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RESIDENTIAL BUILDING STOCK ASSESSMENT: MULTIFAMILY CHARACTERISTICS AND ENERGY USE

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Glossary of Acronyms and Abbreviations

AC	air conditioning
ACS	American Community Survey (U.S. Census)
ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning Engineers
BPA	Bonneville Power Administration
Btu	British thermal unit
CFL	compact fluorescent lamp
Council	Northwest Power and Conservation Council
CRT	cathode ray tube
cu.ft.	cubic feet
DHP	ductless heat pump
DHW	domestic hot water
DVD	digital video disc
DVR	digital video recorder
EB	error bound
EISA	Energy Independence and Security Act
EUI	energy use index
FERC	Federal Energy Regulatory Commission
GPM	gallons per minute
HP	heat pump
HVAC	heating, ventilation, and air conditioning
IECC	International Energy Conservation Code
kBtu	kilo British thermal unit
kBtu/sq.ft.	kilo British thermal units per square foot
kW	kilowatt
kWh	kilowatt hours
kWh/sq.ft.	kilowatt hours per square foot
kWh/unit/yr	kilowatt hours per unit per year
kWh/yr	kilowatt hours per year
LCD	liquid crystal display
LED	light-emitting diode
LPD	lighting power density

Low-E	Low-emissivity (refers to coatings on glazing or glass to control heat transfer through windows)[1]
n	number of observations
NEEA	Northwest Energy Efficiency Alliance
OA	outside air
NOAA	National Oceanic and Atmospheric Administration
PC	personal computer
PRISM	PRInceton Scorekeeping Method
PT	post-tension
PTAC	packaged terminal air conditioner
PTHP	packaged terminal heat pump
PUD	Public Utility District
QC	quality control
RBSA	Residential Building Stock Assessment
RDD	random digit dial
REIT	Real Estate Investment Trust
R-value	thermal resistance value
sq.ft.	square feet
TJI®	Trus Joist I-Joist (TJI is a registered trademark)
TV	television
UA	The sum of the thermal transfer coefficient (U) times the area (A) of the components of the building. Also includes convective losses from infiltration.
VBDD	variable base degree day
VRF	variable refrigerant flow
W	Watts
W/sq.ft.	Watts per square foot
WSHP	water source heat pump
ZCTA	Zip Code Tabulation Area

[1] http://www.energysavers.gov/your_home/windows_doors_skylights/index.cfm/mytopic=13430

Executive Summary

This report is the third in a series of reports summarizing the results of the Residential Building Stock Assessment (RBSA). The RBSA is sponsored by the Northwest Energy Efficiency Alliance (NEEA) and is being conducted by Ecotope, Inc. with support by Ecova™, Delta-T, Inc., ORC International, and Mike Kennedy. The primary objective of the RBSA is to develop an inventory and profile of existing residential building stock in the Northwest based on field data from a representative, random sample of existing homes. The RBSA establishes the 2011 regional baseline for housing stock for three categories of residences: single-family homes, manufactured homes, and multifamily homes. The results will guide future planning efforts and provide a solid base for assessing energy savings on residential programs throughout the Northwest.

This third report summarizes the characteristics observed onsite and energy use data for the multifamily component of the RBSA. The first report[2] (released in September 2012) summarized single-family homes (Baylon et al., 2012), and the second report[3] (released in January 2013) summarized the manufactured housing sector (Storm et al., 2013).

The RBSA was designed to develop a characterization of the residential sector that takes into account the diverse climates, building practices, and fuel choices across the region. The characterization includes both the principal characteristics of the homes (size, insulation level, and heating systems) and the principal characteristics of the tenants and their energy use patterns (e.g., lighting, appliances, electronics, and water heating). As energy efficiency is a primary energy resource in the Northwest, the baseline information generated by the RBSA is an essential element in developing efficiency resources that can meet the region's future energy requirements and growth.

The Northwest has no precedent for a residential field study of the size and representative nature of the RBSA. In this sense, the RBSA is not an update of an existing study or dataset, but rather a new standard for residential characterization studies in the Northwest. Ecotope designed the RBSA sample to include all public and investor-owned utilities in Washington, Oregon, Idaho, and western Montana. The final RBSA sample includes 99 utilities: 89 public utilities, seven investor-owned utilities, and three natural gas-only utilities. Of the 99 utilities represented in the overall RBSA study, 99 were represented in the single-family sample, 52 were represented in the manufactured home sample, and 24 were represented in the multifamily sample. Field surveys were conducted on 1,955 sites for three residence types across the Northwest.

The primary objective of the RBSA multifamily survey was to develop an inventory and profile of existing multifamily residential building stock in the Northwest. The RBSA multifamily study

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[2] See the RBSA Single-Family Characteristics and Energy Use Report at http://neea.org/docs/reports/residential-building-stock-assessment-single-family-characteristics-and-energy-use.pdf?sfvrsn=8

[3] See the RBSA Manufactured Home Characteristics and Energy Use Report at http://neea.org/docs/default-source/reports/residential-building-stock-assessment--manufactured-homes-characteristics-and-energy-use.pdf?sfvrsn=6

was designed to provide an overview of the principal characteristics of the buildings (size, insulation level, HVAC systems, and other features of each building's common area) and the principal characteristics of the individual units and their energy use patterns (e.g., lighting, appliances, electronics, and water heating). The study is based on field data from a representative, random sample of existing multifamily units and buildings. A total of 230 buildings and 552 units were included in the multifamily sample. The total sample includes a large oversample of 130 buildings in four utility service territories.

Background

For more than 30 years, the Northwest has relied heavily on increased efficiency to reduce demand for energy (especially electricity). This effort has resulted in a substantial reduction in the growth of energy demand and obviated the need to expand or build additional power plants across the region. A critical input to this process is the predictability of the savings from efficiency measures. To this end it is important to establish the "base case" efficiency and energy use so that savings take account of current use patterns and efficiency levels. The base case represents the existing conditions in the residential sector that efficiency programs seek to modify.

The RBSA survey is the first comprehensive assessment of the multifamily sector aimed at characterizing the entire sector using a physical survey. The 1992 Pacific Northwest Residential Energy Survey (PNWRES92) (Bonneville Power Administration [BPA], 1993) included nearly 1,400 multifamily units and was the last in a series of four phone-survey–based residential characterization studies conducted by BPA. This study was the most comprehensive residential characteristics survey conducted prior to the RBSA. However, the data were self-reported using a phone survey and are now 20 years old.

In addition to these more general studies, a number of assessments of multifamily building samples usually focused on a particular utility service territory. The RBSA sample, on the other hand, spans the full range of the region's multifamily buildings, including vintages beginning in 1900 and continuing until the present. In this sense, the RBSA sample provides a more complete baseline for this sector than any study fielded in the region to date.

Study Objectives

The multifamily RBSA includes four major objectives:

- Develop a statistically representative sample frame of multifamily units
- Develop a statistically representative field sample of multifamily buildings
- Analyze and summarize building and unit characteristics
- Collect and summarize the energy use of buildings and units in this sector
- Provide utilities with an opportunity to augment the RBSA sample in their territories

In addition to these objectives, an implicit goal of the RBSA was to set a standard for the design and implementation of future RBSA studies. Particular emphasis was placed on the development of the data collection protocols, a representative and reliable sample, a robust and multifaceted quality management approach, and transparent, flexible datasets and documentation.

Methodology

Ecotope designed the sample to be representative of multifamily homes across the Northwest. The sample was designed to achieve a 90%/10% confidence/precision interval. The RBSA multifamily sample was enhanced by four utility oversamples that more than doubled the number of buildings in the RBSA survey.

The multifamily sample frame was developed with a large, region-wide phone survey. Phone surveys were completed using a combination of random digit dial (RDD) and utility customer phone lists. Each housing type, utility type, and geographic sampling stratum was assigned a quota by the sample design. Approximately eight phone surveys were completed for each field survey in the multifamily sample. Recruiters developed the final sample by randomly selecting from this list. The survey data collected on this final sample were cleaned, assembled, and analyzed in order to develop the report summaries. For this report, the multifamily populations were summarized for the region as a whole.

Findings and Observations

The purpose of a characteristics study is to establish base case conditions for a wide variety of components that can provide the basis for program planning, resource planning, and program evaluation.

The salient findings for multifamily buildings include:

- Characteristics of Northwest multifamily exhibit substantial diversity across the region. In this sample, buildings range in size from 5 units to 350 units. The construction types vary from typical low-rise residential construction to complex rigid frame construction. Approximately 56% of the sector was built after 1981.
- About 9% of the sector is senior housing or assisted living. About 18% of the sector is classed as low-income housing[4].
- About 6% of all multifamily buildings include more than three stories, and less than 1% of the buildings are high-rise (more than six stories); 18% of all units in the sector are in buildings more than three stories in height.
- In spite of relatively low insulation values, the heat loss rate (UA) per unit is 50% less than average single-family homes and 30% less when normalized by conditioned floor area. 82% of all window glazing in this sector is double glazed or better and 68% of all window areas reflect current glazing performance standards.
- About 87% of all primary heating is electric, and 80% of all heating is supplied by electric resistance zonal heat. 13% of all multifamily buildings use gas as primary

[4] The manager was asked “Are the audited building occupants limited to low income occupants?” The responses indicated whether the building tenants would be eligible for rent subsidies and thus would have an income test to live in the building. Managers interpreted this question broadly and answered positively even if the income restrictions were not exclusive.

heating, and half of those use a central heating system. 90% of all central heating systems use natural gas as their heating source.

- About 30% of multifamily buildings have some type of cooling system in some or all units, but less than 1% has a central cooling system.
- About 11% of the sector has central domestic hot water (DHW) systems. 75% of these systems are heated with natural gas; the remainder use electricity.
- About 80% of common area lighting consists of compact fluorescent lamps (CFLs) and linear fluorescent lighting and has an overall lighting power density (LPD) of 0.68 Watts per square foot (W/sq.ft.), and 40% of common area lighting is on continuously (no control system).
- About 43% of the buildings have common area laundries, and 15% of buildings have no laundry facilities in either the units or the common areas. Those buildings are generally part of larger complexes with laundry located elsewhere in the complex.
- About 28% of all multifamily buildings have pools, 85% of which are outside and seasonal. 21% of the buildings have spas, 67% of which are interior and used year-round.
- The average weather normalized, electric energy use index (EUI) is 9.5 kWh/sq.ft. of building conditioned floor area with an average usage of 9,188kilowatt hours per unit per year (kWh/unit/yr) across the multifamily sector. The gas EUI for the buildings with valid gas bills is 0.165 therms/sq.ft. of building conditioned floor area.

The salient findings for multifamily units include:

- About 93% of all units use electric heat as their primary heating. More than 90% of those units use zonal electric heating either permanently mounted or portable.
- About 25% of units have cooling; 85% of those systems are zonal window or wall air conditioning units.
- The use of CFL in unit lighting is 27%, which is comparable to the other residential sectors surveyed in the RBSA. Unit level LPD is 1.46 W/sq.ft., which is also fairly comparable to the other residential sectors.
- Each unit has an average of one refrigerator. About 65% of those refrigerators were manufactured since 2000.
- Saturation of all appliance groups is about two-thirds the saturations in the other residential sectors.
- Across the region, multifamily units have about 1.5 televisions (TVs) and 1.0 set-top boxes per unit. About 15% of the set-top boxes have digital video recorder (DVR) capability.
- Although nearly half of all TVs are cathode ray tube (CRT) types, only 6% of TVs purchased after 2009 are CRTs; the rest are flat screens.
- About 51% of all multifamily homes surveyed have at least one computer.
- Tenants report supplemental fuel use (wood) in less than 4% of all in-unit primary and secondary heating systems combined.

1. Introduction

This report is the third in a series of reports summarizing the results of the Residential Building Stock Assessment (RBSA) sponsored by the Northwest Energy Efficiency Alliance (NEEA). NEEA is a non-profit organization working to maximize energy efficiency to meet future energy needs in the Northwest. NEEA is supported by, and works in collaboration with, the Bonneville Power Administration (BPA), Energy Trust of Oregon, and more than 100 Northwest utilities on behalf of more than 12 million energy consumers.[5]

The RBSA was conducted by Ecotope, Inc., with support by Ecova™, Mike Kennedy, and ORC International. The primary objective of the RBSA was to develop an inventory and profile of existing residential building stock in the Northwest, based on field data from a representative, random sample of existing homes. The RBSA establishes the 2011 regional baseline for housing stock for three categories of residences: single-family homes, manufactured homes, and multifamily homes. The results will guide future planning efforts and provide a solid base for assessing energy savings on residential programs throughout the Northwest.

The current report summarizes the characteristics observed onsite and energy use data for the multifamily component of the RBSA. This report summarizes both building characteristics and individual unit characteristics drawn from a regional sample of multifamily residences. The first report (released in October 2012) summarized single-family homes (Baylon et al., 2012); the second report (released in January 2013) summarized manufactured homes (Storm, et al., 2013), and the third report summarizes multifamily homes. Field surveys conducted on multifamily buildings in 2011 and 2012 included general demographic information, a detailed lighting inventory, and characteristics for electronics and major appliances. Although the buildings in this sample were identified through the same phone surveys that were used for single-family and manufactured homes, these respondents were used to identify the buildings that would be surveyed. For each building identified, the recruiters then contacted the building owner or manager and arranged the survey.

Two parallel surveys were conducted:

1. **Multifamily buildings.** These surveys included interviews with building managers and assessments of building envelope, building and unit heating, ventilation, and air conditioning (HVAC) systems, common area and building lighting, and other characteristics of common areas and parking areas associated with these buildings.
2. **Individual multifamily units.** The surveyor was instructed to pick two or three units in each building or complex to conduct a review. This review paralleled the RBSA single-family survey but emphasized lighting, electronics, and appliances. In addition, the surveyor interviewed the tenant using the same format as used in the other housing types. Finally, the surveyor noted unit-level HVAC and domestic hot water (DHW) components and characterized them if those functions were not supplied from a central (building-wide) system.

[5] See the website at www.neea.org.

1.1. Background

For more than 30 years, the Northwest has relied heavily on increased efficiency to reduce demand for energy (especially electricity). This effort has resulted in a substantial reduction in the growth of energy demand and obviated the need to expand or build additional power plants across the region. A critical input to this process is the predictability of the savings from efficiency measures. The engineering of most efficiency measures is reasonably straightforward, but it is important to establish the "base case" efficiency and energy use so that savings take account of current use patterns and efficiency levels. Although data on the overall energy use can be developed from utility bills, program and measure development depend on a more detailed understanding of the current conditions and practices among the utility customers in the region.

The quest to deliver energy efficiency as a resource has driven the region to embark on studies over the years that seek to characterize these base case conditions and provide a basis for conservation measure design and comprehensive resource planning. This style of conservation program design, in which individual savings estimates are less important than aggregate changes in efficiency across all the customers in the region, allows a more simplified approach to program evaluation but also requires more detailed information on existing efficiency patterns.

Since 1978, the region has used a combination of phone surveys and targeted field surveys to piece together a picture of the residential sector. For the most part, the characteristics have been established by self-reported assessment of insulation and appliance use. Although this combination proved effective, the region has not conducted a large-scale residential survey since 1992 and, except for some small scale assessments, few comprehensive characteristics assessments have been conducted during that same period. Until the RBSA, the knowledge accumulated in the 1980s and early 1990s has served as the basis for conservation program design for nearly 20 years.

The RBSA is intended to provide an up-to-date understanding of the regional characteristics for two reasons: (1) to reflect current construction practices as they have evolved over the last two decades; and (2) to assess the suite of appliances and lighting that have been the basis for substantial conservation initiatives in the region.

There is no precedent in the Northwest for a residential field study of multifamily characteristics of the size of the RBSA. In this sense, the RBSA is not an update of an existing study or dataset, but rather a new standard for residential characterization studies in the Northwest. For the multifamily sector, Ecotope designed the RBSA sample to characterize multifamily buildings and units so that they were representative of the region. Individual utilities that were interested in the characteristics in their service territories were encouraged to commission oversamples that would provide further detail. Four utilities commissioned multifamily oversamples: Seattle City Light, Puget Sound Energy, Snohomish County Public Utility District, and the Eugene Water and Electric Board.

The basic RBSA sample was drawn to cover the region in proportion to the occurrence of multifamily residences across the region. A total of 100 buildings were included in the basic RBSA sample. With the addition of 130 oversample buildings in four utility service territories, the total multifamily sample includes 230 buildings. The multifamily sample represents a total of

24 utilities across the Northwest. Three of these are gas-only utilities, three are dual-fuel (gas and electric), and the remaining 18 are electric-only.

1.2. Previous Studies

The RBSA survey is the first comprehensive assessment of the multifamily sector aimed at characterizing multifamily buildings using a physical survey. Two studies have focused on new multifamily buildings (Baylon, et al., 2001) and (RLW, 2007). Several studies have characterized sectors in particular localities; see, for example, Schultz (1989) for Seattle and Brandis, et al. (1992) for Tacoma. Most studies that characterized the sector relied on phone surveys of apartment tenants. This had an inherent limitation when applied to building characteristics. A detailed assessment of Seattle multifamily buildings was completed in the mid 1980s, (Baylon et al., 1987).

The 1992 Pacific Northwest Residential Energy Survey (PNWRES92) (BPA, 1993) was the last in a series of four phone-survey–based residential characterization studies conducted by BPA. Similar surveys were conducted in 1979, 1983, and 1985. The PNWRES92 survey included approximately 20,000 total phone surveys across the Northwest, about 1,400 of which were surveys of multifamily residents. This survey was the most comprehensive residential characteristics survey conducted prior to the RBSA. However, the data are now 20 years old and were collected using phone surveys, which are less comprehensive than onsite surveys especially when addressing multifamily building characteristics.

The RBSA multifamily building protocol and analysis leveraged these studies where possible. On the whole, however, the level of effort and extent of the RBSA sample provide a unique summary and a new baseline of multifamily buildings and occupancy in the Northwest region.

1.3. Study Objectives

The multifamily RBSA was designed to provide a base case reference for practices, attitudes, building characteristics, and technologies that will be the basis for future programs in the multifamily market. The study includes four major objectives:

- **Develop a statistically representative sample frame.** To have a representative sample, all residential units must have an equal probability of participating in the final survey. The development of this sample frame must also provide the basis for contacting and recruiting the potential participants.
- **Develop a geographically representative sample of multifamily buildings and units.** The multifamily sample was designed to characterize the sector across the Northwest. This approach resulted in a regionally representative sample. The multifamily sample does not include smaller geographic subdivisions. Individual units were sampled in the phone survey. These tenants were contacted at random and subsequently became the basis for identifying and recruiting the buildings used in the RBSA multifamily sample.
- **Analyze and summarize building and energy-use characteristics.** The analysis was divided into two sections: overall building characteristics and individual unit characteristics. Characteristics of the building include building shell, building HVAC system characteristics, common area uses and characteristics, and building lighting

characteristics. The multifamily units were characterized using the same protocol used for the other RBSA building types for lighting, appliances, and a limited survey of unit plug loads focusing particularly on electronics and home entertainment. Energy-use characteristics include energy use index (EUI) for the multifamily buildings in the sample.

- **Provide utilities with an opportunity to augment the RBSA sample in their territories.** The RBSA study was designed to allow individual utilities to increase the RBSA samples in their service territories to meet those utilities' particular planning and evaluation needs. Four utilities requested an oversample of multifamily buildings, and those added points were weighted into the overall survey results. The oversamples increased the overall multifamily sample size from 100 buildings to 230 buildings.

In addition to these objectives, an implicit goal of the RBSA was to set a standard for the design and implementation of future RBSA studies. Particular emphasis was placed on the development of the data collection protocols, (i.e., what information would be collected), a representative sample, a robust and multifaceted quality management approach, and transparent, flexible datasets and documentation. To help achieve this goal, NEEA established an advisory group for the RBSA to obtain feedback and advice on critical research activities such as development of the sample design, protocols, characteristics and energy benchmarking reports, and the final databases. For example, the final field survey protocol reflects the input of regional organizations such as BPA and the Northwest Power and Conservation Council (Council) as well as a number of utilities. This process resulted in a comprehensive protocol aligned with regional data requirements and potential measures of interest to regional stakeholders.

1.4. Study Limitations

This RBSA multifamily effort combined the residential survey protocol developed for the single-family and manufactured homes with a simplified commercial building survey focused on the larger buildings in the sample. The surveyors interacted with building managers and with individual residents. In both the building survey and the unit survey, some data could not be collected because a room or area was off-limits to the surveyor, or because the configuration of the building did not allow access. These issues resulted in missing data on some sites in various categories. On the whole, we are confident about the quality of this data collection effort in spite of the known limitations of multifamily surveys. Most of the data were readily obtainable to the surveyors, and the sample bias has been minimized. The resulting dataset provides detailed data for a number of important multifamily measures.

The following list describes potential biases in the study:

- The sample frame was developed from a phone survey, which in turn was developed from random digit dial (RDD) lists of residential phone numbers. The RDD lists were supplemented by similar lists for cell phones in the same localities. In addition, utility customer lists were made available from 10 of the largest utilities. The RDD lists were purchased from reputable providers. Even with all these precautions, the quality of the sample frame depended on people answering the phone, responding to a short questionnaire, and providing sufficient contact information that would allow later recruiting for the field surveys. People can screen calls from an unfamiliar number and can disconnect to avoid talking to a telephone surveyor. For utilities and cell phone lists, similar biases may have been present coupled with the potential underlying limitations of utility customer phone lists and extensive screening requirements for implementing cell-phone-only surveys in specific geographic areas. We have no mechanism for correcting this bias or assessing its impact on the characteristics collected.

- Completed interviews identified the multifamily residence and the building in which the unit was located. Once the building was identified, the recruiters were asked to contact someone at the building and attempt to speak with the owner or manager. This process made the recruiting of individual buildings problematic. The recruiters' success was based on securing contacts with the building representatives in a multi-step process. We do not know what biases this process may have introduced nor do we have the data to correct any bias that did arise.
- The 2010 U.S. Census changed the relationship between the American Community Survey (ACS) and the overall census. In prior years, the ACS was part of the decennial census and was also updated between censuses. In 2010, the ACS became an independent survey. As a result, the summaries used to develop the original RBSA sample based on Zip Code Tabulation Area (ZCTA) were not available in the ACS data released in 2011. The summaries that were available in the 2010 census for housing type, vintage, and other physical characteristics of the home were compiled only by county and state. This change limits potential comparisons between the RBSA results and the ACS results.
- To recruit field survey participants, recruiters called the managers and residents and offered them a cash incentive for participating in the field survey. Recruiters were persistent so as to minimize the possibility of non-response bias from this incentive, but the potential exists for this bias in occupancy and building type that might be reflected in the field data.
- Lighting audits were performed on a room-by-room basis. In some cases, rooms were inaccessible, resulting in a reduced number of lamps and watts in the lighting audit. The quality control (QC) process screened for this result, but some rooms may not have been identified. This factor could result in recording a lower level of lighting power than was in use.
- Heat-loss characteristics such as insulation and wall framing are difficult to observe. The surveyors were given some techniques for assessing these components through indirect observation. In addition the building manager was sometimes able to provide insights. Nevertheless, many of these assignments remain an educated guess. We believe that this guess was unbiased, but we have no mechanism for verifying this assertion.
- This report summarizes 230 multifamily building surveys and 552 apartment unit surveys. Each building had a minimum of two units surveyed, and in some cases three units were surveyed. The surveyor was trained to select the units at random, but the survey was conducted during the day and required an interview with the tenant. This structure may introduce a bias in the tenant surveys, although we do not think the physical characteristics of the unit are influenced. The sample design allowed for some loss of data; however, the multifamily sample is small and even with these precautions, the missing data can result in an elevated level of uncertainty in assessing the distribution of specific characteristics.

2. Methodology

2.1. Sample Design

2.1.1. Sampling Objectives and Approach

Ecotope designed the RBSA multifamily sample to be representative of multifamily buildings and units on a regional basis. Unlike the single-family and manufactured homes samples, geographic divisions of the region such as states were not sampled with a goal of characterizing these subregions separately. In this respect, because the region could be treated as a single large population instead of many small populations, the RBSA multifamily sample was conceptually simpler than the corresponding RBSA single-family and manufactured housing samples.

The multifamily sample was complicated, however, by its dual nature as both a sample of buildings and a sample of residential units within those buildings. The basic philosophy was to sample multifamily units with roughly equal probability across the region, but to sample multifamily buildings in proportion to building size, so that larger buildings would have a proportionally greater chance of being surveyed.

This approach was shaped by both statistical reasoning and regional interests. In-unit energy consumption, usage patterns, and appliance vintages do not differ significantly across building size, so all multifamily units across the region were presumably of equal interest. By contrast, the regional size distribution of multifamily buildings is highly skewed. "Large" multifamily buildings consume much larger amounts of energy, and differ from smaller buildings by construction type, building mechanical systems, and geographic location. Furthermore, as a class, large buildings are more heterogeneous than "small" multifamily buildings. Sampling theory generally implies that unequal-probability sampling is optimal if the variables of interest have highly skewed distributions, and also suggests that sampling intensity should be greater in heterogeneous populations than in homogeneous populations.

The goal of sampling a fixed number of buildings, with probability proportional to unit count, and a sample of units, with equal probabilities, could be achieved by sampling buildings first, with probability proportional to size, and then subsampling a small, constant number of units in each building selected, irrespective of the building's unit count. This approach has obvious practical advantages relative to sampling buildings and units with complete independence, because only one set of building managers would need to be recruited, and the results of the building sample could be directly related to the results of the unit subsample in the same building. Unfortunately, in fact, no enumeration of residential multifamily buildings across the region is available that would be useable as a sample frame detailing building size and location.

Unit count was selected as the most tractable and widely available proxy measure for multifamily building size. Although, formally speaking, the sample design was a regional sample of multifamily buildings with an associated subsample of units in each sampled building, for practical reasons the sampling recruitment started at the unit level and worked upward to the building. U.S. census data and utility residential customer data reported to the Federal Energy Regulatory Commission (FERC Form 861) provide the material for estimating the number and proportions of multifamily residential units across the region. Within any region or subregion, RDD phone lists can be used to contact residents at random, some percentage of whom turn out to live in multifamily buildings. Once a respondent self-identifies as a multifamily tenant, that information can be the basis for recruiting the tenant's building. This indirect method of building recruitment delivers a probability of building recruitment approximately proportional to the number of units in the building, given that each residential unit has an equal probability of being contacted.

