The City of New York
Mayor Bill de Blasio

Urban Green

NYU CUSP

New York City's Energy and Water Use 2014 and 2015 Report

October 2017

Urban Green Council is the New York Affiliate of the U.S. Green Building Council. Our mission is to transform NYC buildings for a sustainable future.

We believe the critical issue facing the world today is climate change. Our focus on climate change requires us to improve energy and other resource efficiencies in buildings, creating a more resilient, healthy and affordable city for all New Yorkers.

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Executive Summary

Climate change is a reality, but there is much that we can do to address it at a local level—especially when it comes to buildings.

That's why in 2009 the City of New York ("City") adopted ambitious, long-term carbon-reduction goals and policies to cut greenhouse gas pollution. The Greener, Greater Buildings Plan (GGBP) targets energy and water use from all the city's large buildings, which account for 23 percent of New York City's overall greenhouse gas emissions.

The GGBP requires owners of buildings 50,000 square feet and larger to annually report their energy and water use, a practice known as benchmarking (Local Law 84 of 2009). Studies have shown that the simple exercise of reporting can raise building owner awareness and often results in significant reductions in energy and water use.[1] Equally important, the information collected from each building allows the City and property owners to understand trends and opportunities. This is why benchmarking is growing in popularity: More than 20 cities across the United States—large ones like Los Angeles and Chicago, as well as smaller ones like Pittsburgh and Orlando—now employ mandates similar to New York's.

New York City's benchmarking data now spans six years, showing significant declines in large-building energy use and greenhouse gas emissions between 2010 and 2015. Over that period, emissions from more than 4,200 regularly benchmarked properties fell by almost 14 percent, while energy use fell by more than 10 percent (Figure 1).

This is encouraging news. While these six years imply a promising trend, there is still much work to be done in order to reach the City's goal to reduce greenhouse gases 80 percent by 2050. Future reductions will be tougher to achieve, since half of these declines are due to a cleaner electrical grid and more efficient district steam generation. Building owners will have to dig deeper into energy efficiency to keep up the pace now that most electricity generation from coal and oil has transitioned to natural gas and renewables in New York State.[2]

It is difficult to know whether these large-building declines reflect a general trend in existing buildings of all sizes. As noted above, the GGBP benchmarking requirement

Air conditioning is now responsible for 9 percent of large buildings' source energy use, a number that is expected to grow.

applies only to buildings 50,000 square feet or larger. This is about 47 percent of New York City floor space or roughly 2.3 billion private square feet, and another 450 million municipal square feet. However, more data is on its way. Last year, the GGBP was expanded to include buildings 25,000 square feet and larger by 2018, adding another 340 million square feet into coverage. Come 2019, we will be able to report on nearly 60 percent of New York City's square footage. That's a stunning achievement for the largest city in the country—a city of an approximated (and mind-boggling) 1 million buildings.

How Buildings Use Energy

This report focuses on the multi-family and office buildings that comprise 83 percent of the city's total benchmarked area and use almost 90 percent of benchmarked energy. Hotels, hospitals, warehouses and universities are the next four largest building categories and account for 7 percent of the total benchmarked area.

Each year, roughly 10 percent of benchmarked buildings also undergo energy audits. Information about building characteristics and energy systems is included in the audit data. In addition to knowing how much energy and water large buildings use overall, we now have auditor estimates on how much each building system uses.

Auditors analyze building energy and water use in order to identify areas for improvement for building owners. This information is also shared with the City, which now has three years' worth of auditing data, covering 30 percent of the city's large buildings. As more of this audit data becomes available, we will better understand how buildings use and waste vital resources, and more easily identify areas for improvement.

This report focuses on three areas: domestic hot water (DHW), metering of electricity and cooling. (Last year's report focused on the single largest energy end-use—space heating—and on areas where space-heating efficiencies can be found. For that reason, space heating receives less attention in this report.)

Based on this year's analysis, we observed the following:

Hot Water Heating Efficiency

Among audited multifamily buildings, almost 90 percent of the floor area is heated by a boiler that works double duty as a domestic hot water heater. If not controlled properly during the summer months, these boilers can waste significant amounts of fuel by running at full capacity. Pre-war multifamily buildings with linked systems were observed to consume over 20 percent more fuel than buildings with separate DHW systems. Across all multifamily buildings, auditors frequently suggested separating heating boilers from linked DHW systems.

Electricity Use Feedback for Tenants

Most of New York City's multifamily tenants are directly metered for electricity. That is, each month they pay their electric utility for the exact amount of electricity they consumed the previous month. Some buildings, however, use master metering—usually metering the entire building on a single meter and then dividing the cost among tenants based on provisions in their leases.

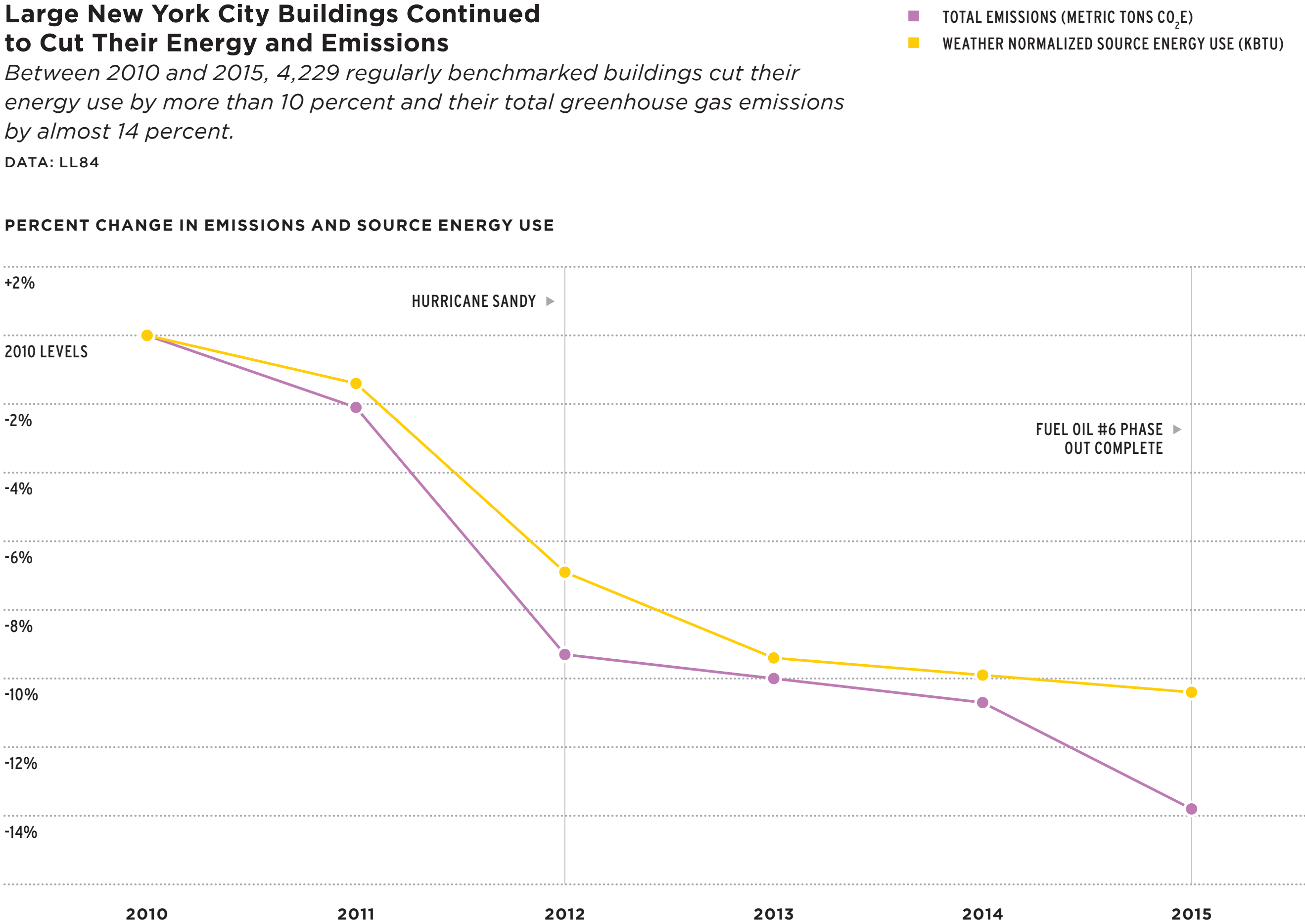
Not surprisingly, the benchmarking data indicates that direct-metered multifamily buildings consumed less electricity per square foot than master-metered buildings. This likely has to do with the circumstances of tenants in master-metered buildings: They don't know how

FIGURE 1

Large New York City Buildings Continued to Cut Their Energy and Emissions

Between 2010 and 2015, 4,229 regularly benchmarked buildings cut their energy use by more than 10 percent and their total greenhouse gas emissions by almost 14 percent.

DATA: LL84



much electricity they use and don't have any direct incentives to reduce consumption.[3]

Effective Cooling Systems

Air conditioning is now responsible for 9 percent of large buildings' source energy use, a number that is expected to grow. For example, only 26 percent of New York City's 11,500 public school classrooms are currently air conditioned, but the City recently pledged to provide cooling in all classrooms by 2022.[4] As more spaces become air conditioned, and the City continues to pursue its emissions goals, understanding the observed differences in energy use between central systems and distributed cooling systems will assume increasing importance. The former includes chillers and direct expansion units. The latter includes window air conditioners and packaged terminal air-conditioners (PTACs).

This is especially true because the City's current data on air conditioning efficiency presents certain paradoxes. Central system equipment is almost always more efficient than distributed systems per unit of cooling produced.[5] However, the auditing data show that large buildings with distributed cooling systems use less electricity per square foot than those with central systems.

Meeting the 80 by 50 Goal

As discussed, New York City has committed to reducing greenhouse gas emissions 80 percent from 2005 levels by 2050. To meet this vital goal, the city's largest source of greenhouse gas emissions—its building sector—must be a driving force behind reductions.

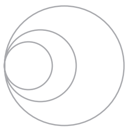
The good news is that large, benchmarked buildings—which account for more than 40 percent of all building emissions—are headed in the right direction. With this report, we can see where emissions are coming from and the opportunities for continued reductions.

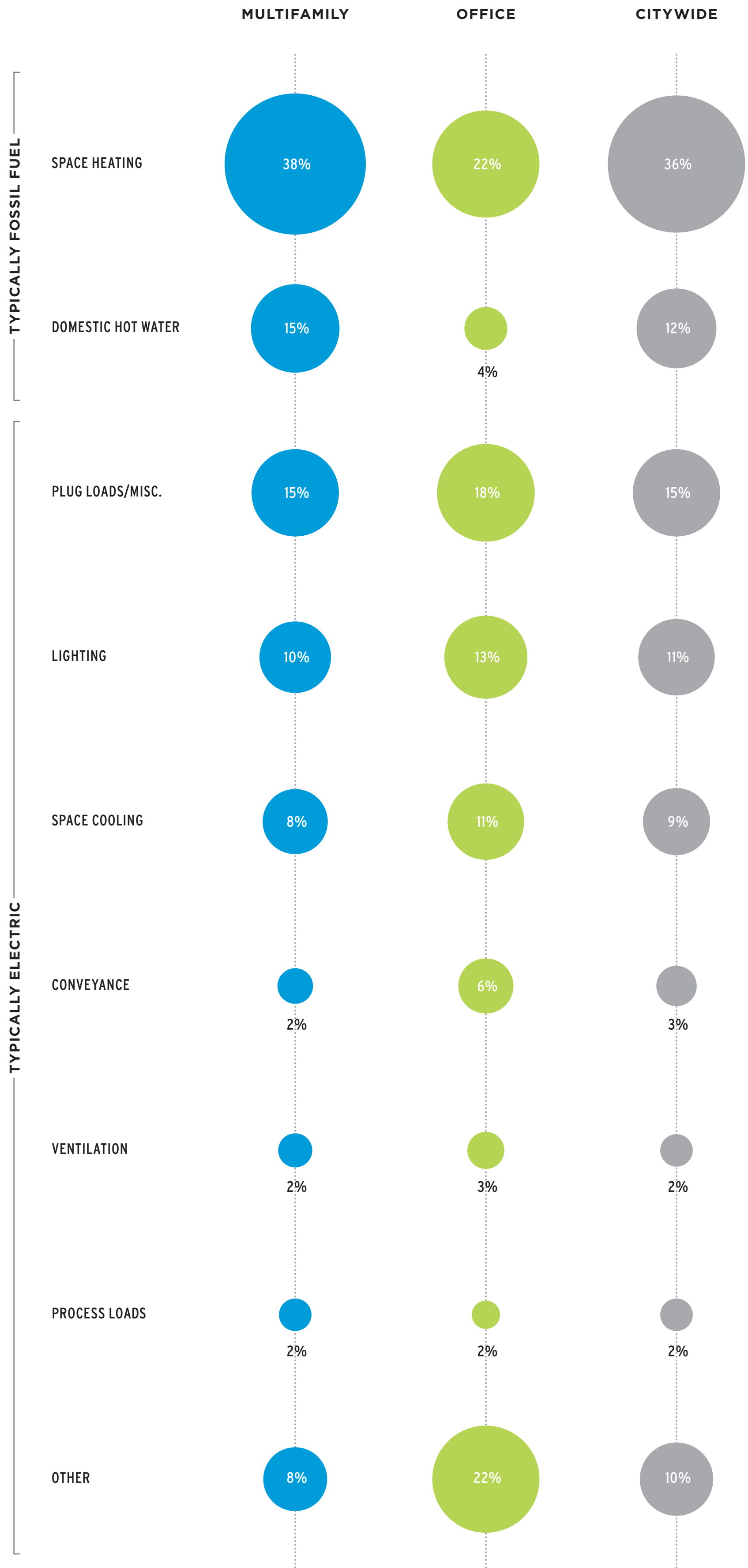
FIGURE 2

Energy End Use Breakdown by Sector and Citywide

Space heating, plug loads, and domestic hot water (DHW) were responsible for the most energy use in New York City's large buildings.

DATA: LL84 & LL87





About this Report

This is the City of New York's fifth report analyzing data collected from Local Law 84 of 2009 and its second report analyzing data from Local Law 87 of 2009. This report focuses on 2014 and 2015 energy and water usage reported in 2015 and 2016 respectively. Both laws are part of the City's Greener, Greater Buildings Plan, designed to reduce greenhouse gas emissions from New York City's largest buildings.

The report was written and designed by Urban Green Council at the direction of the Mayor's Office of Sustainability. Urban Green Council and Urban Intelligence Lab of New York University's Center for Urban Science and Progress (NYU CUSP) performed the data analysis and developed the graphs and charts included in this report.

The individual contributors from each group are included in the report's Acknowledgements.

Come 2019, we will be able to report on nearly 60 percent of New York City's square footage.

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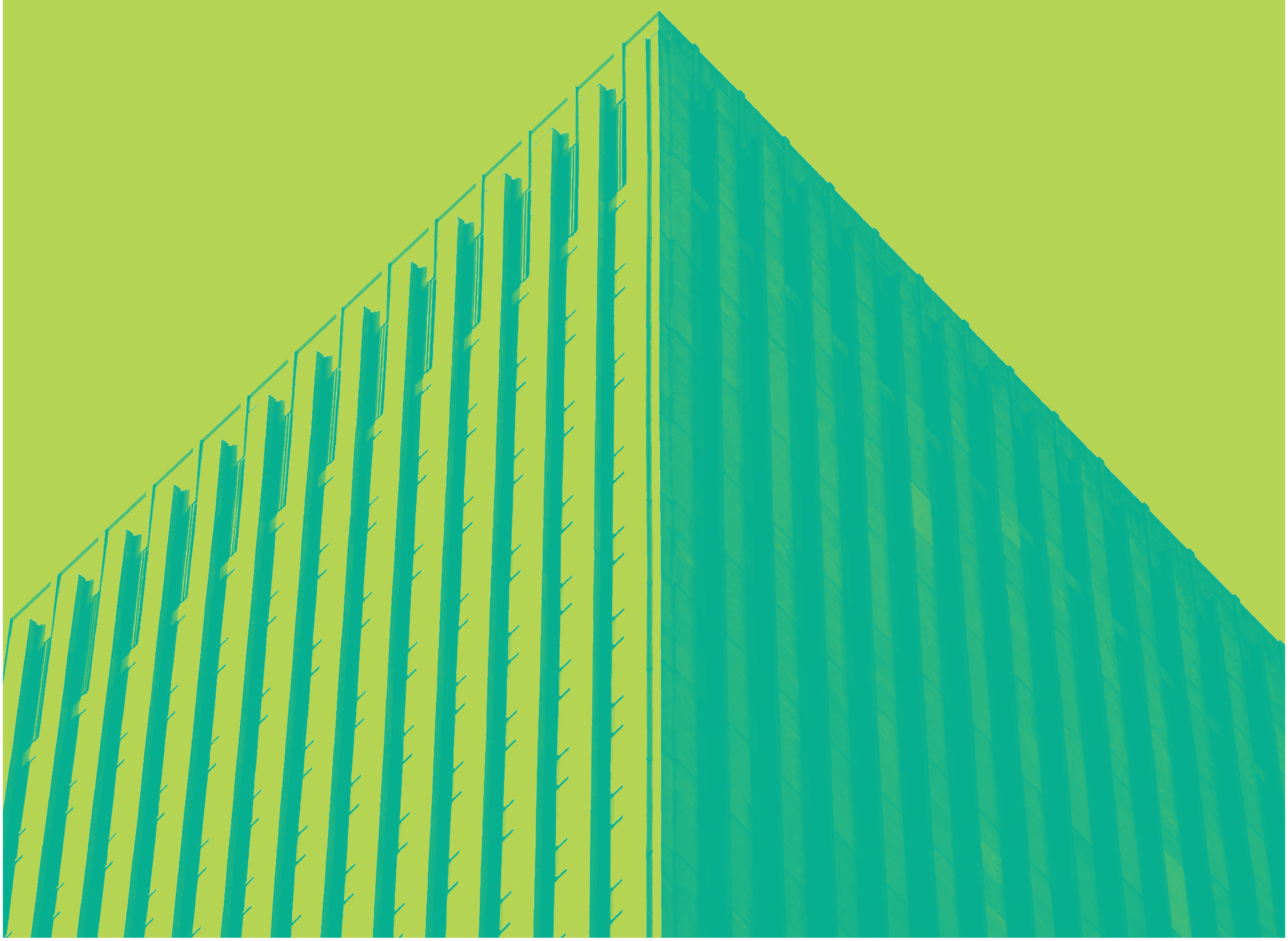


Background

Since 2010, the City of New York has required owners and managers of buildings 50,000 square feet and up to report their buildings' energy and water use each year.

This practice, called "benchmarking," is mandated under New York City's Greener, Greater Buildings Plan (GGBP) and the requirement is called The Benchmarking Law (Local Law 84 of 2009, LL84). Its goal? To reduce greenhouse gas emissions from New York City's largest source: the energy used in buildings.

Local Law 87 of 2009 (LL87), another part of the GGBP, requires every building covered by the Benchmarking Law to undergo an energy audit once every 10 years. Energy auditing provides important information that can help the City and building owners understand and reduce their energy use. The audits include: an inventory of buildings' energy-using equipment, such as light fixtures and boilers; a set of recommended energy conservation measures (ECMs) that can cut buildings' energy use and an estimated breakdown of energy use by activity, such as heating or lighting. The first round of building audits, in about 10 percent of the city's large buildings, were conducted in 2013. Each year since, another 10 percent—roughly 1,400 benchmarked buildings annually—has undergone this auditing process.

To help policymakers, building owners and concerned New Yorkers identify areas for improvement, this report examines benchmarking data from 2010 to 2015, from public and private buildings. It also explores auditing reports filed from 2013 through 2015, which cover slightly more than 4,000 of New York City's largest buildings—about 30 percent of the Big Apple's total.

Benchmarked Building Types

Among the city's large buildings, three kinds predominate: multi-family, office and municipal. New York City has mostly multifamily buildings. Office buildings comprise a fifth of the total benchmarked space, and municipal buildings, such as schools, hospitals, fire stations and other buildings owned and run by the City, comprise another fifth. Hotels, hospitals, warehouses, and many other types of buildings comprise the remainder. (These collectively are tagged as "Other" in this report's graphs and charts.)

Energy use is often reported in energy-use intensity (EUI), the amount of energy used per area. The median value—with half the

Multifamily and office buildings together consume the vast majority of the city's benchmarked source energy.

data points lying above it and half below—is most useful in describing how one building compares with its peers. The median EUI allows for comparison among different kinds of buildings and systems. Each of these terms is described in more detail in the Appendix.

Multifamily and office buildings together consume the vast majority of the city's benchmarked source energy: Benchmarked multifamily properties significantly outnumber offices, but offices use almost 50 percent more energy per square foot.

Understanding the Data

Where appropriate, data for individual building sectors is further described and categorized by building size: low-rise with seven or fewer floors; high-rise with eight or more floors; and very large, which are 500,000 square feet or more, regardless of floor count. The division at seven floors is common in New York City building analysis because 75 feet is the height at which a building is considered a high-rise and tends to have more complicated and centralized systems, such as elevators and elaborate ventilation.

Buildings are also categorized by age in this report, because different eras relied on distinct energy-using technologies. Pre-war buildings, built before 1940, include buildings from the 19th century. Post-war buildings were built from 1940 through the 1970s. Modern buildings are those built after 1980. The LL87 auditing data reflects these changes in technology. For example, central cooling systems were not widespread in residential buildings until the 1960s, so pre-war buildings typically use window and wall air conditioning (AC) units instead.

Greener Greater Building Plan Enacted

LL84: *Benchmarking buildings over 50,000 square feet*

LL85: *NYC Energy Code*

LL87: *Audits and retrocommissioning*

LL88: *Lighting upgrades and submetering*

Year 1

First year of benchmarking data shows large buildings use 45 percent of city-wide energy.

2008 | **2009** | **2010** | **2011** | **2012**

Benefits of Benchmarking

This report is not the only place in which much of this data can be found: Benchmarking Law data is publicly disclosed annually and available online, via the NYC Open Data platform located at opendata.cityofnewyork.us. Urban Green Council has also created a user-friendly website, www.metered.nyc, which enables users to search, compare and reference the energy and water use of individual buildings over time.

Making benchmarking data available to the public gives owners an incentive to enhance their buildings' energy and water performance, while also spurring data-driven decision-making in the real estate market. This report supplements the publicly available data by offering a comprehensive look into the benchmarking building type and energy data available to date.

In particular, the analyses in this report provide:

- data on the prevalence of individual energy systems and their use in audited buildings;
- historical and sector comparisons of large-building energy use;
- ways to apply findings that could further reduce greenhouse gas emissions from New York City's large buildings;
- recommended improvements to the Benchmarking Law.

Making benchmarking data available to the public gives owners an incentive to enhance their buildings' energy and water performance.

Year 4

First year of auditing data shows energy use at the building system level.

2013

Year 6

Sixth year of data shows a 10 percent drop in source energy use.

2014

Greener Greater Building Plan Expansion Enacted

LL132: *Submetering expansion*

LL133: *Benchmarking expansion*

LL134: *Lighting expansion*

2015

Year 8

Expansion will add 342 million square feet to 2017 data, meaning NYC will benchmark 57 percent of its area.

2016

2017

/03

Year Six Results

The 2015 data analyzed in this report is the most comprehensive benchmarking information that the City of New York has collected to date.

More than 90 percent of the private buildings required to submit 2015 use did so, providing nearly 11,000 entries sufficiently detailed to be included in this analysis.

Not only does this report contain the most in-depth analysis so far, it also contains a series of firsts:

- the first benchmarking data from public buildings;
- the first ENERGY STAR score rankings for multifamily buildings (more on these ENERGY STAR rankings below);
- the first integration of data from benchmarking with data available in the City's Greenhouse Gas Inventory—creating a more accurate picture of how New York's large buildings contribute to overall city greenhouse gas emissions.

This report also breaks energy and water use down by building category. Doing so can help the City, utilities, building owners, community organizations, entrepreneurs and other innovators identify buildings and technologies that use less energy without compromising functionality. These best practices can be used to improve efficiency in large buildings and reduce the city's carbon footprint.

Building Characteristics

Main Sectors

By square footage, the three largest sectors of benchmarked buildings are multifamily housing, offices and K-12 public schools. Multifamily buildings occupied 55 percent of the total benchmarked space; offices occupied 18 percent; and K-12 public schools occupied 7 percent. Other property types, referred to in this report as either private or public "Other," made up the remaining 20 percent of benchmarked area (Figure 3) and are further broken down into sub sectors on page 14.

Municipal buildings are maintained and benchmarked by the Department of Citywide Administrative Services (DCAS), and for the first time, more than 2,000 are included in this report. The building types and their energy use are described in more detail on page 15.

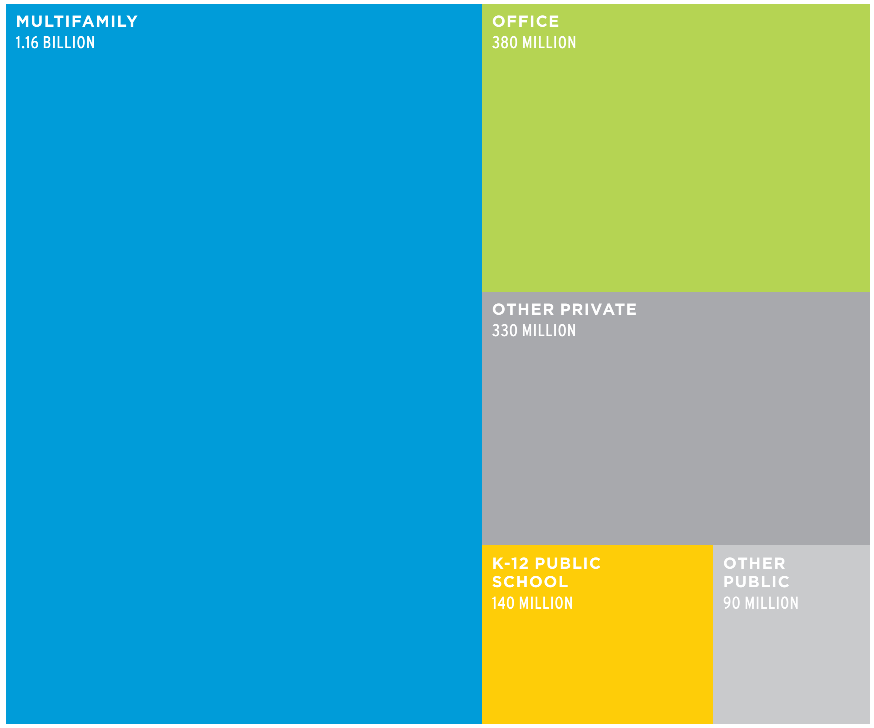
FIGURE 3

2015 Floor Area by Type for Public and Private Buildings

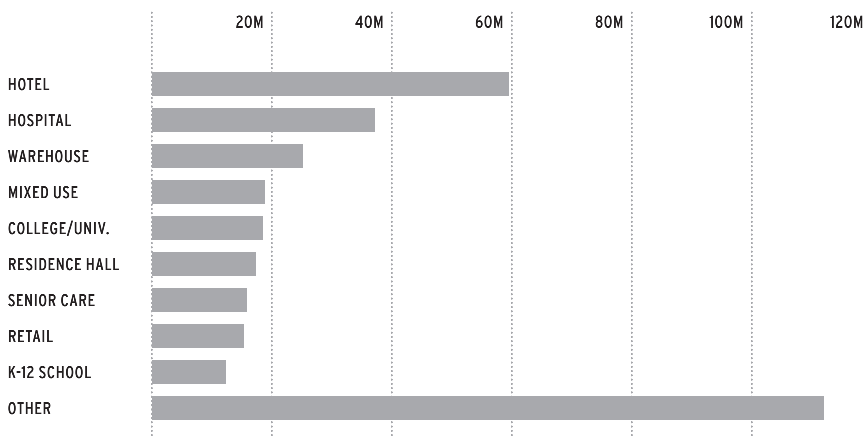
Multifamily buildings occupied the majority of benchmarked space, followed by office buildings, and public, K-12 schools. Hotels and private hospitals accounted for more area than the next five building types combined.

