report

Evaluating New York City's Multifamily Building Energy Data for Savings Opportunities

Turning Data Into Action

Retrofitting Affordability: Version 2

building energy exchange

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report

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contents

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A critical tool for climate action, our study finds that implementing recommended efficiency retrofits would immediately reduce multifamily energy use in NYC by 11% and have a simple payback of less than 6 years.

The one million buildings in New York City (NYC) contribute roughly 70% of our city's greenhouse gas (GHG) emissions and must play a pivotal role in our fight against climate change. Large multifamily buildings, while representing only about 9% of the total number of buildings in NYC, emit nearly 30% of our building sector's GHG[1]. Upgrading this essential part of NYC's fabric will not only lower utility bills and harmful emissions, but will also dramatically improve the indoor health, comfort, and well-being of all New Yorkers.

The road to "80 × 50" – NYC's ambitious commitment to reduce GHG 80% below 2005 levels by 2050 – requires tapping the huge, but often elusive energy savings potential embedded in multifamily buildings. Our second look into the wealth of multifamily building data being collected under the landmark laws of NYC's 2009 Greener Greater Buildings Plan seeks to turn this potential into action. Examining an additional year of energy audit data has confirmed many of the initial findings of *Retrofitting Affordability,* this report's predecessor. Now, with *Turning Data into Action,* we have taken the additional step of organizing energy auditor evaluations of building efficiency upgrade opportunities into complementary "packages" of energy conservation measures (ECMs), that are matched to key touchpoints in a building's financial lifecycle.

By organizing the massive dataset of NYC multifamily building energy use and auditor recommendations into digestible packages, we hope to enable building decision-makers to better understand their retrofit options at critical milestones.

To create these ECM packages, we have divided the diverse portfolio of NYC's multifamily buildings into 12 major segments with similar characteristics, such as age, height, and fuel type. For each of these building segments, we have developed "tearsheets" that outline a suite of ECM packages appropriate at specific phases or "touchpoints" within that building segment's lifecycle. Each tearsheet includes analysis of potential costs, energy savings, and payback periods.

The lifecycle touchpoints used throughout this report are:

- Anytime/Anywhere: Low cost measures that are quick and easy to implement.
- Mid-Cycle Retrofit: Measures that may require some financial planning, but yield higher savings.
- Refinance Retrofit: More capital-intensive measures with longer paybacks and the deepest savings.
- Tenant Turnover: Opportunities specific to tenant-controlled spaces and systems.
- Equipment Replacement: Measures that should be considered when major equipment reaches its end of useful life.

With two years of audit data in hand, our research team found that implementing all the auditors' recommended ECMs would reduce GHG emissions in NYC's covered multifamily buildings by 11% (not including retro-commissioning or tenant controlled energy use). At a total cost of $2.7 billion, this work would yield an annual savings of $467 million in reduced utility bills and would pay back in less than six years, on average. Roughly half of this savings potential comes from measures that improve the performance of two systems – domestic hot water and heating distribution – and pay back within an average of just three years.

However, New York City's low vacancy rate and high cost of construction make achieving these potential savings a challenge. Building decision-makers remain mostly focused on basic building operations and are often unaware of energy-saving retrofit opportunities, or are unconvinced that these projects would yield the promised results. These challenges can be compounded by not having a long-term plan in place to anticipate building and equipment milestones, and weigh the benefits of energy efficiency.

We offer the tearsheets in this report to help illuminate pathways to action. One key finding is that the majority of recommended retrofit measures fall into the "Anytime/Anywhere" category, with average paybacks under three years. These easy-to-implement measures represent 36% of the potential source energy savings identifed across NYC's multifamily buildings, but account for only 16% of the cost, indicating an area of enormous opportunity for energy and cost savings.

Turning Data into Action complements the many other educational resources provided by the Building Energy Exchange, as well as the assistance and guidance provided by the New York City Retrofit Accelerator. It is our hope that these resources will help building owners identify and unlock the huge energy savings and improved comfort potential latent in their buildings and ensure our path to a sustainable future.

introduction

Upgrading New York City's multifamily buildings offers a unique opportunity to simultaneously address one of our biggest sources of harmful greenhouse gas emissions, while also creating healthier and more affordable housing. *Turning Data into Action* looks to identify simple packages of retrofit measures that will lower utility bills, improve our living spaces, and mitigate climate change.

Building energy efficiency is an essential climate change solution, as well as a vital engine to create jobs and address issues of energy affordability for low-income households. Years of successful utility programs and policies have demonstrated that energy efficiency works, but we have only scratched the surface of its remaining potential.

Retrofitting Affordability, published in 2015 by the Building Energy Exchange, in collaboration with Bright Power and Sustainable Energy Partnerships, analyzed the first year of New York City's energy audit data (from Local Law 87, see sidebar), to uncover the energy conservation measures (ECMs) with the most cost-effective impacts. The report grouped NYC's multifamily building stock into 12 segments with similar characteristics, inventoried the top ECMs for each segment, assessed their impacts on energy savings and carbon reduction, and mapped those opportunities across the City's diverse community districts, while cross-referencing concentrations of affordable housing properties.

With the release of an additional year of NYC energy audit data, the authors have updated the first report's findings and taken their analysis one step further in *Turning Data into Action*. The focus of this effort was to simplify the rich information set provided by the combined two years of energy audits, into a format that would be useful and actionable for building decision makers, operators, contractors, and policy makers.

Turning Data into Action– the sequel to *Retrofitting Affordability*– not only expands and updates the top ECM recommendations for each multifamily building segment, but also groups those ECMs into relevant retrofit packages that can be implemented at key touchpoints in a building's financial lifecycle. For 11 of the 12 building segments, the authors have created 'tearsheets' listing suites of retrofit measures that should be considered at key milestones. These range from capital-intensive measures best suited for when a building is refinancing and has access to additional capital, to low-cost measures that can be funded out of operating expenses, and to those in between. This report also addresses opportunities created when costly building systems and equipment must be replaced. A related tearsheet shows the relative economics of completing additional, comprehensive ECMs at the time of equipment replacement, for a better performing, and ultimately more cost-effective package.

NYC Buildings

Buildings are the backbone of New York City. Benchmarking and audit laws help reveal the characteristics of these buildings and their energy use.

New York City is a global hub for finance, design, and innovation. As a leader in sustainability, NYC has developed policies that show a strong commitment to mitigating its contribution to global climate change. Relevant initiatives address transportation, waste, and power generation, but the biggest focus of the City's policies is on buildings. The buildings where New Yorkers live, work, and play contribute nearly 70% of citywide carbon emissions.[2] By addressing energy use in existing buildings, the City will be better positioned to meet its climate action goals.

The Greener, Greater Buildings Plan (GGBP) is a suite of laws that identify buildings that can benefit from energy efficiency retrofits (see sidebar). This legislation originally focused on buildings over 50,000 square feet, referred to as "covered buildings." Though covered buildings make up only 2% of the building stock, they represent nearly 50% of the building area.[3] After seven years of benchmarking buildings under Local Law 84, the Energy Benchmarking and Disclosure Law, and three years of energy audits under Local Law 87, the Energy Audit and Retro-commissioning Law, the City has a strong understanding of the characteristics of these buildings and how they use energy. Multifamily properties represent just under 75% of covered buildings, 64% of source energy use, and 64% of greenhouse gas emissions.[4] Clearly, multifamily buildings must be a central part of the plan to mitigate climate change.

Greener Greater Buildings Plan

The primary source of data for this report comes from data collected in Local Laws 84 and 87, two key elements of the "Greener, Greater Buildings Plan" (GGBP) passed by the NY City Council in 2009.

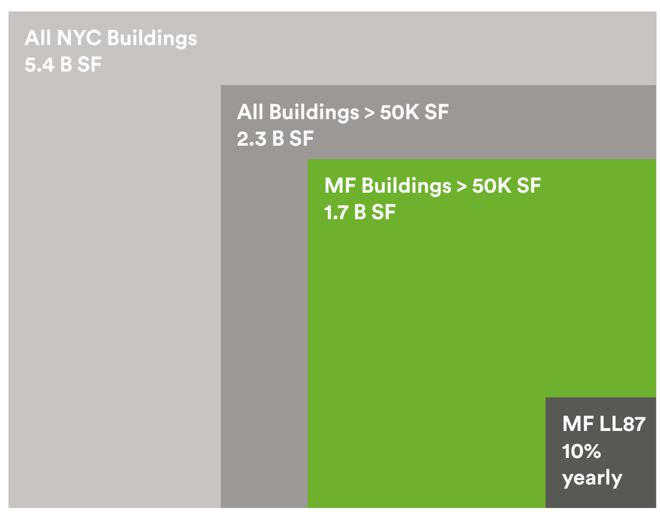
This suite of laws applies to "covered buildings." This includes all buildings over 50,000 square feet, or multiple buildings on a single property totaling 100,00 square feet. These GGBP laws include:

- **Energy Benchmarking and Disclosure Law (Local Law 84):** Reporting and public disclosure of annual energy and water usage, beginning in 2010.
- **Energy Audit and Retro-commissioning Law (Local Law 87):** Conducting an energy audit and retro-commissioning every ten years, beginning in 2010.
- **Lighting and Sub-metering Law (Local Law 88):** Upgrading commercial lighting to meet current code, and sub-metering for large commercial tenants, by 2025.

The GGBP also includes Local Law 85, which requires the NYC Department of Buildings to promulgate and enforce the new NYC Energy Conservation Code. This applies to all renovations, repairs and alterations to existing buildings as well as all new construction.

The information collected through the Benchmarking and Disclosure Law (Local Law 84) and Energy Audit and Retro-commissioning Law (Local Law 87) is submitted to the NYC Department of Buildings and forms the backbone of data used in this study to characterize and identify energy retrofit potential within the multifamily sector. The GGBP was expanded to mid-size buildings (>25,000 SF), starting in 2018. This will add approximately 14,650 buildings (10,195 properties), including 275,000 residential units and 365,000,000 SF of space to the GGBP.[5]

Figure 1: Scale of Built Area



This report focuses on the energy savings opportunity from multifamily buildings over 50,000 SF using data from the Benchmarking and Disclosure Local Law (LL84) and the Energy Audit Local Law (LL87).

Building on the data analysis conducted in *Retrofitting Affordability*, this companion report converts energy auditor recommendations into coordinated suites of retrofit measures that are aligned with key building-based financial milestones, providing building owners and operators with simple and actionable resources.