The basic RBSA multifamily sample was designed so that it could be supplemented in specific service territories by utilities with a substantial multifamily customer base. Four oversamples were drawn for Puget Sound area and Oregon utilities. In those areas, a separate summary could be drawn that provided a direct characterization of the multifamily sector. In other areas, the regional sample did not usually result in sufficient sample to separately characterize those areas with statistical rigor.

The sample was random across the region, with geographical recruitment expected to be proportional to the number of multifamily units in that geography. Thus, a few sampled buildings were located in the less densely populated areas of the region, but most were in the more densely populated areas. Including the oversamples, about 93% of the realized sample is located in the urban areas of western Washington and Oregon.

2.1.2. Sample Frame Development

The key to developing a representative sample is that the selection of sample points must be random and unbiased. Within a defined stratum, any multifamily unit should have an equal chance to be contacted and recruited.

Geographic stratification (which included seven geographic subregions) was used in the design and construction of all three RBSA housing type samples. However, it was used in a fundamentally different way in the multifamily sector than in the single-family and manufactured home sectors.

In the single-family and manufactured homes sampling, geographic strata received different sampling probabilities in order meet the goals of the region. The geographic strata were further subdivided to allow separate sampling for utilities that requested oversamples of their residential sectors.

In the multifamily sector, by contrast, only a regionally representative sample was called for. Explicit sample recruitment quotas were developed for the seven geographic subregions. However, these quotas were by intention proportional to the population of multifamily units in each of the seven subregions. Because of this proportionality, unit recruitment probability was roughly equal across the northwest region, and the resulting sample can be treated as a region-wide random sample. The proportional regional quotas, although not strictly necessary, were useful for recruitment and planning and also served as an additional safeguard of regional representativeness. Only in the case of the utility multifamily oversamples did the multifamily sample intentionally depart from population proportionality.

As discussed below, Ecotope implemented a rigorous, multiphase sampling process in order to ensure the random distribution and representativeness of the final field survey sample.

Phase 1 included the development of the initial population sample frame. The population sample frame was developed using census data, detailed utility information for all the utilities in the region based on a regional database of utilities and their loads, and the Form 861 certification filings with the FERC from 2009[6] that each utility makes to the U.S. Department of Energy as part of their licensing requirements. This information includes total residential customers and total residential energy loads for each utility broken down by each state where the utility operates.

The ratio among single-family homes, manufactured homes, and multifamily units within each sampling stratum was established by using 2000 U.S. Census data (see U.S. Census Bureau, 2002a and 2002b) sorted by Census ZCTAs. Each utility was assigned a set of ZCTAs that corresponded to their service territory. ZCTAs that were split between utilities were reviewed, and the residential population was split according to that review. The distribution of multifamily units was then assembled in the assigned ZCTAs for each utility.

For Phase 2 of the sampling process, Ecotope used a large, region-wide phone survey to develop a representative sample frame (recruiting list) for the field surveys. For the oversample utilities, the quota was adjusted to ensure that sufficient multifamily units were contacted to fulfill the increased sample size for those utilities. The phone survey delivered a total of 814 multifamily completed surveys using a combination of RDD and utility customer phone lists. The initial screening in the phone survey allowed the completed surveys to be used to identify buildings to recruit for the RBSA.

The phone survey was conducted in April and May 2011. Each survey call averaged eight minutes and covered the following broad topic areas:

- Screening questions to determine electrical utility and dwelling type
- Home characteristics
- Demographics
- Contact information

[6] FERC is an independent agency that regulates the interstate transmission of electricity, natural gas, and oil. When the RBSA sample was designed, 2009 data were the latest available FERC data.

Table 1 presents the final distribution of the sample frame for the multifamily field survey.

Table 1. Multifamily Field Survey Sample Frame

State	Total Multifamily Customers	Total Sample Frame
Idaho	79,945	246
Western Montana	52,974	247
Oregon	170,781	355
Washington	240,030	378
Total	**543,730**	**1,226**

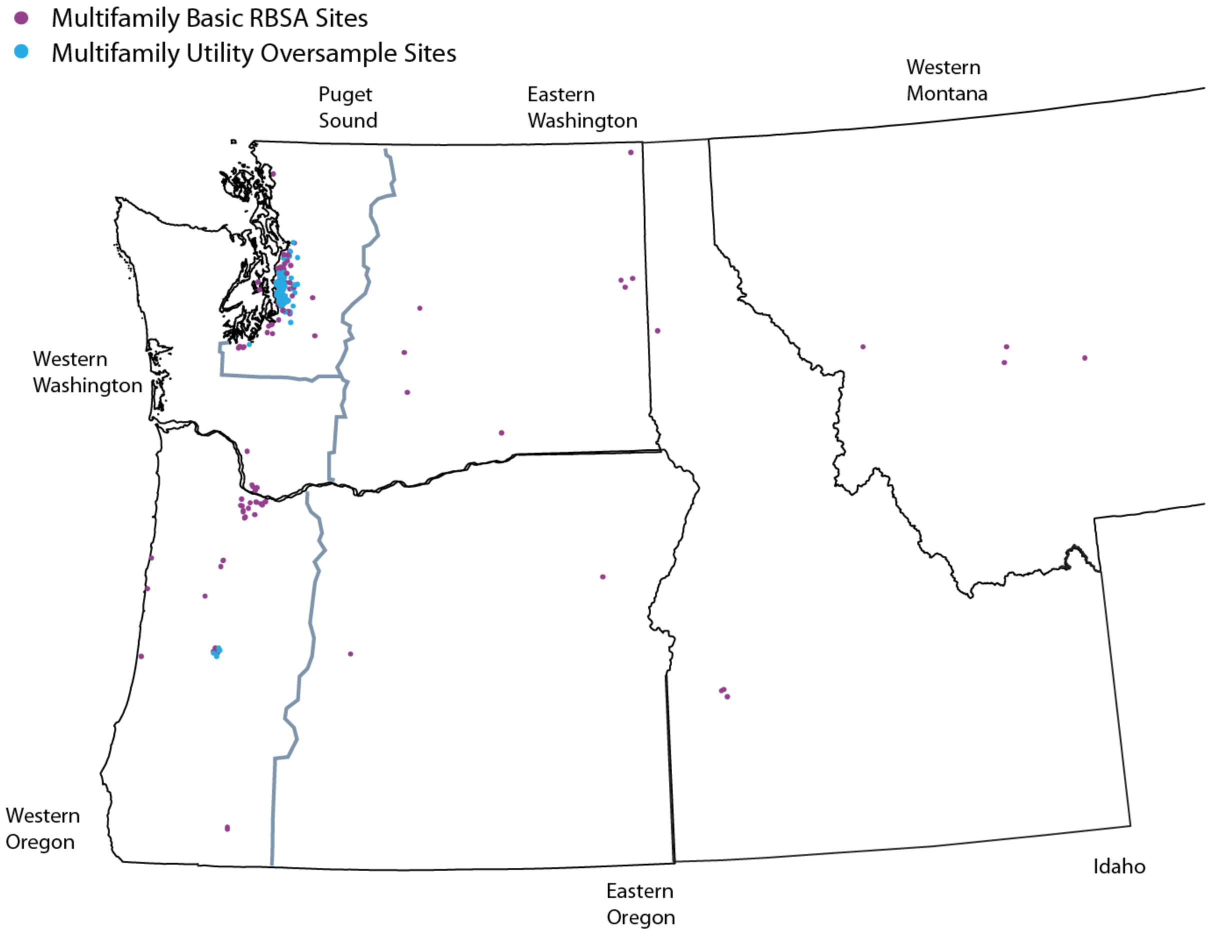
2.1.3. Sample Recruitment and Distribution

Phase 3 of the sampling process included recruitment of the field survey sample. Upon completion of the phone survey, the resulting list of contacts was assembled into the recruiting lists for the field surveys. The addresses given for each respondent that was identified as a multifamily tenant was developed into a reverse directory list that was used to generate phone contacts for the buildings. The individual units were also contacted particularly if the reverse directory listing proved ineffective. Table 2 summarizes the distribution of the RBSA multifamily building field survey sample by state. Figure 1 is a map of the final multifamily sample distribution.

Table 2. Multifamily Sample Distribution

State	Base Sample	Oversample	Total Building Sample	Total Unit Sample
Idaho	4	0	4	10
Western Montana	4	0	4	12
Oregon	30	6	36	96
Washington	62	124	186	434
Total	**100**	**130**	**230**	**552**

Figure 1: Map of Final Sample Distribution of Multifamily Building Field Sites



2.1.4. Sample Weighting

A widely applied principle of data analysis in survey samples is that calculations of population summary statistics such as means, totals, ratios, etc. are weighted inversely proportional to their selection probabilities. This approach is implemented because buildings (or housing units) which make it into the realized sample are representative of more unsampled points.

Sample designs for the RBSA single-family and manufactured housing surveys were stratified on geographic lines, with different strata receiving different sampling intensities (selection probabilities). Because total regional and strata populations of single-family and manufactured housing units could be derived with acceptable accuracy from census and utility customer data, the weights represented the inverse of the true selection probability.

Weights used in summary calculations for the multifamily sample are also closely related to selection probabilities, but they differ in some critical respects from single-family and manufactured housing weights. As noted, multifamily building selection probabilities were proportional to building unit count; hence, building weights were proportional to the inverse of unit count. Because multifamily building unit count in our sample has wide variation (from 5 to 356 units), the difference in weights applied to individual buildings was correspondingly wide, a factor of 70 (rather than a factor of 10).

Because we do not know the regional population of multifamily buildings of various sizes, only the relative selection probabilities is known. That is, we know that a 350-unit multifamily building was 70 times as likely to make it into the sample as a 5-unit building, but we don't know how likely it was to sample either building. This implies, in turn, that the sum of all multifamily building weights in our sample does not add up to the total regional population of multifamily buildings. Moreover, because our sampling weights are relative, all our summary statistics for multifamily buildings must be expressed in terms of ratios (e.g., per building, per square-foot, or per unit) rather than as regional totals.

Weights for unit survey data (as opposed to building survey data) are more equal than weights for any other class of RBSA survey. Two to three units were surveyed in each building, and each unit was weighted depending on the total number of surveyed units in each building. As a result, the weights are based on selection probabilities that represent the total population of multifamily units in the region.[7]

[7] One utility, Seattle City Light, requested a significant large multifamily oversample. The weighting scheme developed for the multifamily data corrected for any sampling bias that might have occurred.

2.2. Onsite Data Collection

The Ecotope team conducted 230 field surveys in multifamily buildings between September 2011 and May 2012. The recruiters were instructed to identify buildings in a random order and recruit their owners or managers into the field sample using quotas. Participating buildings were recruited by contacting the building managers or owners from phone surveys using reverse directories. By randomly assigning the buildings, recruiters prioritized the available recruiting candidates. Recruiters mailed information to potential participants, describing the survey process and incentives. Recruiters followed up the introductory letters with a phone recruitment effort to secure participation and schedule site visits.

Field surveyors participated in a four-day training seminar, with subsequent on-the-job training and coaching through quality assurance activities. Surveyor training focused on the data collection requirements of the study, and on situations that require judgment and interpretation by the surveyors. These situations include the identification of heating equipment type and instruction on how to reflect exceptional circumstances in a prescribed set of database fields.

While onsite, the surveyors obtained signed billing history release forms from participants and managers/owners and conducted manager/owner and tenant interviews to obtain general demographic information as well as background information on energy-use behavior and building characteristics. Surveyors created freehand sketches of the floor plan of each residence surveyed and performed a room-by-room inventory of lighting and electronics characteristics. Surveyors also collected detailed data on the building envelope, the HVAC system, major appliances, and large and unusual loads. Surveyors used tablet personal computers (PCs) for offline data collection. Surveyors entered field survey data using a form interface, and at the end of each day synced the data to the RBSA working database. Appendix A includes the multifamily onsite data collection protocol.

Data collected onsite were divided into two separate surveys. The building surveys focused on building and common area characteristics. The unit surveys focused on unit-specific characteristics. Although these surveys were conducted in parallel, the information gathered was summarized separately.

Data collected onsite included, but were not limited to:

Building Survey

- **Building envelope**
  - General
    - Construction type
    - Number of stories
    - Ownership
  - Windows
    - Window types
    - Total window area (by type)
    - Percentage of south-facing windows

  - Walls
    - Wall types
    - Wall thermal resistance value (R-value)
    - Area
  - Roof
    - Area
    - Height
    - Insulation R-value
  - Floors
    - Floor type
      - Basement
      - Parking
      - Floor construction
    - Insulation R-value
    - Area
- **Lighting (common area by room)**
  - Fixture type
  - Fixture quantity
  - Lamps per fixture
  - Lamp technology by fixture
  - Lamp wattage
  - Control type (e.g., manual, dimmer, motion-sensor, timer, etc.)
  - Area of the room
  - Exterior Lighting
  - Parking area lighting
- **Heating, Cooling, and Ventilation Equipment (central system, common area system)**
  - Heating system
    - System type
    - Fuel type
    - Equipment type
    - Fan type
    - Thermostat/controls type
    - Manufacture year
    - Distribution type
  - Cooling system
    - System type
    - Brand/model
    - Capacity
    - Fan type

  - Ventilation system
    - Central
    - Corridor
    - Ventilation system type
    - Common area
    - Fan size or outside air (OA) volume
    - Controls
    - Functioning/non-functioning
- **Water heater (central or common area)**
  - Fuel type
  - System type (e.g., storage, instantaneous, boiler)
  - Circulation system
  - Tank size
  - Input capacity
  - Manufacture date
  - Location (common area)

Unit Survey

- **Lighting**
  - Fixture type
  - Fixture quantity
  - Lamps per fixture
  - Lamp technology by fixture
  - Lamp wattage
  - Control type (e.g., manual, dimmer, motion-sensor, timer, etc.)
  - Area of the room
- **Appliances**
  - Refrigerator/freezers
    - System type/style (e.g., side-by-side, bottom freezer, etc.)
    - Brand/Model
    - Manufacture year
    - Volume
    - Icemaker type
    - Icemaker functioning/not functioning
    - Usage
    - Location (e.g., conditioned, unconditioned space)
  - Clothes washers
    - System type (e.g., vertical/horizontal axis, stacked, combined, etc.)
    - Brand
    - Manufacture year
    - Usage

    - Clothes dryers
        - Fuel type
        - Manufacture year
        - Usage
    - Dishwashers
        - Manufacture year
        - Usage
    - Cooking
        - Oven fuel
        - Cook top fuel
- **Large and Unusual Loads**
    - Equipment type
- **Electronics, General**
    - Number of electronics chargers plugged in
    - Number of audio equipment components
    - Presence and type of subwoofers
- **Televisions**
    - Number of televisions (TVs)
    - Type (e.g., cathode ray tube [CRT], flat screen)
    - Brand/model
    - Size
    - Manufacture year
    - Primary vs. secondary
    - Primary TV wattage (measured)
    - Number of plugged-in auxiliary items associated with TV
    - Cable/satellite set-top box provider
    - Year set-top box issued
    - Set-top box size (full size or small)
    - Set-top box ability to record
- **Gaming Systems**
    - Number of gaming systems
    - Brand and release
    - Ability to play digital video discs (DVDs) or Blu-ray movies
    - Ability to access the Internet (e.g., email, Netflix, video chat, etc.)
- **Computers**
    - Number of computers/laptops
    - Type
    - Number of screens
    - Screen size
    - Number of plugged-in peripherals (all items plugged into single strip)

2.3. Data Quality Management

The Ecotope team implemented a comprehensive quality management plan focused on the quality assurance and quality control steps required across the full spectrum of the data collection process, starting with the protocol development and surveyor training and continuing through survey implementation and the final data cleaning and analysis phase. The quality management plan was designed to ensure accurate, consistent, and actionable data.

Key steps in the RBSA data quality management process included:

- **Protocol development.** In addition to completeness and correctness, a primary metric for data quality is alignment with study objectives. The data identified in the RBSA protocol were developed with input from numerous regional stakeholders and were designed to provide the level of detail necessary for developing energy efficiency measures in the Northwest. The protocol was developed by senior staff with extensive experience designing and evaluating measures in multifamily buildings.
- **Surveyor training and feedback loops.** The Ecotope team provided clear work instructions for surveyors and established feedback loops, utilizing tools such as conference calls, digital pictures, webinars, and regular feedback of data reported by each surveyor to illuminate and resolve common problems.
- **In-field QC.** A quality review of all field results was conducted. This process identified missing and inconsistent data which were returned to the survey teams to be corrected. Team members with specialized experience implementing multifamily building surveys reviewed the data as they were produced and were available to answer questions.
- **Follow-up site visits.** Surveyors made return visits as needed to gather missing or incorrect data identified in the data QC process.
- **Final data cleaning.** Once the surveys and the various QC steps were complete, Ecotope and Ecova cleaned and analyzed the data. This process involved several distinct activities:
  - Conduct overall checks on the data that identified outliers and allowed correction to be made when these were data collection or typographical errors.
  - Evaluate inconsistent data entries using surveyor notes or engineering judgments.
  - Assess missing data from surveyor notes, or secondary information collected during the survey (e.g., tenant interviews).
  - Over the course of data review, call individual building managers to clarify anomalies that appeared in the data.
  - Where no alternatives were available, arrange a revisit of the site to collect missing or ambiguous data.

2.4. Characteristics Analysis

The RBSA multifamily sample design was based on a regional sample that would provide significance for this sector across the region. The design was developed to provide a framework for utilities with significant multifamily populations to add specific oversamples and still maintain the integrity of the regionally representative sample. Thus, case weights were developed based on all the completed surveys to account for the sampling probability across the region. Within each sampled building, two to three separate units were surveyed for demographics, appliances, lighting, and electronics. This sample was weighted to provide a regionally a representative sample of units.

The second phase of the analysis was to assess and combine the data collected into meaningful summaries. In this population, two separate but parallel analyses were conducted:

1. The survey of the overall building was summarized for the building and assembled across all multifamily buildings. This survey included characteristics of the building shell, the building HVAC system(s), common area lighting, building and/or common area DHW, and common area appliances and other services. This survey also addressed building-level parking areas. Many buildings included non-residential occupancies, such as commercial space. These areas were noted, and overall size and use were recorded; however, the surveyors collected no other details on these spaces.
2. Two to three separate units were surveyed in each building. In general, the unit surveyed was identified by the surveyor while interviewing the building manager/owner at the outset of the survey. The surveyor was instructed to try to get access to the tenant that originally responded to the phone survey. If that unit was unavailable, the manager helped secure the units to be surveyed. The survey of the individual units included a review of the lighting, appliances, and electronics in the unit. This information was collected using the same protocol as the RBSA single-family and manufactured homes survey.

At the outset, the output from the electronic tablet PC software was disaggregated into about 90 database tables for the separate characteristic information in the building survey and about 55 database tables that summarized the unit-level surveys including separate tables for lighting, electronics, etc. For example, about five database tables were constructed and included all the data collected for central water heater systems (e.g., water heater type, circulation system, etc.) in each building. Additional tables were assembled that included all the data collected on water heaters and hot water usage in the units. These tables were reviewed individually by building and units, and later assembled into analytic tables that were used to construct the report summaries.

The summary tables presented in this report were weighted using the case weights associated with each completed survey. These weights were used to compute the mean and the standard error of each variable and combination of variables.

Each table in the report includes weighted mean values and the error bound (EB) on those values. The EB was calculated as a two-sided 90% confidence interval. The tables also generally include the number of sample points used to develop each mean value. The final summaries include all useable data for any particular record (building or unit); as a result, not all summaries include all buildings or units surveyed.

2.5. Billing Data Collection and Analysis

Field surveyors secured a utility service billing release for each building and a separate billing release for each unit surveyed. Ecotope attempted to collect and assemble the billing data for all the units in each building and used these data to develop aggregate summaries of the building energy use. Because not every unit was surveyed, the utilities provided anonymized billing information for the entire building and generally did not provide any unit information that could be assigned to a particular unit (even if the survey collected the release for a few units). This information was used to summarize total energy use (both gas and electric) for each building in the sample.

Ecotope reviewed billing releases to verify accuracy and completeness, and provided them to participating utilities, along with a summary spreadsheet request outlining the site addresses, participants, and their account information at each utility. All personal identifying customer data were transferred between Ecotope and the utility representatives using a secure, password-protected website.

The billing data request included all electric and natural gas utility service records for the field survey sites. Ecotope requested billing records from January 2009 through 2012 for all units in each building and for the building meter. Utilities submitting data were able to provide at a minimum the last two years of billing data for their participant sites.

Utility response rates were high relative to other regional characterization studies. Table 3 shows the utility response rate by utility and the site data submission rate (98% of sites received out of total sites requested). About 92% of electric utilities solicited provided data for the study.

Table 3. Utility Billing Solicitation Response Rate

Utility Service	Utility Response Rate	Site Data Submission Rate
Electric Service	92%	98%
Natural Gas Service	83%	98%

Billing data submitted by each utility were surveyed as they were received to verify that they were as complete as possible, and that every site had been submitted. Ecotope followed up with utilities to clarify missing or ambiguous records. Checks were performed to verify that data submitted matched the accounts and building addresses requested. Kilowatt hours (kWh) and therm readings were checked for duplicates and anomalous readings, and these were resolved or removed from the analysis.

Bills were aggregated by building to provide a basis for the billing analysis. The billing analysis was based on a PRISM-type[8]- variable base degree day (VBDD) billing analysis. Billing data were compared against quality-controlled daily weather files provided by the National Oceanic

[8] PRInceton Scorekeeping Method. See Fels, 1986.

and Atmospheric Administration (NOAA). Ecotope developed a building EUI based on kilo British thermal units per square foot (kBtu/sq.ft.) for each building in the sample.

2.6. Final Database

The summaries included in this report present a subset of the overall data collected in the study. The RBSA multifamily field survey collected nearly 1,100 variables on each building, including nearly 700 building variables and more than 400 unit variables. These variables include observed characteristics, tenant and manager interviews, and energy use. In addition, some composite analytical variables were constructed and included with the final data.[9] The RBSA multifamily data is contained in two, Microsoft Access databases. One database contains all building and common area data; the other database contains all data for the units.

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[9] The most significant of these are building heat-loss rate (UA) (see Glossary of Acronyms and Abbreviations for definition of UA), lighting power density (LPD), and energy use index (EUI, total energy normalized by conditioned floor area).

3. Building Configuration and Demographics

This report focuses on a region-wide perspective to summarize both the building configuration and the demographics, subdivided by building size or vintage.

3.1. Building Configuration

Throughout the report, we distinguish the buildings by size in order to describe the differences between construction types; buildings get larger and denser as the number of stories increases. The following building size categories are used in this report:

1. **Low-rise buildings.** These buildings are three stories or less. They are typically regulated by code as residential buildings throughout the region, and are characterized by smaller buildings, although not necessarily smaller complexes.
2. **Mid-rise buildings.** These buildings are four to six stories and are typical of many urban developments. Buildings of this scale can be built using either high-rise construction techniques or, more commonly, a hybrid construction technique where lower floors (for parking or non-residential uses) are constructed with rigid concrete and post-tension (PT) slab construction, while the upper parts of the building are framed either with wood or steel studs.
3. **High-rise buildings.** These building are seven stories or greater. Such buildings are almost exclusively built with rigid frame construction (either concrete or steel) and include structural elements that are typical of high-rise construction. These buildings are found almost exclusively in urbanized areas, especially the Seattle and Portland markets.

Building vintage is the other principle variable used to characterize the multifamily sector. Table 4 and Table 5 present the distribution of building and units by vintage and size. These tables classify construction vintages in multifamily buildings into six categories:

1. **Pre 1955.** These buildings are often inner-city buildings built with wood framing and brick outside wall finishes. Buildings larger than three stories in this group are rare and generally constructed with rigid frame construction.
2. **1955–1970.** These buildings were built as the populations of Seattle and Portland increased. They are generally low-rise and lightly insulated. In most cases, the insulation is designed for sound control.
3. **1971–1980.** Multifamily buildings constructed in this period are similar to more modern buildings except that they were constructed prior to energy codes, which were not implemented in until after 1981. In many areas, this meant increasing the insulation levels but with an ever increasing reliance on electric heating.
4. **1981–1990.** Multifamily buildings in this period became both larger and more insulated. Oregon and Washington had enforced energy codes by the end of this timeframe, and various rulings on building codes and fire codes allowed mid-rise buildings to be framed with wood (or steel) studs.

5. **1991–2000.** This period used modern energy codes and building codes in the main multifamily markets, although energy codes were not yet enforced in eastern areas of the region (especially Idaho and Montana).

6. **Post 2000.** This building vintage is characterized by an explosion of multifamily construction since 2000. The bulk of the post-2000 buildings are high-rise buildings built in the region and about 15% of all units in the region.

Table 4. Distribution of Buildings by Building Size and Vintage

Vintage		Building Size (Stories)				
		Low-Rise (1–3)	Mid-Rise (4–6)	High-Rise (7+)	All Sizes	n
Pre 1955	%	75.4%	24.0%	0.5%	5.6%	18
	EB	29.5%	29.4%	0.8%	4.3%	
1955–1970	%	95.6%	3.9%	0.4%	22.6%	54
	EB	3.1%	3.0%	0.4%	7.6%	
1971–1980	%	97.3%	2.1%	0.7%	28.4%	51
	EB	1.8%	1.5%	1.0%	7.9%	
1981–1990	%	97.5%	2.4%	0.1%	22.4%	45
	EB	1.9%	1.9%	0.2%	7.3%	
1991–2000	%	90.1%	8.9%	1.0%	14.3%	31
	EB	7.0%	6.7%	1.4%	5.9%	
Post 2000	%	81.9%	13.2%	4.9%	6.7%	31
	EB	16.6%	14.7%	6.1%	4.1%	
All Vintages	%	93.7%	5.5%	0.8%	100.0%	230
	EB	2.5%	2.4%	0.5%		

Table 5. Distribution of Units by Building Size and Vintage

Vintage		Building Size (Stories)				
		Low-Rise (1–3)	Mid-Rise (4–6)	High-Rise (7+)	All Sizes	n
Pre 1955	%	62.2%	32.5%	5.3%	5.2%	18
	EB	27.6%	27.3%	6.6%	2.9%	
1955–1970	%	89.1%	8.0%	2.9%	19.0%	54
	EB	5.7%	5.0%	2.5%	5.3%	
1971–1980	%	90.3%	5.3%	4.4%	29.0%	51
	EB	6.6%	3.6%	5.7%	6.6%	
1981–1990	%	92.6%	6.7%	0.7%	20.3%	45
	EB	4.1%	3.9%	1.1%	5.6%	
1991–2000	%	67.7%	22.8%	9.5%	14.9%	31
	EB	16.1%	13.6%	10.8%	5.0%	
Post 2000	%	57.5%	23.6%	18.9%	11.8%	31
	EB	19.6%	15.2%	14.3%	4.6%	
All Vintages	%	81.9%	12.3%	5.9%	100.0%	230
	EB	4.6%	3.6%	3.0%		

For this study, the many buildings identified through the survey and recruiting process were linked to a complex of buildings. In all cases, the complexes are described as an adjunct supplement to the review of overall characteristics of the building surveyed. Table 6 and Table 7 summarize the percentage of buildings in multi-building facilities, and the percentage of units in multi-building facilities, respectively. As these tables show, more than 60% of all multifamily buildings are in multi-building facilities, and nearly 60% of all units are in these facilities.