DATA: LL84 PUBLIC AND PRIVATE DATA

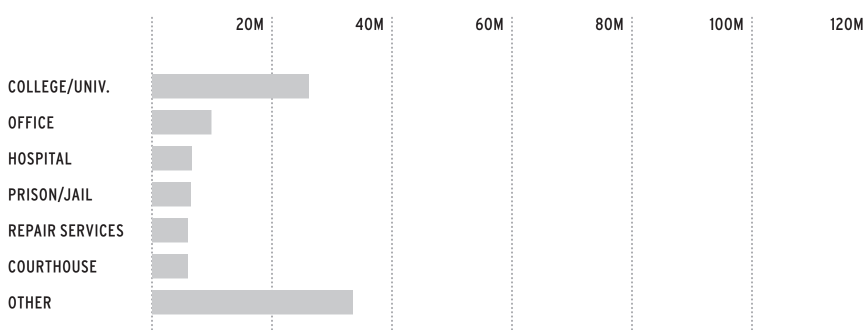
TOTAL GROSS FLOOR AREA (SF)



OTHER PRIVATE: TOTAL GROSS FLOOR AREA (SF)



OTHER PUBLIC: TOTAL GROSS FLOOR AREA (SF)



Sub Sectors

Of the one-fifth of benchmarked floor area that is categorized as "Other," almost 80 percent was made up of private buildings, including hotels, hospitals and warehouses. Public buildings, such as hospitals, repair services and garages, made up the rest of the "Other" buildings. In past years, benchmarking compliance rates for "Other" properties weren't high enough to allow for their inclusion in this report. But with the 2015 reporting year, these rates improved considerably, allowing for a more complete analysis.

In the "Other" category, hotels were the largest single property type (Figure 3), occupying 3 percent of New York City's private benchmarked floor space. New York City is one of the country's largest hotel markets—and that market is growing faster here than anywhere else in the U.S. In 2016, construction began on more than 15,000 new hotel rooms. These new rooms will increase the city's hotel capacity by 14 percent and could add 8 million square feet to one of the most energy intensive building use types.[6]

Private hospitals, occupying 2 percent of benchmarked floor area, made up the next-largest "Other" building type. Non-refrigerated warehouses, mixed-use buildings, private universities and private dormitories each occupied 1 percent of benchmarked area. Public universities occupied another 1 percent and, after K-12 schools, were the largest public-building type.

For the first time, more than 2,000 municipal buildings are included in this report.

Municipal Buildings

This report analyzed not only private sector buildings, but also the roughly 2,300 municipal properties that make up 11 percent of New York City's benchmarked area. About 2,000 of those buildings submitted enough data to be included in this report's analysis. Under LL84, the City must benchmark public buildings greater than or equal to 10,000 square feet (as opposed to 50,000 square feet for private sector buildings, prior to the recent legislative change).

Among the different types of municipal buildings, there were drastically different energy-use intensities (EUIs), depending on variables such as buildings' operating hours and the technologies used in these facilities. The Department of Citywide Administrative Services, which operates and benchmarks City buildings, intends to publish a report on the progress of various City agencies in reducing energy consumption.

Public K-12 schools comprised 61 percent of the municipal building benchmarked area. These schools were relatively low energy users, responsible for only one-third of the energy used in public benchmarked buildings. Reporting a median source EUI of only 112 kBtu/sf, public schools used 15 percent less energy than private schools. Other public-sector building types used considerably more energy: museums, for instance, reported a median source EUI of 354 kBtu/sf; public hospitals reported a median source EUI of 379 kBtu/sf. The City's 76 police stations used less than 2 percent of benchmarked municipal building energy, but were energy intensive, with a median source EUI of 286 kBtu/sf.

Refrigeration and lighting drive energy use in supermarkets, while in hospitals medical equipment, laundry and computers create tremendous hot water, ventilation and plug loads.

Building Size and Property Count
In New York City, only 5 percent of private buildings occupy more than 500,000 square feet. Together, these roughly 550 buildings represent 30 percent of private benchmarked area and, as a result, have a disproportionate impact on energy and water use in the city (Figure 4). The 3 percent of multi-family buildings that were larger than 500,000 square feet occupied a combined one-fifth of benchmarked multifamily area and 12 percent of the city's private benchmarked floor space. They represented only 20 percent of benchmarked office buildings but occupied 60 percent of office benchmarked area and 13 percent of the city's private benchmarked floor space. It is much more common for office buildings to be large (20 percent are over 500,000 square feet) than it is for multifamily buildings (3 percent). But because there are so many more multifamily buildings, the portion of the city's overall private benchmarked floor space with very large office and multifamily buildings is almost the same.

Most large buildings were more moderate in size: Fifty-four percent of New York City's benchmarked properties occupied fewer than 100,000 square feet apiece; together, these buildings accounted for one-fifth of the benchmarked floor area. The other half of the benchmarked area came from buildings between 100,000 and 500,000 square feet in size.

Breaking this information down further, multifamily buildings tended to be smaller than office buildings in general. Eighty-five percent of multifamily buildings occupied fewer than 200,000 square feet, with a median size of 87,000 square feet. Office buildings were typically twice as big, with a median size of 162,000 square feet.

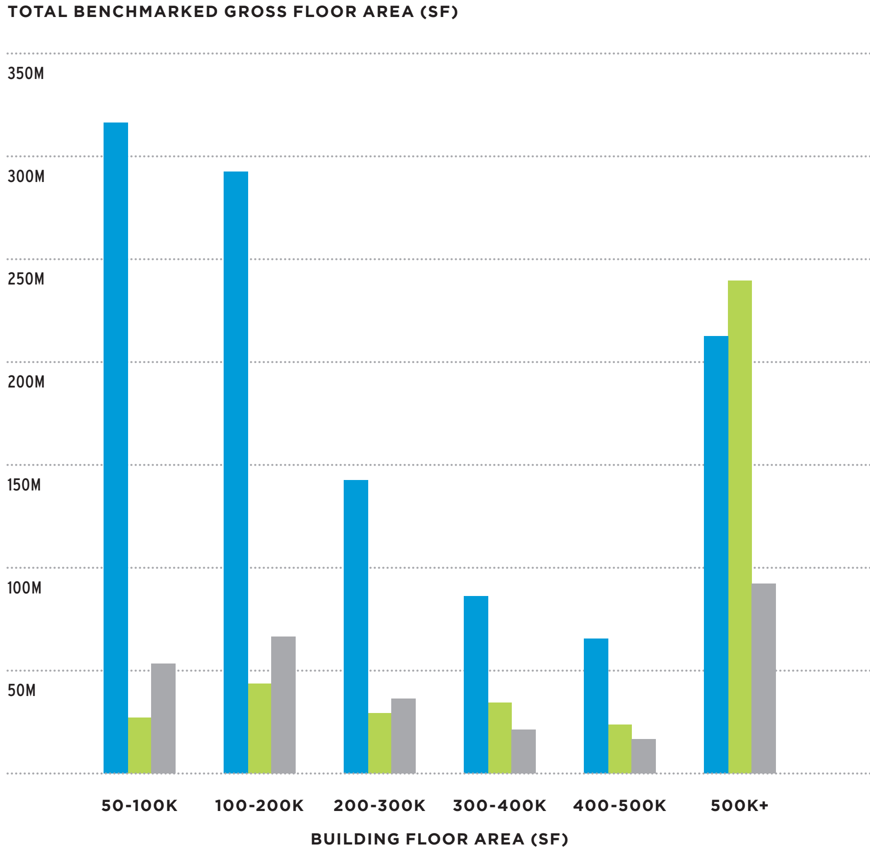
2015 Energy Use

Energy Use by Property Type
Multifamily and office properties—the most common in the benchmarked data set—used 70 percent of all benchmarked source energy (Figure 5). The office sector was the more energy intensive of the two, using 50 percent more energy per square foot than the multifamily building sector. The median source EUI for office buildings was 186 kBtu/sf; for multifamily buildings, it was 125 kBtu/sf. Office buildings tend to use more electricity for cooling, lighting and appliances than do multifamily buildings, which likely explains much of this difference (Figure 2). Hotels are even more energy intensive and used 237 kBtu/sf, due to their many amenities and high hot water load.

While small in size and number, the most energy-intensive sectors were supermarkets and hospitals. They used much more energy per square foot but offices and multifamily buildings used more overall. Refrigeration and lighting drive energy use in supermarkets, while medical equipment, laundry and computers in hospitals create tremendous hot water, ventilation and plug loads. Supermarkets and hospitals still represented only 2.5 percent of total, benchmarked energy consumption.

Energy Use by Building Size and Age
The age and size of office and multi-family buildings can help predict energy use. Larger and newer buildings tended to use more energy per square foot. In fact, multifamily buildings built after 1970 that are larger than 200,000 square feet used an average of 24 percent more energy than the typical multifamily building (Figure 6).

There are many reasons why building age impacts energy use. These include evolving building codes, the use of new, energy-intensive technologies and changes in construction materials and techniques over time. Tenants in newer office buildings may use



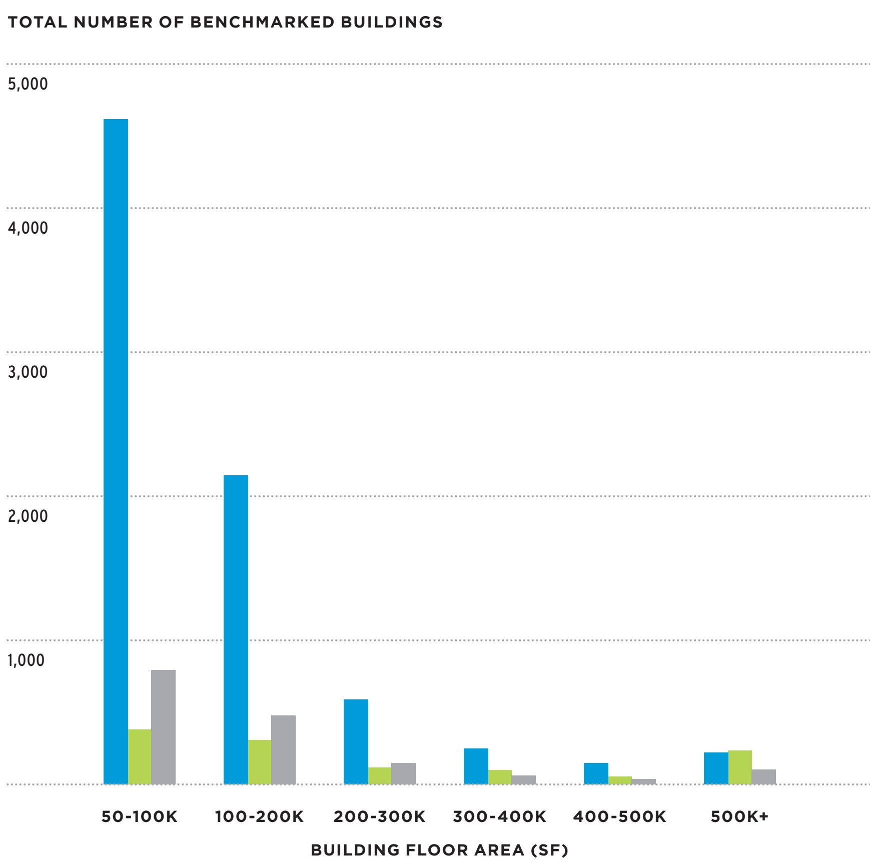


FIGURE 4

2015 Benchmarked Building Count and Gross Floor Area by Building Size and Sector

While most benchmarked buildings were smaller than 100,000 square feet, the majority of benchmarked office floor area was located in buildings larger than 500,000 square feet.

DATA: LL84

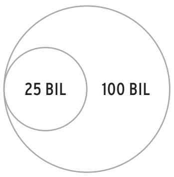
- MULTIFAMILY
- OFFICE
- OTHER

FIGURE 5

Total 2015 Energy Use and Intensity by Sector

Supermarkets and hospitals used the most energy per square foot, but office and multifamily buildings consumed the most energy overall.

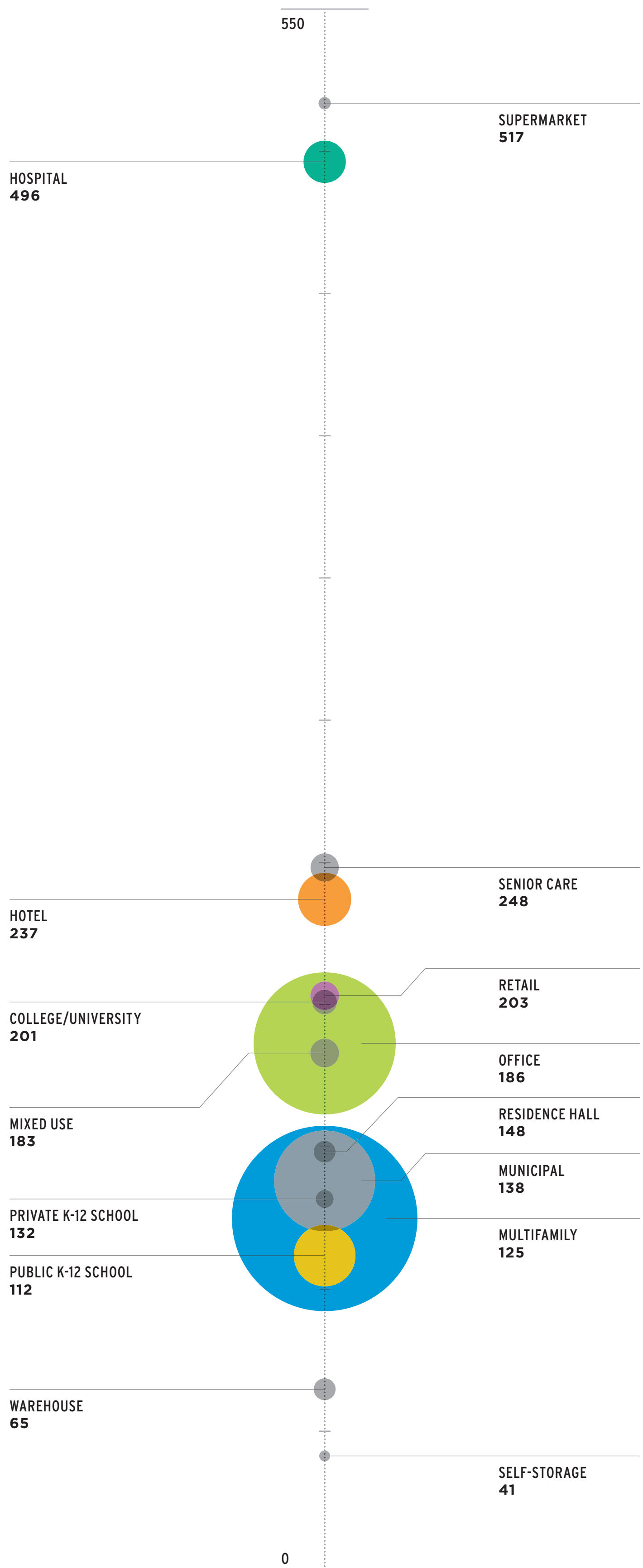
DATA: LL84



NUMBER OF BENCHMARKED BUILDINGS

MULTIFAMILY	8,034
MUNICIPAL	2,035
OFFICE	1,212
PUBLIC K-12 SCHOOL	1,140
HOTEL	253
WAREHOUSE	176
SENIOR CARE	113
RESIDENCE HALL	98
RETAIL	93
SELF-STORAGE	86
PRIVATE K-12 SCHOOL	78
MIXED USE	72
COLLEGE/UNIVERSITY	54
HOSPITAL	44
SUPERMARKET	17

MEDIAN WEATHER NORMALIZED SOURCE EUI (KBTU/SF)



MEDIAN EUI BY FLOOR AREA AND DECADE BUILT

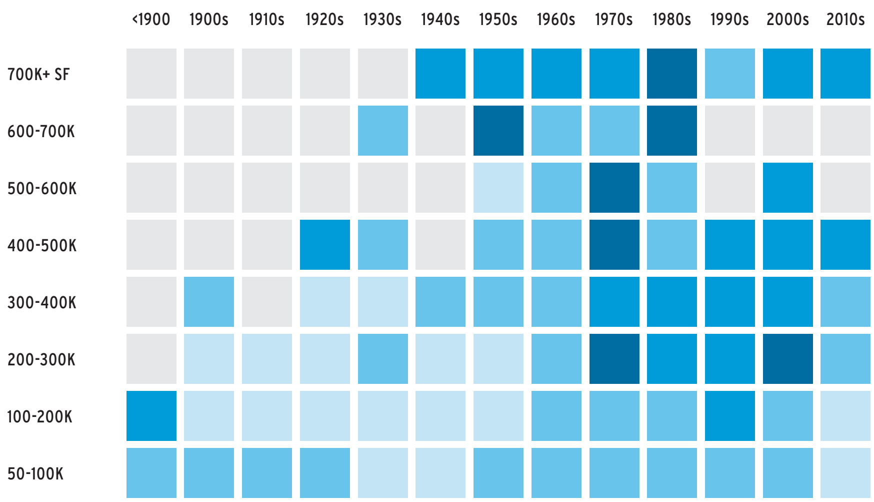


FIGURE 6

2015 Multifamily Energy Use Intensity by Building Age and Size

Per square foot, very large multifamily buildings built in the 1970s and 1980s used more energy than other large residences.

DATA: LL84

WEATHER NORMALIZED SOURCE EUI (KBTU/SF)

- 160+
- 140-160
- 120-140
- 100-120
- NOT ENOUGH DATA

MEDIAN EUI BY FLOOR AREA AND DECADE BUILT

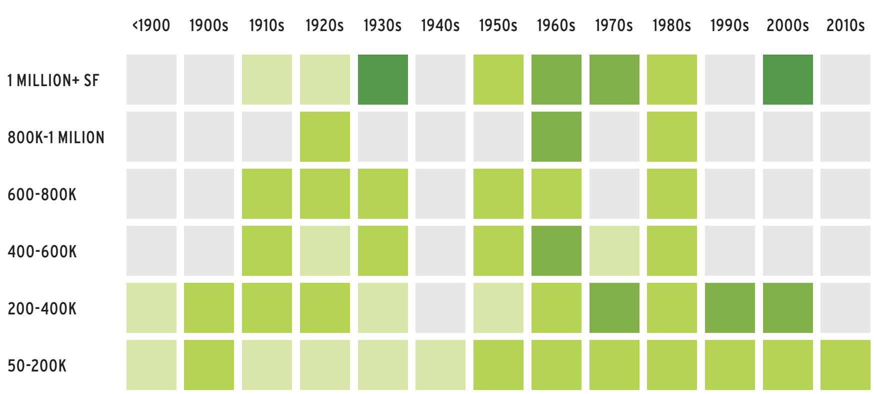


FIGURE 7

2015 Office Energy Use Intensity by Building Age and Size

Larger and newer office buildings used more energy per square foot than older and smaller offices.

DATA: LL84

WEATHER NORMALIZED SOURCE EUI (KBTU/SF)

- 275+
- 225-275
- 175-225
- 125-175
- NOT ENOUGH DATA

The multifamily sector consumed a total of 36 billion gallons of water in 2015, over 13 times the amount that hotels used.

more energy than the norm, with longer operating hours, denser work stations or the presence of trading floors. Older buildings tend to use less electricity than newer buildings. Newer buildings tend to have energy-intensive mechanical ventilation systems, while older buildings rely on natural ventilation for airflow. Newer multifamily buildings are also more likely to have elevators, fitness centers and other amenities that increase energy use.[7]

There were a few exceptions to this trend, but they tended to occur in categories with relatively few buildings. For example, 1950s buildings between 600,000 and 700,000 square feet used more energy. The majority of these buildings are NYCHA developments that use 40 percent or more energy per square foot than the typical multifamily building.[8] See Section 6, Policy Perspectives, to learn more about what NYCHA is doing to improve its building stock.

Age and size are also strong predictors of energy usage in benchmarked office buildings. The same factors explained above play into this trend, seen in Figure 7. Exceptions to this trend are the extremely large, art-deco sky-scrapers built in the 1930s, which were originally constructed to handle communications over telephone wires and some now house energy-intensive tenants such as data centers, financial offices and telecommunications firms. Not surprisingly, their median source EUI was very high—358 kBtu/sf—almost double that of typical office buildings.

The only other group of buildings that reported a median EUI higher than 300 kBtu/sf were buildings larger than one million square feet that were built in the 2000s. Data centers were responsible for 13 percent of the energy consumption in this group. Offices built in the last 20 years tended to be high energy users—a trend that needs further investigation, particularly regarding differences in tenant versus base building energy use.

2015 Water Use

In 2015, New York City's large private buildings used more than 53 billion gallons of water—enough to fill the Central Park Reservoir 50 times over.[9] That amount was also two-and-a-half times the water use reported for 2013 in our last report. Because there was less water-use data available from 2013, this increase is a result of more buildings reporting in 2015, rather than an increase in overall use.

Thanks to the City's rollout of Automatic Meter Reading (AMR) sensors, reporting on water consumption has improved dramatically since the last report. Twice as many buildings submitted data with sufficient enough detail for us to analyze their water use in 2015 compared with 2013 (6,500 vs 3,200).

The 2015 data confirms that multifamily and office buildings were the biggest water users in the city, consuming 86 percent of benchmarked water. Multifamily buildings used 51 gal/sf, while office buildings used 20 gal/sf. Hospitals and hotels were the most intensive water users, with hospitals reporting 82 gal/sf and hotels using 75 gal/sf (Figure 8). Some reasons hospitals and hotels used water so intensively were because of on-site laundry, food preparation and higher occupant density.

While hospitals and hotels used water more intensively, multifamily buildings and offices consumed the lion's share of benchmarked water.

ENERGY STAR® Scores

The federal government's ENERGY STAR program, which promotes energy efficiency, ranks the energy performance of large and mid-sized buildings by comparing them to similar buildings nationwide. Each building's efficiency is ranked on a scale of 1 to 100, with a higher score indicating better performance. New York City's buildings, particularly large office buildings, performed

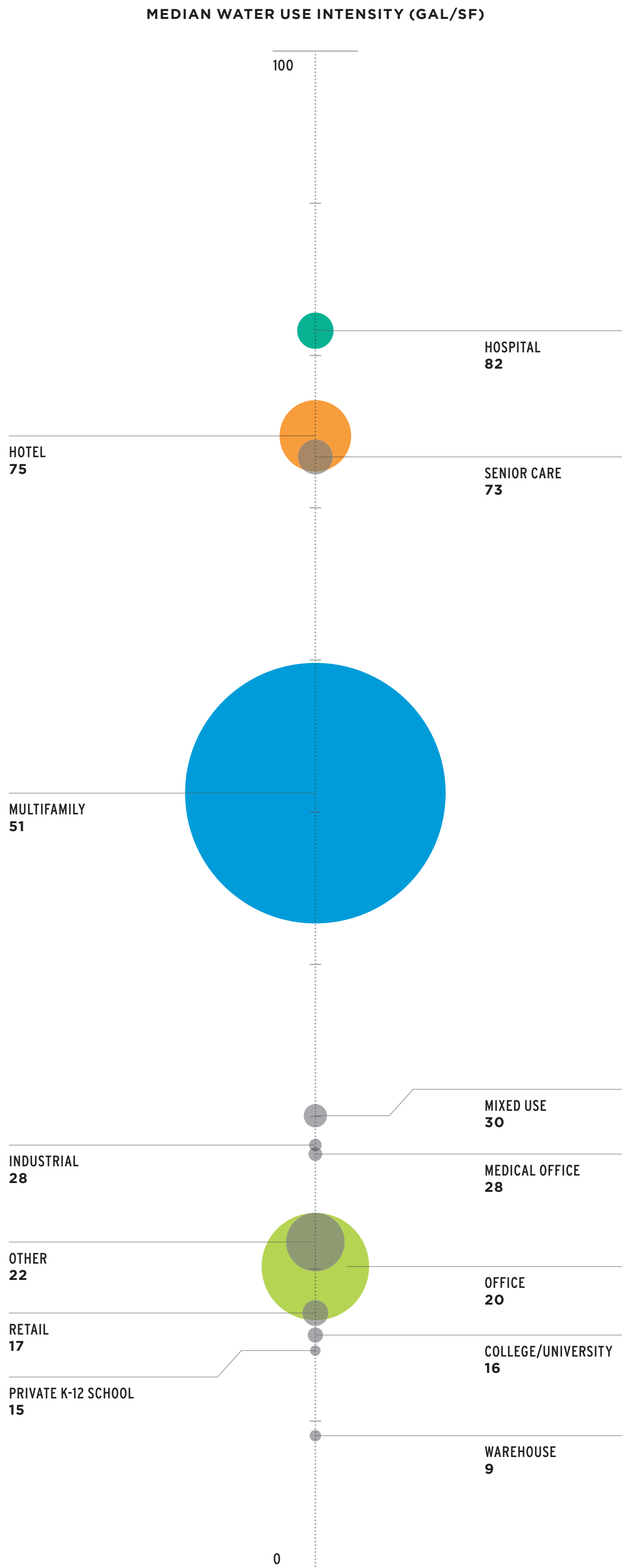


FIGURE 8

Total 2015 Water Use and Intensity by Sector

Hospitals and hotels used the most water per square foot; office and multifamily buildings consumed the largest amount of water, in total.

DATA: LL84

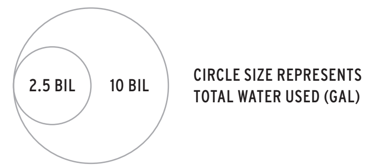
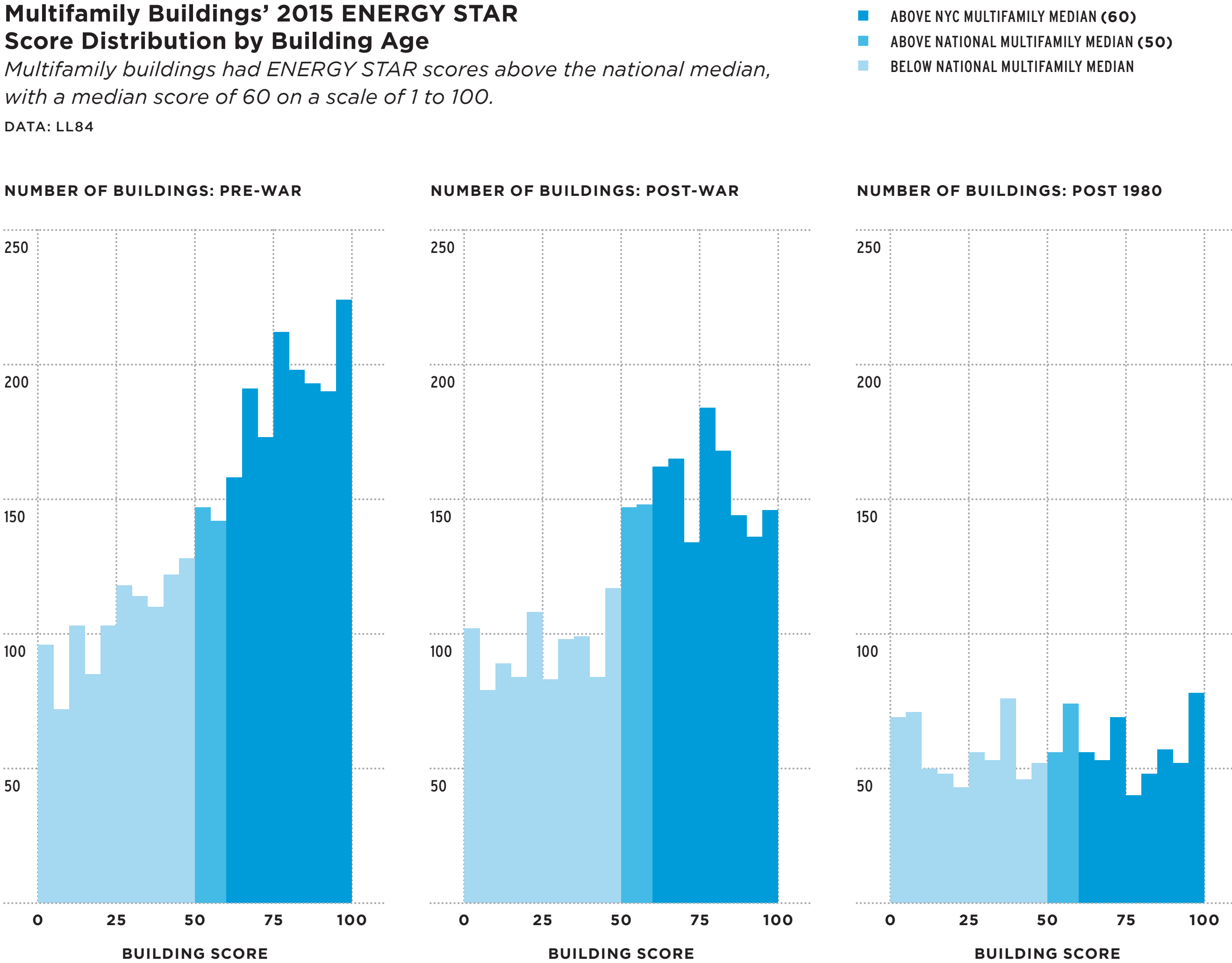


FIGURE 9

Multifamily Buildings' 2015 ENERGY STAR Score Distribution by Building Age

Multifamily buildings had ENERGY STAR scores above the national median, with a median score of 60 on a scale of 1 to 100.

