -	$ -	$ 50.20	$ -	$ -	**$ 50.20**