Table 6. Percentage of Buildings in Multi-Building Facilities by Building Size

Building Size (Stories)	Buildings in Multi-Building Facilities		
	%	EB	n
Low-Rise (1–3)	65.3%	9.0%	151
Mid-Rise (4–6)	35.4%	19.2%	55
High-Rise (7+)	9.3%	8.8%	24
All Sizes	63.1%	8.5%	230

Table 7. Percentage of Units in Multi-Building Facilities by Building Size

Building Size (Stories)	Distribution of Units		
	%	EB	n
Low-Rise (1-3)	63.5%	7.8%	151
Mid-Rise (4-6)	38.0%	15.9%	55
High-Rise (7+)	11.6%	9.6%	24
All Sizes	57.3%	6.9%	230

The surveyors were instructed to collect detailed characteristics data for the buildings that were recruited. In general, this included any facilities that were in that building, even if they were shared with other buildings elsewhere in the complex. However, if services such as pools, recreational areas, or laundries were located in other buildings in the complex, they were not surveyed. The parking areas were assigned to the building that was surveyed, usually by the building manager.

Table 8 shows the distribution of the building uses across the three building sizes. This table divides the spaces in the building into three categories:

1. **Common areas.** These areas include uses such as corridors, lobbies and various tenant services. These uses do not occur in all buildings (particularly low-rise, multi-building facilities) but are universal in larger buildings.

2. **Non-residential spaces.** These spaces are typical of urban high-density buildings. The non-residential spaces were surveyed to characterize the nature of the end uses in the space and the metering information that would allow the space to be separated from the rest of the building. The non-residential uses are located in urban complexes in which the ground floor is non-residential occupancy.

3. **Residential space.** The residential portion of the building, representing nearly 90% of all spaces reviewed, represents the units themselves and separates all corridors access and other spaces that are used to serve these units into common areas.

Table 8. Distribution of Building Floor Area by Floor Area Category and Building Size

Building Size (Stories)		Floor Area Category			
		Common Area	Non-Residential	Residential	n
Low-Rise (1–3)	%	5.5%	0.1%	94.4%	151
	EB	1.5%	0.1%	1.6%	
Mid-Rise (4–6)	%	12.3%	19.0%	68.7%	55
	EB	4.8%	21.5%	17.5%	
High-Rise (7+)	%	11.9%	3.5%	84.6%	24
	EB	2.0%	1.9%	2.7%	
All Sizes	%	7.1%	3.6%	89.3%	230
	EB	1.4%	4.8%	4.6%	

3.1.1. Residential Space

The residential portion of each building is typically divided into individual units. Table 9 shows the distribution of unit types across all buildings. The unit types are classified into four main types: Studio, One-bedroom, Two-bedroom and Three-Bedroom. Each of these types is typically present in most multifamily buildings. There is a striking trend moving from the oldest vintages to the newer vintages. The trend moved away from studio apartments, which represent more than a third of the units built prior to 1955, and toward larger, one- and two-bedroom units which represent more than 80% of all the units built in the most recent vintages. The three-bedroom units are practically non-existent in the early vintages, and constitute 7% to 12% of the units built in the more recent vintages.

Table 9. Distribution of Unit Types by Vintage

Vintage		Unit Type				
		Studio	One-Bedroom	Two-Bedroom	Three-Bedroom	n
Pre 1955	%	36.2%	37.7%	24.9%	1.1%	18
	EB	6.6%	16.6%	15.1%	1.7%	
1955–1970	%	1.4%	50.8%	44.4%	2.5%	54
	EB	1.1%	11.4%	10.8%	2.8%	
1971–1980	%	3.5%	41.4%	49.4%	5.8%	51
	EB	3.2%	10.1%	10.3%	4.8%	
1981–1990	%	1.0%	40.7%	52.9%	5.4%	45
	EB	1.2%	12.4%	12.4%	5.8%	
1991–2000	%	6.3%	29.3%	52.4%	12.0%	31
	EB	5.8%	11.9%	12.8%	7.9%	
Post 2000	%	5.6%	44.0%	43.1%	7.3%	31
	EB	3.3%	15.2%	12.7%	6.6%	
All Vintages	%	5.0%	41.3%	47.6%	5.9%	230
	EB	1.7%	5.2%	5.1%	2.4%	

Table 10 shows the size of the units based on in-unit surveys. A total of 552 units were surveyed. There is a clear indication of an ever-increasing unit size in all building size categories. In each individual unit type, at least a 20% increase in unit size between the pre-1955 vintage and the most recent post-2000 vintage is typical. The overall change of more than 40% in unit size across all vintages and all unit types reflects increased unit size for each individual unit type as well as the fact that fewer studio apartments and more one and two-bedroom units were being constructed.

Table 10. Average Conditioned Unit Floor Area (Sq.Ft.) by Vintage and Unit Type

Vintage		Unit Type					
		Studio	One-Bedroom	Two-Bedroom	Three-Bedroom	All Types	n
Pre 1955	Mean	369	599	715	–	572	39
	EB	377	457	705	–	411	
1955–1970	Mean	369	570	825	947	680	124
	EB	552	263	417	1,381	253	
1971–1980	Mean	424	619	893	1,081	784	136
	EB	806	280	379	1,057	256	
1981–1990	Mean	429	573	872	1,048	779	110
	EB	700	330	429	1,426	298	
1991–2000	Mean	422	605	898	1,099	835	73
	EB	638	494	508	1,102	372	
Post 2000	Mean	413	702	989	1,161	836	69
	EB	319	577	728	2,078	452	
All Vintages	Mean	396	607	883	1,076	766	551
	EB	257	130	171	594	92	

3.1.2. Common Area Characteristics

Common areas of buildings were surveyed separately, and surveyors were asked to characterize both the uses in the common areas and most of the characteristics, including lighting, HVAC, and other equipment.

Table 11 shows the incidence of common areas across all multifamily buildings. As the table shows, all the mid-rise and high-rise buildings maintain some amount of common area space. In no case were any of these larger buildings without some type of common area, regardless of the configuration of the multifamily complex where they were located. In the low-rise buildings, however, only 42% of those buildings have common area. Low-rise buildings include buildings down to five units.

Table 11. Percentage Buildings with Conditioned Common Area by Building Size

Building Size (Stories)	Percentage with Common Area		
	%	EB	n
Low-Rise (1–3)	41.8%	9.0%	151
Mid-Rise (4–6)	100.0%	0.0%	55
High-Rise (7+)	100.0%	0.0%	24
All Sizes	45.5%	8.6%	230

Table 12 shows the distribution of common area spaces of various types across all multifamily buildings. The table summarizes the average area of these common areas as they appear in the individual buildings. The areas are categorized by building size for the average area of these uses. The overall area of the common areas as a percentage of total building area is summarized in Table 13. The summary of common area rooms and spaces does not include buildings with no common areas.

Table 12. Average Common Area Room Type Floor Area (Sq.Ft.) by Building Size

Room Type		Building Size (Stories)				
		Low-Rise (1–3)	Mid-Rise (4–6)	High-Rise (7+)	All Sizes	n
Corridor	Mean	684	2,921	9,307	1,112	117
	EB	254	1,008	1,865	303	
Kitchen	Mean	36	70	201	43	44
	EB	46	70	116	40	
Laundry	Mean	176	93	333	169	117
	EB	29	50	234	26	
Lobby	Mean	38	284	540	77	67
	EB	23	233	343	35	
Mechanical	Mean	43	92	290	53	52
	EB	28	47	211	25	
Office	Mean	103	60	536	105	62
	EB	63	39	335	55	
Recreation	Mean	87	533	887	156	53
	EB	54	511	409	81	
Restroom	Mean	16	51	133	23	42
	EB	11	51	104	11	
Storage	Mean	119	614	621	189	76
	EB	53	442	465	74	
Other	Mean	8	121	386	28	26
	EB	9	131	290	19	

Table 13. Distribution of Building Floor Area by Floor Category and Building Size

Building Size (Stories)		Floor Area Category			
		Common Area	Non-Residential	Residential	n
Low-Rise (1–3)	%	5.5%	0.1%	94.4%	151
	EB	1.5%	0.1%	1.6%	
Mid-Rise (4–6)	%	12.3%	19.0%	68.7%	55
	EB	4.8%	21.5%	17.5%	
High-Rise (7+)	%	11.9%	3.5%	84.6%	24
	EB	2.0%	1.9%	2.7%	
All Sizes	%	7.1%	3.6%	89.3%	230
	EB	1.4%	4.8%	4.6%	

Parking represents a substantial commitment of square footage across the multifamily sector. Even in low-rise, relatively rural settings, parking can represent a substantial percentage of the overall site. Table 14 summarizes the number of parking places provided per unit in each of the three size categories. As the table shows, the total amount of parking is slightly more than one parking stall per unit. In some areas, such as urbanized areas in the Portland and Seattle market, codes require approximately one parking space per unit, and this appears to be the dominant outcome for those larger buildings. The low-rise buildings typically seem to have larger amounts of parking per unit, and often these parking places are open parking lots immediately adjacent to the units themselves. In the mid- and high-rise buildings, enclosed garages are the dominant parking type. This usually means underground or confined security parking that is a physical part of the building.

Table 14. Average Number of Parking Stalls per Unit by Parking Type and Building Size

Building Size (Stories)		Parking Type					
		Covered Parking Lot	Enclosed Parking Garage	Open Parking Garage	Open Parking Lot	All Types	n
Low-Rise (1–3)	Mean	0.180	0.097	0.016	0.984	1.278	151
	EB	0.056	0.047	0.010	0.080	0.070	
Mid-Rise (4–6)	Mean	0.208	0.515	0.044	0.337	1.103	55
	EB	0.111	0.141	0.044	0.101	0.117	
High-Rise (7+)	Mean	0.004	0.731	0.052	0.229	1.017	24
	EB	0.007	0.442	0.062	0.256	0.354	
All Sizes	Mean	0.173	0.187	0.022	0.859	1.241	230
	EB	0.048	0.057	0.011	0.076	0.063	

3.1.3. Non-Residential Space

The surveyor noted the non-residential use in an effort to ensure that the nature of the uses and energy use of the building was properly accounted. The percentage of buildings with non-residential uses is summarized in Table 15. The table shows that low-rise buildings have a tiny percentage of the non-residential uses, while the percentage is significant for mid-rise and high-rise buildings. More than 50% of all buildings have some type of non-residential use, typically separately leased.

Table 15. Percentage of Buildings with Non-Residential Uses by Building Size

Building Size (Stories)	Percentage with Non-Residential Use		
	%	EB	n
Low-Rise (1–3)	0.6%	0.8%	151
Mid-Rise (4–6)	31.5%	23.5%	55
High-Rise (7+)	59.3%	29.9%	24
All Sizes	2.8%	2.0%	230

Table 16 shows the distribution of non-residential uses across multifamily buildings. These uses are dominated by office, retail, and other non-grocery uses, and 'Other' typically means not easily characterized by any of the other categories. Moreover, the percentage of non-residential use available for lease (that is, vacant) is nearly 30% of the total space. The non-residential uses were characterized to include their electric and gas meters and were separated by the surveyor for further characterizing the energy use of these non-residential spaces.

Table 16. Distribution of Non-Residential Floor Area (in Buildings with Non-Residential) by Use Type and Building Size

Non-Residential Use Type		Building Size (Stories)				
		Low-Rise (1–3)	Mid-Rise (4–6)	High-Rise (7+)	All Sizes	n
Grocery	%	–	0.0%	0.3%	0.1%	2
	EB	–	0.1%	0.6%	0.1%	
Office	%	27.3%	0.7%	13.2%	2.3%	11
	EB	42.1%	1.3%	18.0%	3.6%	
Retail	%	27.8%	14.3%	13.1%	14.6%	21
	EB	21.9%	4.5%	13.5%	4.6%	
Vacant	%	11.1%	27.1%	60.2%	28.9%	19
	EB	10.0%	2.0%	37.8%	5.3%	
Other	%	33.8%	57.8%	13.1%	54.2%	11
	EB	29.7%	5.9%	21.4%	10.7%	

Overall, the building characteristics in the multifamily sector suggest a relatively large difference between low-rise buildings and high-rise buildings where multi-story buildings are more easily characterized, as in higher density areas. This typology is maintained throughout this summary, where the mid-rise and high-rise buildings are separated from low-rise buildings, so that the differences in both building shell and HVAC systems can be characterized.

3.2. Demographics

The surveyors asked the building managers to characterize both the building ownership and the nature of the tenancies in the building. Table 17 summarizes the ownership categories that were mentioned as part of the manager interview. As the table shows, the ownership of these buildings is largely characterized by two main categories: (1) corporate or Real Estate Investment Trust (REIT) ownership, in which the building is managed as part of a larger complex of investment properties; and (2) individual ownership where the building is owned by a single, private individual, and often managed by that individual. Additional components that are significant include condos and coops, both of which together represent slightly more than 10% of multifamily buildings, and private non-profit and public agencies, which together represent slightly more than 15% of the buildings.

Table 17. Distribution of Ownership Type by Building Size

Ownership Type		Building Size (Stories)				
		Low-Rise (1–3)	Mid-Rise (4–6)	High-Rise (7+)	All Sizes	n
Cooperative	%	0.7%	5.1%	2.1%	0.9%	4
	EB	1.1%	6.6%	3.6%	1.1%	
Condo Association	%	9.0%	29.0%	38.7%	10.4%	35
	EB	5.5%	15.5%	33.1%	5.3%	
Corporation/REIT	%	42.6%	37.5%	45.9%	42.3%	102
	EB	9.1%	19.0%	31.2%	8.6%	
Individual	%	31.8%	24.1%	–	31.1%	47
	EB	8.8%	25.0%	–	8.4%	
Private Non-Profit	%	11.0%	1.9%	13.3%	10.5%	32
	EB	5.5%	1.7%	11.3%	5.2%	
Public Agency	%	4.9%	2.3%	–	4.8%	10
	EB	4.6%	3.0%	–	4.3%	

Within these ownership types, the manager was asked to characterize the building tenants, along dimensions of both age and income. Table 18 shows the distribution of tenants in three occupancy categories:

- **Assisted Living.** Buildings designed to provide residents with assistance with basic activities of daily living such as bathing, grooming, dressing, and more.
- **Senior Housing.** Buildings designed for older adults, typically 55 years or older.
- **No Demographic Restrictions.** All units without demographic restrictions.

The manager was further asked to characterize the buildings as low-income or unrestricted. In general, the manager used low-income as a category if the building had accepted or otherwise had some public subsidy available to residents. This typically does not mean that low-income tenants are the only tenants in the building; only that they could be renting under various federal city or state programs that provide rent subsidies. As Table 18 shows, about 80% of all units have no income restriction. Alternately, about 90% of the assisted living and senior housing allow low-income tenants.

Table 18. Distribution of Units by Tenant Type and Income Restriction

Tenant Type		Income Restriction			
		Low-Income Only	No Income Restrictions	All Types	n
Assisted Living	%	6.0%	0.5%	1.5%	5
	EB	8.5%	0.5%	1.7%	
Senior Housing	%	28.3%	2.3%	7.2%	21
	EB	15.4%	1.6%	3.5%	
No Demographic Restrictions	%	65.7%	97.2%	91.2%	204
	EB	16.3%	1.7%	3.9%	
All Types	%	18.9%	81.1%	100.0%	230
	EB	5.8%	5.8%		

In the review of the individual units, the surveyors ascertained the age and occupancy of each of the units surveyed. As Table 19 shows, the nature of the age distribution in multifamily buildings is dominated by adults 18 to 64. The number of people per unit is dramatically lower than in the single-family and manufactured home RBSA reports. Overall, the average occupancy is 2.7 occupants per unit in these sectors and about 1.92 for the multifamily units, which is nearly 30% below the occupancy in the other sectors.

Table 19. Average Number of Occupants per Unit by Age Category

Age Category	Average Occupants		
	Mean	EB	n
Children (0 to 17)	0.45	0.11	113
Adults (18 to 64)	1.21	0.16	426
Seniors (65 and Over)	0.27	0.06	145
All Categories	1.92	0.26	684

The building managers were asked to characterize the vacancy rates in these surveyed units. These rates were calculated based on total number of units vacant versus total number of units. The overall vacancy rate is about 5% across all buildings and vintages, and only in the pre-1955 buildings did vacancy rates significantly exceed that amount, with nearly 20% in that vintage. The distribution of vacancy rates is shown in Table 20.

Table 20. Reported Building Vacancy Rate by Vintage

Vintage	Vacancy Rates		
	%		
Pre 1955	19.2%	18.0%	8
1955–1970	3.5%	1.6%	26
1971–1980	4.8%	2.1%	26
1981–1990	3.0%	1.7%	19
1991–2000	3.6%	1.6%	16
Post 2000	6.4%	3.0%	24
All Vintages	4.9%	1.4%	119

4. Building and Common Area Characteristics

This survey characteristics summary is generally divided into two sections. This section focuses on the building as a whole and more specifically on common area uses, lighting, the building envelope, HVAC for the entire building, common area lighting, and equipment and appliances in the common areas. Section 5 focuses on the individual units and characterizes those units on dimensions of unit-level HVAC, DHW, lighting, appliances, and electronics.

4.1. Building Envelope

Multifamily buildings as they are defined by Northwest utilities include all multi-dwelling buildings with five or more units. Thus, the buildings that are considered multifamily range from relatively small buildings that are essentially the same construction types as other residential sectors up to the large-scale multi-story buildings with high-rise construction. This contrast forces a relatively diverse summary that, when combined to assess the overall multifamily sector, leads to comparisons among buildings that are often too different to summarize easily. As a result, the summaries must combine diverse systems and construction types. Due to this diversity, the tables and summaries in this report are expressed by building size when possible (see Section 3.1). As this typology is based on number of stories, the differences in construction type often corresponds to the size divisions used in the report. Like building size, this variable often represents an important differentiation between construction type and details of insulation and window performance. In this section, both of these divisions are employed separately, and in some cases the summaries are unique to particular building types.

The discussion in this section aims to maintain the same basic structure as the review of single-family (Baylon et al., 2012) and manufactured homes (Storm et al., 2013) so that the multifamily homes have comparable indexes to homes surveyed in the other residential sectors.

4.1.1. Construction Type

Multifamily construction is typically divided into two distinct construction types that are employed based on building size, local fire codes, and building codes as enforced in individual states and jurisdictions. The two types are:

1. **Simple framing.** This type of construction uses the techniques of low-rise residential construction as the primary method of constructing the building. The framing uses a combination of stud and header construction to build the structure with elements of sheathing, and trusses add flexibility in the building design. The result of these techniques is that conventional insulation detailing and window detailing are often used, and such buildings can be characterized by the same techniques used in the single-family or manufactured homes sector.
2. **Rigid Frame.** This technique is used to build stronger structures that can be employed in multi-story structures. These techniques are required in buildings taller than about six stories and can be used in smaller buildings depending on the local codes. The fundamental structural elements are a moment frame construction made with either steel or concrete, depending on the needs of the design. The insulation and other components are usually more complex and often involve different detailing and construction to achieve the insulation values required by energy codes. At the same time, these codes are

more lenient for larger buildings. The summaries in this report normalize the heat loss calculation so that buildings using rigid frames can be summarized and compared to low-rise buildings with simple framing.

Over time, the building codes have become less stringent on mid-rise buildings between four and six stories. As a result, today virtually all of these buildings are built with simple residential framing usually on top of a concrete slab or a “post-tension” (PT) slab that forms the base of the building and often includes a parking garage or other non-residential uses. These mid-rise buildings employ a type of hybrid construction in which the lower floors are rigid frame and the upper floors are simple framing. Generally, the residential portions of these buildings use simple framing, and the non-residential, parking, and common areas are located in the lower part of the building.

Table 21 divides these two basic categories into each of their own separate categories. The rigid frame has been divided into concrete rigid frame and steel rigid frame. These two framing strategies are essentially equivalent and are often interchangeable depending on the particular cost structure in any particular local area.

Table 21. Distribution of Structural System Types by Building Size

Building Size (Stories)		Structural System				
		Rigid Frame Concrete	Rigid Frame Steel	Steel Framing	Wood Framing	n
Low-Rise (1–3)	%	0.4%	–	0.1%	99.5%	151
	EB	0.6%	–	0.1%	0.6%	
Mid-Rise (4–6)	%	19.8%	–	4.4%	75.7%	55
	EB	25.7%	–	5.3%	24.9%	
High-Rise (7+)	%	56.8%	2.9%	27.8%	12.5%	24
	EB	32.2%	4.0%	35.2%	10.4%	
All Sizes	%	1.9%	0.0%	0.5%	97.5%	230
	EB	1.8%	0.0%	0.5%	1.9%	

The simple framing is divided into steel framing and wood framing, the latter of which is the most common. Steel framing is used sparingly in this region, but it is employed in larger structures. Simple framing can be used in conjunction with rigid frames as part of either in-fill walls or building skin. In a few cases, the lower floors of the building can be constructed using rigid frame concrete and PT slabs. In some cases, three stores of construction can form the base of the building while four to five stories of simple frame residential construction is built on top of this construction. The surveyors were instructed to characterize the residential portion of the building, and in those cases the framing type noted is simple wood or steel framing.

Table 21 shows that wood framing accounts for more than 97% of the multifamily buildings that were reviewed. The remaining rigid frame construction is typically reserved for the relatively rare cases of high-rise multifamily buildings. To further characterize these larger buildings, Table 22 divides this rigid frame subset of buildings into the types of finish exterior skin. Over the last 60 years, many different skin types have been used depending on the architectural style and building codes of the day. These exterior skin types include brick, concrete, curtain walls, window walls, and steel frame and wood framing in an in-fill capacity within the rigid frame.

Table 22. Distribution of Wall Area by Structural System and Wall Type in Rigid Frame Buildings

Structural System		Wall Type: Brick	Concrete	Concrete Below Grade	Concrete Block	Curtain Wall	Steel Framing	Window Wall	Wood Framing	n
Concrete Rigid Frame	%	45.4%	8.0%	0.4%	15.7%	1.5%	14.3%	1.6%	13.0%	17
	EB	41.1%	8.6%	0.5%	17.6%	2.7%	19.1%	2.3%	21.1%	
Steel Rigid Frame	%	13.3%	–	3.8%	–	–	22.2%	60.6%	–	3
	EB	21.4%	–	6.6%	–	–	36.3%	48.5%	–	
All Systems	%	43.5%	7.6%	0.6%	14.8%	1.4%	14.7%	5.2%	12.3%	20
	EB	39.7%	7.8%	0.7%	16.2%	2.5%	18.2%	7.0%	19.7%	

The dominant wall finish types are window walls and curtain walls. These walls together represent about 80% of the rigid frame construction. Older construction uses extensive amounts of concrete and masonry. Only 12% of these buildings use wood or steel framing on the exterior surface.

4.1.2. Windows

Windows provide the largest source of heat loss for multifamily buildings. However, they are also key to providing a livable environment in a building with a large amount of floor area but a relatively small amount of building perimeter. Table 23 shows the distribution of windows by building vintage and window type.

Table 23. Distribution of Window Area by Building Vintage and Window Type

Vintage		Window Type: Metal Double	Metal Double Low-E	Metal Single	Wood, Vinyl, or Fiberglass Double	Wood, Vinyl, or Fiberglass Low-E	Wood, Vinyl, or Fiberglass Single	n
Pre 1955	%	13.6%	19.3%	13.7%	12.1%	23.1%	18.3%	31
	EB	9.3%	20.8%	11.7%	12.4%	15.6%	20.9%	
1955–1970	%	5.9%	12.4%	42.2%	11.5%	27.8%	0.2%	80
	EB	4.6%	11.3%	15.0%	8.8%	12.9%	0.3%	
1971–1980	%	19.1%	15.4%	24.9%	3.1%	36.8%	0.8%	75
	EB	9.8%	10.4%	12.2%	3.8%	11.5%	0.9%	
1981–1990	%	26.4%	14.4%	4.8%	25.8%	28.4%	0.1%	60
	EB	12.0%	9.6%	7.4%	14.7%	15.1%	0.2%	
1991–2000	%	12.1%	4.0%	1.1%	12.3%	70.4%	–	47
	EB	12.9%	3.4%	1.7%	11.1%	15.3%	–	
Post 2000	%	2.7%	29.3%	–	13.2%	54.8%	–	44
	EB	4.2%	22.3%	–	13.9%	22.0%	–	
All Vintages	%	14.4%	14.7%	16.3%	12.5%	40.9%	1.1%	337
	EB	4.3%	5.3%	5.2%	4.6%	6.6%	1.0%	

The important finding in this summary is that, although 80% of the buildings were built before 1990, nearly 60% of the windows use Low-E coatings, and most of those use modern vinyl frames. Because this type of window was available only after 1990, virtually two-thirds of these window and more than half of the older buildings in this sample apparently have retrofit more modern windows into these buildings. In many parts of the region, individual utilities have supported glazing retrofits in this sector. However, it appears that the pervasiveness of this measure transcends the utility programs and seems to indicate an ongoing effort to upgrade the building value on the part of the building owners themselves.

Metal windows represent about 50% of the windows in all the buildings. About one-third of the metal frame windows are in modern high-rise buildings. Overall, 75% of the windows built after 1990 are modern, efficient windows with double glaze and Low-e coating and usually vinyl framing except in cases where metal curtain walls are a part of the construction detailing.