DATA: LL84



well above the national ENERGY STAR median of 50. Not only were these buildings more energy efficient than most nationwide in 2015, but their efficiency also increased every year.

Multifamily Scores

The ENERGY STAR program first created scores for multifamily buildings in 2014. In New York City, the median ENERGY STAR score (ES score) for multifamily buildings was 60 in 2015 (Figure 9) and 55 in 2014. This 5-point increase contrasts with the stagnant trend in energy use intensity discussed later in this report (Figure 13). More detailed knowledge of ENERGY STAR algorithms is needed to better understand why ES scores for multifamily buildings improved while these buildings' overall energy use intensity remained the same.

Older multifamily buildings used less energy per square foot than newer buildings, and this fact was reflected in their ES scores. In 2015, the median ES score for pre-war multifamily buildings was 64—4 points higher than the median score for similar post-war buildings. Multifamily buildings built after 1980 reported the lowest ES scores, with a median of only 50—the same as the national median (Figure 9).

Office Scores

In 2015, New York City's large office buildings continued to be high performers, with a median ES score of 75. That score was 25 points above the national median and 2 points higher than New York City offices' median score in 2014. In 2015, New York City's large office buildings lagged behind those in Washington, D.C. and Boston, which had median office ES scores of 77 and 81, respectively.

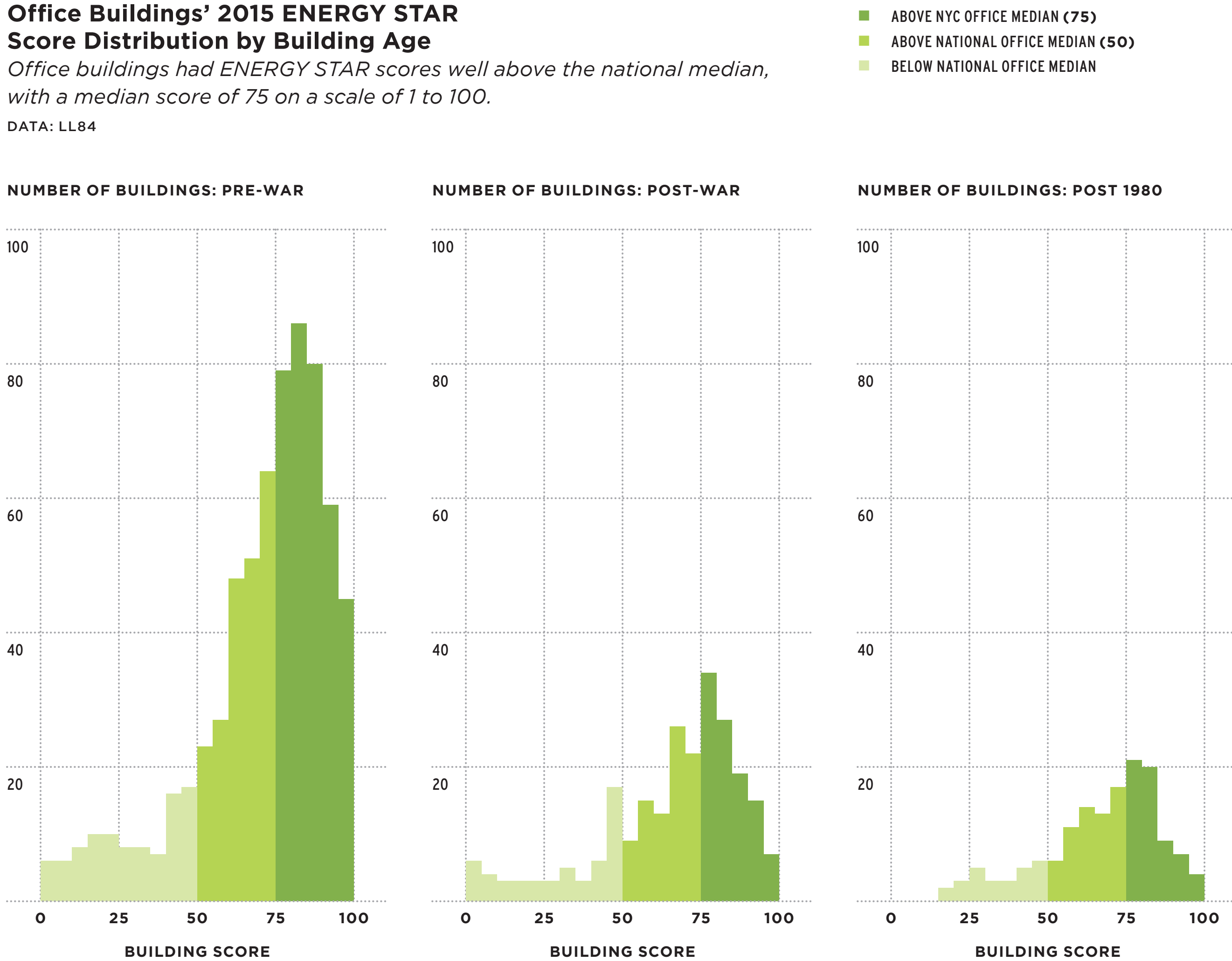
Almost two-thirds of the office buildings that reported ES scores in 2015 were built in the pre-war era. These older buildings reported a median ES score of 77, outperforming post-war and modern office buildings by 5 points (Figure 10).

FIGURE 10

Office Buildings' 2015 ENERGY STAR Score Distribution by Building Age

Office buildings had ENERGY STAR scores well above the national median, with a median score of 75 on a scale of 1 to 100.

DATA: LL84



Benchmarking and Emissions Tracking

Every year, New York City reports greenhouse gas emissions from transportation, waste and buildings citywide in its Greenhouse Gas Inventory.[10] Benchmarked buildings are not included in that report as a distinct group, though their emissions are included under the broad categories of residential and commercial buildings. Similarly, New York City's benchmarking data includes greenhouse gas emissions information generated through Portfolio Manager, an online tool developed by the U.S. Environmental Protection Agency that tracks consumption. However, the geographical boundaries that define its emission rates for Westchester and New York City do not exactly match the City's Inventory.

To obtain accurate estimates of greenhouse gas emissions from buildings one must know the origins of the energy used in the building. That's because some energy generation (for example, coal-powered electricity plants) releases more greenhouse gas than others (for example, hydro plants). Portfolio Manager only provides users with a limited set of options to select for the generation sources, which do not accurately represent the grid in New York City.[11] In this report, we have recalculated the greenhouse gas emissions of New York's large buildings using benchmarked energy data and the emission rates from the Inventory.[12]

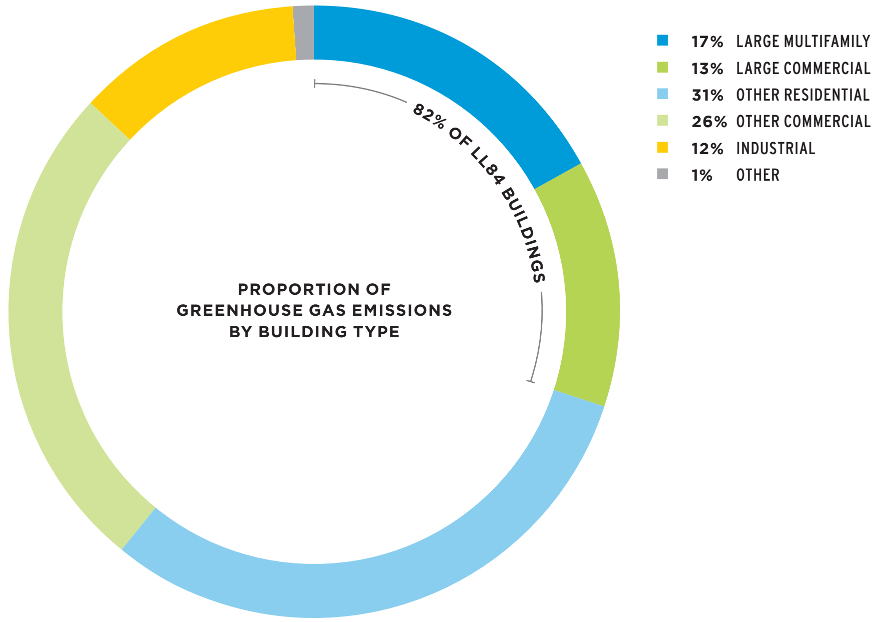
Private benchmarked buildings that submitted enough data to calculate emissions occupied one-third of the building area in the Inventory. These 10,585 buildings accounted for 30 percent of the emissions from residential and commercial buildings (Figure 11). More research is needed to determine if benchmarked buildings emitted less carbon per square foot than the mid-sized and small buildings that were not benchmarked. Commercial benchmarked buildings, including offices, retail locations

FIGURE 11

2015 Citywide Greenhouse Gas Emissions by Private Building Type

Over 10,500 benchmarked buildings were responsible for 30 percent of New York City's building-related greenhouse gas emissions.

DATA: LL84 & NYC GHG INVENTORY



and hotels, were responsible for 13 percent of total emissions, while benchmarked multifamily buildings accounted for 17 percent.

Of the benchmarked buildings, multi-family ones were responsible for the biggest portion of greenhouse gas emissions—47 percent. They were followed by commercial buildings, at 37 percent, and municipal buildings, which accounted for 16 percent (Figure 12).

Multifamily Emissions

Most emissions from multifamily buildings were the result of the burning of natural gas for space heating and hot water, but a full 21 percent of these emissions resulted from the burning of fuel oil. The City's plan to eliminate the dirtiest fuel oils by 2030 by switching heating and hot water fuel to cleaner energy sources should further decrease these emissions.

Commercial Emissions

The largest source of greenhouse gas emissions from benchmarked office buildings was the burning of fossil fuels to generate electricity. Commercial buildings were responsible for 53 percent of the 5.5 million tons of carbon dioxide that resulted from benchmarked electricity use in 2015. Commercial buildings also accounted for two-thirds of district steam emissions in benchmarked buildings.

Municipal Emissions

Public buildings, the smallest group of benchmarked buildings, emitted 16 percent of total city emissions. Their emissions were more evenly distributed among electricity and natural gas use: Forty-two percent of benchmarked public building emissions were from electricity generation and 31 percent of emissions came from burning of natural gas. Municipal buildings still have a significant percentage of their emissions coming from district steam and fuel oil.

Tracking the flow of energy through building sectors, from source energy to greenhouse gas emissions, will enable the City to better understand how its large buildings contribute to greenhouse gas emissions. Armed with better information, the City can design and implement the most effective policies to achieve 80 by 50.

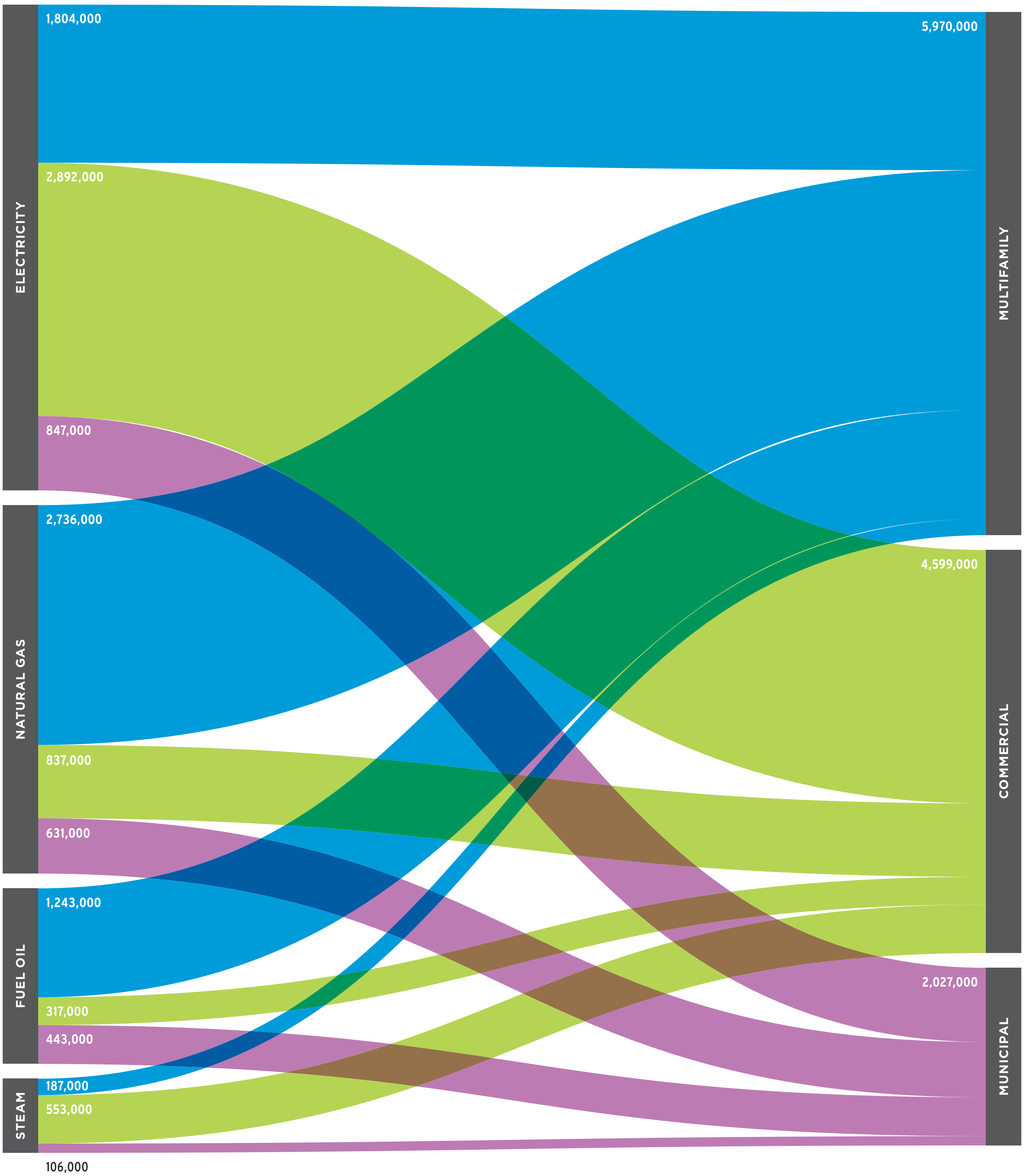
FIGURE 12

2015 Flow of Emissions by Energy Source to Building Sector

Electricity was the biggest emitter in commercial buildings. Most residential emissions resulted from natural gas use.

DATA: LL84

ESTIMATED GREENHOUSE GAS EMISSIONS (METRIC TONS CO_2E)



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Historical Context

With six years of building energy and water usage data available, we now have a good understanding of how large buildings are changing their resource consumption.

Buildings that benchmarked five out of the six years reduced emissions by 14 percent. It is still too early to call this a trend, but New York City is making significant progress on reducing its greenhouse gas emissions in large buildings.

While impressive, these reductions are only partly due to improvements in building energy efficiency. About half are due to more efficient district steam and a cleaner electricity grid.[13] Of the remaining half, 18 percent are due to a switch from oil to gas for heating and approximately 30 percent are from energy efficiency improvements.

Electricity generation for Westchester County and New York City became less carbon intensive between 2010 and 2015. That is the subregion used by Portfolio Manager to calculate building emissions from electricity use. Electricity consumed here in 2015 emitted 11 percent less carbon than in 2010.

Improved steam and electricity generation contributed about half of the source energy savings in consistently benchmarked buildings as well, but other changes contributed to lower consumption.[14] Energy and emissions reductions were also achieved by switching to cleaner energy sources and there have undoubtedly been energy efficiency improvements made to these buildings. This section examines the largest building types and energy sources over time to discover where achievements have been made and where more action is needed.

Energy Intensity Trends by Property Type

Analysis of the largest sectors shows varying energy reductions. Over the six years that data has been collected, each of the largest building types have seen at least a slight decrease in energy intensity. The reductions occurred along different timelines and in different ways.

Multifamily building energy intensities decreased by 5 percent during these six years. But all of that reduction occurred between 2011 and 2012. This large decrease was partly due to long lasting power outages and inoperable boilers damaged by flooding in Superstorm Sandy. But these buildings never rebounded to their 2011 intensities.

Private colleges and universities had the largest reduction in energy intensities.

Replacing old boilers and other systems with new equipment may explain this lower energy plateau. From 2012 to 2015, the median multifamily building energy-use intensity (EUI) remained near 125 kBtu/sf.

Office buildings have decreased EUI 11 percent since 2010. As with multifamily housing, the largest change was between 2011 and 2012; however, since then office EUI has continued to decline. Retail buildings present an interesting case owing to an unexplained 30 percent increase between 2010 and 2011. Since then, retail stores have consistently reduced their energy intensities by 6 percent every year. In 2015 the EUI of retail stores had just fallen below the 2010 level.

Private colleges and universities had the largest reduction in energy intensities. The typical university building cut its EUI by 50 kBtu/sf, or 20 percent. That's twice the reduction that was observed in regularly benchmarked buildings from 2010 to 2015. The NYC Carbon Challenge for Universities may have played a role in their success. In 2007, the City posed the challenge to universities to cut greenhouse gas emissions by 30 percent in 10 years. The challenge was accepted by 17 schools. Five of them—New York University, Barnard College, Fashion Institute of Technology, The Rockefeller University and Weill Cornell Medicine—have already met their initial emissions reduction goal and some schools have signed on to an even more aggressive goal of cutting emissions by 50 percent by 2025.

Additionally, hospitals, hotels and private primary and secondary schools have all decreased their median EUI since 2010. Hotels have achieved an almost 8 percent decrease in EUI over these five years. Since 2015, Mayor de Blasio has expanded the Carbon Challenge by partnering with 19 hotels to reduce their emissions 30 percent by 2025.[15] Some of these hotels have started major renovations to control kitchen exhaust; upgrade to LED lighting with occupancy controls; and install low-flow fixtures for showers.[16] Hospitals are also part of the program. Due to the intensive energy needs of hospitals, an EUI decrease at the scale and speed seen in universities or offices may not be possible but there has been a small, 4 percent energy decrease since 2010. Private K-12 schools experienced a dramatic EUI decrease in 2011. Since then EUI has stagnated near this 2011 level.

Energy Mix

The NYC Clean Heat program was a major factor that contributed to the 14 percent emissions reduction reported between 2010 and 2015.[17] This program, now part of the NYC Retrofit Accelerator, aimed to eliminate the burning of heavy heating oils in New York City. The combustion of these fuel oils causes serious health problems, including asthma and bronchitis, along with environmental damage. This damage comes from greenhouse gas emissions and other harmful pollutants such as sulfur dioxide, nitrogen dioxide and particulate matter or soot..

The Department of Environmental Protection (DEP) outlawed use of the heaviest oils, numbers 5 and 6, as primary heating fuels between 2011 and 2015. The City has achieved nearly full compliance with this regulation and large buildings have switched to cleaner fuels such as natural gas. This emits 30 percent less carbon and 95 percent less soot than number 6.[18] Some buildings kept their existing boilers and switched to number 4, a mix of 2 and 6. This oil emits the same amount of carbon and has 70 percent of the soot that heavy oil emits. Number 4 is due to be banned in New York City buildings by 2030.

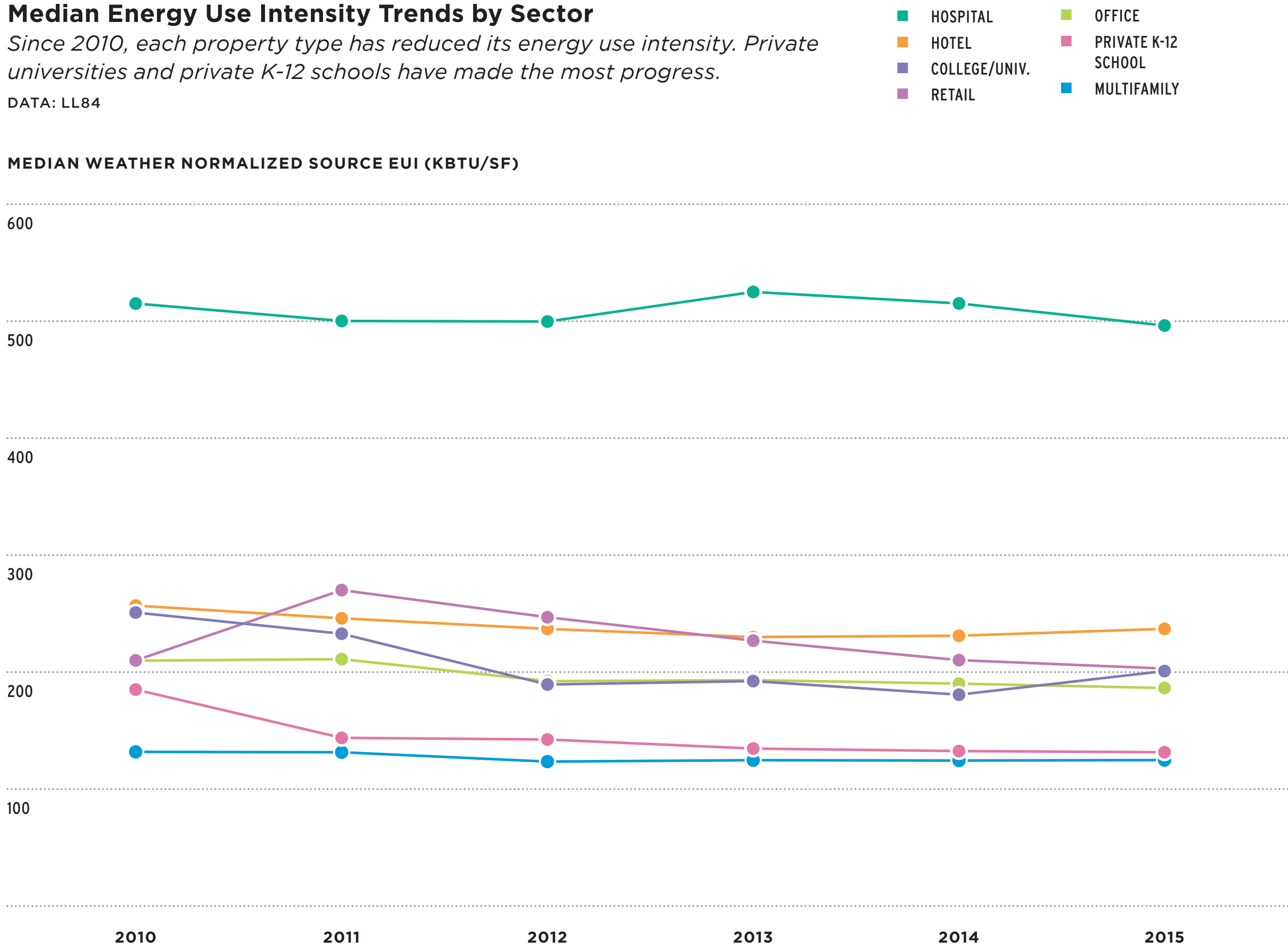
The decrease in heavy fuel oil use was confirmed by the last six years

FIGURE 13

Median Energy Use Intensity Trends by Sector

Since 2010, each property type has reduced its energy use intensity. Private universities and private K-12 schools have made the most progress.

DATA: LL84



of benchmarking data. In 2010, more than 1,000 buildings reported using number 6. Those buildings reduced their heavy fuel energy use 92 percent by 2015 (Figure 14). Buildings switching away from those fuel oils replaced them with natural gas or else Number 2 and 4 fuel oils. Natural gas use in these buildings nearly tripled over the six years, but overall energy use dropped, partly due to efficiencies afforded by new equipment and by building improvements. Transitioning to natural gas is initially more expensive, because new equipment is required, but burning fuel oil is more expensive over time. In 2015, distilled fuel oil was 2.5 times more expensive than gas per unit of energy. This gap has been widening. Fuel oil prices are expected to continue rising while natural gas will remain steady over the next five years.[19]

Switching away from heavy fuel oil has reduced emissions, but it has also improved measured air quality around the city. The NYC Community Air Quality survey shows that soot levels have dropped 18 percent and winter sulfur dioxide (SO_2) levels have dropped 84 percent between 2008 and 2015.[20] The much lower sulfur dioxide levels in winter suggest that cleaner burning boilers have been a major driver of this reduction. The risks that poor air quality pose to public health have been well documented and the fuel switching program has made tremendous progress toward making New York City air healthier and safer to breathe.[21]

Multifamily Energy Mix Trends

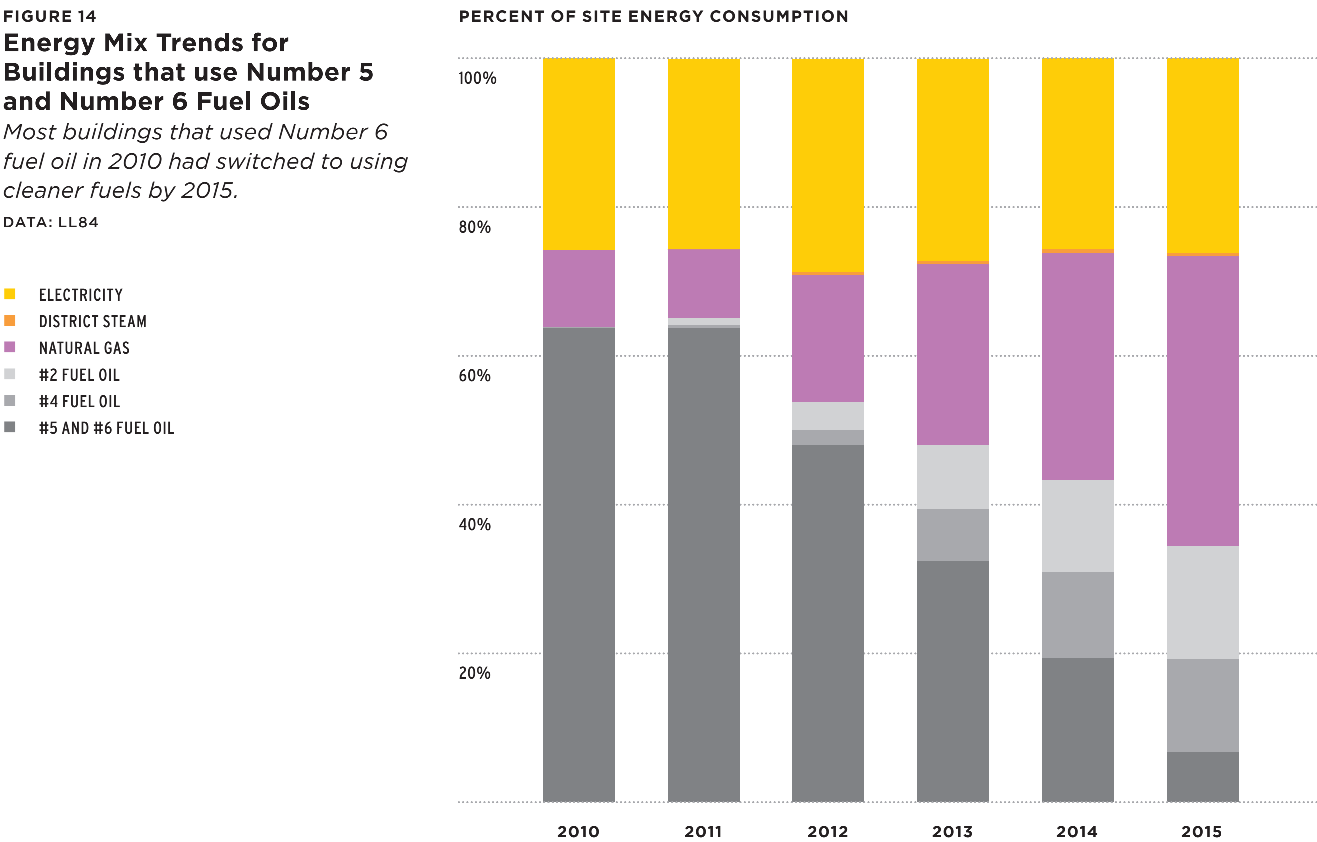
Overall, multifamily building energy mix trends also saw a decrease in fuel oil use. From 2010 to 2015, natural gas and cleaner fuel oils increased by 65 percent in this sector. The largest proportional increase was in number 2, which went from 3 percent of the residential energy mix in 2010 to 8 percent in 2015 (Figure 15). Natural gas had the largest increase in total consumption. It accounted for half of the residential energy mix,

FIGURE 14

Energy Mix Trends for Buildings that use Number 5 and Number 6 Fuel Oils

Most buildings that used Number 6 fuel oil in 2010 had switched to using cleaner fuels by 2015.

