Conservation Applied Research & Development (CARD) Program
INTERIM/FINAL REPORT

MINNESOTA MULTIFAMILY RENTAL CHARACTERIZATION STUDY

Prepared for: Minnesota Department of Commerce, Division of Energy Resources
Prepared by: Energy Center of Wisconsin and Franklin Energy LLC

JUNE 2013
OES-04042011-36082

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ACKNOWLEGEMENTS

This project was supported in whole by a grant from the Minnesota Department of Commerce, Division of Energy Resources through the Conservation Applied Research and Development (CARD) program, which is funded by Minnesota ratepayers.

The authors would also like to acknowledge the following persons for their contributions to the project:

Energy Center of Wisconsin staff who contributed to this project include Ingo Bensch, Steve Buss, Heather Driscoll, LaShanta Goodwin, Scott Hackel, Ben Heymer, Ashleigh Keene, Steve Kihm, Karen Koski, Jeannette LeZaks, Melanie Lord, Andy Mendyk, and Jaimie Rule.

Franklin Energy staff who contributed to this project include David Brandner, Mark Brown, Dean Laube. Meredith Seidl, and Tom Syring.

Additionally, we would like to acknowledge additional advisory support from Russ Landry (Center for Energy and Environment), Janne Flisrand (Minnesota Green Communities), Frank French (The Goodman Group) and Jeanette Blankenship (Minnesota Housing Financial Agency).

NOTIFICATION

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REPORT SUMMARY

The Energy Center of Wisconsin and Franklin Energy received a grant from the Minnesota Department of Commerce to characterize energy use in the state's multifamily sector, and to identify untapped energy efficiency opportunities. In addition, we explored energy-related behaviors and attitudes of multifamily building owners and their tenants.

The multifamily rental housing sector presents particular challenges to energy policy makers and energy efficiency program managers. While all market sectors manifest barriers to energy efficiency investment, the multifamily sector has more than most. Lack of awareness of efficiency benefits, limited capital to invest in new technologies, conflicting priorities for a building owner or manager's time and energy and split incentives between owners and tenants have all been cited as challenges to increasing energy efficiency in this sectors.

The scope of the study includes rental townhomes and multifamily buildings with five or more housing units that are heated with natural gas or electricity. In the state of Minnesota there are about 370,000 such housing units, nearly three-quarters of which are in the seven-county Twin Cities region. In conducting our research, we sampled 120 buildings from across the state, 78 of which are located in the Twin Cities area. We visited the selected sites to obtain building shell, equipment and appliance-related information, and obtained utility energy and water usage histories for most. We placed data-logging equipment in 17 buildings in the Twin Cities area to capture in-unit and common-area temperature and relative humidity data, in-unit lighting usage, and boiler supply and return water temperatures. We gathered information from building owners and tenants through on-line and mail surveys. Participants received small incentive payments in exchange for the time they spent responding to our surveys.

Multifamily Housing Segments
We grouped multifamily buildings by building size (number of units) and vintage (original construction date). In the Twin Cities, building size is skewed toward the large end of the range, with structures having 20 or more units accounting for about 70 percent of the rental multifamily housing units. Outside the Twin Cities area (which we refer to as Greater Minnesota) size is more evenly distributed with approximately a 50-50 split between housing units in buildings with 20 or more units and those with fewer than 20 units.

We identified three primary vintage groups based on construction practices and heating systems in vogue at the time the buildings were erected (Page 13).

- **Pre–World War II** buildings, found mostly in older urban areas, tend to have brick facades, range in size from 5 to about 50 units, and are rarely taller than five or six stories. They often originally used coal-fired steam heating systems, but most have been converted to natural-gas-fired hot-water heating systems. Some are mixed-use (residential and commercial) space.
- **Post-War** buildings were typically built with hydronic (hot-water) boiler systems, which remain in place. Many are three-story buildings that are part of a complex of similar buildings. About two-thirds of the individual buildings have between 10 and 50 units. These buildings are almost exclusively residential.
- **Post-Energy Crisis** (1980 to the present) buildings were constructed subject to energy codes, which is not true for buildings in the other two groups. They are generally better insulated and more energy efficient than their predecessors. They tend to have a wider variety of strategies for heating and cooling. Some buildings reflect the modern resurgence of residential/commercial mixed-use design.

Some buildings, such as townhomes, do not fall into any of these categories, as is the case with a small number of hard-to-classify structures.

End Use Characteristics
Our analysis reveals that the typical Minnesota multifamily building with gas space heat uses one or more boilers to supply a hot-water-based heating system, individual sleeve or window air conditioners for cooling, and centralized, natural-gas systems to provide hot water. There is, however, considerable diversity in the sector.

In terms of lighting, a typical building contains many more in-unit lighting fixtures and plug-in lamps than those found in common areas. Nevertheless, in terms of total energy consumption, the common-area lighting dominates. More than 80 percent of common-area lighting operates continuously, while most in-unit luminaires tend to be on three hours or less per day (Page 35).

We find an efficiency success story in the lighting category—between 80 and 90 percent of the buildings use highly-efficient LED technology in building exit signs. The situation is less favorable in terms of general lighting, where we find three times as many inefficient incandescent bulbs as efficient CFLs (Page 35).

Refrigeration represents the biggest single electricity use in apartment units. Refrigerator efficiency declines with equipment vintage, with units manufactured in 1999 or earlier typically being noticeably less efficient than those manufactured after that date. More than a quarter of the refrigerators in the multifamily sector date to the earlier time period; this number rises to 50 percent for smaller properties (Page 40).

We found laundry facilities in common areas in about three quarters of the buildings. Slightly less than 20 percent of the buildings had in-unit laundry facilities. A small minority had no laundry equipment. We found few high-efficiency washers either in units or in common areas. Dryers in common areas tend to be gas fired with electric dryers being more common when the facilities are in the unit. In about a third of buildings with common-area laundry facilities, the equipment is owned and operated by a third party that shares the revenue with the property owner (Page 43).

Three quarters of the units have gas ranges/ovens with the remainder having electric versions. Slightly fewer than half of the apartment units have a built-in dishwasher (Page 43).

Utility Metering Arrangement and Cost
For the typical multifamily property with central natural gas heat, the property owner/manager is responsible for the natural gas bill (which typically also includes domestic hot water), an electric bill for common areas and the water bill. These costs average about $745 annually per housing unit at current utility rates. Tenants typically pay an electric bill for the lights and appliances in their unit: tenant-paid electricity averages about $360 per year per apartment unit (Page 43).

Efficiency Opportunities
We considered 25 common energy (and water) savings opportunities in multifamily housing, which included:

- Lighting upgrades
- Installation of high-efficiency space and water heating systems
- Installation of showerheads and faucet aerators
- Upgrading to Energy Star appliances

- Installing Energy Star windows

Measures such as replacing incandescent light bulbs, replacing showerheads and installing high-efficiency clothes washers have widespread applicability in Minnesota multifamily buildings. Only relatively low-cost items such as replacing light bulbs and showerheads have both widespread applicability and offer short paybacks (Page 49).

Savings from implementing these measures where applicable could lower utility bills (natural gas, electricity and water) by an average of roughly $100 to $200 per housing unit, depending on the desired payback period. Smaller properties (fewer than 20 units) appear to have more savings potential per housing unit than larger properties (Page 50).

For most efficiency measures, with the exception of installing in-unit CFLs, the landlord would pay for the measure. The benefits analysis is more complicated as some of the savings go to the tenant while others go to the building owner depending on the metering arrangement for the property and the measure being considered. Overall, our analysis suggests that for multifamily buildings with gas heat, about 70 percent of the potential energy and water savings would accrue to building owners and 30 percent would accrue to tenants, with the latter mainly in the form of reduced bills for in-unit lighting and appliances (Page 54).

Tenant demographics, attitudes and behaviors

About 10 percent of Minnesota residents live in rental multifamily housing. Compared to residents of single-family homes, households are typically smaller in size and the residents tend to be less affluent and more mobile than those in single family residences (Page 56).

When deciding where to live, renters focus primarily on building location, apartment size and cost (rent). Energy costs lie within a secondary grouping of factors, along with parking considerations and number of bedrooms in the unit (Page 56).

Tenants report higher comfort levels for the winter months than they do for the summer months, and comfort levels are highest in newer buildings and lowest in older buildings. Tenants frequently reported that common areas have unpleasant odors and are uncomfortably hot in the summer months (Page 58).

Building ownership, management and decision-making

Individuals tend to own small multifamily buildings; limited and general partnership arrangements are more common for larger buildings. For smaller buildings, owners tend to respond to tenant needs and make small repairs, while property managers handle these activities in larger buildings (Page 64).

For small buildings, the primary responsibility for all appliance choice and building maintenance issues lies with the owners. For larger buildings, owners often participate in major decisions, but delegate responsibility for minor decisions to their property managers (Page 66).

Appliance purchases occur regularly in the sector, but frequency varies by type. Over 80 percent of building owners and managers report buying at least one refrigerator in the past two years, but only 20 percent purchased a clothes dryer in that time frame (Page 66).

Energy costs, while not as important to building owners as mortgage, insurance and tax issues, are of some concern to building owners. A majority of owners estimated that energy costs are 11 to 20 percent of their overall costs (Page 71).

Low-income rental properties
We classified 37 of the 120 properties in the study sample as low-income properties. The low-income properties tend to have more units, but in other respects appear to be reasonably similar to the non-low-income properties in the sample. The low-income properties in the sample have somewhat lower savings potential on a per-housing-unit basis among the 25 measures that we examined, though the differences are not statistically significant owing to the small sample size (Page72).

Electrically-heated buildings
According to the Census Bureau's (2007-2011) American Community Survey, about a third of multifamily properties are electrically heated. The study sample includes only nine such buildings. Our conclusions are therefore of a qualitative nature.

The electrically-heated buildings tend to be smaller, and none in the sample are townhomes or from the Pre–World War II period. Of the nine properties in the sample, seven have electric baseboard heat, one has individual electric forced-air furnaces, and one is a newly-built building with geothermal heat. Energy use per square foot appears to be lower than that of gas-heated buildings, but owing to the higher cost of electricity, heating costs are higher. The geothermal site stands as an exception: heating costs for this property were well below average (Page 75).

Townhomes
Townhomes are distinct from multifamily housing in that they typically have no common areas, and have heating, cooling and water heating equipment that is individual to each unit. On a per-housing-unit basis, we found the energy savings potential in our small (n=6) sample of rental townhome properties in the study to be comparable to that for multifamily properties. However, in contrast to multifamily properties, the benefits from efficiency improvements in townhomes would largely accrue to tenants, given that utilities for these properties are generally entirely individually metered and billed directly to tenants.

READER GUIDANCE

There are many audiences that will find the information in this report useful, including but not limited to energy efficiency program implementers, utility staff, policy-makers and multifamily building owners. While the entire report is meant to provide a comprehensive overview, certain audiences may use the findings of the report differently and we offer guidance and suggestions for those potential applications here.

For program implementers and utility staff, the energy and water consumption overview and energy and water savings opportunities may be most relevant. These sections explore energy and water consumption through billing analyses and describe savings opportunities found to be most common in the multifamily sector. The list of savings opportunities is not meant to be exhaustive but should provide a solid foundation upon which program implementers can design and plan future program offerings. The payback charts starting on page 50 provide a succinct comparison across the various measures. Additionally, the results from both the tenant and owner surveys will provide insight into strategies that motivate action and participation in energy efficiency programs.

Energy efficiency policy-makers and program implementers will be able to use information from the equipment, appliances and window characteristics section to understand market penetration of technologies to aid in resource allocation of energy efficiency funding and policy decisions regarding savings targets. Each subsection devoted to a specific technology or building characteristic contains a useful summary table that breaks down the information by building size category (e.g. 5-9 unit buildings, 10-19 unit buildings, etc.). We also provide qualitative results by segments grouped by age and building type that offer a different perspective on buildings classifications, such as Pre–World War II, Post-War buildings, and Post-Energy Crisis buildings. Both methods of classifying buildings characteristics will be constructive in developing strategies that target energy efficiency programs in the multifamily market.

Finally, multifamily building owners may find the ability to benchmark building information against their own buildings to be valuable. The energy consumption data and building characteristics allow building owners or managers to compare their building attributes against the results found in this report. Additionally, owners and managers might turn to the energy and water savings opportunities section to explore ways to invest in energy efficiency and potentially save money in operating costs.

It is worth noting that we have separated out three additional subsections in the Findings section that describe characteristics of low-income multifamily properties, electrically heated-properties and townhomes. The low-income properties section highlights specific comparisons that may aid in future planning for energy efficiency programs targeted to this segment. Electrically-heated buildings and townhomes are separated into standalone segments because our samples for these populations were small. We therefore provide only a qualitative assessment of our findings for these sections (more information on our sample composition can be found in the Introduction).

INTRODUCTION

BACKGROUND AND OBJECTIVE

The Minnesota multifamily building sector offers a significant opportunity for energy efficiency programs with nearly 22 percent of the state's housing units in multi-unit buildings, and 15 percent in rental multifamily units in buildings with five or more units[1] While multifamily buildings are concentrated in the metropolitan areas, they also can be found throughout the state, ranging from smaller walk-up buildings to high-rises in bigger cities.

Up until this time, no comprehensive characterization of the Minnesota rental housing market has been conducted. For this reason, the Minnesota Department of Commerce Division of Energy Resources (DER) has funded this characterization study with the objective of understanding the market more deeply and providing information for energy efficiency programs based on its results.

The multifamily sector has typically been hard to reach for energy efficiency programs. There are a variety of challenges that may stifle investment in energy efficiency, including the lack of awareness of efficiency benefits, limited capital to invest in new technologies, and conflicting priorities for a building owner or manager's time and energy. In addition, an oft-cited challenge of the multifamily sector is the split incentive to invest between the owners of the buildings and the tenants; the person who pays for the energy efficiency investment may not be the person who reaps the benefit of the energy savings. As a precursor to this characterization report, a study was conducted for DER which provides a more detailed examination of these challenges, an analysis of best practices and recommendations for implementing energy efficiency programs in the multifamily sector.[2]

The objectives for this characterization study are to:

- Provide a statistically representative picture of the building characteristics, appliances and equipment in the Minnesota multifamily rental housing stock
- Benchmark energy use in multifamily rental housing
- Assess energy efficiency opportunities
- Explore the knowledge, attitudes and behavior of building tenants, owners and managers

METHOD

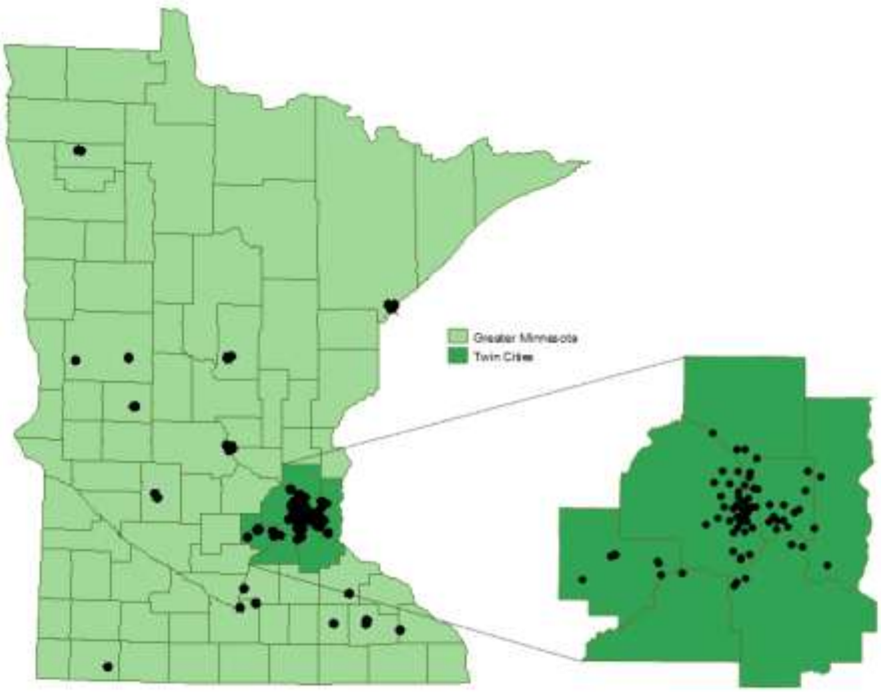
For this study, we sought to recruit a statistically representative sample of Minnesota buildings from which we collected on-site data. The study had a sample of 120 buildings and included rental housing for townhomes and multifamily buildings that had five or more apartment units. Recruiting for the study was stratified in two dimensions: by building size (as represented by number of units in the building) and, geographically, between the Twin Cities area and other parts of the state.

We recruited the buildings for this study from a number of sources: (1) a proprietary database which provided an enumeration of all multifamily properties in the seven-county Twin Cities area, (2) lists of rental properties from community tax rolls in the Greater Minnesota area and (3) contacts at local utilities. For those contacts in the Twin Cities database and the list of community tax rolls, participants were recruited either by phone from randomly-selected phone numbers or were sent postcards for an opt-in participation in the study. Those property owners found through contacts of local utilities were recruited directly via telephone. Figure 1 shows the approximate location of the 120 properties recruited for the

[1] Source: Census 2007-2011 American Community Survey microdata.
[2] http://mn.gov/commerce/energy/images/MultifamilyEnergyEfficiency.pdf

study, as well as the geographic distinction between the seven-county Twin Cities region and the remainder of the state.

Figure 1. Locations of the properties in the study sample.



For each building, we gathered three types of data:

1. **On-site data**—information on heating, ventilation and air conditioning systems, building shell characteristics, appliances and lighting data for common areas were collected by trained auditors. Depending on the size of the building, 2 to 4 units were randomly selected to conduct walk-through audits to gather specific information on unit-level characteristics. These building audits typically took about 2-4 hours to complete.

2. **Survey data**—building owners and building managers were given a survey to capture information on ownership of the building, purchasing practices, maintenance routines and investments made in their building. Additionally, all tenants were given the opportunity to fill out a survey that addressed demographics, attitudes, comfort and energy-savings behavior.

3. **Utility usage records**—we collected utility data for master-metered building accounts paid for by the owner, including gas, electric and water accounts. For tenants who provided a signed utility release, we collected individual unit-level account data for electric and gas paid for by the tenants.

In addition to these basic data elements, we placed logging equipment in a sub-sample of 17 buildings in the Twin Cities area to capture in-unit and common area temperature and relative humidity, in-unit lighting usage, and boiler supply and return water temperatures.

Building owners and managers were offered $100 for completing the owner survey and providing a signed utility release form for the common area and master metered accounts. Participating owners were also offered water saving low-flow showerheads and faucet aerators in addition to CFL bulbs for those units where a walk-through was conducted. In addition, the owners were provided a short summary report of energy efficiency recommendations. Owners did not receive the incentive and recommendation report if they did not fill out the survey or utility release form. However, these incentives did not compel some owners to complete their survey. The final dataset for the owner/manager survey includes 112 responses for a completion rate of 93 percent.

There were two versions of the tenant survey. For buildings with fewer than 50 units, a long-form survey was provided to each tenant. The surveys were either left by the door or slid under the door where possible. For buildings with more than 50 apartment units, 50 randomly-selected units were given the long-form and the remaining units were given a short form to capture basic demographics and information on occupant comfort. Respondents were offered a $20 incentive for completing the long-form survey online and sending in a signed utility release form. Respondents were also given the option to complete the long-form survey on paper for an incentive of $15. Those respondents that completed a short-form survey and sent in the utility release form were entered in a drawing for a $50 gift card.

We received a total of 1,285 tenant survey responses for the 3,692 apartment units in the study sample, representing a 35 percent response rate.

Appendix A and Appendix B provides the full survey instruments used in this study. The on-site data collection form is provided in Appendix C.

SAMPLE COMPOSITION AND WEIGHTING

We used data from the Census Bureau's (2007-2011) American Community Survey as our basis for weighting the study sample. The study scope includes rental properties in townhomes and multifamily buildings with five or more housing units (Figure 2). There are a relatively small number of such properties that are heated with fuels other than natural gas: these are excluded from the scope of this study.

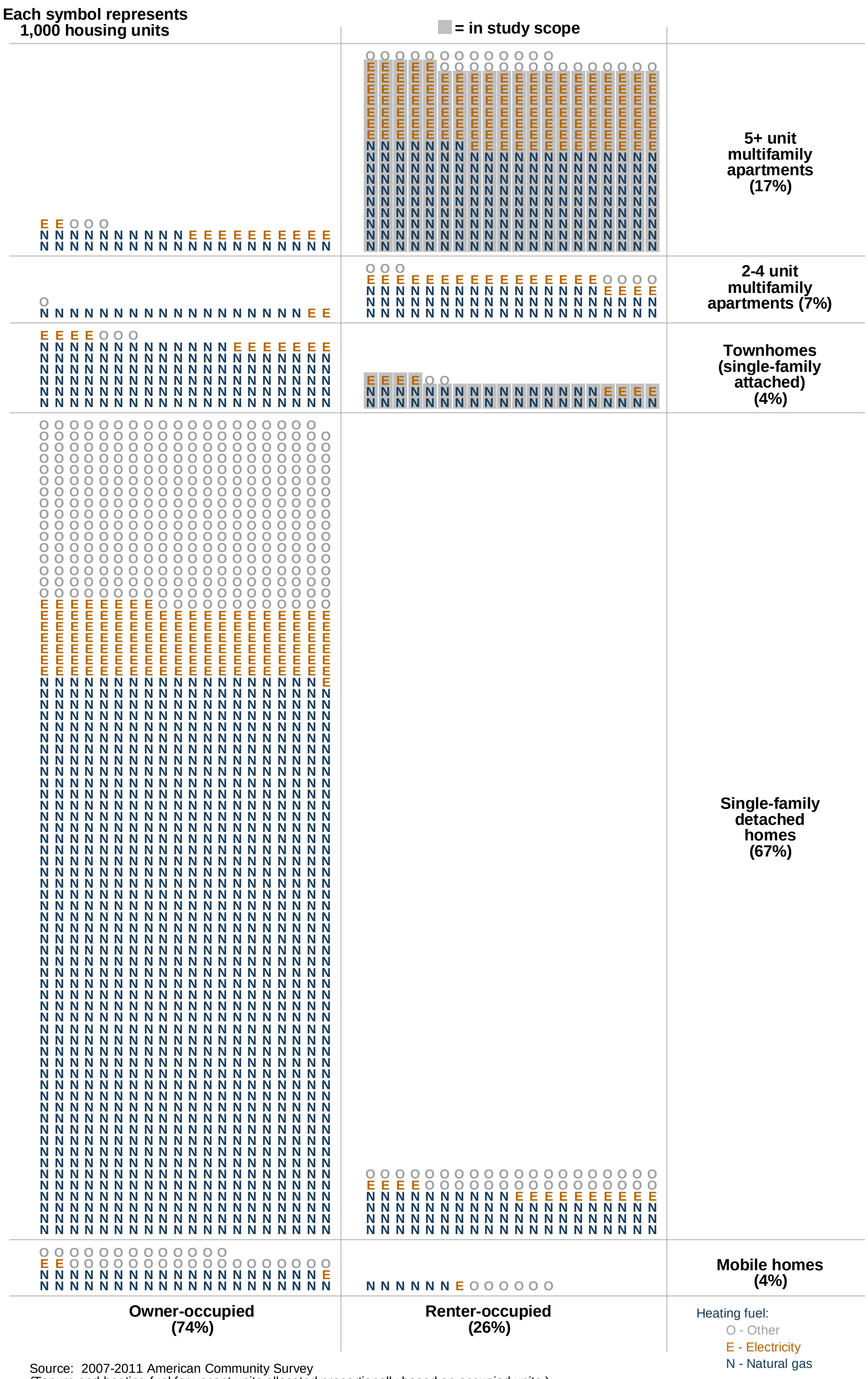
Altogether, housing units within the scope of the study make up about 16 percent of Minnesota's 2.3 million housing units, and 60 percent of rental housing in the state. Seventy percent of the housing in the scope of the study is located in the seven-county Twin Cities area.[3]

The study sample of 120 properties reasonably represents the larger population in terms of geography and building size, with two important exceptions: (a) we were able to recruit only nine multifamily properties with electric heat; and, (b) the sample contains only six townhome properties, all with natural gas space heat. Because of this, we have confined the bulk of our analysis and reporting to gas-heated multifamily properties. However, we include short sections in this report that provides some details about the small number of electrically-heated multifamily properties and gas-heated townhomes in the sample.

All analysis and reporting here is done using weights to adjust the sample to the population proportions from the Census data.

[3] The Twin Cities counties are: Anoka, Carver, Dakota, Hennepin, Ramsey, Scott and Washington.

Figure 2. Graphical depiction of Minnesota housing stock by type of building, tenure and heating fuel.



Source: 2007-2011 American Community Survey
(Tenure and heating fuel for vacant units allocated proportionally based on occupied units.)

FINDINGS

We present findings from the study in the following order:

- We present a broad segmentation of multifamily properties in the state, based largely on building size and age.
- We review characteristics of energy- and water-using appliances and equipment in multifamily buildings with gas heat.
- We benchmark typical electricity, natural gas and water consumption in gas-heated multifamily buildings, based on the results of the analysis of utility consumption histories for the sampled properties.
- We estimate the cost savings potential for efficiency improvements in gas-heated multifamily housing for 25 key measures.
- We review key findings from the owner/manager and tenant surveys.
- We examine attributes for 37 properties in the sample that qualify for low-income weatherization programs.
- We examine nine electrically-heated buildings in more detail.
- We examine six gas-heated townhomes in more detail

SEGMENTATION OF MINNESOTA MULTIFAMILY HOUSING

Segmentation by Census Size Category

The four Census building-size classifications provide a logical starting point for segmenting the diversity of multifamily housing in the state. Figure 3 provides a few examples of buildings in the study sample from each Census size category, and Table 1 provides some basic building characteristics for each of these size break-outs. Some notable general characteristic are:

- Half of all properties were built in the 1960s and 1970s, though a sizeable minority predates the Depression.

- Most Minnesota multifamily properties are two- or three-story structures, though tall buildings are present in the larger size categories.

- About 4 in 10 buildings are part of a larger complex.

- A small fraction of multifamily properties also have commercial space within the structure.

- On average, there is about 1,000 ft^2 of total floor area (counting apartments and common spaces) per housing unit across all size categories.

The Census size categories are important, because they provide a link to population estimates and data, and are the way that the sample was developed and drawn. However, there is another way of segmenting multifamily housing that has less to do with size, and more to do with type of building and the era in which it was built. We turn next to this way of viewing the diversity of this population.

Figure 3: Examples of study buildings by size category

Small | Mid-sized | Large

5-9 units

10-19 units

20-49 units

50 units

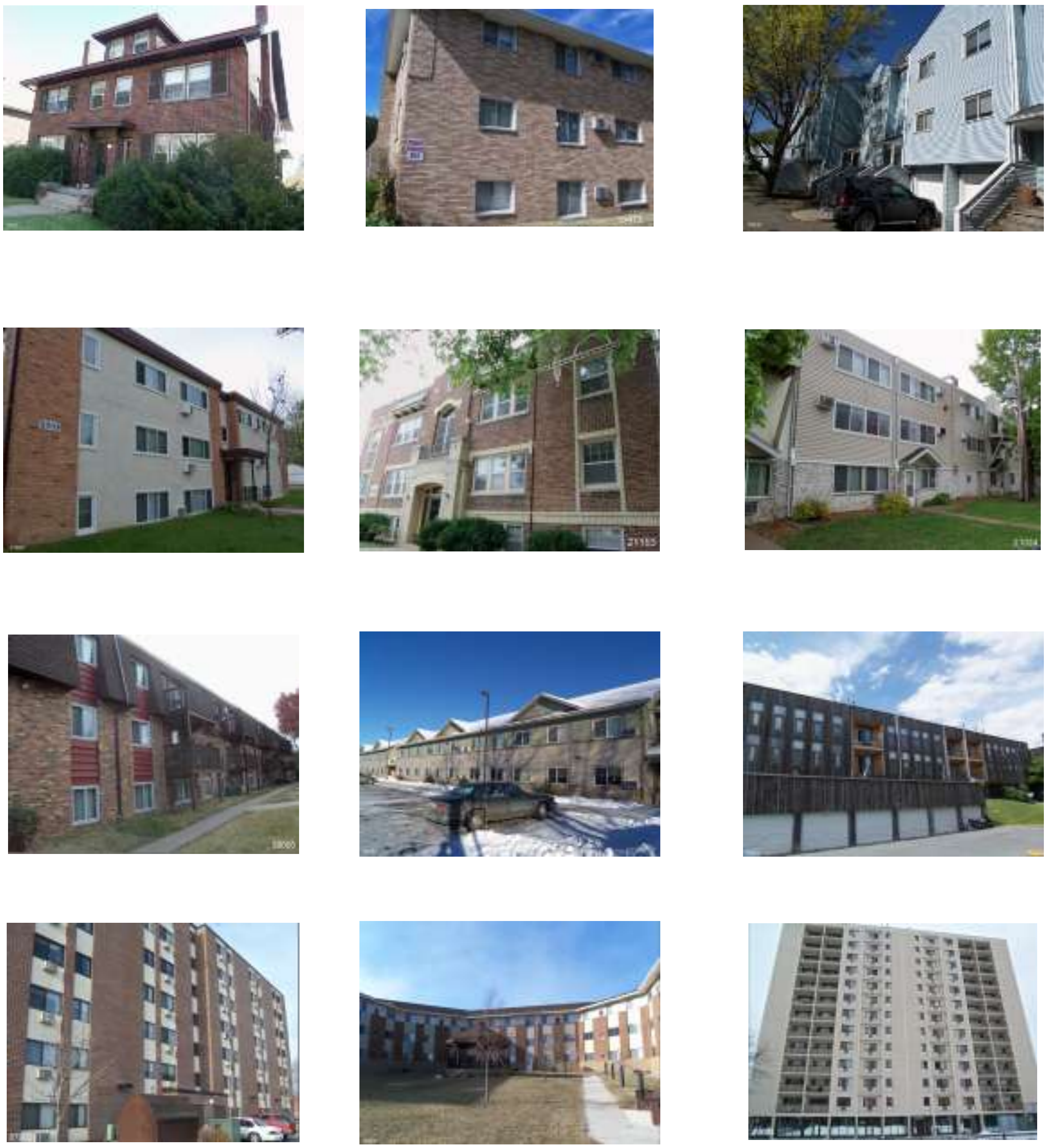


Table 1. **Basic building characteristics for multifamily properties with gas heat, by size category.**

	Building size category									
	5 to 9 units (n=29)		**10 to 19** units (n=26)		**20 to 49** units (n=28)		**50+** units (n=22)		**Overall** (n=105)	
Mean housing units per building	6.7	±0.5	13.2	±1.2	30.2	±3.0	89.7	±11.5	21.5	±1.3
Mean building ft^2 per housing unit (nearest 10)	950	±160	1,070	±90	980	±100	910	±150	1,000	±70
Floors										
1	4%	±7	0%		0%		0%		1%	±3
2	66%	±18	4%	±8	10%	±11	0%		28%	±7
3	31%	±17	89%	±13	72%	±17	68%	±21	62%	±9
4-9	0%		7%	±10	15%	±13	15%	±13	7%	±5
10+	0%		0%		3%	±7	17%	±18	2%	±2
Decade built										
<1930	31%	±17	24%	±17	18%	±15	0%		23%	±9
1930s	10%	±12	0%		0%		0%		4%	±4
1940s	3%	±7	3%	±7	4%	±7	0%		3%	±4
1950s	7%	±9	8%	±11	3%	±7	2%	±5	6%	±5
1960s	21%	±15	40%	±19	26%	±16	33%	±22	29%	±9
1970s	21%	±15	15%	±15	21%	±16	24%	±19	20%	±8
1980s	4%	±7	10%	±9	0%		21%	±19	7%	±4
1990s	4%	±7	0%		14%	±13	0%		4%	±4
2000+	0%		0%		14%	±13	19%	±18	5%	±3
Single building or part of a complex										
single building	66%	±18	69%	±19	50%	±19	56%	±22	63%	±10
part of a complex	34%	±18	31%	±19	50%	±19	44%	±22	37%	±10
Mixed-Use building?										
No	93%	±9	100%		86%	±13	89%	±15	94%	±5
Yes	7%	±9	0%		14%	±13	11%	±15	6%	±5

± values are approximate 95% confidence intervals

Segmentation by Type and Age of Building

Although the stock of multifamily housing is quite diverse, there are some notable natural groupings. The first major distinction is between traditional apartment buildings and townhomes. Apartment buildings generally have common areas such as hallways and laundry rooms, and often (but not always) have centralized space heating and water heating equipment. In contrast, townhomes have a separate entrance for each residence unit, have no common spaces, and have individual heating and hot water systems for each unit. Because of these differences, the Census Bureau technically classifies townhomes as "single-family attached" rather than as multifamily housing. But they are included in the scope of this study, and are treated here as a form of multifamily housing in a more liberal definition of "multifamily."

Because apartment buildings far outnumber townhomes in Minnesota, we'll first focus on these. Apartment buildings can be divided into three major groups based on the period in which the building was constructed: Pre–World War II, Post-War and Post-Energy Crisis.

PRE–WORLD WAR II APARTMENT BUILDINGS

Pre–World War II buildings represent the oldest multifamily housing stock in the state, and are mostly found in older urban areas. They can be identified by older (and often ornate) brick facades (Figure 4). These buildings range in size from 5 to about 50 units, and are rarely taller than five or six stories. They were commonly originally outfitted with coal-fired steam boilers for space heating, but many of these have been converted to natural gas, and now circulate hot water instead of steam. Some steam-heated buildings remain, however, and the study sample contains four such properties.

In addition, some pre-war buildings are mixed-use, with commercial space on the first floor, and apartments above (Figure 5). The heating system for these is often shared between the commercial and residential portions of the building.

About 15 percent of the study sample (19 properties) falls into the Pre-WWII category.

Figure 4. Examples of Pre–World War II apartment buildings.

Figure 5. Example of a Pre-World War II mixed-use building.

POST-WAR APARTMENT BUILDINGS

By the end of World War II, steam heat had fallen from favor, and hydronic (hot-water) boiler systems were the norm for space heating for multifamily buildings. Also, population growth following the war led to suburban development on the edges of cities, including a construction boom for larger apartment buildings. The 1960s and 1970s in particular saw a wave of new, mostly three-story apartment buildings that were often organized in complexes of similar buildings (Figure 6). Typically located on expansive grounds, these properties range in size from fewer than 10 units to more than 100 units, with about two-thirds falling somewhere between 10 and 50 units. Often, the lowest level of units is partly below grade. Post-War apartment buildings almost universally have central, natural-gas hydronic boilers for space heating, central domestic water heating, and individual sleeve air conditioners for cooling. These buildings are almost exclusively residential; very few mix commercial space and apartment units.

Although most rental properties from this time period are low-rise, two- or three-story buildings, a subset of post-War buildings are taller, mid- or high-rise structures (Figure 7).

Almost half of the study sample (43 properties) can be placed in the Post-War category.

Figure 6. Examples of Post-War, low-rise multifamily buildings.

Figure 7. Example of a Post-War mid-rise property.

POST-ENERGY CRISIS BUILDINGS

The energy crises of the 1970s led to the introduction of the first energy codes in Minnesota (as well as in many other states). Properties built after the 1970s may resemble post-War buildings or may have more of a pre–World War II architectural feel (Figure 8)—but are generally better insulated and more energy-efficient than their predecessors.

Post-Energy Crisis buildings also tend to have a wider variety of strategies for heating and cooling. Some have individual forced-air heating systems instead of central boilers for space heating. Some buildings also use a closed water-loop heat pump system in which a central boiler provides heat for a hydronic distribution loop, and individual heat pumps in each unit extract heat and deliver it to the unit. When coupled with a central cooling tower or chiller, this type of system can also provide space cooling in the summer. In the last two decades, geothermal heat pump systems have begun to play a role: the study sample includes one such property.

Another distinguishing feature of buildings from this period is that the New Urbanism movement has led to resurgence in mixed-use buildings that have both residential and commercial space (Figure 9). Some of these properties are gut rehabs of Pre–World War II buildings in gentrifying urban areas; others are newly-constructed structures.

About 15 percent of the study sample (23 properties) falls into the Post-Energy Crisis category.

Figure 8. Examples of Post-Energy Crisis multifamily buildings.

Figure 9. Example of a recently-built mixed-use rental property.

TOWNHOMES

As noted earlier, townhomes are distinguished by the fact that they have no common areas, and have separate heating, cooling and water heating equipment for each unit. Townhomes make up about five percent of the study sample (six properties). Many townhomes are slab-on-grade construction, but some have individual basements, including one in the study sample.

Figure 10. Example of Minnesota townhomes.