Table 24 normalizes the window to wall area by building size. Table 25 normalizes the window to floor area. These ratios are relevant because they are used in most energy codes in the region as the basis for regulating window area. In general, the low-rise and mid-rise buildings in Oregon and Washington are built to residential energy codes. Those codes typically regulate window area to 15% of wall area or 15% of floor area. The low-rise ratios in Table 24 and Table 25 meet or exceed these requirements.

Table 24. Window to Wall Area Ratio by Building Size

Building Size (Stories)	Window to Wall Area Ratio		
	Mean	EB	n
Low-Rise (1–3)	0.145	0.007	151
Mid-Rise (4–6)	0.190	0.029	55
High-Rise (7+)	0.290	0.048	24
All Sizes	0.157	0.008	230

Table 25. Window to Floor Area Ratio by Building Size

Building Size (Stories)	Window to Floor Area Ratio		
	Mean	EB	n
Low-Rise (1–3)	0.107	0.005	151
Mid-Rise (4–6)	0.097	0.023	55
High-Rise (7+)	0.124	0.013	24
All Sizes	0.107	0.006	230

In mid-rise and high-rise buildings, the Washington buildings have been regulated at the same level throughout the period from 1990 to 2010. Oregon, on the other hand, in this building class, has used the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) 90.1 energy code standard for larger residential buildings, which allows up to 30% window to wall ratios for glazing. Table 24 shows that the effect of these regulations has been to allow higher glazing areas in the larger buildings.

The Washington code, and only for the 1990-2010 period, has used the window to floor area ratio. Table 25 shows that when normalized to the overall floor area, window areas in multifamily buildings are close to 10% of conditioned floor area. This calculation is done based on the entire conditioned floor area including all common areas. As also shown in Table 25, the glazing area in high-rise buildings is only about 20% larger (when normalized by floor area) than the low-rise buildings.

4.1.3. Walls

Wall construction as summarized in this report refers to the skin of the building. The underlying structure has been ignored for purposes of this summary so that components that contain the insulation and the other thermal properties of the building are considered.

Table 26 shows the distribution of the wall types used in this summary. Wood framing represents about 90% of all the wall area reviewed, with a small amount of steel framing in both in-fill steel, which is largely within rigid frame buildings, and conventional steel frame stud construction, which is sometimes used as part of conventional low-rise construction. Finally, slightly less than 10% of wall area is of masonry construction, usually in older buildings where concrete construction is more typical of both high-rise and mid-rise structures.

Table 26. Distribution of Wall Area by Building Size and Wall Type

Building Size (Stories)		Wall Types					
		In-fill Steel	Masonry	Steel Frame	Wood Frame	Other	n
Low-Rise (1–3)	%	–	3.7%	–	95.8%	0.5%	200
	EB	–	1.4%	–	1.6%	0.8%	
Mid-Rise (4–6)	%	6.8%	24.9%	–	67.1%	1.2%	89
	EB	10.6%	21.4%	–	21.4%	1.1%	
High-Rise (7+)	%	–	41.2%	12.9%	43.1%	2.8%	33
	EB	–	21.1%	20.3%	24.3%	4.8%	
All Sizes	%	0.9%	8.1%	0.5%	89.8%	0.7%	322
	EB	1.5%	3.8%	0.9%	4.2%	0.7%	

Table 27 shows a distribution of overall insulation levels across the various wall types. In general, wall framing includes a small amount of uninsulated walls, nearly all of which are framed furring on masonry walls, either as part of a below-grade system or even as part of building skin that uses brick faced on frame walls above grade. The "Other" walls are largely curtain walls and in-fill walls and are rarely uninsulated anywhere in the region.

Table 27. Distribution of Wall Insulation by Wall Type

Wall Type		Wall Insulation Levels					
		R0–R7	R8–R13	R14–R20	R21–R23	R24+	n
Frame	%	2.8%	64.7%	30.9%	1.4%	0.1%	208
	EB	2.2%	7.6%	7.5%	2.3%	0.1%	
Masonry/Concrete	%	73.0%	11.9%	13.0%	0.6%	1.5%	117
	EB	15.2%	7.5%	10.8%	1.0%	1.4%	
Other	%	–	81.0%	0.8%	18.2%	–	4
	EB	–	30.6%	1.6%	30.3%	–	
All Types	%	8.7%	60.6%	28.9%	1.7%	0.2%	291
	EB	4.4%	7.3%	6.9%	2.1%	0.2%	

Aside from the masonry construction, however, for most kinds of framing the most common insulation levels are roughly an R-11, installed either in steel studs or wood studs. This insulation can be included as furring in masonry construction or as part of a furring system in curtain wall construction. In this summary, if the wall framing is steel, the insulation has been derated to account for the thermal bridging typical in steel stud framing. This level of insulation performance represents about 60% of the wall systems reviewed. The remaining 30% used are R-19, R-21 or similar, higher grades of insulation.[10]

4.1.4. Ceilings

Ceiling and roof construction are the most straightforward of any of the components in the multifamily sector. Table 28 shows the distribution of various ceiling types. The ceilings and roof structures have been divided into four categories:

1. **Attic Ceilings.** The most dominant ceiling type for low-rise and mid-rise is an attic type ceiling, which uses a cavity constructed above the top floor ceiling. This construction type is particularly common in newer buildings but is also common in smaller building across the sector. About 72% of all the ceiling structures reviewed included attic ceilings.
2. **Roof Deck.** The use of roof deck ceilings is common particularly among high-rise buildings. This type of ceiling is a single layer construction, often concrete, that provides a sheathing and sub-straight for the roof but is insulated only when installation is glued to the roof sheathing prior to roofing or glued to the underside of the decking system prior to final ceiling finish. This ceiling type represents 95% of all the high-rise buildings but is relatively rare in low-rise buildings and represents nearly half of the mid-rise buildings.
3. **Vault Ceilings.** Vault ceilings are a frame ceiling with a cavity that provides an area for insulation material, but the insulation levels are limited to the depth of the cavity provided. Our surveyors typically used the vault ceiling to refer to any type of frame ceiling that has a frame sheathing and not solid roof decking.
4. **Other.** Other ceilings represent miscellaneous construction types that the surveyors had trouble assigning to the other major categories.

[10] The R-19 insulation level is equivalent to the requirements of the Washington energy code for all residential construction (including multifamily buildings) after 1990. In the Oregon code, only the low-rise buildings required this standard. In Idaho and Montana, the insulation requirements were largely ignored in this sector until 2001 with the introduction of the International Energy Conservation Code (IECC).

Table 28. Distribution of Ceiling Area by Building Size and Ceiling Type

Building Size (Stories)		Ceiling Type				
		Attic Ceiling	Roof Deck Ceiling	Vault Ceiling	Other Ceiling	n
Low-Rise (1–3)	%	77.0%	16.2%	5.4%	1.4%	160
	EB	7.0%	6.0%	4.0%	2.1%	
Mid-Rise (4–6)	%	47.2%	47.4%	1.2%	4.2%	63
	EB	20.5%	21.6%	1.5%	4.9%	
High-Rise (7+)	%	3.2%	95.0%	1.8%	–	26
	EB	4.7%	5.9%	3.1%	–	
All Sizes	%	72.4%	21.0%	4.9%	1.6%	249
	EB	6.9%	6.2%	3.5%	1.9%	

Table 29 shows the insulation level in the ceiling structures. This table provides a picture of the insulation levels as they have been historically used in this sector. The ceiling types in this sector are dominated by the attic ceiling types. This ceiling type is the relatively easy to insulate and is the most readily retrofit to meet modern standards. Attic insulation above R-16 represents nearly 80% of all multifamily attics, and in some cases these levels approach R-40 often with blown insulation technologies. More than two-thirds of the ceilings are insulated to greater than R-20. Although this reflects new construction energy code standards in older vintages, these insulation levels are probably due to retrofits in the attic ceilings category.

Roof deck installation is typically uninsulated or insulated modestly using some type of rigid insulation. About two-thirds of the roof decks are effectively uninsulated. The remainder of the roof decks is insulated, which implies roof decks that were built under enforced building codes sometime after 1990.

Typically the vaults are insulated to R-11, even in older vintage types. This factor is often the result of building standards that were employed in the 1960s and 1970s where insulation was used in part to improve the performance of the buildings, but also to reduce sound transmission and noise levels in the apartments in urban areas.

Table 29. Distribution of Ceiling Insulation by Ceiling Type

Ceiling Type		Ceiling Insulation Levels								
		R0–R10	R11–R15	R16–R20	R21–R25	R26–R30	R31–R40	R41–R50	R50+	n
Attic Ceiling	%	11.7%	10.2%	19.9%	9.0%	8.5%	35.0%	4.2%	1.4%	145
	EB	5.5%	5.9%	8.2%	4.8%	4.8%	9.8%	3.0%	1.6%	
Roof Deck	%	65.5%	3.7%	9.1%	–	10.8%	10.9%	–	–	92
	EB	13.0%	4.1%	6.5%	–	7.6%	6.1%	–	–	
Vault Ceiling	%	–	76.0%	17.8%	–	4.3%	2.0%	–	–	11
	EB	–	21.3%	17.8%	–	6.0%	2.8%	–	–	
Other	%	20.8%	–	9.7%	–	69.4%	–	–	–	5
	EB	31.8%	–	18.3%	–	40.5%	–	–	–	
All Types	%	22.6%	11.9%	17.4%	6.5%	9.8%	27.8%	3.1%	1.0%	245
	EB	6.7%	5.4%	6.3%	3.5%	4.2%	7.7%	2.2%	1.1%	

4.1.5. Floors

Multifamily floors represent the most complex component in the building shell assessment. Often these floors are above non-residential occupancies that may or may not be conditioned. In addition, parking and other building services are generally located below the conditioned residential areas and may or may not be conditioned. For our purposes, surveyors attempted to discern which spaces were conditioned and which were unconditioned and defined the floors in terms of what component separated the conditioned residential floors from the unconditioned floors at the base of the building.

Table 30 summarizes the wide variety of floor conditions in multifamily buildings. In general, there are several types of slab floors and several types of frame floors that were used to describe floor systems in this sector. The slab floors are either slab-on-grade or floors over other spaces in the building:

- **Slab-on-Grade.** The slab-on-grade floor systems represent more than half of all floors. These floors dominate the low-rise buildings but are also used extensively in the large buildings. The principle variation is the fact that in low-rise buildings these floors generally face into ground floor units. In the high-rise buildings, these floors face into conditioned common areas on the ground floor of the buildings.
- **Conditioned Basement Slab.** This floor type generally refers to a ground floor below grade that is either part of the residential floor area or part of the conditioned common area. These slabs are mostly uninsulated, although in a few recently constructed cases perimeter insulation was noted on construction documents. The basement slabs were assumed to be uninsulated unless direct evidence of perimeter insulation could be discerned.
- **Slab over Unconditioned Area.** In many mid-rise buildings, the building is constructed with a structural PT slab. The residential units are framed above this slab using the PT slab as a pedestal. In these cases, the area below the slab can be non-residential tenants, parking, or various unconditioned or conditioned spaces. In this floor type, the insulation barrier for the building is taken to be the floor slab, and the heat loss associated with that component is determined by insulation attached to the underside of the floor structure.
- **Slab over Parking.** This is a typical case where the PT slab acts as the ceiling of the parking area. These buildings are generally newer urban buildings where the zoning code requires parking integral to the structure. Insulation in these cases is attached to the underside of the slab and is usually covered with fire-resistant material.
- **Slab over Conditioned Area.** This category is reserved for slab floors that face into units but are above ground-floor non-residential uses. These uses are not generally part of the residential use or the common area of the building and are treated in these summaries as separate spaces outside of the multifamily usage.

The principle alternative floor structure is a frame floor. These floor types are typically wood or Trus Joist I-Joist (TJI®) construction.[11] There are several variations in floor framing that are relevant to this analysis. The following floor construction options roughly parallel the slab options developed above:

- **Frame Floor Over Crawlspace.** This is the most common type of frame floor and is almost exclusively found in low-rise buildings. The floor is framed over an unconditioned crawlspace and is typically insulated, but the crawlspace provides a buffer that improves the effectiveness of the floor insulation.
- **Frame Over Unconditioned Area.** Aside from crawlspaces, the floor framing is occasionally over an unconditioned area such as storage. In this case, like the slab floors in similar situations, the insulation level is derived from the insulation above this unconditioned space.
- **Frame Floor Over Parking.** The use of frame floor over parking areas is relatively rare. There is only a small amount of this floor type in this sector and only in low-density low-rise buildings.
- **Frame Floor Over Conditioned Area.** This is also rare and refers to the same condition as the slab floor where the floor is over a non-residential space that is outside the residential and common areas of the building.

Table 30. Distribution of Floor Area by Building Size and Floor Type

Floor Type		Building Size (Stories)				
		Low-Rise (1–3)	Mid-Rise (4–6)	High-Rise (7+)	All Sizes	n
Conditioned Basement Slab	%	5.3%	23.8%	3.0%	7.2%	28
	EB	3.6%	26.5%	3.3%	4.5%	
Frame Floor Over Crawlspace	%	29.0%	5.4%	–	25.8%	45
	EB	8.7%	4.1%	–	7.7%	
Frame Floor Over Conditioned	%	0.2%	4.5%	20.6%	1.2%	26
	EB	0.3%	2.8%	8.8%	0.6%	
Frame Floor Over Parking	%	5.4%	5.4%	–	5.3%	26
	EB	3.2%	5.3%	–	2.9%	
Frame Floor Over Unconditioned	%	1.0%	6.2%	0.0%	1.5%	32
	EB	0.9%	5.1%	0.1%	0.9%	
Slab Over Conditioned	%	0.2%	4.5%	20.6%	1.2%	26
	EB	0.3%	2.8%	8.8%	0.6%	
Slab Over Unconditioned	%	0.2%	0.2%	1.1%	0.2%	12
	EB	0.2%	0.3%	1.3%	0.2%	
Slab Over Parking	%	0.9%	22.1%	37.9%	4.0%	42
	EB	1.0%	13.0%	10.1%	1.8%	
Slab on Grade	%	57.8%	27.9%	16.8%	53.6%	127
	EB	8.8%	14.3%	21.5%	8.0%	

[11] TJI® construction uses a manufactured structural wood product that is factory milled to optimize structural strength. This type of construction is typical in multifamily framing between floors and in some cases is used for the floor below the residential area.

The insulation levels in these floors have been combined into the various classes of insulation shown in Table 31. Generally, these classes are the effective performance levels that were developed as part of subsuming insulation observations across the various floor types. A low level of floor insulation is common in about one-third of the buildings. These levels reflect the relative importance of floor insulation and most detailing prior to the energy codes. In most cases, buildings outside of Washington and Oregon built prior to 1990 did not use building codes, and we assumed that the floors were uninsulated unless the surveyors were able to directly observe the insulation.

Table 31. Distribution of Floor Insulation Levels by Floor Type

Floor Type		Floor Insulation Levels							
		None	R0–R3	R4–R10	R11–R15	R16–R22	R23–R27	R28–R35	n
Over Crawlspace	**%**	25.3%	–	41.5%	2.5%	20.7%	0.7%	9.3%	45
	EB	16.8%	–	18.0%	2.3%	14.9%	0.7%	8.3%	
Over Other Unconditioned	**%**	5.9%	21.7%	–	19.6%	12.9%	1.3%	38.7%	115
	EB	3.2%	15.1%	–	13.8%	7.7%	2.1%	14.9%	
Over Unconditioned Basement	**%**	–	–	58.3%	30.8%	10.9%	–	–	3
	EB	–	–	51.0%	46.3%	20.0%	–	–	
All Types	**%**	19.2%	6.7%	28.8%	7.9%	18.2%	0.8%	18.3%	159
	EB	12.0%	5.5%	13.2%	5.2%	10.6%	0.8%	8.1%	

About 55% of all buildings have relatively little or no floor insulation. In the remaining buildings, the floor insulation is typically either R-19 or R-30 depending on local codes. These insulation levels are typically either as rigid foam insulation on the underside of slabs over parking garages or other kinds of unconditioned space, or part of frame floors that are located either over crawlspaces or over garage or other unconditioned areas. Typical of these applications, fire-protective sheet rock is part of the floor structure that divides these uses from the residential space.

4.1.6. Overall Heat Loss Performance

The heat loss rate of the surveyed buildings has been calculated using the insulation summaries shown in Table 27, Table 29 and Table 31 in addition to the window performance in Table 23. It should be noted that the heat loss rate reported in these summaries does not include heat loss from infiltration or ventilation that might occur in these buildings. The heat loss calculation has been normalized in two different ways: one based on an average heat loss rate per unit in each building summarized by building size and vintage; and the second based on heat loss rate per square foot of conditioned floor area that normalizes heat loss rate across all conditioned floor area including residential space and common areas.

Table 32 and Table 33 show the results of the heat loss rate normalized by unit. Heat loss rate per unit is low and does not vary much by building size, as shown in Table 32. Table 33 on the other hand shows the distribution of heat loss rates by vintage across all buildings, and this summary shows the heat loss rate trending downward for newer buildings. The buildings built after 1990 show heat loss rates that average per unit about one-third of the oldest vintage and only 60% of the rate for vintages built prior to 1981.

Table 32. Average UA per Unit by Building Size

Building Size (Stories)	Heat Loss Rate (UA per Unit)		
	Mean	EB	n
Low-Rise (1–3)	199	13	151
Mid-Rise (4–6)	229	96	52
High-Rise (7+)	186	43	24
All Sizes	202	16	227

Table 33. Average UA per Unit by Vintage

Vintage	Heat Loss Rate (UA per Unit)		
	Mean	EB	n
Pre 1955	404	160	18
1955–1970	239	22	54
1971–1980	200	20	50
1981–1990	188	33	44
1991–2000	153	12	31
Post 2000	144	22	30
All Vintages	202	16	227

When the overall heat loss rate of individual units is compared to the single-family RBSA summaries, the overall heat loss rates of multifamily residences without ventilation is less than one-third of the heat loss rate in single-family homes. This finding includes the fact that a large percentage of the multifamily sector is relatively uninsulated, especially prior to the 1980 vintages. This reflects the importance of the small amount of surface relative to floor area in the multifamily sector compared to individual, separately heated homes in the single-family sector. Table 34 reinforces this point, showing the heat loss rate of the buildings normalized by conditioned floor area. As the size of the buildings increases, the heat loss rate decreases. Thus, mid-rise and high-rise buildings have 25% less heat loss rate per square foot of conditioned space than the low-rise buildings, even though the low-rise buildings are often as well or better insulated.

Table 34. Average UA per Conditioned Sq.Ft. by Building Size

Building Size (Stories)	Heat Loss Rate (UA per Sq.Ft.)		
	Mean	EB	n
Low-Rise (1–3)	0.234	0.016	151
Mid-Rise (4–6)	0.173	0.026	52
High-Rise (7+)	0.166	0.029	24
All Sizes	0.219	0.013	227

The average heat loss rates for the multifamily buildings are about 50% more than the RBSA single-family homes when normalized by conditioned floor area. Again, this apparent increase in efficiency is largely due to the reduced surface area associated with the conditioned space enclosed in a multifamily building.

4.2. Building and Common Area HVAC Systems

Because the multifamily sample was drawn as a random sample of buildings across the region, the dominant form of these buildings is relatively small, low-rise wood frame structures averaging about 20 units or less. Thus, the summary of HVAC systems in such buildings is dominated by the types of systems found in these smaller buildings. As shown in Table 4, approximately 1% of multifamily buildings are high-rise buildings, and only 5% are larger than three stories. However, the sample also includes a large oversample in the Puget Sound area.

4.2.1. Heating Systems

Table 35 and Table 36 summarize primary heating systems. In both tables, the systems are divided into two sections. The first three rows are central systems that assume a central distribution system; the next four rows are systems that are installed at each individual unit. The heating system types are:

- **Central Air Conditioning (AC) and Ventilation.** This system assumes an air-side delivery system that provides both ventilation and heating to the units from a central system such as a furnace or heat pump. Usually these systems are small and reflect a small number of units gathered together around a single air-distribution system.
- **Central Water Source Heat Pump (WSHP) Loop/ Variable Refrigerant Flow (VRF).** These systems are uncommon but are used extensively in larger buildings. In general, the HP loop is set up as a water-based system that circulates to each individual unit, or to the common areas, and is centrally controlled by a boiler heat source and a cooling tower evaporative cooler. The individual units or zones have a small heat pump that uses this water source as input to meet heating and cooling demand. The VRF system is a central system in which the heat pump loop is a refrigerant controlled by a central compressor or compressor system and individual air handling units that are controlled by the tenant for heating and cooling.
- **Central Hydronic/Steam.** A central hydronic system is typically a single boiler-based system that provides radiant heat throughout the building. These systems include hydronic water-based systems and steam systems. In a few cases, the hot water is circulated through an air handler unit in the unit, which is controlled by the tenant. In most these cases, there is a water-cooled chiller that also can supply the air handler unit with chilled water for cooling.
- **Baseboard Heater.** The zonal heating system is based on a single zone electric control in every room, usually with individually thermostats by zone so the tenant controls the temperature in all the zones in the individual apartment unit.
- **Forced Air Furnace.** The forced-air system is a single furnace supplying the individual unit. This furnace can be fired either with electric resistance elements, heat pumps, or gas furnaces.
- **PTHP/PTAC/DHP.** This category includes packaged terminal heat pumps (PTHP), packaged terminal air conditioners (PTAC) with electric resistance heating elements, or ductless heat pumps (DHP) that provide single zone heating and cooling to the unit.

- **Stove**. Stoves are either a heat-rated fireplace or similar stove that uses a thermostat or tenant preference, and can provide heating to at least the central area of an apartment, and often to the entire unit.

The central systems are typically located in the larger buildings (Table 36), but baseboard heating is a significant part of that population, accounting for more than 65% of all heating in high-rise construction, and nearly 70% of all the heating in mid-rise construction.

With few exceptions, the central systems use natural gas for the primary heating fuel. Nearly 90% of the central systems use gas for their heating. Only about 7% of the individual unit zonal heating is handled by natural gas (Table 72).

Baseboard heaters are the most common in-unit systems (Table 35). It is pervasive in virtually all vintages. The other in-unit systems account for approximately 12% of the overall region and are, like the baseboard heaters, controlled autonomously at each individual unit. The central systems represent only a small percentage, less than 7%, of all units and are almost exclusively located in high-rise buildings in the urban core (Table 36).

Table 35. Distribution of Primary Heating Systems by System and Fuel Type

Primary Heating System		Fuel Type						
		Air Source Heat Pump	Electric	Natural Gas	Oil	Purchased Steam	All Types	n
Central AC/Ventilation	%	–	–	2.3%	–	–	2.3%	1
	EB	–	–	3.7%	–	–	3.7%	
Central WSHP Loop/VRF	%	0.2%	–	0.0%	–	–	0.2%	3
	EB	0.4%	–	0.0%	–	–	0.4%	
Central Hydronic/Steam	%	–	–	3.3%	0.7%	0.0%	4.0%	15
	EB	–	–	3.0%	1.2%	0.0%	3.2%	
Baseboard Heater	%	–	80.6%	–	–	–	80.6%	192
	EB	–	7.2%	–	–	–	7.2%	
Forced Air Furnace	%	1.8%	0.8%	3.1%	–	–	5.7%	10
	EB	2.8%	1.0%	2.7%	–	–	4.0%	
PTHP/PTAC/DHP	%	3.5%	–	–	–	–	3.5%	4
	EB	3.1%	–	–	–	–	3.1%	
Stove	%	–	–	3.7%	–	–	3.7%	6
	EB	–	–	3.7%	–	–	3.7%	
All Systems	%	5.5%	81.4%	12.3%	0.7%	0.0%	100.0%	231
	EB	4.1%	7.1%	6.2%	1.2%	0.0%		

Table 36. Distribution of Primary Heating System by Building Size

Primary Heating System		Building Size (Stories)				
		Low-Rise (1–3)	Mid-Rise (4–6)	High-Rise (7+)	All Sizes	n
Central AC/Ventilation	**%**	2.4%	–	–	2.3%	1
	EB	3.9%	–	–	3.7%	
Central WSHP Loop/VRF	**%**	–	–	29.3%	0.2%	3
	EB	–	–	34.8%	0.4%	
Central Hydronic/Steam	**%**	4.2%	1.5%	5.6%	4.0%	15
	EB	3.4%	1.6%	6.5%	3.2%	
Baseboard Heater	**%**	81.4%	68.7%	65.1%	80.6%	192
	EB	7.5%	24.1%	33.6%	7.2%	
Forced Air Furnace	**%**	5.5%	10.5%	–	5.7%	10
	EB	4.2%	10.1%	–	4.0%	
PTHP/PTAC/DHP	**%**	2.6%	19.0%	–	3.5%	4
	EB	2.8%	25.9%	–	3.1%	
Stove	**%**	3.9%	0.3%	–	3.7%	6
	EB	3.9%	0.5%	–	3.7%	

Table 37 and Table 38 show the distribution of secondary systems. About 98% of the unit population has no secondary system. Of the remaining 2%, there are several systems that are zonal systems. These systems typically provide backup either to the combustion stoves in the case of electric resistance, or to some central system that has a backup to an older hydronic loop or radiant system. In general, these secondary systems are not designed to heat or cool the whole unit or the whole building, but are designed to provide a measure of additional comfort and control to systems that might otherwise not be easily controlled or distributed throughout the apartment.