To make energy audit data actionable, the authors divided the covered multifamily building stock from the LL87 data into 12 segments based on the construction and operational characteristics of each building (see Table 7). These segments have been adjusted slightly since our previous report, *Retrofitting Affordability*, to better align with the segments determined by the Technical Working Group (see page 18). A list of ECM opportunities was generated for each segment, based on energy audit data. From this information, the authors have developed specific tearsheets for 11 of the segments featuring packages of ECMs. Each tearsheet suggests the best time to implement an ECM within a building's lifecycle. This resource is designed to guide building owners in their pursuit of energy efficiency retrofits.

These tearsheets provide an estimate of the expected cost, energy savings, and payback for the suite of ECMs aligned with each touchpoint. These estimates have been calculated using accepted expectations for potential savings and fuel costs derived from NYC multifamily building EnergyScoreCards–Bright Power's cloud-based energy analysis and benchmarking service.

Touchpoints

In addition to knowing the potential savings and payback of an ECM, as reported in the first *Retrofitting Affordability* study, it is also crucial for building owners to know the most appropriate times to implement specific ECMs and to complete energy efficiency retrofits.

This report identifies key touchpoints in a building's financial lifecycle. Touchpoints were determined by considering the difficulty of a measure's implementation, expected costs, and expected payback. These touchpoints range from "Anytime/Anywhere," consisting of simple measures with a quick payback, to "Refinance Retrofit," consisting of measures that are more capital intensive and have longer paybacks. Creating packages of actionable ECMs for each building segment at each touchpoint allows building owners and operators to plan for and realize both short-term and long-term energy efficiency retrofit opportunities. (See "Touchpoints" sidebar.)

In addition to touchpoints during a building's financial lifecycle, the authors have identified two other key milestones when there are unique opportunities to implement energy efficiency measures. The first is during tenant turnover, a time when building owners have the opportunity to address issues within a unit. The second is when a major piece of equipment must be replaced because it has reached the end of its useful life. At such times, it is important not only to install a more efficient replacement (e.g. a new boiler), but to also upgrade the associated equipment (e.g. valves and thermostats). Although upfront costs are increased by including a more comprehensive suite of measures, projects that replace associated equipment as well as the major piece of equipment pay back more quickly over time. The equipment replacement opportunities identified in this report include:

- Boiler
- Windows
- Roof
- Domestic Hot Water System

ECM Package Tearsheets

Grouping ECMs into packages by touchpoint makes it easier for building professionals to understand which efficiency measures to undertake and when to do the work.

Building segment-specific packages are sets of ECMs grouped by touchpoint. These constitute a suite of measures that a building owner may want to implement together, according to the building's stage in its financial lifecycle. Lifecycle touchpoints were assigned to each ECM based on LL87 audit reported cost and payback time as well as some expert opinion, and are not part of the LL87 audit data.

The packaging of ECMs by building segment and lifecycle touchpoint make it easier for building owners and operators to understand which measures are appropriate for their buildings

Touchpoints

Anytime/Anywhere
These ECMs can be implemented quickly and easily. They generally have a low cost, require minimal capital investment, and have a quick payback. Usually, these cost less than $0.25/SF and payback in about 2.5 years.

Mid-Cycle Retrofit
Though these ECMs require some planning or investment, they typically are associated with greater energy savings. Usually these ECMs cost no more than $1.00/SF and pay back in about 6 years.

Refinance Retrofit
These retrofit measures are capital-intensive and best implemented at a time of refinancing. Though these can offer the deepest energy savings, they are expensive (often more than $1.00/SF) and often have payback periods greater than 10 years.

Tenant Turnover
These are measures that require access to an apartment. Ideally, these should be implemented when a tenant vacates an apartment and before a new tenant moves in. Often, these measures can also be completed "anytime/anywhere," or as "mid-cycle retrofits."

Equipment Replacement
When a major piece of equipment reaches the end of its useful life, it is not only an opportunity to install a more efficient replacement, but also to invest in related system components to ensure that everything operates as efficiently as possible. These projects generally require substantial capital and may have long payback periods.

Equipment Icons


Boiler


Domestic Hot Water Heater


Roof


Windows

retrofit packages: post-war gas low-rise

This tearsheet shows packages of energy conservation measures at key milestones in a building's lifecycle that can reduce utility bills, maximize energy savings, and improve value and performance.

Typical Building Characteristics

Age	1947–1979
Height	7 stories or fewer
Facade	Masonry
Heating System	Hydronic or two pipe steam
Heating Fuel	Gas or dual fuel
Ventilation System	Central ventilation and natural ventilation
Cooling	Through-wall or window ACs

Segment Characteristics

Size	1,032 properties; 152,966,300 square feet
Area	9% of all covered multifamily buildings
Potential Savings	12% of all potential GHG reduction

Typical Retrofit Costs

Touchpoint	Anytime/Anywhere	Midcycle Retrofit	Refinance	Tenant Turnover
Description	Lower cost; simple measures	Low to medium cost; mid-level measures	Long-term investment; deeper saving	Requires tenant unit access
Cost	$14,560	$70,000	$418,000	
Savings	$5,200	$10,000	$31,000	
ROI	2.8	7.0	13.5	

All costs and savings reflect a 100 unit, 100,000 SF building

post-war gas low-rise

Building Touchpoint

Energy Conservation Measure	Anytime/ Anywhere	Midcycle Retrofit	Refinancing/ Substantial Retrofit	Tenant Turnover	Payback (years)	Cost per SF	Energy Savings per SF
Install Exhaust Fan Timers	•	•	•		5.0	$	
Install Submetering		•	•		2.0	$$$	
Install Solar/Photovoltaic			•		17.0	$$$$	
Upgrade Motors		•	•		5.5	$$	
Upgrade Lights		•	•		2.5	$	
Install Lighting Sensors		•	•		4.0	$	
Upgrade Burner			•		6.5	$$	
Upgrade Boiler			•		>20	$$$$	
Install TRVs and Zone Control		•	•		6.5	$$$	
Install Heating Controls and Thermostats		•	•		2.5	$$	
Insulate Condensate Tank	•	•	•		2.5	$	
Replace or Repair Steam Traps	•	•	•		3.5	$$	
Insulate Pipes	•	•	•		2.0	$	
Install or Upgrade Master Venting		•	•		3.0	$$	
Replace Windows and Glazing			•		>20	$$$$	
Increase Wall Insulation			•		>20	$$$$	
Increase Roof Insulation			•		>20	$$$	
Complete Air sealing	•	•	•	•	6.0	$$	
Separate DHW from Heating			•		6.5	$$$	
Install Low-Flow Showerheads	•	•	•	•	1.0	$$	
Install DHW Controls	•	•	•		0.5	$	
Install Low Flow Aerators	•	•	•	•	1.5	$$	
Insulate Pipes and Tank	•	•	•		6.0	$	

Energy Conservation Measure

- Ventilation & Cooling
- Other
- Lighting
- Heating Equipment
- Heating Distribution
- Envelope
- Domestic Hot Water

Cost per Square Foot

$	<$.05
$$	$0.05-$0.25
$$$	$0.26-$1.00
$$$$	>$1.00

Energy Savings per SF (kBtu)

- 0–3
- 3.1–8
- 8.1–12
- >12

Notes

This list of Energy Conservation Measures (ECM) is based on LL87 audit data and therefore may be incomplete. Suggested ECMs for each Building Touchpoint are representative, and not necessarily applicable to every building. Variety in specific building systems and condition of equipment must be considered in determining the appropriate packages of ECMs for individual buildings. The first step of any upgrade should be to work with a qualified service provider to develop a scope of work appropriate for your building.

This building segment-specific "tearsheet" constitutes relevent packages of retrofit measures applicable at key touchpoints in a building's lifecycle. A tearsheet has been created for all building segments, except for Very Large.

at any given time, and which measures they should plan to implement in the future. The package tearsheets give building owners the opportunity to align energy efficiency retrofits with their property's financing cycle and to plan for a phased retrofit. Additionally, the packages serve to highlight the audit findings for each given building type, and provide a more digestible way for building owners and operators to take action around their audits.

The cost, energy savings, and payback of each individual ECM were derived directly from the LL87 data. However, full package costs, savings, and payback have been calculated based on the expectation that an "Anytime/ Anywhere" retrofit can deliver 5% energy savings, "Midcycle" retrofits can deliver 10% energy savings, and "Refi" retrofits can deliver 30% energy savings. The authors used these savings assumptions as well as fuel costs derived from NYC multifamily building EnergyScoreCards to calculate potential monetary savings and costs of each package of ECMs at each touchpoint.

It is crucial to note that each building has a different baseline of energy consumption and unique features. Therefore, it is important to work with an expert to develop a scope of work appropriate for your building. The analysis in this report is based on the first two years of reported data, and the quality of that data has yet to be determined (see "Data Quality" sidebar). While all conservation measures listed on the package tearsheets are derived from the LL87 audits, the tearsheets do not list every ECM recommended by the auditors. Rather, industry experts have selected the most common and effective measures from the audits to be included in the package tearsheets. These packages provide guidance, but building owners should consult with an energy service provider or a NYC Retrofit Accelerator Efficiency Advisor before proceeding. Because of their unique building characteristics, Very Large Buildings and NYCHA properties are not addressed in the ECM package tearsheets (see sidebars on page 19).

Equipment Replacement Tearsheets

The end of useful life of a major piece of building equipment is a perfect time to implement energy saving upgrades.

The equipment replacement opportunities identified in this report relate to boiler replacement, domestic hot water system upgrades, window replacement, and roof replacement. The authors offer recommendations for potential related upgrades to consider undertaking when completing any of these projects.

Cost estimates in the "Equipment Replacement Tearsheets" were derived from the LL87 data. However, savings opportunities were calculated based on expert opinion of reasonable savings percentage expectations and fuel costs derived from NYC multifamily building EnergyScoreCards.

Retrofit Financing

Access to financing is a key element of achieving New York City's energy efficiency goals.

Energy efficiency opportunities are abundant in nearly every multifamily building in NYC, but access to financing is necessary to scale the investment. Financing barriers in the multifamily buildings market include:

- Building owners face capital and financing constraints to cover up-front costs, despite the attractive economics of energy efficiency and distributed generation investments.

NYCEEC — Updated Accomplishments
The New York City Energy Efficiency Corporation (NYCEEC) is a nonprofit dedicated to financing energy efficiency and clean energy projects in multifamily and commercial buildings. NYCEEC works with incentive providers and financial partners like the New York State Energy and Research Development Authority (NYSERDA) and utilities.

Buildings in all sectors are eligible for NYCEEC financing products, provided that the measures financed result in reduced energy usage and avoided greenhouse gas emissions. NYCEEC finances energy efficiency, Passive House, clean fuel conversions, renewables, cogeneration, and demand management. NYCEEC's financial products to date include pre-development loans, equipment loans (secured and unsecured), energy services agreements, power purchase agreements and green mortgages.