DATA: LL84



increasing from only one-third of the energy mix in 2010. Meanwhile, number 6 decreased from 25 percent of the residential energy mix to less than 3 percent in 2015. Electricity use has consistently been about 25 percent of multifamily building energy use.

Office Energy Mix Trends

The energy mix in office buildings is drastically different from the energy mix in multifamily buildings. Offices had a much more consistent fuel mixture over time. District steam, at 7 percent, and electricity, at 60 percent of the total, have remained largely unchanged over the past six years and are responsible for 67 percent of the energy mix in this sector (Figure 16). In 2015, natural gas accounted for only about 30 percent of the energy mix in offices and has varied over the six years. Trends in fuel oil use in the office building sector are consistent with overall fluctuations in the energy mix. While no offices reported using Number 2 fuel oil in 2010, this cleaner fuel oil increased to 2 percent of the office energy mix in 2015.

Water Use

Water information has improved since benchmarking began, but more consistency is needed to draw definitive conclusions. Over the past four years of benchmarking data (2012-2015) office properties' water use intensity (WUI) correlates with the number of cooling degree days (CDD) (Figure 17). CDDs are calculated by the National Oceanic and Atmospheric Administration (NOAA) based on how frequently, and by how much, the mean daily temperature is more than 65 degrees Fahrenheit.[22] Years with warmer temperatures also report a higher median WUI in benchmarked offices. According to the audit data, further explored in Section

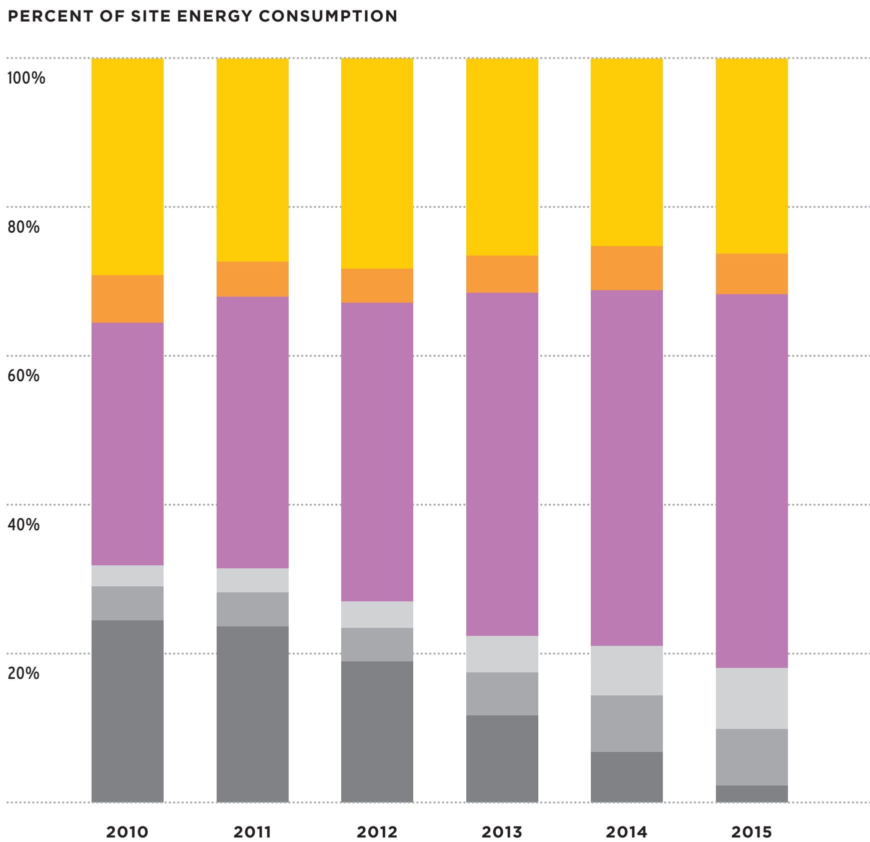


FIGURE 15
Multifamily Buildings' Energy Mix Trends

From 2010 to 2015, multifamily buildings increased their use of natural gas.

DATA: LL84

- ELECTRICITY
- DISTRICT STEAM
- NATURAL GAS
- #2 FUEL OIL
- #4 FUEL OIL
- #5 AND #6 FUEL OIL

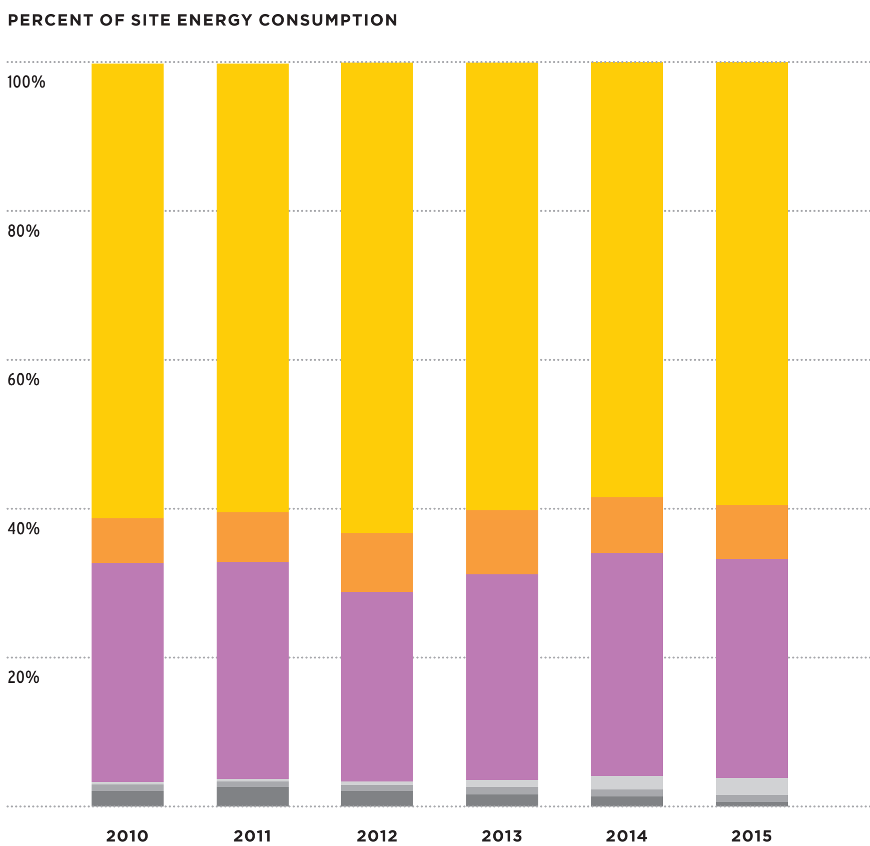


FIGURE 16
Office Buildings' Energy Mix Trends

Between 2010 and 2015, the energy mix in office buildings remained constant.

DATA: LL84

- ELECTRICITY
- DISTRICT STEAM
- NATURAL GAS
- #2 FUEL OIL
- #4 FUEL OIL
- #5 AND #6 FUEL OIL

FIGURE 17

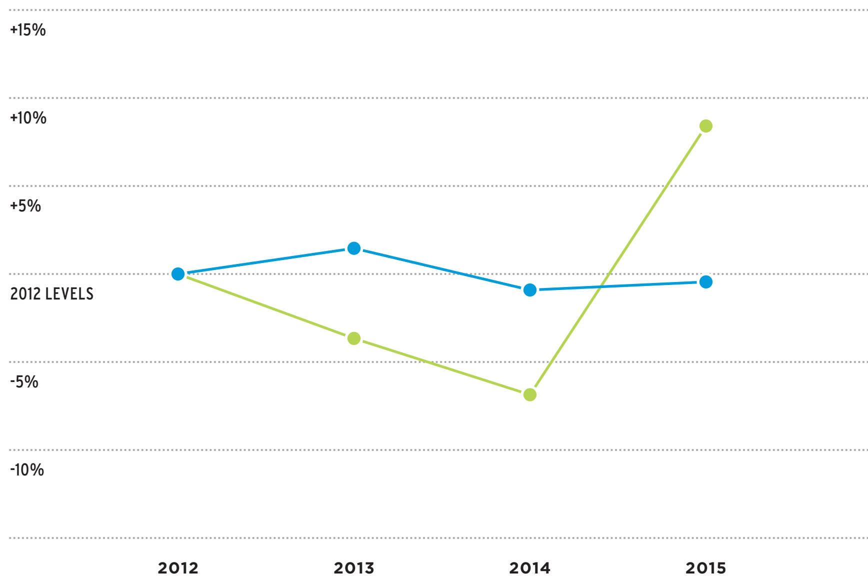
Multifamily and Office Buildings' Water Use Trends

Office building water use intensity was correlated with cooling demand. In multifamily buildings, water use intensity and cooling demand were unconnected.

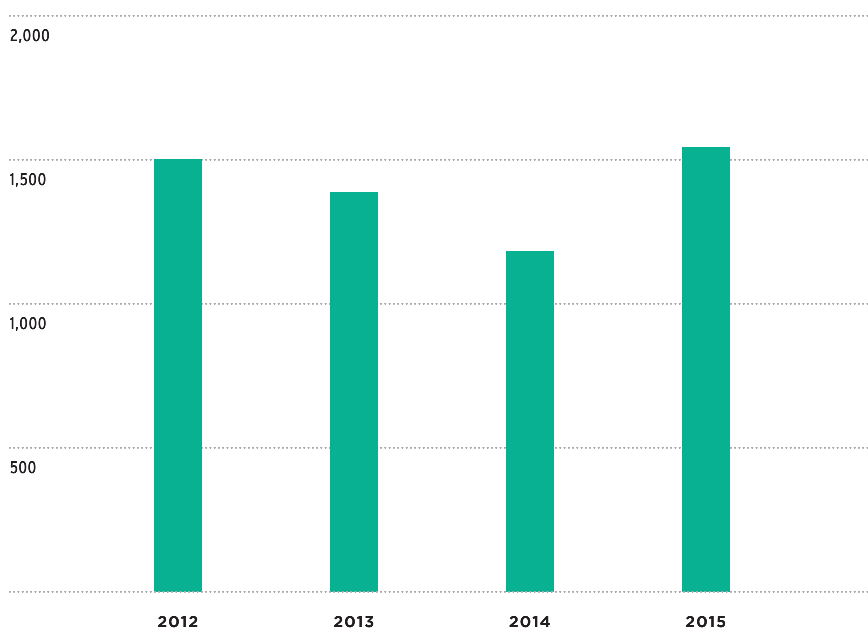
DATA: LL84 & NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

- MULTIFAMILY WATER USE PER RESIDENTIAL UNIT (GAL/UNIT)
- OFFICE WATER USE INTENSITY (GAL/SF)

PERCENT CHANGE IN WATER USE



COOLING DEGREE DAYS PER YEAR



5, office buildings predominantly use central systems, and many of those have cooling towers that move heat outside by allowing water to evaporate. Therefore, the more days throughout the year that these central systems are on, the larger the water load is in large office properties. While water use is likely affected by more than just cooling degree days, this correlation is important to consider as temperatures continue to rise.

Water use in multifamily buildings is closely tied to occupancy and tenant behavior, rather than square footage. Therefore, two different metrics were developed to analyze water use trends in office and multifamily properties. For office buildings, total water use intensity (WUI in gal/sf) was the preferred metric. For multifamily buildings, water use per residential unit (WPU in gal/unit) was used with residential units as a proxy for number of occupants. When a multifamily building has more people, the demand is higher for showers, laundry, and water for heating and cooling systems.

WPU in multifamily buildings stayed relatively consistent over the past four data years. Unlike offices, it is not correlated with CDDs. The trends in residential water usage are driven by other factors. Further data and analysis is needed to understand trends in water use in multifamily buildings.

As temperatures continue to rise there may be more water used in office buildings.

/05

Energy-Using Systems

Together, three systems significantly influence how much energy NYC's large buildings use: water-heating systems, space cooling and energy metering.

Two of these systems—domestic hot water (DHW) and space cooling—alone account for 21 percent of the energy consumed in the city's large audited buildings. And energy metering, while itself not an end use, correlates with significantly reduced energy consumption. By understanding these systems' impacts, the City and its landlords can design policies and implement changes that significantly reduce energy use.

We'll also look at the energy conservation measures (ECMs) most commonly recommended by auditors under LL87, with attention to the savings associated with these changes and how they're useful to building owners as general guides to energy efficiency retrofits.

Domestic Hot Water

Domestic hot water systems are benchmarked buildings' third-largest energy end-use and account for 12 percent of all source energy consumption. Multifamily buildings consume most of this energy that heats hot water—nearly three times as much as offices per square foot. That's because residents take many more showers, and wash far more dishes and clothes at home than in commercial buildings.

Buildings with separate DHW systems—systems that are not connected to their space-heating boilers—had substantially lower fuel-related energy-use intensities than did buildings with DHW systems that connect to their space-heating boilers. In fact, our analysis found that a typical multifamily building with a linked DHW system used 10 kBtu/sf more fuel than a similar building with a separate DHW system, an amount equal to 16 percent of a typical multifamily building's fuel use.[23] Nevertheless, 80 percent of multifamily properties used their space-heating steam boilers to serve both their heating and hot water needs (Figure 21).

Separate vs Linked Systems

The correlation between separated DHW systems and lower fuel energy-use intensity (EUI) appeared even when buildings were grouped by age, height, size or type and compared in aggregate.

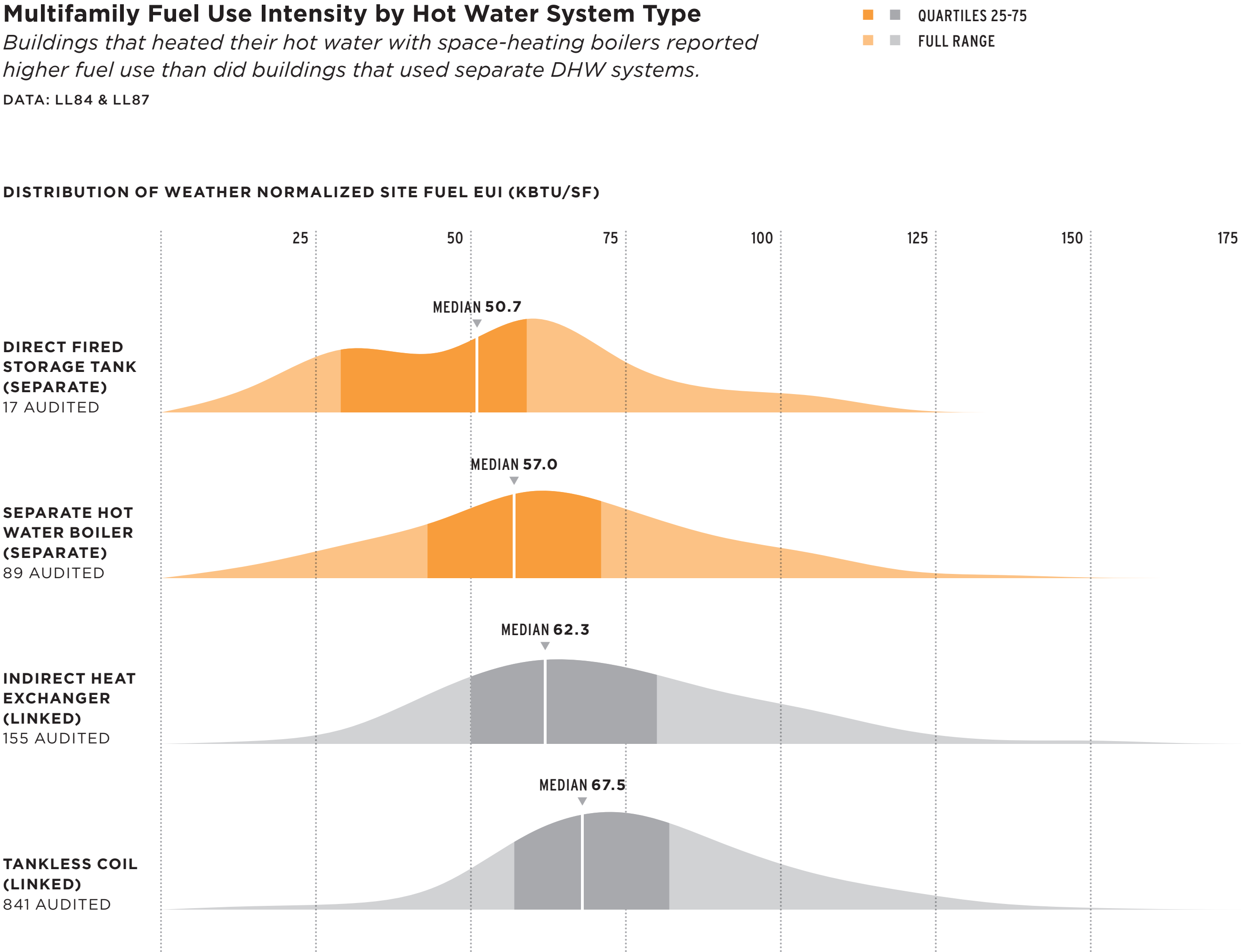
Different types of linked and separated DHW technologies result in different energy use profiles (Figure 18). For instance, the mean fuel EUI

FIGURE 18

Multifamily Fuel Use Intensity by Hot Water System Type

Buildings that heated their hot water with space-heating boilers reported higher fuel use than did buildings that used separate DHW systems.

DATA: LL84 & LL87



for multifamily buildings using the kind of linked systems called indirect heat exchangers is 16 percent higher than for those using separate DHW systems. Linked systems in multi-family buildings that use "tankless coils" have a fuel EUI that is 27 percent higher than multifamily buildings with separate DHW systems.[24]

Though separate DHW systems correlate with significantly lower energy use, they only serve 17 percent of all audited floor space—and only 10 percent of the overall multifamily audited area.

The correlation between DHW and fuel EUI can be seen in Figure 19, where audited multifamily buildings were broken down into groups based on DHW system type, age (year built) and size (gross floor area).[25] Four groups of buildings had enough records to control for these factors. In three of these four groups, the average fuel use was lower in the group of buildings with separate DHW systems. For example, the average fuel EUI for pre-war, low-rise multifamily buildings with separate DHW systems was 19 percent lower than the average fuel EUI for comparable buildings with linked DHW.[26]

System age also affects the fuel consumption of hot water systems. Older hot water systems tend to use more fuel, especially as their burners and other components degrade over time.[27] In modern buildings (post-1980), the age of hot water systems is roughly the same, regardless of whether they are linked or separate. But in pre-war multifamily buildings, the age of DHW systems varies significantly. In these buildings, linked systems are generally two to three times older than similar buildings with separate systems. This is likely the case because separate hot water systems in pre-war and post-war buildings are probably the result of a retrofit rather than systems included in their original construction. The newer equipment in these buildings potentially explains some of their lower fuel usage.

FIGURE 19

Multifamily Fuel Use Intensity for Hot Water Systems by Building Age and Size

In three of four groups, buildings with linked DHW systems reported higher fuel use than did buildings of similar age and size that used separate systems.

DATA: LL84 & LL87

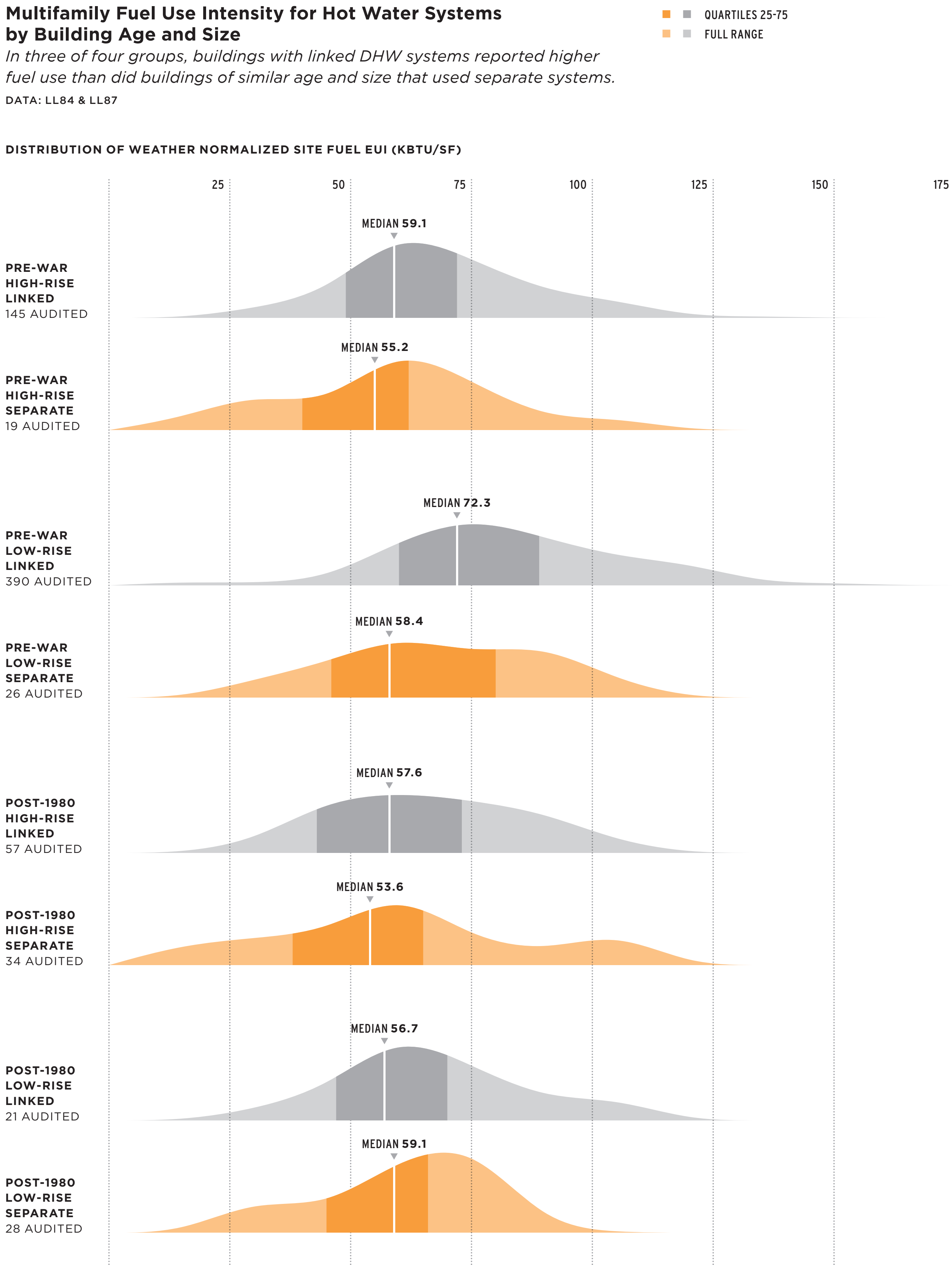
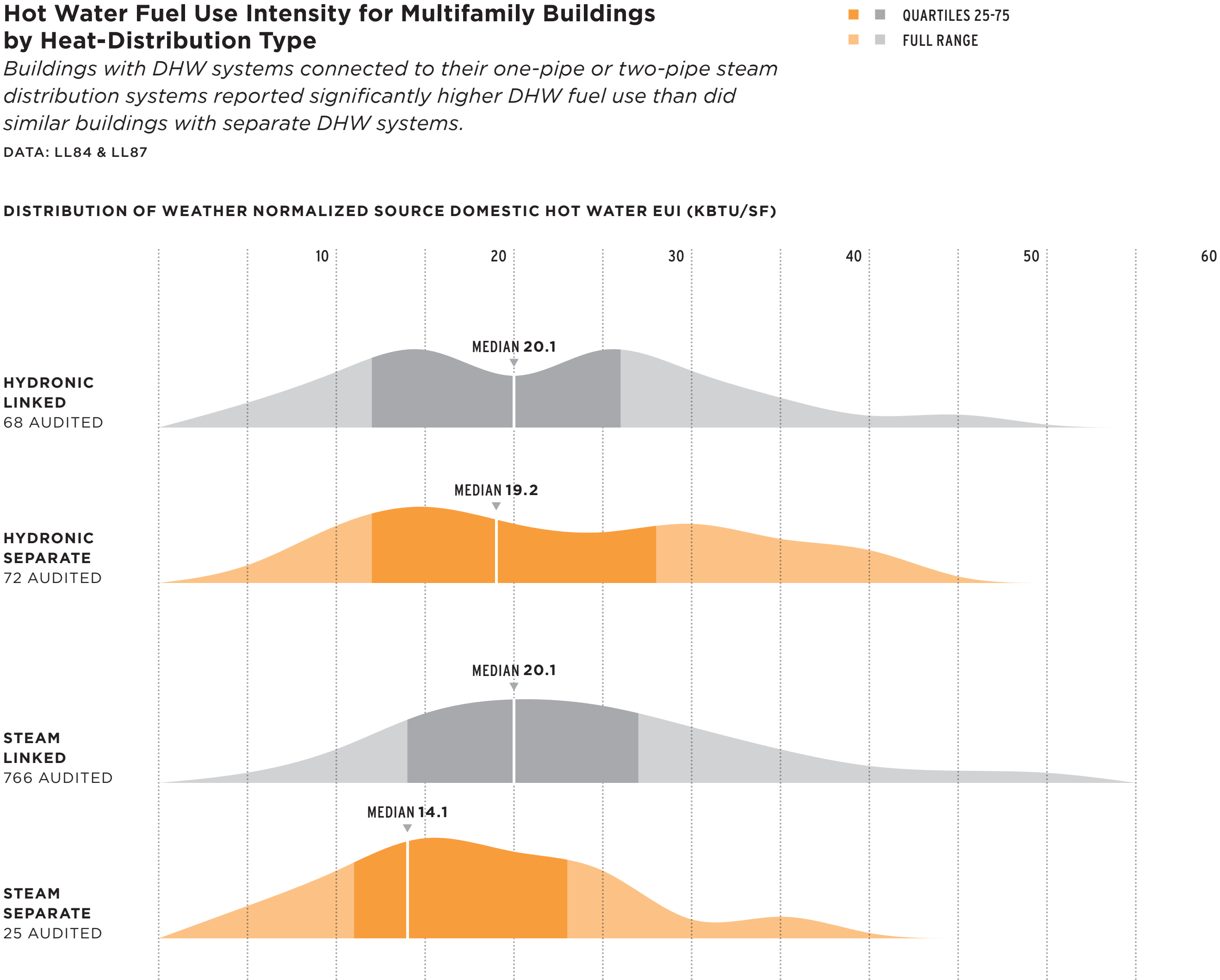


FIGURE 20
Hot Water Fuel Use Intensity for Multifamily Buildings by Heat-Distribution Type

Buildings with DHW systems connected to their one-pipe or two-pipe steam distribution systems reported significantly higher DHW fuel use than did similar buildings with separate DHW systems.