Table 37. Distribution of Secondary Heating Systems by System and Fuel Type

Secondary Heating System		Fuel Type					
		Air Source Heat Pump	Electric	Natural Gas	None	All Types	n
Central WSHP Loop/VRF	**%**	0.1%	–	0.0%	–	0.2%	5
	EB	0.2%	–	0.0%	–	0.2%	
Baseboard Heater	**%**	–	0.8%	–	–	0.8%	16
	EB	–	0.6%	–	–	0.6%	
Forced Air Furnace	**%**	0.3%	0.0%	0.1%	–	0.4%	20
	EB	0.2%	0.0%	0.1%	–	0.2%	
PTHP/PTAC/DHP	**%**	0.2%	0.5%	–	–	0.7%	15
	EB	0.2%	0.5%	–	–	0.5%	
Stove	**%**	–	–	0.2%	–	0.2%	3
	EB	–	–	0.2%	–	0.2%	
None	**%**	–	–	–	97.8%	97.8%	191
	EB	–	–	–	1.0%	1.0%	
All Systems	**%**	0.6%	1.3%	0.3%	97.8%	100.0%	250
	EB	0.4%	0.9%	0.2%	1.0%		

Table 38. Distribution of Secondary Heating System by Building Size

Secondary Heating System		Building Size (Stories)				
		Low-Rise (1–3)	Mid-Rise (4–6)	High-Rise (7+)	All Sizes	n
Central WSHP Loop/VRF	%	–	0.6%	14.8%	0.2%	5
	EB	–	1.1%	17.4%	0.2%	
Baseboard Heater	%	0.5%	4.7%	11.4%	0.8%	16
	EB	0.5%	4.2%	11.5%	0.6%	
Forced Air Furnace	%	0.1%	3.0%	13.1%	0.4%	20
	EB	0.1%	2.3%	12.1%	0.2%	
PTHP/PTAC/DHP	%	0.4%	2.4%	18.9%	0.7%	15
	EB	0.5%	3.2%	16.6%	0.5%	
Stove	%	–	3.2%	2.1%	0.2%	3
	EB	–	4.1%	3.6%	0.2%	
None	%	99.0%	86.1%	39.7%	97.8%	191
	EB	0.8%	9.2%	29.7%	1.0%	

Table 39 summarizes common area heating. This summary is limited to buildings with heating systems that are designed for common areas only. The top three rows are central systems that supply the entire common area but not the remainder of the building. The remaining rows describe systems that serve individual zones within the common area. As with the overall building, the dominant systems are baseboard heaters with relatively few alternative systems used throughout the common areas. This summary represents approximately 40% of all buildings; however, it also represents approximately two-thirds of all the buildings with conditioned common area. The bulk of the remaining one-third of the common areas not summarized in Table 39 either have no space heat or are indirectly heated by air or heat circulating from the units into the common area.

Table 39. Distribution of Common Area Primary Heating Systems by System and Fuel Type

Primary Common Area Heating System		Fuel Type					
		Air Source Heat Pump	Electric	Natural Gas	Purchased Steam	All Types	n
Central AC/Ventilation	%	1.4%	4.7%	5.8%	0.1%	12.0%	40
	EB	2.3%	4.4%	3.5%	0.2%	6.6%	
Central Hydronic/Steam	%	–	–	4.9%	0.2%	5.0%	6
	EB	–	–	5.3%	0.3%	5.3%	
Central WSHP Loop/VRF	%	–	–	–	–	–	0
	EB	–	–	–	–	–	
Baseboard Heater	%	–	77.2%	–	–	77.2%	41
	EB	–	10.9%	–	–	10.9%	
Forced Air Furnace	%	0.0%	2.1%	2.0%	–	4.1%	4
	EB	0.1%	3.4%	3.2%	–	4.7%	
PTHP/PTAC/DHP	%	1.4%	0.3%	–	–	1.7%	3
	EB	2.4%	0.4%	–	–	2.4%	
All Systems	%	2.8%	84.2%	12.7%	0.3%	100.0%	94
	EB	3.4%	8.6%	7.5%	0.3%		

4.2.2. Cooling Systems

Like most residential buildings in the region, only a limited amount of cooling is provided to multifamily buildings. Only about 38% of all buildings have some type of cooling system. Table 40 summarizes the cooling systems in the multifamily sector. The systems noted are diverse but are largely focused on zonal cooling in the units:

- **Central Water Source Heat Pump (WSHP)/VRF.** This is a central cooling system that uses a heat pump loop. In all cases, these systems also supply heating to the units and common areas.
- **Central Fan Coils/Chiller.** This is a water based system that provides cooling from a chilled water loop. Cooling is provided by fan coils located in the units. In all cases, a parallel hot water loop provides heating to these same fan coils.
- **Ductless AC/HP.** These systems are zonal DHPs that supply cooling and/or heat to the units.
- **Forced Air AC/HP.** These systems are conventional, residential, ducted, forced air split systems using either a heat pump or some other fuel for heating and an outdoor compressor for cooling.
- **Packaged Terminal.** These systems are a variety of single-zone packaged units including window AC units and through-the-wall packaged terminal air conditioner (PTAC) units.
- **Building Ventilation System.** In some buildings, the ventilation supply fan is configured with a cooling coil or controlled to provide outside air to cool the common area. This system generally works like an economizer to cool the common areas of the building.

Table 40. Distribution of Unit Cooling Systems

Cooling System	Percentage of Units		
	%	EB	n
Central WSHP/VRF	0.2%	0.4%	3
Central Fan Coils/Chiller	0.3%	0.6%	1
Ductless AC/HP	2.6%	2.7%	4
Forced Air AC/HP	4.3%	4.0%	5
Packaged Terminal	23.1%	7.8%	30
No Cooling	62.9%	8.8%	182
Unknown	6.5%	5.3%	5

Less than 1% of the units are cooled by central systems, which are usually either WSPHs or four-pipe fan coils with chillers. The most dominant systems are zonal systems that are installed in the units, including both DHPs and packaged terminal units. A small number of multifamily units have forced-air with split air conditioning. These systems are installed in small buildings with individual forced-air systems as part of the unit air-conditioning. Similar to the RBSA single-family findings, a percentage of units (about 38%) use cooling directly, and more than 60% of all units have no cooling.

Table 41 summarizes the cooling supplied to the common areas. Like the overall buildings, nearly 70% have no recorded cooling. The remaining 25% of the common area is cooled with packaged terminal units or ductless systems. The remaining systems are supplied from central systems.

Table 41. Distribution of Common Area Cooling Systems

Cooling System	Percentage of Common Areas		
	%	EB	n
Building Vent System	1.6%	1.3%	11
Ductless AC/HP	3.1%	2.8%	16
Evaporative Cooler	0.5%	0.9%	2
Fan Coils/Chiller	0.0%	0.0%	1
Forced Air AC/HP	2.9%	2.1%	22
Packaged Terminal	20.1%	15.7%	15
WSHP/VRF	0.6%	0.7%	5
None	69.2%	16.3%	53
Unknown	1.9%	3.2%	1

4.2.3. Building Ventilation Systems

Table 42 summarizes building ventilation systems. The systems used for building ventilation can be a major factor in the efficiency of the entire building. Generally, these systems are in larger buildings where some ventilation is required for areas such as corridors, elevators, and lobbies. The building ventilation system types include:

- **100% Corridor/Common Supply.** These systems are installed to supply and pressurize the corridors. These systems use fuel to ensure that the delivery temperature is not a comfort issue for tenants as they pass through the corridor.
- **Building Exhaust Fans.** These are central fans that depressurize the building common areas and draw make-up air through the units, stair wells, and other parts of the common areas. These systems generally do not include a heating fuel or system.
- **Corridor/Common Supply with Return.** These systems ventilate the corridor and common areas, but there is a mechanism that allows this ventilation air to be made up by return fans or return ducts. In these cases, heat is generally supplied to the supply side of the ventilation system.
- **No Building System.** The building has no ventilation system.

Table 42. Distribution of Central Building Ventilation Systems by System and Fuel Type

Ventilation System		Fuel Type						
		Air Source Heat Pump	Electric	Gas	Other	None	All Types	n
100% Corridor/Common Supply	%	0.2%	0.5%	0.5%	0.0%	0.1%	1.3%	34
	EB	0.4%	0.6%	0.3%	0.0%	0.1%	0.8%	
Building Exhaust Fans	%	–	–	–	–	0.1%	0.1%	3
	EB	–	–	–	–	0.1%	0.1%	
Corridor/Common Supply with Return	%	–	0.2%	0.3%	–	–	0.6%	8
	EB	–	0.3%	0.4%	–	–	0.5%	
No Building System	%	–	–	–	–	98.1%	98.1%	180
	EB	–	–	–	–	0.9%	0.9%	
All Systems	%	0.2%	0.7%	0.8%	0.0%	98.2%	100.0%	225
	EB	0.4%	0.7%	0.5%	0.0%	0.9%		

Table 43 shows the distribution of central ventilation systems across all building sizes. Although more than 98% of all multifamily buildings do not have a central ventilation system, only about 25% of high-rise buildings have no central ventilation. Alternatively, 75% of high-rise buildings use some type of central ventilation as part of their HVAC design. Only about 1.5% of mid-rise buildings and no low-rise buildings use central ventilation. In general, this ventilation summary suggests that only a limited number of buildings use outside air ventilation as part of their central system, and almost all of those buildings are high-rise construction.

Table 43. Distribution of Central Building Ventilation Systems by System Type and Building Size

Ventilation System		Building Size (Stories)				
		Low-Rise (1–3)	Mid-Rise (4–6)	High-Rise (7+)	All Sizes	n
100% Corridor/Common Supply	%	0.1%	0.7%	0.5%	1.3%	34
	EB	0.1%	0.6%	0.4%	0.8%	
Building Exhaust Fans	%	–	0.1%	–	0.1%	3
	EB	–	0.1%	–	0.1%	
Corridor/Common Supply with Return	%	0.3%	0.3%	0.0%	0.6%	8
	EB	0.4%	0.4%	0.0%	0.5%	
No Building System	%	93.4%	4.4%	0.2%	98.1%	180
	EB	2.5%	2.2%	0.3%	0.9%	

4.3. Building Domestic Hot Water Systems

The majority of buildings in the multifamily sector are designed to use individual hot water systems installed in the individual units. Approximately 90% of all units use in-unit systems. The hot water systems in these buildings are divided into the following categories, as summarized in Table 44:

- **Central Water Heater for Units.** Buildings with central DHW systems providing hot water to each unit and to the common area uses.
- **Central Water Heater for Units and Separate Common Area Water Heater.** Buildings with a central DHW system for the units but a separate smaller system that provides hot water to the common area uses.
- **In-Unit Water Heater Only.** Buildings with only unit-level hot water and no real common area or other hot water.
- **In-Unit Water Heater and Separate Common Area Water Heater(s).** Buildings with unit-level hot water and a similar system used only in the common areas of the building.

Table 44. Distribution of DHW Service Type by Building Size

DHW Service Type		Building Size (Stories)				
		Low-Rise (1–3)	Mid-Rise (4–6)	High-Rise (7+)	All Sizes	n
Central Water Heater for Units	%	2.7%	–	–	2.5%	2
	EB	3.9%	–	–	3.7%	
Central Water Heater for Units and Separate Common Area Water Heater	%	8.3%	9.6%	48.2%	8.7%	56
	EB	4.6%	7.4%	30.9%	4.3%	
In-Unit Water Heater Only	%	58.0%	54.3%	22.7%	57.6%	88
	EB	9.2%	19.6%	28.6%	8.7%	
In-Unit Water Heater and Common Area Water Heater(s)	%	31.0%	36.1%	29.0%	31.2%	84
	EB	8.5%	16.7%	34.9%	8.0%	

This section focuses on the central DHW systems that serve both the common areas and the units. The characteristics of the in-unit only DHW systems are described in Section 5.2.

Central systems are common in high-rise buildings in lieu of individual in-unit DHW systems. Nearly half of the high-rise buildings use a central system as their primary hot water system (Table 44). This finding is in contrast to the mid-rise and low-rise buildings where less than 10% of the buildings use a central system.

Table 45 summarizes central DHW systems. About 75% of these systems are gas fired. These systems are typically either boilers or tanks. Frequently, the tank is an adjunct to an additional boiler that is used for central heating in the building. About 40% of the tank-based systems are electric tanks. These systems are usually in smaller buildings where the size of the tank reflects a low hot water demand. Only about 2% of the central DHW systems use purchased steam. These steam systems are typically part of a district heating system that is connected to the building (classified as “Other” in Table 45).

Table 45. Distribution of Central DHW Systems by Fuel Type

Central DHW System		Fuel Type				
		Electric	Gas	Gas/Electric	Purchased Steam	n
Boiler	%	1.5%	98.5%	–	–	34
	EB	2.5%	2.5%	–	–	
Multiple Systems	%	–	–	100.0%	–	3
	EB	–	–	0.0%	–	
Tank	%	41.9%	58.1%	–	–	18
	EB	25.3%	25.3%	–	–	
Other	%	–	–	–	100.0%	3
	EB	–	–	–	0.0%	
All Systems	%	20.4%	75.2%	2.2%	2.2%	58
	EB	13.7%	13.8%	2.2%	2.2%	

Table 46 summarizes the common area systems that serve the DHW load in only the common area and do not supply the individual units. These systems are typically individual tanks, or in some cases boilers, supplying laundries or other common area facilities. Common area DHW systems usually also provide space heat elsewhere in the building but not DHW to units. With the exception of the boiler systems, the two-thirds of the remaining systems dedicated to common area DHW are fired by electric systems, mostly individual tanks designed for limited use in common area laundries, kitchens, etc.

Table 46. Distribution of Common Area DHW Systems by Fuel Type

Common Area DHW System		Fuel Type				
		Electric	Gas	Gas/Electric	Purchased Steam	n
Boiler	%	2.9%	97.1%	–	–	35
	EB	3.6%	3.6%	–	–	
Multiple Systems	%	–	33.3%	66.7%	–	3
	EB	–	44.9%	44.9%	–	
Tank	%	82.7%	17.3%	–	–	98
	EB	8.3%	8.3%	–	–	
Other	%	–	–	–	100.0%	3
	EB	–	–	–	0.0%	
All Systems	%	66.9%	31.7%	0.5%	0.8%	139
	EB	8.9%	8.8%	0.6%	0.8%	

The DHW systems used in the common areas and in the central systems are often controlled by circulation pumps. This water distribution type is particularly present in larger multi-story buildings with central DHW heaters. Table 47 summarizes the 57 DHW systems in the multifamily sector that use circulation control. As Table 47 shows, approximately 42% of all the circulating pumps have no controls, meaning that they operate continuously as long as electrical energy is supplied to the building. The remaining 58% of the pump systems likely use an intermittent occupancy sensor either using pressure as a part of the demand system or a timer that shuts off the circulation pump during times of low demand. In a few of these cases, a booster pump is the only system that is operating. The booster pumps operate on pressure, and they are turned on to ensure that there is adequate water pressure at the level of the units. In this case, the systems are relatively small and the booster pump is all that is required to ensure adequate water pressure throughout the system.

Table 47. Distribution of DHW Pump Systems by Control Type

Pump System		Circulation Control Type: Booster Pumps Only	Booster and Circulation Pumps	Circulation Pumps Only	All Types	n
Demand	%	–	4.8%	32.2%	37.0%	26
	EB	–	5.6%	23.2%	24.5%	
Timer Control	%	–	0.5%	0.5%	1.0%	3
	EB	–	0.8%	0.8%	1.2%	
Other	%	7.7%	0.2%	5.4%	13.2%	7
	EB	9.1%	0.3%	7.2%	12.1%	
No Control	%	–	3.1%	39.0%	42.2%	13
	EB	–	4.7%	32.5%	31.4%	
Unknown	%	–	0.4%	6.2%	6.6%	8
	EB	–	0.5%	7.7%	7.8%	
All Systems	%	7.7%	8.9%	83.4%	100.0%	57
	EB	9.1%	8.1%	13.1%		

4.4. Common Area and Building Lighting

Approximately 46% of all multifamily buildings have a common area, including corridors, lobbies, and an assortment of services such as laundry areas and kitchens. The remaining buildings have no common area, although they often have exterior building lighting and parking area lighting. These common and building lighting loads are independent of the unit lighting and are metered and billed to the building. This section characterizes lighting in common, exterior, and parking areas. Lighting for individual units is presented in Section 5.3

The lighting systems in these multifamily buildings are fairly efficient, with the exception of the interior control systems. It is apparent from the LPD that efficient lighting has become a priority for many managers and owners, and the use of efficient lighting has become the dominant strategy in the common areas in the multifamily sector.

4.4.1. Interior Common Area Lighting

Table 48 shows the number of lamps in common areas normalized to the number of units in the building. This table shows the relative scale of the common area lamps relative to the number of units. Each unit has an average of 2.6 common area lamps across all building sizes. When the number of common area lamps is combined with the average number of approximately 23 in-unit lamps (Table 82 in Section 5.3.1), the total number of per-unit lamps increases by 11%. The number of common area lamps in high-rise and mid-rise buildings is about one-third greater than the average across all buildings.

Table 48. Average Number of Common Area Lamps per Unit by Building Size

Building Size (Stories)	Common Area Lamps per Unit		
	Mean	EB	n
Low-Rise (1–3)	2.23	0.59	84
Mid-Rise (4–6)	3.45	0.74	52
High-Rise (7+)	3.52	0.78	22
All Sizes	2.60	0.45	158

Table 49 shows the distribution of lamp types in common areas. The types are classified into the same overall lamp categories used throughout the RBSA study:

- **Compact Fluorescent.** Lighting technology used in standard A-line sockets and typically installed in place of incandescent or halogen lights that were originally installed.
- **Halogen.** Halogen lamps are usually more efficient than incandescent lamps and are rarely installed in multifamily buildings.
- **Incandescent.** Incandescent lamps are typical residential scale lamps, although in multifamily buildings, incandescent lamps represent a relatively small proportion of the total lighting.
- **Linear Florescent.** Linear fluorescents are common in multifamily buildings, especially in corridors.
- **Other.** Other lamps are a diverse group of lamp types, including light emitting diode (LED), mercury vapor, high-pressure sodium, etc. These represent a relatively small percentage of all lamps in multifamily buildings.

Table 49. Distribution of Common Area Lamps by Lamp Type and Building Size

Building Size (Stories)		Lamp Type					
		Compact Fluorescent	Halogen	Incandescent	Linear Fluorescent	Other	n
Low-Rise (1–3)	**%**	30.6%	2.6%	12.3%	49.9%	4.6%	7,237
	EB	11.4%	2.1%	4.9%	9.5%	2.4%	
Mid-Rise (4–6)	**%**	49.4%	0.9%	12.0%	33.4%	4.4%	11,981
	EB	11.7%	0.5%	3.9%	11.1%	1.8%	
High-Rise (7+)	**%**	57.7%	4.3%	5.8%	25.4%	6.8%	15,324
	EB	10.5%	2.4%	3.2%	10.4%	4.5%	
All Sizes	**%**	39.9%	2.3%	11.4%	41.6%	4.8%	34,542
	EB	7.9%	1.3%	3.0%	7.0%	1.5%	

More than 80% of the lamps are compact fluorescent lamps (CFLs) or linear fluorescent. The saturation of these fluorescent lamps in the common areas results in efficient common area lighting. In addition, only a small number of these lamps are affected by the Energy Independence and Security Act of 2007 (EISA, 2007) (Table 51), and the common area LPD is significantly lower than the unit LPD (Table 52 and Table 85)

Table 50 shows the distribution of these lamp types across various room types. The distribution of lamps in the individual rooms is dominated by CFLs in the corridor and lobby, and by incandescent lamps in more lightly-used spaces, such as storage and restroom areas.

Table 50. Distribution of Common Area Lamps by Common Area Room Type and Lamp Type

Common Area Room Types		Compact Fluorescent	Halogen	Incandescent	Linear Fluorescent	Other	Unknown	n
Commercial Kitchen	%	9.1%	–	2.3%	88.6%	–	–	88
	EB	19.0%	–	5.0%	21.5%	–	–	
Corridor	%	54.7%	2.1%	4.6%	30.5%	7.1%	1.2%	26,679
	EB	10.3%	2.0%	2.4%	9.7%	3.3%	1.3%	
Laundry	%	11.3%	–	19.4%	68.7%	0.5%	–	880
	EB	5.3%	–	12.1%	12.7%	0.9%	–	
Lobby	%	46.1%	6.4%	22.9%	20.3%	3.8%	0.5%	2,446
	EB	15.0%	4.3%	11.7%	15.1%	3.7%	0.8%	
Mechanical	%	5.0%	–	8.3%	84.3%	2.3%	–	624
	EB	4.4%	–	7.0%	11.2%	3.9%	–	
Office	%	10.4%	2.6%	8.1%	77.5%	1.4%	–	1,218
	EB	10.2%	3.9%	7.4%	15.1%	2.1%	–	
Recreation	%	15.1%	2.3%	18.7%	61.3%	2.7%	–	2,633
	EB	10.1%	2.2%	12.1%	18.1%	3.8%	–	
Restroom	%	10.0%	5.7%	44.9%	39.4%	–	–	406
	EB	7.9%	8.8%	24.7%	26.5%	–	–	
Storage	%	9.0%	2.9%	40.6%	47.3%	0.1%	–	1,292
	EB	5.5%	4.6%	16.4%	16.7%	0.2%	–	
Other	%	28.5%	6.2%	26.8%	37.1%	1.4%	–	1,542
	EB	18.9%	6.5%	24.8%	22.4%	1.5%	–	
All Types	%	39.3%	2.3%	11.3%	41.5%	4.9%	0.7%	37,808
	EB	7.4%	1.3%	2.8%	7.0%	2.0%	0.8%	

With the implementation of the federal lighting standards mandated by EISA, many lamps that would have been targets of the utilities' efficient lighting programs would now be mandated to be adapted to high efficacy lamps such as CFLs. The lighting audit recorded the characteristics of the lamps in each building. Based on the detailed lamp descriptions, the lamps identified in the audit were divided into three categories:

- **EISA compliant.** Lamps that already meet the EISA standards.
- **EISA non-compliant.** Lamps that would eventually have to be replaced with high efficacy lamps under the EISA standards.
- **EISA exempt.** Lamps that would not be required to meet EISA standards regardless of their efficiency.

These standards are being phased in 2012 through 2014. For this analysis, we used the lighting standards at full implementation as the basis for categorizing the lamps in the lighting audits in the three categories above in order to assess the potential for the amount of lighting wattage that may be eligible for utility programs because they are exempt from EISA standards.

Table 51 summarizes the impact of the use of the EISA standards on common area lighting as it is currently installed in multifamily buildings across the region. The vast majority of lamps are either exempt from the standard (decorative or other specialty lamps), or already qualified. The qualified group includes virtually all CFLs and linear fluorescent lamps.

Table 51. Distribution of Common Area Lamps by EISA Lamp Category

EISA Category	Percentage Common Area Lamps		
	%	EB	n
Exempt	6.4%	2.1%	2,226
Non-Qualified, Non-Exempt	8.4%	2.8%	1,042
Qualified or Not Affected	85.2%	3.5%	36,290

4.4.2. Interior Lighting Power Density

The presence of relatively low-wattage fluorescent lighting equipment throughout the common areas of multifamily buildings results in a relatively small common area LPD.[12] As summarized in Table 52, the common area LPD across the multifamily sector is about 0.7 watts per square foot (W/sq.ft.). In addition, there is relatively little difference in common area LPDs across vintage bins. This finding suggests that that many of the buildings across all vintage bins have been retrofit with efficient lighting.

Table 52. Average Common Area LPD (W/sq.ft.) by Building Vintage

Vintage	Average Common Area LPD		
	Mean	EB	n
Pre 1955	0.767	0.158	13
1955–1970	0.549	0.084	42
1971–1980	0.729	0.179	31
1981–1990	0.717	0.248	24
1991–2000	0.602	0.112	17
Post 2000	0.733	0.069	24
All Vintages	0.685	0.070	151

Throughout the region, the, the impact of fluorescent technologies has become the norm in virtually all multifamily common areas. On average, the values observed in this study approach the standards of the energy codes for new multifamily buildings in the Northwest.[13]

Table 53 summarizes common area by building size. There is relatively little difference in LPDs across building sizes.

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[12] LPD is the typical index value used to assess the lighting efficiency in most commercial energy programs and in most energy codes. It is calculated as total Watts (W) of lighting divided by the total conditioned square feet in which that lighting is installed (W/sq.ft).

[13] The common area LPD in the Washington State Energy Code 2013 is 0.6, in the 2012 IECC it is 0.6, and in the 2010 Oregon Specialty Code it is 0.58.

Table 53. Average Common Area LPD (W/sq.ft.) by Building Size

Building Size (Stories)	Average Common Area LPD		
	Mean	EB	n
Low-Rise (1–3)	0.739	0.104	81
Mid-Rise (4–6)	0.587	0.072	50
High-Rise (7+)	0.630	0.143	20
All Sizes	0.685	0.070	151

Table 54 further breaks out the distribution of common area LPD by individual room type as well as by building size. Rooms that are extensively used throughout the multifamily sector, such as corridors, typically have lower LPDs than the average. These rooms, however, typically have virtually no control and are on continuously. On the other hand, building areas such as storage and restrooms have large lighting power densities but usually represent a small percentage of the common area in any building.

Table 54. Average Common Area Room LPD (W/Sq.Ft.) by Building Size

Common Area Room Type		Building Size (Stories)				
		Low-Rise (1–3)	Mid-Rise (4–6)	High-Rise (7+)	All Sizes	n
Commercial Kitchen	**Mean**	–	–	1.59	1.59	1
	EB	–	–	0.00	0.00	
Corridor	**Mean**	0.62	0.54	0.51	0.58	105
	EB	0.11	0.09	0.14	0.07	
Laundry	**Mean**	0.80	0.63	0.95	0.80	109
	EB	0.13	0.20	0.41	0.12	
Lobby	**Mean**	1.02	0.55	0.85	0.79	61
	EB	0.29	0.15	0.17	0.18	
Mechanical	**Mean**	0.88	0.94	0.52	0.87	47
	EB	0.12	0.14	0.15	0.10	
Office	**Mean**	1.06	0.96	0.79	1.03	55
	EB	0.26	0.12	0.52	0.23	
Recreation	**Mean**	0.89	0.75	1.07	0.88	47
	EB	0.13	0.24	0.22	0.11	
Restroom	**Mean**	3.19	1.68	1.80	2.80	37
	EB	1.94	0.44	0.22	1.37	
Storage	**Mean**	0.80	0.64	0.37	0.72	67
	EB	0.28	0.13	0.11	0.16	
Other	**Mean**	0.63	0.79	1.09	0.82	22
	EB	0.47	0.07	0.31	0.28	
All Types	**Mean**	0.78	0.59	0.62	0.71	151
	EB	0.08	0.07	0.12	0.06	

4.4.3. Lighting Control

Lighting control in common areas is strongly linked to the overall efficiency of lighting systems in multifamily buildings. For example, motion sensors turn the lamps off when there is not occupancy, resulting in reduced energy usage.

Table 55 summarizes the distribution of common area lighting power (Watts) across various control strategies. The most prominent finding is that virtually no common area wattage is controlled by an automated system. For about 38% of the wattage, the lights are on continuously 24 hours a day ("24 Hour Operation") and are often directly wired to the circuit breaker. More than 50% of the wattage is controlled by a manual switch operated by tenants or the building manager. Timers, motion sensors, and photo sensors are the only automatic controls observed in the sample, and together they control only about 5% of the common area lighting wattage. The lack of advanced controls in these buildings coupled with the large percentage of continuous operation suggests an opportunity for program incentives and improved energy codes for automated control strategies.