OTHER MULTIFAMILY

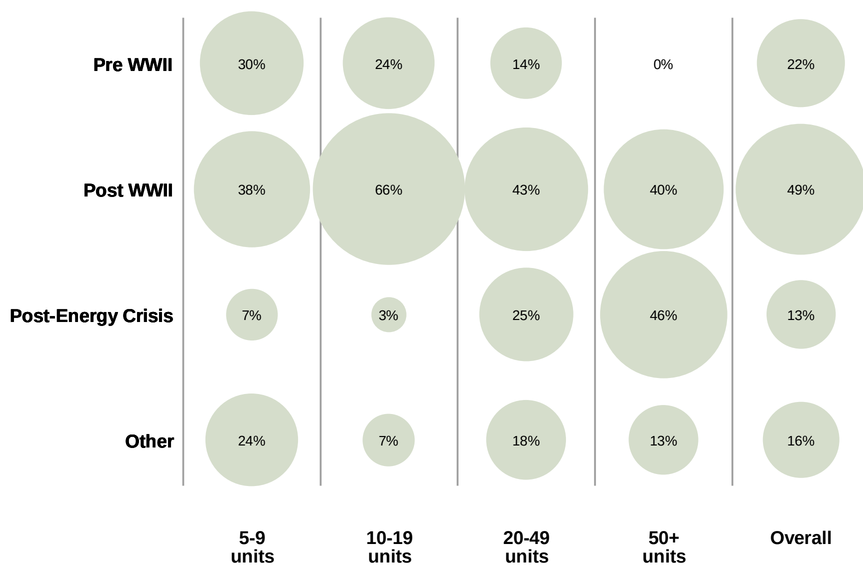
Not all properties fit neatly into the preceding categories. Some are buildings that were built as single-family homes or for another purpose, and have been re-purposed for multifamily housing; others have been partly renovated or had new sections added, and thus reflect characteristics of multiple construction eras; still others are simply unusual. Figure 11 shows some examples of properties that we classified as "Other," because they did not clearly fit into the defined categories. For instance, the photo in the top left section of Figure 11 shows a building that may have been a single-family home but was at one point divided into five units. The building in the top right is a post-war building that was built into the side of a hill and has some individual entrances. Part of the building in the bottom left picture was built in the late 1940's while another part of the building was built 30 years later. The building in the bottom right has separate entrances, like a townhome, but is significantly older than typical townhomes and has a common basement.

Properties like these represent about 15 percent of the study sample (20 buildings).

Figure 11. Examples of multifamily properties that are not easily categorized.

For the multifamily properties with gas heat (excluding townhomes) that dominate the study sample, Figure 12 maps the building types above into the building size categories used by the Census Bureau on a weighted basis. For the remainder of this report, we mainly report statistics by Census size category, since this was the primary stratification variable for recruiting and analyzing the sample. Figure 12 shows that the smallest size category (5-9 units) is largely a mix of Pre-World War II and Post-War properties, the 10-19 unit size category is dominated by Post-War buildings, and the two largest size categories (20-49 and 50+ units) represents a mix of Post-War and Post-Energy Crisis properties.

Figure 12. Multifamily building types (gas-heated) by Census size category.



Columns sum to 100%
Area of shaded circles are proportional to column percent

EQUIPMENT APPLIANCE AND WINDOW CHARACTERISTICS OF MULTIFAMILY BUILDINGS WITH GAS HEAT

Heating Systems

For Minnesota multifamily properties that use natural gas for space heating, central boilers are found in about nine of every ten buildings, and forced-air furnaces in about one in ten (Table 2). The study sample also included two properties with district steam heat and one property with central roof-top package heating.[4]

Table 2. Heating system characteristics for multifamily properties with gas heat.

	Building size category				
	5 to 9 Units (n=29)	**10 to 19** units (n=26)	**20 to 49** units (n=28)	**50+** units (n=22)	**Overall** (n=105)
Heating system type*					
Boiler	82% ±14	92% ±11	90% ±11	87% ±16	87% ±7
Forced air furnace	18% ±14	8% ±11	0%	13% ±16	10% ±6
Other	0%	0%	10% ±11	0%	2% ±2
Boiler systems					
Hydronic	96% ±8	96% ±9	92% ±11	100%	95% ±5
Steam	4% ±8	4% ±9	8% ±11	0%	5% ±5
Mean boilers per building	1.1 ±0.1	1.3 ±0.2	2.1 ±0.5	3.5 ±1.1	1.6 ±0.2
Mean kBtu$_i$ per boiler	320 ±70	360 ±70	560 ±230	990 ±460	530 ±100
Mean total kBtu$_i$ per HU	49 ±15	32 ±6	24 ±8	21 ±9	35 ±6
Vent damper**	8% ±11	18% ±17	28% ±22	0%	15% ±9
Pipes fully insulated	19% ±13	5% ±9	29% ±18	87% ±17	23% ±7
Pipes partially insulated	10% ±15	23% ±17	32% ±18	6% ±13	20% ±9
Pipes uninsulated	71% ±19	72% ±19	39% ±19	6% ±13	56% ±10
Hydronic boiler systems					
Condensing-type	11% ±13	13% ±15	14% ±17	21% ±17	15% ±8
Outdoor reset or cutout control	47% ±23	54% ±22	77% ±15	70% ±27	62% ±11
Constant circulation	26% ±15	55% ±19	51% ±21	83% ±21	49% ±10
Forced air furnaces* **					
Package unit					12%
Condensing-type					38% ±65
Mean kBTU$_i$ per furnace					49 ±3

± values are approximate 95% confidence intervals
*Dominant type serving apartment units
**Proportion of non-condensing systems
***sample size too small for size-category break-outs

kbtu$_i$ = 1,000 Btu per hour input firing capacity
HU = housing unit

[4] District heating is a system in which steam or hot water is produced at a central plant, and then distributed via underground piping to nearby buildings.

Boilers can be subdivided into *hydronic* systems that heat and distribute hot water and *steam* systems. The study sample suggests that the vast majority of boilers are of the former type. Steam systems can be further classified as single-pipe or two-pipe, though the four steam systems in the study sample were all of the single-pipe variety.

Given the preponderance of hydronic systems in Minnesota multifamily buildings, we focus here on the key energy-related features of this technology:

Figure 13. Example of high-efficiency, condensing boilers in a multifamily building.

- The efficiency class of the boiler—a non-condensing boiler is limited to about 85 percent efficiency, but condensing boilers (Figure 13) can achieve efficiencies well above 90 percent by recovering heat from water vapor in combustion products. The study sample indicates that only about one in seven hydronic boilers are condensing-type units. Field measurements of steady-state combustion efficiency for non-condensing boilers averaged about 78 percent, but ranged from 69 to 88 percent (Figure 16).

- The presence of a vent damper—non-condensing boilers are typically natural-draft appliances. A vent damper (Figure 14) reduces heat loss from the boiler when it is not firing. The study sample indicates that vent dampers are uncommon in small buildings and large buildings, but are present for about half of boilers in buildings with 20 to 49 housing units.

Figure 14. Example of a vent damper on a space-heating boiler.

- The existence of controls to regulate the temperature of the delivered hot water—*reset* control can improve comfort and save energy reducing the delivered water temperature in warmer weather; *cutout* control shuts the boiler down entirely when the outdoor temperature exceeds the point at which space heating is needed (these controls are often combined) (Figure 15). Some form of reset/cutout control is present for about half of buildings with hydronic space heat.

- The type of distribution system—boiler systems in smaller buildings may have separate pumps to distribute hot water to each apartment; large buildings often have a central circulation loop in which hot water constantly circulates. Overall, about half of properties with hydronic space heat employ constant circulation.

As noted above, steady-state combustion efficiency measurements taken for 48 non-condensing boilers indicate that the typical boiler has an efficiency of about 78 percent, but some boilers tested at less than 70 percent and some at more than 85 percent efficient (Figure 16). The efficiency for boilers on the low end of the distribution could likely be improved with tuning.

Automatic reset control can improve comfort and system efficiency for hydronic systems by matching boiler supply water temperature to outdoor conditions. Recorded supply temperatures at the time of the site visit suggest that some of these controls may be non-functional (or mis-set), because some sites with reset controls showed high supply temperatures (>150F) at relatively warm outdoor temperatures. However boiler temperatures at the time of the site visit were recorded from gauge readings or from infrared measurements of system piping, and so may not be entirely accurate.

Figure 15. Example of a boiler reset control.

We installed data loggers to track boiler supply and return temperatures as part of more detailed data collection for a small sub-sample of the study sites with hydronic boilers. As Figure 17 shows, three of these sites (Sites A through C) lack reset controls and show relatively constant boiler temperatures across a range of outdoor temperatures. Site D also lacks a reset control, but exhibits signs of manual adjustment to boiler temperature settings. The remaining sites (E through M) have automatic reset control and show evidence of this in a decrease in boiler water temperature in warmer weather, though some show more change than others. As the sole high-efficiency, condensing system in the sample, Site M is notable in its low return-water temperatures: this is desirable for condensing boilers, because high return water temperatures reduce the effective efficiency of these systems.

Figure 16. Distribution of measured steady-state efficiency for non-condensing boilers.

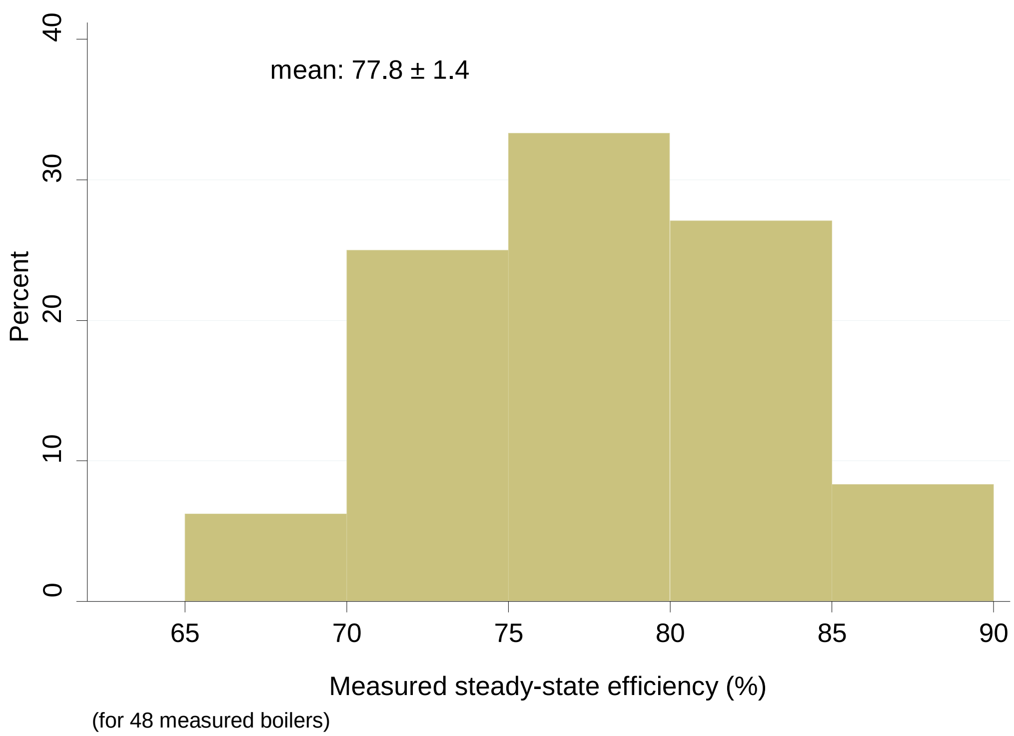
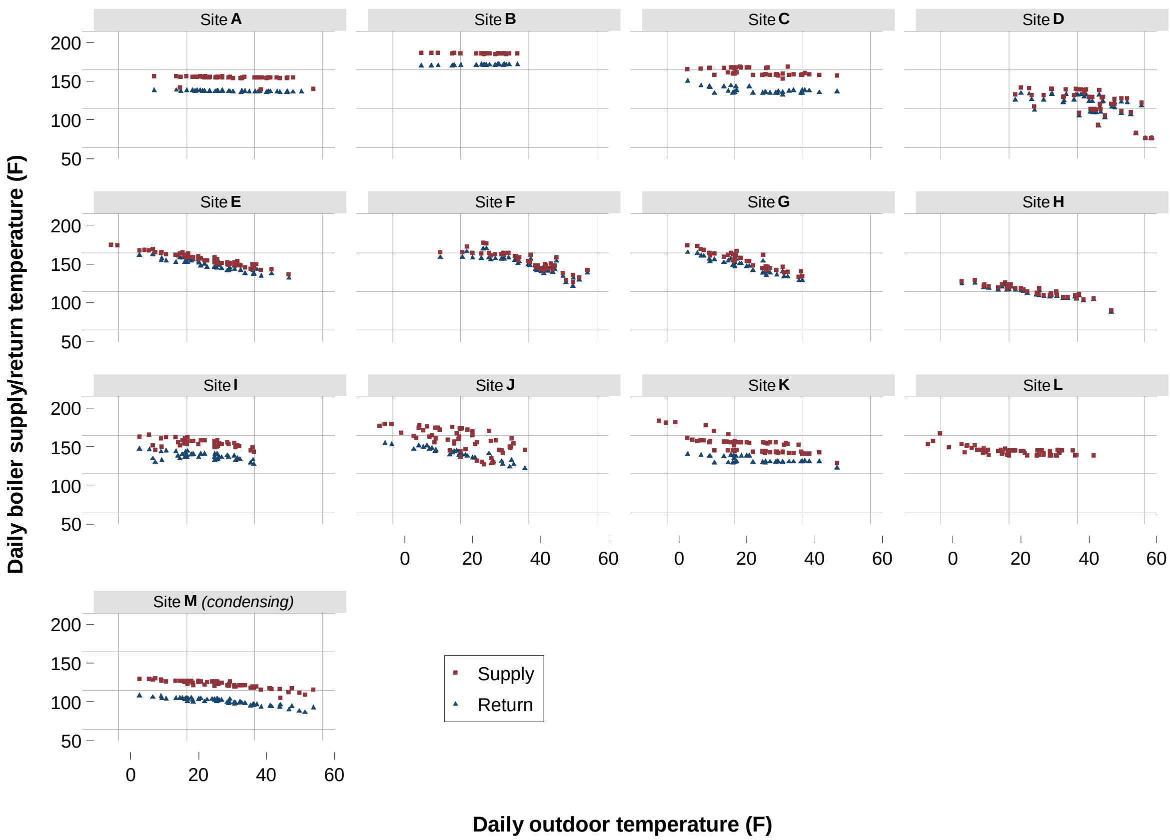


Figure 17. Monitored supply and return temperatures for 13 hydronic boilers.



Boiler characteristics did not vary strongly across the three key segments: Pre–World War II, Post-War and Post-Energy Crisis. Newer buildings appear to be slightly more likely to have condensing boilers and energy-saving features like reset controls and vent dampers, but the small sample size for these properties means that the observed differences are not statistically significant.

For the roughly one in ten multifamily buildings heated by forced air furnaces, the most important feature is whether the unit is a high-efficiency condensing type. Among the furnaces encountered in the study sample, about a third were condensing models—but owing to the small number of buildings with this type of heating, that proportion is highly uncertain (Table 2). It is also noteworthy that about 10 percent of the furnaces in the study sample were indoor package units that combine heating and cooling capability with through-the-wall venting. These are typically found in larger buildings with individual heating and cooling units for each apartment.

Air Conditioning in Multifamily Buildings with Gas Heat

Figure 18. Examples of sleeve (left) and window (right) air conditioners.

Most space cooling in gas-heated Minnesota multifamily buildings is done with individual sleeve or window (Figure 18) air conditioners (Table 3). Because they were built prior to the introduction of air conditioning technology, nearly one in five Pre–World War II buildings has no air conditioning, and nearly all of the properties with air conditioning have window units. Most properties built after World War II have provisions for sleeve units.

The majority of these units are supplied by the landlord, but tenants are responsible for providing the air conditioner in about a quarter of buildings with this cooling type overall, and in about 70 percent of the cases among Pre–World War II properties. Nameplate efficiency ratings that were available for about 100 such units in 47 buildings showed an average EER of 9.0 with a range from 8.2 to 10.8 (Figure 19).

A small proportion of larger buildings have indoor package units that combine a forced-air furnace and an air conditioner in a self-contained unit located in a utility closet.

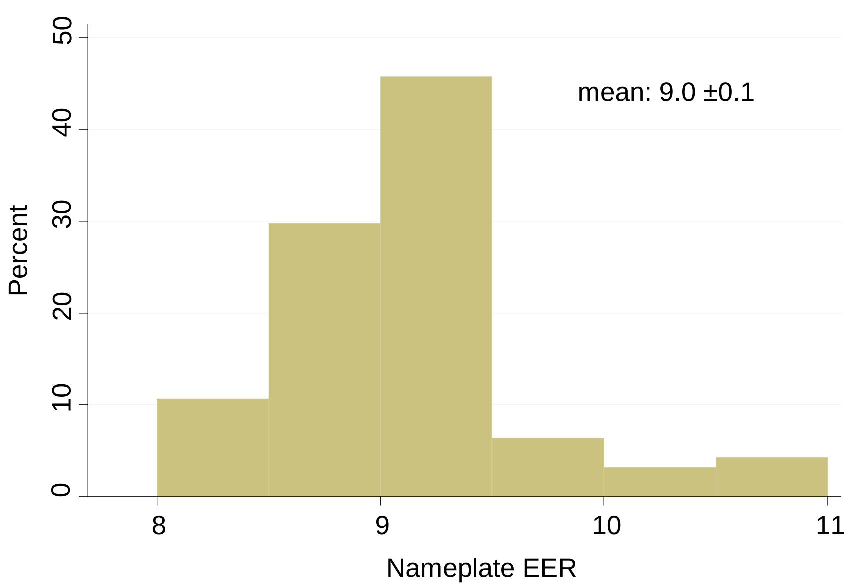
Central systems for cooling apartment units are rare in Minnesota rental properties, but common areas may be cooled by such systems.

Table 3. Air conditioning characteristics.

	Building size category				
	5 to 9 units (n=26)	**10 to 19** units (n=23)	**20 to 49** units (n=24)	**50+** units (n=17)	**Overall** (n=90)
AC type					
individual sleeve unit	45% ±19	61% ±20	75% ±17	70% ±21	59% ±10
individual window unit	44% ±18	28% ±17	11% ±12	6% ±11	28% ±9
individual package unit	0%	0%	0%	13% ±16	1% ±1
other	4% ±7	0%	11% ±12	6% ±11	4% ±4
none	7% ±10	11% ±12	3% ±7	6% ±11	7% ±6
Sleeve/window unit					
provided by landlord	58% ±20	86% ±15	92% ±12	72% ±21	76% ±9
provided by tenant	42% ±20	14% ±15	8% ±12	28% ±21	24% ±9

± values are approximate 95% confidence intervals

Figure 19. Distribution of nameplate EER for sleeve/room air conditioners.



For 94 units with nameplate information.

Water Heating Equipment in Multifamily Buildings with Gas Heat

SYSTEM TYPES

We encountered four strategies for providing domestic hot water (DHW) in the study sample, as described below and in more detail in Figure 20:

- Individual tank-type water heater
- Central tank-type water heater
- Dedicated boiler used to indirectly heat potable water in a separate storage tank
- Space heating boiler used to indirectly heat potable water in a separate storage tank

Overall, central tank-type water heaters account for the majority of systems, but individual water heaters are found in about 15 percent of small multifamily properties, and indirect-fired systems make up 40 percent of DHW systems in larger properties (Table 4).

Table 4. Prevalence of domestic hot water system types in gas-heated multifamily buildings, by building size category.

	Building size category									
	5 to 9 units (n=29)		**10 to 19** units (n=26)		**20 to 49** units (n=30)		**50+** units (n=22)		**Overall** (n=107)	
Individual conventional tank	15%	±12	3%	±7	6%	±8	0%		8%	±5
Central conventional tank	75%	±16	73%	±18	53%	±19	61%	±23	68%	±9
Indirect-fired with dedicated boiler	3%	±7	15%	±15	30%	±17	20%	±19	15%	±7
Indirect-fired with shared boiler	7%	±9	8%	±11	10%	±11	20%	±19	9%	±6

Columns may sum to more than 100% due to multiple system types in the same building

± values are approximate 95% confidence intervals.

Figure 20. Domestic hot water system types.

Individual tank-type water heater	 	• Conventional residential water heater with one unit per apartment. • May be gas or electric. • Typically 30-50 gallons of storage capacity. • Gas unit firing capacity typically 30-40 kBtu/hr
Central tank-type water heater		• One or more tank-type water heaters directly heats potable water for all apartments. • Typically commercial-sized unit, though residential-sized equipment may be found in smaller buildings • Typically 75-150 gallons of storage capacity. • Typically gas-fired with input of 75-500 kBtu/hr. • May be used in conjunction with a circulation system that distributes hot water throughout the building via a closed-loop.
Indirect-fired with dedicated boiler		• Dedicated boiler indirectly heats potable water in a separate storage tank • Typically 80-200 gallons of storage capacity. • Typically gas-fired with input of 180-750 kBtu/hr. • May be used in conjunction with a circulation system that distributes hot water throughout the building via a closed-loop.
Indirect-fired via shared space-heating boiler		• Space-heating boiler also indirectly heats potable water in a separate storage tank • Typically 80-200 gallons of storage capacity. • May be used with a circulation system that distributes hot water throughout the building via a closed-loop.

Among the small proportion of gas-heated multifamily buildings with individual water heating equipment, electricity is the dominant fuel (Table 5). Individual water heating is most likely to be found among Pre–World War II properties. Based on the 20 properties of this vintage in the study sample, somewhere between a third and three-quarters of properties have this type of DHW system.

Central gas domestic hot water systems can be subdivided into relatively inefficient natural-draft equipment and higher efficiency sealed-combustion or power-vent equipment. Natural-draft equipment can be further subdivided by the presence or absence of a vent damper, which helps reduce energy loss when the water heater is not firing.

As Table 5 shows, the large majority of central tank-type water heaters are of the less efficient natural-draft variety, though about half of these have vent dampers to provide some improvement in efficiency. On the other hand, a substantial fraction of indirect-fired systems heat potable water for domestic use with high efficiency condensing boilers. Altogether, the study sample suggests that about 14 ± 7 percent of buildings with gas-fired DHW systems can be considered to be high efficiency.

Table 5. Domestic hot water system fuel and venting (gas-heated multifamily buildings), by system type.

	DHW system type							
	Individual conventional tank (n=9)		Central conventional tank (n=86)		Indirect-fired, dedicated boiler (n=18)		Indirect-fired, shared boiler (n=11)	
Electric	71%	±33	0%		0%		0%	
Low efficiency: Gas, atmospheric, no vent damper	29%	±33	55%	±10	51%	±25	22%	±24
Mid efficiency: Gas, atmospheric, vent damper	0%		39%	±11	12%	±18	26%	±29
High efficiency: Gas, sealed-combustion or power-vented	0%		6%	±5	37%	±24	52%	±32

± values are approximate 95% confidence intervals.

RECIRCULATION

Many central DHW systems are configured to circulate hot water in a closed loop through the building in order to minimize the time required for hot water to reach fixtures that are distant from the central water heating and storage equipment. The study data show that 41 (±10) percent of buildings with central domestic hot water have a recirculation system. About 60 percent of Post-Energy Crisis buildings in the study sample had a recirculation system, compared to about a third of other building types. This difference is not statistically significant owing to the relatively small number of Post-Energy Crisis properties in the sample.

FIRING CAPACITY AND STORAGE VOLUME PER HOUSING UNIT

Central gas-fired DHW systems in the study sample generally had between 5,000 and 20,000 Btu per hour of total input firing capacity per housing unit (Figure 21). This range remains relatively constant across building sizes. In contrast, the ratio of storage capacity per housing unit drops markedly as the size of the building increases (Figure 22).

Figure 21. Total input firing capacity versus housing units for central gas domestic hot water systems in gas-heated multifamily buildings.

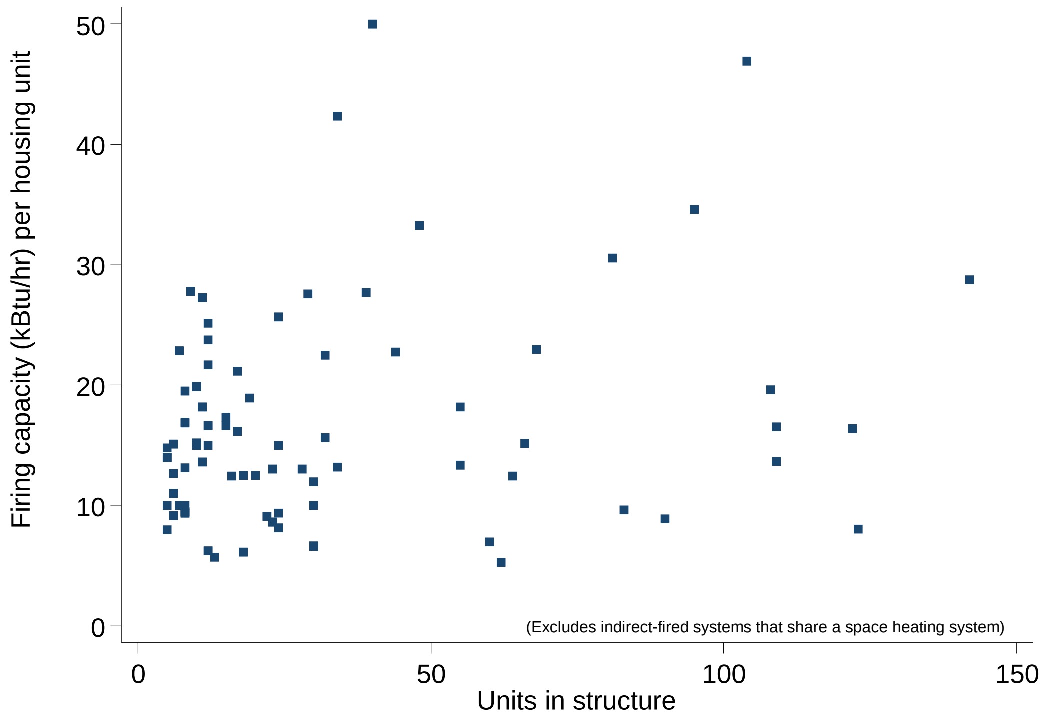
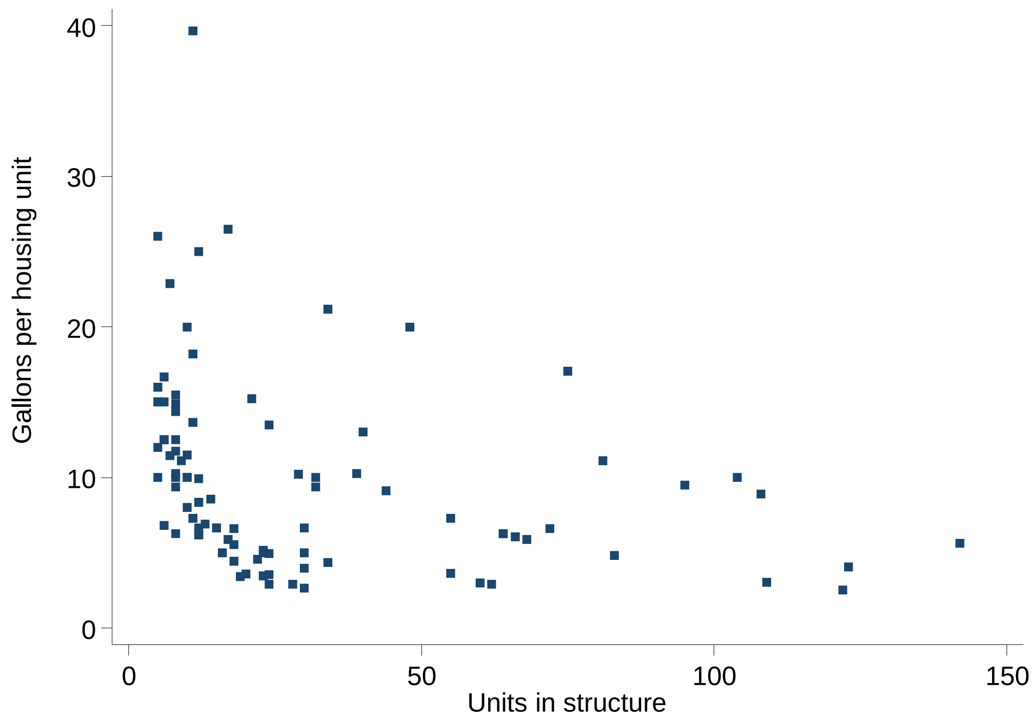


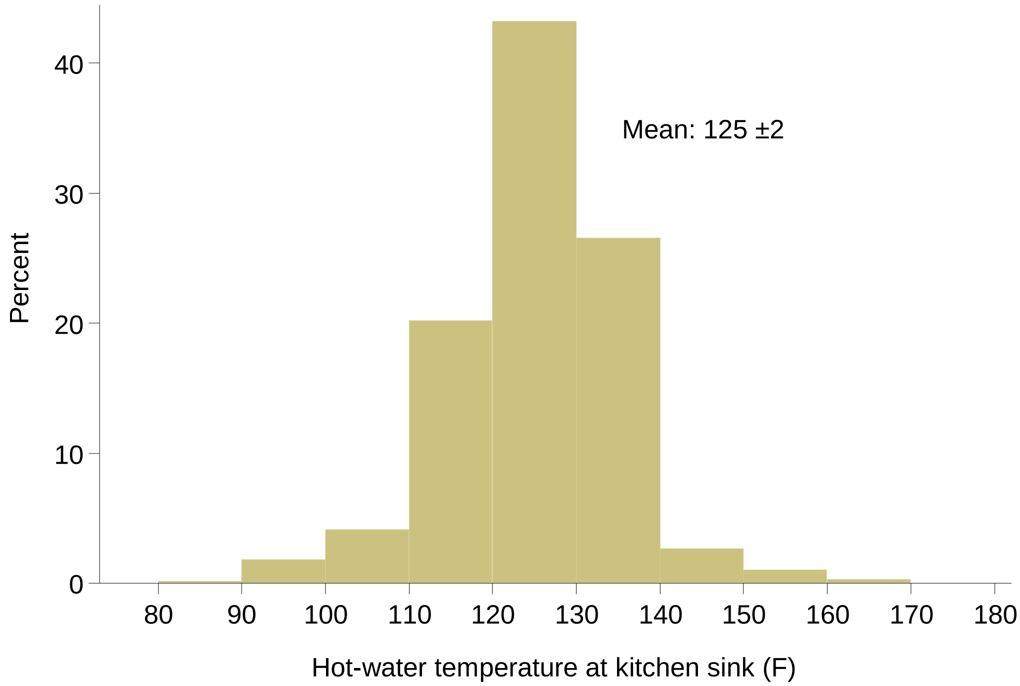
Figure 22. Gallons of storage volume per housing unit versus number of housing units for central, gas domestic hot water systems in gas-heated multifamily buildings.



DELIVERY TEMPERATURE

The delivery temperature of the hot water was measured at the kitchen sink in sampled apartments in each building. Hot water temperatures ranged from less than 100F to more than 180F, with an average of 126 ±2 F (Figure 23). We found no strong relationship between the type of water heating system, size of the building, building age and the delivery temperature.

Figure 23. Hot-water delivery temperature at kitchen sink in gas-heated multifamily buildings.



For measurements in 299 apartments

Showerheads and Faucets

Measured flow rates for showerheads in sampled apartments ranged from less than 1 gallon per minute (gpm) to more than 7 gpm, but most showerheads tested between 1.5 and 3.0 gpm (Figure 24 and Table 6).

Low-flow replacement showerheads generally have rated flow rates of 1.5 or 1.75 gpm: by these benchmarks, showerhead replacement would result in energy and water savings in about 95 percent and 85 percent of cases, respectively.

Leaking shower diverters have also been cited as a source of energy and water waste in bathrooms with tub/shower combinations. The study data suggest that between 5 and 20 percent of apartments have a shower diverter that leaks noticeably. The median leak rate among the 18 observed leaking units was 0.9 gpm.

Kitchen and bathroom faucets have somewhat lower flow, averaging slightly less than 2 gpm (Table 6). The study data suggest that 85 percent of multifamily faucets would see energy savings if a 1.5 gpm aerator was installed.

Figure 24. Distribution of measured showerhead flow in gas-heated multifamily buildings.

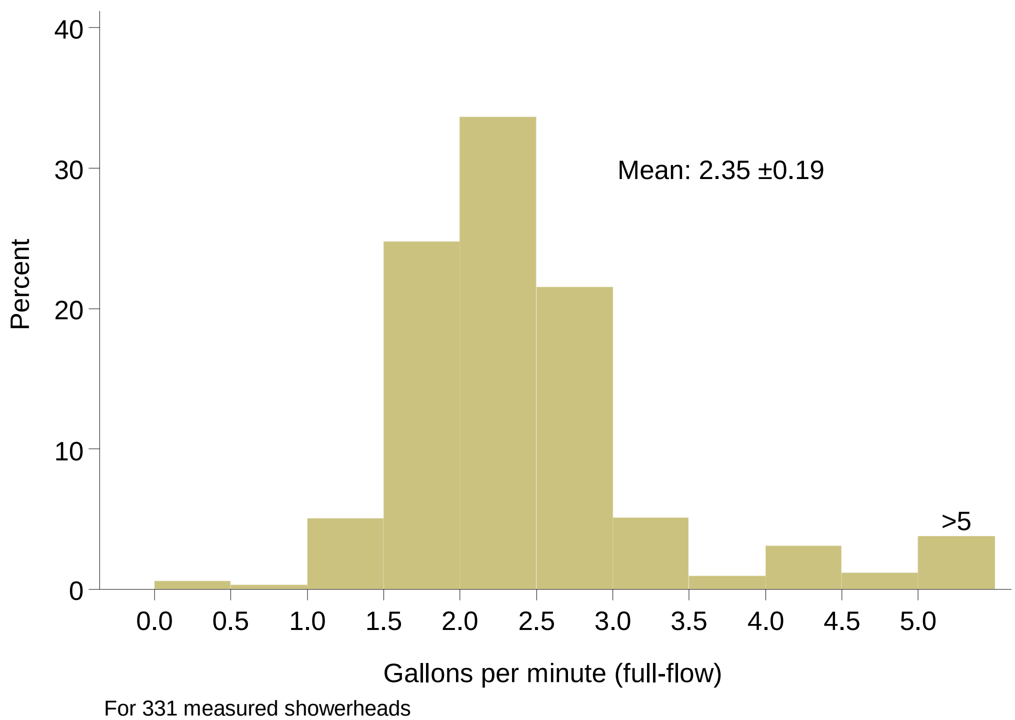


Table 6. Measured flow rates (full-on) for apartment showerheads and faucets in gas-heated multifamily buildings, by building size category.

	Building size category									
	5 to 9 units		**10 to 19** units		**20 to 49** units		**50+** units		**Overall**	
Showerhead	(n=82)		(n=69)		(n=89)		(n=91)		(n=331)	
<1.5 gpm	0%		6%	±7	9%	±11	5%	±5	6%	±4
1.5-1.9 gpm	19%	±13	23%	±12	14%	±10	36%	±17	25%	±7
2.0-2.4 gpm	39%	±17	35%	±13	30%	±15	34%	±18	34%	±9
2.5-2.9 gpm	37%	±22	20%	±11	30%	±13	10%	±7	22%	±6
3+ gpm	5%	±5	16%	±12	17%	±11	14%	±12	14%	±6
mean flow (gpm)	2.32	±0.16	2.53	±0.39	2.35	±0.27	2.26	±0.40	2.35	±0.19
Kitchen faucet	(n=78)		(n=61)		(n=82)		(n=84)		(n=305)	
<1.5 gpm	8%	±12	25%	±16	6%	±9	20%	±10	15%	±6
1.5-1.9 gpm	38%	±16	33%	±15	37%	±15	41%	±16	38%	±8
2.0-2.4 gpm	33%	±11	27%	±16	43%	±13	32%	±17	34%	±8
2.5-2.9 gpm	6%	±6	8%	±9	2%	±3	6%	±5	5%	±3
3+ gpm	15%	±9	6%	±6	12%	±8	0%	±1	7%	±3
mean flow (gpm)	2.18	±0.23	1.97	±0.31	2.18	±0.25	1.78	±0.15	1.99	±0.12
Bath faucet	(n=87)		(n=68)		(n=91)		(n=94)		(n=340)	
<1.5 gpm	7%	±8	26%	±16	6%	±7	24%	±14	17%	±7
1.5-1.9 gpm	45%	±19	25%	±11	42%	±15	44%	±17	40%	±9
2.0-2.4 gpm	27%	±14	40%	±16	45%	±15	24%	±11	34%	±7
2.5-2.9 gpm	7%	±6	6%	±9	2%	±3	4%	±5	4%	±3
3+ gpm	15%	±12	3%	±6	5%	±5	4%	±5	5%	±3
mean flow (gpm)	2.16	±0.31	1.78	±0.18	1.95	±0.19	1.81	±0.23	1.89	±0.12

± values are approximate 95% confidence intervals.