DATA: LL84 & LL87



The same correlation between separate DHW systems and lower fuel EUI was seen regardless of a building's space heating system, although the difference between separate and linked DHW systems was greatest in steam-heated buildings. Among the roughly 85 percent of the audited multifamily buildings that use one- or two-pipe steam heat systems for space heating, linked DHW systems were associated with 34 percent higher DHW EUIs than steam-heated buildings with separate DHW systems (Figure 20). The difference between these steam heat means is statistically significant.

Types of Linked Systems

Buildings with linked systems generally employ one of two types of hot water heating technologies: either tankless coils or indirect heat exchangers.

Tankless coils heat hot water as it flows through tubing inside the main boiler. These systems supply hot water to 35 percent of New York City's audited floor space.

Indirect heat exchangers are also linked to a building's boiler but pipe hot water through a heat exchanger located in a nearby hot water storage tank. This type of system supplies almost 25 percent of audited floor area.

Both of these linked systems provide hot water year-round but sometimes operate at lower-than-rated efficiencies in warm weather when boilers designed primarily for space heating (which requires a substantial amount of energy) are just heating hot water.[28]

Types of Separate Systems

Separate systems are most commonly found in post-1980 multi-family buildings; they provide hot water to one-third of the audited area. The main types of separate

DHW systems are direct-fired storage tanks and separate DHW boilers with storage tanks.

Considerations Before Separate System Installation
Multifamily buildings with separate DHW systems use less fuel, but separate systems can be more expensive to install. That's because they may require dedicated chimneys and space in the mechanical room and, in the case of direct-fired units, have a shorter life span. As a result, it may cost less to continue using a linked system.

DHW in Office Buildings
DHW is responsible for only 4 percent of office buildings' total energy use. For this reason, office buildings often heat their hot water differently than most residential ones. Instantaneous, point-of-use systems, which heat water nearer the tap, are found in 24 percent. (Point-of-use systems use electric resistance to heat water quickly but can sometimes save energy by eliminating heat lost from supply pipes.) But as in residential buildings, the most common type of DHW system in audited offices are still linked systems; they're found in 36 percent of audited office area, the majority of which is indirect heat exchangers.

The two types of separate DHW systems, direct fired and separate boilers with storage, serve only 20 percent of audited office area. The remaining audited area uses less common DHW systems.

Cooling Systems

Cooling accounts for 8 percent of total source energy used in multifamily buildings and 11 percent in office buildings.[29] This makes air conditioning the sixth-largest energy use in New York's audited buildings, after space heating, plug load, DHW, lighting and "other." Air conditioning presents another challenge—it's needed in summer, and drives up overall electricity demand to its highest level.[30] This costs New Yorkers, including owners of public and private buildings, additional money because utilities must either build expensive plants to meet this extra demand or help consumers lower their air conditioning use through incentive programs.

Trends in Energy Use for Cooling
As more spaces across the city become air-conditioned, energy use for cooling will increase. In 2016, for instance, New York State helped almost 700 low-income households in the city obtain air conditioning through its Home Energy Assistance Program.[31] And this year, the City announced that it will add cooling to an additional 11,500 classrooms, so that every New York City classroom will be air conditioned by 2022.[32] As climate change pushes temperatures higher with greater frequency of heat waves, the city's air-conditioning load will increase, too. For these reasons, choosing energy-efficient cooling systems will be key to lowering energy use as well as greenhouse gas emissions from air conditioning. Supporting the use of technologies, demand reduction programs and retrofits that can reduce cooling load is also key.

Each of the city's large buildings has a unique set of cooling requirements. Certain cooling system types can meet those requirements while consuming less energy, but other system types may contribute to increased energy use.

New York City's cooling systems can be categorized as distributed and central. Distributed systems cool almost 43 percent of the entire audited building area, and 75 percent of all multifamily housing area. In particular, these systems cool 90 percent of low-rise multifamily building area.

Distributed Cooling Systems
Distributed systems generally come in three forms: window air conditioners (ACs); through-the-wall cooling units, which are similar to window units but are slotted through openings in building walls; and packaged terminal air conditioners (PTACs). These self-

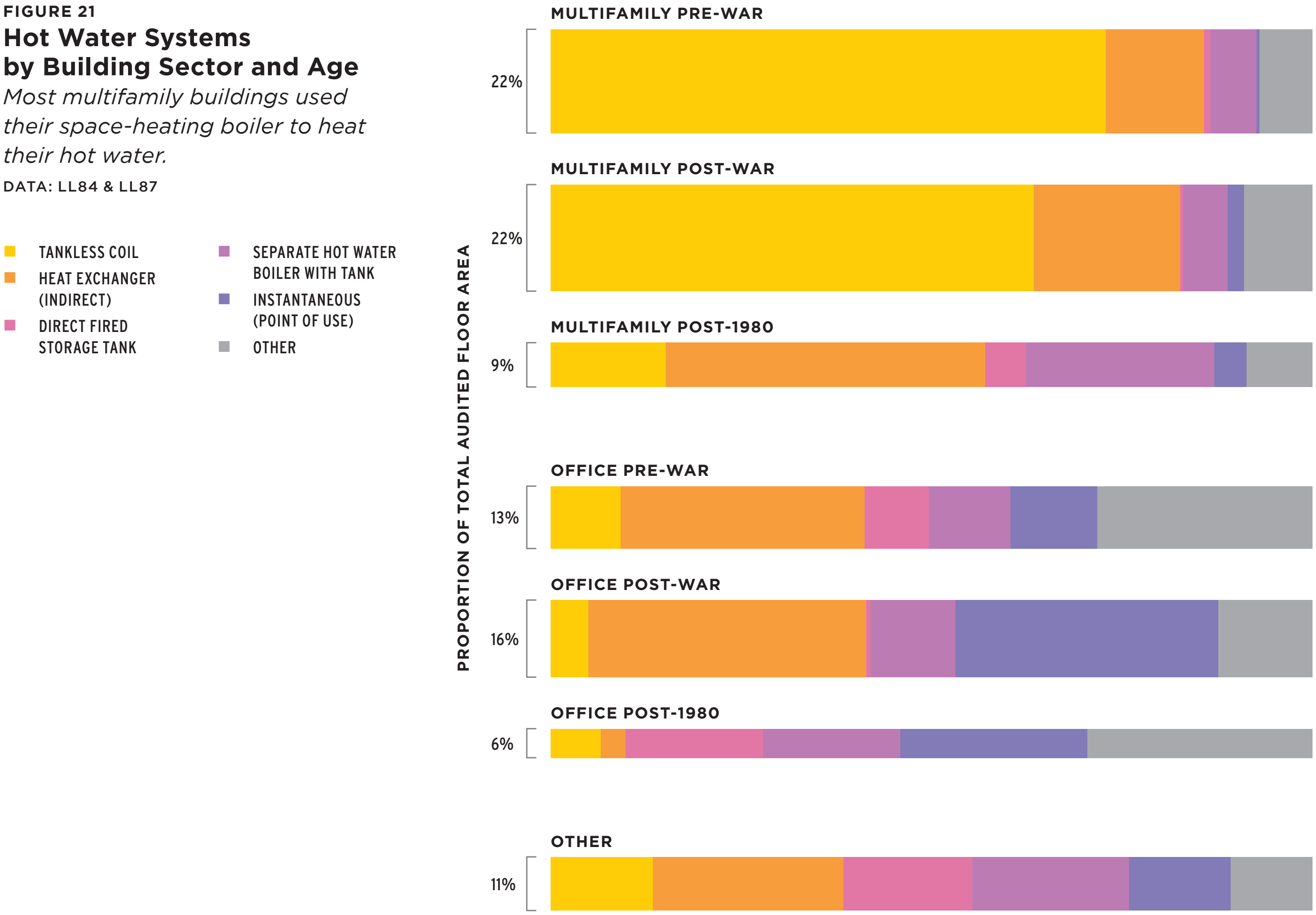
Buildings with separate DHW systems had substantially lower fuel-related energy-use intensities than did buildings with DHW systems that connect to their space-heating boilers.

FIGURE 21

Hot Water Systems by Building Sector and Age

Most multifamily buildings used their space-heating boiler to heat their hot water.

DATA: LL84 & LL87



contained units go through walls and have their own vents. Each of these systems serves an individual room and is turned on and off by the people within. Distributed systems typically have low first costs and tenants are often responsible for buying their own.

Another variation is the so-called split system. These systems are different from window AC units because their components are separated: The parts that cool air are installed inside, while the parts that release heat are outside. This separation ensures that building envelopes remain sealed and can improve efficiency.

In benchmarked buildings, the use of window and through-the-wall AC units is widespread, despite the fact that these are the least efficient options. Even the average ENERGY STAR-rated window AC unit has a 20 percent lower Energy Efficiency Rating (EER) than most split systems. It is also 45 percent less efficient than the minimum efficiency required by code for the main component of a central system.[33]

Central Cooling Systems

Central systems, which are common in office buildings and some very large multifamily buildings, cool the other 57 percent of the audited building area. (Central systems are almost always more costly than distributed systems. This may be one reason they are mostly in larger buildings, where owners can distribute these greater costs over a larger square footage.) Central

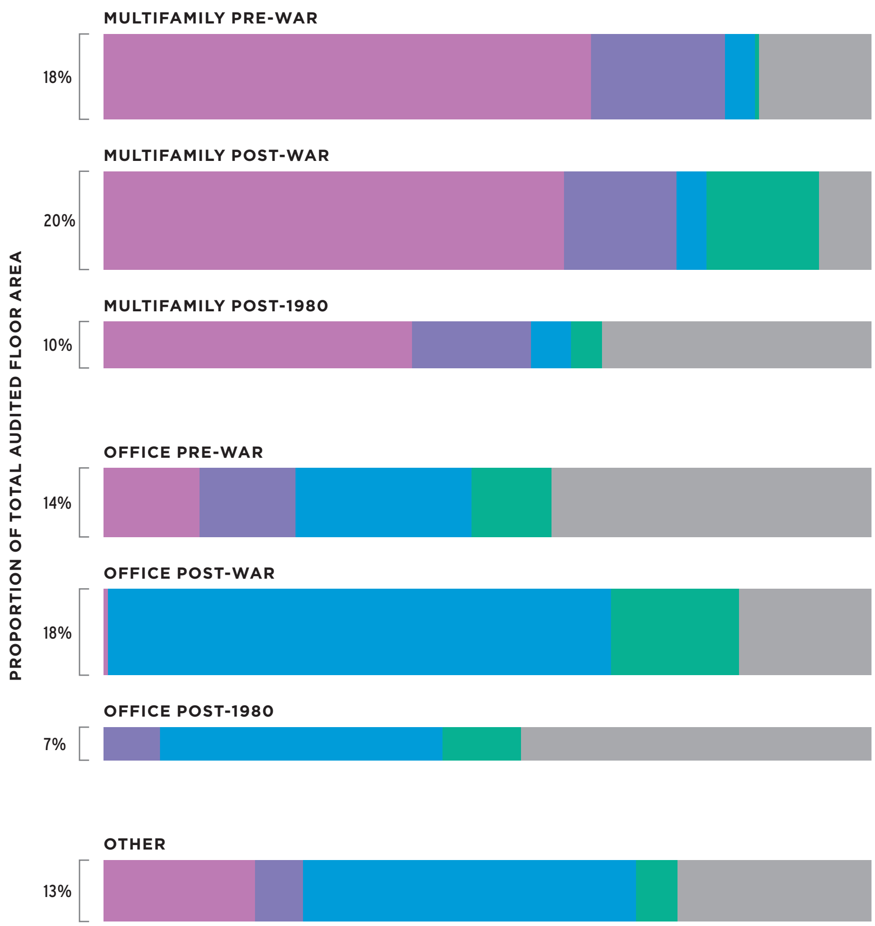


FIGURE 22
Cooling Systems by Building Age and Sector
Distributed systems were more common in multifamily buildings, while central systems were more common in office buildings.
DATA: LL84 & LL87

- PTAC/WINDOW OR WALL UNIT
- SPLIT SYSTEM
- CENTRAL CHILLER
- ABSORPTION CHILLER
- PACKAGED/DX UNIT/ OTHER

systems serve large tenant spaces or entire buildings and are often integrated with other systems, such as ventilation and heating.

The most common type of central system involves an electric-powered chiller. These machines chill water for distribution throughout a building. The water then enters air-handling units to absorb heat from ventilation air, thus cooling the space. Electric chillers run through their cycles much more efficiently than do window air conditioners.

Electric chillers are used in nearly 60 percent of very-large-office-building audited area, and about 16 percent of the total audited area. They are more likely to be found in post-war and modern office buildings than any other type of system. Very large buildings with high cooling loads benefit from the efficiencies of electrical chillers, which may explain these systems' popularity.

Other Cooling System Types

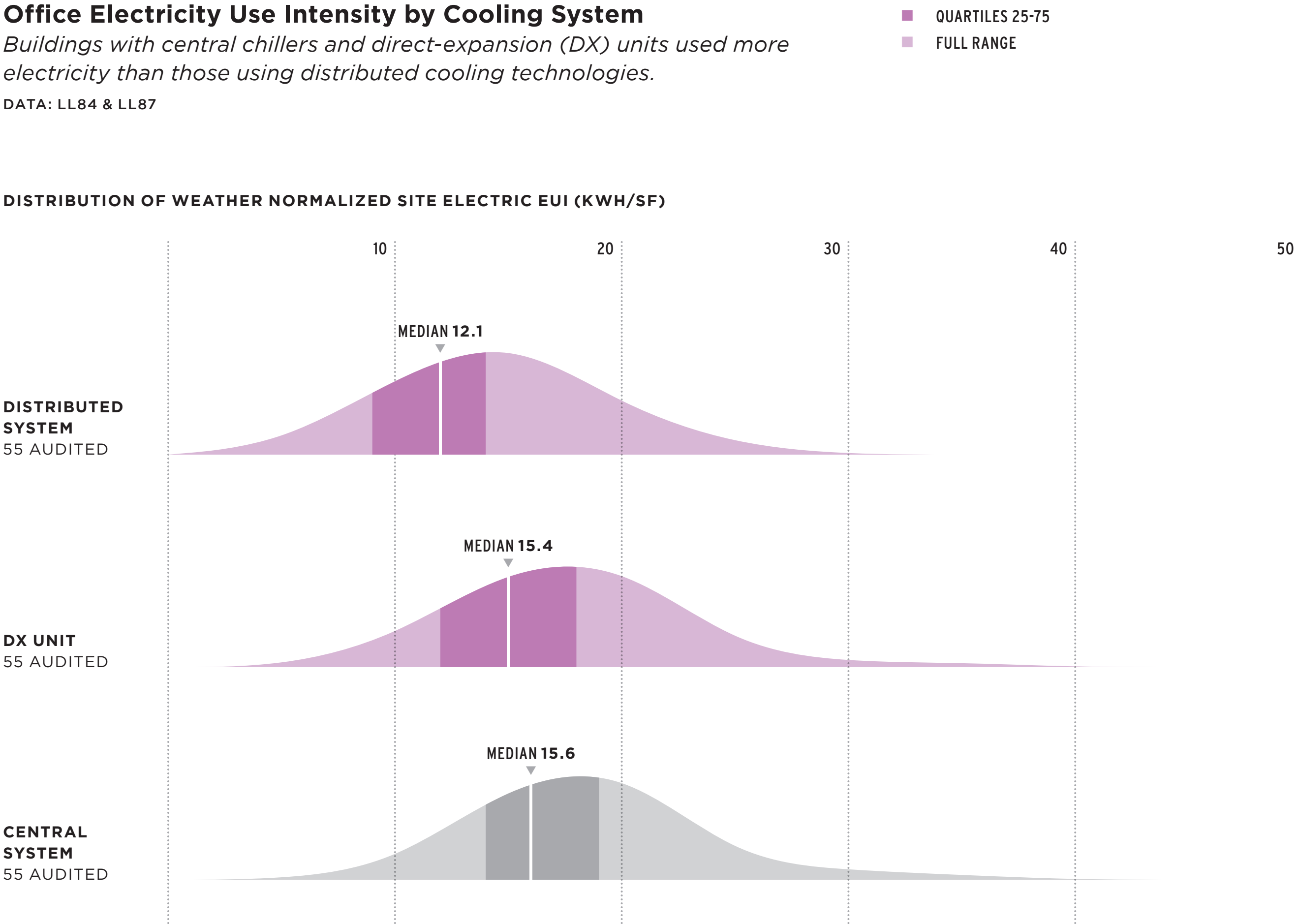
Direct expansion (DX) and packaged units can fall into either the central or distributed category, as they may cool individual spaces or an entire building floor. They use a technology that is similar to that of electric chillers, except that they deliver cooled air directly to the conditioned space rather than distributing chilled water or another chilled liquid to air-handling units. They provide cooling to nearly 25 percent of audited office space, 15 percent of audited multi-family space and 16 percent of the city's entire audited area. These technologies enable landlords to

FIGURE 23

Office Electricity Use Intensity by Cooling System

Buildings with central chillers and direct-expansion (DX) units used more electricity than those using distributed cooling technologies.

DATA: LL84 & LL87



bill tenants more easily. Separate, smaller units do not require that a licensed operator be present, as is the case with larger chillers.

Not all cooling equipment runs on electricity. An absorption chiller uses surplus heat to initiate a thermo-chemical process that produces cooling. Absorption chillers are used in almost 10 percent of the city's audited area. They are most common in post-war multifamily high rises, where they cool more than 20 percent of that category's audited area, and in very large office buildings.

Electricity Consumption by System Type

We analyzed the various types of cooling systems used in offices and multifamily buildings to understand how differences in equipment, building type and location might explain differences in electricity consumption. This comparison was performed by combining the cooling system audit data with the bench-marked electrical consumption and building type.

Though central chillers generally use electricity more efficiently than distributed systems, office buildings using distributed systems—window air conditioners, PTACs, etc.—used less electricity per area overall than did centrally-cooled office buildings. In fact, these buildings used at least 20 percent less electricity than centrally-cooled buildings.

For our analysis, we grouped offices with central, electrically-driven chillers; DX units; and various distributed systems. We found almost no difference in the distribution of energy use among buildings using chillers and DX units.

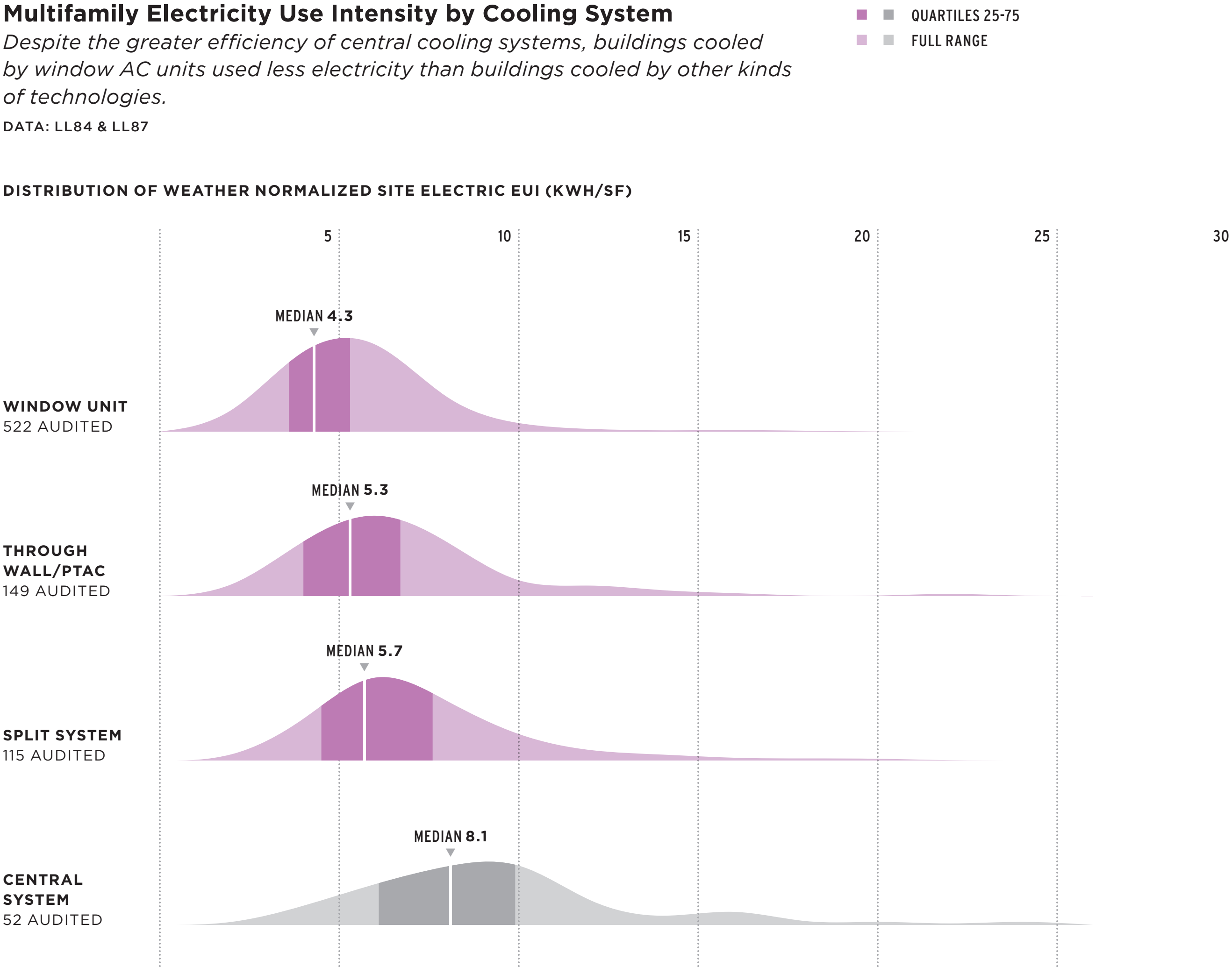
To understand this energy paradox better, we compared data from more than 50 multifamily buildings that use central cooling systems with data from hundreds of multifamily buildings that use PTACs, through-the-wall ACs, window ACs and split systems. Interestingly, the energy use of buildings with different types of distributed systems varied only slightly. But typical multifamily buildings with central cooling used over 40 percent more electricity overall than did multifamily buildings employing distributed cooling systems. Multifamily buildings generally have lower electrical

FIGURE 24

Multifamily Electricity Use Intensity by Cooling System

Despite the greater efficiency of central cooling systems, buildings cooled by window AC units used less electricity than buildings cooled by other kinds of technologies.

DATA: LL84 & LL87



demands than offices, but both types of consumption appear to be influenced by these different cooling types. Figures 23 and 24, which both group buildings by building type and by cooling type, show these differences.

Controlling for Other Factors that Impact Electricity Use

The cooling paradox can likely be explained by factors that go beyond cooling system efficiency. Leaky windows and building envelopes, occupant density, unknown electrical demands and the ways ventilation systems bring heat into buildings can all impact cooling systems' effectiveness.

To explore the variety of factors that impact site electric EUI, we performed a regression analysis, controlling for building type, cooling system, age, height and size. Building type—multifamily or office—had the strongest influence on electricity use. But cooling system type had the next strongest. For example, centrally-cooled multifamily buildings in our analysis used 2.2 kWh/sf more electricity than buildings that used distributed cooling—about 40 percent of a typical multifamily building's electricity intensity. (A typical multifamily building's electricity use intensity is 5.5 kWh/sf.) The difference between central and distributed cooling systems in office buildings was even larger—3.9 kWh/sf, or 25 percent of the typical office's electricity consumption. A higher floor count also had an impact, but neither gross square footage nor building age played a significant role in energy use.[34]

The cooling regression analysis confirmed that cooling systems appear to have an impact on electricity consumption in office and multifamily buildings. However, the regression had one noteworthy limitation—it was not able to control for a building's location.

Typical multifamily buildings with central cooling used over 40 percent more electricity overall than did multifamily buildings employing distributed cooling systems.

Pairing Buildings for Analysis
Location matters because a building in Manhattan may cater to tenants with different energy demands than a building in Queens. The difference shows in the data: A typical multi-family building in Manhattan uses 24 percent more electricity per square foot than one in Queens.

Since location impacted electrical demand, we controlled for it, using a method called paired-difference testing. In each pair, one building was centrally cooled, while the other used distributed cooling. Both buildings were in the same neighborhood, or, in some cases, another neighborhood with the same median income. (Our analysis was somewhat limited by the fact that central chiller systems are uncommon in multifamily buildings and window ACs are less common in large office buildings.) The building pairs were matched by age, height and size. To ensure the buildings followed real-world patterns of use, the analysis also required that both buildings have occupancy rates higher than 90 percent, use electricity for cooling and do not use electricity for hot water generation or space heating.

Figure 25 shows the pairs and their electrical EUIs. Again, central cooling was correlated with higher electrical EUIs in both office and multifamily buildings. In nearly 80 percent of the pairs—36 out of 46 buildings—the ones with distributed cooling used significantly less electricity than centrally cooled buildings. (It's possible that in some of these pairs, one building had features that significantly increased its electricity use—a swimming pool or a gym, for instance.) But a high-usage tenant or space could have been located in either building type, and it's likely that the trend seen here—that centrally cooled buildings consumed more energy than those using distributed cooling—was more than a coincidence. Adding to that conclusion is the fact that the differences found in the building pair analyses were statistically significant, which increases the likelihood that the buildings differ based on their cooling systems.

The paired-difference comparison helped confirm the results of the regression analysis. The average difference between pairs shows that centrally-cooled offices used 4.0 kWh/sf more than offices with distributed cooling. That energy is equal to 25 percent of typical office electricity consumption. Multifamily buildings show a similar trend, at 2.1 kWh/sf, which is more than 35 percent of the typical multifamily building electricity consumption. Both of those results are nearly identical to the weights found in the regression.

Potential Reasons for Higher Energy Use in Centrally Cooled Buildings
Cooling system energy use does not depend on the efficiency of a building's cooling components alone. System controls, areas cooled, occupant behavior and ventilation systems all affect how much cooling energy a building uses. The size of a conditioned area—whether it's a hallway, lobby or other common area—and the desired temperature both influence the consumption of cooling energy, as anyone who has ever worked in a frigid, centrally-cooled office building knows well. In multifamily buildings with window or wall AC units, tenants might only cool one or two occupied rooms at a time. The remaining apartment area and all of the building's hallways are often unconditioned. In a centrally-cooled building, by contrast, most of these spaces tend to stay at a constant, cool temperature all summer long.

Other factors that can increase energy use in centrally cooled buildings include electric pumps that circulate chilled water and fans that push a steady supply of air for ventilation. Ventilation fans also bring hot outdoor air into buildings that must then be cooled and dehumidified before being moved to a conditioned space. A building with distributed cooling may have

FIGURE 25

Comparing the Electricity Use of Similar Buildings by Cooling-System Type

Even after controlling for building type, age, size, height, and location, buildings that used distributed cooling systems consumed less electricity than buildings that used central chillers and direct expansion (DX) units.