Table 55. Distribution of Common Area Lighting Power (Watts) by Control Type

Control Type	Percentage of Common Area Watts		
	%	EB	n
24 Hour Operation	38.3%	7.6%	545
Dimmer Switch	0.1%	0.1%	11
Manual Switch	52.6%	7.2%	905
Motion Sensor	3.2%	3.3%	60
Other Control	3.2%	3.5%	4
Photo Sensor	0.1%	0.2%	4
Photo and Motion Sensor	0.0%	0.1%	2
Timer Control	1.6%	1.0%	85
Unknown Control	1.0%	1.5%	2

4.4.4. Exterior Lighting and Control

This section summarizes exterior lighting and control based on the total wattage averaged across the buildings. The tables summarizing exterior lighting are divided into five exterior lighting types and are summarized as the percentage of total exterior lighting wattage or lamps in each type:

- **Building.** All general building lighting, including entries, walkways, etc.
- **Covered Parking Lot.** Lighting in parking areas typically covered by a building overhang.
- **Enclosed Parking Garage.** Lighting in enclosed parking garages that are typically part of the building.
- **Multiple Parking Areas.** Lighting in a combination of garages and parking areas that are partially covered.
- **Open Parking Garage.** Lighting in carport type parking typically separated from the building itself.

Table 56 shows the distribution of exterior lighting power (Watts) in these five exterior categories. This summary is normalized by total exterior wattage. Table 56 uses the same typology of lamp types as the interior lighting summaries. In this case, however, the dominant exterior lamp type is high-pressure sodium covered in the “Other” category. About half the exterior lamps in the other category is high-pressure sodium, and about one-third of this category is metal halide lamps.

Table 56. Distribution of Exterior Lighting Power (Watts) by Lamp Type and Exterior Category

Exterior Category		Lamp Type						
		Compact Fluorescent	Halogen	Incandescent	Linear Fluorescent	Other	Unknown	n
Building	**%**	32.9%	3.4%	25.4%	6.0%	32.3%	0.1%	186
	EB	6.9%	2.0%	14.2%	3.2%	10.3%	0.1%	
Covered Parking Lot	**%**	6.8%	16.1%	5.0%	63.1%	9.1%	–	25
	EB	8.0%	20.1%	9.2%	37.6%	13.2%	–	
Enclosed Parking Garage	**%**	2.5%	10.8%	10.3%	42.6%	33.5%	0.3%	53
	EB	2.3%	13.5%	15.0%	19.2%	21.9%	0.4%	
Multiple Parking Areas	**%**	16.6%	–	8.3%	51.6%	23.5%	–	18
	EB	17.4%	–	11.7%	21.5%	18.0%	–	
Open Parking Garage	**%**	55.6%	–	–	22.1%	22.3%	–	17
	EB	31.5%	–	–	26.6%	27.8%	–	
All Categories	**%**	16.8%	9.3%	13.5%	36.4%	23.8%	0.1%	241
	EB	6.5%	6.4%	8.3%	22.4%	11.0%	0.1%	

Table 57 shows the distribution of lamps by percentage of total exterior lamps. In this summary, CFLs and linear fluorescents dominate. When compared to the same summary normalize by Watts (Table 58), the impact of the high-wattage high-pressure sodium and metal halide makes the “Other” category dominant, even though they represent only 10% of the exterior lamps.

Table 57. Distribution of Exterior Lamps by Lamp Type and Exterior Category

Exterior Category		Lamp Type						
		Compact Fluorescent	Halogen	Incandescent	Linear Fluorescent	Other	Unknown	n
Building	**%**	67.8%	2.0%	12.7%	6.8%	10.4%	0.4%	3,366
	EB	7.0%	1.2%	5.3%	3.5%	4.3%	0.5%	
Covered Parking Lot	**%**	16.4%	5.6%	3.1%	72.8%	2.2%	–	593
	EB	20.8%	8.2%	6.1%	32.2%	3.5%	–	
Enclosed Parking Garage	**%**	6.3%	3.8%	8.0%	59.8%	21.8%	0.2%	3,682
	EB	4.5%	4.8%	11.9%	17.6%	16.2%	0.3%	
Multiple Parking Areas	**%**	41.1%	–	7.4%	42.9%	8.6%	–	366
	EB	30.3%	–	11.2%	27.3%	10.8%	–	
Open Parking Garage	**%**	81.3%	–	–	14.3%	4.4%	–	390
	EB	20.3%	–	–	18.6%	6.7%	–	
All Categories	**%**	39.8%	3.3%	7.9%	39.5%	9.3%	0.2%	8,397
	EB	15.9%	2.3%	4.5%	23.5%	4.9%	0.2%	

Table 58 presents the total average exterior power (Watts), distributed by building size. Overall, the exterior wattage represents about 11% of the total common area lighting wattage and an increase of about 12% in the interior conditioned common area LPD. This added wattage is reflected in the energy use of the common area lighting energy requirements.

Table 58. Average Exterior Lighting Power (Watts) by Exterior Category and Building Size

Exterior Category		Building Size (Stories)				
		Low-Rise (1–3)	Mid-Rise (4–6)	High-Rise (7+)	All Sizes	n
Building	Mean	574	862	2,061	603	212
	EB	114	331	702	110	
Covered Parking Lot	Mean	97	53	–	93	24
	EB	99	53	–	93	
Enclosed Parking Garage	Mean	30	323	2,107	64	40
	EB	22	198	2,007	30	
Multiple Parking Areas	Mean	5	154	301	16	15
	EB	4	142	343	10	
Open Parking Garage	Mean	5	32	27	6	13
	EB	4	41	46	4	
All Categories	Mean	710	1,424	4,496	784	220
	EB	150	485	2,578	147	

Table 59 shows the distribution of control systems for exterior lighting. The most significant finding is that somewhat more than 50% of all exterior lighting is controlled by photo or motion sensors. These controls apply to both the building lighting and the parking lighting. Nearly 20% of the wattage has either no controls or only manual controls. These strategies represent the dominant approach in a few cases, especially in enclosed garages. Of the remaining control strategies, only the timer is used extensively. Timer controls are more typical in older building vintages. Overall, most of the exterior lighting is controlled by some type of automatic control accounting for approximately 75% of all the exterior wattage.

Table 59. Distribution of Exterior Lighting Power (Watts) by Control Type and Exterior Category

Exterior Category		Lighting Control Type								
		24 Hour Operation	Manual Switch	Motion Sensor	Photo Sensor	Photo Sensor and Motion	Timer Control	Other	Unknown	n
Building	%	2.7%	9.3%	1.4%	55.3%	3.5%	26.0%	0.0%	1.8%	7,450
	EB	1.4%	5.4%	1.7%	10.7%	3.2%	9.5%	0.1%	1.5%	
Covered Parking Lot	%	–	–	0.4%	26.9%	7.0%	5.8%	–	60.0%	593
	EB	–	–	0.7%	28.6%	12.6%	7.7%	–	40.0%	
Enclosed Parking Garage	%	83.9%	10.8%	–	5.1%	–	0.2%	–	–	3,563
	EB	15.5%	14.9%	–	5.3%	–	0.2%	–	–	
Multiple Parking Areas	%	42.1%	19.4%	–	21.5%	–	17.0%	–	–	366
	EB	30.7%	20.3%	–	20.5%	–	16.5%	–	–	
Open Parking Garage	%	22.0%	1.0%	–	60.5%	–	16.5%	–	–	390
	EB	26.6%	1.7%	–	29.1%	–	14.7%	–	–	
All Types	%	9.5%	8.3%	1.1%	47.4%	3.6%	21.2%	0.0%	8.8%	12,362
	EB	4.0%	4.5%	1.3%	10.4%	2.9%	8.1%	0.1%	10.8%	

4.5. Common Area Equipment and Appliances

Tenant services designed to serve all units are typically located in multifamily common areas. These common areas vary substantially throughout the sector, with significantly more services provided to specialized multifamily buildings such as senior housing and assisted living, and considerably less provided in low-density low-rise buildings. Once a common area is included in a building, however, certain functions are almost always present. These include storage, corridors, parking, and laundry rooms (especially in older buildings).

This section summarizes common area equipment in multifamily buildings. Surveyors were instructed to do an accounting of equipment as they proceeded through the building survey, with special emphasis on laundry and other large loads that influence the overall energy requirements of the building. This section has been divided into three parts:

- Common area laundry equipment.
- Elevators, pools, and spas
- Miscellaneous equipment, including kitchen equipment, office equipment, etc.

4.5.1. Common Area Laundry Equipment

Common area laundries are reasonably pervasive throughout the sector. The use of common area laundries as a part of multifamily buildings has varied over time as the sector has changed. Table 60 shows the distribution by vintage bin of common area laundry versus in-unit laundry equipment. The total number of common areas weighted by building size that have common area laundries exceeds 50% of all the buildings built before 1980. The remaining buildings for the most part included either in-unit laundry facilities themselves or a combination of in-unit and common area laundries.

Table 60. Distribution of Building Laundry Type by Building Vintage

Vintage		Laundry Type: Common Only	In-Unit Only	In-Unit and Common	None	n
Pre 1955	%	39.2%	–	1.4%	59.3%	18
	EB	33.5%	–	2.1%	34.2%	
1955–1970	%	57.9%	18.0%	0.6%	23.6%	54
	EB	19.7%	15.6%	0.6%	18.3%	
1971–1980	%	45.1%	25.7%	14.9%	14.3%	51
	EB	16.6%	14.2%	9.6%	10.6%	
1981–1990	%	21.4%	68.4%	8.8%	1.4%	45
	EB	14.6%	16.5%	9.5%	2.3%	
1991–2000	%	12.3%	64.0%	11.8%	11.9%	31
	EB	14.9%	22.3%	14.1%	18.0%	
Post 2000	%	8.0%	90.9%	1.2%	–	31
	EB	9.7%	10.0%	1.3%	–	
All Vintages	%	35.1%	42.0%	8.2%	14.7%	230
	EB	8.3%	8.7%	4.1%	7.0%	

In buildings constructed after 1980, the incidence of common area laundry is less common. In the post-2000 period, 90% of all units have their own clothes washers and dryers; only 10% of the units are in buildings with a common area laundry. Overall, slightly more than one-third of units have access to a common area laundry in their building, while more than 40% have only in-unit laundry. The remaining group, and about 15% of all units, have no laundry, and the laundry facilities are provided either in another building (in a multi-building facility) or at a local laundromat off-site.

Table 61 presents the distribution of equipment vintages of the clothes washers within the common area laundries. Table 61 also includes the distribution of major washer types.

Table 61. Distribution of Common Area Clothes Washer Type by Washer Vintage

Clothes Washer Type		Clothes Washer Vintage: Pre 1980	1980–1989	1990–1994	1995–1999	2000–2004	2005–2009	Post 2009	All Vintages	n
Horizontal Axis Washer	%	–	–	4.5%	8.1%	59.2%	25.7%	2.4%	33.9%	38
	EB	–	–	5.2%	8.6%	24.6%	24.7%	2.5%	7.90%	
Stacked Washer/Dryer	%	–	–	–	1.5%	–	98.5%	–	5.77%	4
	EB	–	–	–	3.1%	–	3.1%	–	4.13%	
Vertical Axis (With Agitator)	%	0.5%	21.3%	4.0%	24.9%	27.4%	15.6%	6.3%	60.2%	64
	EB	0.8%	19.9%	4.1%	14.7%	16.4%	9.4%	6.9%	8.17%	
Vertical Axis (Without Agitator)	%	–	–	–	–	100.0%	–	–	0.03%	1
	EB	–	–	–	–	0.0%	–	–	0.03%	
All Types	%	0.3%	12.8%	4.0%	17.8%	36.7%	23.8%	4.6%	100.0%	107
	EB	0.5%	13.1%	3.0%	9.6%	13.9%	12.0%	4.3%		

Horizontal-axis washers, which are noticeably more efficient than the typical vertical access, appear in about one-third of the cases. The vertical axis standard residential coin-operated laundries represent about two-thirds of all the washer equipment in common areas. This laundry equipment is as much as 40 years old in some cases.

Table 62 shows the distribution of laundry use among tenants in the buildings surveyed. Surveyors asked this question directly to the tenants in the units, and thus the distribution is associated with the total unit count, not the total building count. For this purpose, we have re-weighted it to reflect the building weights used in establishing building characteristics. When only common area laundry is available, tenants wash more than 40% less loads than when using in-unit only. This finding seems to be consistent in both the cases where only common area laundry is available and where no laundry is available in the building, suggesting that when a laundry is not available in the individual unit, the number of laundry loads is reduced regardless of the alternative to the in-unit laundry. The in-unit and common area laundry refers to buildings in which there is a common area laundry but some units have individual washers available.

Table 62. Average Number of Clothes Washer Loads per Week by Laundry Type

Laundry Type	Average Loads per Week		
	Mean	EB	n
Common Only	2.51	0.76	230
In-Unit and Common	3.57	1.90	67
In-Unit Only	4.43	1.24	214
None	2.84	1.88	33
All Types	3.42	0.51	539

In some multifamily buildings, tenants are not allowed to install laundry equipment in their units, especially in older units with relatively small electrical systems. A washer and dryer can draw 30 to 40 amps, and for older units, this represents a substantial percentage if not all of the amperage allowed to the unit. Thus, even tenants with means to purchase in-unit laundries are not likely have laundry equipment except in buildings that have already been designed to handle this load.

Table 63 summarizes the distribution of common area dryers by the equipment vintage. More than 80% of the dryers are less than 20 years old, while 32% are less than 10 years old. Only 4% were purchased after 2009.

Table 63. Distribution of Common Area Dryers by Dryer Vintage

Dryer Vintage	Clothes Dryers		
	%	EB	n
Pre 1980	0.3%	0.6%	1
1980–1989	14.3%	14.5%	4
1990–1994	3.5%	3.0%	7
1995–1999	17.6%	8.9%	28
2000–2004	32.2%	13.7%	31
2005–2009	28.0%	13.0%	26
Post 2009	4.0%	4.1%	8

4.5.2. Elevators, Pools, and Spas

This section summarizes large loads, including elevators, swimming pools, and spas (hot tubs) located at or within multifamily buildings.

Table 64 shows the distribution of elevators across building sizes. Overall, 11% of the buildings have elevators in use in the building. In high-rise and mid-rise buildings, nearly 80% of the buildings have an elevator present. Most low-rise buildings have no elevators. The prevalence of this building size accounts for the relatively low saturation of elevators across the sector. In high-rise buildings, the use of elevators is mandatory but even in mid-rise buildings, especially those more than four stories, an elevator is a typical part of the building equipment. Table 65 shows the average number of elevators in buildings that have elevators in each of the size categories.

Table 64. Percentage of Buildings with Elevators by Building Size

Building Size (Stories)	Percentage with Elevators		
	%	EB	n
Low-Rise (1–3)	6.9%	4.1%	149
Mid-Rise (4–6)	71.3%	18.4%	55
High-Rise (7+)	100.0%	0.0%	24
All Sizes	11.3%	4.4%	228

Table 65. Average Number of Elevators (in Buildings with Elevators) by Building Size

Building Size (Stories)	Number of Elevators		
	Mean	EB	n
Low-Rise (1–3)	1.04	0.06	22
Mid-Rise (4–6)	1.20	0.14	46
High-Rise (7+)	1.79	0.39	24
All Sizes	1.15	0.08	92

Overall, buildings with elevators have slightly more than about one elevator per building. However, this applies only to the 11% of buildings that have elevators.

In the case of pools and spas, multifamily buildings are nearly twice as likely to have these amenities as to have an elevator. Table 66 shows that 28% of all buildings have a pool. About 85% are outside and can be expected to operate seasonally. The remaining 10% can be expected to operate year round. This latter group is largely associated with assisted living and senior housing, but interior pools can also be located as amenities in higher-end apartments and virtually all size categories.

Table 66. Percentage of Buildings with Pools by Pool Type and Building Size

Building Size (Stories)		Pool Type: Exterior Pools	Interior Pools	All Pools	n
Low-Rise (1–3)	%	26.9%	4.0%	29.0%	151
	EB	7.4%	2.9%	7.6%	
Mid-Rise (4–6)	%	7.3%	9.9%	17.2%	55
	EB	6.4%	11.4%	13.0%	
High-Rise (7+)	%	21.9%	6.0%	27.8%	24
	EB	28.6%	5.8%	28.5%	
All Sizes	%	25.8%	4.3%	28.4%	230
	EB	6.9%	2.8%	7.1%	

Table 67 shows the distribution of spas across the building sizes. About 20% of buildings have some type of spa, including hot tub, whirlpool baths, or other types of exercise therapy. For buildings with assisted living and elderly populations, this amenity is fairly typical. More than 40% of the spas are located in interior spaces within the common area of the building.

Table 67. Percentage of Buildings with Spas by Spa Type and Building Size

Building Size (Stories)		Spa Type: Exterior Spas	Interior Spas	All Spas	n
Low-Rise (1–3)	%	14.8%	8.7%	21.4%	151
	EB	6.4%	4.3%	7.1%	
Mid-Rise (4–6)	%	5.4%	12.0%	17.5%	55
	EB	5.3%	11.9%	13.0%	
High-Rise (7+)	%	1.7%	30.7%	32.4%	24
	EB	2.3%	34.5%	34.1%	
All Sizes	%	14.2%	9.1%	21.3%	230
	EB	6.0%	4.1%	6.7%	

4.5.3. Miscellaneous Equipment

Although there are many types of miscellaneous equipment scattered throughout common areas in these buildings, we have summarized only a few of them that appeared in a noticeable percentage of the surveys. We have summarized kitchen equipment and computers, largely because they indicate activities in common areas that might reflect on the energy use in the building.

Table 68 shows the saturation of kitchens in common areas across the building sizes. There are about .06 kitchens per building across all building sizes, but more than half of the high-rise buildings have some type of kitchen facility in the common area. Table 68 summarizes two kitchens types. The first is in the relatively small group of buildings that have assisted living or senior housing. These kitchens provide food service, and commercial kitchen equipment is usually present in these cases. In the high-rise buildings, a second type of kitchen is typically present. Kitchens are a common area amenity provided to the tenants for purposes of entertaining or to provide a service that can be an adjunct to the units themselves.

Table 68. Average Number of Kitchen Facilities by Building Size

Building Size (Stories)	Number of Kitchens		
	Mean	EB	N
Low-Rise (1–3)	0.046	0.035	13
Mid-Rise (4–6)	0.152	0.099	17
High-Rise (7+)	0.563	0.312	18
All Sizes	0.056	0.033	48

Table 69 shows the distribution of refrigerators throughout common areas. This is a saturation and reflects the number of refrigerators on average across the common areas of all the buildings. Overall, there are about .06 common area refrigerators per building. For the most part, the saturation of refrigerators reflects the saturation of kitchens, and relatively few additional refrigerators are present in the common areas in the absence of a kitchen facility.

Table 69. Average Number of Common Area Refrigerators by Building Size

Building Size (Stories)	Number of Refrigerators		
	Mean	EB	n
Low-Rise (1–3)	0.046	0.035	13
Mid-Rise (4–6)	0.199	0.149	18
High-Rise (7+)	0.599	0.320	17
All Sizes	0.059	0.034	48

Table 70 shows the distribution of common area computers by ownership type. Overall, buildings have an average of only about .07 common area computers, and in almost all cases, these computers are associated with an office service amenity available to the tenants or with a rental office located in the common area. A small number of other types of electronic equipment are also present in these common areas but are not summarized in Table 70.

Table 70. Average Number of Computers in Common Areas by Building Ownership Type

Ownership Type	Number of Computers		
	Mean	EB	n
Cooperative	0.810	1.222	3
Condo Association	0.024	0.023	6
Corporation/REIT	0.081	0.085	20
Individual	0.000	0.000	0
Private Non-Profit	0.145	0.108	16
Public Agency	0.112	0.174	4
All Types	0.065	0.040	49

5. Unit Characteristics

This section characterizes the individual apartment units in the multifamily sector. For this characterization, the surveyor was asked to select two to three units in each building. The selection was based on the unit identified during the phone survey and additional unit(s) selected at random from the building. This process was done in cooperation with the building manager or owner. It was necessary that the unit tenant be present throughout the survey and participate in the same short questionnaire used in the single-family and manufactured home surveys. If the tenant originally interviewed was not available, that unit was replaced by using the same processes as the other units selected.

The unit surveys were conducted using essentially the same protocol as the RBSA surveys in the single-family and manufactured home sectors. In the case of the multifamily surveys, however, some of the information typical of the other sectors was collected and summarized using the building survey. This information included the building envelope, the common or central HVAC and DHW systems (if any), exterior and common area lighting, and other common area functions shared among all units.

The unit surveys included:

- **Unit HVAC.** Heating and cooling systems in each unit were reviewed, with particular attention to systems that were serving that unit only.
- **Unit DHW.** The unit DHW system was reviewed if the hot water system was supplied by equipment in the individual unit.
- **Lighting.** This part addressed all in-unit lighting. All lamps and fixtures were reviewed and information was collected to assemble the total wattage and the LPD for the particular unit.
- **Appliances.** A census of the major appliances in each unit was conducted, including make, model, and vintage. In some cases, details about the appliance were also collected.
- **Consumer electronics.** This part focused on the home entertainment and related equipment. Particular attention was paid to the TVs and set-top boxes, although a census was taken of audio equipment and computer equipment as well.

In addition, an interview was conducted with the tenant and was used to summarize the demographic and other characteristics.

5.1. Unit Heating, Cooling, and Ventilation (HVAC)

Each unit survey included a review of HVAC systems. This review was designed to assess all of the available heating and cooling equipment located in each unit. Where multiple heating systems where present, the surveyors first interviewed the tenants and asked which heating system they use most. The surveyors then reviewed the systems and, in a few cases, modified the homeowner’s designation to a “secondary” heating system. This adjustment was typically made when wood heat and electric heat were present in the same home. When the electric system was controlled by a thermostat and in use, the primary system was defined as electric.

5.1.1. Heating Systems

Although central systems were present in some units, the units sometimes did not use the central heating as a primary heating source. Central systems are summarized in Section 4.2. For this section on units, the central systems are not detailed by type but are included in the summary of heating systems (and, in Section 5.1.2, cooling systems) to provide a complete picture of the unit heating systems.

Table 71 categorizes the in-unit primary heating equipment and the distribution of fuel choice in the primary systems. The systems include air source heat pump differentiated from forced air furnaces even though these options use similar distribution and control systems. Electric zonal systems include three categories:

1. **Baseboard heaters**. These systems consist of permanently installed and electric zonal equipment controlled by thermostats. They are baseboard style, fin tube electric convectors.
2. **Wall heaters.** Wall heaters are electric zonal heaters installed in sheet metal pockets in walls. They are thermostated alternatives to baseboards and usually include a small fan that distributes the heat.
3. **Ceiling or floor radiant cable.** This style of electric zonal heat uses electric resistance cables embedded below the floor or ceiling finish. These systems are controlled by zonal thermostats similar to the baseboards or wall heaters.

In addition, some units use portable electric heaters moved from room to room. They are sometimes the primary heating system, especially in cases where the tenant finds the existing system unacceptable.

Table 71. Distribution of Primary In-Unit Heating Systems by System and Fuel Type

Primary Heating System		Fuel Type				
		Electric	Gas	Wood	All Types	n
Air Source Heat Pump	%	1.1%	–	–	1.1%	4
	EB	1.7%	–	–	1.7%	
Baseboard Heater	%	81.7%	–	–	81.7%	435
	EB	5.2%	–	–	5.2%	
Boiler	%	–	1.1%	–	1.1%	4
	EB	–	1.7%	–	1.7%	
Ductless Heat Pump	%	1.7%	–	–	1.7%	6
	EB	1.9%	–	–	1.9%	
Forced Air Furnace	%	2.1%	4.3%	–	6.4%	25
	EB	1.8%	3.2%	–	3.6%	
Heating Stove	%	–	1.1%	0.3%	1.5%	7
	EB	–	1.2%	0.6%	1.3%	
PTAC/PTHP	%	1.8%	–	–	1.8%	5
	EB	1.7%	–	–	1.7%	
Plug-In Heater	%	4.6%	–	–	4.6%	24
	EB	2.1%	–	–	2.1%	
All Systems	%	93.1%	6.6%	0.3%	100.0%	510
	EB	3.8%	3.8%	0.6%		

Approximately 6% of the primary heating systems are central systems that supply heat from the building, as shown in Table 35. The heating system distributions in Table 71 do not generally include these systems. In a few cases, the surveyor classified the central system as the secondary system. In those cases, the tenant typically used plug-in heaters that are noted in Table 71 as the primary heating system.

The gas heating in this sector is largely forced air furnaces. These are ducted systems and are used in smaller scale buildings. The other gas-fired heating option is the heating stove, which generally includes a permanently installed fireplace that has sufficient heating capacity to heat the entire unit. In some case, secondary electric heat is installed, especially in peripheral living zones.

In the buildings without central heating, the incidence of zonal electric resistance heating is about 90%. Overall, about 93% of the multifamily sector is electrically heated from all sources (Table 71). When the central systems are taken into account, the incidence of electric space heat falls to about 87%. The remaining heating systems are either central system (supplied by the building) or gas heating in the form of forced air furnaces or heating stoves.

Table 72 summarizes the secondary heating systems in units. Although these systems account for an unknown portion of the space heat required within the units, like the primary systems, these systems are overwhelmingly electric heat. More than 80% of all secondary heat is electric. The electric heat in this case is divided between plug-in and baseboard zone heaters and small packaged terminal units. These could be either heat pumps or electric resistance (once the units with no secondary heating system have been removed). On the whole, these secondary systems do not change the picture that the region's multifamily units are predominately electrically heated.