Window Characteristics in Multifamily Buildings with Gas Heat

We collected data on basic window characteristics within each building, including size and type of window, framing material and the prevalence of storm windows. Generally, the square footage of windows per number of units in the building indicates that there are slightly smaller sized windows for larger multifamily buildings than for smaller buildings. Large buildings (50+ units) appear to have less window area per unit than smaller buildings, but the difference is not statistically significant. For most building sizes, the windows are double-pane and typically have vinyl frames. Larger buildings show more prevalence of aluminum frames than smaller buildings, which tend to have a mix of wood and aluminum frames. About a quarter of smaller buildings have storm windows with single-pane windows. Storm windows are less common in larger buildings: these properties are more likely to have double-pane windows. Triple-paned windows were non-existent or very rare.

Table 7: Window characteristics.

			Building size category								Overall	
			5 to 9 units (n=29)		**10 to 19** units (n=26)		**20 to 49** units (n=28)		**50+** units (n=22)		**Overall** (n=105)	
Windows Characteristics												
		Mean total area	606	±123	1219	±185	2534	±470	6817	±1463	1780	±182
		Square foot per unit	84	±13	93	±12	83	±11	77	±14	86	±7
Panes & frames (% of window area)												
Single Pane	Wood	Storm	24%	±11	12%	±8	9%	±7	8%	±6	11%	±4
		No storm	5%	±5	5%	±5	0%		0%		2%	±1
	Aluminum	Storm	1%	±2	7%	±6	10%	±7	19%	±9	11%	±4
		No storm	2%	±3	1%	±2	0%		0%		1%	
	Vinyl	Storm	0%		0%		2%		0%		0%	
		No storm	0%		0%		0%		0%			
Double Pane	Wood		14%	±8	14%	±13	0%		0%		5%	±3
	Aluminum		7%	±9	15%	±9	18%	±10	17%	±16	16%	±7
	Vinyl		47%	±13	46%	±14	63%	±12	56%	±16	54%	±8
Triple Pane			0%		0%		0%	±	1%	±2	0%	±1

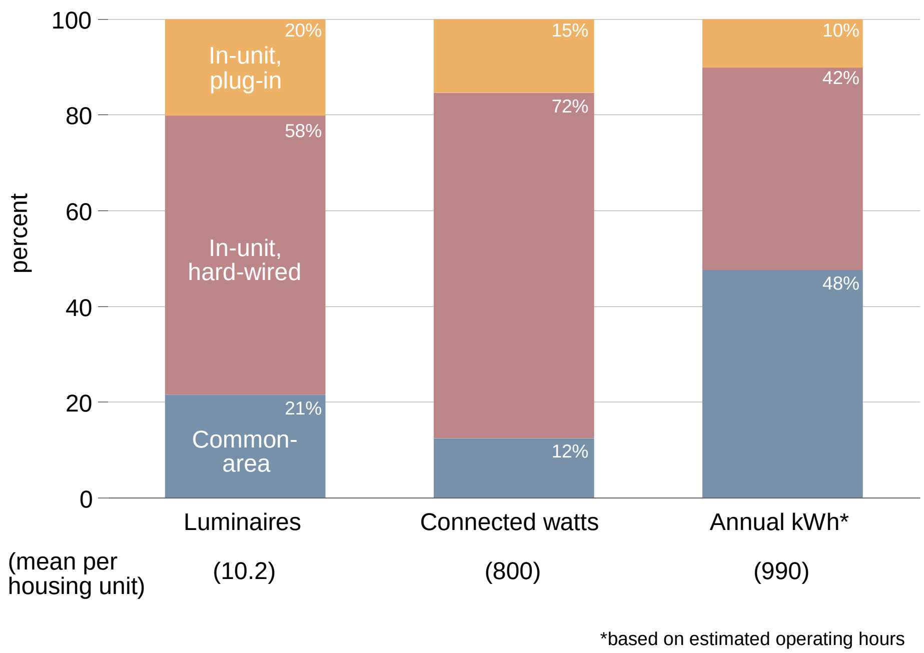
± values are approximate 95% confidence intervals

Lighting in Multifamily Buildings with Gas Heat

Lighting in multifamily buildings can be divided between luminaires in common-area spaces such as hallways and stairwells versus luminaires in apartment units.[5] Property owners and managers typically bear the direct energy cost of the former, and tenants bear the cost of the latter. In-unit luminaires can be further subdivided into hard-wired fixtures that are the responsibility of the landlord and plug-in lighting supplied by the tenant.

Broadly speaking, while in-unit lighting dominates in terms of total luminaires and connected wattage, common area lighting is often operated 12 to 24 hours a day, and thus makes up a disproportionate share of total lighting energy use (Figure 25).

Figure 25. Distribution of luminaires, watts and annual lighting energy between common-area and in-unit lighting in gas-heated multifamily buildings.



COMMON-AREA LIGHTING

Interior hallway and stairwell lighting makes up more than half of the total luminaires in multifamily buildings (except for the smallest building-size category), and the majority of this lighting is fluorescent (Table 8). More than 80 percent of this interior lighting operates 24/7.

Exterior lighting makes up the next most frequent location for common-area lighting. About half of exterior luminaires use some variety of high-intensity discharge lighting, with CFLs making up most of the remainder.

[5] In the parlance of the lighting industry, a *luminaire* is a complete lighting unit such as a ceiling fixture or table lamp containing one or more *lamps* such as a compact fluorescent (CFL) or incandescent.

Table 8. Common-area lighting characteristics for gas-heated multifamily buildings.

			Building size category: 5 to 9 units (n=29)		10 to 19 units (n=26)		20 to 49 units (n=28)		50+ units (n=22)		Overall (n=105)	
Number of luminaires												
		per building	13	±4	28	±5	69	±13	280	±46	54	±5
		per housing unit	2.0	±0.5	2.1	±0.3	2.3	±0.3	3.2	±0.4	2.2	±0.2
By space type*												
		Foyer	0%		1%	±1	1%	±1	4%	±2	2%	±1
		Hallway	23%	±12	36%	±13	49%	±11	49%	±11	44%	±7
		Stairwell	14%	±8	20%	±9	19%	±7	11%	±5	15%	±4
		Laundry	3%	±2	5%	±3	3%	±2	1%	±1	3%	±1
		Basement	16%	±8	12%	±5	8%	±4	3%	±2	7%	±2
		Garage	5%	±5	3%	±4	3%	±3	15%	±9	8%	±4
		Exterior	31%	±11	22%	±8	17%	±5	8%	±5	15%	±3
		Other	8%	±6	1%	±2	1%	±1	9%	±4	6%	±2
By lamp type												
Non-exit luminaires	Linear fluorescent	T8	10%	±8	13%	±8	8%	±5	27%	±9	18%	±5
		T12	8%	±7	6%	±4	16%	±7	9%	±7	10%	±4
	CFL	Pin-base	16%	±11	21%	±9	32%	±10	23%	±9	25%	±5
		Screw-base	27%	±10	40%	±12	14%	±5	12%	±6	19%	±4
	LED		1%	±1	0%		3%	±4	7%	±6	4%	±3
	Incandescent	Incandescent	23%	±9	7%	±4	2%	±1	2%	±1	5%	±1
		Halogen	0%	±1	1%	±1	1%	±1	1%	±1	1%	±1
	High-intensity discharge	HPS	5%	±5	2%	±2	5%	±3	4%	±4	4%	±2
		MV	3%	±2	5%	±4	3%	±2	0%		2%	±1
		MH	0%		0%		1%	±1	1%	±1	1%	±1
	Other		0%		0%		0%		3%	±4	1%	±2
Exit luminaires		Incandescent	1%	±1	0%	±1	3%	±2	2%	±2	2%	±1
		Fluorescent	0%		0%		1%	±1	1%	±1	1%	±1
		LED	5%	±5	4%	±5	13%	±6	9%	±5	9%	±3
By control type												
		24/7	25%	±12	42%	±12	75%	±6	82%	±6	68%	±5
		Switch	32%	±10	14%	±6	9%	±4	9%	±3	12%	±2
		Photocell	19%	±9	14%	±6	9%	±3	7%	±4	9%	±3
		Timer	21%	±9	26%	±14	6%	±3	2%	±2	9%	±3
		Motion sensor	4%	±4	3%	±4	1%	±1	0%	±1	1%	±1

± values are approximate 95% confidence intervals

*excludes exit lighting

CFL = Compact fluorescent
HPS = High pressure sodium
MH = Metal halide
LED = Light emitting diode
MV = Mercury vapor

Exit lights are relatively uncommon in smaller multifamily properties, but among buildings with 20 or more apartments, there is an average of about one exit light for every 3.3 housing units. The large majority (80-90%) of these have already been converted to efficient LED fixtures.

IN-UNIT LIGHTING

The typical multifamily apartment unit has about eight luminaires, though apartments in smaller buildings tend to have more lighting and those in larger buildings have fewer (Table 9). Pre–World War II properties average somewhat fewer in-unit luminaires per housing unit (6.8 ± 1.2) compared to the other building segments.

About three-quarters of in-unit luminaires are hard-wired fixtures and a quarter are plug-in table or floor lamps. The saturation of CFLs within apartment luminaires stands at about 25 percent; nearly all of the remaining lighting is provided by incandescent bulbs. Somewhat surprisingly, Pre–World War II properties in the study sample had the highest saturation of CFLs (38%) and Post-Energy Crisis properties showed the lowest saturation (20%).

Table 9. In-unit lighting characteristics for gas-heated multifamily buildings.

	Building size category: 5 to 9 units (n=58)	10 to 19 units (n=53)	20 to 49 units (n=79)	50+ units (n=87)	Overall (n=277)
Number of luminaires per apartment					
Kitchen	1.6 ±0.2	1.5 ±0.2	1.5 ±0.3	1.2 ±0.2	1.4 ±0.1
Living/dining room	2.0 ±0.3	2.3 ±0.4	2.5 ±0.7	2.1 ±0.4	2.2 ±0.3
Bedroom	2.4 ±0.4	2.4 ±0.4	2.0 ±0.4	1.7 ±0.4	2.0 ±0.2
Bathroom	1.3 ±0.3	1.3 ±0.2	1.3 ±0.2	1.1 ±0.2	1.2 ±0.1
Hallway	0.9 ±0.4	0.9 ±0.3	1.0 ±0.3	1.2 ±0.3	1.0 ±0.2
Other	0.3 ±0.3	0.0 ±0.0	0.2 ±0.2	0.1 ±0.1	0.1 ±0.1
All locations	8.5 ±1.0	8.4 ±0.8	8.4 ±1.4	7.4 ±0.9	8.0 ±0.6
Luminaire type					
Ceiling	60% ±5	59% ±6	58% ±7	51% ±8	56% ±4
Wall	14% ±4	14% ±2	16% ±5	19% ±7	16% ±3
Undercabinet	3% ±2	2% ±1	3% ±2	1% ±1	2% ±1
Plug-In	23% ±5	25% ±6	23% ±4	29% ±7	26% ±3
Bulb type					
Incandescent	76% ±10	69% ±9	75% ±6	71% ±10	73% ±4
Screw-Base CFL	19% ±9	26% ±9	20% ±6	17% ±6	20% ±4
Pin-Base CFL	1% ±1	3% ±3	2% ±2	9% ±6	5% ±2
Linear Florescent	2% ±2	2% ±2	3% ±3	1% ±1	2% ±1
Other	1% ±2	0% ±	0% ±	0% ±1	0% ±
Bulb wattage					
Incandescent	58.7 ±1.9	57.4 ±3.8	57.4 ±3.6	56.6 ±2.7	57.3 ±1.7
Screw-base CFL	13.8 ±0.7	14.7 ±1.0	15.0 ±1.0	15.4 ±1.5	14.9 ±0.6
Pin-base CFL	33.1 ±8.5	21.5 ±7.0	25.4 ±4.4	23.3 ±7.3	23.6 ±5.3
Linear Florescent	34.8 ±4.9	28.0 ±6.2	35.9 ±4.4	34.0 ±3.9	33.6 ±2.9
Other	15.7 ±20.1	100.0	260.1 ±241.9	26.1 ±15.0	51.6 ±55.3

± values are approximate 95% confidence intervals

MONITORING OF IN-UNIT LIGHTING

The study scope included some limited monitoring of in-unit lighting, primarily to refine estimates of operating hours. The monitoring was implemented in 39 apartments located within 16 of the study properties in the Twin Cities area. The monitoring was installed between late October and late December 2012, and was removed in mid-February, for a median monitoring period of 71 days.

The study protocol called for monitoring four luminaires in each apartment unit:

- the primary kitchen luminaire;
- a random selection between the primary bathroom and master bedroom hard-wired luminaire;
- a randomly selected plug-in luminaire in the master bedroom; and,
- a randomly selected plug-in luminaire in the living room.

We monitored hard-wired fixtures with light loggers that used a photocell to detect when the target luminaire was turned on or off, and recorded the date and time for each event. For plug-in lighting, we used appliance line loggers that recorded elapsed watt-hours on an interval basis, from which the hours of operation could be calculated with knowledge of the wattage draw of the luminaire. The recording interval for these loggers varied from 2 to 34 minutes according to the length of the deployment period, with a median of 17 minutes.

The results of the monitoring suggest daily operation of between about 1.5 and 3 hours for in-unit lighting, depending on the location of the luminaire (Table 10), though the small sample sizes make these estimates somewhat imprecise. It is also possible that these estimates are biased toward longer operation to some extent, since the monitoring occurred during the darkest part of the year.

The monitoring data suggest that bathroom lighting has the flattest time-of-day profile, and living room lighting has the sharpest peak, which occurs in the evening (Figure 26).

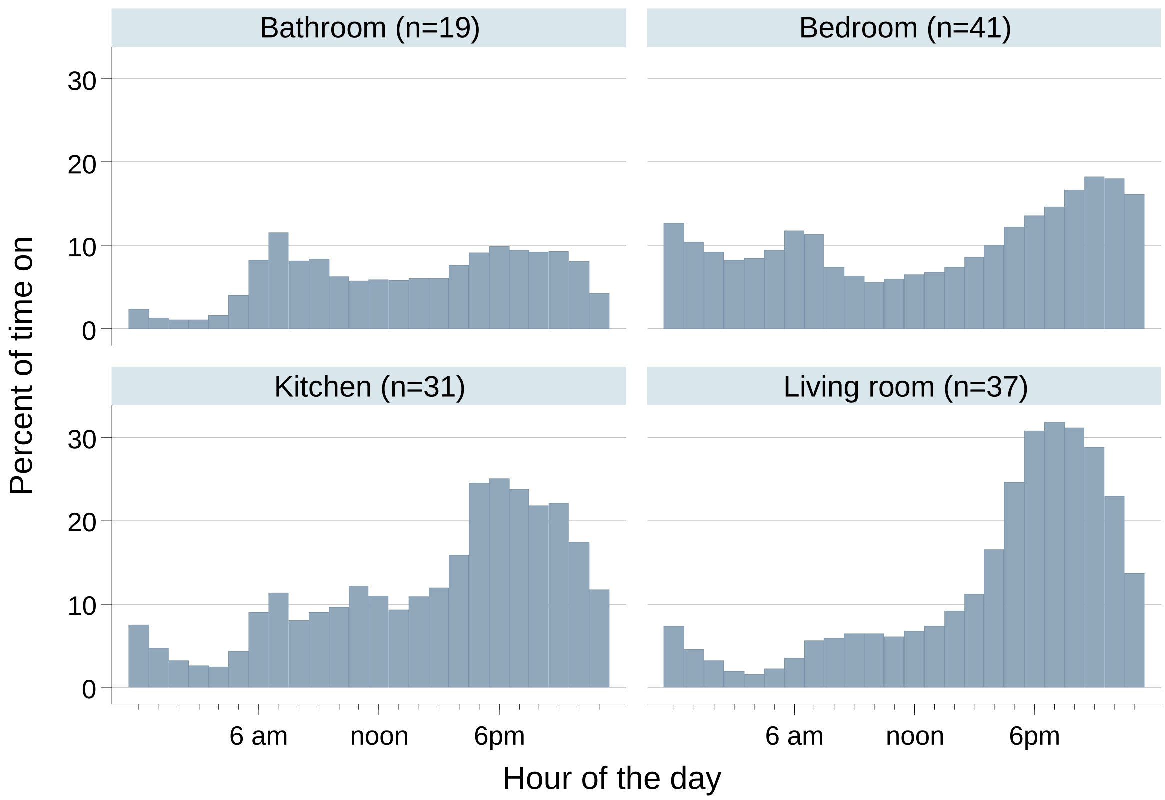
Table 10. Monitoring results for in-unit lighting.

Type	Location	n	Mean hours per day operated	
Hard-wired fixture	Kitchen	31	2.8	±1.2
	Bedroom	17	2.3	±1.1
	Bathroom	19	1.5	±0.9
Plug-in	Living room	35	2.6	±0.8
	Bedroom*	23	1.8	±1.4

± values are approximate 95% confidence intervals

*Excludes one luminaire that was operated 21 hours per day on average. Including this case raises the category average to 2.7±2.2 hours per day

Figure 26. Average time-of-day profile for in-unit lighting, by room.



Combined results for hard-wired and plug-in luminaires

Appliances in Multifamily Buildings with Gas Heat

REFRIGERATORS

The single highest-energy-consuming device in most apartments is the refrigerator. Nearly all refrigerators encountered in the study sample were top-freezer models with no special features (such as through-the-door ice or water). The average refrigerator has about 15 ft^3 of capacity and is about 10 years old, though units in smaller buildings are noticeably older on average than those in newer buildings (Table 11).

Refrigerator age is the key determinant of energy efficiency: though energy use by refrigerators has been declining since the 1970s, units manufactured after 1999 are significantly more efficient than older units. More than a quarter of all refrigerators in Minnesota multifamily buildings—and nearly half of units in smaller properties—date to 1999 or earlier. Not surprisingly, newer properties tend to have newer appliances, so the incidence of older refrigerators is lowest among Post-Energy Crisis properties in the sample.

Table 11. Refrigerator characteristics.

	Building size category									
	5 to 9 units (n=45)		**10 to 19** units (n=45)		**20 to 49** units (n=62)		**50+** units (n=69)		**Overall** (n=221)	
Size (nearest ft^3)										
10	2%	±4	8%	±9	8%	±7	8%	±8	7%	±4
12	3%	±5	12%	±11	2%	±4	2%	±4	4%	±3
14	34%	±19	16%	±12	26%	±11	13%	±6	20%	±6
15	33%	±15	29%	±14	25%	±11	12%	±9	22%	±6
16	0%		7%	±6	8%	±7	17%	±11	10%	±5
17	17%	±11	27%	±13	28%	±12	31%	±12	27%	±6
18	9%	±8	2%	±4	2%	±4	13%	±8	7%	±3
20+	3%	±4	0%		1%	±2	4%	±4	2%	±2
mean size	15.2	±0.5	14.8	±0.6	15.0	±0.5	15.8	±0.7	15.3	±0.3
Defrost										
Manual	51%	±19	49%	±17	46%	±12	14%	±8	37%	±6
Auto	49%	±19	51%	±17	54%	±12	86%	±8	63%	±6
Year of manufacture										
pre 1990	10%	±8	16%	±11	0%		3%	±4	6%	±3
1990-1994	6%	±7	14%	±11	16%	±9	1%	±3	9%	±4
1995-1999	20%	±12	15%	±11	10%	±8	12%	±8	13%	±5
2000-2004	29%	±16	25%	±13	34%	±12	30%	±11	30%	±6
2005+	35%	±16	30%	±13	40%	±12	54%	±13	42%	±7
mean age (yrs)	10.9	±2.2	12.4	±2.5	9.5	±1.5	7.7	±1.4	9.6	±0.9

± values are approximate 95% confidence intervals

LAUNDRY

Most Minnesota multifamily properties have one or more common laundry rooms for tenants to use, though some have individual in-unit laundry equipment and a few have no on-site laundry facilities (Table 12). For properties with common laundry equipment, there is an average of about one washer and dryer for every six or seven apartment units. Most common-area laundry dryers are fueled with natural gas, but nearly all dryers in apartment units are electric. Few washers are high efficiency. Also, it is noteworthy that a third of common-area equipment is provided and maintained by a third party, with the property owner/manager simply sharing in the revenue.

Table 12. Laundry characteristics.

	Building size category								Overall	
	5 to 9 units (n=29)		**10 to 19** units (n=26)		**20 to 49** units (n=28)		**50+** units (n=22)		**Overall** (n=105)	
Type of facilities										
Common laundry room(s)	82%	±14	100%		86%	±13	72%	±21	88%	±6
In-unit laundry	11%	±11	0%		14%	±13	28%	±21	10%	±5
None	7%	±10	0%		0%		0%		3%	±4
Common laundry										
washers per HU	0.19	±0.06	0.18	±0.02	0.11	±0.02	0.10	±0.02	0.16	±0.02
dryers per HU	0.20	±0.06	0.18	±0.02	0.11	±0.02	0.11	±0.02	0.17	±0.02
Energy Star washer	4%	±9	0%		20%	±20	2%	±5	6%	±6
Electric dryer	17%	±13	26%	±20	23%	±8	18%	±22	22%	±9
Gas dryer	83%	±13	74%	±20	77%	±8	82%	±22	78%	±9
Tenants pay for use	95%	±10	100%		100%		85%	±20	97%	±3
Share revenue w/ laundry company that provides equipment	15%	±15	38%	±18	38%	±18	49%	±28	32%	±10
In-unit Laundry*										
top-load washer									96%	±5
front-load washer									4%	±5
Electric dryer									97%	±4
Gas dryer									3%	±4

± values are approximate 95% confidence intervals

HU = housing unit

*Sample too small to report results by building size category

OTHER APPLIANCES

About three-quarters of multifamily apartment units have an electric range and oven and a quarter have a gas range. Somewhat fewer than half of units have a built-in dishwasher.

Table 13. Incidence of other appliances.

	Building size category				
	5 to 9 units (n=29)	**10 to 19** units (n=26)	**20 to 49** units (n=28)	**50+** units (n=22)	**Overall** (n=105)
Range/Oven fuel					
Electric	60% ±16	72% ±18	82% ±15	84% ±16	71% ±9
Gas	36% ±14	28% ±18	18% ±15	16% ±16	28% ±9
Mixed	4% ±7	0%	0%	0%	1% ±3
Dishwasher in unit					
None	79% ±16	54% ±20	32% ±18	26% ±19	56% ±10
Present in some units	14% ±13	24% ±17	29% ±18	22% ±19	21% ±8
Present in all units	7% ±10	21% ±14	39% ±19	52% ±23	23% ±8
Other appliances* (mean number per household)					
microwave	0.94 ±0.08	1.03 ±0.09	0.94 ±0.05	1.01 ±0.06	0.98 ±0.03
dehumidifier	0.13 ±0.10	0.03 ±0.03	0.06 ±0.03	0.03 ±0.01	0.05 ±0.02
humidifier	0.21 ±0.11	0.23 ±0.09	0.26 ±0.08	0.21 ±0.04	0.23 ±0.04
TV	1.47 ±0.20	1.70 ±0.18	1.52 ±0.10	1.45 ±0.08	1.52 ±0.06
desktop computer	0.23 ±0.14	0.31 ±0.10	0.35 ±0.09	0.27 ±0.06	0.30 ±0.04
laptop computer	0.90 ±0.23	0.82 ±0.23	0.71 ±0.10	0.79 ±0.08	0.79 ±0.07

± values are approximate 95% confidence intervals

*From tenant survey data.

ENERGY AND WATER CONSUMPTION FOR MULTIFAMILY BUILDINGS WITH GAS HEAT

Energy costs for multifamily buildings are typically paid partly by property owners and managers and partly by the building tenants, though some buildings with individually metered heating and hot water have utilities that are entirely tenant-paid, and a few buildings have utilities that are entirely landlord-paid.

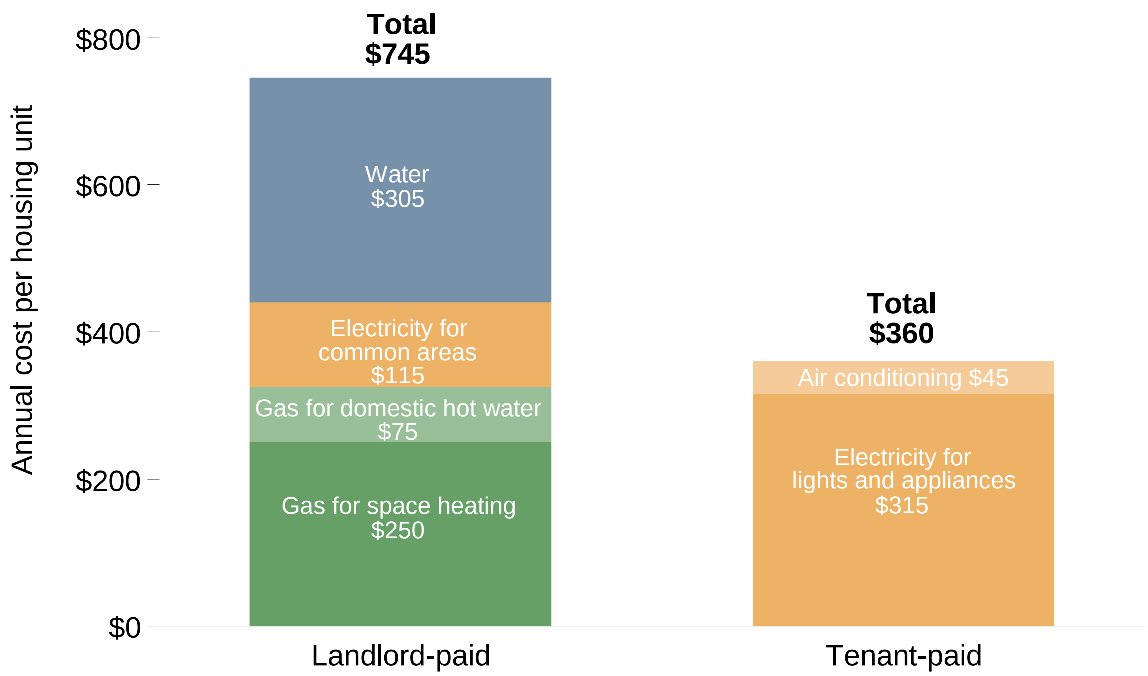
Statistical analysis of utility bills for the study sample indicates that the average building with natural gas heat uses about 530 therms per housing unit annually, of which about three-fourths is for space heating (Table 14). Because these are most often buildings with central heat and domestic hot water, natural gas bills are typically paid by the landlord.

Overall electricity consumption averages about 4,500 kWh annually per housing unit, three quarters of which is billed directly to tenants for in-unit lighting, appliances and air conditioning (Table 15). The remainder is billed to the landlord for common area lighting and air conditioning, exterior lighting and other uses.

Water consumptions averages about 110 gallons per day per housing unit (Table 16).

Figure 27 shows how typical costs for these utilities break out for the most common metering configuration among Minnesota multifamily properties: a building where tenants pay the cost of electricity used in their apartment units, and landlords pay the remainder of the utilities, including the cost of natural-gas space heat and domestic hot water.[6] Of the roughly $1,100 per housing unit in annual utility costs, two-thirds is borne by the landlord. Interestingly, this average annual landlord utility cost is about equal to the statewide average monthly rent ($713).[7] In a similar vein, tenants pay about two-week's worth of rent per year for utilities.

Figure 27. Annual utility costs per housing unit for a typical Minnesota multifamily property with central gas heat, central gas domestic hot water and individual sleeve air conditioning.



For building with central gas space heat, gas domestic hot water and individual sleeve AC
Natural gas rate: 62 cents/therm
Electricity rate: 9 cents/kWh, landlord; 11 cents/kWh, tenant
Water rate: $7.50 per 1,000 gallons
Excludes fixed meter charges and taxes
All values rounded to nearest $5

[6] These costs are based on statewide average utility rates for 2012. Sources: Energy Information Administration (natural gas and electricity); weighted average of water and waste-water rates for sampled properties with water utility data (water). Note also that values shown in Figure 27 may differ slightly from those in Table 14 and Table 15, because the figure is restricted to a specific type of property (central, gas heat and hot water and individual sleeve/window air conditioners) while the tables report average values for all multifamily properties with gas heat.

[7] Source: Census American Community Survey 1997-2011 microdata.

Table 14. Average natural gas cost and use for multifamily buildings with gas heat.

	Building size category: 5 to 9 units (n=18)		10 to 19 units (n=21)		20 to 49 units (n=25)		50+ units (n=18)		Overall (n=82)	
Per building										
Therms (nearest 100)										
Heating	3,100	±500	6,400	±1,100	9,700	±1,900	35,800	±12,600	9,200	±1,400
Other*	900	±300	1,700	±400	3,300	±600	9,200	±2,800	2,600	±300
Total	4,000	±600	8,200	±1,400	13,000	±2,200	44,700	±15,000	11,800	±1,700
Dollars** (nearest 100)										
Heating	$2,000	±300	$4,000	±700	$6,000	±1,200	$22,300	±7,800	$5,700	±900
Other	$600	±200	$1,100	±200	$2,100	±400	$5,700	±1,700	$1,600	±200
Total	$2,600	±400	$5,100	±800	$8,100	±1,400	$27,900	±9,200	$7,300	±1,000
Per housing unit										
Therms (nearest 10)										
Heating	440	±60	470	±60	320	±40	380	±110	410	±30
Other*	120	±30	120	±20	110	±10	100	±20	120	±10
Total	560	±70	590	±70	430	±40	470	±120	530	±40
Dollars** (nearest 10)										
Heating	$280	±30	$290	±40	$200	±20	$240	±70	$260	±20
Other*	$80	±20	$80	±10	$70	±10	$60	±10	$70	±10
Total	$350	±40	$370	±50	$270	±20	$290	±80	$330	±20
Metering arrangement										
House and tenant meters ***	11%	±16	15%	±15	8%	±11	7%	±13	11%	±8
House meter only	83%	±19	85%	±15	92%	±11	93%	±13	87%	±8
Tenant meters only	6%	±12	0%		0%		0%		2%	±3
Heating energy intensity (Btu/ft^2/HDD)	5.7	±1.3	6.3	±0.9	4.9	±1.1	5.2	±1.2	5.6	±0.6

± values are approximate 95% confidence intervals HDD = heating degree day

*Excludes buildings with no non space-heating gas usage.

**Based on 62 cents/therm for master-meterd accounts; 78 cents/therm for individually metered accounts. Excludes monthly fixed meter charges.

***If both tenant and house meters present in building.

Table 15. Average electricity use and cost for multifamily buildings with gas heat.

	Building size category									
	5 to 9 units (n=18)		**10 to 19** units (n=21)		**20 to 49** units (n=23)		**50+** units (n=19)		**Overall** (n=81)	
Per building										
kWh (nearest 100)										
Cooling*	3,900	±1,400	6,600	±2,000	17,700	±6,700	59,700	±12,500	15,600	±2,600
Other**	25,100	±6,200	60,400	±14,200	124,500	±26,200	454,000	±84,200	104,300	±11,800
Total	27,700	±7,100	65,500	±14,700	140,700	±31,900	513,700	±91,900	116,800	±13,200
Dollars*** (nearest 100)										
Cooling*	$400	±200	$700	±200	$1,900	±700	$6,200	±1,200	$1,700	±300
Other**	$2,700	±700	$6,300	±1,500	$12,800	±2,700	$45,700	±7,800	$10,700	±1,200
Total	$2,900	±800	$6,900	±1,600	$14,600	±3,300	$51,900	±8,500	$12,000	±1,300
Per housing unit										
kWh (nearest 10)										
Cooling*	530	±180	460	±130	550	±150	680	±120	530	±80
Other**	3,610	±780	4,310	±810	4,120	±590	5,090	±690	4,130	±410
Total	3,960	±880	4,660	±830	4,620	±700	5,770	±750	4,550	±440
Dollars*** (nearest 10)										
Cooling*	$60	±20	$50	±10	$60	±10	$70	±10	$60	±10
Other**	$380	±80	$450	±90	$420	±60	$510	±60	$430	±40
Total	$420	±90	$490	±90	$480	±70	$580	±70	$470	±50
Metering arrangement										
House and tenant meters	81%	±16	93%	±8	86%	±12	92%	±7	87%	±7
House meter only	7%	±10	7%	±8	14%	±12	8%	±7	9%	±5
Tenant meters only	12%	±13	0%		0%		0%		4%	±4
Tenant-metered % of total electric use****	81%	±6	81%	±4	73%	±8	62%	±12	77%	±3

± values are approximate 95% confidence intervals.

*Excludes buildings with no cooling equipment.

**Includes incidental space heating, if present.

***Based on 9 cents/kWh for master-metered accounts; 11 cents/kWh for individually metered accounts. Excludes monthly fixed meter charges.

****If both tenant and house meters present in building.

Table 16. Average water use and cost.

	Building size category								Overall	
	5 to 9 units (n=10)		10 to 19 units (n=14)		20 to 49 units (n=18)		50+ units (n=16)		(n=58)	
Gallons per day per housing unit	97	±24	113	±30	114	±14	124	±19	111	±13
Annual dollars per housing unit*	$266	±66	$309	±82	$312	±38	$339	±52	$304	±35

± values are approximate 95% confidence intervals.

*At $7.50 per 1,000 gallons volume charge. Excludes fixed meter charges.

Of course, averages tell only part of the story regarding energy consumption and costs. As Figure 28 shows, while nearly half of gas-heated multifamily buildings in the sample have heating energy intensity between 4 and 6 Btu per square foot per heating degree day, some properties fall well above and below this range. A building with heating energy intensity above 8 Btu/ft^2/HDD likely represents a property with heating savings opportunities regardless of its age.

As might be expected, newer buildings tend to be on the lower end of the distribution for heating energy intensity, and older buildings on the higher end (Figure 29). Thus, there is a progression in average heating energy intensity among the vintage-based segments: Pre–World War II properties have the highest average intensity (7.0 ± 1.5 Btu/ft^2/HDD), Post-War the next highest (5.7 ± 0.6) and Post-Energy Crisis the lowest (4.0 ± 1.4).

Interestingly, the situation is reversed for electricity consumption: Pre–World War II properties average about 2,800 ± 500 kWh per year per housing unit, Post-War properties average about 3,500 ± 400 kWh per year and Post-Energy Crisis buildings average 3,800 ± 500 kWh annually.

Figure 28. Distribution of heating energy intensity for gas-heated buildings.

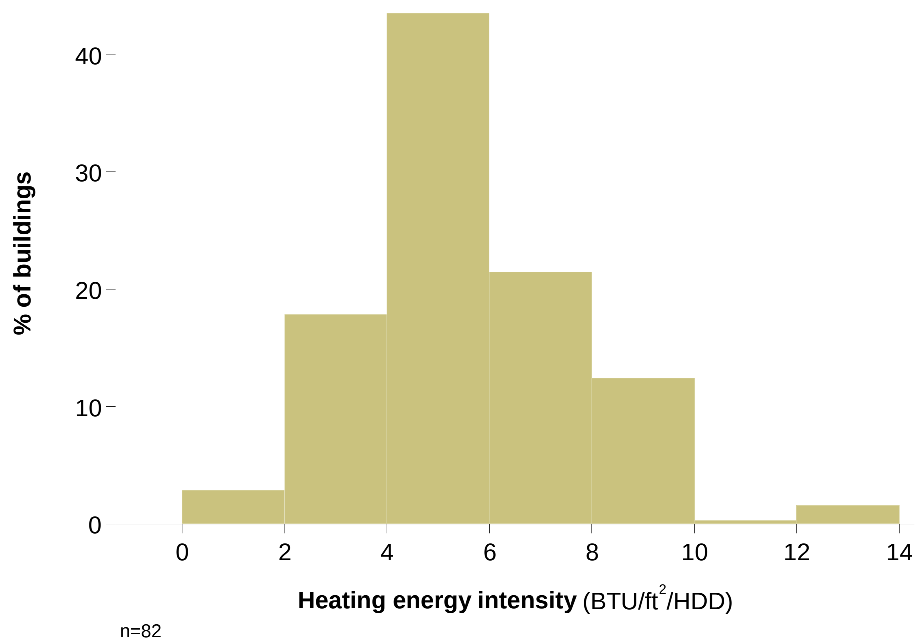
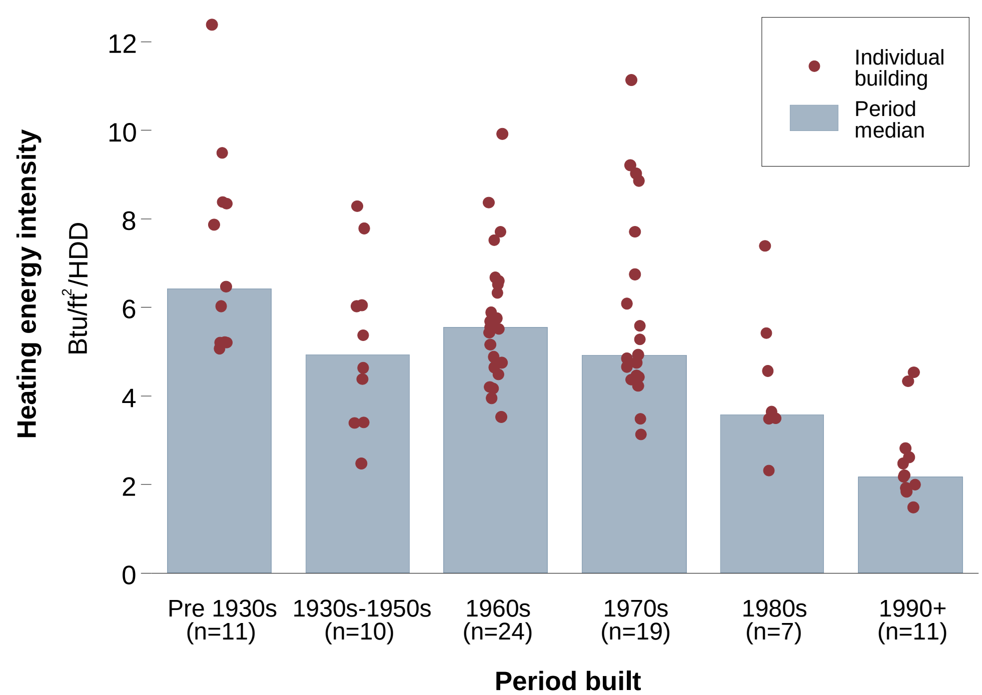


Figure 29. Heating energy intensity for gas-heated buildings, by period built.