To date, NYCEEC has financed nearly $100 million USD of clean energy projects across 7.2 million square feet of NYC buildings—eliminating over 629,000 metric tons of greenhouse gases and resulting in the creation of over 1,000 jobs. NYCEEC has established several lender partnerships, resulting in greater capital access for efficiency.

CPC — *Underwriting Efficiency*
Produced by The Community Preservation Corporation (CPC) and developed with the support of Energy Efficiency for All, *Underwriting Efficiency* is a handbook for lenders on incorporating energy and water efficiency into the mortgage finance process.

It provides lenders with information on the tangible benefits of efficiency measures, ways to discuss the topic with building owners, and guidance for incorporating potential energy savings into the underwriting process. By increasing the level of efficiency literacy among borrowers and lenders, the housing finance industry will play a key role in improving the financial and physical quality of the buildings and communities in which we live and work.

- Building owners are often highly- leveraged, hesitant to take on additional debt, and have competing priorities for investment in more visible and proven property improvements (e.g., aesthetic lobby upgrades, new in-unit appliances).

New York City building owners and managers have access to a wide variety of resources for financing building efficiency retrofits. Most of these resources are catalogued in the NYC Carbon Challenge's *Handbook for Multifamily Buildings*, prepared by the Mayor's Office of Sustainability.

Another unique resource is the New York City Energy Efficiency Corporation (NYCEEC), which successfully established a flexible, multi-faceted financing platform able to accommodate the capital requirements of many different energy conservation measures and clean energy technologies. NYCEEC has successfully served the financing needs of affordable multifamily properties, among many other property types (see sidebar). The organization is financing product agnostic, and has developed and promoted a range of financial tools to help drive energy efficiency, including construction, equipment and pre-development loans, "green" mortgages, ESAs, and PPAs.

NYCEEC's work is complemented by that of other organizations, such as the Community Preservation Corporation (CPC), which provides financial solutions to advance energy efficiency, particularly by incorporating efficiency into the mortgage process. CPC recently published a report on this subject (see sidebar).

opportunities

New York City's stock of large multifamily buildings will play a significant role in achieving our goal of an 80% reduction in citywide greenhouse gas emissions by 2050. Analysis of Energy Audit Law reporting provides clear insights into which energy conservation measures have the biggest savings opportunities, and which building typologies can have the greatest impacts.

Context

This report builds on previous work and makes LL87 data more actionable for building owners, operators, and policy makers.

This report's predecessor, *Retrofitting Affordability: Evaluating New York City's Multifamily Building Energy Data for Savings Opportunities*, used NYC Energy Benchmarking Law and Energy Audit Law data to identify high-level savings opportunities in multifamily buildings.

It divided multifamily buildings into 12 segments based on age, height, and primary heating fuel, and used the energy audit data to identify the energy conservation measures (ECMs) that would have the greatest impact in each segment. The report found that if all ECMs were completed across all building segments, the City would be able to reduce its GHG emissions from multifamily buildings by 11%. The greatest reduction came from Post-War Oil and Gas heated buildings, and from ECMs related to heating and distribution and domestic hot water.

With the addition of a second year of audit data, in this report, BE-Ex seeks to validate and build

Data Quality

Except where specifically noted, all ECM savings and costs are calculated directly from the first two years of LL87 energy audits. However, there are concerns regarding the quality of this data, including the following:

- Some measures may not generate as much savings as auditors have estimated;
- There is some mixing of ECMs and Retro-Commissioning Measures (RCMs), and this analysis did not review RCM cost or savings data due to the very spotty quality of the RCM reporting;
- Many experts feel that there are additional cost-effective savings opportunities beyond the ECMs identified in the audits; and
- There are some inconsistencies in the naming of energy conservation measures.

Despite these caveats, the audit data still provides a useful summary of the types of ECMs applicable in NYC buildings, and the resulting project economics.

upon the first year's findings. Once again, this report finds that if all ECMs were completed across all building segments, the City would be able to reduce GHG emissions from multifamily buildings by 11%. The greatest opportunity for total source energy savings comes from the Very Large building segment, and the greatest depth of savings come from the Post-war Gas Low-rise segment.

NYC Policy Opportunities

The findings and resources from this report are aligned with the goals of the New York City Mayor's Office of Sustainability.

In September 2014, Mayor Bill de Blasio committed New York City to an 80% reduction in GHG emissions by 2050 ("80 × 50").

At the same time, the City also published *One City: Built to Last*, a strategic climate action plan that focused on improving buildings as a means of improving the City. The report outlined 22 initiatives, including the convening of a Technical Working Group (TWG) to determine long-term pathways to carbon reduction in NYC's buildings, and the creation of the NYC Retrofit Accelerator to help owners of privately-owned buildings overcome market barriers and complete energy and water efficiency upgrades.

The NYC Retrofit Accelerator

In September 2015, the City launched the NYC Retrofit Accelerator, a free program that offers one-on-one advisory services to help building owners and property managers complete successful retrofits. This City program, developed in partnership with the New York Energy Efficiency Corporation (NYCEEC) and the Building Energy Exchange, provides building owners with access to education, financing, workforce development, and project guidance in order to reach the City's interim goal of a 30% reduction in GHG emissions by 2025 ("30 × 25").

The program is geared towards large buildings that fall under the GGBP. It employs a data-driven outreach approach combining energy audits and benchmarking data, publicly-available information, and City analyses (such as that of the Technical Working Group) to identify buildings and portfolios that would benefit most from energy efficiency retrofits. Over the first three years of this 10-year program, the Retrofit Accelerator aims to complete projects in at least 1,500 properties. The Retrofit Accelerator is well on its way to achieving this goal, and it is projected to reduce carbon emissions from buildings by 11% over the next three years.[6]

This report and the associated tearsheets seek to help the Retrofit Accelerator staff provide easy-to-understand recommendations to participants.

The Technical Working Group

Mayor de Blasio convened the Buildings Technical Working Group (TWG) to identify the most effective strategies to reduce energy and GHG emissions in both new and existing buildings. The TWG included more than 50 leaders and experts from backgrounds including: real estate, architecture, engineering, construction, finance, affordable housing, and environmental advocacy organizations.

The TWG published a report of their findings in April 2016, titled *One City: Built to Last, Transforming New York city Buildings for a Low Carbon Future*. The report summarizes a comprehensive energy analysis of New York City buildings; identifies 21 different building typologies based on primary use, age, height, and size; evaluates the cost and energy reduction potential from various deep retrofit paths for several different typologies; and outlines new initiatives to help the City meet its “80 × 50”goal. Additionally, the TWG report models the impact of different deep retrofit paths on seven different building typologies. It includes recommendations to realize key identified savings opportunities, as well as an analysis of potential efficiency pathways for unregulated loads and future energy codes. It serves to evaluate the technical potential for building retrofits and provide long-term policy guidance based on energy models and engineering assumptions.

It differs from this report in that it incorporates many data sources beyond the LL87 energy audit information and does not correlate ECMs to touchpoints in a building's lifecycle. In order to situate this report within a larger, consistent framework, the authors have chosen to adopt some of the TWG’s methodology. As a result, minor adjustments to ECM categories and building typologies have been made between the first report, *Retrofitting Affordability*, and this one.

Overall Potential

Implementation of all recommended LL87 measures would result in energy savings of nearly 25 TBTU, a 17.7% increase from year one findings.

This study finds that the implementation of all recommended LL87 measures by the City’s covered multifamily buildings would reduce their GHG emissions by 11%. With a total cost of $2.7 billion and an annual savings of $467 million, these measures would pay back in less than 6 years, on average. This is a reduction of over 1 MMTCO2e, and nearly 25 TBTU of energy savings. It is important to remember that these savings only apply to the owner-controlled energy use in the building (not tenant spaces) and do not account for retro-commissioning measures.

Very Large Buildings

To maintain consistency with analysis done by the Mayor’s Technical Working Group, this report added “Very Large Buildings” as a new building segment in this year’s analysis. Very large buildings (buildings over 500,000 square feet) make up only 4% of covered properties, but 30% of the total source energy use and 29% of square footage. They also represent nearly 20% of all potential energy savings from multifamily covered buildings. However, due to their size and the relatively small number of these properties throughout the city, creating a set of packages for these properties would not be adequately scalable. The majority of these Very Large Buildings have dedicated energy management staff and usually already have a comprehensive energy management plan in place. Though the information contained in this report can give building owners and operators of Very Large Buildings a sense of the cost and savings associated with different ECMs, they should consult with their internal energy teams for a more accurate understanding of the potential benefits of a retrofit in their building.

NextGen NYCHA

NYCHA is the largest landlord in New York City, housing 1 in 12 New Yorkers. NYCHA properties represent 16% of the total square footage of the covered buildings dataset, and make up nearly half of all of the buildings in the Very Large segment. This institution has its own strategic plan, called “NextGeneration NYCHA” which will improve the way NYCHA is funded, operates, rebuilds, and engages with residents. As an extension of the plan, the *NextGeneration NYCHA Sustainability Agenda*, includes energy efficient capital upgrades as well as operations and management improvements, with the overarching goal of providing healthy and comfortable homes that will withstand the challenges of climate change. These upgrades, which include improving heating and hot water efficiency, upgrading lighting, and deploying renewable energy resources, are expected to reduce NYCHA's GHG by 27% by 2025. With the goal to create an 80×50 roadmap for the years 2025-2050, NYCHA will also test deep retrofit technology and construction methods to learn which work best, disrupt residents the least, and are the most cost-effective.

To learn more about NextGen NYCHA and its Sustainability Agenda, please visit: https://www1.nyc.gov/site/nycha/about/nextgen-nycha.page and http://j.mp/green-nycha.

Although combining the first two years of LL87 audits resulted in a similar overall GHG emissions reduction potential to just the first year of audits (11%); the total energy savings has increased by approximately 3.7 TBTUs, or 17.7%.

Opportunities by Touchpoint

While the fraction of savings from each touchpoint is fairly consistent across building segments, savings from each touchpoint varies widely across ECM categories.

The lifecycle touchpoints ("Anytime/Anywhere", "Midcycle" and "Refinance"), can be additive. For example, measures that one would implement during an "Anytime/Anywhere" retrofit, can likely also be done during a "Midcycle" retrofit, as well as during a "Refinance" retrofit. This is reflected in Table 1. Tenant turnover measures, on the other hand, are stand-alone, as they are often completed on an as needed basis, with little connection to the greater financial lifecycle of a building.

The majority of recommended measures fall into the "Anytime/Anywhere" category. This touchpoint represents 36% of the total building stock potential source energy savings but only 16% of the cost, and pays back within three years, on average.

While the tearsheets list each of the potential measures for each building segment by touchpoint, Table 1 gives a high-level view of the energy savings potential for each touchpoint. The fraction of possible source energy savings in each touchpoint is fairly consistent across different building segments, as seen in Figure 2.