Table 72. Distribution of Secondary In-Unit Heating Systems by System and Fuel Type

Secondary Heating System		Fuel Type					
		Electric	Gas	Wood	None	All Types	n
Baseboard Heater	%	9.1%	–	–	–	9.1%	45
	EB	3.2%	–	–	–	3.2%	
Heating Stove	%	–	2.5%	3.3%	–	5.8%	33
	EB	–	2.0%	1.9%	–	2.7%	
PTAC/PTHP	%	13.0%	–	–	–	13.0%	41
	EB	5.1%	–	–	–	5.1%	
Plug-In Heater	%	2.4%	–	–	–	2.4%	19
	EB	1.4%	–	–	–	1.4%	
None	%	–	–	–	69.7%	69.7%	427
	EB	–	–	–	6.0%	6.0%	
All Systems	%	24.5%	2.5%	3.3%	69.7%	100.0%	565
	EB	5.8%	2.0%	1.9%	6.0%		

5.1.2. Cooling Systems

The surveyors were instructed to gather all available information on cooling equipment while onsite. In some cases, they asked for information about systems that had been stored for the winter, as would be expected for equipment such as window air conditioners. Table 73 shows the saturation of cooling equipment across the sector. Table 74 shows the distribution of equipment that supplies this cooling. Table 73 shows that about 25% of all units have some type of cooling equipment, while Table 74 shows that about 80% of this cooling is from zonal cooling equipment.[14] Only the DHP option represents an efficient zonal cooling system. It should be noted, however, that the DHP is a relatively new technology, and this system accounts for about 7% of all the cooling in the units in this sector.

Table 73. Percentage of Units With In-Unit Cooling Systems by Building Size

Building Size	Units With In-Unit Cooling Systems		
	%	EB	n
Low-Rise (1–3)	26.8%	6.9%	382
Mid-Rise (4–6)	15.2%	12.6%	121
High-Rise (7+)	20.6%	24.1%	49
All Sizes	25.0%	6.1%	552

Table 74. Distribution of In-Unit Cooling Systems by System Type and Building Size

Cooling Systems		Building Size				
		Low-Rise (1–3)	Mid-Rise (4–6)	High-Rise (7+)	All Sizes	n
Air Source Heat Pump	**%**	2.8%	0.4%	–	3.1%	4
	EB	4.5%	0.6%	–	4.5%	
Ductless Heat Pump	**%**	1.7%	4.9%	–	6.5%	8
	EB	1.9%	5.4%	–	5.6%	
PTAC/PTHP	**%**	42.9%	0.4%	3.1%	46.4%	46
	EB	12.9%	0.6%	4.5%	12.9%	
Unit Central AC	**%**	7.3%	1.8%	–	9.1%	8
	EB	6.8%	2.9%	–	7.3%	
Window AC	**%**	32.2%	1.9%	0.7%	34.8%	29
	EB	11.9%	1.7%	0.9%	12.0%	
All Systems	**%**	86.8%	9.3%	3.9%	100.0%	95
	EB	4.6%	3.6%	3.0%		

[14] Zonal cooling equipment is single-zone equipment controlled by the tenant. In this case, these systems are PTACs, window ACs, and DHPs.

5.1.3. Thermostats

The surveyors asked participants about their heating and cooling thermostat behavior. Table 75 summarizes the self-reported thermostat heating setpoints, cooling setpoints, and setback behavior across the surveyed units. In the multifamily units, the heating setpoint is somewhat lower than the other residential sectors, but the prevalence of night setback behavior is significantly lower than either the single-family or manufactured homes surveyed.[15] Where setback is used, the size of the setback is equivalent to the other sectors.

Table 75. In-Unit Thermostat Settings and Behavior

Category	Thermostat Characteristics		
	Mean	EB	n
Heating Thermostat Setpoint	67.4	0.6	533
Tenants Reporting a Heating Setback	48.0%	4.4%	267
Average Size of Heating Setback	7.9	0.7	267
Cooling Thermostat Setpoint	70.9	1.2	120
Tenants Reporting a Cooling Thermostat Setup	24.8%	8.3%	32

Table 75 also presents the cooling thermostat behavior in those units reporting cooling. The summaries include buildings where central systems provide cooling as well as units with some type of zonal cooling. About a quarter of these tenants report a cooling setup.[16] In contrast to the heating thermostat behavior, the cooling thermostat behavior is different from the other sectors. The setpoints reported are lower and the amount of cooling setup is significantly higher.

5.1.4. Ducts

Duct systems in the multifamily sector are rare and specialized. There are two categories of ducts in this study:

1. Ducts associated with small buildings that could be characterized as row houses with a single floor and ducts in a crawlspace under the floor.
2. Ducts that serve the units from a fan coil or other air handler with all the ducts located entirely within the unit.

Table 76 summarizes in-unit multifamily duct systems. Only about 12% of units have duct systems, and only 12% of those systems are in unheated buffer spaces. These findings suggest that duct systems are generally avoided by multifamily builders. Duct insulation is present in only 10% of the units with ducts installed.

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[15] Night setback is the process of adjusting the heating thermostat setting down during sleeping hours. The duration of this setback determines the amount of energy savings that might result. Typically, the home thermostat provides this capability, and the setback is programmed into the thermostat. In those cases, the setback is automatic. In other cases, the tenant manually adjusts the thermostat on a nightly basis.

[16] For cooling, the setting adjustment occurs during the day when the home is unoccupied. This adjustment often takes the form of turning off the AC equipment during the day and using it only in the hours after work. In that case, the interview question may not have captured that behavior.

Table 76. In-Unit Duct Characteristics

Category	Duct Characteristics		
	%	EB	n
Units With Duct Systems	11.6%	4.7%	552
Percentage of Ducts in Unconditioned Space per Unit	12.1%	8.4%	46
Duct Insulation: R1-R4	10.8%	13.1%	14
Duct Insulation: None	35.5%	20.2%	5
Duct Insulation: Unknown	53.7%	20.9%	27

5.2. Unit Domestic Hot Water (DHW)

Surveyors collected water heater characteristics during the appliance audit of the individual units. In about 19% of the cases, the DHW needs of the unit were supplied by a central system that served all the units in the building. Section 4.3 characterizes the building DHW system. Table 77 shows the distribution of DHW equipment across the units.

Table 77. Distribution of Unit Water Heaters by Type

Heater Type	Water Heaters		
	%	EB	n
Central Building System	18.7%	5.4%	132
Instantaneous	0.1%	0.1%	1
Storage	81.2%	5.4%	419

Table 78 shows the distribution of water heaters by size and fuel used in units. This table includes only the units with individual DHW systems. In general, this distribution reflects the dominance of electric fuel for the DHW system. Only about 5% of the units used individual, in-unit gas DHW systems. As would be expected, the size of the tanks in this sector is typical of residential DHW systems throughout the RBSA surveys.

Table 78. Distribution of In-Unit Water Heater Tanks by Size and Fuel Type

Water Heater Fuel Type		Tank Size			
		0–55 Gal	>55 Gallon	All Sizes	n
Electric	**%**	87.9%	6.9%	94.7%	394
	EB	5.3%	4.0%	3.7%	
Gas	**%**	5.3%	–	5.3%	17
	EB	3.7%	–	3.7%	
All Types	**%**	93.1%	6.9%	100.0%	411
	EB	4.0%	4.0%		

Table 79 shows the regional distribution of water heater vintage. Water heaters are generally distributed uniformly between 1990 and 2010, with only a few water heaters being more than 20 years old. This distribution is consistent with a water heater life of about 10 years on average, given that about 60% of the in-unit water heaters were installed prior to 2005.

Table 79. Distribution of In-Unit Water Heaters by Vintage

Vintage	Water Heaters		
	%	EB	n
Pre 1990	3.3%	2.0%	10
1990–1999	31.6%	6.4%	109
2000–2004	24.9%	6.2%	89
2005–2009	29.2%	6.0%	111
Post 2009	11.0%	4.3%	42

In addition to gathering data on DHW systems for the units, the surveyors took a census of showerheads in units, using a flow measurement device called a Micro-Wier™ to measure the flow rate of the main showerhead when the faucets are turned on full. Table 80 shows the distribution of showerhead flow rates. It should be noted that two-thirds of these showerheads are low-flow, which is two gallons per minute (GPM) or less. When compared to the single-family and manufactured home surveys, the incidence of these low-flow showerheads is significantly higher. In those surveys, only about half the showerheads tested were in the low-flow categories.

Table 80. Distribution of Showerhead Flow Rate

Flow Rate (GPM)	Showerheads		
	%	EB	n
<=1.5	25.1%	5.3%	119
1.6–2.0	40.4%	5.8%	226
2.1–2.5	21.5%	4.4%	105
2.6–3.5	9.2%	2.6%	69
>3.5	3.9%	1.8%	22

5.3. Unit Lighting

The multifamily unit survey included a detailed lighting audit. The lighting audit established the characteristics of lighting systems, the type of lighting technologies used, the number of lamps, and total lighting power in each unit surveyed. Surveyors were instructed to move from room to room throughout the unit. In each room, surveyors completed a fixture review, which included fixture types, lamps per fixture, and fixture count. Lamps were characterized by lamp type and lamp wattage. All types of fixtures (hard-wired, table top, and floor lamps) were included. In addition, an associated room area was measured, computed, and included with the lighting characteristics. This dataset was then compiled to develop both the LPD for each room and an overall LPD for the home, with LPD expressed as W/sq.ft.

The lighting audit was designed to identify lamp types and allow an after-the-fact judgment on the status of the lamp types relative to the federal regulation of lamp efficacies. With the implementation of the federal lighting standards mandated by EISA (2007) and scheduled to be phased in from 2012 through 2014, many lamps that would have been targets of the utilities' efficient lighting programs would now be mandated to be adapted to high efficacy lamps such as CFLs. The lighting audit recorded the characteristics of the lamps in each unit.

Based on the detailed lamp descriptions, the lamps identified in the audit were divided into the same three categories used in the lighting audit of the building and common areas, as described in Section 4.4.1:

- **EISA compliant.** Lamps that already meet the EISA standards.
- **EISA non-compliant.** Lamps that would eventually have to be replaced with high efficacy lamps under the EISA standards.
- **EISA exempt.** Lamps that would not be required to meet EISA standards regardless of their efficiency.

For this analysis, we used the lighting standards at full implementation as the basis for categorizing the lamps in the lighting audits into the three categories described above. The lamps were categorized into the EISA categories in order to assess the potential for the amount of lighting wattage that may be eligible for utility programs because they are exempt from EISA standards. Table 81 shows the distribution of lamps relative to this federal standard.

Table 81. Distribution of Lamps by EISA Category

EISA Category	Percentage of Lamps		
	%	EB	n
Exempt	5.8%	1.6%	802
Non-Qualified, Non-Exempt	59.7%	3.2%	7,502
Qualified or Not Affected	34.5%	3.5%	4,589

EISA-exempt lamps typically include specialty lamps. In this sector, this category covers a fairly minor portion (only about 6%) of the in-unit lighting. This percentage of the lighting is significantly lower than in either the single-family or manufactured home surveys. Nearly 60% of the lamps that are regulated by EISA do not currently meet the lumens per wattage standards of the full EISA implementation. These are mostly incandescent lamps, although some other lamp types are included.

5.3.1. Lamp Quantity and Description

Table 82 shows the average lighting and lamp characteristics across multifamily units. This summary includes all the lamps and fixtures observed in each unit. The summary does not include any exterior lamps that might be associated with those units.

Table 82. Lighting Characteristics

Category	Lighting Characteristics		
	Mean	EB	n
Fixtures per Unit	13.9	0.8	7,782
Lamps per Unit	23.2	1.7	12,894
CFLs Installed per Unit	6.3	0.7	3,681
Halogen Lamps Installed per Unit	0.9	0.3	662
Incandescent Lamps Installed per Unit	13.9	1.2	7,521
Linear Fluorescent Lamps Installed per Unit	1.7	0.3	849
Other Lamp Types Installed per Unit	0.4	0.4	138

The total lamp count, across the region, is approximately 23 lamps per home. In contrast, the lamp count in the single-family sector is about 63 lamps per home and in the manufactured home sector the lamp count is about 35 lamps per home. In the single-family sector, the number of lamps average about 3.1 lamps per 100 sq.ft. of conditioned space. In the manufactured homes, the average is about 2.8 lamps per 100 sq.ft of conditioned space. In multifamily units, the lamp count is about 3.2 lamps per 100 sq.ft. Overall, the density of lamps in each of these housing types is equivalent.

Table 82 also shows the number of fixtures per home. As with lamp counts, fixture counts are consistent among the residential building types surveyed in RBSA, once the conditioned floor area is taken into account.

5.3.2. Lamp Type

Table 83 summarizes the distribution of lamp types in the units. The average number of each of these lamps types is summarized in Table 82.

Table 83. Distribution of Lamps by Type

Lamp Type	Percentage of Lamps		
	%	EB	n
Compact Fluorescent	26.8%	3.2%	3,681
Halogen	3.3%	1.0%	662
Incandescent	62.2%	3.4%	7,521
Linear Fluorescent	6.3%	1.2%	849
Other	1.2%	1.1%	138
Unknown	0.2%	0.1%	42

Lamp types were divided into five general categories: CFL, halogen (including MR16 types), incandescent, linear fluorescent, and other. Most of the instances in the “Other” category are LED lamps, although other types of specialty display lamps occur in this category as well. As shown in Table 83, the mean saturation of CFLs throughout the multifamily units in the region is about 27% of all lamps. This summary is based not on the number of lamps in any particular home, but the total population of CFLs throughout the units as a percentage of the total number of lamps. When compared with the single-family and manufactured homes, the saturation of CFL fixtures in the Northwest is essentially identical across the residential sector.

Linear fluorescent lamps were observed throughout the residential sector. In the multifamily sector, the saturation of this lamp type is 30% less than in the manufactured home or single-family sectors.

The largest lamp type category is incandescent, representing more than 60% of the lamps. Like other features of the lighting audit, the saturation of incandescent lamps in the residential sector is essentially the same across all building types.

Table 84 shows the distribution of lamp types by room. All the lighting data collected during the audit included the room type in which the fixtures and lamps were observed. The use of CFLs is reasonably similar across most room types. Of interior rooms, only kitchens, bathrooms, and laundry rooms have an appreciably lower incidence of CFLs.

Table 84. Distribution of Lamps by Type and Room

Room Type		Lamp Type						
		Compact Fluorescent	Halogen	Incandescent	Linear Fluorescent	Other	Unknown	n
Bathroom	%	20.6%	1.3%	74.8%	3.0%	0.2%	0.1%	3,171
	EB	4.8%	0.6%	5.3%	2.0%	0.2%	0.1%	
Bedroom	%	30.0%	2.7%	63.9%	2.3%	0.6%	0.5%	1,861
	EB	5.2%	1.2%	5.4%	2.4%	0.3%	0.6%	
Closet	%	25.7%	1.7%	69.4%	3.1%	–	–	182
	EB	10.4%	1.7%	9.5%	2.2%	–	–	
Dining Room	%	30.6%	1.8%	66.7%	0.6%	0.4%	–	430
	EB	11.4%	1.5%	11.4%	0.9%	0.7%	–	
Family Room	%	33.3%	–	66.7%	–	–	–	28
	EB	20.9%	–	20.9%	–	–	–	
Garage	%	7.2%	–	34.3%	58.5%	–	–	18
	EB	12.6%	–	45.5%	48.5%	–	–	
Hall	%	31.7%	2.6%	64.8%	0.3%	0.4%	0.1%	944
	EB	7.1%	1.8%	7.3%	0.4%	0.7%	0.2%	
Kitchen	%	23.8%	6.9%	39.4%	26.8%	2.9%	0.3%	2,262
	EB	4.7%	2.6%	5.5%	5.4%	4.2%	0.5%	
Laundry Room	%	19.8%	0.4%	62.6%	3.0%	14.2%	–	131
	EB	9.3%	0.7%	8.8%	3.5%	14.6%	–	
Living Room	%	29.1%	3.8%	59.5%	6.6%	0.9%	0.1%	2,780
	EB	5.1%	1.4%	5.4%	2.3%	0.7%	0.1%	
Master Bedroom	%	25.8%	3.0%	69.0%	0.2%	1.9%	–	462
	EB	6.8%	2.4%	7.1%	0.3%	3.1%	–	
Office	%	36.3%	6.4%	50.2%	2.5%	4.6%	–	86
	EB	11.5%	4.3%	14.4%	3.2%	4.8%	–	
Other	%	7.1%	1.4%	69.5%	18.3%	3.7%	–	115
	EB	7.0%	2.5%	6.0%	6.4%	5.6%	–	
All Rooms	%	25.7%	3.3%	61.9%	7.8%	1.1%	0.2%	12,470
	EB	3.3%	0.9%	3.7%	1.4%	0.9%	0.1%	

5.3.3. Lighting Power Density (LPD)

The surveyors were instructed to assess the wattage of each lamp. The surveyors used direct observation or, in some cases, a schedule of typical wattages based on fixture and lamp type. The surveyors were encouraged to find the exact wattage, although an approximation was allowed where this determination was not possible. Thus, the lamps observed were assigned a wattage designation, and that wattage was, at a minimum, in a class consistent with the type of lamps observed.

Analysts then combined these wattages to develop the LPD for each room and for the unit as a whole. Each room had a measured floor area in addition to the lighting audit. The overall square footage of the unit was also calculated during the survey. This area was calculated from the sum of all the areas in the unit.

Table 85 shows the distribution of average LPD across various room types. The LPD for each room was based on the rooms' interior areas and calculated separately. The list of rooms, from a "pick list" that the surveyors used to assign rooms during the survey, shows about an 18% difference between the LPD estimated by room from interior dimensions and LPD estimated by total conditioned floor area. Most of this difference springs from the fact that the sum of interior room areas is typically about 10% lower than the area calculated from the home's exterior dimensions.

Table 85. Average Lighting Power Density (LPD) by Room Type and Overall

Room Type	LPD (W/sq.ft.)		
	Mean	EB	n
Bathroom	3.20	0.30	540
Bedroom	0.47	0.04	470
Closet	1.47	0.20	113
Dining Room	1.03	0.17	116
Family Room	0.45	0.17	6
Garage	0.31	0.13	5
Hall	1.08	0.13	351
Kitchen	0.54	0.13	476
Laundry Room	1.63	0.65	79
Living Room	0.24	0.02	513
Master Bedroom	0.53	0.08	154
Office	0.54	0.22	26
Other	0.37	0.10	47
Unit Lighting Power Density	1.46	0.08	512

The LPDs in Table 85 are summarized based on the interior area of the individual rooms. The total number of room audits conducted in this sample was about 3,000, or slightly more than five rooms per unit. The patterns shown in the Table 85 are not surprising; the highest LPD is bathrooms. The lowest interior LPDs occur in the living room and bedrooms. The living rooms and bedrooms have relatively lower LPD in part due to the use of stand lights, which usually do not light the room as completely as a central lighting system.

The last line in Table 85 shows the LPD calculated from the total wattage. The total per unit LPD is normalized by the total number of units in the survey for which an LPD could be calculated (n=512). The overall LPD is 1.46, which is comparable to the LPD in the single-family sector (1.42 W/sq.ft.) and somewhat higher than the LPD in the manufactured home sector. The LPD in this study is consistent with the Council's assumption (Council, 2010) given the presence of 27% high-efficacy CFLs in this multifamily study.

5.4. Unit Appliances

The appliance audit focused on a detailed accounting and characterization of the appliances in each unit. The audit was designed to provide a picture of the appliance stock in the multifamily sector. This effort focused on characterizing the appliance types and characteristics. The efficiency of the individual appliances was of secondary interest and is not summarized.

The surveyors developed a detailed census of appliances throughout the homes. For this purpose, appliances are defined as large "white goods." This process documented the presence of the appliance, and any key factors that were thought to have an impact on energy use and/or potential market impacts of utility programs.

The large appliance audit characterized the major energy-using components of these appliances as well as their age. Table 86 shows the average number of the household appliances per home for the total region.

Table 86 Average Number of Appliances per Unit by Type

Appliance	Number of Appliances per Unit (n = 552)	
	Mean	EB
Clothes Washer	0.47	0.07
Dishwasher	0.78	0.06
Dryer	0.47	0.07
Freezer	0.04	0.02
Refrigerator	1.03	0.02
Water Heater	1.00	0.00

In contrast with the rest of the residential sector, multifamily units do not necessarily have a full complement of appliances. The laundry equipment is largely a feature of newer buildings and units which were built to accommodate in-unit laundry areas. Older buildings typically supply common area laundries (see Section 4.5.1). In the case of refrigerators, these units average one refrigerator per unit, in contrast to about 1.3 refrigerators per home in the single-family survey. Standalone freezers are relatively rare in this sector.

5.4.1. Refrigerator/Freezers

The survey of refrigerators focused on vintage and style. Table 87 shows the distribution of refrigerator/freezer vintages. This table includes both refrigerators and standalone freezers. With about two-thirds of the refrigerators in this sector manufactured since 2000, the appliance stock seems to have a higher turnover in this sector compared to the remainder of the residential sector. Federal appliance standards for refrigerator/freezers began in 1990, but in 1994 the efficiency standard was improved. The level of turnover probably contributes to better refrigerator efficiency as a result.

Table 87. Distribution of Refrigerator/Freezers by Vintage

Vintage	Refrigerators/Freezers		
	%	EB	n
Pre 1980	0.4%	0.3%	5
1980–1989	2.7%	1.4%	18
1990–1994	10.9%	3.8%	52
1995–1999	20.6%	4.8%	102
2000–2004	23.0%	5.3%	108
2005–2009	32.5%	5.3%	186
Post 2009	9.8%	3.4%	46

Table 88 shows the distribution of refrigerator types by position of the refrigerator doors and freezers. This table does not include standalone freezers.

Table 88. Distribution of In-Unit Refrigerators by Type

Refrigerator Type	Refrigerators		
	%	EB	n
Full Size Refrigerator Only	0.0%	0.0%	1
Refrigerator With Bottom Freezer	2.8%	1.4%	22
Refrigerator With Side-by-Side Freezer	4.1%	1.9%	27
Refrigerator With Top Freezer	91.3%	2.6%	497
Side-by-Side Refrigerator With Bottom Freezer	0.1%	0.2%	1
Undercounter Refrigerator	0.7%	0.9%	5
Refrigerated Wine/Beverage Cooler	0.6%	0.5%	6
No Refrigerator	0.3%	0.6%	1

Surveyors generally recorded the volumes for refrigerators and freezers from the information provided in the model number and manufacturer's literature. Table 89 shows the average refrigerator volume by type of refrigerator across the region. The average refrigerator size is approximately 17 cubic feet (cu.ft.). This size is about 15% smaller than the average size in the other residential sectors.

Table 89. Average In-Unit Refrigerator Volume by Type

Refrigerator Type	Volume (cu.ft.)		
	Mean	EB	n
Full Size Refrigerator Only	12.0	0.0	1
Refrigerator With Bottom Freezer	18.9	1.4	22
Refrigerator With Side-by-Side Freezer	22.0	0.9	26
Refrigerator With Top Freezer	16.8	0.4	492
Undercounter Refrigerator	10.2	2.4	5
Refrigerated Wine/Beverage Cooler	7.0	2.1	5
All Types	17.0	0.4	551

5.4.2. Clothes Washers

Surveyors determined the age and type of clothes washers in the units. This effort was either based on model numbers that were observed onsite and referenced later from literature available for those models, or based on the participant interview and/or documentation provided by the participant.

Table 90 shows the distribution of clothes washer vintages. The bulk of these washers (about 60%) were manufactured since 2000. The average age of the washers is less than 10 years.

Table 90. Distribution of In-Unit Clothes Washers by Type and Vintage

Vintage		Clothes Washer Type						
		Combined Washer/Dryer, One Drum	Horizontal Axis Washer	Stacked Washer/Dryer	Vertical Axis With Agitator	Vertical Axis Without Agitator	All Types	n
Pre 1980	%	–	–	–	2.1%	–	2.1%	1
	EB	–	–	–	3.4%	–	3.4%	
1980–1989	%	–	–	0.8%	4.8%	–	5.6%	12
	EB	–	–	0.8%	2.8%	–	2.9%	
1990–1994	%	–	–	2.4%	7.3%	–	9.7%	22
	EB	–	–	2.4%	4.8%	–	5.3%	
1995–1999	%	–	2.2%	4.3%	14.5%	1.1%	22.1%	40
	EB	–	3.5%	2.9%	6.3%	1.7%	7.6%	
2000–2004	%	0.4%	2.7%	4.1%	12.5%	0.7%	20.4%	51
	EB	0.6%	2.5%	2.2%	5.6%	1.1%	6.2%	
2005–2009	%	0.1%	3.2%	10.1%	20.5%	–	34.0%	94
	EB	0.2%	2.5%	3.7%	7.5%	–	7.8%	
Post 2009	%	0.1%	0.6%	1.5%	2.9%	1.0%	6.1%	18
	EB	0.2%	0.6%	1.3%	2.3%	1.2%	2.9%	
All Vintages	%	0.7%	8.7%	23.2%	64.7%	2.8%	100.0%	238
	EB	0.7%	5.9%	6.3%	8.0%	2.3%		

Table 90 also shows the distribution of clothes washer types across the region. These types are characterized as horizontal (front-loading) or vertical axis (top-loading) washing machines as well as stacked and combination washer/dryers. As shown, about two-thirds of washing machines in this sector are conventional vertical axis washing machines, with only about 9% of the washing machines being high-efficiency horizontal axis machines. A variation on this horizontal axis technology is the vertical axis without agitator. Combined, these two washer types account for nearly 12% of the current stock of in-unit clothes washers, compared to nearly 40% for single-family homes and about 25% for the manufactured homes.

5.4.3. Clothes Dryers

Surveyors recorded only the vintage and usage for clothes dryers. Table 91 shows the distribution of clothes dryer vintages. In general, the vintage distribution is similar to clothes washer vintages, suggesting that these appliances were matched and purchased by the participants at the same time. Less than 1% of the dryers in units are gas fueled.

Table 91. Distribution of In-Unit Clothes Dryers by Vintage

Vintage	Clothes Dryers		
	%	EB	n
Pre 1980	1.9%	3.2%	1
1980–1989	5.3%	2.7%	13
1990–1994	8.7%	4.2%	21
1995–1999	18.4%	6.6%	36
2000–2004	19.2%	5.4%	57
2005–2009	31.4%	7.3%	97
Post 2009	6.0%	2.7%	19
Unknown	9.0%	4.9%	16

When surveyors interviewed participants about their clothes washer use, they also asked participants to estimate the percentage of the washer loads that became dryer loads. Table 92 shows the responses to these questions.

Table 92. In-Unit Laundry Characteristics

Category	Laundry Characteristics		
	Mean	EB	n
Clothes Washer Loads per Week	4.51	0.59	259
Dryer Loads per Washer Load	91.6%	2.4%	260

The number of loads of laundry per week in the units with in-unit laundry is comparable to the responses in the other residential sectors. It differs dramatically from the responses of tenants that did not have in-unit laundry. In those cases, the number of loads per week was reduced by a factor of two (see Section 4.5.1).