ENERGY AND WATER SAVING OPPORTUNITIES

To examine the potential for energy and water savings in Minnesota multifamily buildings, we assessed each building in the study sample for a number of commonly-implemented energy efficiency opportunities. Our list of measures was not intended to be an exhaustive assessment of all savings possibilities in multifamily housing, because some measures (such as detailed boiler staging and control strategies or hot water distribution system changes) were beyond the scope of what could be readily analyzed within our broad overview of properties. Also, there were some measures (such as ceiling insulation) where we could not gather adequate on-site data to include in our assessment. Nonetheless, the 25 measures that we were able to include cover most of the measures that are typically included in multifamily energy-efficiency programs. In particular, we examined:

- Lighting upgrades and bulb replacement, both in common areas and in apartments
- Installation of high-efficiency heating systems, as well as controls and tune-ups for existing systems
- Installation of high-efficiency water heaters
- Installation of energy (and water) saving showerheads and faucet aerators
- Upgrading appliances to Energy Star qualified units
- Installation of Energy Star qualified windows

The details of our methods for determining when an opportunity for a particular measure exists, and how much it saves and costs in a particular building are documented in Appendix F. Here, we provide a high-level review of the results of this analysis, and note that our analysis estimated installation costs and utility costs savings for electricity, natural gas and water. [8] We used these values to calculate the simple payback period for each measure in each building, for which median values are shown in Figure 30.

We also note here that our payback estimates are based on full retrofit costs and savings for some measures and on upgrade-on-replacement costs and savings for others. The former set of measures includes those that typically are implemented primarily for energy savings. The latter set involves measures for which it is not cost effective to replace the equipment solely for energy savings, but for which it may be cost effective to upgrade to a more energy-efficient product if the equipment is being replaced anyway. Examples of retrofit measures include boiler vent dampers and low-flow showerheads; examples of upgrade measures include high efficiency heating and cooling equipment and window replacements.

We begin with an examination of the incidence of savings opportunities; that is, the fraction of buildings where a given measure could be installed given the existing equipment and the consideration of payback on installation costs. Measures such as replacing incandescent light bulbs in apartments, replacing showerheads and installing high-efficiency clothes washers have widespread applicability in multifamily buildings, meaning that one could walk into most Minnesota multifamily buildings and find opportunities for these measures (Figure 31). Opportunities for other measures, such as converting electric clothes dryers to gas are relatively uncommon. Only relatively low-cost items such as replacing light bulbs and showerheads have both widespread applicability and offer short paybacks.

If the 25 measures considered here were implemented wherever applicable without regard to cost effectiveness, annual savings would average roughly $150 to $225 per housing unit (Figure 32). This drops into the range of $75 to $200 if payback is taken into consideration.

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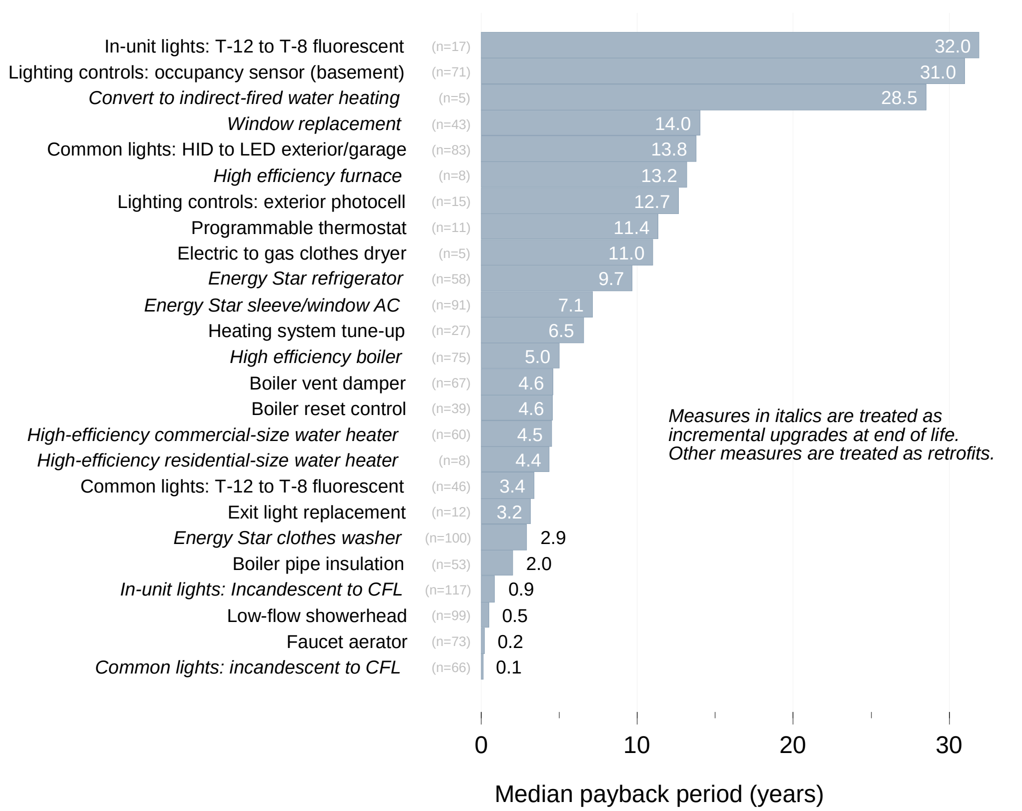
[8] As noted elsewhere, our assumed average costs associated with these are as follows: electricity – 9 cents/kWh (master-metered), 11 cents/kWh (tenant-paid); natural gas – 62 cents/therm (master-metered), 78 cents/therm (tenant-paid); and, water – $7.50 per 1,000 gallons.

While savings potential *per building* will obviously be higher among larger buildings owing to their greater size and energy consumption, the average savings potential *per housing unit* is highest for small properties, and lowest for large properties—though the difference becomes less pronounced when examining only short-payback measures (Figure 32). The difference appears to be mainly attributable to less potential for showerheads and aerators, common-area lighting and washing machine upgrades among larger properties.

We did not find large differences in savings potential among Pre-World War II, Post-War, and Post-Energy Crisis multifamily buildings, though not surprisingly, the last showed the lowest average potential of the three. Compared to Post-War properties, Pre-World War II buildings appear to have fewer opportunities for in-unit lighting and more opportunities to upgrade single-pane windows. Not surprisingly, Post-Energy Crisis properties have fewer boiler upgrade opportunities. But they also appear to have somewhat more exterior and garage lighting opportunities.

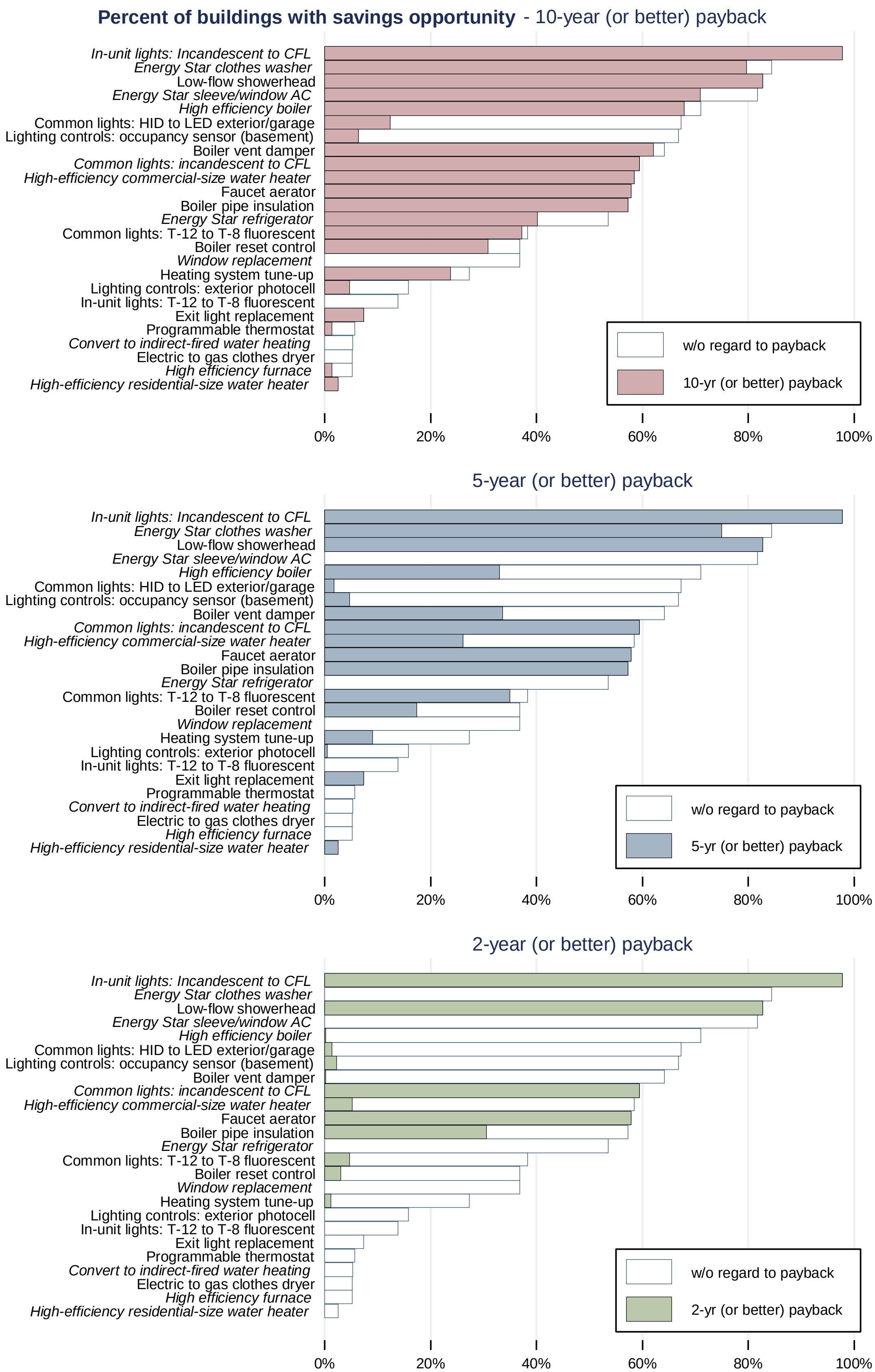
Figure 30. Median simple payback in multifamily buildings with gas heat, by measure.



(n = number of buildings in study sample where measure was judged to be applicable)

Another way to judge the savings potential for various measures is to look at how much each contributes to the total aggregate savings potential in multifamily buildings with gas heat. In this view, while there are a wide variety of measures that can contribute meaningfully to savings when payback is not considered, when screened down to measures with relatively short paybacks, the range of options is narrower, and the percentage of total available savings is more concentrated in fewer measures (Figure 33).

Figure 31. Percent of gas-heated multifamily buildings with measure opportunity, by payback period.



Measures in italics are treated as incremental upgrades at end of life. Other measures are treated as retrofits.

Figure 32. Mean annual savings potential per housing unit in multifamily buildings with gas heat, by payback period and building size category.

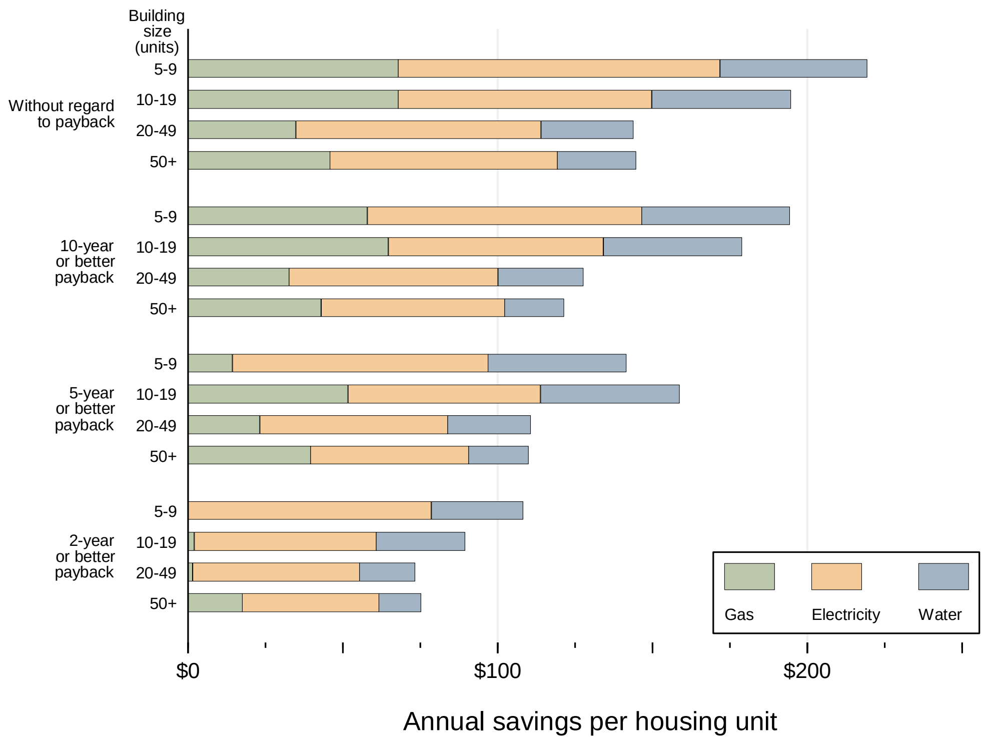
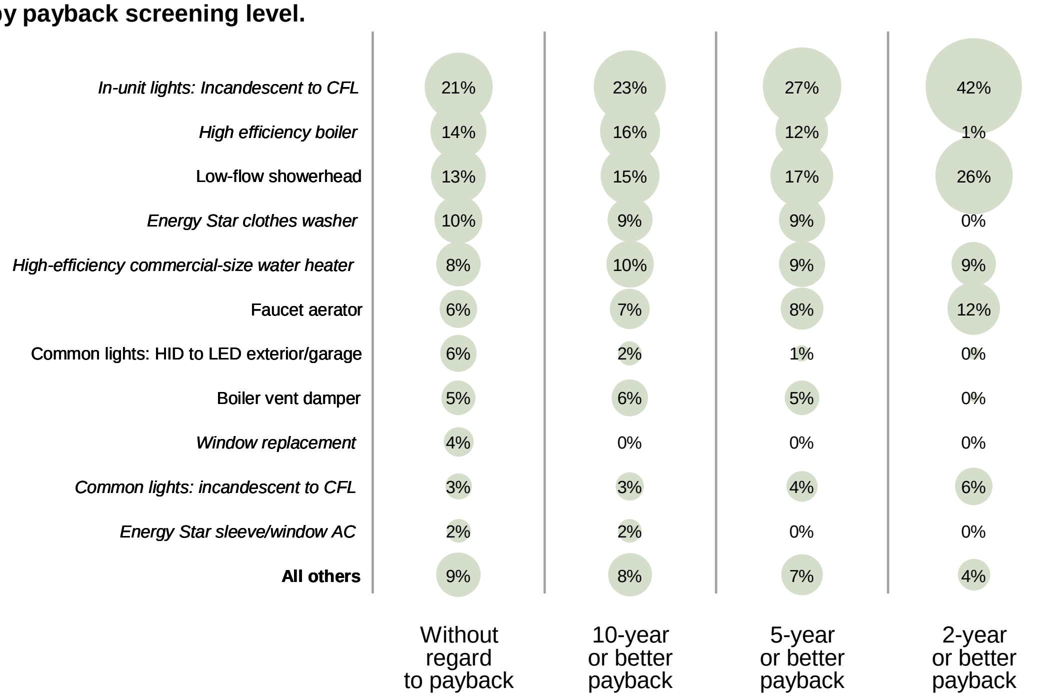


Figure 33. Measure contributions to aggregate cost savings potential in buildings with gas heat, by payback screening level.



Columns sum to 100%
Area of shaded circles are proportional to column percents
Measures in italics are treated as incremental upgrades at end of life. Other measures are treated as retrofits

Thus far, we have concerned ourselves only with utility costs savings regardless of who pays for—and who reaps the benefits from—the various measures. However, one of the vexing aspects of encouraging efficiency improvements for multifamily properties is the so-called “split-incentives” problem, in which landlords are reluctant to invest in energy efficiency improvements that will primarily benefit tenants. We turn next to an examination of this issue.

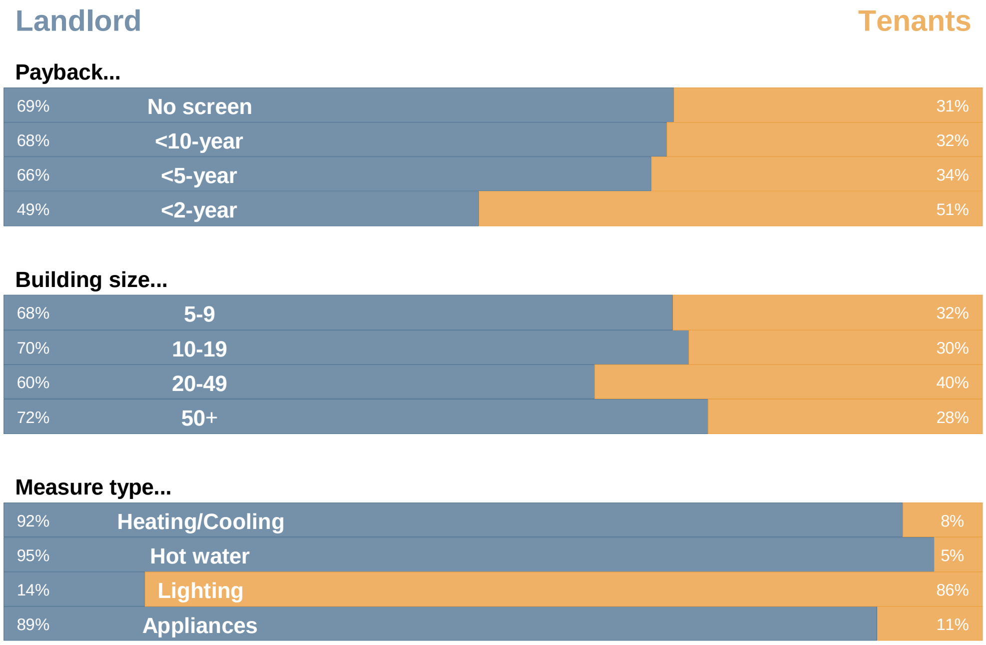
The question of “Who pays?” is easily answered: it is overwhelmingly landlords who would pay for the measures that we considered. Of the 25 measures that we looked at, we considered that tenants would be responsible for paying for only two – and even then only in some instances. The two situations are: light bulb replacements for plug-in luminaires in apartment units, and room air conditioner replacement in buildings where tenants are expected to provide their own air conditioning unit. These two situations account for only about one percent of the total costs across the study sample.

The question of “Who benefits?” is more complex, and depends on the utility metering arrangement for the building as well as the measure in questions. For a central boiler replacement, the landlord would reap the direct bill savings from the increase in space heating efficiency. Similarly, tenants would enjoy the savings for replacing furnaces in a building with individually metered heat.

However, the situation is complicated in some situations. For example, replacing windows may save the landlord on winter heating bills, and also save on tenant air conditioning bills in the summer. Moreover, the impacts of measures are not always positive to both parties: replacing the refrigerators in an apartment building with individual electric meters can be expected to reduce tenant electric bills, but will also increase the heating bill for the landlord if the building has central heat. (This is because electricity consumed inside a building is converted to heat, and this partially offsets the need for heating equipment to operate: if more efficient appliances reduce electricity consumption, there is also a reduction in this offsetting effect.)

We took these situations into account, and allocated the estimated cost savings (and indirect energy impacts) to landlords and tenants according to the particular equipment and metering arrangement for each building in the study sample. Overall, the results suggest that about two-thirds of the cost savings potential would accrue to landlord-paid utilities and one-third to tenant-paid utilities (Figure 34). However, as the figure shows, it is in-unit lighting savings that account for the majority of savings that accrue to tenants; most savings from other measures accrue to landlords within the population of multifamily properties with gas heat.

Figure 34. Landlord/tenant split for total potential cost savings in multifamily buildings with gas heat, by payback level, building size and measure type.



TENANT DEMOGRAPHICS, ATTITUDES AND BEHAVIOR

Demographics

As described earlier, all tenants in our study sample of buildings were given surveys to complete which included questions regarding comfort, attitudes, behavior and demographics. Table 17 shows various demographic characteristics of multifamily renters based on this tenant survey data. Just over ten percent of Minnesota residents live in multifamily rental housing.[9] Overall, these households tend to be smaller; more than half are one-person households. The demographic data from the study sample suggest that the sample is somewhat skewed toward large households and low-income households. Census (ACS) data show an average of 1.6 persons per household and 35 percent low-income households for residents of multifamily buildings with gas heat, compared to 1.8 persons per household and 60 percent low-income in the study sample.

Not surprisingly, rental households are more mobile; more than half have lived at their current address for two years or less. Three quarters of rental households have at least one member with education beyond high school. Household income tends to be lower with just over two-thirds earning under $40,000 a year and 60 percent falling below 200 percent of the 2012 Federal Poverty Guideline.

The demographics of multifamily renters also vary by building size. As Table 17 shows, larger buildings are more likely to house one-person households and seniors, and are less likely to have households with children. Buildings with five to nine units are more likely to house low-income residents.

[9] Source Census Bureau, 2007-2011 American Community Survey microdata.

Table 17. Tenant demographics, multifamily buildings with gas heat.

	Building size category								Overall	
	5 to 9 units (n=72)		10 to 19 units (n=111)		20 to 49 units (n=275)		50+ units (n=701)		(n=1,159)	
Household composition										
Household members	1.7	±0.3	2.2	±0.3	1.7	±0.2	1.6	±0.1	1.8	±0.1
% one person household	64%	±12	51%	±11	59%	±7	63%	±4	59%	±4
% w/ senior	9%	±8	6%	±5	13%	±4	18%	±3	13%	±2
% w/ children	13%	±9	32%	±10	18%	±7	13%	±3	18%	±3
Years in current unit										
< 1 year	40%	±13	30%	±9	26%	±6	29%	±4	29%	±3
1 to 2 years	21%	±10	31%	±10	24%	±6	29%	±4	27%	±3
3 to 4 years	19%	±10	14%	±7	19%	±7	18%	±3	18%	±3
5 to 10 years	14%	±9	11%	±6	21%	±5	17%	±3	16%	±3
More than 10 years	7%	±8	14%	±7	11%	±4	8%	±3	10%	±2
Education*										
Grade school	0%		0%		3%	±2	2%	±2	2%	±1
High school	16%	±9	22%	±8	23%	±6	19%	±4	21%	±3
Technical school	35%	±13	27%	±10	26%	±6	22%	±4	26%	±4
Undergrad college	40%	±13	38%	±10	41%	±7	41%	±5	40%	±4
Advanced college	9%	±7	13%	±7	7%	±3	15%	±3	11%	±2
Income**										
Less than $20,000	56%	±14	42%	±10	50%	±7	43%	±5	46%	±4
$20,000 to $29,999	16%	±9	21%	±8	17%	±5	11%	±3	16%	±3
$30,000 to $39,999	14%	±10	16%	±9	14%	±5	13%	±3	14%	±3
$40,000 to $49,999	9%	±7	8%	±5	9%	±4	11%	±3	9%	±2
$50,000 to $74,499	5%	±4	11%	±6	6%	±	14%	±3	10%	±2
$75,000 or more	0%		2%	±2	4%	±3	8%	±2	4%	±1
low-income household***	71%	±13	61%	±11	66%	±7	50%	±5	60%	±4

± values are approximate 95% confidence intervals

*Highest level reported for any adult household member. Includes completion of coursework w/o degree.

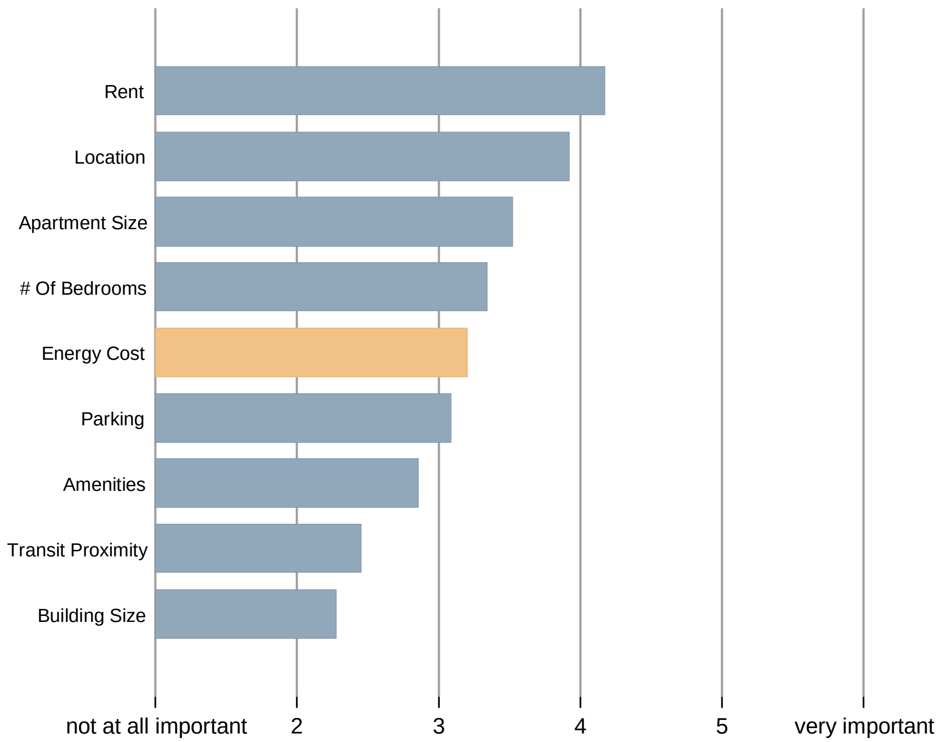
**'Prefer not to respond' responses were removed

***Estimated based on income per household member at or below 200% of 2012 Federal Poverty Guideline

Factors in deciding where to rent

The tenant survey data indicate that rent amount, building location, and the size of the apartment are the strongest drivers in influencing why people choose to rent where they do (Figure 35). Energy costs rate in the middle of the pack, at about the same level of importance as factors such as parking and number of bedrooms. These rankings are similar across various building sizes as well as across renters who pay for their heating costs directly versus those where heating is included in the rent.

Figure 35. Factors in deciding where to rent

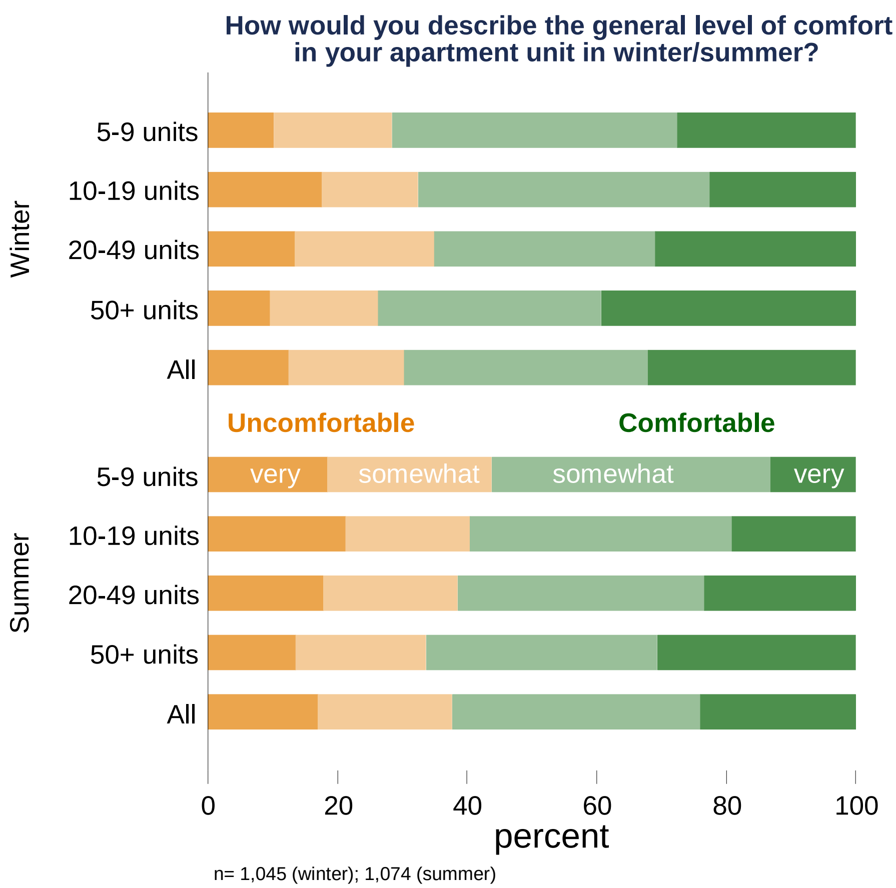


Comfort

APARTMENT COMFORT

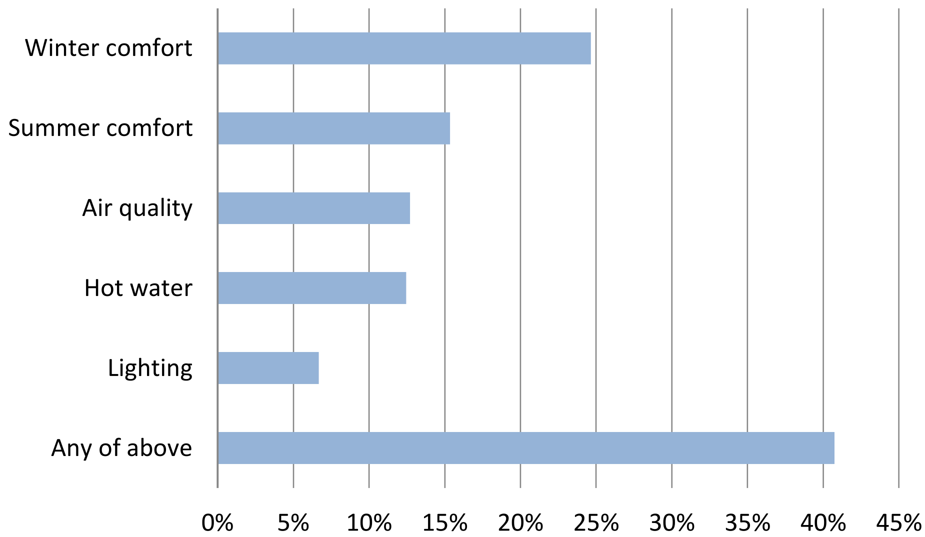
The tenant survey asked respondents to rate the general level of comfort in their apartment during the winter and the summer. The results indicate higher levels of comfort in winter over summer (Figure 36). Within the same season, differences among the building size categories are generally smaller and not statistically significant. However, there are notable differences among the building-vintage segments: Pre-World War II properties have the lowest rated comfort, Post-Energy Crisis properties have the highest, and Post-War buildings are between these two.

Figure 36. Tenant comfort in the winter and summer.



Just over forty percent of tenants report notifying their landlord about a temperature, air quality, lighting or hot water issue during the previous year (Figure 37). The most complaints came from tenants living in buildings with 10-19 units.

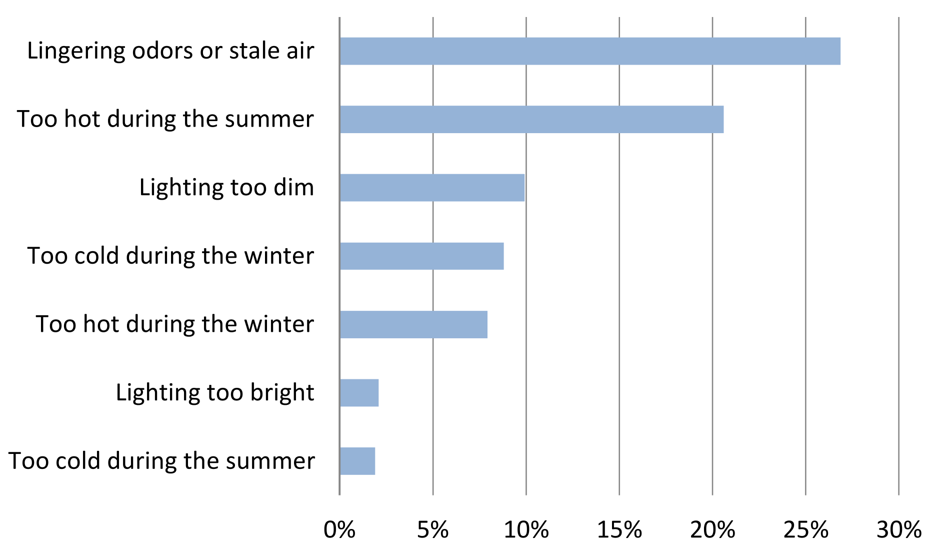
Figure 37. Incidence of reporting an apartment comfort problem to landlord.



COMMON-AREA COMFORT ISSUES

Among tenants of buildings with common areas, lingering odors and temperatures too hot in the summer lead the list of reported comfort issues in common areas (Figure 38). More than one in four tenants reported problems with lingering odors or stale air in common areas “most of the time” or “always,” and about one in five tenants reported issues with common areas being too warm in the summer.

Figure 38. Incidence of common-area comfort issues.



Thermostat-related Behavior

Tenants in rental housing have more limited opportunities to reduce their home's energy consumption than do homeowners, but one of the more meaningful steps they can take is to control the temperature of their unit in the winter. Reducing—or setting back—the temperature to which one heats one's home when asleep or away is generally the single-most effective energy-saving opportunity available to tenants, who otherwise have little say in the efficiency level of the equipment in their building. However, most tenants pay heating costs only to the extent that it is indirectly reflected in their rent, and so may have little incentive to save on heating costs. And some tenants have no ability to control the temperature in their apartment at all. To better understand temperature-setting practices among Minnesota renters, we analyzed responses to our tenant survey, and supplemented these with actual indoor temperature data for a small sample of apartments where data loggers were installed to track in-unit temperature during part of the 2012-13 heating season.

ABILITY TO CONTROL TEMPERATURE

The survey data show that a large majority of tenants in gas-heated buildings have some ability to control their unit's temperature, and most have a thermostat with temperature settings (Table 18).

Table 18: Type of apartment temperature control for buildings with gas heat.

"What type of temperature control for heating do you have in your apartment?"	Percent	
Regular thermostat(s) with temperature settings	59%	±4
Clock or programmable thermostat(s)	3%	±1
Dial control(s) without temperature indicator	17%	±3
Simple on/off switch	4%	±2
No control over temperature of apartment	18%	±3

± values are approximate 95% confidence intervals
Source: tenant survey (n=1,041)

SELF-REPORTED PRACTICES

Of households that do have control over the temperature in their apartment, four-fifths indicated that they change their temperature on a regular basis by doing one or more of the following:

- change the temperature setting by hand "usually every day" (during the prior winter);
- maintain different temperatures during sleeping hours or while away than they did while awake in the unit (during the prior winter);
- lower the heating thermostat at night or when away either "most of the time" or "always."