However, when looking at the savings opportunity for each touchpoint between categories, the story is a bit different (see Figure 3). There is significant source energy savings potential from Anytime/Anywhere ECMs from the Lighting, Domestic Hot Water and Heating and Distribution categories, whereas very few ECMs from the Envelope and Ventilation and Cooling categories fall into the Anytime/Anywhere touchpoint. For more information on how ECMs in each category match to different touchpoints, please refer to the tear-sheet for each particular building segment type.

Table 1: ECM Savings By Touchpoint

Lifecycle Touchpoint	Percent of ECMs	Source Energy Savings Potential (TBTU)	% Total Source Energy Savings Potential	GHG Reduction Potential (MMTCO2e)	% Total GHG Reduction Potential	Total Citywide Cost (Million $)	% of Citywide Cost	Average Payback (Years)
Anytime/Anywhere	**62%**	**8.3**	**36%**	**0.4**	**38%**	**400**	**16%**	**2.9**
Midcycle	**21%**	**7.8**	**35%**	**0.3**	**30%**	**950**	**38%**	**4.7**
Refinance/ Substantial	**17%**	**6.7**	**29%**	**0.3**	**32%**	**1,170**	**46%**	**12.6**
Total	100%	22.7	100%	1.0	100%	2,520	100%	5.8

*The numbers for Midcycle and Refinance touchpoints in this table are incremental (i.e. additional savings achieved from implementing the Midcycle package over just the Anytime/Anywhere package).

Figure 2: Savings by Touchpoint for Each Segment

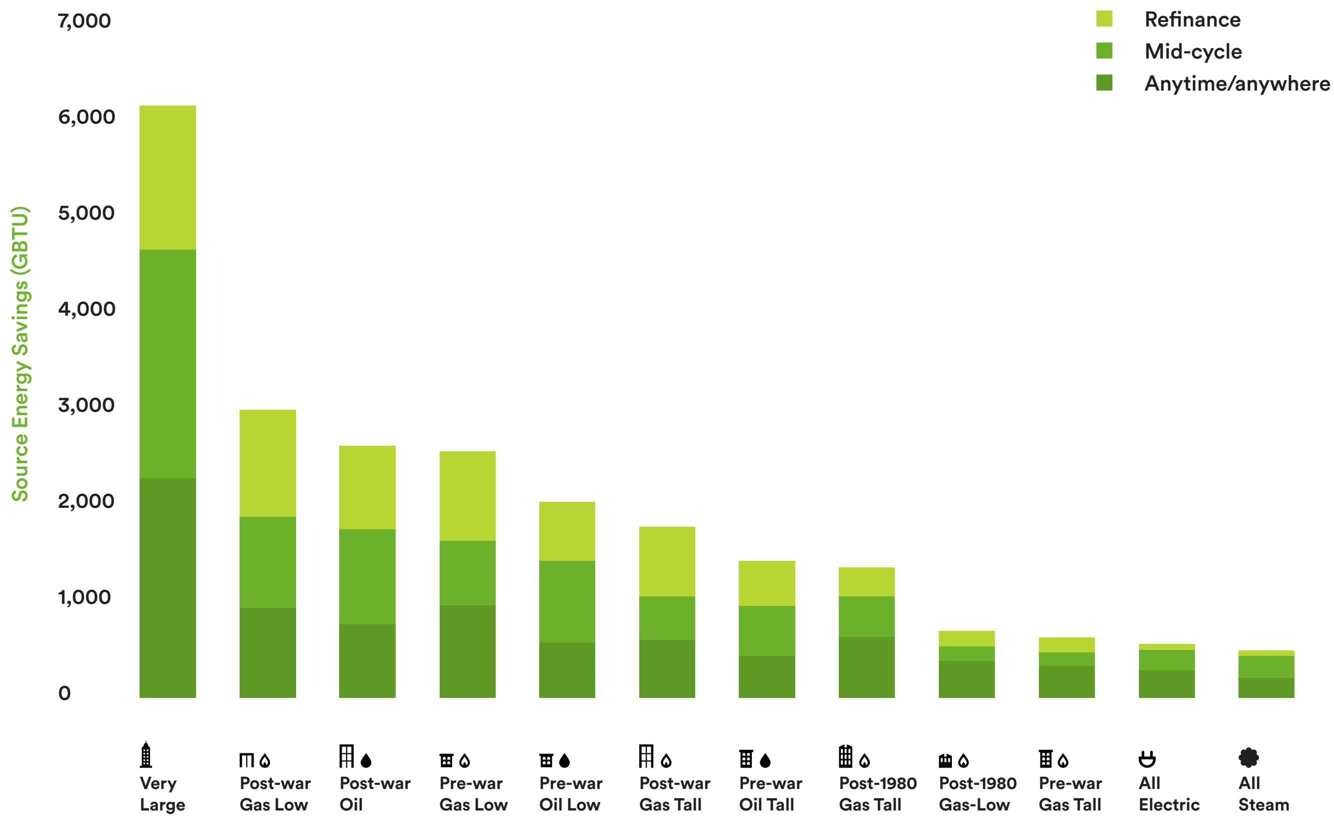


Figure 3: Savings By Touchpoint For Each Category

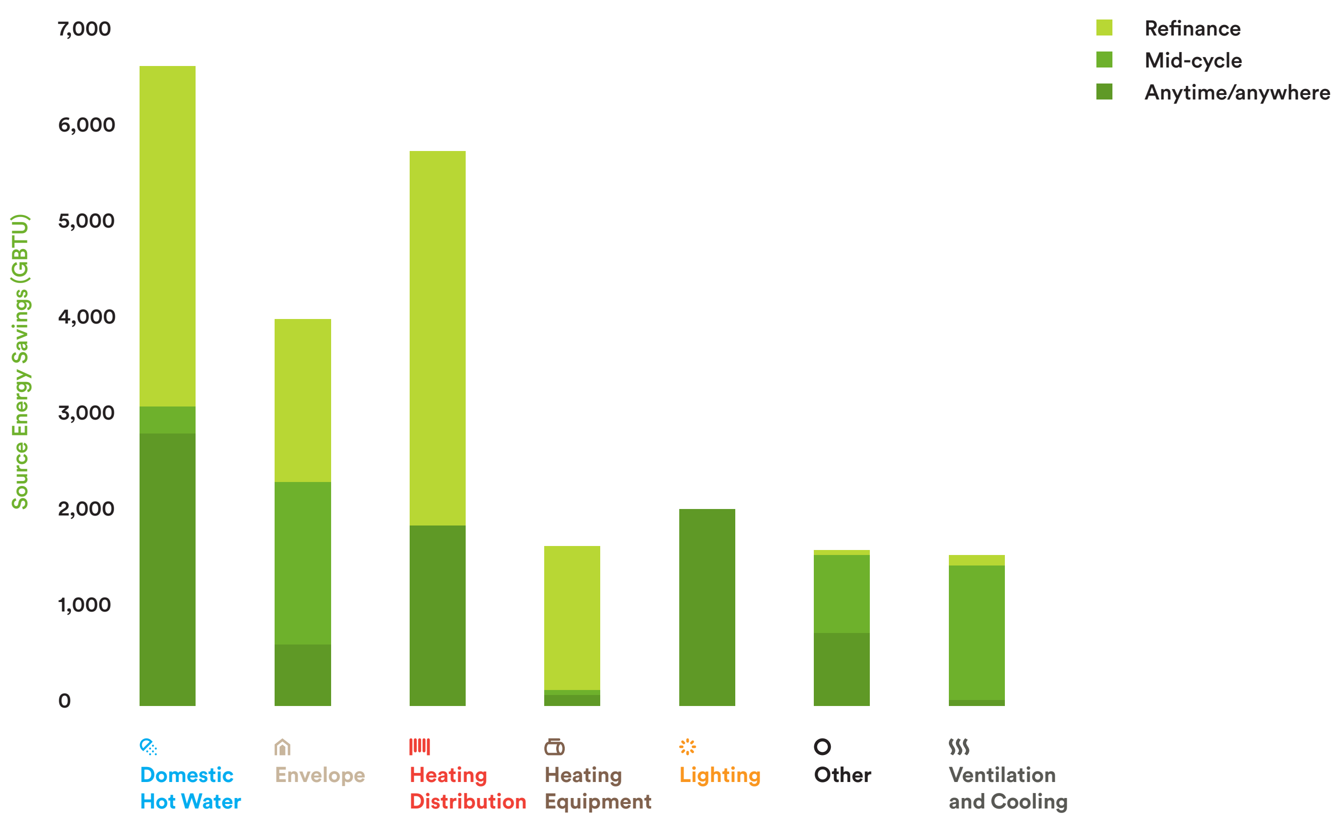
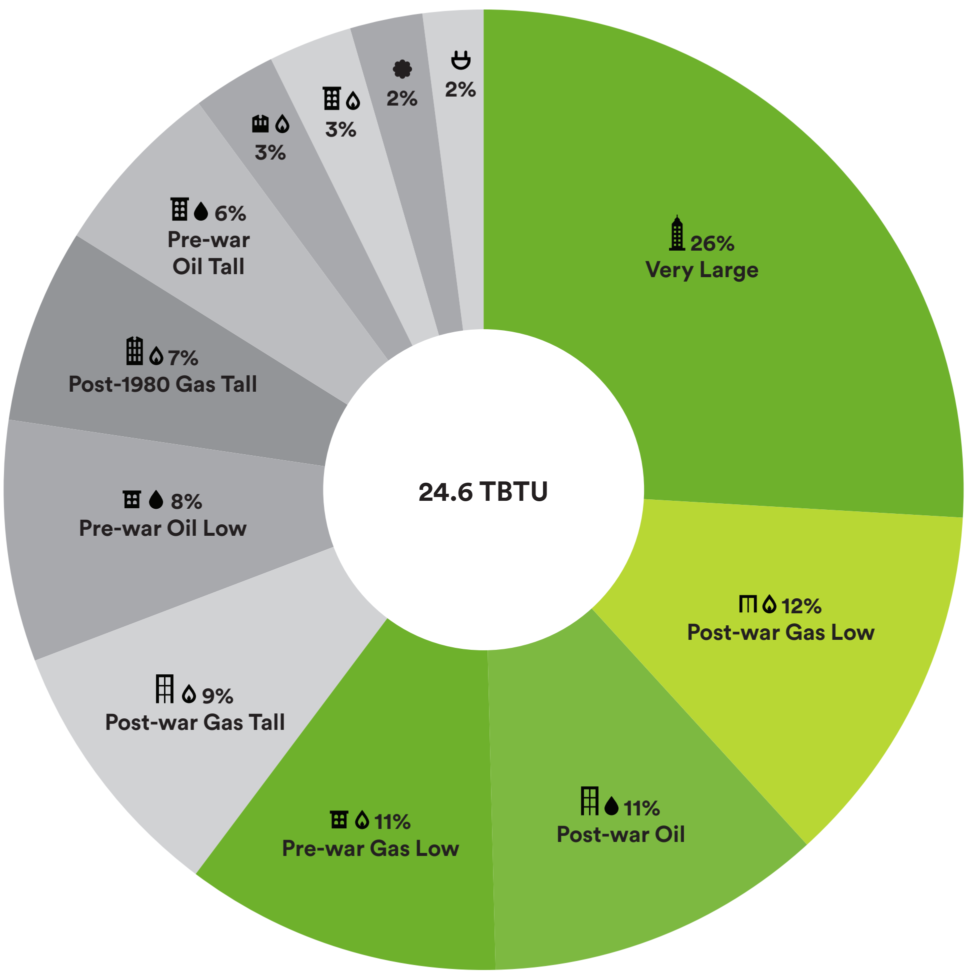