Approximately 90% of all washer loads become dryer loads across the region, and this percentage is similar to the single-family results.

5.4.4. Kitchen Appliances

The multifamily sector includes units with modest or no kitchens. This section describes the kitchen equipment present in multifamily buildings.

As with clothes dryers, surveyors recorded only the vintage and usage for dishwashers. They determined vintages onsite using model numbers or by information and/or documentation provided by the participant. Table 93 shows that only about 40% of the dishwashers were purchased since the year 2000. In addition, about 20% of all units do not have a dishwasher.

Table 93. Distribution of In-Unit Dishwashers by Vintage

Vintage	Dishwashers		
	%	EB	n
Pre 1980	1.3%	1.3%	6
1980–1989	3.7%	2.0%	25
1990–1994	5.7%	2.5%	33
1995–1999	11.7%	3.3%	66
2000–2004	15.7%	4.2%	77
2005–2009	20.9%	4.8%	127
Post 2009	3.9%	1.9%	25
None	21.8%	5.6%	132
Unknown	15.3%	4.7%	61

Surveyors also asked the tenants about their use of the dishwasher. The overall average across units with dishwashers was about 2.1 loads per week, as shown in Table 94. This is somewhat less than responses to this question in the other residential sector surveys.

Table 94. In-Unit Kitchen Appliance Characteristics

Category	Kitchen Appliance Characteristics		
	Mean	EB	n
Dishwasher Loads per Week	2.09	0.26	453
Cook Top Fuel: Electric	96.6%	2.1%	527
Cook Top Fuel: Gas	3.4%	2.1%	25
Oven Fuel: Electric	96.9%	2.1%	531
Oven Fuel: Gas	3.1%	2.1%	21

Table 94 also shows the distribution of cook top and oven fuel for the region. The multifamily sector has a high saturation of electric cooking equipment. With 97% of the cooking equipment electric fired, this exceeds even the manufactured home sector and is 25% higher than the electric cooking saturation in the single-family sector.

5.5. Unit Consumer Electronics

Surveyors conducted the electronics audit on a room-by-room basis. Table 95 summarizes the results of the electronics audit. The review gathered considerably more detail on the TVs than on the other equipment. Table 95 summarizes all the systems and is followed by a more detailed description of the TVs.

Table 95. In-Unit Electronics Characteristics

Category	Electronics Characteristics		
	%	EB	n
Televisions Per Unit	1.52	0.09	509
Primary Television On-Time Hours Per Day Per Unit	6.76	0.54	537
Set-Top Boxes per Unit	1.16	0.09	418
Units With Set-Top Boxes	75.1%	4.7%	418
Set-Top Boxes With DVR Capability	15.0%	5.2%	67
Units With Gaming Systems	20.9%	4.8%	105
Gaming Systems Per Unit With Gaming Systems	1.28	0.10	105
Computers Per Unit	0.71	0.09	317
Units With Computers	51.0%	5.3%	317
Audio Systems Per Unit	0.80	0.08	303
Passive Subwoofers Per Unit	0.10	0.03	55
Powered Subwoofers Per Unit	0.11	0.04	57
Total Subwoofers Per Unit	0.25	0.05	112

Surveyors were asked to categorize set-top boxes as the devices that received the cable or satellite feed for the television. Other devices such as gaming systems or Internet connections were not included in this category. The surveyors also noted the type of set-top box and digital video recorder (DVR) capability. Table 95 summarizes those results.

The number of set-top boxes in the multifamily units is comparable with the other RBSA building types. In all these building types, the saturation of set-top boxes is about two-thirds that of TVs.

Across the region, about 21% of the units have gaming systems. The average number of gaming systems that are present in units that have gaming systems is about 1.3 systems.

The surveyors conducted a census of computers by room. They counted only computers that were plugged in or in some way directly in use. Thus, laptops that were not immediately obvious were not included. Table 95 presents the saturation of computers per unit across the multifamily sector. The percentage of units is much smaller than the other residential sectors. Only about 50% of the multifamily units have a computer. This compares with more than 90% in the single-family survey and about 75% in the manufactured home survey.

Surveyors observed the number of audio systems and certain aspects of these audio systems, especially the presence of passive and powered subwoofers. Table 95 describes the average number of audio systems and subwoofers. On average, each unit in the region has about 0.8 audio systems. The subwoofers were classified as “passive,” which run off amplifier power, and “powered,” where the device requires its own power source to boost the performance and has an ongoing standby load. Table 95 shows the saturation of subwoofers per home by type. The saturation is around 20% for all subwoofers, and less than half of these are powered subwoofers.

Ecotope developed the saturation of TVs per home by compiling all the TVs in the individual rooms. Table 95 shows that the overall number of TVs across the region is about 1.5 TVs per multifamily unit. This compares to 2.3 TVs per home in the single-family sector and 2.1 in the manufactured homes sector.

Surveyors also asked participants to report the number of hours the primary TV was turned on per day. Table 95 also summarizes these reports. The number of hours of TV "on time" in this sector is about 35% longer than in the single-family RBSA sample and about equivalent to the manufactured home sector.

When the information was accessible, the surveyors also recorded television power in Watts for primary TVs. Table 96 shows the television power for the measured TVs by TV vintage. The surveyors measured TV power on approximately 65% of the TVs in the sample.

Table 96. Average In-Unit Television Power by Vintage

Vintage	Television Power (W)		
	Mean	EB	n
Pre 1990	73	15	7
1990–1999	104	34	59
2000–2004	88	8	90
2005–2009	121	17	168
Post 2009	110	13	87
All Vintages	109	10	439

Table 97 shows the percentage of TVs in each vintage bin and screen type. TVs were categorized into two types. CRT denotes conventional tube type TVs that for the most part were made obsolete in the last eight years. Nevertheless, this type of TV was dominant in the earlier time periods. The "Other Type" indicates flat screen TVs, although the surveyor was not asked to try to determine the differences among Plasma, LED, and liquid crystal display (LCD) because those were thought to be inscrutable relative to the available documentation. We can assume that the dominance of the "Other Type" category reflects an ever increasing saturation of LED and LCD TVs as we move to the newer vintages.

Table 97. Distribution of In-Unit Television Screens by Type and Vintage

Vintage		Television Screens		
		CRT	Other	n
Pre 1990	**%**	100.0%	–	13
	EB	0.0%	–	
1990–1999	**%**	93.6%	6.4%	96
	EB	6.4%	6.4%	
2000–2004	**%**	94.4%	5.6%	144
	EB	3.3%	3.3%	
2005–2009	**%**	27.1%	72.9%	275
	EB	7.0%	7.0%	
Post 2009	**%**	5.5%	94.5%	144
	EB	3.7%	3.7%	
All Vintages	**%**	47.5%	52.5%	672
	EB	5.4%	5.4%	

Table 98 shows the location of TVs throughout the units. Living rooms in the multifamily units are the most common locations for televisions.

Table 98. Distribution of In-Unit Televisions by Room Type

Room	Televisions		
	%	EB	n
Bathroom	0.1%	0.1%	1
Bedroom	28.1%	3.5%	194
Dining Room	0.1%	0.1%	1
Family Room	0.1%	0.1%	3
Hall	0.0%	0.1%	1
Kitchen	1.8%	1.2%	16
Laundry Room	0.1%	0.2%	2
Living Room	60.5%	3.5%	441
Master Bedroom	7.1%	1.8%	69
Office	0.7%	0.6%	7
Other	1.5%	1.3%	10

6. Building Energy Benchmarking

This section presents the results of the billing analysis and energy benchmarking for the multifamily sector. The RBSA sample presents a unique opportunity to develop energy-use profiles for these buildings. Ecotope requested electric and gas bills for all participants in the multifamily RBSA.

The surveyors obtained billing releases from each building manager or owner and from the tenants for the surveyed units (two or three per building). For some utilities, these releases were not adequate to obtain bills for the entire buildings, and those utilities would not provide bills for any units other than those where a billing release was secured. This approach made further billing analysis of those buildings (and utilities) impossible. About 4% of the buildings were dropped as a result of the difficulties of securing billing data. For the remaining buildings, the utilities anonymized the bills and provided them without a direct reference to the individual customer.

Because of anomalous bill readings and unexplained consumption variations, some of the bills collected could not be used and were removed from the analysis. Overall, electric bills for 210 buildings were summarized, and used for the energy-use analysis.[17]

6.1. Bill Assembly and Screening

The multifamily sector presents some significant challenges to the development of an energy consumption estimate from utility billing records. There are numerous opportunities for confusion and missing bill streams that make the development of a benchmark uncertain:

- **Unit meters.** In buildings with individual meters, the utility is not always clear if the unit is part of a particular building. In multi-building facilities, it is also difficult to be sure that the bills are assigned to the units in the building surveyed. Even when surveyors attempted to write down all the meter numbers for a particular building, there is always a chance that numbers are transposed or dropped or unreadable. The utility may be able to catch these problems, but in many cases the procedure for responding to the request for bills is able to address only the meters identified.
- **Common meters.** The buildings in this study range in size from five units up to 356 units. This level of variation has no precedence in any other part of the residential sector. Moreover, the building meters are generally not residential meters but are referred to as "house meters" and billed as commercial or "general service" customers. As a result, it is often difficult to be sure that all the meters that are assigned to the building are part of the multifamily building itself or part of a street-level non-residential use that is metered as a separate commercial use. Considerable effort was spent to resolve these issues with the common area and non-residential meters, but some errors may still remain.

[17] Utility bills were requested for the period beginning in January 2009 and ending in late 2012 depending on the utility billing cycle. Although most utilities provided bills over this time period, changes in meters, tenants, and other factors resulted in a reduced billing set in a number of cases.

- **Missing common area meters.** The surveyors tried to find all the meters at a particular building, but many buildings have multiple meter rooms that serve separate parts of the building. It is possible that some of the common area meters are missed in this process. The billing request to the utility asked for all the meters at a particular address. This generally solved the problem, but in a few cases there may have been meters that were not included in the common area billing analysis.
- **Facilities.** About 60% of the multifamily buildings in this sample are located in a multi-building facility. In these cases, the individual unit meters are usually unambiguous, but the common area meters are not. The surveyor tried to resolve the meter numbers so that only the common meter of the building that was surveyed was included in the billing request. Because we instructed utilities to err on the side of inclusion for meters that were located at the common building address, some meters from adjacent buildings were often included. A careful review usually allowed us to have confidence in the common area assigned, but facility meters may have been included in a particular building's common area usage in some cases.

The process of assembling the bills for each building used a combination of utility inquiries, survey information, searches using Google Earth, and occasional calls to the building. We believe that this process resulted in a relatively complete record of the units at each building and a resolution of meters that were not a part of the residential facility. In cases where the meter was missed by the surveyor and the utility, we probably did not correct for this unknown usage. In cases where extra facility meters were present, we usually resolved the final list of meters to have confidence in the common area usage that was used in the billing analysis. All of these steps have the potential for error, but this process minimized the error that might be developed in this complicated process.

6.2. Billing Analysis Procedure

Ecotope used a standard VBDD approach to analyze utility bills. This procedure results in an estimate of the portion of any bill that is temperature-dependent. The estimate of the temperature dependence determines the space heat estimate for each home. The procedure for deriving and correcting these estimates was developed in Fels (1986) and expanded more recently in Geraghty & Baylon (2009).

The application of these techniques to the multifamily sector used techniques developed to expand this methodology to the multiple bills and zone problem presented by multifamily buildings (Fels & Reynolds, 1992) and used a building-level analysis to evaluate energy use. This approach was refined in an evaluation in this region (Heller et al., 2009). In this approach, the bills of all the units were combined. Individual billing periods were established so that the billing combination did not result in a different billing period in a particular building. The bills were then totaled for each billing period, and the normalization process proceeded with these aggregated bills.

In addition to developing a space heating estimate, the results of the VBDD analysis allow the bills to be adjusted to account for changes in weather and to be "normalized" to long-term weather data. The normalization process ensures that sites can be compared to one another and to future energy use without biasing the comparison as a result of short-term transients in the weather.

Ecotope applied the VBDD procedure to the electric and gas bills associated with each home. In the case of the electric bills, many buildings do not use a clear electric heating signature, so the use of VBDD largely fails to produce statistically acceptable estimates of electric space heat. To account for this, Ecotope screened results based on the "fit" and size of the heating signature. Bills that failed this screen were totaled and annualized. To annualize these cases, Ecotope averaged the monthly consumption over the number of years available.

Because of the anomalies introduced by combining the units, a single electric heating estimate was not developed. The weather normalization, however, was used to develop annualized consumption for all sites where the VBDD regression fit was available.

For gas bills, the combination of master metered buildings and frequent inclusion of other buildings in the complex resulted in a reduced set of bills that could be used for this summary. The gas summaries were not combined with the electric bills because the bias associated with these missing bills could not be assessed. Although the combination of bills would give a better picture of the particular buildings where both bill streams were available, nearly 30% of the buildings that were identified with some type of gas service are not represented in this summary. To avoid this issue, we have maintained separate summaries for the two fuel types.

6.3. Building Electric Energy Use Indices

The individual units were aggregated into a single analysis for each building. Table 99 and Table 100 summarize the results of the aggregate unit meters. These summaries include the average residential electric bill across the multifamily sector. These summaries do not include any of the house meters or other facility meters. They also do not include the buildings that were master metered.

To construct Table 99, the bills from an individual building were aggregated and weighted. The summaries were normalized by the number of units in each building. This procedure provided the overall average per-unit consumption across the region. For Table 100, the same process was used except that the total unit square footage in each building was used as the normalizing parameter.

Table 99. Average Annual Unit Electric Consumption by Building Size

Building Size (Stories)	Electric kWh per Unit		
	Mean	EB	n
Low-Rise (1–3)	8,230	1,356	137
Mid-Rise (4–6)	6,040	686	50
High-Rise (7+)	5,360	1,773	18
All Sizes	7,824	1,137	205

Table 100. Average Annual Unit Electric Consumption by Unit Size and Building Size

Building Size (Stories)	Unit kWh per Sq.Ft.		
	Mean	EB	n
Low-Rise (1–3)	10.17	1.67	137
Mid-Rise (4–6)	6.89	0.81	50
High-Rise (7+)	5.66	0.81	18
All Sizes	9.49	1.38	205

Table 101 and Table 102 show the equivalent calculation for the common areas. Like the unit-level tables, these summaries provide the regional average common area usage in the multifamily sector. Table 101 shows the common area usage normalized by number of units. This value is the incremental increase in unit electric energy use as a result of common area functions. Table 102 shows the common area electric usage normalized by conditioned common area square feet. Energy use in common areas in high rise buildings is much larger than the rest of the sample due to the larger amount of common area functions and the use of separate common area ventilation systems in these building types.

Table 101. Average Annual per Unit Common Area Electric Consumption by Building Size

Building Size (Stories)	Common Area kWh per Unit		
	Mean	EB	n
Low-Rise (1–3)	1,879	522	66
Mid-Rise (4–6)	1,950	464	50
High-Rise (7+)	4,487	1,924	18
All Sizes	2,171	457	134

Table 102. Average Annual per Square Foot Common Area Electric Consumption by Building Size

Building Size (Stories)	Common Area kWh per Sq.Ft.		
	Mean	EB	n
Low-Rise (1–3)	19.0	6.3	66
Mid-Rise (4–6)	12.0	1.9	50
High-Rise (7+)	31.8	11.5	18
All Sizes	18.1	4.1	134

6.4. Building Gas Energy Use Indices

The use of gas in the multifamily sector is more limited. In general, natural gas is supplied to the building but not to the unit. In this summary, only about 11% of all multifamily buildings have gas service directly to the individual tenants. The remaining gas customers were served through one or more master meters billed directly to the multifamily building or complex.

A total of 95 buildings had gas service present; however, some of them were either not received or were not useable for this summary. A total of 73 gas customers proceeded in the analysis. The three primary reasons for dropping the sites were:

1. The gas bill that was provided represented multiple buildings, and the surveyed building could not be separated.

2. The number of gas bills was insufficient to assemble an annual consumption estimate.
3. The survey did not identify gas equipment, and the surveyor was not aware of a natural gas meter.

Table 103 and Table 104 show the gas usage in multifamily buildings. This set of bills has been evaluated as individual buildings; the units and common area are combined to yield a single billing set. This procedure was proposed in 1992 (Fels & Reynolds, 1992) following several billing analyses that showed anomalous results (see, for example, Tonn & White, 1988). The gas results have been normalized by overall building square feet and by overall number of units in the building. These summaries were not done on the unit usage separately because few buildings provided gas service to the individual units. In those cases, the unit gas bills were combined with the building gas bills to provide the basis for annualizing the gas consumption.

Table 103. Average Annual Total Residential Gas Therms Per Residential Unit by Building Size for Buildings With Gas Service

Building Size (Stories)	Gas Therms per Unit		
	Mean	EB	n
Low-Rise (1–3)	178	45	39
Mid-Rise (4–6)	152	61	18
High-Rise (7+)	108	32	16
All Sizes	163	33	73

Table 104. Average Annual Residential Gas Therms Per Sq.Ft. by Building Size for Buildings With Gas Service

Building Size (Stories)	Gas Therms per Sq.Ft.		
	Mean	EB	n
Low-Rise (1–3)	0.196	0.051	39
Mid-Rise (4–6)	0.126	0.053	18
High-Rise (7+)	0.096	0.037	16
All Sizes	0.165	0.036	73

The gas usage pattern in this summary is that the per unit gas consumption in low-rise buildings is nearly double that of the high-rise buildings. This difference is partly explained by the fact that most of the high-rise buildings are new (built since 1990), while the gas consumption in the low-rise buildings includes older buildings in colder eastern regions. When consumption is normalized by unit, this difference is reduced, but normalized consumption per unit is more than 65% higher in the low-rise buildings compared to the high-rise buildings.

These gas summaries were not combined with the electric bills for this report. Although the combination of bills would give a better picture of the particular buildings where both bill streams were available, nearly 30% of the buildings that were identified with some type of gas service are not represented in this summary. In those buildings, a combination would be biased. To avoid this issue, we have maintained separate summaries for the two fuel types.

6.5. Building Total Electric Energy Use Indices

The total EUI for the building is designed to express the building benchmark and typically includes all utility bills. The analysis of gas bills already represents a building-wide summary, so only the electric bills are included in this section. Table 105 and Table 106 summarize the aggregate electric energy EUI across the multifamily sector. The overall area normalization uses the sum of all the common area and all the unit areas.

Table 105. Average Annual Total Electric Consumption by Building Size

Building Size (Stories)	Annual Total kWh per Unit		
	Mean	EB	n
Low-Rise (1–3)	9,338	1,340	140
Mid-Rise (4–6)	7,955	714	51
High-Rise (7+)	9,650	3,268	22
All Sizes	9,188	1,125	213

Table 106. Average Annual Total Electric Consumption per Unit Square Foot by Building Size

Building Size (Stories)	Annual Total kWh per Sq.Ft.		
	Mean	EB	n
Low-Rise (1–3)	11.0	1.6	140
Mid-Rise (4–6)	7.5	0.6	51
High-Rise (7+)	8.8	1.3	22
All Sizes	10.3	1.3	213

For the multifamily sector, this summary suggests a great deal of commonality in electric energy use. The average electric energy use per unit is slightly more than 9,000 kilowatt hours per year (kWh/yr), and the EUI per square foot of multifamily building is about 10 kWh/sq.ft.

7. Conclusions and Comparisons

The nature of the RBSA was to collect as many characteristics of the residential sector as possible. For multifamily buildings, this process focused on a regionally representative sample with the assumption that the results would apply to the region as a whole. The lack of prior comprehensive reviews of existing multifamily buildings and units make direct comparison to historical surveys difficult. The principle comparison presented below contrasts the multifamily results with the RBSA single-family and manufactured homes findings.

It is important to note that this sample was designed to sample larger buildings with higher probability than smaller buildings. The unit sample developed from the phone survey was the basis of this sample, but the onsite audit and the characteristics focused on building-wide characteristics. The unit sample was limited to units selected at random in the buildings recruited. Because the underlying sample was designed to produce a regional summary, only a few areas where utilities requested oversamples can be summarized. In this report, they have been weighted into the overall sample to minimize the possibility of bias in the final characteristics summaries.

7.1. Building Size and Age

In the RBSA, the multifamily building summaries show that about 56% of the buildings surveyed and about 53% of the units surveyed were built before 1981, whereas in the single-family RBSA about 63% were built before 1981. In the more urban portion of the sample, about 65% of the buildings were constructed before 1981.

The average size of units surveyed in this sample (selected at random from the building surveyed) is about 766 square feet. This compares with the 1992 PNWRES survey result (of multifamily units) of about 980 square feet based on a phone survey (BPA, 1993). The review of unit sizes done in the 1984 Seattle survey (DelaHunt et al. 1984) suggests an average unit size of 700 square feet. The variation here does suggest some differences in the samples between the RBSA and the PNWRES, although the data in this survey are not sufficient to resolve these differences.

The single-family RBSA study reported an average number of people in each home as 2.7. This average compares with the 1.9 people reported in the multifamily RBSA. This result appears consistent with the size and nature of the units in this survey.

7.2. Building Envelope

For some of the multifamily buildings, the construction type is not really comparable with the other residential buildings in the RBSA surveys. About 2% of the multifamily sector (weighted) is constructed using rigid frame and in-fill walls. This represents a relatively minor portion of the sector, although this construction type is important in areas where high-rise construction is typical such as dense, urban areas of Portland and Seattle.

Overall, the heat loss rates of units in this survey is about one-third of the per-home heat loss in the single-family survey. When these values are normalized to the amount of conditioned square feet, the heat loss rate (conductive only) is about 30% lower than the single-family homes surveyed. This reduced heat loss reflects the difference in size of units and the impact of the building geometry on the effective heat loss of each unit.

Window specification across the RBSA multifamily sector focused on the window frame material and glass types. The window types in multifamily buildings include nearly 70% non-metal frames or high performance metal frames and about 82% double-glaze glass or better. Given the age of these buildings, this result suggests a substantial amount of retrofit with newer high-performance windows. The overall window area for the RBSA single-family home is 12.5% of conditioned floor area. In the multifamily sector, the average widow to floor ratio is about 11%.

7.3. Lighting

The number of lamps per unit in this survey is 23.2. When compared with the single-family sample, the density of lamps (lamps/sq.ft.) is comparable. Furthermore, the percentage of the lamps in multifamily units that are fluorescent lamps is similar. Taken as a whole, the LPD of the units in this survey is 1.46 W/sq.ft., which is fairly comparable to the findings of the single-family survey (1.42 W/sq.ft.).

The common area lighting in the multifamily surveys is surprisingly efficient. The overall LPD in the common area is about 0.68 W/sq.ft. About 80% of the lamps in common area surveys are fluorescent (either linear or CFLs).

7.4. HVAC

In this survey, about 6% of all multifamily buildings have central heating systems. About 90% of these systems rely on natural gas as the primary heating fuel; 10% are electric heat pump systems.

In the remaining buildings, the heat is provided at each unit. In the buildings without central heating, the incidence of zonal electric resistance heating is about 90%. Overall, about 93% of the multifamily sector is electrically heated from all sources. In the single-family survey, about 41% of the homes reported electric heat. When compared to the manufactured home sector, the two surveys are more comparable. The use of electric space heat of all types in the manufactured home sector is about 70%. The manufactured home sector is about 70% electric heated.

About 30% of the RBSA multifamily surveys reported cooling equipment. This result compared with about 42% in the single-family sector. About 75% of the cooling is supplied by zonal equipment located in each unit.

7.5. Domestic Hot Water

About 11% of the multifamily buildings supply DHW via a central system. Three-quarters of these systems are fueled by natural gas. The remaining systems are smaller electric systems using a dedicated DHW tank.

The remaining systems are all in-unit tanks. About 95% of these systems are electric heated. In the RBSA single-family survey, the fuel type for water heat is 55% electric and 43% gas, with the balance being propane or other fuel. Overall, electric fired DHW systems account for about 81% of all the units surveyed.

7.6. Common Area Equipment and Appliances

The building survey focused on the common area equipment. This category is dominated by the laundry area. About 44% of the buildings have a common area laundry used by the tenants. For most of these cases, there are no clothes washing capabilities in the individual units. When the tenants were surveyed on their clothes washing habits, they said they used their in-unit washing machine about twice as often as tenants that did not have in-unit laundry equipment.

Pools and spas are present in about 30% of multifamily buildings. Pools are mostly exterior and seasonal; about two-thirds of spas are interior and used year round. This latter group tends to be associated with higher-end multifamily buildings.

Elevators are located in about 11% of the buildings. The elevators are present in virtually all multifamily buildings more than four stories tall and in a small number (6%) of low-rise buildings.

All the RBSA surveys recorded the saturation of appliances. In the multifamily survey, the appliance saturation is typically less than the single-family and manufactured homes. About 1.0 refrigerators per unit are present in this sector compared to about 1.3 in the single-family survey. The saturation of dishwashers is about 89% in the single-family survey and about 78% in the multifamily survey. The appliance stock itself is comparable between the sectors once the reduced saturations were taken into account.

7.7. Electronics

The average number of TVs per home is 2.3 in the RBSA single-family survey and about 1.5 in the multifamily survey. Saturations of set-top boxes, gaming systems, and audio equipment are about one-third less than the single-family survey. In the RBSA single-family sector, more than 90% of homes have a computer, and the average number of computers is 1.67 per home. In the multifamily survey, the saturation of computers is about 70%.

7.8. Energy Use

In the RBSA multifamily survey, electricity bills were collected for about 98% of the sample. Gas bills were also collected, but only 77% of these bills were useable in the final summaries.

Electric bills were summarized for both common area uses (“house” meters) and aggregated units. A normalized EUI was then calculated using the conditioned floor areas recorded during the building survey. A separate EUI was calculated that normalized the electric consumption by unit. Overall, electric energy use in the common area averages 18 kWh/sq.ft. of common area. The overall unit consumption averages about 9.5 kWh/sq.ft. of unit area. Overall, the electric consumption is about 10.3 kWh/sq.ft. across the multifamily sector. This translates to an overall electric energy use of about 9,188 kilowatt hours per unit per year (kWh/unit/yr).

The gas customers showed some variation by building size. On average, the normalized consumption for high-rise buildings is about 55% of the usage in low-rise buildings. Overall, the gas usage in this sector averages 0.165 therms/sq.ft. per building and about 163 therms per residential unit.

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