Arguably, the most indicative self-reports of setback practices are by tenants who provided actual temperatures at which they kept their units during the prior winter. About 500 survey respondents provided their typical temperature settings at three times of the day: when home and awake, when asleep, and when away. Slightly more than half of these respondents indicated that they varied their temperature at least somewhat, and a substantial majority of them (45 percent of respondents overall) said that they changed the temperature by more than two degrees. Those who pay for their heat were more likely to report setting back their temperature—particularly when they are away from their unit—but a meaningful share of tenants whose heat is included in the rent do set back their temperature as well.

Table 19: Self-reported setback practices

	Heat paid by tenant?				Overall	
	Yes		No			
Temperature difference awake/sleep						
higher (any amount)	9%	±13	6%	±2	6%	±2
no difference	23%	±19	57%	±5	56%	±5
lower by 1-2 degrees	14%	±15	9%	±3	10%	±3
lower by 3+ degrees	53%	±26	27%	±5	29%	±5
Temperature difference awake/away						
higher (any amount)	0%		1%	±1	1%	±1
no difference	19%	±18	57%	±6	55%	±5
lower by 1-2 degrees	5%	±9	7%	±3	7%	±3
lower by 3+ degrees	77%	±19	35%	±5	38%	±5
Sample size	17		448-468		465-485	

± values are approximate 95% confidence intervals

As shown in Table 19, setting back temperatures when away from the unit was somewhat more common, with 38 percent of respondents who provided temperature settings lowering their temperature during these times by more than two degrees. In comparison, 29 percent said they lowered their temperature by more than two degrees during sleeping hours.

Overall, the mean self-reported setback among all renters who provided temperature settings was around 2.9 ± 0.5 degrees when tenants were away from the unit and 1.5 ± 0.4 degrees during sleeping hours, with no meaningful differences between those who pay for their heat and those who don't. Among those who set back their temperature, reductions of two to ten degrees were most common when occupants were away, while most reductions during sleeping hours were generally between two and five degrees.

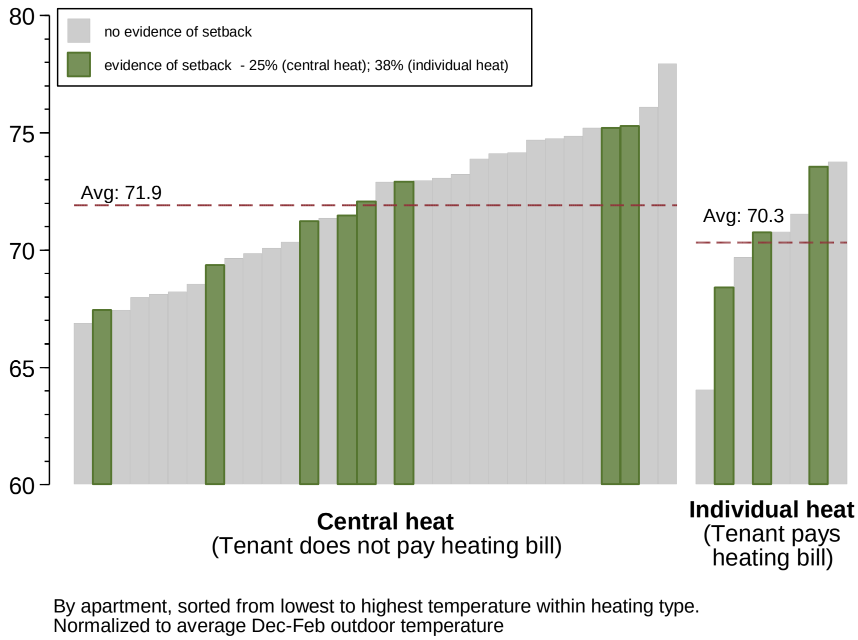
We also compared setback practices among those renters who have a temperature indicator on their thermostat and those whose heating controls comprise either an on/off switch or a dial without any temperature settings. Tenants reported similar levels of setback activity regardless of whether their heating control includes a temperature indicator.

OBSERVED PRACTICES

In addition to self-reported thermostat behavior from the tenant survey, we also measured actual in-unit temperatures for a sample of 40 apartments in 16 buildings to provide a direct indication of tenant practices. Only two of these buildings had individual heat that was paid directly by the tenants. For this analysis, we looked at overall average indoor temperature, and also examined median temperature by hour of the day over the monitoring period, which spanned late fall and early winter during the 2012-13 heating season. We classified households as setback-practicers if the highest median hourly temperature differed by more than two degrees from the lowest median hourly temperature.

Among the 40 apartments that we monitored, a sizeable minority of tenants appear to be practicing setback behavior (Figure 39), including tenants in buildings with central heat. The setback incidence is higher—and average indoor temperature is lower—among tenants with individual heat, but the fact that we had only two such buildings in our monitoring sample makes it difficult to draw conclusions about whether this is true in general.

Figure 39. Monitored temperatures in 40 apartments.



However, the fact that both the tenant survey and the monitoring data show evidence of setback behavior among tenants in centrally heated buildings is surprising, and bears additional investigation.

BUILDING OWNERSHIP, MANAGEMENT AND DECISION-MAKING

The owners or managers of the buildings in the study sample were asked to complete an in-depth survey on investment choices, maintenance practices and decisions concerning the sampled building. In buildings with fewer than 20 units, surveys were typically completed by the owner, while for buildings with more than 20 units, the surveys were more likely to be completed by a non-resident manager or employee of a management company, or a resident manager or building superintendent.

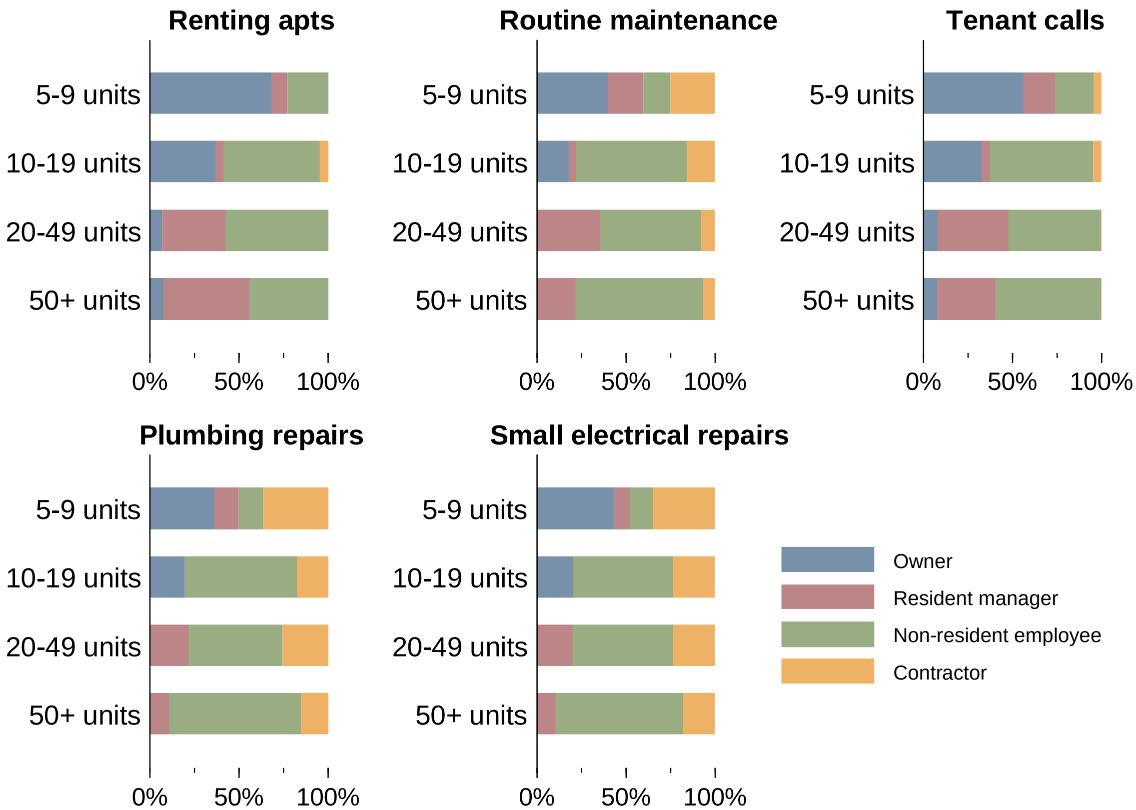
The results of the survey indicate that the majority of smaller multifamily buildings are owned by individual investors. As the building size increases, proportion of buildings owned by individual investors decreases and the majority shifts to partnership owners (Table 20).

Table 20: Building ownership

Type of ownership	Building size category								Overall	
	5 to 9 units (n=24)		10 to 19 units (n=25)		20 to 49 units (n=28)		50+ units (n=22)		(n=99)	
Individual investor	67%	±19	46%	±20	33%	±18	13%	±16	48%	±10
Partnership (limited or general)	25%	±18	46%	±20	39%	±17	56%	±23	38%	±10
Real estate or other corporation	0%		0%		14%	±14	8%	±12	4%	±3
Non-profit institution	4%	±8	8%	±11	7%	±10	11%	±15	7%	±5
Public Housing	4%	±8	0%		7%	±10	6%	±11	4%	±4

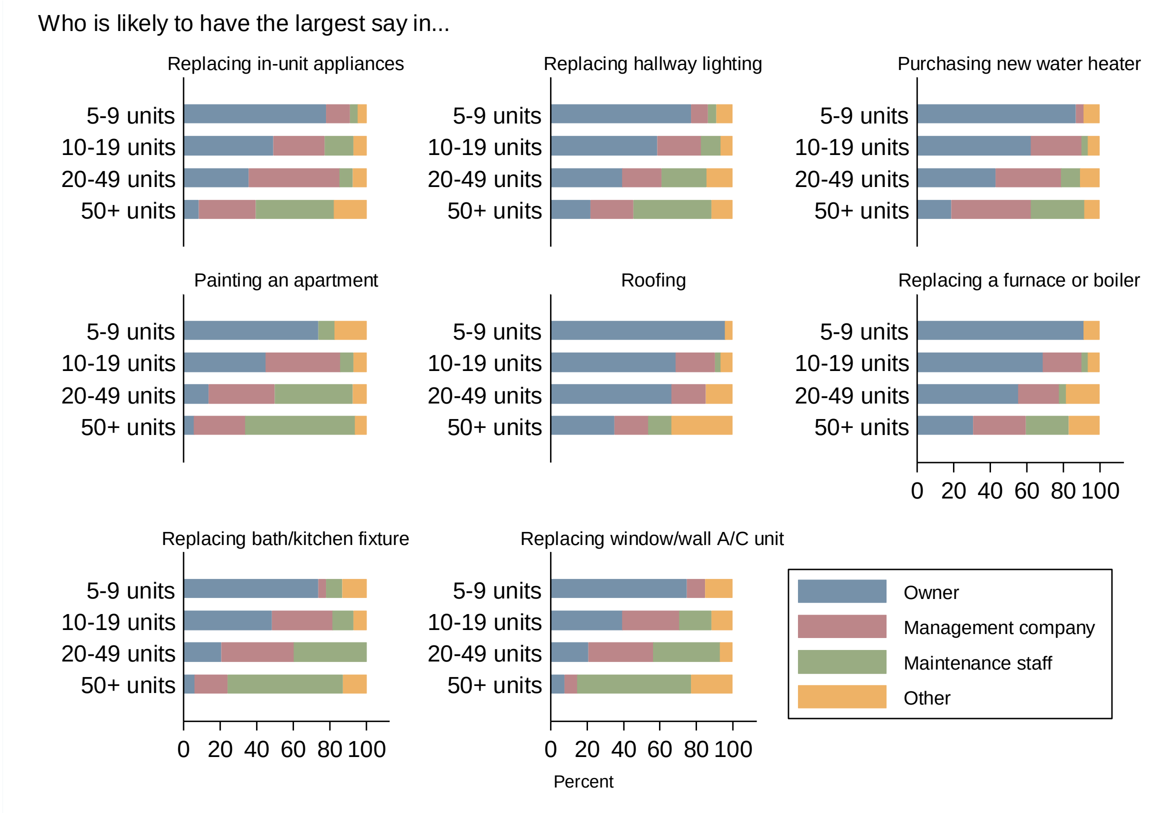
When the owners and managers were asked who handles routine activities, such as responding to tenant needs and making small repairs, there was a range of responses between building size categories (Figure 40). For smaller buildings, the owner often handles these routine activities but in larger buildings the responsibilities shift to a mix of both non-resident employee and resident managers and to a lesser extent, contractors.

Figure 40: Who handles building management activities, by activity and building size.



The owner/manager survey included a question about the decision-making process, specific to who has the largest say when repairing and making investments in the building system. The survey results show that the owners of smaller buildings (between 5 and 19 units) have the largest say in most maintenance decisions, including appliance and equipment upgrades as well as general building maintenance. In larger buildings, the responsibilities of maintenance shift to either a management company or hired maintenance staff. In the largest of buildings (with over 50 units), the owners play less of a role in regular maintenance and smaller investments such as painting of apartments or replacing in-unit fixtures. When making more significant purchases such as replacing a furnace or roofing, the owners of these large buildings play a larger role in comparison to management companies or maintenance staff (Figure 41).

Figure 41: Who has the largest say in various maintenance decisions.



Appliance Purchase Practices

When asked about recent appliance purchases in the past two years, the responses indicate that at least some refrigerators and room air conditioners are purchased for a significant percent of properties each year (Table 21). Using the responses on the number of units purchased, we estimate an annual replacement rate of about 6.5% for refrigerators. Owners and managers also reported some investment in dishwashers, clothes washers and clothes dryers, but to a lesser extent. These data generally suggest that multifamily purchases of appliances are a routine activity.

Table 21: Appliance purchases rates reported by owners/managers.

"Have you installed or purchased any of the following major appliances for this building in the past two years?"
(Percent "Yes")

	Building size category									
	5 to 9 units		10 to 19 units		20 to 49 units		50+ units		Overall	
Refrigerator	82%	±17	83%	±16	82%	±15	84%	±16	83%	±9
Room A/C	50%	±23	71%	±19	65%	±18	47%	±25	60%	±11
Dishwasher	12%	±17	33%	±20	56%	±20	50%	±24	34%	±10
Clothes washer	20%	±19	9%	±12	44%	±20	37%	±23	23%	±9
Clothes dryer	11%	±15	4%	±9	42%	±21	37%	±23	18%	±8

± values are approximate 95% confidence intervals.

When making appliance purchases, owners and managers of smaller buildings are more likely to make on-the-spot selections of appliances, while the purchase process followed by owners and managers of larger buildings varies between pre-negotiated contracts, bidding processes and on-the-spot selection (Table 22). It is more likely to see appliance purchases made at a local appliance dealer or a national chain. For the largest buildings, purchases are also likely to be made through the distributor or wholesaler. Purchasing appliances directly from manufacturers is the least likely method of purchase. Across all sizes of buildings, owners and managers typically purchase appliances new rather than used.

Table 22: Appliance purchase process

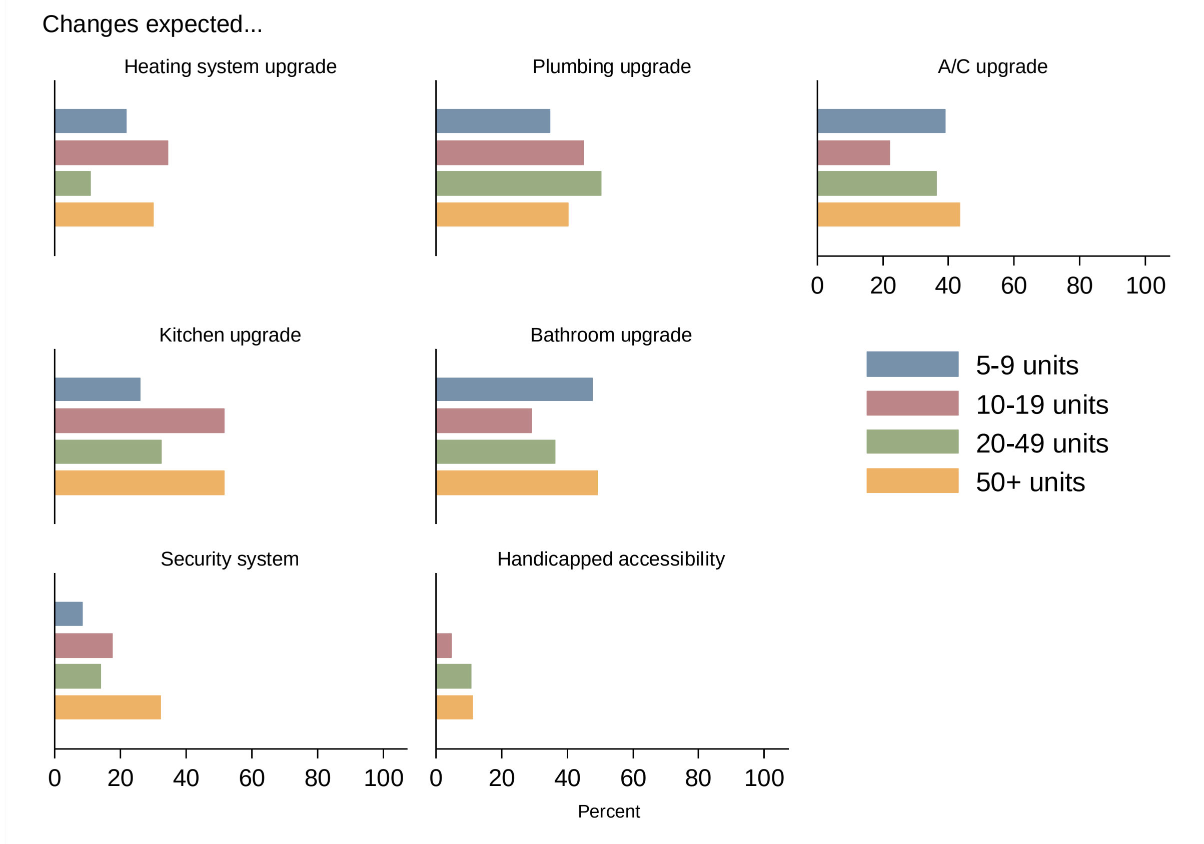
	Building size category 5 to 9 units		10 to 19 units		20 to 49 units		50+ units		Overall	
Appliance purchase process	(n=24)		(n=24)		(n=28)		(n=21)		(n=97)	
Pre-negotiated contract	21%	±17	32%	±19	32%	±18	34%	±23	28%	±10
Bidding process	0%		9%	±12	21%	±15	19%	±17	9%	±5
On-the-spot selection	67%	±20	50%	±21	36%	±19	20%	±19	50%	±11
Other	12%	±14	9%	±12	11%	±12	26%	±21	12%	±7
Where appliances are purchased	(n=24)		(n=25)		(n=27)		(n=21)		(n=97)	
Local/regional appliance dealer	50%	±21	27%	±18	48%	±19	29%	±21	40%	±11
National chain	37%	±20	47%	±21	19%	±15	23%	±20	36%	±11
Distributor/wholesaler	13%	±13	26%	±17	19%	±15	32%	±22	20%	±8
Manufacturer	0%		0%		15%	±14	8%	±13	4%	±3
Other	0%		0%		0%		8%	±7	1%	±1
Used or New?	(n=24)		(n=25)		(n=28)		(n=22)		(n=99)	
Mostly new	75%	±18	85%	±14	82%	±15	100%		82%	±9
Sometimes new or used	21%	±17	9%	±12	15%	±13	0%		13%	±8
Mostly used	0%		0%		3%	±7	0%		1%	±1
Mostly used	4%	±8	7%	±8	0%		0%		4%	±4
Always used	3%	±5	6%	±7	0%		0%		3%	±3

± values are approximate 95% confidence intervals.

Building Upgrade and Repairs

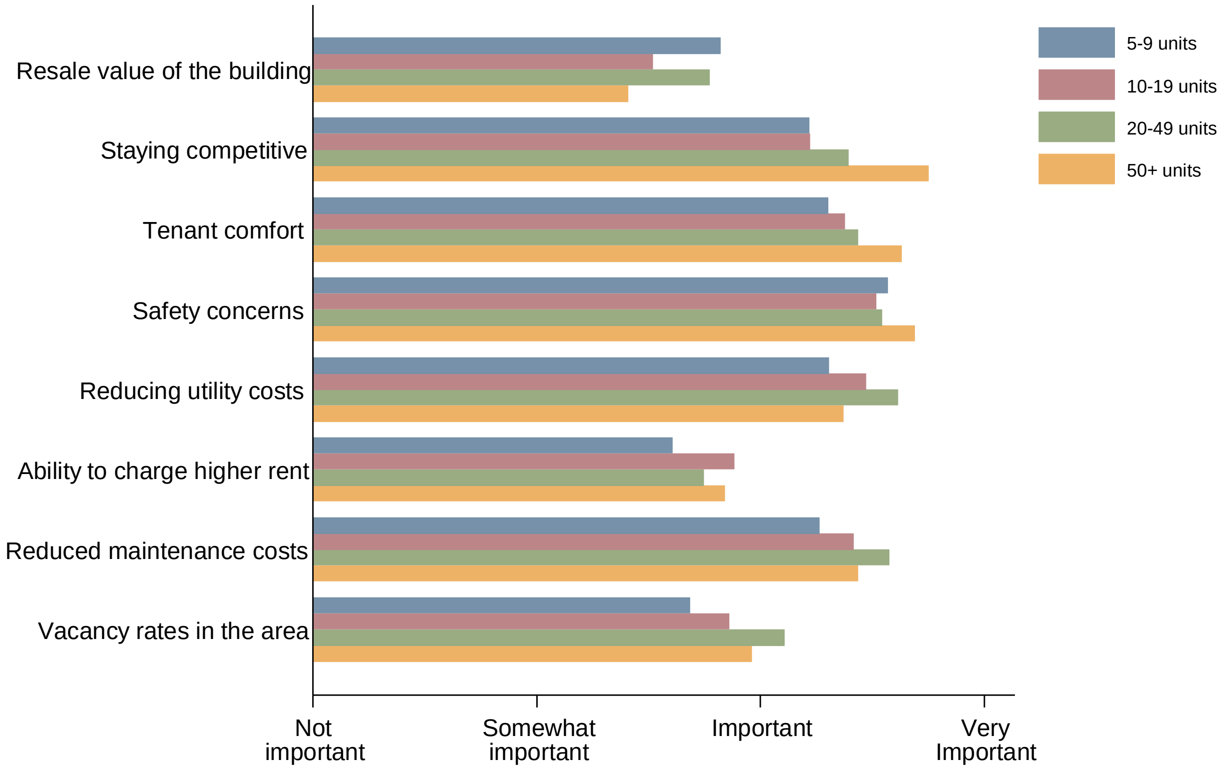
Our survey results suggest that between 30 and 50 percent of owners and managers plan for upgrades of air conditioning, heating, kitchen, bathroom and plumbing in the next five years (Figure 42). A smaller percentage of building owners and managers are planning on making changes to handicapped accessibility or security systems, with the exception of security systems for buildings with more than 50 units.

Figure 42: Building upgrades and repairs expected in the next five years.



When making decisions about building changes and investments (Figure 43**Error! Reference source not ound.**), the owners and managers who participated in this study largely place similar importance on the variety of factors provided in the survey. Factors that held greater weight than others included safety concerns, tenant comfort, reducing utility costs and reducing maintenance costs. Owners and managers of larger buildings tended to rate these factors with slightly higher importance than owners of smaller buildings. The ability to charge higher rent and vacancy rates in the area held less comparative importance to other factors. The differences in factor importance between larger and smaller buildings were greatest in the category of resale value of the building.

Figure 43: Landlord factors in deciding whether to make building changes



Building Operating Costs

The owner/manager survey asked respondents to identify the first, second, and third highest items contributing to their operating costs from the list below:

- Taxes of all types
- Mortgages, interest and insurance
- Energy and other utility costs
- Maintenance and repairs
- Management fees

For most building size categories, the results suggest that mortgages, interest and insurance comprise the highest operating costs (Table 22). For 10-19 unit buildings, owners and managers also cite maintenance and repairs as a top operating cost. Taxes were the second most often cited item as a building's highest operating costs. Owners and managers rarely cited energy costs as their building's highest cost but energy costs did come into play when looking at second or third highest costs.

Table 23: Operating cost ranking

	Units in the Building: 5 to 9 units (n=23)		10 to 19 units (n=22)		20 to 49 units (n=24)		50+ units (n=18)		Overall (n=87)	
Top operating costs cited										
Taxes, all types	17%	±16	9%	±12	17%	±16	10%	±15	14%	±8
Mortgages/interest/insurance	65%	±20	33%	±21	67%	±20	73%	±23	56%	±11
Energy and other utility costs	9%	±12	4%	±8	4%	±8	7%	±14	6%	±6
Maintenance and repairs	4%	±9	40%	±21	8%	±12	3%	±6	17%	±8
Management fees	4%	±9	10%	±13	0%		7%	±14	5%	±6
Percent where energy is cited as second or third highest operating cost										
Second highest*	43%	±21	17%	±16	31%	±19	26%	±20	31%	±11
Third highest**	31%	±16	60%	±21	41%	±21	48%	±24	44%	±11

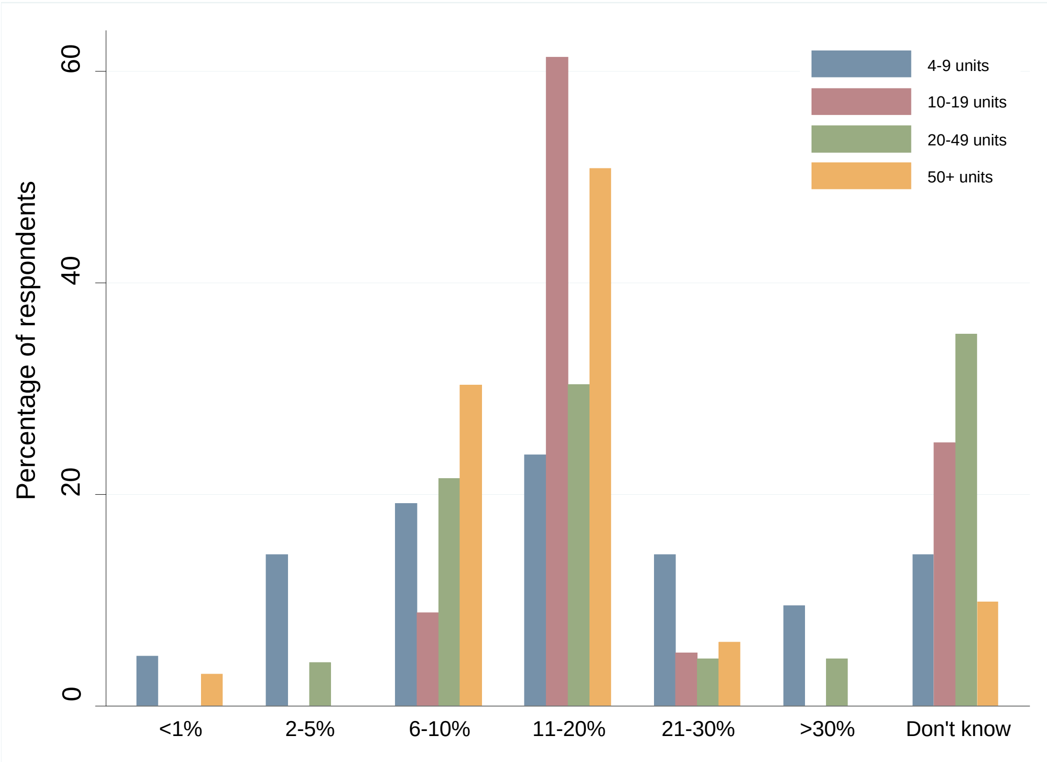
*Total response for this question ranges from 18 (50+ category) to 30 (5-9 category)

**Total response for this question ranges from 18 (50+ category) to 31 (5-9 category)

± values are approximate 95% confidence intervals.

When specifically asked about the percentage that energy costs comprised of their total operating costs, a majority of respondents for all buildings estimated that their energy bills make up between 11 and 20 percent and to a lesser extent 6 to 10 percent (Figure 44). About 20 percent of those that took this survey did not how to respond to this question, however.

Figure 44: Energy costs as a percent of total operating costs (owner/manager survey)



LOW-INCOME MULTIFAMILY PROPERTIES

Rental properties that are dominantly occupied by low-income households are eligible for federal- and utility-funded programs targeting energy efficiency, and are therefore of special interest. As noted previously, we classified 37 of the 120 properties in the study sample as low-income properties, based on our determination that they would be eligible for weatherization services under the federal Weatherization Assistance Program or meet state guidelines for treatment as a low-income property under Minnesota utility Conservation Improvement Programs. The latter includes properties that are eligible for CIP based on being certified to receive tax incentives that are targeted for affordable housing, or for having a documented use restriction that requires renting a portion of units to low-income tenants. Thirty-two of the 37 low-income properties are on one or more of these lists; the other five are included based on tenant survey responses that suggest a high probability that two-thirds or more of the residents are at or below 200 percent of the 2012 federal poverty guideline, and thus would qualify for the federal program (see Appendix E). We report here on the 30 multifamily properties with gas heat.

Table 25 compares selected characteristics of the low-income properties with the non-low-income, gas-heated multifamily properties in the sample. The low-income properties are larger (in terms of number of units, not in square footage per unit), but in other respects appear to be reasonably similar to the non-low-income properties in the sample. The low-income properties in the sample are somewhat more likely to be classified as “Other” in terms of building type, and have a higher incidence of individual heating systems that are paid directly by tenants. However, these observed differences are not statistically significant due to the small sample size, meaning that we cannot be confident that the differences hold true for the larger population of low-income and non-low-income properties.

When analyzed in terms of the savings potential for the 25 measures that we examined, low-income properties appear to have somewhat lower savings potential on a per housing unit basis (Figure 45), though again the differences are not statistically significant owing to the small sample size. In descending order, the key measures that account for the observed difference in savings potential are: in-unit CFLs, showerheads, boiler upgrades, washer upgrades and aerators.

Figure 45. Estimated savings potential in multifamily buildings with gas heat, for low-income and non-low-income properties.

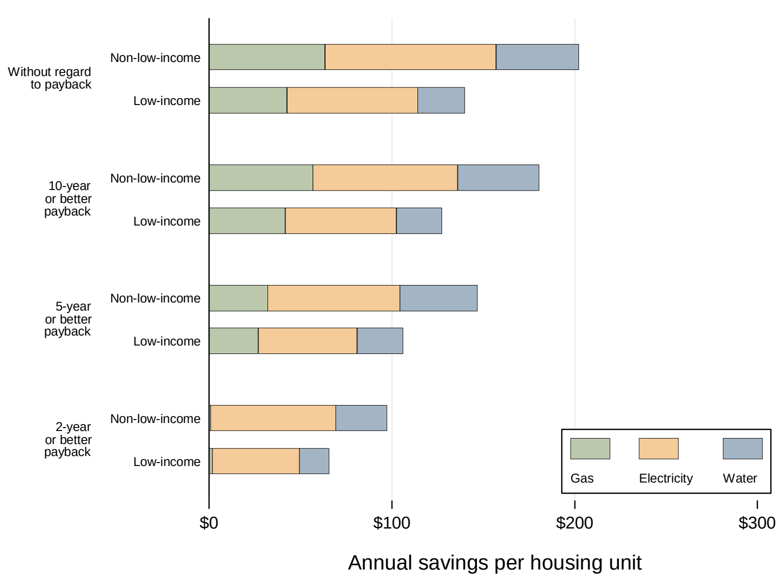


Table 24. Selected characteristics for low-income versus non-low-income multifamily properties with gas heat.

	Low-Income (n=30)		Non Low-Income (n=75)	
Building size				
5-9 units	17%	±16	42%	±5
10-19 units	28%	±18	34%	±5
20-49 units	41%	±17	16%	±5
50+ units	15%	±8	7%	±2
mean units per building	32.6	±9.6	18.5	±2.2
mean ft^2 per housing unit	985	±104	999	±81
Building type				
Pre–World War II	17%	±16	23%	±10
Post World-War II	41%	±21	51%	±12
Post Energy Crisis	18%	±13	12%	±7
Other	24%	±18	14%	±8
Heating system type				
Boiler	90%	±10	86%	±8
Forced air furnace	3%	±5	13%	±8
Other	7%	±9	1%	±2
Cooling system type				
Sleeve/window AC	77%	±17	91%	±7
Other	10%	±10	4%	±4
None	13%	±14	6%	±6
Water heating type				
Central conventional tank	68%	±19	41%	±12
Individual conventional tank	3%	±6	36%	±11
Indirect-fired with dedicated boiler	16%	±14	15%	±8
Indirect-fired with shared boiler	13%	±14	8%	±6
Lighting				
Mean common-area luminaires per housing unit	2.6	±0.5	2.1	±0.2
Mean in-unit luminaires per housing unit	7.1	±1.0	8.5	±0.7
Who pays the heating bill?				
Tenants	2%	±4	7%	±6
Landlord	98%	±4	93%	±6
Do Tenants pay an electric bill?				
Yes	78%	±15	93%	±6
No	22%	±15	7%	±6

± values are approximate 95% confidence intervals

ELECTRICALLY HEATED PROPERTIES

The bulk of this report focuses on buildings with natural-gas space heating, because this represents the dominant heating fuel in Minnesota multifamily buildings. However Census Bureau data suggest that about a third of multifamily properties are electrically heated. Unfortunately, the study sample includes only nine such buildings—too few to reliably include in the main body of the report. In this section, we examine results for these nine properties and contrast them to the gas-heat buildings in the sample. Because the number of buildings is so small, only broad, qualitative observations are possible.

Table 25 compares selected characteristics for the electric-heat properties to the remainder of the study sample of gas-heated buildings. The electric-heat buildings in the sample tend to be smaller, and none are townhomes or from the Pre–World War II period. In terms of space heating, seven of the nine properties have electric baseboard heat, one has individual electric forced-air furnaces, and one is a newly-built (2009), 40-unit building with a central geothermal heat pump system (owned by an affordable-housing non-profit and meant for transitional housing for homeless and chronic substance-abuse individuals).

As might be expected, tenants are much more likely to pay their own heating bill: all seven of the buildings with baseboard heating have tenant-paid heat (the geothermal building has no individual utilities). Interestingly, five of the nine buildings have gas-fired central water heaters.

We were able to obtain usable utility data for six of the electric-heat properties, but because these were mostly individually-metered and tenant response to the survey was low for these properties, it is difficult to accurately gauge their heating energy consumption. Nonetheless, we present the available data in Table 26 along with photos of the buildings in Figure 46. In general, although heating energy intensity (Btu per ft^2 per heating degree day) at the site level is well below the average for the gas-heated properties in the sample, heating *costs* per housing unit are significantly higher. While the amount of heat used per square foot may be lower for the electrically heated buildings (due perhaps to a combination of better construction and the fact that tenants pay their heating costs directly), at current prices, it is about four times more expensive to heat with electricity than natural gas on a delivered Btu basis.

The important exception to this is the geothermal property. Geothermal systems are much more efficient (also, the property is quite new), so this building has a per-unit heating cost that is far below the others.

In analyzing the savings potential for these buildings, we removed the new geothermal property, averaged the results for the remaining eight properties, and compared this to the results for the gas-heat buildings. The results (Figure 47) suggest that electrically heated multifamily buildings have savings potential that is comparable to gas-heated properties, though the small sample prevents any definitive conclusion.

The measures that contribute to these savings are different for the two types of buildings, however. First, unlike gas-heated buildings, electrically heated properties do not have opportunities for heating system efficiency improvements. Second, measures that reduce electricity consumption by end uses like lighting and refrigeration provide no savings during the heating season in electrically heated buildings, because every kWh saved for, say, indoor lighting is offset by an additional kWh that needs to be provided by the building's heating system. The savings potential for these measures is therefore lower in electrically heated buildings. On the other hand, the study sample suggests that there is greater potential for savings from showerheads, aerators, window upgrades and washing machines among electric-heat properties.

Table 25. Selected characteristics for buildings with electric heat versus those with gas heat.