Table 2: Source Energy Savings Potential By Segment

Segment	Source Energy Savings Potential (TBTU)	% Total Source Energy Savings Potential	GHG Reduction Potential (MMTCO2e)	% Total GHG Reduction Potential	Retrofit Cost (Million $)	% Total Retrofit Cost	Payback (Years)
Very Large	6.4	26%	0.23	22%	$550	21%	5.6
Post-war Gas Low-rise	3	12%	0.13	12%	$250	9%	9.3
Post-war Oil	2.8	11%	0.14	14%	$410	15%	4.5
Pre-war Gas Low-rise	2.6	11%	0.11	11%	$290	11%	8.7
Post-war Gas High-rise	2.2	9%	0.09	9%	$170	6%	6.9
Pre-war Oil Low-rise	2	8%	0.12	11%	$380	14%	5.3
Post-1980 Gas High-rise	1.6	7%	0.06	6%	$100	4%	5.0
Pre-war Oil High-rise	1.5	6%	0.08	7%	$280	10%	5.1
Post-1980 Gas Low-rise	0.7	3%	0.03	3%	$70	3%	8.8
Pre-war Gas High-rise	0.7	3%	0.03	3%	$60	2%	6.1
All Steam	0.6	2%	0.02	2%	$60	2%	4.7
All Electic	0.5	2%	0.01	1%	$60	2%	3.9
Total	24.6	100%	1.05	100%	$2,680	100%	5.7

Figure 4: Source Energy Savings Potential By Segment



This chart shows the contribution of each segment to the overall source energy savings (24.6 TBTU) that can be achieved if all ECMs are implemented. Very Large, Post-war Gas Low, Post-war Oil, and Pre-war Gas Low represent the segments with the biggest potential energy savings. See Figure 5 for the depth of savings within each segment.

Opportunities by Segment

Each of the segments of multifamily housing types, and their respective recommended energy conservation measures, were analyzed to identify the most impactful opportunity for energy savings and carbon emissions reductions.

Table 2 shows the contribution from each segment to the overall potential source energy savings (24.6 TBTU) that can be achieved if all recommended ECMs are implemented. See Table 3 for the depth of savings within each segment.

The largest opportunity for energy savings is found in the Very Large buildings segment, which accounts for 26% of the source energy savings opportunities across all segments. This is followed by Post-war Gas Low-rise (12%), Post-war Oil (11%), and Pre-war Gas Low-rise (11%). Together, these four building segments represent 58% of total covered multifamily area, 60% of potential source energy savings, 59% of potential GHG savings and 56% of the citywide-implemented cost. The average payback for measures in these segments is about 7 years.

However, the greatest potential percent reduction in current source energy use comes from Post-war Gas Low-rise (16%) and Pre-war Oil Low-rise (14%) buildings (see Table 3). Post-war Gas Low-rise buildings provide the “biggest bang for the buck” from that group, as their ECMs cost only about $80 million per TBTU in energy savings, compared with Pre-war Oil Low-rise at $190 million/TBTU reduced. Very Large buildings, while one of the less expensive segments to retrofit citywide, at $90 million/TBTU reduced, show only a 8% reduction in current energy use. The low cost and correspondingly low energy reduction may indicate that the ECMs recommended for this segment tend to be less deep than other building segments. This is explored further in the “Why aren’t all buildings reaching their potential” sidebar.

From a high-level overview of the building segments, targeting retrofits in Post-war Gas Low-rise, Pre-war Oil Low-rise, Pre-war Gas Low-rise, Post-war Oil, Pre-war Oil High-rise, and Post-war Gas High-rise buildings would most likely have the greatest overall impact on the city.

Deep Retrofit Challenges

Deep energy retrofits have enormous benefits – increased asset value, decreased energy bills and GHG emissions, and improved health and comfort –but they are not easy. Deep retrofits can be costly, disruptive to residents, and challenging to implement properly. For most NYC multifamily buildings, achieving the maximum performance potential requires upgrades to three major systems: the central heating plant, the ventilation system, and the envelope. Upgrading these systems each has a unique set of challenges:

Heating: A central steam plant heats most NYC multifamily buildings. New, high-efficiency systems require significant capital outlays, as well as work within resident’s units. For example, condensing boilers can require re-piping the entire building and air source heat pumps can require increased electric service.

Ventilation: Many NYC buildings are under-ventilated or have non-functioning ventilation systems. Bringing these systems up to code improves health and comfort, but can be costly and require in-unit work. They can also require increasing building ventilation, which increases energy costs.

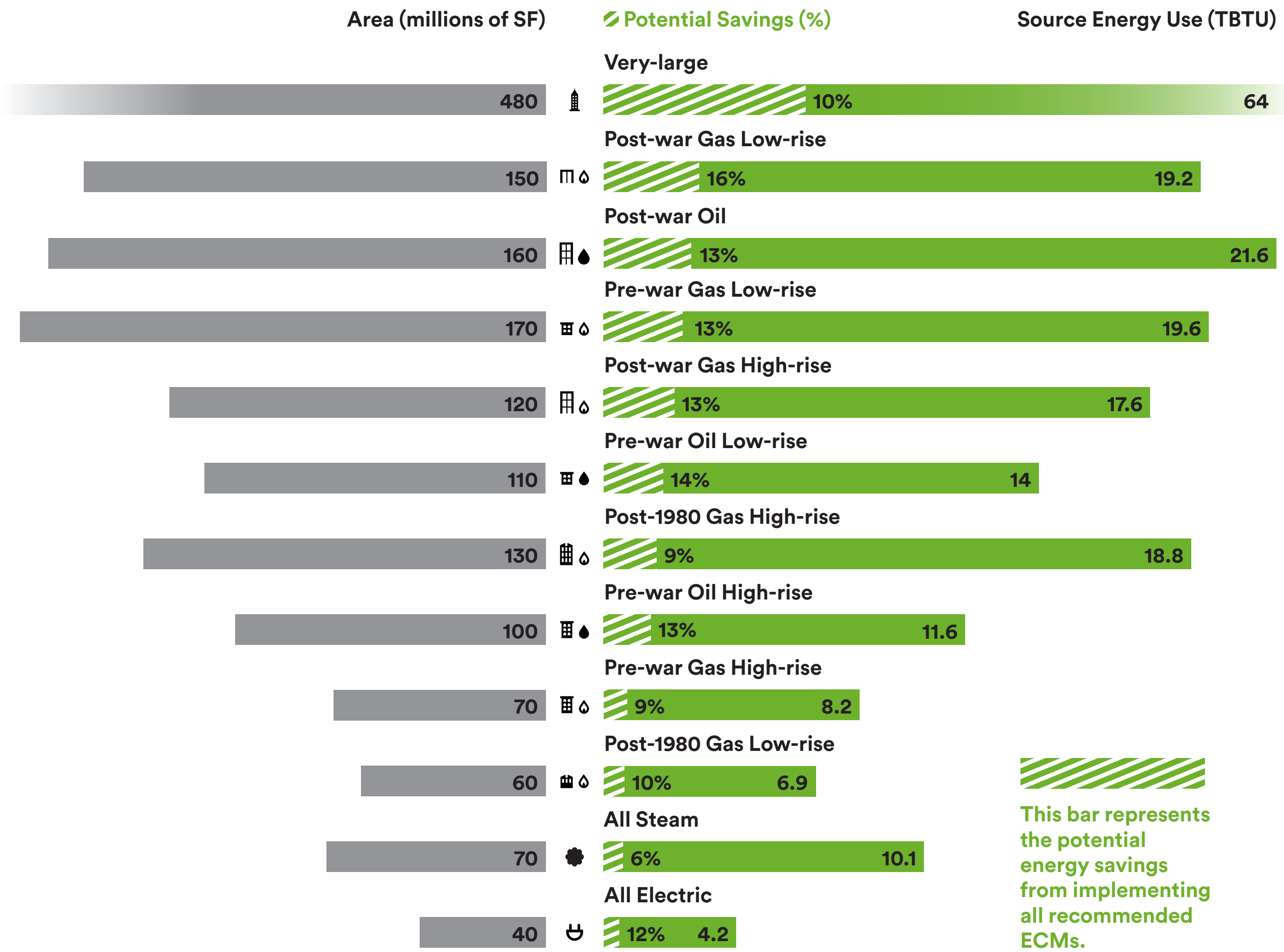
Envelope: Many multifamily building exteriors lack adequate (if any) insulation, and allow significant amounts of air infiltration, causing drafts. While some buildings may have upgraded their windows or replaced their roof, the building’s walls are typically unchanged. Exterior Insulation and Finish Systems provide major energy savings, but can be costly, change the building’s appearance, and present zoning challenges. Interior spray foam air sealing and insulation are effective, but are disruptive and typically only implemented during substantial renovations.

Realizing the enormous energy and health benefits of multifamily building deep retrofits will require creative solutions to both the cost barriers and the inconvenience that implementation poses to building residents. Models do exist for scaling up deep energy retrofits in existing buildings, such as the Dutch Energiesprong, which brings together technological, political and financial innovation. Energiesprong is now being adopted in New York under the RetrofitNY program.