DATA: LL84 & LL87

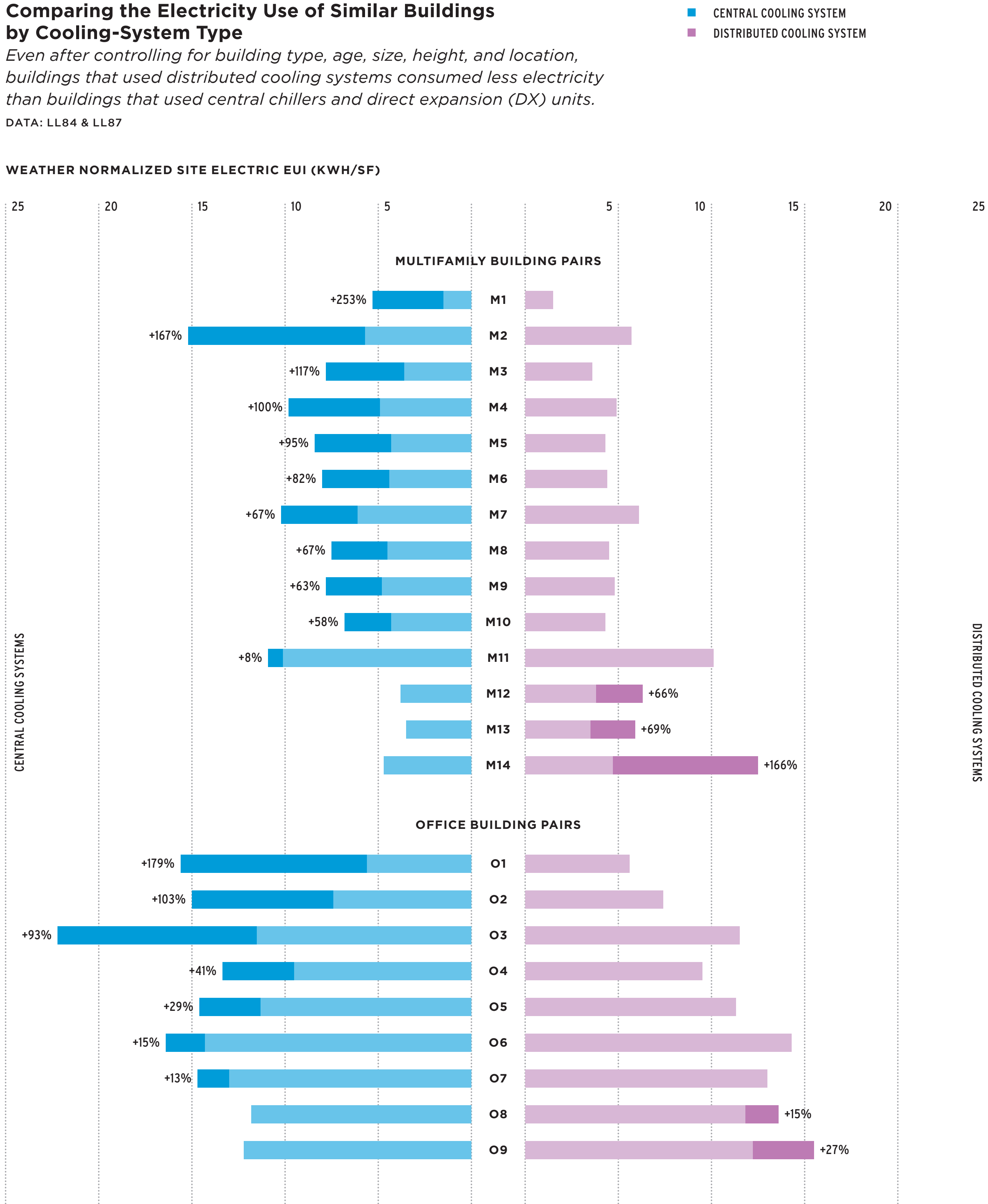
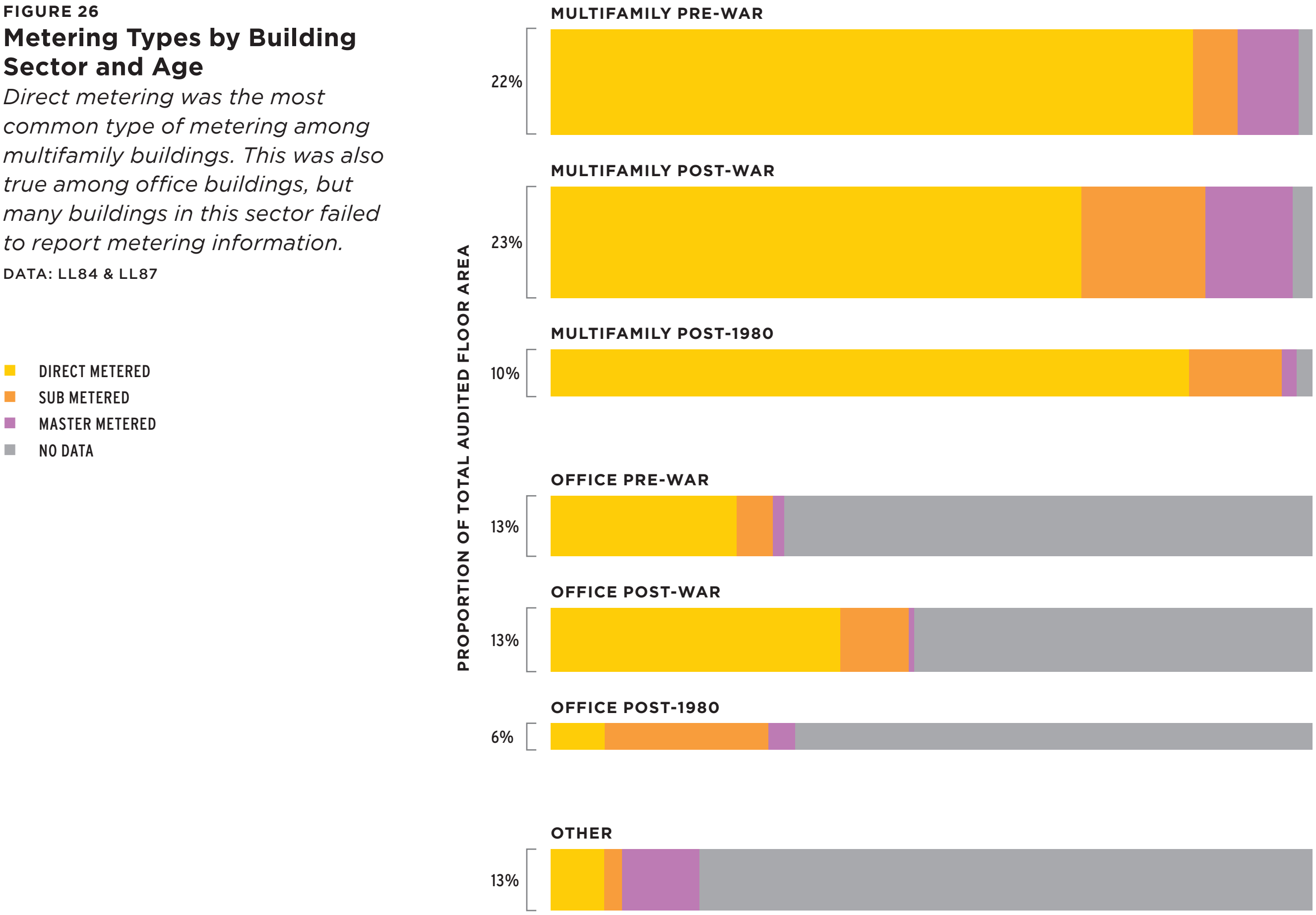


FIGURE 26

Metering Types by Building Sector and Age

Direct metering was the most common type of metering among multifamily buildings. This was also true among office buildings, but many buildings in this sector failed to report metering information.

DATA: LL84 & LL87



no electric ventilation at all and may rely entirely on a trickle of infiltration through the windows to keep occupants supplied with fresh air.

While each of these factors offers possible explanations for the differences we observed between the two types of cooling systems, more research is needed to understand why buildings with central systems used more electricity than their counterparts using distributed systems.

Electrical Metering Systems

Energy metering enables owners and tenants to understand how much energy they use and allows utilities to bill consumers based on exact usage. Studies indicate that all on its own, metering can have a significant impact on how much energy tenants and the buildings they live in consume.[35] Metering creates financial incentives for tenants to save energy.

This year's report will show how different metering technologies impact energy use in buildings. Multifamily buildings that were either direct or submetered were observed to use 20 percent less electricity than mastered-metered buildings.

Electricity meters have the highest quality audit data. That makes sense: Electricity is usually the most expensive form of energy, which gives owners an incentive to install a tool that ensures their tenants pay for their actual energy use.

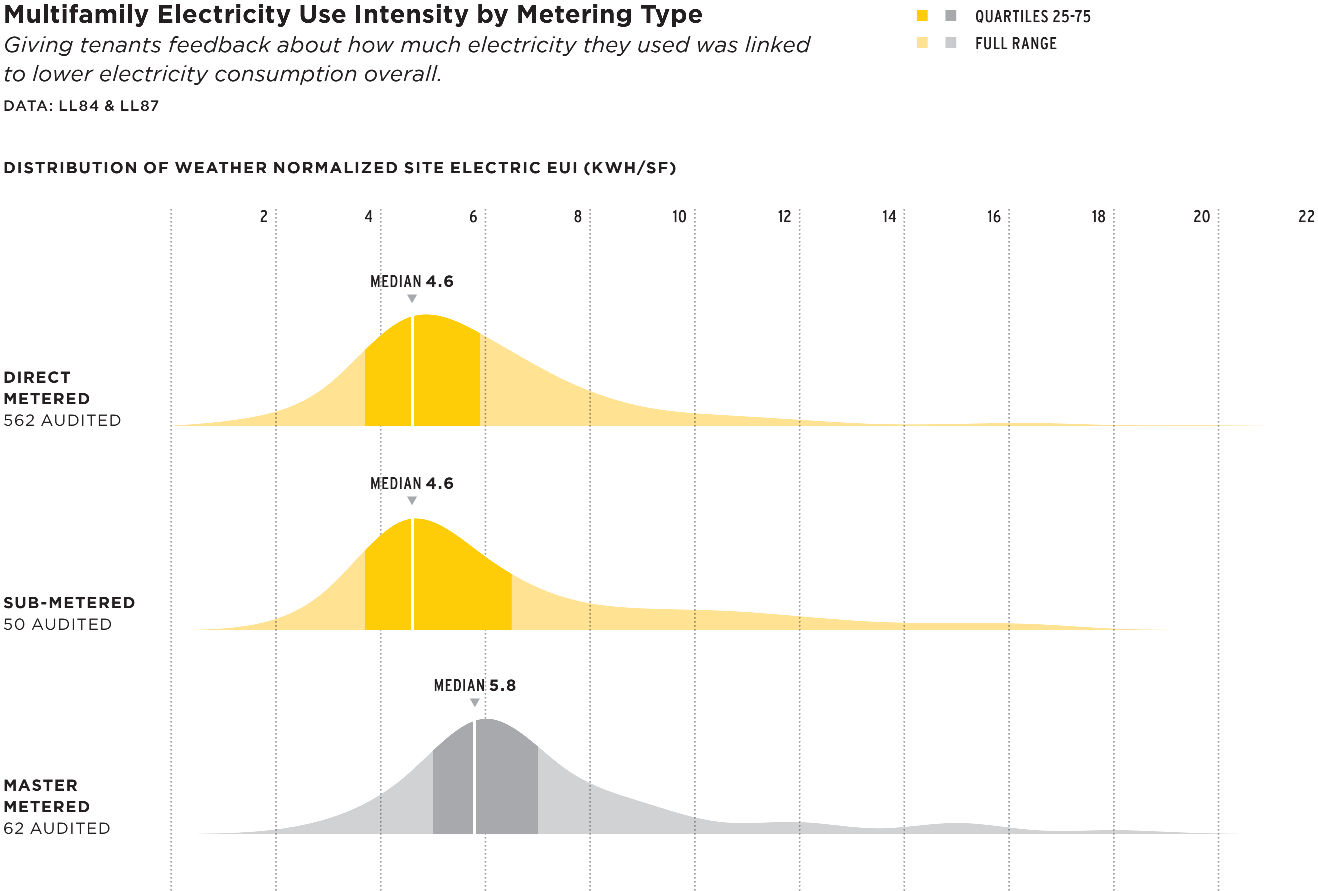
In New York City, more than half of all audited building area is directly metered for its electrical

FIGURE 27

Multifamily Electricity Use Intensity by Metering Type

Giving tenants feedback about how much electricity they used was linked to lower electricity consumption overall.

DATA: LL84 & LL87



consumption. Another 20 percent of the audited area is master metered, which means the landlord gets the utility bill and then passes costs down to tenants based on their lease or measurements from a submeter. (Master metering has been most commonly reported in high-rise multifamily buildings, likely because in the mid-20th century, builders and building owners believed that electricity would become "too cheap to meter."[36]) Submetered spaces make up half of this master-metered, audited area.

It is unclear how the remaining 30 percent of audited building area is metered. Most of these are office buildings and they either reported contradictory metering technologies or did not report any. In fact, 62 percent of audited office area did not report which type of metering they used. (By comparison, only 2 percent of audited multifamily area did not report their metering type). Determining how these buildings are metered can not only help owners and managers understand and possibly reduce their building energy use. It can also help them comply with LL88 of 2009, which requires the submetering of commercial tenant spaces by 2025.

Electricity Use by Metering System

To understand how metering affects electricity consumption, we compared electricity use in audited multifamily buildings using direct meters, master meters and submeters. To ensure the reliability of our results, we made sure these buildings used more than 90 percent of their area for residences, used electricity for cooling and used only fossil fuels for heating and hot water.

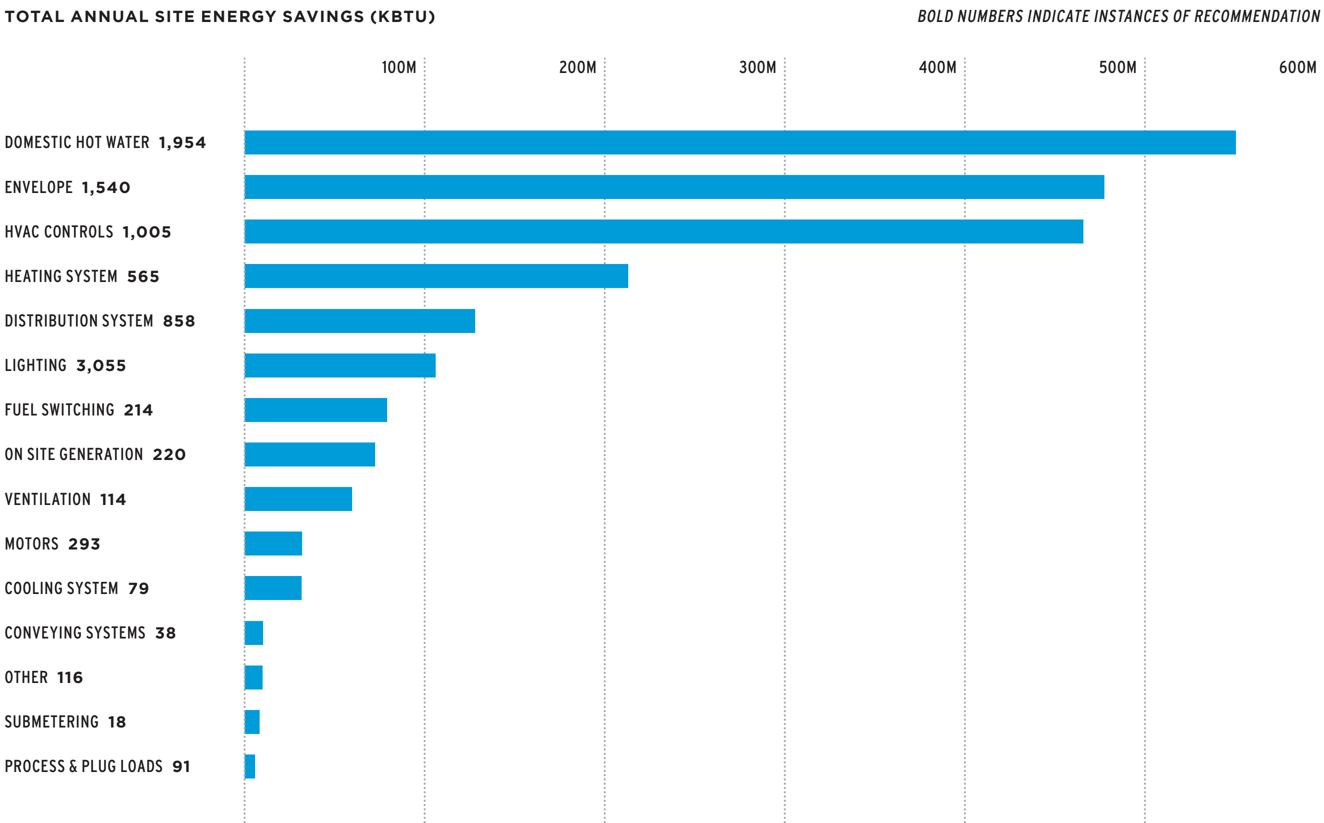
When controlled for the factors mentioned above, direct-metered and submetered buildings show no significant difference in terms of their electricity use per square foot. Direct- and master-metered buildings, however, did. Master-metered buildings used 1.2 kWh/sf more than submetered or direct-metered buildings (Figure 27). In a regression analysis that controlled for year, height and size, master-metered buildings were tied to an increase of 1.35 kWh/sf on average in weather normalized Site Electric EUI compared to direct-metered buildings.

FIGURE 28

Multifamily Energy Conservation Measure (ECM) Estimated Energy Savings

Were multifamily buildings to implement all of the ECMs that auditors recommended, these buildings could save almost 2.3 billion kBtus, combined. That amount is equal to only 5 percent of audited multifamily energy use.

DATA: LL84 & LL87



Auditor-recommended ECMs

As required by LL87, auditors inventoried building systems and energy use and recommended improvements to them called "energy conservation measures," or ECMs. What we report on here are not individual recommendations—guidance for specific buildings—but aggregated ones. Thus, these aggregated recommendations highlight promising areas for energy savings in the overall group of audited buildings but not for individual buildings. They can be used to guide an owner considering a renovation or operational improvements. More importantly for the city's effort to reduce greenhouse gas emissions, these recommendations can justify prospective government and private utility programs.

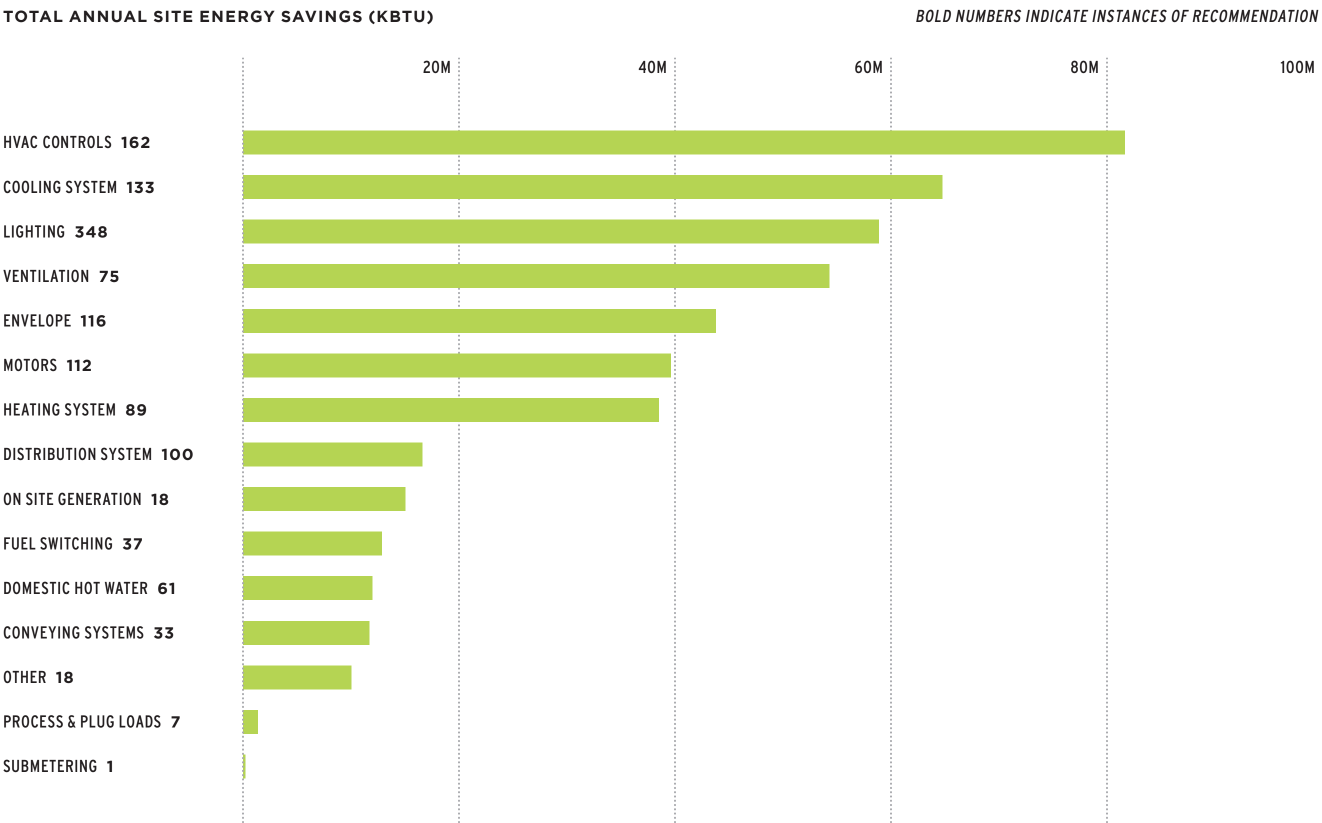
Interestingly, the typical audit did not find significant amounts of cost-effective energy savings to be had in the city's large buildings, regardless of type. Auditors may have come to this conclusion based on the language of Local Law 87, which mandates audits to identify 'reasonable measures'—a term open to many interpretations. Many commercial buildings may have already implemented low hanging fruit like variable-frequency drives (VFDs) and lighting upgrades. Researchers and practitioners in other settings have consistently found opportunities for significant savings. In 2016, for instance, the New York City Buildings Technical Working Group found that implementing all cost-effective ECMs in multifamily buildings could cut their emissions by 35 percent.[37] A Natural Resource Defense Council and Urban Land Institute program showcasing commercial tenant renovations showed that projects could achieve 27 percent savings on average.[38] And a 2017 Pacific Northwest National Laboratory study concluded that commercial buildings could cut their overall energy use 29 percent simply by installing better controls for lighting and HVAC systems. By comparison, the building auditors who examined energy use in New

FIGURE 29

Office Energy Conservation Measure (ECM) Estimated Energy Savings

If they implemented all the ECMs auditors recommended in 2015, office buildings could save more than 460 million kBtus. That amount is equal to only 2 percent of audited office building's 2015 energy consumption.

DATA: LL84 & LL87



York City's large buildings reported that only 3.36 billion kBtus could be saved cost-effectively using currently available technologies—That's only about 4.5 percent of the city's audited office and multifamily building energy use total.

The total energy savings predicted if all ECMs recommended by auditors were implemented are equivalent to 25 percent of New York State's electric energy produced by wind in 2015. Most of this total comes from recommendations made about multifamily buildings, but even those 2.3 billion kBtus of savings only represent 5 percent of the sector's energy use in 2015 (Figure 28). The total savings from office ECMs was just over 460 million kBtus (Figure 29). (Annual audited office source energy use is more than 50 times larger, at 27 billion kBtus.) Other audited buildings could save up to 600 million kBtus. These results are consistent with last year's report and indicate that auditors underestimated the true potential for energy savings in New York City's largest buildings.

Lighting

Lighting upgrades were the most frequently recommended ECM in both multifamily and office buildings. If all of these lighting upgrades were completed, they would save more than 250 million kBtus annually. For landlords, these upgrades offer attractive financial paybacks. They are also relatively easy and expose owners to fewer risks than replacing or retrofitting other energy-using systems, such as cooling and heating. Moreover, electricity is costly enough to make the energy savings from lighting upgrades valuable even before utility incentive programs are applied.

DHW Systems

In multifamily buildings, upgrades to DHW systems were the second-most recommended ECM. This indicates that many auditors believe these systems could use significantly less energy. Indeed, audited multifamily buildings alone could save almost 550 million kBtus if all of the DHW

FIGURE 30

Multifamily Energy Conservation Measure (ECM) Recommendation Rates

In multifamily buildings, upgrades to lighting systems and retrofits to domestic hot water systems were the ECMs auditors recommended most often.

DATA: LL87

AUDITOR'S RECOMMENDATION RATE FOR MULTIFAMILY BUILDINGS

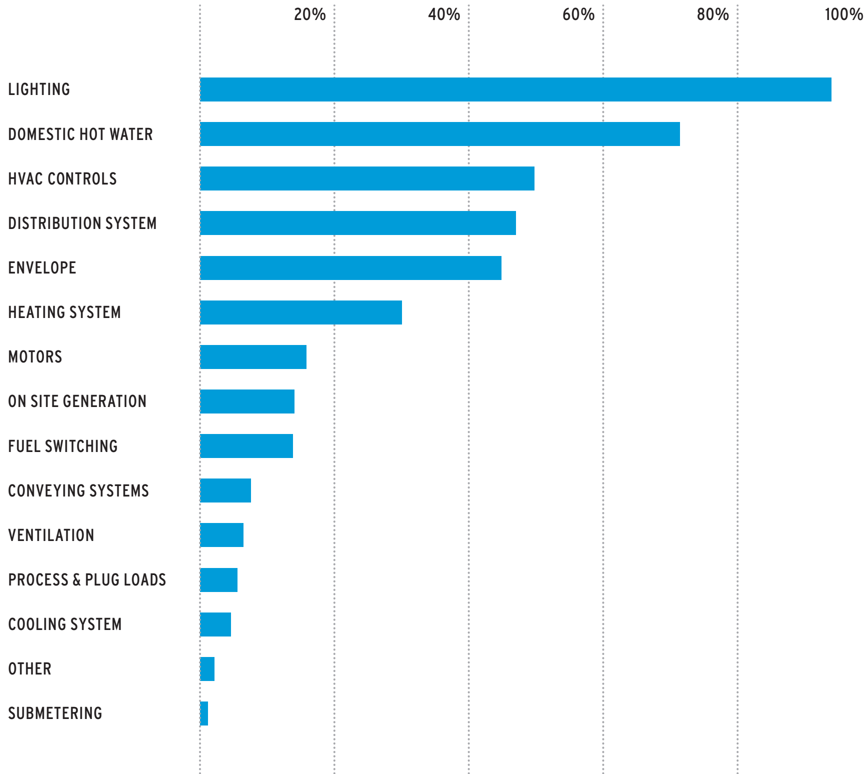


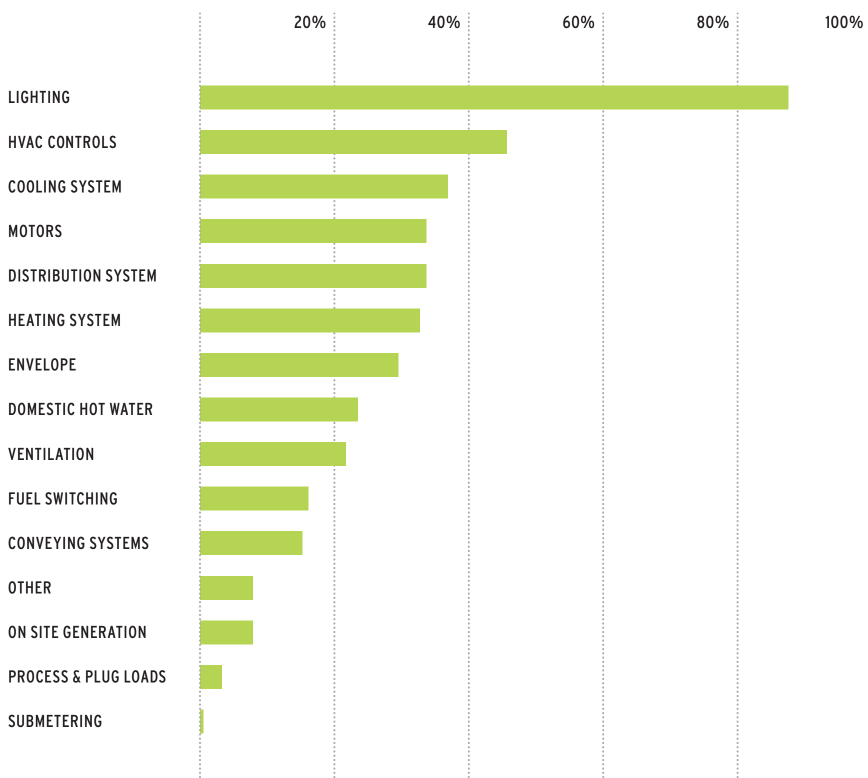
FIGURE 31

Office Energy Conservation Measure Recommendation Rates

In office buildings, auditors most often recommended upgrades to lighting systems and HVAC controls.