	Electric heat (n=9)		**Gas heat** (n=105)	
Building size				
5-9 units	39%		37%	
10-19 units	39%		33%	
20-49 units	22%		21%	
50+ units	0%		9%	
mean units per building	15.4	±3.8	21.5	±1.3
mean ft^2 per housing unit	844	±123	996	±71
Building type				
Pre World-War II	0%		22%	±9
Post World-War II	37%	±34	49%	±10
Post Energy Crisis	34%	±39	13%	±6
Other	29%	±19	16%	±8
Heating system type				
Boiler	0%		87%	±7
Forced air furnace	13%	±26	10%	±6
Electric baseboard	76%	±34	0%	
Geothermal	11%	±22	0%	
Other	0%		2%	±2
Cooling system type				
Sleeve/window AC	63%	±34	87%	±7
Other	24%	±34	5%	±4
None	13%	±26	7%	±6
Water heating type				
Central conventional tank (gas)	60%	±29	48%	±10
Central conventional tank (electric)	10%	±19	0%	
Individual conentional tank (electric or gas)	30%	±31	28%	±9
Indirect-fired	0%		24%	±8
Lighting				
Mean common-area luminaires per housing unit	1.6	±0.5	2.2	±0.2
Mean in-unit luminaires per housing unit	6.5	±2.6	8.0	±0.6
Who pays the heating bill?				
Tenants	76%	±34	6%	±5
Landlord	24%	±34	94%	±5
Do Tenants pay an electric bill?				
Yes	89%	±22	90%	±6
No	11%	±22	10%	±6

± values are approximate 95% confidence intervals

Table 26. Selected characteristics and heating use/cost for electrically heated buildings with utility data on heating consumption.

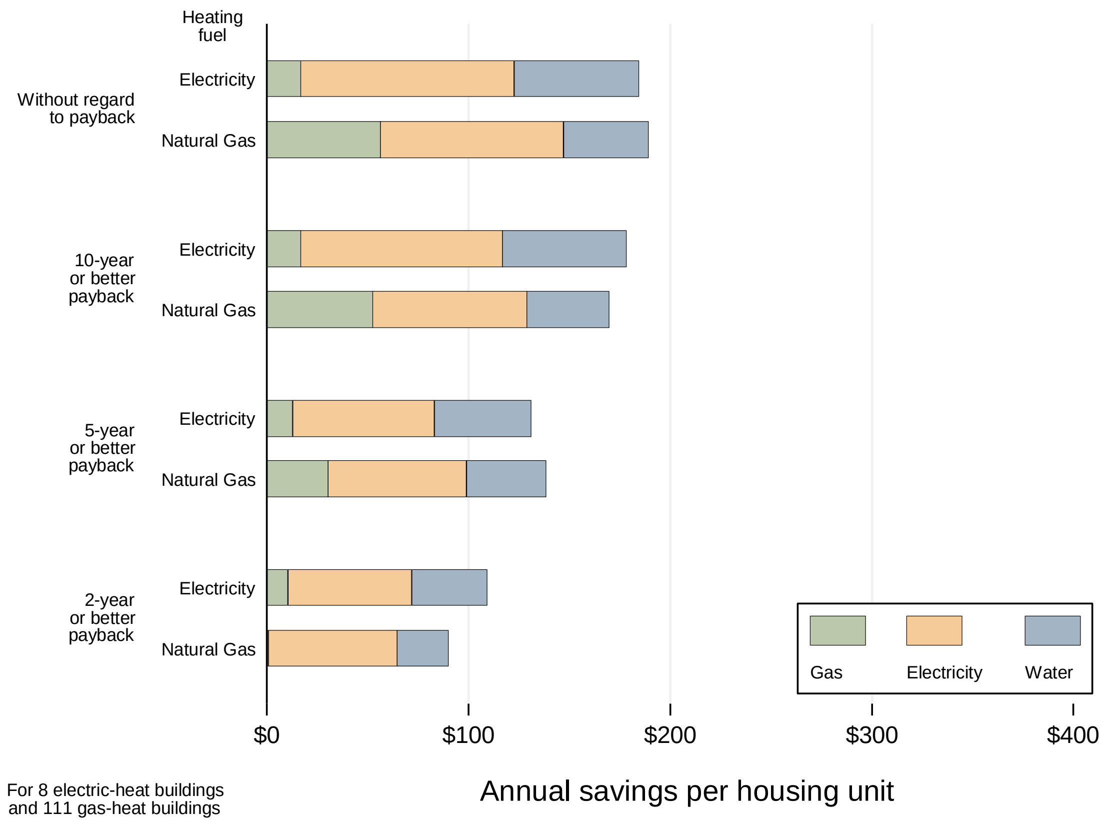
Building ID	decade built	Units in structure	Heating type	tenant accts with utility data	Average annual heating cost per unit	Estimated Heating energy intensity (Btu/ft^2/HDD)
A	1940s	17	Electric baseboard	4	$377	1.0
B	1970s	8	Electric baseboard	1	$167	1.1
C	1970s	24	Electric baseboard	5	$631	2.7
D	1980s	8	Electric baseboard	2	$563	1.6
E	1990s	12	Electric furnace	**	$779	4.6
F	2000+	40	Geothermal	**	$67	0.6
Average for gas-heat buildings:					$250	5.6

Note: first floor of Building A is commercial space

**Master-metered electric

Figure 46. Electrically heated buildings with utility data on heating consumption.

Figure 47. Estimated savings potential in gas-heat buildings vs. electric-heat buildings



TOWNHOMES

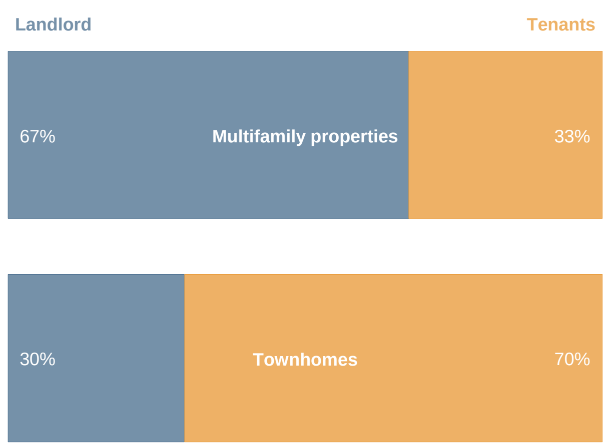
This section reviews key findings for the six townhome properties in the study sample, which were built in the 1960s (1), 1970s (2) and 1980s (3). Townhomes differ from multifamily apartment properties in some important ways. First, by definition, townhomes have individual heating systems instead of the central heating systems that typify multifamily apartment buildings. Though townhomes may be electrically heated (Census data suggest that about one in six rental townhomes has electric heat), all of the townhome properties in the study have gas heat: five of the six have individual forced-air furnaces; the sixth has individual hydronic boilers for each unit.

All of the townhome properties in the sample also have individual gas water heaters. Three have window or sleeve air conditioners for cooling; the other three have a split system for each housing unit that makes use of the furnace air handler and ductwork. For laundry, three of the sample properties have individual washers and dryers in each unit, two have no laundry equipment on the property, and one has a common laundry room (in a separate building in the complex).

Townhomes also have individual entrances for each unit and lack common areas. Because of this, and because there is no central energy-using equipment, the large majority (if not all) of the energy costs for townhomes are paid directly by the tenants in most cases. However, the sample suggests that landlords are likely to foot the bill for water consumption in townhome properties: four of the six property owners/managers provided master-metered water-bill account information to us.

The fact that water is typically master-metered for townhomes means that water-saving measures such as aerators and showerheads can provide some savings that go directly into the pockets of landlords. In fact, our analysis suggests that about a third of the total savings potential in townhomes would accrue to landlords, mainly due to these measures (Figure 48).

Figure 48. Landlord/tenant split for total potential cost savings in buildings with gas heat, by type of property.



We obtained gas-usage data for at least some units for three of the properties and electric data for four properties. Analysis of this information suggests gas consumption of about 560 therms per year per unit, of which 390 therms is for space heating. Annual electricity usage averages about 6,000 kWh per unit, of which about 800 kWh is for space cooling.

The six townhome properties suggest an average energy and water savings potential of about $190 per housing unit (if unconstrained by payback), which is comparable to the savings potential for gas-heated multifamily properties. Key contributors to townhome savings potential are also similar to those in multifamily buildings: in-unit lighting, aerators and showerheads. The important difference is that heating and water heating upgrade measures are oriented around individual forced-air furnaces and water heaters for townhomes, versus central boilers and central water heaters for multifamily properties. Programmable thermostats are more likely to play a role in savings in townhomes given that these properties have individual heating systems and tenant-paid heat.

APPENDIX A: TENANT SURVEYS

LONG FORM TENANT SURVEY

Resident Survey: Minnesota Rental Housing Energy Use Study

YOUR APARTMENT

1. How long have you lived in this apartment unit?
(Circle the number of your answer below.)

1 Less than 1 year
2 1 to 2 years
3 3 to 4 years
4 5 to 10 years
5 More than 10 years

2. Which of the following best describes your apartment unit?
(Circle the number of your answer below.)

1 Single room with no bathroom
2 Efficiency or studio
3 One bedroom
4 Two bedrooms
5 Three bedrooms
6 Four or more bedrooms

3. Does your individual apartment unit have its own basement?
(Circle the number of your answer below.)

1 No ▸ ▸ ▸ ▸ **Skip to Question 4**
2 Yes →

Do you use any of the basement as a regular part of your living space?
(Circle the number of your answer below.)

1 No
2 Yes

4. How important were each of the following factors in deciding to rent at this location?
(Circle the number of your answer for each item below.)

	Not at all Important					Very Important
Location	1	2	3	4	5	6
Size of apartment	1	2	3	4	5	6
Number of bedrooms	1	2	3	4	5	6
Monthly rent	1	2	3	4	5	6
Energy costs	1	2	3	4	5	6
Amenities	1	2	3	4	5	6
Size of the building/complex	1	2	3	4	5	6
Proximity to mass transit	1	2	3	4	5	6
Availability of parking	1	2	3	4	5	6

5. Overall, how well is your apartment building insulated?
(Circle the number of your answer below.)

1 No insulation
2 Poorly insulated
3 Adequately insulated
4 Well insulated
5 Don't know

APPLIANCES

6. Who provided the following appliances for your apartment unit?
(Enter the number of appliances that you have of each type in the appropriate column.)

	Provided by landlord	Provided by You
Standard refrigerator		
Compact (mini) refrigerator		
Stand-alone freezer		

7. Which of the following best describes where your household does clothes washing?
(Circle the number of your answer below.)

1 In your apartment unit
2 In your building, but not in your apartment unit
3 In a different building in your apartment complex ▸ ▸ ▸ ▸ Skip to Question 11
4 At a Laundromat or somewhere else outside the apartment building or complex ▸ ▸ ▸ ▸ Skip to Question 11

8. Who provided the clothes washer and dryer that you use?
(Fill in the response that applies to each item below)

	Your landlord	You	Don't have
Clothes Washer	❍	❍	❍
Clothes Dryer	❍	❍	❍

9. About how many loads of laundry do you wash per week? _____
(Write in your answer above.)

What percent of these are…
(Write in your answers below)

…hot water washes? ______ percent
…warm water washes? ______ percent
…cold water washes? ______ percent

2

10. About how many loads of laundry do you dry per week in a clothes dryer? _____
(Write in your answer above.)

11. Do you have an automatic dishwasher in your apartment unit?
(Circle the number of your answer below.)

1 No ▸ ▸ ▸ ▸ ▸ ▸ **Skip to Question 12**
2 Yes →

About how many times a week do you run it? _______
(Write in the number of your answer above.)

Is it a built-in dishwasher or a portable dishwasher that you hook up to a faucet?
(Circle the number of your answer below.)

1 Built in
2 Portable →

12. About how many showers are taken in your home in a typical week? _______
(Write in your answer above.)

13. About how many baths are taken in your home in a typical week? _______
(Write in your answer above.)

14. How many of the following items are used in your home?
(Circle the appropriate number for each appliance. If you have more than three, circle three.)

	None	One	Two	Three or more
Television	0	1	2	3
VCR or DVD player	0	1	2	3
Stereo system	0	1	2	3
Microwave oven	0	1	2	3
Humidifier	0	1	2	3
Air filter/cleaner	0	1	2	3
Heated waterbed	0	1	2	3
Heated aquarium (20 gallons or more)	0	1	2	3

15. Do you have a dehumidifier in your apartment unit?
(Circle the number of your answer below.)

1 No ▸ ▸ ▸ ▸ ▸ ▸ **Skip to Question 16**

2 Yes →

How much is it used?
(Circle the number of your answer below.)

1 It is rarely used

2 It is used for a part of the summer

3 It is used all summer long

Who provided the dehumidifier?
(Circle the number of your answer below.)

1 You

2 Your landlord

16. Do you have one or more personal computers that you use in your apartment unit?
(Circle the number of your answer below.)

1 No ▸ ▸ ▸ ▸ **Skip to question 19**

2 Yes

17. Of the personal computers that you use at home at least once a month, how many are…
(Circle the appropriate number for each appliance below. If you have more than three, circle three.)

	None	One	Two	Three or more
Laptop computers	0	1	2	3
Desktop computers with a regular monitor	0	1	2	3
Desktop computers with a flat-panel monitor	0	1	2	3

18. Altogether, how many hours per week is your computer equipment turned on in your apartment unit?
(Circle the number of your answer below.)

1 Less than 2 hours per week

2 Two to 15 hours per week

3 Sixteen to 40 hours per week

4 More than 40 hours per week, but not turned on all the time

5 Turned on all the time

19. How many of the following home office devices are used in your apartment unit?
(Circle the appropriate number for each appliance below. If you have more than three, circle three.)

	None	One	Two	Three or more
Laser, inkjet, or other computer printer	0	1	2	3
Stand-alone fax machine	0	1	2	3
Stand-alone photocopier	0	1	2	3
Combination fax/copier/scanner	0	1	2	3

20. Is there any other large equipment that uses a lot of electricity in your apartment unit?
(Examples: welding equipment, medical equipment, kiln, etc., **but not** air conditioners)
(Circle the number of your answer below.)

1 No
2 Yes →
Please specify: ____

____

COMFORT IN THE WINTER

21. What type of temperature control for heating do you have in your apartment?
(Circle the number of your answer below.)

0 You have no control for the temperature of your apartment ▸ ▸ ▸ ▸ **Skip to question 25**
1 Simple on/off switch
2 Dial control(s) on a radiator or heater with*out* temperature settings
3 Regular thermostat(s) with temperature settings
4 Clock or programmable thermostat(s) →

Do you use the thermostat to automatically change the temperature at different times of the day or night?
(Circle the number of your answer below.)

1 No
2 Yes

5

22. This past winter, how often did you or someone in your household change the temperature setting by hand? (For a clock or programmable thermostat, this would temporarily override your automatic settings.)
(Circle the number of your answer below.)

0 Didn't live in this apartment unit last winter ▸ ▸ ▸ ▸ ▸ ▸ **Skip to Question 34**
1 Never or rarely
2 A few times a month
3 A couple of times a week
4 Usually every day →

When did you change the settings by hand?
(Circle all that apply.)

1 In the morning
2 At bed time
3 When needed to be more comfortable

23. Do you know the approximate temperature at which you kept your apartment unit last winter?
(Circle the number of your answer below.)

1 Yes → **At what temperature did you keep your apartment unit last winter…**
(Write in your answers below.)

…When someone was awake at home? ______ degrees
…During sleeping hours? ______ degrees
…When no one was home? ______ degrees

2 No → **Compared to when you were awake at home, how did you set the heat last winter…**
(Circle the number of your answers below.)

	Didn't change the setting	Turned the heat off	Turned the heat down	Turned the heat up
…During sleeping hours?	1	2	3	4
…When no one was home?	1	2	3	4

24. People don't always agree about what temperature is most comfortable in the winter. Last winter how much of the time did members of your household agree about the temperature setting?
(Circle the number of your answer below.)

1 Never or rarely agreed
2 Sometimes agreed
3 Usually agreed
4 Always agreed
5 Not applicable (there are no other household members)

6

25. How would you describe the general level of comfort in your apartment unit in the winter?
(Circle the number of your answer below.)

0 Haven't lived here during the winter yet ▸ ▸ ▸ ▸ ▸ ▸ **Skip to Question 34**
1 Very uncomfortable
2 Somewhat uncomfortable
3 Somewhat comfortable
4 Very comfortable

26. How often do you or other members of your household find your apartment unit <u>too cold or drafty</u> during the winter?
(Circle the number of your answer below.)

1 Never or rarely ▸ ▸ ▸ ▸ **skip to Question 29**
2 Some of the time
3 Most of the time
4 Always

27. How often do you do each of the following when you find your apartment unit too cold or drafty?
(Circle the number of your answer for each item below.)

	Never	Rarely	Some of the time	Most of the time	Always
Turn up the thermostat	1	2	3	4	5
Turn on a portable heater	1	2	3	4	5
Turn on the oven	1	2	3	4	5
Start a fire in the fireplace	1	2	3	4	5
Put on more clothing or a blanket	1	2	3	4	5
Move to a more comfortable part of the apartment	1	2	3	4	5
Other (describe:_____________)	1	2	3	4	5

28. Are there specific places in your apartment unit where—or times when—you or members of your household often feel too cold or feel uncomfortable drafts?
(Circle the number of your answer below.)

1 No
2 Yes →
Please describe: ____

____

7

29. How often do you or other members of your household find your apartment unit <u>too hot or stuffy</u> during the <u>winter</u>?
(Circle the number of your answer below.)

1 Never or rarely ▸▸▸▸ **skip to Question 32**
2 Some of the time
3 Most of the time
4 Always

30. How often do you do each of the following when you find your apartment unit too hot or stuffy in the winter? *(Circle the number of your answer for each item below.)*

	Never	Rarely	Some of the time	Most of the time	Always
Turn down the thermostat	1	2	3	4	5
Open a window or door to the outside	1	2	3	4	5
Put on lighter clothing	1	2	3	4	5
Move to a more comfortable part of the apartment	1	2	3	4	5
Turn on a fan	1	2	3	4	5
Other (describe):	1	2	3	4	5

31. Are there any specific places in your apartment unit where—or times when—you or members of your household often feel too hot or stuffy in the winter?
(Circle the number of your answer below.)

1 No
2 Yes →
Please describe: ______________________________

____

32. How often do you or other members of your household find your apartment unit too dry during the winter?
(Circle the number of your answer below.)

1 Never or rarely
2 Some of the time
3 Most of the time
4 Always

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33. How often did water bead up or frost form on your windows last winter?

(Circle the number of your answer below.)

1 Never or rarely
2 Sometimes
3 Often
4 Always

COMFORT IN THE SUMMER

34. Do you have central air conditioning in your apartment unit?

(Circle the number of your answer below.)

1 No ▸ ▸ ▸ ▸ ▸ ▸ ▸ **Skip to question 36**
2 Yes

35. Which of the following best describes how you control your central air conditioning?

(Circle the number of your answer below.)

1 You have no control for the air conditioning in your apartment unit
2 Regular thermostat(s) with temperature settings
3 Clock or programmable thermostat(s) →

Do you use the thermostat to automatically change the temperature at different times of the day or night?

(Circle the number of your answer below.)

1 No
2 Yes

36. Do you have one or more room or window air conditioners in your apartment unit?

(Circle the number of your answer below.)

1 No ▸ ▸ ▸ ▸ ▸ ▸ **If you have central air conditioning, skip to question 37**
▸ ▸ ▸ ▸ ▸ ▸ **If you have no air conditioning at all, skip to question 40**
2 Yes →

How many individual room or window units do you have? ________

(Write in your answer above.)

Who provided the air conditioner(s)?

(Circle the number of your answer below.)

1 You
2 Your landlord
3 You provided some and your landlord provided some

Which of the following statements best describes what you do with your room air conditioner(s) in the winter?
(Circle the number of your answer below.)

0 Haven't lived here in the winter
1 Take the air conditioner(s) out of the window
2 Leave the air conditioner(s) in the window, but with a cover on
3 Leave the air conditioner(s) in the window, with no cover

37. How many rooms do you cool with your air conditioning equipment?
(Circle the number of your answer below.)

0 Haven't lived here long enough to use the air conditioning ▸ ▸ ▸ ▸ ▸ ▸ **Skip to question 40**
1 None of the rooms ▸ ▸ ▸ ▸ ▸ ▸ **Skip to question 40**
2 Some of the rooms
3 All the rooms

38. Which of the statements below best describes the way you used your air conditioning last summer?
(Circle the number of your answer below.)

1 Not used at all ▸ ▸ ▸ ▸ ▸ ▸ **Skip to question 40**
2 Turned on only a few days or nights when really needed
3 Turned on a few times each week
4 Turned on just about all summer
5 Left it on all the time, and let the thermostat control how much it ran

39. Do you know the approximate temperature at which you kept your apartment unit last summer when you ran your air conditioning?
(Circle the number of your answer below.)

1 Yes → **At what temperature did you keep your apartment unit last summer…**
(Write in your answers below.)

…When someone was awake at home? ______ degrees
…During sleeping hours? ______ degrees
…When no one was home? ______ degrees

2 No → **Compared to when you were awake at home, how did you set the air conditioning last summer…**
(Circle the number of your answer for each item below.)

	Didn't change the setting	Turned it off	Turned it to a warmer setting	Turned it to a cooler setting
…During sleeping hours?	1	2	3	4
…When no one was home?	1	2	3	4

10

40. **How would you describe the general level of comfort in your apartment unit in the summer?**
(Circle the number of your answer below.)

0 Haven't lived here long enough to know ▶ ▶ ▶ ▶ ▶ ▶ **Skip to question 45**
1 Very uncomfortable
2 Somewhat uncomfortable
3 Somewhat comfortable
4 Very comfortable

41. **How often do you or other members of your household find your apartment unit too hot during the summer?**
(Circle the number of your answer below.)

1 Never or rarely ▶ ▶ ▶ ▶ ▶ ▶ **Skip to question 44**
2 Some of the time
3 Most of the time
4 Always

42. **How often do you do each of the following when you find your apartment unit too hot?**
(Circle the number of your answer for each item below.)

	Never	Rarely	Some of the time	Most of the time	Always
Turn on the central air conditioner	1	2	3	4	5
Turn the central air to a cooler setting	1	2	3	4	5
Turn on room air conditioners(s)	1	2	3	4	5
Turn the room air conditioner(s) to a cooler setting	1	2	3	4	5
Turn on fans	1	2	3	4	5
Open windows or doors	1	2	3	4	5
Move to a more comfortable part of the house	1	2	3	4	5
Close shades/blinds	1	2	3	4	5
Wear lighter clothing	1	2	3	4	5
Take a cool shower	1	2	3	4	5
Other (describe):_____________________	1	2	3	4	5

43. **Are there specific places in your apartment unit where—or times when—you or members of your household are often hot and uncomfortable?**
(Circle the number of your answer below.)

1 No
2 Yes →
Please describe: ____

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44. How often do you or other members of your household find your apartment unit too cold or clammy during the summer?
(Circle the number of your answer below.)

1 Never or rarely
2 Some of the time
3 Most of the time
4 Always

COMFORT THROUGHOUT THE YEAR

45. How often are you or is someone in your household uncomfortable with the air quality in your apartment unit in the following ways?
(Circle the number of your answer for each item below.)

	Never	Rarely	Some of the time	Most of the time	Always
Air smells moldy	1	2	3	4	5
Air smells of cooking or other odors	1	2	3	4	5
Air is stale	1	2	3	4	5

46. How often are you or a member of your household dissatisfied with your hot water in the following ways?
(Circle the number of your answer for each item below.)

	Never	Rarely	Some of the time	Most of the time	Always
Not enough hot water	1	2	3	4	5
Water is not hot enough	1	2	3	4	5
Water is too hot	1	2	3	4	5
Hot water pressure is too low	1	2	3	4	5
Water takes too long to get hot	1	2	3	4	5

47. How often are you or a member of your household dissatisfied with the lighting provided with your apartment unit in the following ways?
(Circle the number of your answer for each item below.)

	Never	Rarely	Some of the time	Most of the time	Always
Lighting is too dim	1	2	3	4	5
Lighting is too bright	1	2	3	4	5
Don't like the color or quality of the lighting	1	2	3	4	5
Not enough daylight gets in	1	2	3	4	5

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48. Have you notified your landlord about any of the following comfort problems in your apartment unit during the last year?
(Circle the number of your answer for each item below.)

	No	Yes
Comfort during the winter	1	2
Comfort during the summer	1	2
Odors or indoor air quality problems	1	2
Problems with the hot water	1	2
Lighting problems	1	2

COMFORT IN COMMON AREAS

49. Does your building have common areas such as hallways or entryways that are used by more than one tenant?
(Circle the number of your answer below.)

1 No ▸ ▸ ▸ ▸ ▸ ▸ ▸ **Skip to question 52**
2 Yes

50. How often have you experienced the following comfort problems <u>in the common areas</u> in your building in the last year?
(Circle the number of your answer for each item below.)

	Never or Rarely	Some of the time	Most of the time	Always
Too cold during the winter	1	2	3	4
Too hot during the winter	1	2	3	4
Too cold during the summer	1	2	3	4
Too hot during the summer	1	2	3	4
Lingering odors or stale air	1	2	3	4
Lighting too dim	1	2	3	4
Lighting too bright	1	2	3	4
Other (describe:__________________________)	1	2	3	4

51. Have you notified your landlord about any comfort problems with common areas in the last year?
(Circle the number of your answer below.)

1 No
2 Yes

ENERGY BILLS

52. How familiar are you with your household's monthly energy bills?
(Circle the number of your answer below.)

1 Not very familiar
2 Somewhat familiar
3 Very familiar

53. Which of the following best describes <u>electricity</u> bills for your apartment unit?
(Circle the number of your answer below.)

1 Your landlord pays the bill, and electricity is included in the rent →
2 You pay an electric bill directly to a utility, and the bill includes only your apartment unit →
3 You divide an electric bill with other tenants in your building →

54. Which of the following best describes <u>natural gas</u> bills for your apartment unit?
(Circle the number of your answer below.)

1 You do not use any natural gas →
2 Your landlord pays the bill, and natural gas is included in the rent →
3 You pay a natural gas bill directly to a utility, and the bill includes only your apartment unit →
4 You divide a natural gas bill with other tenants in your building →

55. Which of the following best describes <u>propane or fuel oil</u> bills for your apartment unit?
(Circle the number of your answer below.)

1 You do not use any propane or fuel oil ▸ ▸ ▸ ▸ ▸ ▸ **Skip to question 56**
2 Your landlord pays the bill, and propane or fuel oil is included in the rent ▸ ▸ ▸ ▸ ▸ ▸ **Skip to question 56**
3 You pay a propane or fuel oil bill directly to a provider, and the bill includes only your apartment unit →
4 You divide a propane or fuel oil bill with other tenants in your building →

Which of the following do you pay for in your propane or fuel oil bills?
(Circle ALL that apply)

	Propane	Fuel Oil	Neither
Space Heating	1	2	3
Water Heating	1	2	3
Range or Oven	1	2	3
Clothes Dryer	1	2	3

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56. Do you have a wood-burning fireplace in your apartment unit?
(Circle the number of your answer below.)

1 No ▸ ▸ ▸ ▸ ▸ ▸ **Skip to question 57**
2 Yes →

How often do you use your wood-buring fireplace during the heating season?
(Circle the number of your answer below.)

1 Never
2 Rarely
3 A few times a month
4 A few times a week
5 Daily

Which of the following statements best describes how you obtain the wood?
(Circle the number of your answer below.)

1 You purchase it yourself
2 You obtain it yourself for free
3 Your landlord provides it

57. Government agencies and utilities have programs to help households who can't pay all of their energy bills. Has your household received this kind of help since moving into this apartment unit?
(Circle the number of your answer below.)

1 No ▸ ▸ ▸ ▸ ▸ ▸ **Skip to question 58**
2 Yes

What program did you receive assistance from?
(Circle the number of your answer below.)

1 Energy Assistance Program
2 Weatherization Assistance Program
3 Your utility
4 Other (please describe) ________________________________
5 Don't know

SAVING ENERGY

58. In your opinion, which of the following statements best describes the opportunities for energy savings in this building that could be taken by the owners or management company?
(Circle the number of your answer below.)

1 There is little or nothing management could do to further reduce energy costs in this building
2 There are a few things management could do to further reduce energy costs in this building
3 There are many things management could do to further reduce energy costs in this building
4 Don't know

59. In your opinion, which of the following statements best describes the opportunities for energy savings in this building that could be taken by tenants?
(Circle the number of your answer below.)

1 There is little or nothing tenants could do to further reduce energy costs in this building
2 There are a few things tenants could do to further reduce energy costs in this building
3 There are many things tenants could do to further reduce energy costs in this building
4 Don't know

60. Have you *added* any of the following features to your apartment?
(Circle the number of your answer for each item below.)

	No	Yes
Caulking or weatherstripping	1	2
Put up plastic or other insulation on windows	1	2
Installed low-flow showerheads	1	2
Installed faucet aerators	1	2
Wrapped hot water pipe	1	2
Wrapped water heater	1	2
Other:_______________________	1	2

61. How often do you take the following sorts of actions?
(Circle the number of your answer for each item below.)

	Never	Rarely	Some of the Time	Most of the Time	Always	Doesn't Apply
Lower the heating thermostat at night	1	2	3	4	5	6
Lower the heating thermostat when you are going away for awhile	1	2	3	4	5	6
Limit use of the air conditioner to a few very hot days	1	2	3	4	5	6
Turn off unused lights	1	2	3	4	5	6
Turn off unwatched televisions	1	2	3	4	5	6
Run the dishwasher only when it is full	1	2	3	4	5	6
Run the dishwasher on the energy-efficient setting	1	2	3	4	5	6
Run the clothes washer only with full loads	1	2	3	4	5	6
Use the energy efficiency setting on the microwave	1	2	3	4	5	6

62. People take energy-saving actions for different reasons. For each of the following actions, choose the single most important reason for that action.
(Circle the number of your answer for each item below. If you don't take the action, circle 'Doesn't apply'))

	Home comfort	Health and air quality	Save money	Help the Environ-ment	Don't like to waste	Doesn't apply
Use less heat	1	2	3	4	5	6
Use less air conditioning	1	2	3	4	5	6
Turn off lights	1	2	3	4	5	6
Turn off unused appliances	1	2	3	4	5	6
Run only full dishwasher or laundry loads	1	2	3	4	5	6

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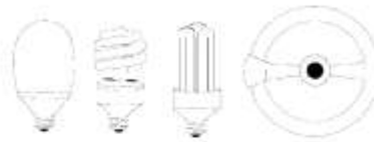
63. Have you installed any compact fluorescent lights in your apartment?
Compact fluorescent bulbs screw into regular (incandescent) light bulb sockets and come in different styles, such as those shown at right.
(Circle the number of your answer below.)

1 No
2 Yes
3 Not sure



64. What is the most effective thing you could do to save energy in your apartment unit?
(Write in your answer below.)

____

____

YOUR HOUSEHOLD

65. How many people in each of the following age groups, including yourself, have lived in your household at least 6 months in the past year?
(Fill in the blank for each age group below.)

______ 0 to 5 years of age
______ 6 to 17 years of age
______ 18 to 64 years of age
______ 65 or more years of age
______ **Total persons in household**

66. What is the highest level of education completed by you and other adults in the household responsible for making household decisions
(Circle the number of your answer below for each adult in the household.)

	You	Adult #2	Adult #3	Adult #4
(Not present in this household)		0	0	0
Grade School	1	1	1	1
Some high school	2	2	2	2
High school graduate or GED	3	3	3	3
Some technical school/junior college	4	4	4	4
Technical school/junior college *graduate* (Associate degree)	5	5	5	5
Some college but no degree	6	6	6	6
Bachelor's degree	7	7	7	7
Advanced degree	8	8	8	8

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67. Would you categorize this household as unrelated adults living as roommates?
(Circle the number of your answer below.)

1 No
2 Yes

68. Which of the following categories best describes the total income of your household in 2011?
(Circle the number of your answer below.)

1 Less than $20,000
2 $20,000 to $29,999
3 $30,000 to $39,999
4 $40,000 to $49,999
5 $50,000 to $74,499
6 $75,000 or more
7 Prefer not to answer

69. Is there anything else you would like to tell us about your home or energy activities?

____
____
____
____

70. May we contact you in the future if we have questions about this or other studies?

1 No
2 Yes

Please provide your contact information so we can send you the thank you gift:

Name:

Mailing address:

Phone number:

Email address:

Thank you for taking the time to fill out this survey. Your information will help us a great deal in completing our research.

Please fill out and sign the attached utility release form—return both in the attached postage-paid envelope to:

Minnesota Rental Housing Energy Use Study
Energy Center of Wisconsin
455 Science Drive, Suite 200, Madison, WI 53711

Call with any questions regarding this survey: 1-877-807-8599 (9am – 5pm)

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SHORT FORM TENANT SURVEY

1. How long have you lived in this apartment unit?
(Circle the number of your answer below.)

1 Less than 1 year
2 1 to 2 years
3 3 to 4 years
4 5 to 10 years
5 More than 10 years

2. Which of the following best describes your apartment unit?
(Circle the number of your answer below.)

1 Single room with no bathroom
2 Efficiency or studio
3 One bedroom
4 Two bedrooms
5 Three bedrooms
6 Four or more bedrooms

3. How would you describe the general level of comfort (temperature, humidity, draftiness) in your apartment unit?
(Circle the number of your answer below for each season.)

	Haven't lived here this season	Very uncomfortable	Somewhat uncomfortable	Somewhat comfortable	Very comfortable
In winter	0	1	2	3	4
In summer	0	1	2	3	4

4. How often are you or is someone in your household uncomfortable with the air quality in your apartment unit in the following ways?
(Circle the number of your answer for each item below.)

	Never	Rarely	Some of the time	Most of the time	Always
Air smells moldy	1	2	3	4	5
Air smells of cooking or other odors	1	2	3	4	5
Air is stale	1	2	3	4	5

5. How often are you or a member of your household dissatisfied with your hot water in the following ways?
(Circle the number of your answer for each item below.)

	Never	Rarely	Some of the time	Most of the time	Always
Not enough hot water	1	2	3	4	5
Water is not hot enough	1	2	3	4	5
Water is too hot	1	2	3	4	5
Hot water pressure is too low	1	2	3	4	5
Water takes too long to get hot	1	2	3	4	5

6. How often are you or a member of your household dissatisfied with the lighting provided with your apartment unit in the following ways?
(Circle the number of your answer for each item below.)

	Never	Rarely	Some of the time	Most of the time	Always
Lighting is too dim	1	2	3	4	5
Lighting is too bright	1	2	3	4	5
Don't like the color or quality of the lighting	1	2	3	4	5
Not enough daylight gets in	1	2	3	4	5

7. How many people in each of the following age groups, including yourself, have lived in your household at least 6 months in the past year?
(Fill in the blank for each age group below.)

______ 0 to 5 years of age
______ 6 to 17 years of age
______ 18 to 64 years of age
______ 65 or more years of age
______ Total persons in household

8. Which of the following categories best describes the total income of your household in 2011?
(Circle the number of your answer below.)

1 Less than $20,000
2 $20,000 to $29,999
3 $30,000 to $39,999
4 $40,000 to $49,999
5 $50,000 to $74,499
6 $75,000 or more
7 Prefer not to answer

Thank you for taking the time to fill out this survey. Your information will help us a great deal in completing our research.

Please fill out and sign the attached utility release form, and return both in the attached postage-paid envelope to:

Minnesota Rental Housing Energy Use Study
Energy Center of Wisconsin
455 Science Drive, Suite 200, Madison, WI 53711

APPENDIX B: OWNER SURVEY

Minnesota Rental Housing Energy Use Study

Owner/Manager Survey

The questions that follow pertain to the rental building at ______________________________
(to be completed by field staff)

ABOUT THE BUILDING

S1. When was this building built?
(Circle the number of your answer below.)

1 1990 or later
2 1980-1989
3 1970-1979
4 1960-1969
5 1950-1959
6 1940-1949
7 1930-1939
8 Prior to 1930

S2. Is this building part of a complex of buildings at this location, or is it the only building at this location?
(Circle the number of your answer below.)

1 The only building at this location ▸ ▸ ▸ ▸ **Skip to Question S3**
2 Part of a complex of buildings →

How many separate buildings with apartments are at this location?
(Write in your answer below.)

_____Separate buildings

How many total rental units are at this complex?
(Write in your answer below.)

_____ Total units

Is this building typical of buildings in this complex?
(Circle the number of your answer below.)

1 No → **How does it differ?** ______________________________
2 Yes

S3. How many on-site staff are there for this building/complex?
(Write in your answer below.)

_________ Number of on-site staff

Version MN_OM 1

ABOUT THE APARTMENTS

A1. What is the *lowest* monthly rent in this building?
(Write in your answer below.)

$ __________ Lowest monthly rent

What is the approximate square footage of the unit with the lowest rent?
(Write in your answer below.)

__________ Square feet

A2. What is the *highest* monthly rent in this building?
(Write in your answer below.)

$ __________ Highest monthly rent

What is the approximate square footage of the unit with the highest rent?
(Write in your answer below.)