Table 3: Depth Of Savings Potential

Segment	Current Source Energy Use (TBTU)	Source Energy Savings Potential (TBTU)	% Source Energy Reduction	Current GHG Emissions (MMTCO2e)	GHG Reduction Potential (MMTCO2e)	% GHG Reduction Potential	Retrofit Cost (Million $)	Cost per TBTU (Million $/ TBTU)
Very-large	64	6.4	10%	2.92	0.23	8%	$550	$90
Post-war Gas Low-rise	19.2	3	16%	0.81	0.13	15%	$250	$80
Post-war Oil	21.6	2.8	13%	1.12	0.14	13%	$410	$150
Pre-war Gas Low-rise	19.6	2.6	13%	0.86	0.11	13%	$290	$110
Post-war Gas High-rise	17.6	2.2	13%	0.72	0.09	13%	$170	$80
Pre-war Oil Low-rise	14	2	14%	0.80	0.12	15%	$380	$190
Post-1980 Gas High-rise	18.8	1.6	9%	0.71	0.06	8%	$100	$60
Pre-war Oil High-rise	11.6	1.5	13%	0.61	0.08	13%	$280	$190
Pre-war Gas High-rise	8.2	0.7	9%	0.32	0.03	8%	$60	$90
Post-1980 Gas Low-rise	6.9	0.7	10%	0.30	0.03	10%	$70	$100
All Steam	10.1	0.6	6%	0.41	0.02	6%	$60	$100
All Electric	4.2	0.5	12%	0.11	0.01	7%	$60	$120
Total	215.8	24.6	11%	9.7	1.0	11%	$2,680	$110

Figure 5: Comparison of Area and Source Energy by Segment



Each segment has a different amount of energy saving potential. This graphic shows the percent of energy saved from implementing all ECMs in each segment, compared to the area and the current source energy use of each segment. Figure 7 shows how these savings can be achieved through the recommended ECMs.

Table 4: Source Energy Savings Potential by ECM Category

Category	Source Energy Savings Potential (TBTU)	% Total Source Energy Savings Potential	GHG Potential Reduction (MtCO2e)	% of Total GHG Emissions Reduction Potential	Total Citywide Cost (Million $)	Percent of Citywide Cost	Payback (Years)
Domestic Hot Water	6.5	26%	0.3	28%	$290	11%	3.4
Heating & Distribution	5.8	24%	0.3	25%	$150	6%	2.7
Envelope	4.0	16%	0.2	18%	$1,240	46%	8.3
Heating Equipment	2.4	10%	0.1	10%	$270	10%	7.0
Ventilation & Cooling	2.1	8%	0.1	9%	$180	7%	7.6
Lighting	2.0	8%	0.1	8%	$200	7%	3.6
Other	1.9	8%	0.0	2%	$350	13%	6.1
Total	24.6	100%	1.0	100%	$2,680	100%	5.7

Figure 6: Source Energy Savings Potential by ECM Category

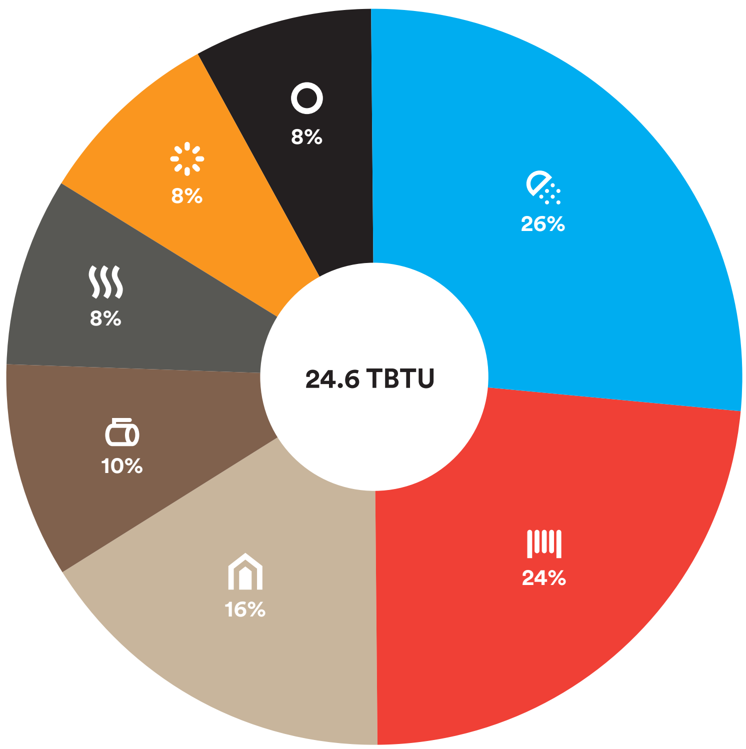


Figure 6 shows the contribution of each ECM category to the total source energy savings identified by the Energy Audit submissions.

Energy Conservation Measure Categories

On the Energy Audit Law submission form, auditors can recommend ECMs from fifteen different categories. For the purpose of simplicity we have condensed these fifteen categories into seven.

Domestic Hot Water | Building Envelope | Heating Equipment | Heating & Distribution | Lighting | Ventilation & Cooling | Other

The savings potential for each category is shown above in Table 4 and Figure 6.

2013 vs 2013 + 2014 Combined LL87 Data
Overall, the savings opportunities found in the 2013 and 2014 combined data were pretty similar, both by segment and by ECM category, to those found in the 2013 data alone. Again, Post-war Oil and Post-war Gas Low-rise properties had significant savings opportunities. However, in the 2013 and 2014 combined data, Pre-war Oil Low-rise had a more significant proportion of the savings as compared to 2013 alone, whereas All Electric had a smaller proportion of the savings. These fluctuations in savings opportunities represented in the Energy Audit data may be due in part to the random selection of properties required to undergo audits each year. Due to the adaptation of the methodology to stay contemporary with other recent publications in this area, such as the TWG report, *Turning Data into Action* is not an apples to apples comparison to the previous report. However, in reapplying this report's methodology to the 2013 data, the total savings, as well as the savings from each segment and category, are very similar between years.

Retro-Commissioning
All properties covered by the Energy Audit Law (Local Law 87) are required to "retro-commission" (RCx) their central building systems, which involves adjusting and properly maintaining the existing systems to optimize performance. RCMs are required to be implemented, while ECMs, which are typically more capital-intensive and tend to involve equipment replacement, are optional. Unfortunately, projected savings from RCMs were reported less systematically in the audit data, and therefore were not included in our analysis.

Savings from implementing RCMs, while not included in this analysis, can be significant. In a small subset of buildings where the RCM savings were reported, they ranged from $0.02 to over $1.00 per square foot. In addition, in the first Energy Audit Law submission to the City (by Bright Power in November 2013), a multifamily building in Brooklyn saved between 3-6% of its energy usage through implementing the RCMs alone.

In order to better understand the full savings potential of the Energy Audit Law, it would be helpful for the Department of Buildings to provide additional guidance to energy auditors on properly reporting RCMs.

Opportunities By Energy Conservation Measure

Grouping energy conservation measures into seven categories illustrates which ECM categories provide the greatest opportunity for savings along with the most cost effective payback.

Energy conservation measure (ECM) analysis gives a detailed view of the opportunities in multifamily buildings identified by the auditors. The ECMs in the Energy Audit Law submissions for each segment were analyzed, grouped into seven categories (see sidebar), and then their energy impact was scaled up to represent the total savings potential for all covered buildings in each category (see Table 4).

Together, Domestic Hot Water and Heating Distribution measures represent 50% of the potential source energy savings, pay back in about three years, and make up under 20% of the total citywide cost of implementing ECMs.

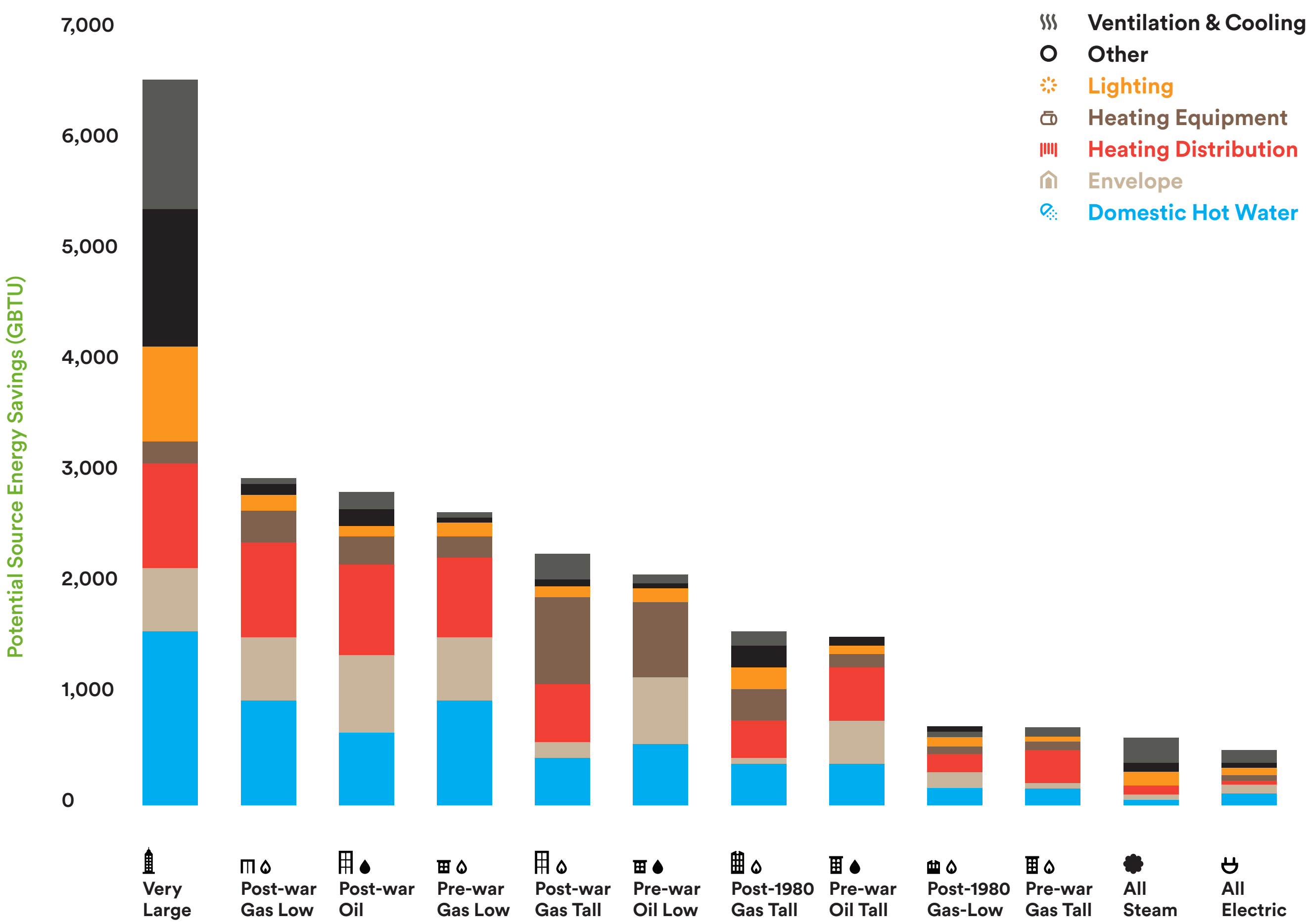
The authors also analyzed the relative impact of each individual ECM, looking at the frequency of the recommendation within a building segment, cost per square foot, potential source energy savings, potential GHG reduction, payback, and citywide cost. The top five ECMs (combined across all segments) represent nearly 50% of the total energy and GHG potential savings (see Table 5).