DATA: LL87

AUDITOR'S RECOMMENDATION RATE FOR OFFICE BUILDINGS



ECMs were completed. Within this ECM category, separating DHW from heating systems was the most highly recommended measure; installing low-flow fixtures to limit the use of hot water was the second most commonly recommended DHW improvement.

Submetering

Despite the significant energy savings that can come from submetering, this ECM was the one auditors were least likely to recommend. This may be because relatively few multifamily buildings remain master metered, only about 100 buildings. As previously mentioned, 67 percent of the audited office area had conflicting or missing data on metering, so it's unclear how many offices could benefit from better metering.

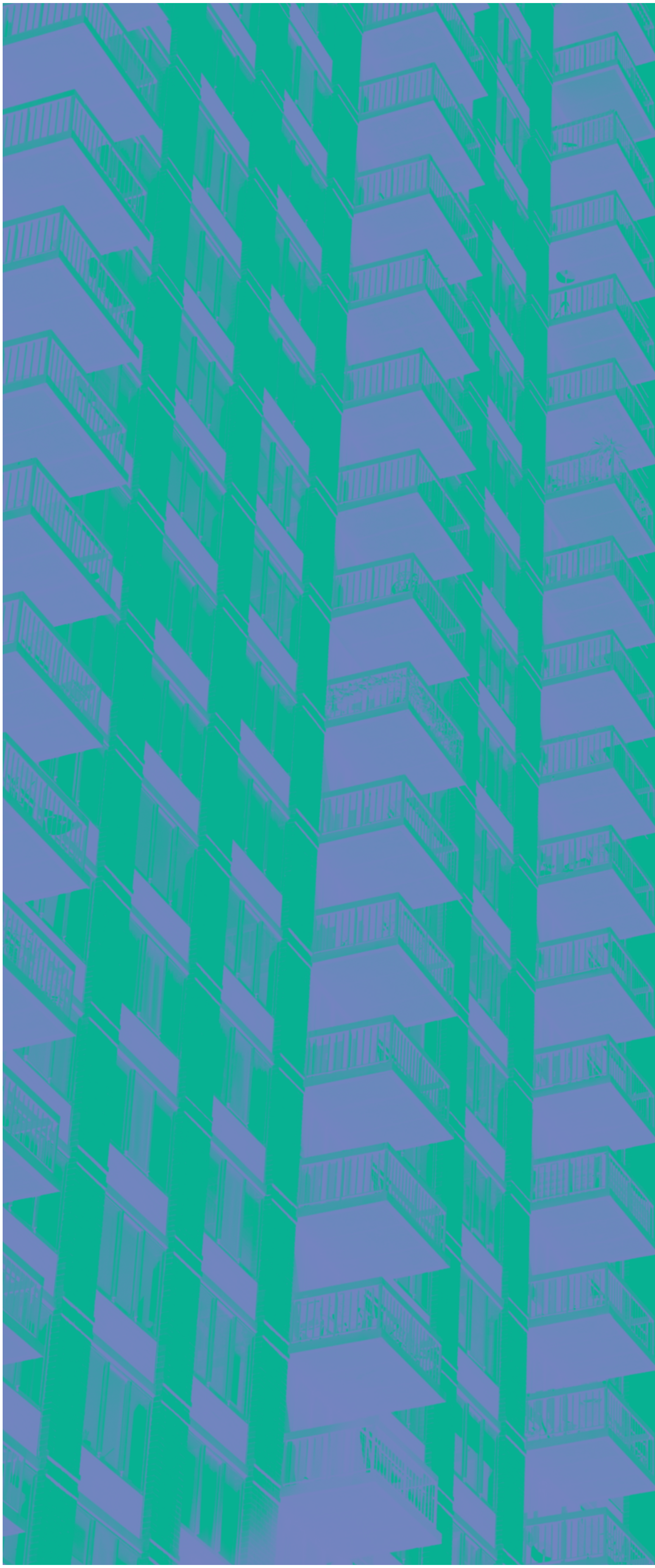
HVAC, Heating and Cooling

Recommendations for office buildings focused on controls and sensors for HVAC systems, along with improvements to heating and cooling systems. Making upgrades to cooling tower systems was the most common cooling recommendation; it was closely followed by recommendations to upgrade central cooling chillers. Upgrades and fixes to boilers or furnaces were the most common suggestions for heating systems. Installing heat recovery, for exhaust ventilation or steam condensate, was the second on the list of improvements for heating systems. Envelope upgrades were only suggested half as frequently as HVAC controls and sensors, despite the fact that many of New York City's commercial buildings lack insulation and air sealing. Installing these could drastically reduce space heating energy consumption.

Implications

As discussed, the results presented above should not be applied to individual buildings. Instead, they can and should be used as an indication of what might happen, citywide, if recommended measures are pursued. They can also serve as a guide for government and private utility program planners.

Auditors underestimated the true potential for energy savings in New York City's largest buildings.



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Policy Perspectives

Science-based programs and policies require quality data. Since two-thirds of NYC's greenhouse gas emissions come from energy used in buildings, the City needs reliable building data to reach 80 by 50.

In 2015, the City improved its data collection. It required that all benchmarked data be run through Portfolio Manager's data quality check and that buildings initially reporting zero energy use submit their information again.[39] As a result, we saw fewer outliers and duplicate records.

Our policy observations focus on the three systems highlighted in this report: Domestic Hot Water (DHW), cooling and electrical metering. Why these three? Because DHW and cooling together were responsible for a full 21 percent of energy used in the city's large buildings. And, all on its own, tenant submetering has been shown to save as much as 22 percent of a building's electric use.

Energy Efficiency of Key Systems

Separating DHW from Space Heating

The benchmarking and auditing data show that multifamily buildings with separate DHW systems use less fuel than buildings with connected systems. This report's Advisory Committee, however, cautioned against assuming causality, noting that separate DHW systems tend to be newer. To investigate the link between DHW systems and energy savings further, case studies should be produced about fuel use before and after a building separates its DHW system. This will help establish whether these retrofits save energy and should be recommended as a standard practice.

Expanding Data on Cooling Systems

This study shows that multifamily and office buildings with distributed cooling systems use less electricity than centrally cooled buildings. This is a paradox, as central cooling equipment is generally more energy efficient than the equipment used in distributed cooling.

Much remains unknown about why New York City's centrally cooled, large buildings consume more energy than comparable buildings using distributed cooling. Current benchmarking and auditing data does not accurately report the total area cooled, the temperatures of tenant spaces, or the total operational time of different systems.

Current benchmarking and auditing data also does not include the type and amount of mechanical ventilation and natural infiltration in buildings. These airflows are

Better metering practices, including direct metering and submetering, can save energy in New York City multifamily buildings.

foundational to understanding how much energy large buildings use for cooling. The data collection process should be improved to incorporate these additional details. They would contribute to a better understanding of the overall efficiency of different cooling systems and how occupant behavior influences cooling-related energy use.

Submetering Tenants

Pursuant to Local Law (NYC Local Law 88 of 2009 as amended by Local Law 132 of 2016), by 2025, commercial buildings larger than 25,000 square feet in size must submeter tenants who occupy spaces larger than 5,000 square feet and give the tenants monthly electricity use reports. Submetering will give commercial tenants precise information about their electricity consumption; it could also prompt the creation of new lease agreements that would promote more efficient tenant behavior and fit-outs. But nothing in the law requires billing based on use—even though doing so would provide commercial tenants with an even greater reason to use less electricity.

The City should also consider a plan for submetering large multifamily buildings. This report shows that multifamily buildings that measure tenant electrical consumption use less electricity than do master-metered buildings. Other research studies confirm this. Better metering practices, including direct metering and submetering, can save energy in New York City multifamily buildings.[40] The New York State Energy Research and Development Authority (NYSERDA) has an Electric Reduction in Master-Metered Multifamily Buildings Program dedicated to installing submeters in master-meter buildings. The City plans to work with NYSERDA and local utilities to increase the uptake of building submetering in large multifamily buildings. However, there is currently no requirement to submeter residential buildings in New York City.

Updates Since 2016

Last year's report discussed space heating and lighting systems that offer important opportunities for energy savings. Together, space heating and lighting are responsible for almost 50 percent of energy use in the city's large buildings. Since the report's release in August 2016, there has been noteworthy progress with these systems.

Steam Heat Systems

Space heating is the largest energy end use in New York City's audited buildings. Steam heat, the most common form of heat distribution, relies on outdated and inefficient systems that overheat the indoors and cause other, uncomfortable conditions. However, these systems also offer abundant opportunities for upgrades and savings.

Options for reducing the amount of energy steam heat systems use include training operators, upgrading systems and incorporating better controls. These cost-effective measures can reduce heating fuel use by as much as 20 percent. Converting steam heat systems to hydronic systems, while expensive, is also extremely effective—leading to as much as 40 percent in energy savings.[41]

In 2017, the NYC Retrofit Accelerator launched the Better Steam Heat campaign to provide outreach and assistance to steam-heated buildings. This campaign qualifies heating service companies to perform comprehensive steam heat upgrades. It also connects interested building decision-makers with these companies and aids in project implementation. As a result of the Better Steam Heat campaign, more than 230 upgrades have been undertaken to date.

Energy Loss from AC Units

More than 70 percent of New York City audited multifamily buildings reported using distributed cooling systems. These room air conditioners may help tenants use less cooling energy, but they can create leaks in the building envelope. Openings between these units and the walls and windows they pass through allow hot air to slip in during the summer and escape during the winter. On an annual basis, these leaks translate into a combined operating cost penalty of between $130 million and $180 million for owners and tenants.[42]

To spur change, the NYC Retrofit Accelerator will launch a campaign to help prevent energy loss from room air-conditioning units. The campaign will encourage building owners to reduce air leakage throughout their buildings, including tenant spaces, elevator and stair shafts. In addition, recent upgrades in the NYC energy code improve building envelopes by accounting for the thermal bridging from through wall and packaged units in new construction. In many types of buildings, infiltration will be measured and capped.[43]

Lighting

Lighting is the fourth-largest user of energy in New York City's audited buildings and is responsible for more than 11 percent of source energy use. Despite the significant savings that can be gained from lighting upgrades, about one-quarter of audited multi-family is illuminated by inefficient incandescent lighting or by older, inefficient fluorescent lamps.

Additionally, auditors are required by law to inventory tenant owned equipment, but their reporting is inconsistent. Instead most auditors have focused on base building systems. Updates to the audit form are necessary in order to understand whether inefficient lighting is pervasive in both common areas and tenant-owned spaces.

Local Law 88 of 2009 and Local Law 134 of 2016 mandate that by 2025, large and mid-size commercial buildings upgrade their lighting to meet the New York City Energy Conservation Code.[44] The code has extensive requirements for lighting systems and controls, such as timers and occupancy sensors, and for high efficiency fixtures, so these laws are expected to have a significant impact.

Improvements and Accomplishments to Date

Expanded Benchmarking

In October 2016, the City amended Local Law 84 of 2009 with Local Law 133 of 2016. This amendment, called the Benchmarking Law, lowered the reporting property size threshold from 50,000 square feet to 25,000 square feet. Once it takes effect in 2018, this expansion will add roughly 10,000 properties to the benchmarking data set, increasing the amount of covered floor space to almost 60 percent of New York City's gross square footage.

NYC Carbon Challenge

In 2007, the Mayor's Office of Sustainability launched the NYC Carbon Challenge to encourage the private building sector to reduce its greenhouse gas emissions. With this program, participants have pledged to voluntarily reduce their building-based emissions by 30 percent or more over the course of 10 years. There are now 17 universities, 10 hospital organizations, 24 commercial tenants, 10 commercial owners, 20 residential property management companies and 19 hotels that have committed to the program. Current participants represent more than 325 million square feet and have reduced greenhouse gas emissions by over 340,000 metric tons of carbon dioxide equivalent (CO_2e), a standard unit for measuring carbon footprints. To date, participants have achieved an average reduction of 20 percent, and 10 participants have already achieved their full reduction goals.[45] This program demonstrates that buildings can achieve ambitious emissions reduction goals in short periods.

Public Buildings

City operations, which represent approximately 6.5 percent of citywide greenhouse gas emissions, includes 2,300 buildings among other emissions sources. When the Mayor's Office of Sustainability set its first ambitious 30 by 30 citywide goal in 2007, the City government committed to reducing its emissions in an accelerated time frame of 10 years, or 30 by 17. And when the City committed to an even more aggressive citywide target of 80 by 50 in 2014, it extended and upped the city government goal to require a 35 percent reduction by 2025.

Most of the reductions from City buildings will have to come from the vast existing building stock. But new buildings need to become radically more efficient, too. That's why the City Council passed two new laws in 2016: Local Law 31 and Local Law 32. The new legislation requires most new City buildings and major retrofits in municipal buildings to achieve LEED Gold ratings and cut their energy use in half as compared to code or the median benchmarked score for that type of building.

NextGeneration NYCHA Sustainability Agenda

The NextGeneration NYCHA Sustainability Agenda expresses the New York City Housing Authority's (NYCHA's) commitment to creating healthy and comfortable homes that will withstand the challenge of climate change. NYCHA's public housing portfolio serves 400,000 of New York City's lowest-income households and represents 13 percent of the 2015 benchmarked residential units. NYCHA is also the largest public housing authority in the nation. Each development houses an average of 2,700 residents and uses 40 percent more energy per square foot than the average multifamily building in New York. This higher energy intensity may be due to higher relative occupancy and limited electrical submetering in these buildings.

This building portfolio aims to start on the path toward 80 by 50 by addressing climate adaptation and resiliency in all capital planning; and incorporate sustainability into the management of all properties.[46]

Improving Data Quality and Compliance

The Benchmarking Help Center

In January 2016, in partnership with the City University of New York's Building Performance Lab, the City of New York relaunched the NYC Benchmarking Help Center (BHC). Originally started in 2010, it provides assistance for owners and managers who must comply with the NYC Benchmarking Law. Its goal is to increase compliance and data quality by offering free support to those who need help in the benchmarking process.

The City recognizes that many owners of the mid-size buildings newly required to benchmark may have limited resources. To address this, the BHC's Jump Start program offers training and one-on-one assistance to help mid-size building owners begin the benchmarking process well in advance of their first benchmarking deadline, May 1, 2018.

Read more at nyc.gov/benchmarkinghelpcenter.

Automatic Uploading of Data Utility

The expansion of the Benchmarking Law in 2016 to include mid-size buildings was predicated on the availability of automatic, whole-building energy data uploads from energy utilities. Both Con Edison and the National Grid energy company have agreed to provide automatic uploads to Portfolio Manager for mid-sized and large buildings, in time for the first benchmarking reporting deadline for mid-size buildings.

Automatic uploading to Portfolio Manager as a free service will significantly reduce data entry errors from manual entry, protect individual tenant privacy, and minimize the burden of benchmarking on building owners, thereby increasing compliance.

Training Building Professionals

GPRO, Urban Green Council's training and certificate program, trains the workforce on how to build and maintain high-performance buildings. GPRO's trade-specific modules are designed for building professionals—building operators and managers, plumbers, electricians, superintendents and so on—who seek to integrate sustainable practices into their everyday work. In 2016, as part of a partnership with the Real Estate Board of New York (REBNY), more than 600 building professionals became certificate holders in GPRO Operations and Maintenance Essentials. Since 2010, more than 6,500 tradespeople in New York City have been trained in GPRO.

New York City likewise intends to encourage the training of more benchmarking service providers. The City monitors benchmarking accuracy and will align training, certification programs and policies to improve benchmarking services.

LL84 Seven-point Review System
To help building owners, benchmarking data submitted prior to the deadline now undergoes a seven-point review; the Department of Buildings notifies owners of any deficiencies in their data and reporting. These reports are reviewed for property information, property floor area and building count. They are also reviewed for their energy data, including metered area, site energy-use intensity (EUI) and source EUI. Finally, if building owners or managers are required to report water data, the DOB verifies that data with the Department of Environmental Protection (DEP).

Improving Transparency and Understanding

Metered New York
Metered New York, developed by Urban Green Council, uses public benchmarking data to show how New York City buildings actually perform. The website, www.metered.nyc, provides easy-to-understand graphs that communicate building energy use information at a glance, including how each property compares with similar buildings in New York and how its energy use has changed over time.

Buildings can also be filtered and searched to see, for instance, which Brooklyn office properties built before 1950 are the best—or worst—performers.

Performance Snapshots
The City is considering the use of easy-to-read reports, or "snapshots," directly to building owners who have complied with the Benchmarking Law. These snapshots would provide visualizations of each building's energy performance over time. The goals of this project are to engage building owners in energy tracking and savings; encourage accuracy in data reporting and energy upgrades.

Energy and Water Performance Map
The New York City Energy & Water Performance Map, developed by New York University's Center for Urban Science and Progress (NYU CUSP), is a web-based tool that visualizes benchmarked buildings' energy and water use and greenhouse gas emissions. It includes building performance analytics; allows for queries about buildings by age, type and size; and is accompanied by additional academic research. The map is available at nyc.gov/benchmarking.

Cost-effective measures, including training operators, upgrading systems and incorporating better controls, can reduce heating fuel use by as much as 20 percent.

/07

Appendix

A comprehensive data cleaning methodology was used to create the analyses in this report.

Urban Intelligence Lab of New York University's Center for Urban Science and Progress (NYU CUSP) and Urban Green Council (Urban Green) worked together to clean up data and make calculations. The final LL84 and LL87 data sets that were used have been rigorously cleaned to remove outliers and entries that contained errors or failed to report necessary and vital information.

Data-cleaning Methodology

LL84: Building Identification Information

To make the best use of the 2015 LL84 dataset, the original 13,828 entries were filtered based on the types of erroneous data entries they contained. Depending on the kinds of analyses we intended to perform—examining energy end proportions versus total water consumption—we used different combinations of data filters to allow for the appropriate removal of inaccurate or missing data. Our first round of cleaning removed entries that misreported or failed to report identifying information, such as a building's borough, block and lot (BBL) number. However, whenever possible, we filled in missing BBL numbers and corrected those that were reported incorrectly using the NYC_Geoclient API tool, which allows users to search for buildings by address and postal code. The tool is a free geocoding service developed by the New York City Department of Information Technology and Telecommunications for public and City government use.

In our second round of cleaning, we removed duplicate entries, wherein more than one entry had the same Energy Star Portfolio Manager ID number, or the same combination of BBL and Building Identification Numbers (BIN). In order for multiple buildings on the same lot to be reported separately, we retained duplicate BBL entries if each entry had a unique BIN. However, if more than one entry had the same BIN and reported different BBLs, we included only one of these entries in our analyses. When dealing with duplicates, we kept only the most recent submission in the data set (this information was based on the release dates listed in ENERGY STAR Portfolio Manager records).

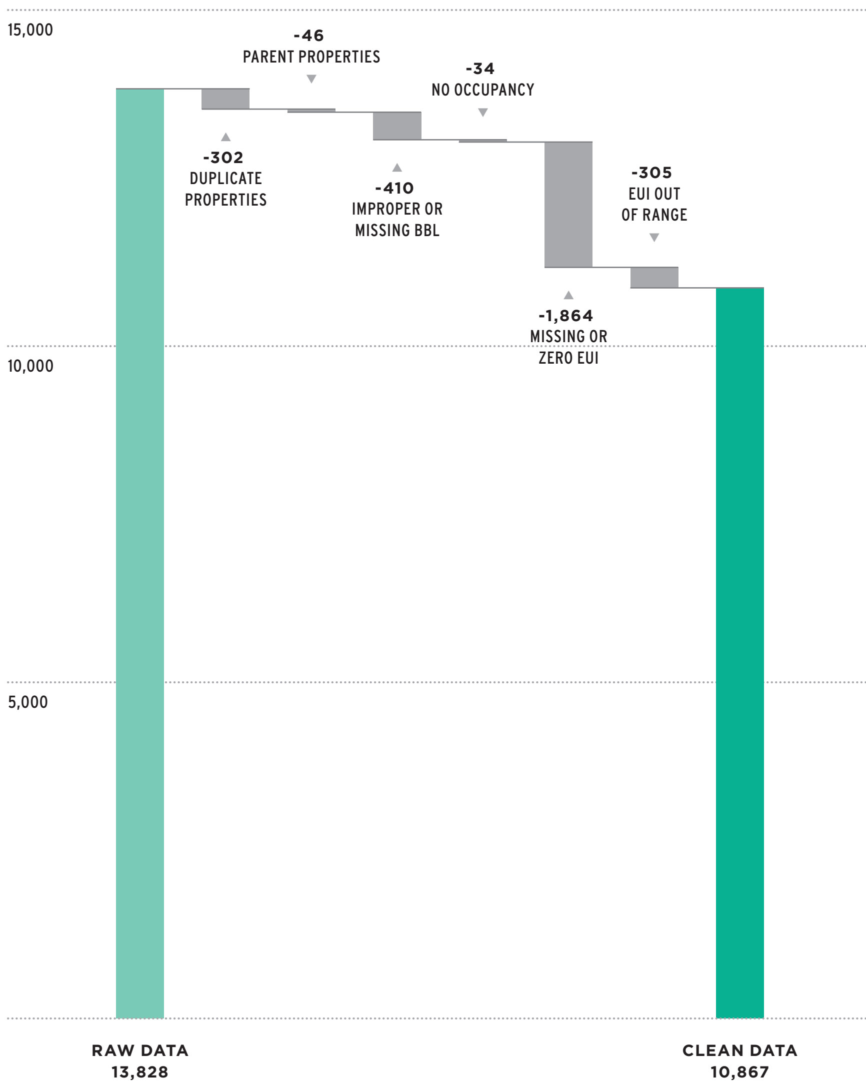
ENERGY STAR Portfolio Manager uses the term "parent properties" to report campus-level, multi-building properties in one entry.

FIGURE 32

Cleaning Processes for Local Law 84 Benchmarking Data

To ensure the accuracy of the 2015 benchmarking data and guarantee the veracity of this report's conclusions, we engaged in several data-cleaning processes that included removing duplicate records and other inaccurate entries.

DATA: LL84



These parent properties are not actual buildings; their so-called child properties are. To ensure that we didn't erroneously include parent properties that did not represent actual buildings, we removed them in a third round of cleaning. We identified parent properties and removed them when the parent property ID field equaled the unique property ID. These three levels of cleaning were applied for all of the analyses we conducted for this report. As a result, we eliminated 792 LL84 observations, leaving 13,036 for further exploration.

LL84: Energy, Water and Greenhouse Gas Use

In our final rounds of cleaning, we identified entries with questionable energy, water and greenhouse gas emissions data. We applied different sets of data filters depending on the type of analysis. That way, if a building reported energy use but not water use, we were still able to include it in analyses relating to energy.

To define upper and lower limits for energy-use and water-use outliers, we used a statistical method that removed values at the tail ends of the distributions for weather normalized, source-energy-use intensity and water-use intensity. First, building energy-use intensity (EUI) distributions were normalized in order to identify outliers. The data were log-transformed based on EUI, as its unaltered distribution skewed to the right—similar to a distribution of individual incomes. By taking the natural logarithm of EUI, the distribution becomes symmetrical and allows for the use of the standard deviation as a threshold to detect outliers. Following that transformation, we identified outliers as observations that were greater or less than two standard deviations from the calculated mean and removed them from the analysis data set. We applied this outlier-detection methodology, by property type, for all property types that had at least 50 unique entries (we grouped property types with fewer than 50 entries for effective cleaning). For all properties types with at least 50 unique entries, we set statistical limits for energy, water and greenhouse gas emissions independently.

After cleaning for duplicates, missing building identification information and outliers, there were 10,867 buildings with usable energy data in 2015 and 7,385 buildings with usable water data in 2015.

LL87: System Standardization and BBL

This report analyzes three years of LL87 audit data—data from 2013, 2014 and 2015. Because the LL87 data-collection process is more complex, requiring auditors to input information manually into Microsoft Excel forms and then send to the City, cleaning the LL87 dataset was also more complicated—for example, standardizing the formatting and language of these entries required more effort. In addition, in the cleaning process, we relied more heavily on filtering entries than on discarding them. Because there were many variables that could be analyzed independently, filtering enabled us to include buildings in some instances but not others, depending on which information they reported correctly. For example, a buildings' lighting energy conservation measures could be analyzed even if that same building did not report its heating system type.

To properly analyze the original 3,156 entries in the LL87 audit dataset, we needed to extract, clean and transform the data, which was collected using the Energy Audit Data Collection Tool. This Tool is a simple spreadsheet that allows auditors to record information from their building inspection. Frequently, the collected data contained significant errors—improper and missing entries, for instance—because the energy auditors who entered the audit-related numeric and categorical data in the forms did so by hand. For continuous inputs, such as floor area and energy, all non-numeric records that could not be directly converted into numbers were stripped of spaces, commas and appropriate units (e.g. kBtu for Energy Savings). For categorical inputs that don't have numerical value, such as Heating System Type and Exterior Wall Type, there were significant differences in the ways individual auditors entered their data. For example, in the Heating System Type field, when a building's fuel source was district steam, some auditors wrote "Steam Boiler" while others listed it as "Other." For the purpose of analysis, we identified the remaining non-numeric records—which consisted of symbols, comments and indications that the data was unavailable—as missing data.

Once we standardized the format for the LL87 data, we removed duplicates using a cleaning process similar to the one we used for the LL84 data. In this case, we removed entries that did not report BIN information or misreported it. Accurate BBL and BIN information is important for LL87 audit data because this identification information is used to match building system information with corresponding energy and water information from the LL84 data.

Filtering enabled us to include buildings in some instances but not others, depending on which information they reported correctly.

Our analyses often required merging the LL84 and LL87 data sets, managing issues such as individual properties reporting different floor areas and energy-use intensities.

In the second part of the cleaning process, we removed duplicate entries if more than one entry used the same BBL and BIN combination. As with the LL84 data cleaning, we removed all identified duplicates except for the most recent entry, with the assumption that the most recent record would contain the most complete and correct data. Our final, cleaned dataset contained 2,454 entries.

LL87: Energy Conservation Measures

We structured the LL87 dataset differently to clean auditors' energy conservation measure (ECM) recommendations. Each individual ECM was a unique observation with energy savings, cost savings and building identification information associated with it. If the BBL and BIN combination was marked as a duplicate in the standard format LL87 dataset, then it was considered a duplicate here as well and was removed. Records were also removed if the auditor recommended no ECMs for the property.

The second part of the ECM cleaning process was to remove erroneous and outlier ECM entries based on their estimated total annual energy savings. Because some auditors reported savings as negative numbers, we first took the absolute value of each expected energy saving. Then, to identify outliers, we used a statistical approach similar to what was used for LL84 energy data. We removed ECMs that reported energy savings that were greater than or less than two standard deviations away from the log normalized mean of the entire set. This process produced a list of 16,336 unique ECMs.

Linking LL84 and LL87 Data

Our analyses often required merging the LL84 and LL87 data sets. Combining these data sets enabled us, for instance, to investigate the impact of different types of domestic hot water systems on fuel use. Accurately combining these data sets required the managing of several issues. Specifically, individual properties found in both the LL84 and LL87 data sets often listed considerably different floor areas and energy-use intensities.

Properties found in both data sets sometimes also reported fuel information using different types of EUIs. Properties listed in LL87 report only site EUIs, rather than source EUIs, while properties in the LL84 data set report weather normalized site and source EUIs. It can be difficult to accurately convert between these types. In order to make comparisons, we used the fuel information provided in LL87 to calculate source energy use based on the same national coefficients used for LL84 data. LL84 source EUIs tend to be lower than those reported in LL87 for the same property. Differences here may be a result of differently defined reporting periods—LL84 reporting is for a single, complete calendar year, whereas LL87 reporting does not specify a particular reporting period. Because we were unable to accurately compare the EUIs, we did not discard any entries on the basis of different EUIs between data sets. Instead, analyses using the merged data set relied on LL84 for total energy data and LL87 for buildings' system-level data.

Combining the two datasets resulted in a total of 1,891 entries, about three-quarters of the number of entries found in the cleaned LL87 2013-2015 dataset.