__________ Square feet

A3. Are rents for units in this building regulated?
(Circle one number)

1 No
2 Yes →
What are the regulations? ____
____

A4. How many of each type of unit are in this building?
(Write in your answers below. If there are none of a type put in 0)

__________ Single-room units with no bathroom
__________ Efficiency or Studio units
__________ 1 bedroom
__________ 2 bedrooms
__________ 3 or more bedrooms
__________ **Total units in building**

A5. What percent of the units in this building are occupied by...?
(Write in your answers below. If there are none of a type put in 0. Percents below need not total 100)

...Students ______ percent
...Low-income tenants ______ percent
...Elderly tenants ______ percent

OWNERSHIP AND MANAGEMENT

O1. For this particular property, are you. . . . ?
(Circle the number of your answer below.)

1 …an owner of the property
2 …a resident manager or superintendent
3 …a non-resident manager or someone employed by a management company responsible for managing the property
4 …somebody else (Please specify: ____)

O2. How would you describe the ownership of this particular building?
(Circle the number of your answer below.)

1 Individual investors (e.g., husband/wife)
2 Partnership (limited or general)
3 Real estate investment trust
4 Real estate or other corporation
5 Non-profit institution
6 Other (Please specify: ____)

O3. How many years have you been in business owning and or managing multi-family housing properties?
(Write in your answer below.)

_______________Years

O4. How long have you owned or managed this building?
(Circle the number of your answer below.)

1 Less than 1 year
2 1 to 2 years
3 3 to 4 years
4 5 to 10 years
5 More than 10 years

Version MN_OM 3

O5. Who handles each of the following activities for this building?
(Circle the number of your answer(s) for ALL that apply below.)

	Owner(s)	Resident employee(s)	Non-resident employees	Contractors hired for tasks	Other - describe
Renting of apartments	1	2	3	4	5 ___________
Routine maintenance	1	2	3	4	5 ___________
Calls from tenants	1	2	3	4	5 ___________
Small plumbing repairs	1	2	3	4	5 ___________
Small electrical repairs	1	2	3	4	5 ___________

O6. Considering just Minnesota, about how many properties and dwelling units do you ...
(Write in your answers below.)

	Properties	Dwelling Units
Own and manage	_____	_____
Manage only	_____	_____
Own but not manage	_____	_____

O7. Does this building or complex have clothes washers and dryers in a common area?
(Circle the number of your answer below.)

1 No ▸ ▸ ▸ ▸ **Skip to Question R1**

2 Yes → **Do tenants pay to use the washers or dryers?**

  1 No ▸ ▸ ▸ ▸ **Skip to Question R1**

  2 Yes

O8. Which of the following describes your arrangement with respect to the common-area laundry equipment?
(Circle the number of your answer below.)

1 You own or lease the equipment and collect all the revenue

2 You share the revenue with the company that provides the laundry equipment

3 Something else (Please describe: _________________________________)

RENTING CHARACTERISTICS

R1. How familiar are you with what tenants look for when renting an apartment?
(Circle the number of your answer below.)

1 Not at all familiar ▸ ▸ ▸ ▸ Skip to Question T1
2 Somewhat familiar
3 Very familiar

R2. How important do you think each of the following characteristics are to potential tenants?
(Circle one number for each characteristic below.)

	Not at all Important					Very Important
Location	1	2	3	4	5	6
Size of apartment	1	2	3	4	5	6
Number of bedrooms	1	2	3	4	5	6
Monthly rent	1	2	3	4	5	6
Energy costs	1	2	3	4	5	6
Amenities	1	2	3	4	5	6
Size of the building/complex	1	2	3	4	5	6
Proximity to mass transit	1	2	3	4	5	6
Availability of parking	1	2	3	4	5	6

R3. When prospective tenants are looking to rent in this building, what percent of them ask about energy costs?
(Circle the number of your answer below.)

1 None
2 Less than 25 percent
3 Between 26 and 50 percent
4 Between 51 and 75 percent
5 More than 75 percent

TENANT UTILITY BILL CHARACTERISTICS

T1. Which of the following best describes how the costs for heating the individual apartment units are paid for this building?
(Circle the number of your answer below.)

1 Included in the rent
2 Paid by the tenants directly to the fuel provider
3 Other (please describe: ____
____)

T2. **Do tenants in this building pay an electric bill directly to the electric utility?**
(Circle the number of your answer below.)

1 No
2 Yes →

T3. **Do tenants in this building pay a natural gas bill directly to the natural gas utility?**
(Circle the number of your answer below.)

1 No
2 Yes →

T4. **Do tenants in this building pay a propane bill directly to a provider?**
(Circle the number of your answer below.)

1 No
2 Yes →

T5. **Do tenants in this building pay a fuel oil bill directly to a provider?**
(Circle the number of your answer below.)

1 No
2 Yes →

APARTMENT APPLIANCES

W1. **Who provides the appliances below for typical rental units in this building?**
(Circle the number of your answer for each item below.)

	Included with rental unit	Provided by tenant	Not typically present in rental unit
Refrigerator	1	2	3
Range/Oven	1	2	3
Dishwasher	1	2	3
Microwave	1	2	3
In-unit clothes washer and dryer	1	2	3
Window or wall air conditioner	1	2	3

▸ ▸ ▸ ▸ **If you circled "2" or "3" to <u>all</u> of these items, skip to Question C1.**

W2. Have you installed or purchased any of the following major appliances for this building in the past two years?

(Circle the number of your answer below; write in your answers for any appliances that have been installed in the last two years.)

	Replaced in last two years?			If Yes, how many…	
	No	Yes		…replaced existing units?	…were additions that did not replace existing units?
Refrigerator	1	2	→	_____#	_____#
Room air conditioner	1	2	→	_____#	_____#
Dishwashers	1	2	→	_____#	_____#
Clothes washers	1	2	→	_____#	_____#
Clothes dryers	1	2	→	_____#	_____#

W3. How likely is it that you will purchase or replace any of these appliances in the *next year* for this building?

(Circle the number of your answer for each item below.)

	Very Unlikely	Somewhat Unlikely	Somewhat Likely	Very Likely
Room Air Conditioner	1	2	3	4
Refrigerator	1	2	3	4
Dishwasher(s)	1	2	3	4
Clothes washer(s)	1	2	3	4
Clothes dryer(s)	1	2	3	4

W4. When you purchase major appliances for this building, are you more likely to buy them…?

(Circle the number of your answer below.)

1 …from models available through pre-negotiated contract
2 …through a bidding process
3 …making an on the spot selection from models that are available
4 …other (please specify:____)

W5. **Which of the following best describes where you purchase major appliances for the apartments in this building?**
(Circle the number of your answer below.)

1 Local or regional appliance dealer
2 National chain (such as Best Buy, Sears, or other department store)
3 Local distributor or wholesaler
4 Manufacturer's distributor or manufacturer such as GE or Whirlpool
5 Other (please specify ______________________________)

W6. **When you purchase major appliances for the apartments in this building, are they more likely to be new or used?**
(Circle the number of your answer below.)

1 Always new
2 Mostly new
3 Sometimes new and sometimes used
4 Mostly used
5 Always used

W7. **When you are purchasing major appliances for the apartments, how important are each of the following in your decision regarding what to purchase?**
(Circle the number of your answer for each item below.)

	Not at all Important			**Very Important**
Replacing with an identical or nearly identical model	1	2	3	4
Expected life of the appliance	1	2	3	4
Price	1	2	3	4
Past experience with the brand	1	2	3	4
Reliability	1	2	3	4
Ease of maintenance	1	2	3	4
Energy use	1	2	3	4

BUILDING COMFORT

C1. Overall, how well would you say this building is insulated?
(Circle the number of your answer below.)

1 No insulation
2 Poorly insulated
3 Adequately insulated
4 Well insulated
5 Don't know

C2. How would you describe the general level of comfort in this building in the <u>winter</u>?
(Circle the number of your answer below.)

1 Very uncomfortable
2 Somewhat uncomfortable
3 Somewhat comfortable
4 Very comfortable
5 Don't know

C3. How would you describe the general level of comfort in this building in the <u>summer</u>?
(Circle the number of your answer below.)

1 Very uncomfortable
2 Somewhat uncomfortable
3 Somewhat comfortable
4 Very comfortable
5 Don't know

C4. In the past year, how frequently have tenants contacted you regarding ...
(Circle the number of your answer for each item below.)

	Never	Rarely	Occasionally	Frequently
Living units too cold or drafty in the winter	1	2	3	4
Living units too hot in the winter	1	2	3	4
Living units too cold or drafty in the summer	1	2	3	4
Living units too hot in the summer	1	2	3	4
Problems with the hot water	1	2	3	4
Problems with odors from other units	1	2	3	4
Problems with lighting (other than burnt out bulbs)	1	2	3	4
Comfort problems in common areas	1	2	3	4
Other (describe: ____________________)	1	2	3	4

BUILDING CHANGES OR IMPROVEMENTS

B1. In the past five years have any of the following changes been made to this building?
(Circle the number of your answer for each item below.)

	No	Yes
Upgraded the heating system	1	2
Plumbing upgrades or changes	1	2
Added or upgraded air conditioning	1	2
Renovated kitchen(s)	1	2
Renovated bathroom(s)	1	2
Added a security system	1	2
Made building more accessible to the handicapped	1	2

B2. Has this building received an energy audit from a utility representative or other energy professional in the past? (An energy audit would include recommendations regarding changes you could make to the building to save energy.)
(Circle the number of your answer below.)

1 No
2 Yes
3 Don't know

B3. In your opinion, which of the following statements best describes the opportunities for energy savings in this building that could be taken by the owners or management company?
(Circle the number of your answer below.)

1 There is little or nothing management could do to further reduce energy costs in this building
2 There are a few things management could do to further reduce energy costs in this building
3 There are many things management could do to further reduce energy costs in this building
4 Don't know

B4. In your opinion, which of the following statements best describes the opportunities for energy savings in this building that could be taken by tenants?
(Circle the number of your answer below.)

1 There is little or nothing tenants could do to further reduce energy costs in this building
2 There are a few things tenants could do to further reduce energy costs in this building
3 There are many things tenants could do to further reduce energy costs in this building
4 Don't know

B5. When you are making upgrades to this building or its equipment, what financial criterion is applied?
(Circle the number of your answer below.)

1 Payback period of _______ years or less
2 Return on investment of ________ percent
3 No specific financial criteria applied
4 Other (please describe:_________________)

B6. When equipment in this building is changed or replaced, who is most likely to have the largest say in determining what is purchased?

(Circle the number of your answer for each item below.)

	Owner	Mgt. company	Maint. staff	Other	→ Describe
Replacing in-unit appliances	1	2	3	4	________
Replacing hallway lighting	1	2	3	4	________
Purchasing a new water heater	1	2	3	4	________
Painting an apartment	1	2	3	4	________
Roofing	1	2	3	4	________
Replacing a furnace or boiler	1	2	3	4	________
Replacing in unit bathroom or kitchen fixture	1	2	3	4	________
Replacing a window/wall air conditioner	1	2	3	4	________

B7. Are there any plans for major modifications or remodeling to this building within the next two years?

(Circle the number of your answer below.)

1 No

2 Yes →

What changes are planned? ______________________________

____

____

____

B8. How important is each of the following in the decision to make changes to this building?

(Circle the number of your answer for each item below.)

	Not at all Important	Somewhat important	important	Very Important
Resale value of the building	1	2	3	4
Staying competitive in the rental market	1	2	3	4
Tenant comfort	1	2	3	4
Safety	1	2	3	4
Reducing utility costs	1	2	3	4
Ability to charge higher rent	1	2	3	4
Reduced maintenance costs	1	2	3	4
Vacancy rates in the area	1	2	3	4

B9. **Have you ever installed energy-saving items or measures and then been dissatisfied with them?**
(Circle the number of your answer below.)

1 No
2 Yes →
Which items? ____
____

In what way(s) were you dissatisfied? ____________________
____
____

MAINTENANCE AND REPAIRS

M1. **How often is the heating equipment in this building cleaned and tuned?**
(Circle the number of your answer below.)

1 More than once a year
2 Once a year
3 Every other year
4 Every 3-6 years
5 Hardly ever
6 Never
7 Don't know

M2. **Does this building have one or more boilers for space heating?**
(Circle the number of your answer below.)

1 No ▸▸▸▸▸ **Skip to Question M6**
2 Yes

M3. **Which of the following describes your heating control systems?**
(Circle the number of your answer below.)
1 Manual Controls ▸▸▸▸ Skip to Question M5
2 Automatic boiler controls with outdoor air reset

M4. **If heating control systems are on automatic control with outdoor air reset, how often do you check on whether the boiler temperature is appropriate for the season?**
(Circle the number of your answer below.)
1 More than once a year
2 Once a year
3 Every other year
4 Every 3-6 years
5 Hardly ever

6 Never
7 Don't know

M5. How often do you add water treatment?
(Circle the number of your answer below.)

1 More than once a year
2 Once a year
3 Every other year
4 Every 3-6 years
5 Hardly ever
6 Never
7 Don't know

M6. How often is air conditioning equipment cleaned or serviced?
(Circle the number of your answer below.)

0 There is no air conditioning equipment in this building ▶▶▶▶ **Skip to Question P1**
1 More than once a year
2 Once a year
3 Every other year
4 Every 3-6 years
5 Hardly ever
6 Never
7 Don't know

M8. Which of the following best describes what is done with window or wall air conditioners in the winter?
(Circle the number of the answer that describes what you do with most of your units.)

0 Don't have window or wall air conditioner(s)
1 Tenants are responsible for the handling of window/wall air conditioner(s) in the winter
2 Cover the air conditioner and leave it in the window/wall
3 Take the air conditioner(s) out of the window
4 Other (please describe: ____)

M9. Has this building required any substantial repairs in the last two years?
(Circle the number of your answer below.)

1 No ▶▶▶▶ **Skip to Question P1**
2 Yes → Please describe what was done:

____
____
____

M10. Did any of the repairs above address <u>water damage</u>?
(Circle the number of your answer below.)

1 No ▸ ▸ ▸ ▸ ▸ **Skip to Question M11**

2 Yes →

What caused the water damage?
(Circle the number of your answer(s) for ALL that apply below.)

1 Roof leak

2 Plumbing leak

3 Ice dams

4 Window leaks

5 Condensation

6 Other
(please describe: ____)

M11. Did any of the repairs above address problems with <u>mold</u>?
(Circle the number of your answer below.)

1 No ▸ ▸ ▸ ▸ ▸ **Skip to Question P1**

2 Yes →

Where was the mold, and how did you deal with it?

____

____

OPERATING COSTS

P1. Below are 6 types of costs to operate an apartment building. Please indicate the three largest annual operating costs by putting the letter associated with the cost on the appropriate line below.

(Write in the letters of your answers below.)

A Taxes, all types
B Mortgages/interest/insurance
C Energy and other utility costs
D Maintenance and repairs
E Management fees
F Other (please describe: ____)

_______ Highest annual operating cost
_______ Second highest annual operating cost
_______ Third highest annual operating cost

P2. Approximately what percentage of the total operating cost for this building is spent on energy?

(Circle the number of your answer below.)

1 Less than 1 percent
2 Between 2 and 5 percent
3 Between 6 and 10 percent
4 Between 11 and 20 percent
5 Between 21 and 30 percent
6 More than 30 percent
7 Don't know

P3. Compared to other operating costs, how important is it to decrease your energy costs?

(Circle the number of your answer below.)

Not at all Important				Very Important
1	2	3	4	5

P4. How interested are you (is your company) in making aesthetic or other types of improvements to this rental building, other than for energy efficiency purposes?
(Circle the number of your answer below.)

Not at all Interested				Very Interested
1	2	3	4	5

P5. How interested are you (or is your firm) in making energy efficiency improvements to this rental building?
(Circle the number of your answer below.)

Not at all Interested				Very Interested
1	2	3	4	5

P6. Do you have specific plans to improve the energy efficiency or to reduce the energy costs to operate this facility in the next three years?

1 No

2 Yes →

What do you plan to do to reduce energy costs? ____________________

____

____

P7. May we contact you in the future if we have questions about this or other studies?

1 No

2 Yes →

Your name: ________________________

Telephone number: ___________________

Thank you for taking the time to fill out this survey. Your information will help us a great deal in completing our research. Please hand this completed questionnaire to the energy advisor that visits your building, or mail it in the postage-paid envelope to:

Minnesota Rental Housing Energy Use Study
Energy Center of Wisconsin
455 Science Drive, Suite 200, Madison, WI 53711

(to be filled in by field crew)
Building ID: _________

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APPENDIX C: ON-SITE FIELD DATA COLLECTION FORMS

Page 1 of 11 Building ID#

MN MF EE Potential Study - Data Collection Sheets					
Prior to Site Visit		**Building ID#**		(also enter ID# in header)	
Initial Contact Date:		Franklin Representative:			
Proposed Site Visit Date(s):					
On-site contact:		Phone:			
BUSINESS NAME:					
If no name found, use street address.					
Community (Project) Address:					
City:		State: MN		Zipcode:	
On-Site Contact Name:			Email:		
Phone #(s):			Fax #:		
Affordable Housing: ☐ Yes ☐ No		Type:			
Management Company or Property Owner:					
Contact Name:			Email:		
Address:					
City:		State:		Zipcode:	
Phone #:		Fax #:			
Utility Information:					
Utility release signed: ☐ yes ☐ no					
Electric Utility:		Who pays?	☐ Resident	☐ Landlord	☐ both
Meter #:		Account #:			
Gas Utility:		Who pays?	☐ Resident	☐ Landlord	
Meter #:		Account #:			
Building Details					
Total # of Units:	# Elevators:			Year Built:	
# Floors:	# Units per Floor:			Is there a pool? Y N	
System of Unit Numbering:					
First Floor:					
Second Floor:					
Repeated Number of Floors:					

Building Sketch: (footprint including dimensions of slab, crawlspace, and basement, other dimensions, number of stories, and orientation of building)

Sill box lineal feet_____

Sq Ft: Walls_______ Ceiling_______ Basement_______ Underground Garage_______ Crawlspace_______ Slab _______

On-Site Visit - Common Areas		
Site Visit Date:	Energy Advisor:	Field Technician:
Arrrival Time	Outdoor Air temp. _______F	Cloud cover ☐0-33% ☐34-66% ☐67-100%

Windspeed mph________	Indoor Air temp. ________F	Departure Time

Building Information:

Number of above ground floors:			Number of Units:		
Photo sides? 2 4		Photo address? Y N	Building Sketched? Y N		
Roof:	Flat ☐	Pitched ☐	Exterior Foundation Insulation R-value:_____		Not visible ☐

Shielding Class 1 2 3 4 5 (circle one)

Key: 1-no obstructions, 2-few trees or shed, 3-thick hedge or building, 4-building or trees most directions, 5-large obstructions surrounding perimeter (within 30' of building

orientation	Windows (Quantity per size window).			(Circle WS if weather stripping opportunity)		
N NE (circle one)	A______ ws	B______ ws	C______ ws	D______ ws	E______ ws	F______ ws
Counts per side:						
E SE (circle one)	A______ ws	B______ ws	C______ ws	D______ ws	E______ ws	F______ ws
Counts per side:						
S SW (circle one)	A______ ws	B______ ws	C______ ws	D______ ws	E______ ws	F______ ws
Counts per side:						
W NW (circle one)	A______ ws	B______ ws	C______ ws	D______ ws	E______ ws	F______ ws
Counts per side:						

Windows	Material			Pane			Storm			
A: Size	Wood	Alum	Vinyl	Single	Double	Triple	Wood	Alum	Vinyl	None
B: Size	Wood	Alum	Vinyl	Single	Double	Triple	Wood	Alum	Vinyl	None
C: Size	Wood	Alum	Vinyl	Single	Double	Triple	Wood	Alum	Vinyl	None
D: Size	Wood	Alum	Vinyl	Single	Double	Triple	Wood	Alum	Vinyl	None
E: Size	Wood	Alum	Vinyl	Single	Double	Triple	Wood	Alum	Vinyl	None
F: Size	Wood	Alum	Vinyl	Single	Double	Triple	Wood	Alum	Vinyl	None

Exterior Lighting

Type fixture (circle one)	Qty fixtures	Watts/bulb	Bulbs/fixture	Control	Ballast
I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw P 24 M T	M E N
I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw P 24 M T	M E N
I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw P 24 M T	M E N
I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw P 24 M T	M E N
I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw P 24 M T	M E N

Incandescent PinCFL ScrewCFL Halogen HighPresureSodium MercuryVapor MetalHalide LED	Control: Switch PhotoCell 24/7 Motion Timer
Put length in feet in front of T8 or T12.	Ballast: Magnetic Electronic None
Other description:	Extra1
	Extra2
	Extra3
	Extra4

Garage Lighting:

Type fixture	Qty fixtures	Watts/bulb	Bulbs/fixture	Control	Ballast
I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw 24 M	M E N

I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw 24 M	M E N
I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw 24 M	M E N
I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw 24 M	M E N
I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw 24 M	M E N
Incandescent PinCFL ScrewCFL Halogen HighPresureSodium MercuryVapor MetalHalide LED			Control: Switch 24/7 Motion sensor		
Put length in feet in front of T8 or T12.			Ballast: Magnetic Electronic None		
Other description:					

Basement Lights

Type fixture	Qty fixtures	Watts/bulb	Bulbs/fixture	Control	Ballast
I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw 24 M T	M E N
I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw 24 M T	M E N
I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw 24 M T	M E N
I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw 24 M T	M E N
I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw 24 M T	M E N
				Control: Switch 24/7	
Describe Other:				Motion Timer	

Wall Construction

Veneer: (circle one) Brick Stucco Wood Vinyl Aluminum Cementboard Other___________ Thickness_____"		
Wall structure: (circle one) Block Concrete Studs Other___________ Thickness 4" 6" Other_________"		
Furring Thickness_______"		
Continuous Insulation Y N	Material__________	Thickness___"
Interior Finish: Plaster Gypsum Other__________		
Cavity Insulation Y N	Type______________	Cannot determine ☐

	Extra1
	Extra2
	Extra3
	Extra4

Common Area: (write description)		Square Feet	
	Qty:		T-stat:____F ☐Prog. ☐Non-Prog Prog. in use Y N
	Qty:		T-stat:____F ☐Prog. ☐Non-Prog Prog. in use Y N
	Qty:		T-stat:____F ☐Prog. ☐Non-Prog Prog. in use Y N

	Qty:		T-stat:____F ☐Prog. ☐Non-Prog Prog. in use Y N
	Qty:		T-stat:____F ☐Prog. ☐Non-Prog Prog. in use Y N
	Qty:		T-stat:____F ☐Prog. ☐Non-Prog Prog. in use Y N
	Qty:		T-stat:____F ☐Prog. ☐Non-Prog Prog. in use Y N
			Check here if more on back of page ☐

Common Area Lighting

	Exit Lights:	Incandescent Qty___	LED Qty___		CFL Qty___	
Area	**Type fixture**	**Qty fixtures**	**Watts/bulb**	**Bulbs/fixture**	**Control**	**Ballast**
F H S L RR O	I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw 24 M T	M E N
F H S L RR O	I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw 24 M T	M E N
F H S L RR O	I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw 24 M T	M E N
F H S L RR O	I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw 24 M T	M E N
F H S L RR O	I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw 24 M T	M E N
F H S L RR O	I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw 24 M T	M E N
F H S L RR O	I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw 24 M T	M E N
F H S L RR O	I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw 24 M T	M E N
F H S L RR O	I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw 24 M T	M E N
F H S L RR O	I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw 24 M T	M E N
F H S L RR O	I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw 24 M T	M E N
F H S L RR O	I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw 24 M T	M E N
F H S L RR O	I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw 24 M T	M E N
F H S L RR O	I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw 24 M T	M E N
F H S L RR O	I ___T8 ___T12 PCFL SCFL H HPS MV MH LED Other				Sw 24 M T	M E N

Area Key: F- foyer H-hallway S-stairwell L-laundry RR-recreation room, O-other	Check here if more on back of page ☐
Describe Other:	

Common Area Appliances (photo appliances and nameplates)			Check here if more on back of page ☐
Location	Type	Model	Qty
Location	Type	Model	Qty
Location	Type	Model	Qty
Location	Type	Model	Qty

Commercial/Non-residential Space in Building	(For example - retail on first & second floor)		
Use________________	SqFt_______________	Floor(s)__________	Occupied Y N
Shared Heating with Res. Space: Y N	Hours Occupied:		

Common Area Laundry Type 1	Location:		Number of rooms same size and equipment:________			
Room Sq Ft:	Brand	Model	Owner: ☐ Leased	☐ Resident	☐ Landlord	Source
Washer Top Load: Y N			Year mfg.______ No info ☐	Qty:_______	Energy Star: Y N	
Dryer ☐ Elec ☐ Gas			Year mfg.______ No info ☐	Qty:_______	Energy Star: Y N	

Common Area Laundry Type 2	Location:		Number of rooms same size and equipment:________			
Room Sq Ft:	Brand	Model	Owner: ☐ Leased	☐ Resident	☐ Landlord	Source
Washer Top Load: Y N			Year mfg.______ No info ☐		Energy Star: Y N	
Dryer ☐ Elec ☐ Gas			Year mfg.______ No info ☐		Energy Star: Y N	

Humidity Data Detailed Assessments Only		Detailed Assessments Only		Detailed Assessments Only			
Basement _________% Temp____F							
Hallways	RH	Floor1_____%	Floor2____%	Floor__ ___%	Floor__ ___%	Floor__ ___%	Floor__ ____%	Floor__ ____%
	Air Temp	Temp_____F	Temp____F	Temp____F	Temp____F	Temp____F	Temp____F	Temp____F
	RH	Floor__ ___%	Floor__ ___%	Floor__ ___%	Floor__ ___%	Floor__ ___%	Floor__ ____%	Floor__ ____%
	Air Temp	Temp____F	Temp____F	Temp____F	Temp____F	Temp____F	Temp____F	Temp____F

Insulation Values Guide	R-Value/inch				
Type	Batts/Loose	Board	Dense Pack		
Fiberglass	3.5	4	4		
Mineral Wool	3	4	XX		Extra1
Cellulose	3	3	3		Extra2
Vermiculite/Perlite	2.1	XX	XX		Extra3
Polystyrene	XX	4.5	XX		Extra4
Midpoint values from Krigger & Dorsi, 2009, *Residential Energy*, p. 292.					

Type of Heating System:							
Central	☐ Central Boiler		☐ Water	☐ Steam	☐ Gas	☐ Electric	☐ Oil ☐________
☐ Rooftop Unit	☐ Heatpump	☐ Gas furnace	☐ other______________				# units served________
Individual	See individual unit section						

Boiler Type 1			Quantity:_______________
Brand	Year Installed:		Serial #:

Model #:	AFUE:_________%		SSE_______%	(do not test condensing units of 90%+ efficiency)		
Input:			Output:			
Boiler Supply Temperature_______F		Return Temperature_________F				
Flame Rollout? (photo if yes)	☐ Yes	☐ No	☐ N/A	Rust:	☐ Yes	☐ No
Combustion Air:	☐ Yes	☐ No	Size Acceptable for Unit:		☐ Yes	☐ No
Low H_2O Cutout:	☐ Yes	☐ No	Staging:	☐ Yes	☐ No	☐ N/A
I/O Reset ☐ Yes	☐ No	Sensor Location: N ☐ S ☐ E ☐ W ☐			Shutdown Outdoor Temperature__________F	
If <90% eff: Standing Pilot: Y N		Make up air? Y N		Vent Damper: Y N		VentOperable Y N
Boiler Type 2				Quantity:_______________		
Brand	Year Installed:			Serial #:		
Model #:	AFUE:_________%		SSE_______%	(do not test condensing units of 90%+ efficiency)		
Input:			Output:			
Boiler Supply Temperature_______F		Return Temperature_________F				
Flame Rollout? (photo if yes)	☐ Yes	☐ No	☐ N/A	Rust:	☐ Yes	☐ No
Combustion Air:	☐ Yes	☐ No	Size Acceptable for Unit:		☐ Yes	☐ No
Low H_2O Cutout:	☐ Yes	☐ No	Staging:	☐ Yes	☐ No	☐ N/A
I/O Reset ☐ Yes	☐ No	Sensor Location: ☐ N ☐ S ☐ E ☐ W				
If <90% eff: Standing Pilot: Y N		Make up air? Y N		Vent Damper: Y N		VentOperable Y N
Pipes Insulated:	☐ Yes	☐ No	R-Value R_________		Pipe diameter_____________inches	
Hot Water Piping	Total Piping Length_______________					
% of pipe in conditioned space:_____%			Air Temp____F	Insulated pipe ft______(est.)		Un-insulated ft_______
% of pipe in unconditioned space:_____%			Air Temp____F	Insulated pipe ft______(est.)		Un-insulated ft_______
Circulation System	Hydronic ☐	Steam ☐ 1 pipe	2 pipe ☐			
Continuous ☐	Controlled ☐		Zone Valves Y N			
Pump Type 1 Qty____	HP_______	# Units controlled_______		Common Areas Controlled_______________		
Pump Type 2 Qty____	HP_______	# Units controlled_______		Common Areas Controlled_______________		
Pump Type 3 Qty____	HP_______	# Units controlled_______		Common Areas Controlled_______________		
Pump Type 4 Qty____	HP_______	# Units controlled_______		Common Areas Controlled_______________		
GasFurnace Type 1	Brand	Model	Year mfg._______ No info ☐			# of type 1 furnaces_______
AFUE:________ SSE:________				BTU/hr in:____________		BTU/hr out:
(do not test condensing units of 90%+ efficiency)						
Gas Furnace Type 2	Brand	Model	Year mfg._______ No info ☐			# of type 2 furnaces_______
AFUE:________ SSE:________				BTU/hr in:____________		BTU/hr out:
(do not test condensing units of 90%+ efficiency)						

Ducts Insulated:		☐ Yes	☐ No	Duct Leakage ☐ Yes		☐ No		
Duct R-Value	R_______			(photo leakage if yes)				
Domestic Water Heating System Type 1						**Quantity:**____________		
Type of DHW:		☐ Stand Alone Tank		☐ Central Storage Tank		☐ Indirect Fired		
☐ Ground Source HP		☐ Solar		☐ other__________				
Brand:		Model:		Year Installed:		Serial #:		
Fuel:	☐ Gas	☐ Electric	☐ Oil	☐ LP	☐ other_________		Gallons:_______	
Size Input:______________			Recovery Rate:_______			Power Vent	☐ Yes	☐ No
Rust:		☐ Yes	☐ No	Flame Rollout Present:		☐ Yes	☐ No	
Vent Damper:		☐ Yes	☐ No	Temperature Set Point: _______			AFUE:________%	
Standing Pilot:		☐ Yes	☐ No	Tank Wrap: ☐ Yes		☐ No	SSE:_______%	
Venting:	☐Atmospheric	☐Power Vent		☐Sealed Combustion				
Recirculating System		☐Y ☐N	HP_____	Recirculating Set Temp_____		Hours/day_______		
Domestic Water Heating System Type 2						**Quantity:**____________		
Type of DHW:		☐ Stand Alone Tank		☐ Central Storage Tank		☐ Indirect Fired		
☐ Ground Source HP		☐ Solar		☐ other__________				
Brand:		Model:		Year Installed:		Serial #:		
Fuel:	☐ Gas	☐ Electric	☐ Oil	☐ LP	☐ other_________		Gallons:_______	
Size Input:______________			Recovery Rate:_______			Power Vent	☐ Yes	☐ No
Rust:		☐ Yes	☐ No	Flame Rollout Present:		☐ Yes	☐ No	
Vent Damper:		☐ Yes	☐ No	Temperature Set Point: _______			AFUE:________%	
Standing Pilot:		☐ Yes	☐ No	Tank Wrap: ☐ Yes		☐ No	SSE:_______%	
Venting:	☐Atmospheric	☐Power Vent		☐Sealed Combustion				
Recirculating System		☐Y ☐N	HP_____	Recirculating Set Temp_____		Hours/day_______		
Central Air Conditioning:		☐ N/A						
Unit Type 1	# units______		☐Central	Brand	Model#	SEER	KW	
			☐Chiller	Brand	Model#	SEER	KW	
Notes:								
Unit Type 2	# units______		☐Central	Brand	Model#	SEER	KW	
			☐Chiller	Brand	Model#	SEER	KW	
Notes:								
Waste Drain Pipes		Total # of drains within 50' of hot water heaters_____						
Drain type1	Diameter___"	Qty	Exposed Vertical Ft_____		Feet from DHW_____		Est. Units Served_____	
Drain type2	Diameter___"	Qty	Exposed Vertical Ft_____		Feet from DHW_____		Est. Units Served_____	
Notes:								
Basement and Crawlspace Insulation								
Basement R-Value: Above_____		Walls_____			R-value	Assumed ☐	Measured ☐	
Crawlspace R-Value: Above_____		Walls_____	Floor_______		R-value	Assumed ☐	Measured ☐	

Attic (X below insulation type & measure avg. inches)				Attic Hatch Insulated: Y N		Attic Hatch Weather-stripped? Y N
Insulation	Batt	Loose	Board	Inches	Exhaust: ☐ Common ☐ Individual ☐	
Fiberglass					Combined Kitchen/Bath Fan (if individually vented)? Y N	
Cellulose						
Min. Wool					Potential for increase in R-value? Y N	
Polystyrene	-----	-----			Inches of clearance for additional insulation:_________	
Vermiculite	-----		-----			
Perlite	-----		-----		Duct Sealing Opportunity? Y N	

Parking						Sq Ft:	(per floor)
Type	☐ Lot	☐ Attached Garage		☐ Detached Garage		☐ Underground # Floors_____	
Garage Heated? Y N		Input:		Output:		Ambient Air Temperature___	
Gar. Ceiling R-value_______		Assumed ☐	Measured ☐	Garage Wall R-value_______		Assumed ☐ Measured ☐	
Ventilation: 24/7 ☐		CO detector ☐		Fan diameter (inches):_____		Flow rate (cfm):______	(if running)
						Fan HP (if labeled)	

Pool ☐ (attach separate pool sheet)

Stand Alone Common Area Heating/Cooling						
Location	Type of Heating/Cooling Unit	T-stat in room	Dials on Units	KW	BTU/hr in	BTU/hr out
		Y N	Y N			
		Y N	Y N			
		Y N	Y N			
		Y N	Y N			
		Y N	Y N			
		Y N	Y N			
		Y N	Y N			
		Y N	Y N			
		Y N	Y N			
Type Key: Electric resistance, PTAC, PTHP, Gas Furnace					Extra1	Extra2
					Extra3	Extra4

Other building information:

Individual Units (one page for each unit)			**Unit #**		**Survey #**		**Floor #**
Exterior Door: Y N		Dimensions:_______		Door Material: Wood FiberGlass Steel			Sq Ft of Unit
Programmable Tstat: Y N		Using program? Y N		KFaucet gpm_______		KFaucet gpm_______	
Bathroom Fan: Y N		Fan Switch: Y N		Fan operable: Y N			K Faucet H20 Temp._______
SH1gpm_____	SH1gpm_____	SH1FF Y N	FF=Fixed Flow	Bath1 Faucet GPM_______		Bath1 Faucet GPM_______	
SH2gpm_____	SH2gpm_____	SH2FF Y N	FF=Fixed Flow	Bath2 Faucet GPM_______		Bath2 Faucet GPM_______	
Leaking tub diverter: Y N		If Y, gpm_____					
Toilet1 GPF (per label)_____		Toilet2GPF (per label)_____		(put NA if no toilet label)			CO Alarm: Y N
Detailed Only: bath fan balometer readings			**Passive CFM:**		**Fan on CFM:**		

Lighting

Room	Location	Type Bulb	Qty fixtures	Watts/bulb	Bulbs/fixture	Control	Ballast	
Kitchen	C W U Rc Tr Pl	I PCFL SCFL Other				Sw D M	M E N	
Kitchen	C W U Rc Tr Pl	I PCFL SCFL Other				Sw D M	M E N	
Kitchen	C W U Rc Tr Pl	I PCFL SCFL Other				Sw D M	M E N	
LR	C W U Rc Tr Pl	I PCFL SCFL Other				Sw D M	M E N	
LR	C W U Rc Tr Pl	I PCFL SCFL Other				Sw D M	M E N	
DR	C W U Rc Tr Pl	I PCFL SCFL Other				Sw D M	M E N	
Hallway	C W U Rc Tr Pl	I PCFL SCFL Other				Sw D M	M E N	
Bath	C W U Rc Tr Pl	I PCFL SCFL Other				Sw D M	M E N	
BR1	C W U Rc Tr Pl	I PCFL SCFL Other				Sw D M	M E N	
BR1	C W U Rc Tr Pl	I PCFL SCFL Other				Sw D M	M E N	
BR2	C W U Rc Tr Pl	I PCFL SCFL Other				Sw D M	M E N	
BR2	C W U Rc Tr Pl	I PCFL SCFL Other				Sw D M	M E N	
______	C W U Rc Tr Pl	I PCFL SCFL Other				Sw D M	M E N	
______	C W U Rc Tr Pl	I PCFL SCFL Other				Sw D M	M E N	
Outside	C W U Rc Tr Pl	I PCFL SCFL Other				Sw D M	M E N	

Location: C-ceiling, W-wall, U-undercabinet, Rc-recessed can, Tr-track, Pl-plug-in — Control: Switch Dimmer Motion

Describe Other: — Fixture Key: Incandescent, PinCFL, ScrewCFL

Check here if more on back of page ☐

Appliances		(photograph each appliance and nameplate)				Vented Range/Stove: Y N		
Refrigerator		Brand	Model	Year mfg.______	No info ☐	CuFt______	Door Ice Y N	
Type	☐Top Freezer	☐Bottom Freezer		☐Side-by-Side		☐Other:______		
	Anti-sweat/energy saver switch?		Y N	Defrost: ☐Manual ☐ Auto ☐		No Info	EnergyStar ☐	
Dishwasher ☐		Brand	Model	Year mfg.______	No info ☐		EnergyStar ☐	
Stovetop ☐	Elec. ☐Gas	Brand	Model	Year mfg.______	No info ☐	Pilot: Y N	EnergyStar ☐	
Oven ☐	Elec. ☐Gas	Brand	Model	Year mfg.______	No info ☐	Pilot: Y N	EnergyStar ☐	
Sleeve A/C1 ☐	EER______	Brand	Model	Year mfg.______	No info ☐	BTU/hr	EnergyStar ☐	WS opp ☐
Other:______		Brand	Model	Year mfg.______	No info ☐		EnergyStar ☐	

In-Unit Laundry		(photograph each appliance and nameplate)					
Washer	Top Load: Y N	Brand	Model	Year mfg.______	No info ☐		Energy Star: Y N
Dryer ☐ Elec	☐ Gas	Brand	Model	Year mfg.______	No info ☐		Energy Star: Y N
Stacked W/D set? Y N							
Notes:							

In-Unit Heating		(photograph heater and nameplate)					
Electric Baseboard ☐		Dials on units Y N		T-stat each room: Y N		KW______	
Gas Fired Furnace ☐		Brand	Model	Year mfg.______	No info ☐		
AFUE:	SSE:				BTU/hr in:		BTU/hr out:
Magic Pak ☐		Brand	Model	AFUE:	Heat BTU/hr in:		BTU/hr out:
Heat: Gas ☐ Elec ☐		Year mfg.______	No info ☐	EER	Cool BTU/hr in:		BTU/hr out:
PTAC ☐		Brand	Model	Year mfg.______	No info ☐	EER	BTU/hr:______
PTHP ☐		Brand	Model	Year mfg.______	No info ☐	EER	BTU/hr:______
Electric Furnace ☐		Brand	Model	Year mfg.______	No info ☐	EER	BTU/hr:______
Other:______ ☐		Brand	Model	Year mfg.______	No info ☐	EER	BTU/hr:______

In-Depth Data Collection - Selected Buildings Only — **Detailed Assessments Only**

Blower Door Test Completed? Y N

Whole building/common area fan motors	(large fans only -		(photo nameplates)		
Model	Annual Hours:	Full Load Amps:		Voltage Phase:	HP
Type of control:	☐ 24/7	☐ Outdoor air reset	☐ Humidistat	☐ Other_______________	
Nameplate CFM_____	Fan hole diameter:		VSD/VSM: Y N		
Model	Annual Hours:	Full Load Amps:		Voltage Phase:	HP
Type of control:	☐ 24/7	☐ Outdoor air reset	☐ Humidistat	☐ Other_______________	
Nameplate CFM_____	Fan hole diameter:				
			VSD/VSM: Y N		
Model	Annual Hours:	Full Load Amps:		Voltage Phase:	HP
Type of control:	☐ 24/7	☐ Outdoor air reset	☐ Humidistat	☐ Other_______________	
Nameplate CFM_____	Fan hole diameter:				
			VSD/VSM: Y N		
Model	Annual Hours:	Full Load Amps:		Voltage Phase:	HP
Type of control:	☐ 24/7	☐ Outdoor air reset	☐ Humidistat	☐ Other_______________	
Nameplate CFM_____	Fan hole diameter:		VSD/VSM: Y N		
Model	Annual Hours:	Full Load Amps:		Voltage Phase:	HP
Type of control:	☐ 24/7	☐ Outdoor air reset	☐ Humidistat	☐ Other_______________	
Nameplate CFM_____	Fan hole diameter:				
			VSD/VSM: Y N		

APPENDIX D: WEATHER NORMALIZATION

We requested utility consumption records for all master- and individually-metered natural gas and electricity accounts where the property owner/manager or a tenant survey respondent provided a signed utility-data release form. Altogether, we received utility data for about 1,100 distinct customer accounts served by 34 Minnesota utilities.