Looking at each building segment individually, it is possible to identify categories of ECMs that have the biggest energy savings potential (see Figure 7). This chart can help direct property owners and efficiency program managers towards areas to target their retrofit efforts. For example, on a citywide scale, addressing Heating Distribution and Heating Equipment measures in Post-war Oil buildings will have a greater energy savings impact than implementing all recommended measures in All Steam properties.

Table 5: Five ECMs with the Greatest Source Energy Savings Potential

Category	ECM	Source Energy Savings Potential (TBTU)	% Total Source Energy Savings Potential	GHG Reduction Potential (MMTCO2e)	% Total GHG Reduction Potential	Total Citywide Cost (Million $)	% of Citywide Cost	Total Citywide Savings (Million $)	Payback (years)
Heating Distribution	*Install/Upgrade Controls and Thermostats*	3.7	15%	0.17	16%	$80	3%	$40	2.0
Domestic Hot Water	*Separate DHW from Heating*	3.4	14%	0.16	15%	$200	7%	$40	5.0
Domestic Hot Water	*Install Low Flow Aerators*	1.9	8%	0.09	8%	$40	1%	$30	1.3
Lighting	*Upgrade Lights*	1.7	7%	0.07	7%	$160	6%	$40	4.0
Envelope	*Replace Windows and Glazing*	1.4	6%	0.07	6%	$650	24%	$20	32.5
Total Top 5 ECMs		12.2	49%	0.56	53%	$1,130	42%	$170	6.6
Total of All ECMs		24.6		1.0		$2,680		$470	5.7

Figure 7: Energy Savings Potential for Each Segment by ECM Category



This graphic shows how each segment can achieve its full potential source energy reduction. The potential source energy savings from each ECM category can be compared across segments. However, the source energy savings impact of each ECM may also differ across segments.

Photo credit: David McSpadden

updated multifamily analysis

Adding a second year of City data to this report's predecessor, *Retrofitting Affordability*, has more than doubled the number of energy audits we analyzed. NYC's diverse building stock has again been divided into representative segments sharing similar characteristics, with small modifications made to better align these typologies with the City's own report, *One City: Built to Last TWG*.

Datasets And Shared Analysis

The analysis in this report is based predominantly on 2014 benchmarking data and combined 2013 and 2014 energy audit data, collected by New York City's Department of Buildings under the Greener Greater Buildings plan (see sidebar, page 11). This data is supplemented by the NYC Department of Finance's PLUTO dataset, as well as analyses that have been conducted by the City since the publication of *Retrofitting Affordability* in 2015. The energy benchmarking and energy audit datasets have grown over the past two years, making the analysis more robust (see Table 6). The majority of this report's data cleaning and analysis follows the methodology established in the previous report (see in-depth "Methodology" section in the Appendix), although some things have been adjusted slightly to improve alignment with the City's recent initiatives.

There has been a 6% increase in energy benchmarking submissions between 2013 and 2014. Since energy audit compliance is randomly assigned, there were fewer multifamily properties required to submit in 2014 than in the previous year.

Methodology

Typologies

Using the energy benchmarking data, the authors divided NYC's multifamily buildings into "building segments," based on age, height, size, and primary heating fuel. In order to ensure that our results would align with the City's initiatives, we adjusted our building typologies from those

Table 6: Summary of LL84 and LL87 Submissions, 2013 and 2014

Dataset	Received Submissions	Cleaned Submissions	Cleaned MF	Scaled MF	Scale Factor	Early Compliance (All types)	MF Early Compliance
2013 LL84	**12,805**	**10,367**	**7,731**	**10,043**	**1.299**		
2013 LL87	**1,230**	**1,398**	**826**			**653**	**429**
2014 LL84	**13,052**	**11,061**	**8,219**	**10,351**	**1.259**		
2014 LL87	**1,102**	**905**	**579**			**23**	**17**
2013+2014 LL87		**2248**	**1405**			**674**	**445**

Figure 8: Comparison of LL84 and LL87 Characteristics

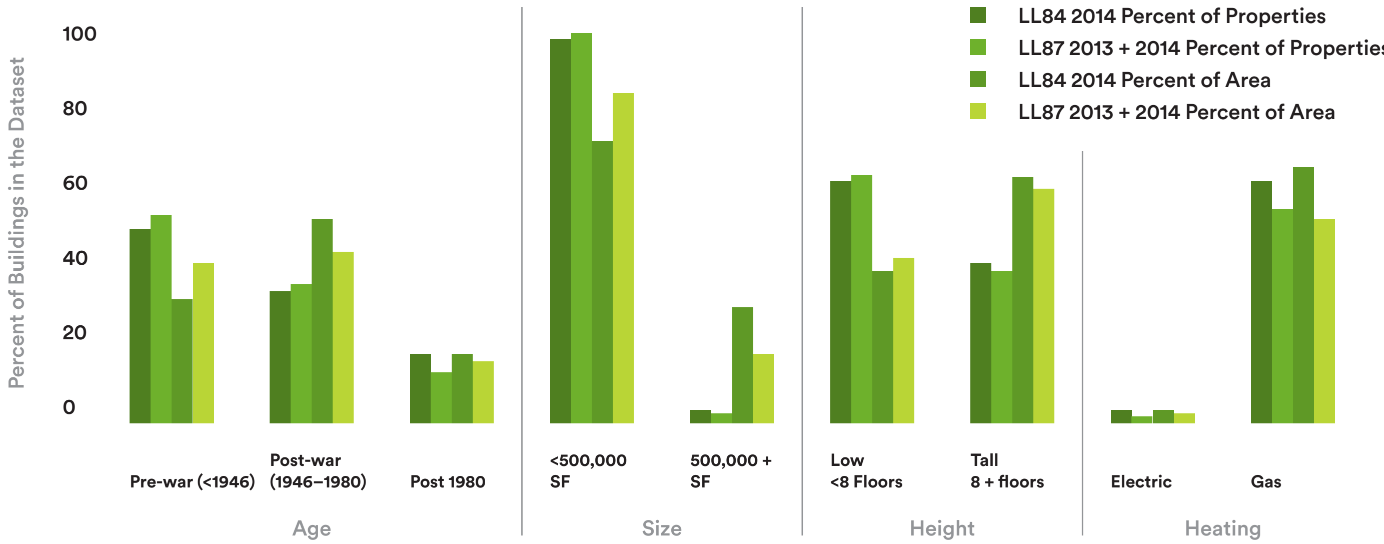


Table 7: Characteristics of Multifamily Segments

Characteristics		LL84 2014 Percent of Properties	LL87 2013+2014 Percent of Properties	LL84 2014 Percent of Area	LL87 2013+2014 Percent of Area
Age	**Pre-war (<1946)**	**49%**	**52%**	**31%**	**40%**
	Post-war (1946-1980)	**33%**	**35%**	**51%**	**43%**
	Post-1980	**18%**	**13%**	**18%**	**16%**
	Total	100%	100%	100%	100%
Size	**Not very large (50,000 - 500,000 SF)**	**96%**	**97%**	**71%**	**83%**
	Very large (500,000+ SF)	**4%**	**3%**	**29%**	**17%**
	Total	100%	100%	100%	100%
Height	**Low-rise (<8 floors)**	**60%**	**62%**	**39%**	**41%**
	High-rise (8+ floors)	**40%**	**38%**	**61%**	**59%**
	Total	100%	100%	100%	100%
Heating Fuel	**Electric**	**4%**	**2%**	**4%**	**3%**
	Gas	**60%**	**53%**	**64%**	**51%**
	Oil	**33%**	**40%**	**25%**	**35%**
	Steam	**4%**	**5%**	**6%**	**11%**
	Total	100%	100%	100%	100%
	Totals	8219	1316	1522	208

used in our last report to be more consistent with the Technical Working Group analysis. We added a typology for Very Large buildings (those over 500,000 square feet) and adapted our height criteria to differentiate buildings with less than eight floors (Low-rise) from buildings with eight or more floors (High-rise). The City's analysis also distinguishes between buildings built in the Post-War period (1945-1979) and Post-1980 (after the first energy codes were implemented in New York City). This updated age characteristic only affected buildings using gas as their primary heating fuel. The authors compared the frequency of these characteristics in the Energy Benchmarking dataset to that in the Energy Audit dataset. As with the original report, the distribution

Figure 9: Comparison of Number of Properties vs. Area and Source Energy Use in MF Segments