End-use Breakdown and Post-stratification

Our breakdown of overall energy end uses and end use by sector (Figure 2) is one example of the importance of the linked LL84 and LL87 data set. This analysis required that each record report energy for the majority of end uses. To ensure accuracy, we removed building records that did not report any energy for space heating, cooling, DHW or lighting. (The one exception to this rule—we did not require office buildings to report the energy they used for DHW because offices have low DHW loads and report it infrequently.) This cleaning produced a final data

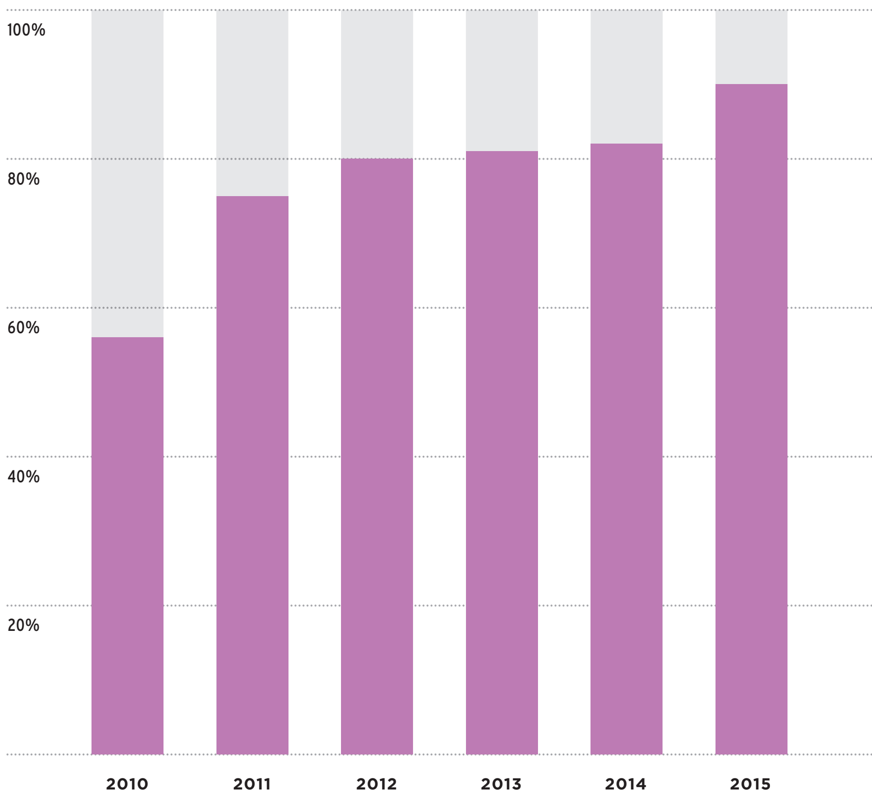


FIGURE 33
Local Law 84 Compliance Rate Trend
Compliance with the benchmarking rule skyrocketed, with 90 percent of required buildings reporting energy and water use in 2015.
DATA: LL84 & LL84 COVERED BUILDING LIST

set containing 600 records. Without this cleaning step, records that did not report their space heating would over represent all other end uses, thereby distorting the proportion of source energy that each end use consumes.

To eliminate sampling errors that might arise from this selective cleaning process, we calculated post-stratification weights, which were then applied to each sample. This is a technique often used in Residential Energy Consumption Survey (RECS) reports conducted by the U.S. Energy Information Administration (EIA) and is designed to adjust values within a random sample in order to represent a larger population.[47] In this analysis, the variables used for post stratification were primary property type, year built and gross floor area. These proportions were calculated using the original, cleaned LL84 data and were applied to the 600 records included in this analysis.

Energy and Greenhouse Gas Trend Interpolation

As compliance with LL84 continues to improve and the city collects more data, there has been an incremental decrease in the number of buildings that benchmark consistently. One reason for this is that buildings with a change in ownership are not required to benchmark until the first full calendar year following the transfer of ownership. Another reason for the decrease in consistently benchmarked properties is that major retrofit projects result in a change in BBL if separate tax lots are combined into one larger property.

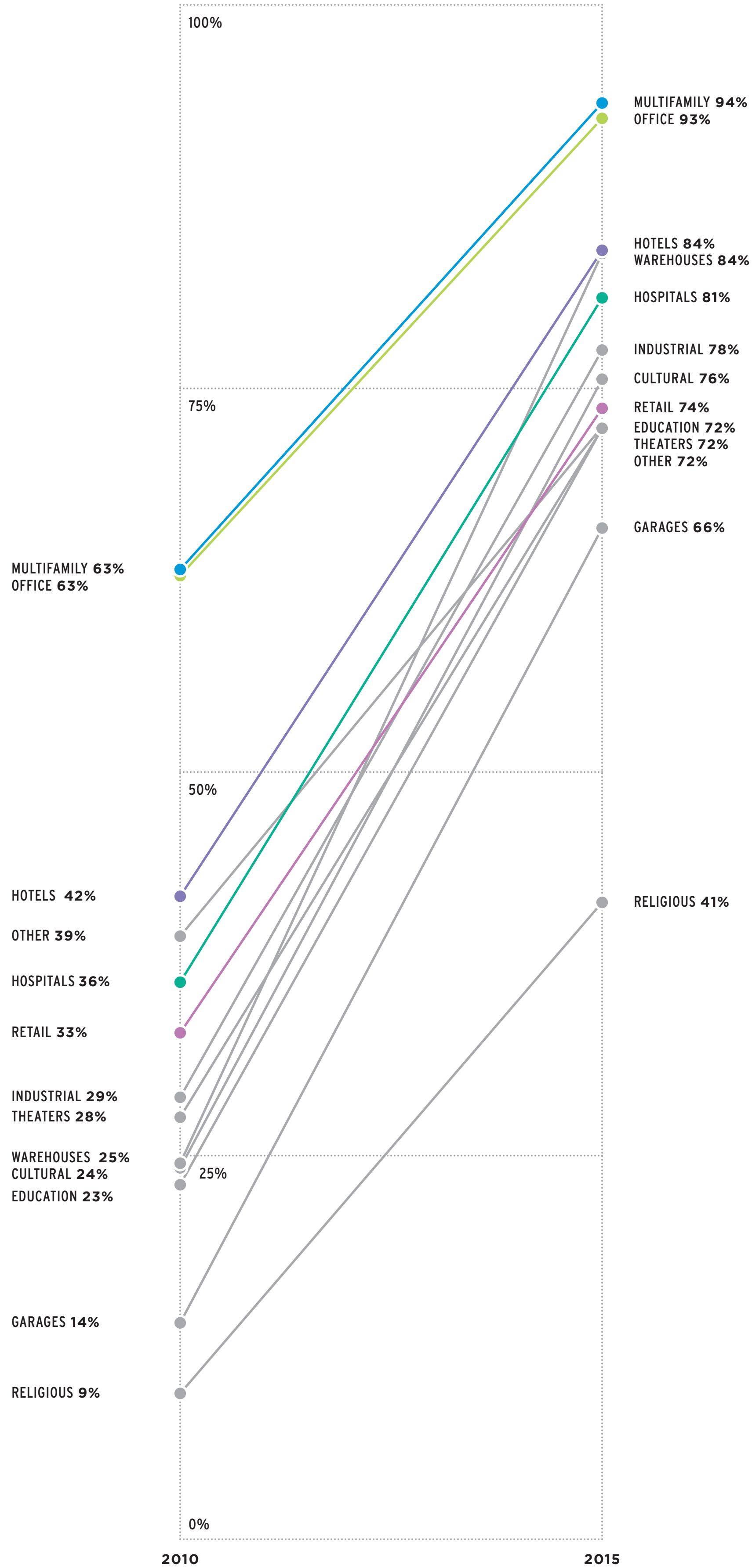
Therefore, to demonstrate how the emissions and energy use of the benchmarked building stock has changed between 2010 and 2015, we included in Figure 1 all buildings that reported energy-use data for at least five of the six benchmarking reporting years. If a building was missing energy data for a single reporting year

FIGURE 34

Local Law 84 Compliance Rate Changes by Sector

Multifamily and office buildings had the highest benchmarking compliance rate. Since 2010, warehouses and garages have seen the largest compliance improvements.

DATA: LL84 & LL84 COVERED BUILDING LIST



between 2011 and 2014, we then calculated the difference between the two surrounding years' energy use and filled in the value directly between those data points. After all necessary data cleaning steps, we found 2,200 records that consistently reported energy use between 2010 and 2015. This interpolation methodology almost doubled the number of records we were able to include in the total source-energy trend line found in Figure 1. This gives a more complete picture of trends over time in the benchmarked building stock.

Compliance

Figure 33 shows that compliance with LL84 has continued to improve; indeed, 90 percent of the properties that were required to benchmark submitted data in 2015. One reason for this improvement may be that building owners and data consultants have become more familiar with the City's benchmarking requirements. Figure 33 reflects the compliance rate based on the Covered Buildings List, a list of the buildings required to benchmark that is published by the Department of Finance (DOF) each year.

Since 2010, compliance has increased for New York City as a whole, as well as by property type (Figure 34). While some property types benchmark more commonly than others, the overall improvement in compliance rates indicates that benchmarking has finally become the norm for owners and managers of New York City's large buildings.

The multifamily and office sectors continue to comply most consistently (Figure 34), while warehouses, garages and the cultural sector—which started off with some of the lowest compliance rates—have seen the largest improvements in reporting over the last six years (in 2015, more than one-third of the buildings in these three property types reported LL84 data). In Figure 34, compliance rates for 2010 and 2015 are based on the Covered Building List from that given reporting year.

Based on the National Electric Manufacturers Association's (NEMA's) 2016 benchmarking compliance survey, 82 percent of facility managers who were in compliance with LL84 said they made investments in equipment to improve their buildings' energy efficiency as a result of New York City's Benchmarking Law. Eighty-four percent of facility managers who were in compliance with LL84 said they made operational changes as a result of measuring energy performance in their buildings. According to this study, the act of reporting your energy is enough impetus to implement energy efficiency measures, stressing the importance of benchmarking compliance.

The improvement in compliance rates indicates that benchmarking has finally become the norm for owners and managers of New York City's large buildings.

/08

Glossary

Building System Terms

absorption chiller
space cooling technology where a central plant uses a thermochemical process to cool a space. These systems are usually less efficient per unit of energy than typical electric chillers, so they are most commonly used where there is a source of free heat or a need to use cooling without increasing electric demand.

central chiller
space cooling technology where a central plant cools water for distribution throughout a building. The chilled water then enters air-handling units to absorb heat from ventilation air and cool the space.

direct fired storage tank
hot water heating technology that is separate from the base building boiler. Cold water enters the bottom of a storage tank with an interior tube. A burner is fired into the tube that consumes fuel and gases. Heat from the flames warms water and hot water is released to pipes from the top of the boiler. These systems have high operating efficiencies and relatively lower costs. But they also have limited design flexibility and tend to have shorter lifespans.

direct metered
the utility company measures energy consumption for individual tenants and tenants are billed for their own energy use.

hydronic heating system
space heating distribution technology that requires the combustion of fuel to boil water; also referred to as radiant heat. The system circulates hot water from a boiler through closed loops of piping to radiators and radiant floors to warm the building.

indirect heat exchangers
hot water heating technology that is linked to the base building boiler. Hot water is pumped through a heat exchanger in a storage tank linked to the space heating boiler. The very hot water from the boiler transfers heat to water stored in the tank. This hot water is dispatched as needed.

instantaneous point-of-use
hot water heating technology typically uses electric resistance heat to warm water quickly close to the point where it is used. This can sometimes save energy by eliminating heat lost from supply pipes and storage tanks.

master metered
the utility company measures and supplies energy for the entire building, not taking into account actual consumption per tenant space. Individual tenant energy use cannot be used as the basis for billing.

packaged/DX unit
space cooling technology that operates similarly to central chillers except that they deliver cooled air directly to the conditioned space rather than distributing chilled water to air-handling units.

packaged terminal air conditioner (PTAC)
distributed space cooling technology with vents and piping that go through walls to provide cool air to individual spaces. Refrigerant is pumped to coils to attract warm air away from a space.

separate hot water boiler with tank
hot water heating technology that is separate from the base building boiler. This system comprises a boiler sized to meet just the DHW loads with a separate storage tank. These systems have greater design flexibility, longer lifespans, and increased operating efficiencies.

split system
two-part system that involves cooling air with an evaporator inside a building and releasing hot air with a condenser outside a building. The separation allows envelopes to stay tightly sealed. Split systems are limited in New York City due to many factors including aesthetics—the outdoor units affect the appearance of building facades.

steam heating system
space heating distribution technology that requires the combustion of fuel to boil water and convert it to steam. Steam is carried from the boiler through distribution pipes to warm the building.

submetered
the utility company supplies energy for the entire building and the building owner measures energy consumption per tenant space. Individual tenant energy consumption may be used as the basis for billing.

tankless coils
hot water heating technology that is linked to the base building boiler. Water is heated as it flows through copper-finned tubing, which is inserted into the base building boiler. Once the water makes its way through the heating coils, it is delivered directly to water pipes and facets; unlike indirect heat exchangers the system includes no storage tanks.

window/wall AC
distributed space cooling technology where air runs through refrigerant-cooled coils and is then pushed by a fan into a room. Window and wall ACs are similar in function, however a window unit sits in the tenant’s window while a through-the-wall cooling unit is a slotted hole within the building wall.

Energy and Emissions Terms

coefficient of performance (COP)
the ratio of the amount of heat removed for cooling (or the amount of heat delivered for heating) to the amount of work or energy input required. It is the basic parameter used to report the efficiency of refrigerant-based systems. A high COP value equates to better energy efficiency.

domestic hot water energy use intensity
annual energy consumed per square foot to operate DHW systems; measured in thousands of British thermal units per square foot. This metric is calculated from a combination of DHW end use energy reported in LL87 and weather normalized source energy data from LL84. This decouples the fuel that is used for space heating from the fuel that is used for faucets and other hot water loads.

energy use intensity (EUI)
annual energy consumption divided by gross floor area; measured in thousands of British thermal units (kBtu) per square foot. EUI normalizes energy use across buildings of different sizes which enables the comparison of energy use in large and small buildings.

electricity use intensity
annual electric energy consumption divided by gross floor area; measured in kilowatt hours (kWh) per square foot. Electric EUI isolates the electricity usage from the rest of the energy used in the building. A higher electric EUI indicates that a building is using electricity more intensely than other buildings. Electric EUI can be affected by an array of systems but electricity-heavy processes like air cooling impact electricity use as well as metering type.

fuel energy use intensity
annual fuel energy consumption divided by gross floor area; measured in thousands of British thermal units per square foot. Fuel EUI isolates the amount of energy used from fuel from the total site energy used in the building. A higher fuel EUI indicates that a building is using more fuel relative to other buildings. Fuel EUI is impacted by domestic hot water (DHW) loads, space heating loads and other fuel burning end uses.

greenhouse gas emissions
carbon dioxide (CO_2) and other gases such as methane released into the atmosphere as a result of energy generation, transmission and consumption at the property. Emissions are measured in carbon dioxide equivalent (CO_2e), which normalizes the global warming potential of each gas to an equivalent quantity of carbon dioxide. Direct greenhouse gas emissions are emissions from sources that are owned or controlled by the organization (a building). Indirect greenhouse gas emissions are emissions from sources upstream of the building, such as power plants.

kW per ton
the ratio of energy consumption in kilowatts to the rate of heat removal in tons at the rated condition. The term is commonly used to measure the cooling load efficiency for large commercial and industrial cooling systems. The lower the kW/ton, the more efficient the system.

seasonal energy efficiency ratio (SEER)
the cooling output of a typical cooling-season divided by the total electric energy input during the same period as defined by the Air Conditioning, Heating, and Refrigeration Institute; measured in British thermal units (Btu) per watt-hour. It represents the expected overall performance for a typical year's weather in a given location. A high SEER equates to a more energy-efficient system.

site energy
the total metered energy a building consumes on site; typically measured in thousands of British thermal units (kBtu) or in thousands of watt hours (kWh). Site energy, while not all inclusive, is a good metric to track building energy use over an extended period of time.

site-source ratio
the conversion factor used to calculate source energy from site energy. Because LL84 requires building owners to submit their energy data through the U.S. Environmental Protection Agency's (EPA's) Portfolio Manager tool, this report uses EPA's national conversion factors to calculate source energy. EPA updates the electricity conversion factor approximately once every five years to account for the growing renewable energy portion of our electrical grid. It was most recently updated in March 2013 and is scheduled to be updated again in August 2018 in conjunction with the updated ENERGY STAR 1-100 score models. Unlike fossil fuels, solar, wind and hydroelectric power are not subject to generation losses at the power plant. When computing the national electricity conversion factor, these renewable sources have a 1:1 conversion ratio.

source energy
on-site energy consumption plus transmission, delivery and production losses; measured in thousands of British thermal units (kBtu). Source energy, unlike site energy, includes the thermal energy needed to generate electricity and the energy needed to push gas through a pipeline. This metric is more inclusive of the whole energy a building is using.

weather normalized
Portfolio Manager adjusted energy use data to account for periods that are hotter or colder than average (based on 30-year average heating and cooling degree days). This adjusts energy use to meet what are considered average conditions (also referred to as climate normals) and enables building energy comparisons to be made across time and across geographic regions with the same climate.

Statistical Terms

correlation
a relationship between variables. Groups can have positive, negative or no relationship or connection. Correlation does not imply one variable causes another variable to occur.

distribution
a description of the relative numbers of times each possible outcome will occur in a number of observations. It is a graphical method for organizing and displaying useful information about data. ***Quantiles*** divide a distribution into groups of equal probability. For example, the median is the 0.5 quantile.

mean
the average of a set of numbers; the sum of the numbers within a data set divided by the amount of numbers in the data set.

median
the middle point of a set of numbers, in which half the data points are above the median and half are below. It is most useful in describing how one building compares to its peers and is resistant to outliers, so it can be reliably used to analyze buildings within a small sample size.

multiple linear regression
a statistical technique used to determine how well multiple dependent variables predict a single outcome. This test is important because it isolates the impact that many different building characteristics have on energy use.

p-value
the p-value is used to determine if a result is significant. In this report p-values are reported for multiple linear regressions and t-tests. If the p-value is less than 0.05 then the result is due to a true difference in the groups, not from random sampling.

paired difference test
a common technique used to analyze observational data. Each record is matched to another record that is identical in all but one variable. The difference in one parameter is then compared for each pair and averaged. The test reduces underlying bias, increases statistical power and strengthens the ability for a direct comparison of a single variable to be made.

r-squared
the R^2 value is used to determine how well data fits a regression line by explaining the variability within the data set. The higher a R^2 value is, the better a model is. This report also uses ***adjusted*** R^2 ***values***. The adjusted R^2 value is used in multiple linear regressions to normalize the variation explained by the number of dependent variables instead of treating the model as a whole.

t-test
a ratio used in hypothesis testing for determining if two groups are meaningfully different from each other. If the means of a parameter from the two groups are found to be statistically significantly different, then it is unlikely that the difference occurred because of random sampling. This report uses both an unpaired and paired t-test. The ***unpaired t-test*** compares the mean of a single variable (in our case energy use intensity, or EUI) between two groups. The ***paired t-test*** compares the mean of a single variable (in our case EUI) between two groups when each observation in one group is paired with a related observation in the other group.

Notes

1 American Council for an Energy-Efficient Economy (ACEEE), "Multifamily benchmarking can save energy—with the right support." (2017). Retrieved from: aceee.org/blog/2017/09/multifamily-benchmarking-can-save

2 Portfolio Manager reduced emissions from electricity generation by 12 percent from 2010 to 2015, and decreased steam emissions by 16 percent. This change in electricity emissions reduced the overall emissions by 5 percent and the change in steam emissions reduced the overall emissions by 2 percent.

3 "The New York City Energy and Water Use Report" results are consistent with the findings of the New York State Energy Research & Development Authority (NYSERDA) case studies on multifamily buildings: www.submeteronline.com/pdf/subman2001.pdf

4 New York City Office of the Mayor, "Mayor de Blasio, Chancellor Fariña and City Council Announce Every Classroom Will Have Air Conditioning by 2022." (April 25, 2017.) Retrieved from: www1.nyc.gov/office-of-the-mayor/news/261-17/mayor-de-blasio-chancellor-fari-a-city-council-every-classroom-will-have-air

5 U.S. Department of Energy, "Energy Saver—Central Air Conditioning." Retrieved from: energy.gov/energysaver/central-air-conditioning

6 Hite, Amanda, "US Hotel Industry Performance 2016, STR Global." (2016). Retrieved from: www.sps.nyu.edu/content/dam/scps/pdf/200/200-4/200-4-16/Tisch-Conference-STR-Presentation.pdf

7 The Washington Post "An amenities arms race heats up in the apartment industry." Retrieved from: www.washingtonpost.com/news/where-we-live/wp/2017/04/24/an-amenities-arms-race-heats-up-in-the-apartment-industry

8 New York City Housing Authority and Mayor's Office of Technology and Innovation, "NYCHA and Mayor's Office of Tech + Innovation Announce Winning Proposals to Improve Energy Efficiency." (March 15, 2017.) Retrieved from: www1.nyc.gov/site/nycha/about/press/pr-2017/nycha-mayors-office-of-tech-and-innovation-announce-winning-proposals-to-improve-energy-efficiency-20170315.page

9 Greensward Group, LLC, "The Reservoir in Central Park." Retrieved from: www.centralpark.com/guide/attractions/reservoir.html

10 The City of New York, Mayor's Office of Sustainability, "Inventory of New York City Greenhouse Gas Emissions in 2015." (April, 2017.) Retrieved from: www1.nyc.gov/assets/sustainability/downloads/pdf/publications/NYC_GHG_Inventory_2015_FINAL.pdf

11 U.S. Environmental Protection Agency (EPA), "ENERGY STAR Portfolio Manager Technical Reference: Greenhouse Gas Emissions." (2013.) Retrieved from: portfoliomanager.energystar.gov/pdf/reference/Emissions.pdf

12 There are 26 eGrid subregions. The NYC electricity emission rate in 2015 was 257 kg CO_2e/MWh, but the eGrid subregion for our area was 318 kg CO_2e/MWh: www.epa.gov/sites/production/files/2015-10/documents/egrid2012_summarytables_0.pdf

13 The group of 4,229 consistently bench-marked buildings reduced greenhouse gas emissions by 13.8 percent from 2010 to 2015. Cleaner electricity and cleaner district steam were responsible for 36 percent and 15 percent of that reduction respectively, based on emission factor changes in Portfolio Manager and the fuel mixture in the building set.

14 Consistently benchmarked buildings reduced their energy use by 10.4 percent from 2010 to 2015. The Portfolio Manager site-to-source ratio for electricity dropped in 2013 by 8 percent, resulting in a 5 percent drop in this set's source energy. This aligns with the site energy consumption drop of 4.8 percent during the same period.

15 The City of New York, Office of the Mayor, "With Holiday Tourism Underway, Mayor de Blasio Announces 16 Hotels to Join NYC's Fight Against Climate Change, Commit to 30 Percent Reduction in Emissions in Next 10 Years." (December 29, 2015.) Retrieved from: www1.nyc.gov/office-of-the-mayor/news/979-15/with-holiday-tourism-underway-mayor-de-blasio-16-hotels-join-nyc-s-fight-against

16 New York Times, "New York Hotels Make a Green Pledge." (January 19, 2016). Retrieved from: www.nytimes.com/2016/01/24/travel/green-hotels-new-york-city.html

17 Fuel switching accounted for 18 percent of this reduction based on the assumption that each unit of energy previously supplied by Number 5 or 6 fuel oil was replaced with Number 2 or 4 fuel oil or natural gas based on the proportional growth of those fuels.

18 U.S. Environmental Protection Agency, "AP 42, Compilation of Air Emission Factors, Fifth Edition." (1995) Retrieved from: www3.epa.gov/ttnchie1/ap42/ch01/final/c01s03.pdf

19 Bloomberg News, "Natural Gas prices Are Expected to be Volatile But Steady over The Next Five Years, While Fuel Oil Prices Will Increase by 5 Percent Over That Time." www.bloomberg.com/energy ; www.cmegroup.com/trading/energy/

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21 Frank J. Kelly and Julia Fussell, "Air Pollution and Public Health: Emerging Hazards and Improved Understanding of Risk." Environmental Geochemistry and Health 37, no. 4 (June 4, 2015): 631–649. Retrieved from: www.ncbi.nlm.nih.gov/pmc/articles/PMC4516868

22 U.S. National Oceanic and Atmospheric Administration, "Monthly Cooling and Heating Degree Day Data." (2017.) Retrieved from: www.nyserda.ny.gov/About/Publications/EA-Reports-and-Studies/Weather-Data/Monthly-Cooling-and-Heating-Degree-Day-Data

23 Multivariate linear regression results for multifamily buildings indicate that DHW system type has a statistically significant impact on site fuel EUI ($F(2,1069) = 16.28$, $p < .001$, R2 = .05, R2 adjusted = .05).

24 Both of these differences are statistically significant. Buildings with tankless coils use significantly more fuel than buildings with separate DHW ($t(945) = -6.43$, $p < .001$). Buildings with heat exchangers were observed to use significantly more fuel than buildings with separate DHW ($t(259) = 3.14$, $p < .01$).

25 See appendix for explanation of criteria for age and size groups.

26 This difference is statistically significant. Statistically significant difference based on t-test ($t(414) = 1.65$, $p < .005$).

27 Gabriel D. Ayala and Derek Zobrist, “Best Practices for Efficient Hot Water Distribution in Multifamily Buildings.” In “ACEEE Summer Study on Energy Efficiency in Buildings: Fueling Our Future with Efficiency, Asilomar Conference Center, Pacific Grove, Calif., August 12-17, 2012.” Washington, D.C.: American Council for an Energy-Efficient Economy. Retrieved from: aceee.org/files/proceedings/2012/data/papers/0193-000030.pdf

28 “...during the summer, the boiler is less likely to be hot, and the on-off cycling to heat water wastes a lot of energy...the average efficiency [of linked tankless coil systems] during that period may be as low as 25 percent.” BuildingGreen: www.buildinggreen.com/blog/using-your-heating-system-heat-water

29 Cooling as an end use does not include ventilation fans or condenser water loop pumps.

30 New York electrical demand in summer can be over 30 percent higher than winter demand, and this difference is mostly due to building air conditioning. Power Trends 2016 – NYS ISO: www.nyiso.com/public/webdocs/media_room/publications_presentations/Power_Trends/Power_Trends/2016-power-trends-FINAL-070516.pdf

31 New York State funds program with 3M dollars to expand air conditioning

32 City announces cooling expansion to all city schools

33 Average window AC EER (11) calculated based on Energy Star minimums and chiller EER (16) based on ASHRAE 90.1 2013.

34 This large difference was not due to cooling type alone—many other factors contributed. Plug loads were a major factor that could not be controlled for directly. Size had the smallest impact since EUI is already controlled for floor area. One year of added building age increased EUI by 0.01 kWh/sf and an additional 10 floors increased EUI by 0.9 kWh/sf in terms of WN Site Electric EUI on average. ($F(5,987) = 281.99$, $p < .001$, $R2 = 58$, $R2$ adjusted = .58)

35 Hirschfeld, Herbert, “Integration of Energy Management, Electrical Submetering and Time Sensitive Pricing in a Large Residential Community Utilizing Wireless Communications: Phase 3.” (2010.) In ACEEE Summer Study on Energy Efficiency in Buildings: The Climate for Efficiency is Now, Asilomar Conference Center, Pacific Grove, Calif., August 15-20, 2010.” Washington, D.C. American Council for an Energy-Efficient Economy. Retrieved from: aceee.org/files/proceedings/2010/data/papers/1939.pdf

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38 ULI NYC and Philadelphia Case Studies: tenantenergy.uli.org/case-studies

39 Portfolio Manager is an online tool created by the Environmental Protection Agency. It allows building owners to input their energy use information into a standardized format. New York City can use the tool to track energy and greenhouse gas emissions from all large buildings.

40 Hirschfeld, Herbert, “Integration of Energy Management, Electrical Submetering and Time Sensitive Pricing in a Large Residential Community Utilizing Wireless Communications: Phase 3.” (2010.) In ACEEE Summer Study on Energy Efficiency in Buildings: The Climate for Efficiency is Now, Asilomar Conference Center, Pacific Grove, Calif., August 15-20, 2010.” Washington, D.C. American Council for an Energy-Efficient Economy. Retrieved from: aceee.org/files/proceedings/2010/data/papers/1939.pdf

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