To process the data, we first aggregated each building's monthly data across accounts, using an algorithm to pro-rate consumption periods with different meter read dates. We did this separately by fuel and type of account (master-metered and individually-metered). This yielded an average use per day in each monthly consumption period for each fuel and account type.

We then assigned each site to a nearby weather station with daily temperature data, and implemented one of three weather-normalization models, depending on the fuel in question and the type of space-heating and space-cooling equipment in the building:

1. Heating-only
2. Cooling-only
3. Heating-and-cooling

The heating-only and cooling-only models are subsets of the more comprehensive heating-and-cooling model, which we describe here. The heating-and-cooling model has the following form:

$$UPD = \beta_1 hdd_{\tau h} + \beta_2 cdd_{\tau c} + \beta_0 + \epsilon$$

where

UPD is average use per day in a given monthly consumption period;

$hdd_{\tau h}$ is the mean heating degree days per day at reference temperature τ_h for the given consumption period; and,

$cdd_{\tau c}$ is the mean cooling degree days per day at reference temperature τ_c for the given consumption period.

Daily heating and cooling degree days (to arbitrary reference temperature τ_h) for any given day are calculated as:

$$HDD_{\tau h} = \max(\tau_h - T_d, 0)$$
$$CDD_{\tau c} = \max(T_d - \tau_c, 0)$$

where

T_d is the observed daily temperature (F) for the assigned weather station near the property.

We customized the values of τ_h and τ_c for each premise by fitting the model over a range of possible values, and selecting the value of τ with the best fit. It is not uncommon for this approach to occasionally yield values for τ that are at or near the extremes of the above range due to outliers in the monthly consumption data. To mitigate this phenomenon, we incorporating a Bayesian loss function centered on typical values for these parameters. The loss function essentially prevents the value of τ from deviating strongly from typical values unless the improvement in fit is large.

The results of this exercise provide a model of energy use for each premise that separates total consumption into heating ($\beta_1 HDD_{\tau h}$), cooling ($\beta_2 HDD_{\tau c}$) and non-heating (β_o) components. Weather-normalized annual consumption (NAC) can then be estimated for each premise as:

$$NAC = 365.25(\beta_1 hdd_{N\tau h} + \beta_2 cdd_{N\tau c} + \beta_0)$$

Where $hdd_{N\tau h}$ and $cdd_{N\tau h}$ are the 20-year (1993-2012) average heating and cooling degree days per day for the assigned weather station at reference temperature τ.

The heating-only and cooling-only models are similar, but omit either the cooling or heating part of the model as appropriate.

For cases where there was no space-heating or space-cooling consumption involved, we simply annualized the available data. We also used this approach for the water consumption data that we received for 72 of the properties in the study.

Tenant-level utility data were only available for survey-respondents who provided a signed utility-release form. To scale tenant energy consumption up to the building level, we multiplied the mean consumption per tenant account by the total number of housing units in the building.

APPENDIX E: CLASSIFICATION OF LOW-INCOME TENANTS AND PROPERTIES

This appendix describes how we went about determining if tenants of the properties sampled for the study could be classified as low-income, as well as how we classified the properties themselves as dominantly low-income and therefore eligible for low-income weatherization programs.

Our definition of "low-income" here means at or below 200 percent of the 2012 Federal poverty guideline (see table at right).

Persons in household	Federal 2012 Poverty guideline
1	$11,170
2	$15,130
3	$19,090
4	$23,050
5	$27,010
6	$30,970
7	$34,930
8	$38,890
each additional person	$3,960

CLASSIFICATION OF TENANT-SURVEY RESPONDENTS

For individual tenants, the Tenant Survey asked about the number of persons in the household, and also posed the following income question:

Which of the following categories best describes the total income of your household in 2011?
(Circle the number of your answer below.)

1 Less than $20,000
2 $20,000 to $29,999
3 $30,000 to $39,999
4 $40,000 to $49,999
5 $50,000 to $74,499
6 $75,000 or more
7 Prefer not to answer

Based on the number of household members and the income category selected, in most cases it was possible to unambiguously classify respondents as low-income or not. However, in about 15 percent of cases, the combination of income and household size led to an ambiguous determination. For example, the 200% income threshold for a one-person household is $22,340; if such a respondent selected the $20,000 to $29,999 income category, their income might be above or below the threshold. In such a case we would draw a random number between 0 and 1, and impute the respondent as low-income if the result was ≤ 0.234, which represents the proportion of the income bracket falling below the threshold.

In addition, the survey asked the following question about whether the household had received assistance from government energy-assistance programs:

Government agencies and utilities have programs to help households who can't pay all of their energy bills. Has your household received this kind of help since moving into this apartment unit?
(Circle the number of your answer below.)

1 No ▸ ▸ ▸ ▸ ▸ ▸ ▸ **Skip to question 58**
2 Yes

What program did you receive assistance from?
(Circle the number of your answer below.)

1 Energy Assistance Program
2 Weatherization Assistance Program
3 Your utility

4 Other (please describe) ________________________________
5 Don't know

Respondents who answered affirmatively to this question were classified as low-income.

About 15 percent of the 1,285 survey respondents did not answers these questions, and therefore could not be classified in this way.

CLASSIFICATION OF PROPERTIES

For a multifamily property to be eligible for whole-building treatment through the federal Weatherization Assistance Program or Minnesota utility low-income weatherization programs it must either be on a list of pre-qualified properties, or be shown to be dominantly occupied by low-income households. The latter generally means that two-thirds or more of the households must be income-qualified at or below 200% of the FPG.

The Minnesota CIP statues require that utilities spend a portion of their program budgets on programs for low-income and rental customers. There are currently three methods by which a Minnesota multifamily property may be identified as a low-income building for CIP reporting[10]:

1. Be on a federal list of properties that are pre-qualified for the federal Weatherization Assistance Program;
2. Be certified by the Minnesota Housing Finance Agency as eligible for low-income property tax incentives, and appear on the Low-Income Rental Classification Assessor Report; and/or,
3. Have a documented use restriction that requires a portion of the units to be rented to tenants at or below 60 percent of area median income.

The federal government and the State of Minnesota both maintain the lists referred to in items 1 and 2, respectively. We cross-referenced the properties in the study sample with these lists, restricting the search to properties that were reported by respondents to the Owner/Manager Survey as having 50 percent or more low-income residents. Specifically we first searched the 2012 Minnesota Low-Income Rental Classification (LIRC) report prepared by the Minnesota Housing Finance Agency. If the property was not found on that list, we then searched the Housing and Urban Development Multifamily Properties Eligible for Weatherization Assistance list compiled by the U.S. Department of Energy. Finally, the non-profit agency HousingLink graciously allowed us to search their database of Minnesota affordable housing for properties known to meet the use-restriction requirement above.[11] We identified 32 low-income properties in this manner.[12]

To account for the fact that properties may be program-eligible but not on a pre-qualified list, we also used the low-income classifications from the tenant survey to assess the fraction of respondents in each building that were low-income. However, this assessment was complicated by the fairly low response rate to the tenant survey (35%). In a few cases, we had enough tenant respondents to unambiguously classify the property as dominantly low-income or not. But in the majority of cases, there was uncertainty in our tenant-survey based estimate of the low-income proportion for the building. We classified properties as low-income only if the survey-based estimate of the low-income proportion passed a

[10] See http://mn.gov/commerce/energy/images/ConserveProgLowIncomeGuide.pdf
[11] www.housinglink.org
[12] Note that there is a third way that a Minnesota property may be pre-qualified for low-income weatherization: documentation of a use restriction in which the property owner declares that a portion of units will be rented to low-income households. However, no central list of these properties is available.

statistical test for whether the proportion was at or above two-thirds at a 95 percent confidence level. This may have led to missing a few properties that could have been so-classified but did not pass the required level of confidence. But it means that we can be relatively confident that few if any properties that were not in fact dominantly low-income were falsely classified as such

The tenant survey data led to classifying five additional properties as dominantly low-income.

APPENDIX F: MEASURES ASSUMPTIONS FOR SAVINGS AND COSTS

MEASURE	ESTIMATE OR ALGORITHM	SOURCES & ASSUMPTIONS
Lighting Measures		
Upgrade T-12 fixtures to T-8		
Definition of opportunity	Convert fluorescent light fixtures with T-12 and magnet ballasts to T-8 tubes and electronic ballasts.	MN TRM
Savings	This measure goes from a base kW value of .097 to .0736. (21.3%) for two+ tubes 0.06 to .051 kW (27.8%) for single tubes. Savings includes both replacing tubes and ballast. Indirect heating and cooling impacts (see *Indirect Impacts* below) See *Hours of usage assumptions for lighting* below.	MN TRM
Cost	$43.45 per fixture (for two+ bulb fixtures). $41.45 per fixture (for one bulb fixtures).	MN TRM
Upgrade from exterior / garage HID fixture to an LED fixture.		
Definition of opportunity	Applicable to upgrades exterior HID and garage HID lights. Hours of operation assumed to be dependent on control types (see *Hours of usage assumptions for controls measures* section below)	Composite savings and costs of all such conversions in the MN TRM.
Savings	77.0%	MN TRM
Cost	$627.80 per fixture.	MN TRM
Exit Lights – upgrade to a Light Emitting Capacity (LEC) exit light		
Definition of opportunity	Replace a 30 watt, incandescent exit light with a .025 watt LEC exit light *or* replace an 11 watt CFL exit light with a .025 watt LEC exit light. Assumed on 24 hours a day.	MN TRM
Savings	99.4% for incandescent. 97.7% for CFL.	MN TRM, calculated
Cost	$76.16	MN TRM

MEASURE	**ESTIMATE OR ALGORITHM**	**SOURCES & ASSUMPTIONS**
Photocell – add a photocell to exterior fixtures		
Definition of opportunity	Any 24/7 exterior fixture. See *Hours of usage assumptions for controls measures* section below.	
Savings	50% (8760 hours/year/2 = 4380 hours/year)	Assumed savings from shutting off during daylight hours.
Cost	$65	MN TRM
Incandescent to CFL		
Definition of opportunity	Replace incandescent bulbs with CFL's	
Savings	66.6% Indirect heating and cooling impacts (see *Indirect Impacts* below) See *Hours of usage assumptions for lighting* below.	WI Characterization Study
Cost	$2.54	MN TRM
Occupancy Sensors		
Definition of opportunity	Put occupancy sensors on fixtures in common areas that are either on 24/7 or switched.	
Savings	8760 hours/year / 2 = 4380 hours (50%) for 24/7 fixtures. 2 hours/day (8.3% of 24 hours) for switched fixtures. Indirect heating and cooling impacts (see *Indirect Impacts* below) See *Hours of usage assumptions for controls measures* section below.	MN TRM, WI Characterization Study
Cost	$65	MN TRM

MEASURE	ESTIMATE OR ALGORITHM	SOURCES & ASSUMPTIONS

Indirect impacts for Lighting Measures (for interior spaces)

Indirect Savings/penalty factors	
Indirect Electrical Factor, C_{ELECT} =0.001149	$\Delta kWh_{INDIRECT} = C_{ELECT} * \Delta kWh_{DIRECT} * CDD\ (°F*day) / COP_{COOLING}$
Indirect Gas Factor, C_{GAS} =-0.00047	$\Delta kBtu_{INDIRECT} = C_{GAS} * \Delta kWh_{DIRECT} * HDD\ (°F*day) / \eta_{HEATING}$

Sources & Assumptions: Building energy simulations using eQuest software.

Hours of usage assumptions for lighting

Location	Type	Mean hours per day
Kitchen	wired	2.8
Bedroom	wired	2.3
Bath oom	wired	1.5
Living room	plug-in	2.6
Bedroom	plug-in	1.8
Hallw y Other	wired	1.5

Sources & Assumptions: Usage assumptions derived from monitored data. All room locations were monitored except for "Hallway/Other" which has an assumed hours of operation per day.

Hours of usage assumptions for controls measures

Control type	Assumed hours of operations	Notes
24/7	8760	On all year round
Timer	4380	Assumed functional 1/2 hours of the year
Switch	6570	Switch default is 6 am to 12 pm
Motion sensor	5840	Motion sensor is 6am to 12 pm less 2 hours
Photocell	4380	Assumed functional 1/2 hours of the year

Sources & Assumptions: See notes to the left for assumptions

Appliances

Energy Star washing machines

MEASURE	ESTIMATE OR ALGORITHM	SOURCES & ASSUMPTIONS
Definition of Opportunity	Replace conventional top-load wash machine with an Energy Star washer	
Savings	Annual savings = (number of loads / year) x (kWh savings / load) + (number of loads / year) x (therm savings/load) + (number of loads / year) x (gallons of water savings / load)	ConsumerEnergyCenter.org, EnergyStar.gov, MN TRM.

MEASURE	ESTIMATE OR ALGORITHM	SOURCES & ASSUMPTIONS
	Loads per year = • 274 loads per year for in-apartment machines in buildings with fewer than 20 housing units. • 235 loads for in-apartment machines in buildings with 20 or more housing units. • 950 loads for machines installed in common areas. Savings per load = • 0.5714 kWh per load for installations with electric dryers and water heaters. • 0.3597 kWh per load, .0074 therms per load for gas dryer and electric water heater. • 0.2474 kWh per load, .0156 therms per load for electric dryer and gas water heater. • 0.0607 kWh per load, .0230 therms per load for gas dryer and gas water heater. Water savings per load = • 15.2 gallons for all configurations.	Load numbers adjusted to account for differences in persons per housing unit assumed in MN TRM in found in this study.
Cost	$374	MN TRM
Fuel switch – electric dryers to natural gas dryers		
Definition of Opportunity	Replace electric dryers in basement installations with gas dryers.	Dryers in other locations were not considered due to gas plumbing and venting complexity and cost.
Savings	Reduce annual electricity use by 1,000 kWh, add 25 therms of gas usage per unit.	
Cost	$1,000	Web review of natural gas dryers
Upgrade to Energy Star refrigerator		

MEASURE	**ESTIMATE OR ALGORITHM**	**SOURCES & ASSUMPTIONS**
Definition of Opportunity	Upgrade existing refrigerators with Energy Star refrigerators on replacement	
Savings	73 kWh/year for Energy Star top freezer 101 kWh kWh/year for Energy Star Side-by-side freezer	MN TRM
Cost	$54	MN TRM
Domestic Hot Water Measures		
Install indirect water heater connected to existing boiler		
Definition of Opportunity	Replace central conventional gas water heater with an indirect water heater connected to existing high efficiency condensing boiler.	
Savings	Assumed 125 therms / housing unit base usage and an 11% savings rate	125 therms / housing unit calculated from usage surveys collected for this study.
Cost	$4,000	Web review of current prices plus an estimate of professional removal and installation time and material costs.
Central high efficiency water heater		
Definition of Opportunity	Upgrade central conventional gas water heater with high efficiency, condensing gas water heater on replacement.	
Savings	Assumed 125 therms / housing unit base usage and a18.75% savings rate	125 therms / housing unit calculated from utility data collected for this study.
Cost	Assume baseline cost of a new water heater is $2,500 + $15/kBTU input. Assume efficient water heater carries a 20% price premium.	Web review of current prices

MEASURE	**ESTIMATE OR ALGORITHM**	**SOURCES & ASSUMPTIONS**
In-unit high efficiency water heater		
Definition of Opportunity	Upgrade existing, in-apartment, standard gas water heater with Energy Star water heater on replacement.	
Savings	Assumed 125 therms / housing unit base usage And a 12% savings rate.	125 therms / housing unit calculated from utility data collected for this study. EnergyStar.gov
Cost	$51	MN TRM
Install kitchen and bath aerators		
Definition of Opportunity	Install aerators where flow rates are higher than 2.8gpm (kitchens) and 2.0 gpm (bathrooms)	
Savings	savings=((GPM_base * L_base - GPM_low * L_low) * Household size * 365.25 *Drain factor / faucets per household) * Energy Per Gallon * Throttling factor where: GPM_base = measured data L_base = L_low = 9.85 minutes (both kitchen and bath) Household size = 2.2 for 5-20 unit bldgs, 1.6 for 20+ unit bldg., per tenant survey Drain factor (bathroom) = 0.9 Drain factor (kitchen) = 0.75 Faucets per household = 1 (savings per one faucet) Energy per gallon (EPG) = 0.0045 therms/gal OR 0.0894 kWh/gal Throttling Factor = 0.50% (assumed factor based on IL TRM calculations)	IL TRM, unless otherwise noted in savings calculations description (http://ilsag.org/yahoo_site_admin/assets/docs/Illinois_Statewide_TRM_Effective_060112_Final_Technical_Version_082012_Clean.267210030.docx)
Cost	$5	MN TRM
Install low flow showerheads		
Definition of Opportunity	Install low-flow showerheads where flow rates are greater than 2.0 gpm	
Savings	savings=((GPM_base * L_base - GPM_low * L_low) * Household * Showers per day * 365.25 / SPH) * Energy Per Gallon	IL TRM, unless otherwise noted in savings calculations

MEASURE	ESTIMATE OR ALGORITHM	SOURCES & ASSUMPTIONS
	L_Base = L _low = 8.20 minutes GPM_base = measured flow GPM_low = GPM_base – 1.5 (fixed flow fixtures) GPM_low = (0.691 + 0.542 * GPM_base) – 1.5 (non-fixed flow) (source for non-fixed flow calc = http://www.homeenergy.org/show/article/nav/utilityprograms/page/10/id/1062) Household size = 2.2 for 5-20 unit bldgs, 1.6 for 20+ unit bldg., per tenant survey Showers per day = 0.75 # of showers per household (SPH) = 1.3 Energy per gallon (EPG) = 0 .0063 therms/gal OR 0.127 kWh/gal	description (http://ilsag.org/yahoo_site_admin/assets/docs/Illinois_Statewide_TRM_Effective_060112_Final_Technical_Version_082012_Clean.267210030.docx)
Cost	$12	MN TRM
Space heating measures		
Upgrade to a high efficiency boiler		
Definition of Opportunity	Install a high efficiency, condensing boiler to replace a non-condensing boiler	
Savings	1-(78%/90%) = 13.3% of space heating consumption	
Cost	Cost = $7.00 per kBtu output	MN TRM
Boiler reset and cutout controls		
Definition of Opportunity	Installing boiler reset and cutout controls on hydronic boilers	MN TRM
Savings	3.8% of space heating consumption	
Cost	$600 / boiler	
Boiler and Furnace clean and tune-up		
Definition	Cleaning and tuning existing furnaces and boilers	MN TRM

MEASURE	**ESTIMATE OR ALGORITHM**	**SOURCES & ASSUMPTIONS**
of Opportunity		
Savings	2% of annual heating usage	
Cost	$300	
Installation of a boiler vent damper		
Definition of Opportunity	Install vent dampers on boilers that do not currently have vent dampers	
Savings	5% of space heating consumption	MN TRM
Cost	$2.50 per nominal pre-modification kBtu/h output	
Pipe insulation on boilers		
Definition of Opportunity	Install pipe insulation on uninsulated pipes	
Savings	Steam systems: 6.77 * 0.29 * pipe diameter + 0.1131 Hydronic systems: 3.45 * 0.413 * pipe diameter + 0.178	Whole Building Design Guide
Cost	$4.29 per lineal foot	Franklin Energy program costs
Upgrade to a high efficiency furnace		
Definition of Opportunity	Upgrade to high efficiency condensing furnace	
Savings	1-(80%/92%) = 13% of space heating consumption	
Cost	$500	Estimate, based on WI weatherization program installation costs.[13]
Install programmable thermostats		
Definition of Opportunity	Installation of in-unit programmable thermostats in buildings that have individual gas-fuel heating and where tenants pay their own gas heating bill. This measure assumes that all units will be retrofit simultaneously.	

[13] The MN TRM uses $1,342 as the incremental cost for a high-efficiency condensing furnace, but values for this measure are under review.

MEASURE	**ESTIMATE OR ALGORITHM**	**SOURCES & ASSUMPTIONS**
Savings	3% of space heating consumption	IL TRM – Adjusted for multifamily sector
Cost	$75 per unit.	WI Weatherization program cost
Cooling Measures		
Upgrade to an Energy Star window or sleeve air conditioning unit		
Definition of Opportunity	Upgrade window or sleeve A/C unit with an Energy Star unit on replacement. Applies to all units with EER below current Energy Star specifications.	
Savings	$\Delta kW = BTUH \times (1/EER\_base - 1/EER\_eff) / 1000$ $\Delta kWh = \Delta kW * Annual\ hours$ Where: BTUH (Btu/hr cooling output) = Nameplate value, or 10,000 (if unknown) EER_base = 9.8 for window unit 8.5 for sleeve unit EER_eff = 10.8 for window unit 9.4 for sleeve unit Annual hours = 181 for Climate Zone 1 353 for Climate Zone 2 565 for Climate Zone 3	MN TRM
Cost	$50	MN TRM
Window replacements		
Replace single-pane windows with double-pane with storm		
Definition of Opportunity	Upgrade windows from standard double-pane to higher-efficiency, double-pane on replacement. Applies to properties with existing single-pane, or single-pane-with-storm windows.	

MEASURE	**ESTIMATE OR ALGORITHM**	**SOURCES & ASSUMPTIONS**
Savings	Baseline assumption: U-value of 0.35, low-e Upgrade assumption: U-value of 0.25, low-e $\Delta kWh = 0.00738 * A_{WINDOW} (ft^2) * CDD (°F*day) / COP_{COOLING}$ $\Delta kBtu = 0.00158 * A_{WINDOW} (ft^2) * HDD (°F*day) / \eta_{HEATING}$	Factors were determined through building energy simulations using eQuest software.
Cost	$4.5 / ft^2	Estimated 15 percent price premium applied to $30/ft2 window installation cost (National Residential Efficiency Measures Database from the National Renewable Energy Laboratory)

The tables that follow summarize the results of applying these methods and assumptions to the multifamily buildings with gas heat in the study sample. Results are weighted means of building-level estimates, expressed on a per-housing-unit basis. Note that for in-unit measures (such as showerheads) where an opportunity may exist for some units but not others, the values shown may be less than the per-unit cost and savings in units where the measure is applicable.

			Mean per housing unit				
Unscreened for payback Measure		Percent of buildings with opportunity	Measure cost	Annual gas savings (therms)	Annual electric savings (kWh)	Annual water savings (gallons)	Annual utility cost savings
AC-01	Upgrade window/wall A/C with energy star	82%	$32.21	0.0	39	0	$4.25
AP-01	Upgrade to energy star refrigerator	54%	$35.96	-0.8	39	0	$3.60
AP-02	Fuel switch from electric dryer to natural gas dryer	5%	$167.94	-4.2	168	0	$15.20
AP-03	Upgrade to energy star washing machine	85%	$89.69	3.3	20	2,460	$22.38
HT-01	Upgrade to high efficiency boiler	71%	$185.87	57.0	0	0	$35.33
HT-02	Upgrade to high efficiency furnace	5%	$500.00	45.7	0	0	$32.95
HT-03	Boiler reset cutout controls	37%	$60.65	16.6	0	0	$10.28
HT-04	Clean and tune-up furnace/boilers	27%	$35.36	8.5	0	0	$5.25
HT-05	Install vent damper	64%	$67.12	22.8	0	0	$14.14
HT-06	Adding pipe insulation on boilers pipes	57%	$14.30	10.5	0	0	$6.51
LT-01	Common lights: T-12 to T-8	38%	$20.68	-2.9	92	0	$6.48
LT-02	Common lights: HID to LED garage/exterior	67%	$141.65	0.0	163	0	$11.51
LT-03	Common lights: upgrade to CFLs	59%	$1.21	-8.0	225	0	$15.27
LT-04	Exit lights: upgrade to LECs	7%	$21.92	-3.2	98	0	$6.83
LT-10	Controls: 24/7 or switch to occupancy sensors	67%	$19.71	-0.7	22	0	$1.53
LT-11	Controls: exterior photocells	16%	$9.25	0.0	14	0	$0.96
LT-20	In-unit lights: T-12 to T-8	14%	$32.18	-0.5	13	0	$1.05
LT-21	In-unit lights: Incand to CFLs	98%	$30.26	-14.6	432	0	$35.78
SH-06	Add programmable t-stats	6%	$75.00	8.2	0	0	$6.38
WA-01	Install kitchen and/or bath aerators	58%	$3.80	9.6	13	2,262	$24.62
WA-03	Install low-flow showerheads	83%	$9.60	14.2	30	2,493	$30.94
WH-01	Upgrade to an indirect DHW	5%	$278.26	17.7	0	0	$10.99
WH-02	Upgrade commercial storage tank	59%	$107.07	35.9	0	0	$22.23
WH-03	Upgrade residential storage tank	3%	$51.06	14.9	0	0	$11.64
WI-01	Upgrade to double-pane, storm, low-e, wood/vinyl window	37%	$328.07	10.7	137	0	$21.57

			Mean per housing unit				
10-year simple payback screen Measure		Percent of buildings with opportunity	Measure cost	Annual gas savings (therms)	Annual electric savings (kWh)	Annual water savings (gallons)	Annual utility cost savings
AC-01	Upgrade window/wall A/C with energy star	71%	$32.61	0.0	42	0	$4.56
AP-01	Upgrade to energy star refrigerator	40%	$35.87	-0.8	39	0	$3.70
AP-02	Fuel switch from electric dryer to natural gas dryer	0%					
AP-03	Upgrade to energy star washing machine	80%	$76.68	3.3	19	2,431	$22.04
HT-01	Upgrade to high efficiency boiler	68%	$184.19	58.2	0	0	$36.11
HT-02	Upgrade to high efficiency furnace	1%	$500.00	64.5	0	0	$50.34
HT-03	Boiler reset cutout controls	31%	$53.12	17.2	0	0	$10.67
HT-04	Clean and tune-up furnace/boilers	24%	$32.25	8.5	0	0	$5.25
HT-05	Install vent damper	62%	$66.94	23.2	0	0	$14.38
HT-06	Adding pipe insulation on boilers pipes	57%	$14.30	10.5	0	0	$6.51
LT-01	Common lights: T-12 to T-8	37%	$21.10	-3.0	94	0	$6.65
LT-02	Common lights: HID to LED garage/exterior	12%	$100.87	0.0	286	0	$21.16
LT-03	Common lights: upgrade to CFLs	59%	$1.21	-8.0	225	0	$15.27
LT-04	Exit lights: upgrade to LECs	7%	$21.92	-3.2	98	0	$6.83
LT-10	Controls: 24/7 or switch to occupancy sensors	6%	$15.23	-3.6	114	0	$8.04
LT-11	Controls: exterior photocells	5%	$8.59	0.0	20	0	$1.45
LT-20	In-unit lights: T-12 to T-8	0%					
LT-21	In-unit lights: Incand to CFLs	98%	$30.26	-14.6	432	0	$35.78
SH-06	Add programmable t-stats	1%	$75.00	11.1	0	0	$8.68
WA-01	Install kitchen and/or bath aerators	58%	$3.80	9.6	13	2,262	$24.62
WA-03	Install low-flow showerheads	83%	$9.60	14.2	30	2,493	$30.94
WH-01	Upgrade to an indirect DHW	0%					
WH-02	Upgrade commercial storage tank	59%	$107.07	35.9	0	0	$22.23
WH-03	Upgrade residential storage tank	3%	$51.06	14.9	0	0	$11.64
WI-01	Upgrade to double-pane, storm, low-e, wood/vinyl window	0%					

5-year simple payback screen			Mean per housing unit				
Measure		Percent of buildings with opportunity	Measure cost	Annual gas savings (therms)	Annual electric savings (kWh)	Annual water savings (gallons)	Annual utility cost savings
AC-01	Upgrade window/wall A/C with energy star	0%					
AP-01	Upgrade to energy star refrigerator	0%					
AP-02	Fuel switch from electric dryer to natural gas dryer	0%					
AP-03	Upgrade to energy star washing machine	75%	$61.23	3.3	16	2,364	$21.19
HT-01	Upgrade to high efficiency boiler	33%	$165.96	69.1	0	0	$42.83
HT-02	Upgrade to high efficiency furnace	0%					
HT-03	Boiler reset cutout controls	17%	$37.84	17.8	0	0	$11.01
HT-04	Clean and tune-up furnace/boilers	9%	$18.63	8.3	0	0	$5.13
HT-05	Install vent damper	34%	$59.18	26.7	0	0	$16.57
HT-06	Adding pipe insulation on boilers pipes	57%	$14.30	10.5	0	0	$6.51
LT-01	Common lights: T-12 to T-8	35%	$21.56	-3.1	98	0	$6.92
LT-02	Common lights: HID to LED garage/exterior	2%	$103.37	0.0	894	0	$65.29
LT-03	Common lights: upgrade to CFLs	59%	$1.21	-8.0	225	0	$15.27
LT-04	Exit lights: upgrade to LECs	7%	$21.92	-3.2	98	0	$6.83
LT-10	Controls: 24/7 or switch to occupancy sensors	5%	$15.05	-4.5	143	0	$10.10
LT-11	Controls: exterior photocells	0%	$6.62	0.0	21	0	$1.47
LT-20	In-unit lights: T-12 to T-8	0%					
LT-21	In-unit lights: Incand to CFLs	98%	$30.26	-14.6	432	0	$35.78
SH-06	Add programmable t-stats	0%					
WA-01	Install kitchen and/or bath aerators	58%	$3.80	9.6	13	2,262	$24.62
WA-03	Install low-flow showerheads	83%	$9.60	14.2	30	2,493	$30.94
WH-01	Upgrade to an indirect DHW	0%					
WH-02	Upgrade commercial storage tank	26%	$79.97	43.4	0	0	$26.92
WH-03	Upgrade residential storage tank	3%	$51.06	14.9	0	0	$11.64
WI-01	Upgrade to double-pane, storm, low-e, wood/vinyl window	0%					

2-year simple payback screen			Mean per housing unit				
Measure		Percent of buildings with opportunity	Measure cost	Annual gas savings (therms)	Annual electric savings (kWh)	Annual water savings (gallons)	Annual utility cost savings
AC-01	Upgrade window/wall A/C with energy star	0%					
AP-01	Upgrade to energy star refrigerator	0%					
AP-02	Fuel switch from electric dryer to natural gas dryer	0%					
AP-03	Upgrade to energy star washing machine	0%					
HT-01	Upgrade to high efficiency boiler	0%	$114.66	98.1	0	0	$60.81
HT-02	Upgrade to high efficiency furnace	0%					
HT-03	Boiler reset cutout controls	3%	$8.66	16.6	0	0	$10.29
HT-04	Clean and tune-up furnace/boilers	1%	$4.48	6.7	0	0	$4.17
HT-05	Install vent damper	0%	$40.95	36.8	0	0	$22.80
HT-06	Adding pipe insulation on boilers pipes	31%	$8.54	9.4	0	0	$5.85
LT-01	Common lights: T-12 to T-8	5%	$14.61	-4.1	126	0	$8.77
LT-02	Common lights: HID to LED garage/exterior	1%	$78.48	0.0	1028	0	$75.88
LT-03	Common lights: upgrade to CFLs	59%	$1.21	-8.0	225	0	$15.27
LT-04	Exit lights: upgrade to LECs	0%					
LT-10	Controls: 24/7 or switch to occupancy sensors	2%	$16.45	-6.8	217	0	$15.33
LT-11	Controls: exterior photocells	0%					
LT-20	In-unit lights: T-12 to T-8	0%					
LT-21	In-unit lights: Incand to CFLs	98%	$30.26	-14.6	432	0	$35.78
SH-06	Add programmable t-stats	0%					
WA-01	Install kitchen and/or bath aerators	58%	$3.80	9.6	13	2,262	$24.62
WA-03	Install low-flow showerheads	83%	$9.60	14.2	30	2,493	$30.94
WH-01	Upgrade to an indirect DHW	0%					
WH-02	Upgrade commercial storage tank	5%	$47.35	57.8	0	0	$35.83
WH-03	Upgrade residential storage tank	0%					
WI-01	Upgrade to double-pane, storm, low-e, wood/vinyl window	0%					