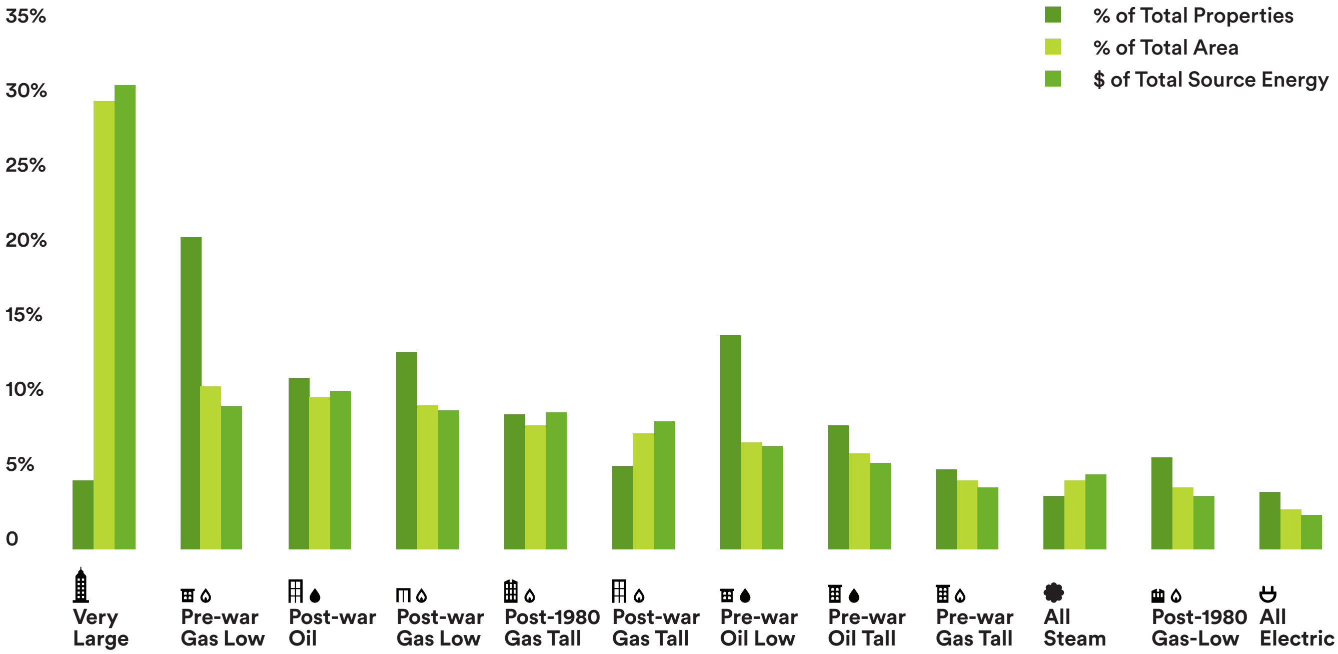


Table 8: Characteristics of Multifamily Building Segments

	Number of Properties	% of Total Properties	Area (Million sqft)	Percent of Total Area	Total Annual Source Energy Use (TBTU)	Percent of Total Source Energy Use	Total Annual GHG Emissions (MTCO2e)	Percent of GHG Emissions
Very Large	433	4%	480	29%	64	30%	2.9	30%
Pre-war Gas Low-rise	2,070	20%	170	10%	20	9%	0.9	9%
Post-war Oil	1,123	11%	160	10%	22	10%	1.1	12%
Post-war Gas Low-rise	1,300	13%	150	9%	19	9%	0.8	8%
Post-1980 Gas High-rise	875	8%	130	8%	19	9%	0.7	7%
Post-war Gas High-rise	535	5%	120	7%	18	8%	0.7	7%
Pre-war Oil Low-rise	1,414	14%	110	7%	14	6%	0.8	8%
Pre-war Oil High-rise	792	8%	100	6%	12	5%	0.6	6%
Pre-war Gas High-rise	509	5%	70	4%	8	4%	0.3	3%
All Steam	343	3%	70	4%	10	5%	0.4	4%
Post-1980 Gas Low-rise	597	6%	60	4%	7	3%	0.3	3%
All Electric	359	3%	40	2%	4	2%	0.1	1%
Totals	10,351	100%	1,660	100%	216	100%	10	100%

of these characteristics is similar across both datasets, allowing the authors to scale the findings from the Energy Audit dataset to all covered multifamily buildings, as represented in the Energy Benchmarking dataset.

The distributions of building characteristics between the Local Law 84 2014 submissions and the Local Law 87 2013 and 2014 submissions are very similar, allowing the authors to scale the findings from Local Law 87 to the entire covered multifamily building set as represented by Local Law 84.

Segment Characteristics

Age: Pre- and Post- War properties include significantly different construction materials and typically include different types of energy use systems.

Pre-War
Properties built before 1947. These buildings have shallower floor plates, and were generally built without central ventilation systems or central air conditioning. For heating, they typically have radiators with 1-pipe or 2-pipe steam distribution.

Post-War
Properties built between 1947 and 1980. These generally have bigger windows and may also have central ventilation and central cooling systems. The heating distribution system is more varied, and may include electric, forced air, hydronic, heat pumps and vacuum 2-pipe steam.

Post-1980s
Properties constructed post-1980, after the first New York State Energy Conservation Construction Code was established. These are typically equipped with either two-pipe steam systems or hydronic systems, which use hot water rather than steam to deliver space heating.

Height: The height of buildings is a broad indicator of construction type and energy savings opportunities. For example, the tallest buildings tend to have more opportunities for controlling airflow in elevator shafts, trash chutes, and ventilation systems; while shorter buildings have a higher ratio of envelope to floor area.

Low-rise
7 or fewer floors above grade.

High-rise
8 or more floors

Very Large Buildings
Over 500,000 SF

Primary Heating Fuel: The type of heating fuel directly impacts the types of conservation measures under consideration. There are four heating fuel categories.

Electric
Properties that use electricity as their primary heating fuel are typically Post-War construction.

Gas
Natural gas is used as a primary heating fuel in buildings of all heights and vintage

Oil
Includes all oil grades; cleaner and lighter #2 heating oil, as well as the heavier and dirtier #4, #5, and #6 heating oils. All buildings using heavy oil (#6) must convert to cleaner fuels by 2016. (See Clean Heat Sidebar)

District Steam
Provided by Consolidated Edison, and is only available in parts of Manhattan.

These characteristics allow the authors to evaluate energy use and recommended measures for 12 distinct segments of the NYC building stock. A citywide energy usage profile for each segment was calculated using the Energy Benchmarking data.

Energy Conservation Data

In addition to building upon the findings from this report's predecessor, the authors have revisited last year's methodology for analyzing Energy Audit Law data, to improve the accuracy of our estimate of potential savings across all multifamily buildings. The authors analyzed the 2013 and 2014 Energy Audit datasets' lists of ECMs (representing 1,520 properties after cleaning the data), taking into account the estimated cost, payback, source energy, and GHG reduction of each measure within each segment. These findings from the Energy Audit data were then scaled up to all covered multifamily buildings in New York City in order to estimate the total potential energy savings and GHG reductions. The total potential source energy savings were estimated based on the number of times an ECM was recommended within a building segment and its average potential source energy savings. The results allow for an estimate of the total energy savings potential within New York City's multifamily building stock if all of the recommended ECMs were applied across all covered multifamily buildings.

challenges

Energy efficiency continues to be a low priority for decision-makers, many of whom are focused simply on maintaining, leasing, and financing a New York City building. Furthermore, uncertainty about the actual outcomes and realized benefits of implementing an energy efficiency retrofit continues to deter action.

Efficiency is a Low Priority

Building owners and operators rightfully prioritize improvements that require immediate attention to preserve the safety and comfort of their tenants. However, they often overlook or are unaware of the opportunity for energy efficiency retrofits that can be implemented as part of these improvements. It may also be unclear who is responsible for making the financial and technical decisions for a building. The equipment replacement packages provided in this report can help building owners better understand the numerous energy efficiency options available to them when replacing a piece of major equipment.

Outcome Uncertainty

The lack of documented and verified retrofit projects may make building owners and operators uncomfortable with pursuing energy efficiency opportunities. Since the cost, savings, and benefits can be unclear and the perceived financial risks high, many property owners choose not to implement retrofit measures. Though more studies are underway to quantify energy savings, it can be very difficult to normalize the outcomes across different building types.

Financial Constraints

Multifamily financing is different for each building, and becomes even more complicated for subsidized affordable housing. It may be hard to determine if ECM implementation would draw from the operating budget or the capital budget, and where the savings are applicable. Timing is also a critical piece of the puzzle. By organizing ECMs around touchpoints and providing estimates of the costs, energy savings, and payback, building owners and operators may be better able to align their financial capabilities with their energy efficiency goals.

path forward

New York City and State are acting on ambitious climate and clean energy goals with new initiatives, policies, and legislation, which include a renewed focus on multifamily buildings. Realizing the potential efficiency gains and environmental benefits possible in this diverse sector will require the continued expansion of available education, assistance, and resources. The Building Energy Exchange proposes a sustained effort to scale and build confidence in the retrofit market through a growing portfolio of successful case studies, targeted campaigns, and turn-key solutions that make energy efficiency into an easy, predictable, and standard practice.

We believe a successful path forward to accelerating multifamily building energy efficiency should include:

- **Robust Assistance:** Expand the NYC Retrofit Accelerator program to help more property owners implement retrofit projects.
- **High Performance Retrofit Track:** Expand the High Performance Retrofit Track of the NYC Retrofit Accelerator to create and share widely a broader knowledge of practical deep energy retrofit pathways for a large variety of building typologies.
- **Case Studies:** Identify, track, document, and publicize the energy cost savings as well as implementation costs of successful energy efficiency retrofit projects from diverse building typologies, in order to transfer knowledge and inspire confidence in results.
- **Data Collection:** Improve procedures to increase the quality of energy benchmark and audit data, and create a system to more effectively host, aggregate, and share the data.
- **Training & Education:** Increase outreach and education to all stakeholders to increase awareness and understanding of best practices and retrofit benefits, including topics on high performance buildings, deep energy retrofits, and standards such as Passive House.
- **Technical Research:** Study deep energy retrofit pathways and implement well documented pilot projects, for a variety of building types, to create capital master plans that achieve significant savings.
- **Financing:** Expand access to financial tools, like PACE (Property Assessed Clean Energy), that can leverage energy savings to help fund energy retrofits.
- **Exemplary Building Competition:** Launch a competition for multifamily buildings of excellence.

Set The Stage

New York City and State continue to advance initiatives that drive building efficiency, including expanding and streamlining available data sets to better direct policies, identify opportunities, and inform building decision-makers.

Actions to Date

Both the City and State of New York have made great strides towards meeting their climate action goals. For example, the recently completed NYC Clean Heat program worked to ensure that buildings in the City no longer burn heavily polluting No. 6 oil as a primary heating fuel. Other City initiatives, such as the NYC Carbon Challenge and Retrofit Accelerator, have created a network of enaged New Yorkers who are aware of energy efficiency projects and their positive impact on a building's bottom line. To increase participation in such programs, the City and State have also undertaken market research to better understand the players and decision-makers in the energy efficiency sector.

As datasets from NYCs Energy Benchmarking and Energy Audit Laws grow, so too does the diversity and reach of analysis. The NYC TWG has created detailed energy-use profiles for all building types in NYC and has identified top ECMs that can have a large impact citywide. The Mayor's Office is introducing policy that will make implementation of these measures mandatory, and also plans to expand the TWG study by evaluating the economic feasibility of proposed measures.

New York State has launched the Clean Energy Fund, which is reshaping the State's energy efficiency, clean energy, and energy innovation programs. Governor Cuomo has recently announced more aggressive energy efficiency targets for 2025, which will increase annual electricity savings over 3% by 2025 (see sidebar, page 37). These changes are targeted at encouraging action among building owners and operators.

At the same time, Passive House, a high performance building standard, is gaining traction in both NYC's public and private sectors. This is evidenced by its reference in the TWG report and by the increasing number of projects in the multifamily space.[7] Retrofitting existing buildings to the Passive House standard, which mandates whole building energy use to be less than 38 kBTU/SF, would have a tremendous impact on reducing the GHG emissions of New York City buildings.

Data Considerations

New York City will continue to collect building energy data under the Energy Benchmarking and Energy Audit Local Laws. While compliance has been increasing, and datasets are well-utilized, there is a need to improve data quality. In 2016, the NYC Department of Buildings added a data quality check on Energy Benchmarking submissions from EPA Portfolio Manager, to ensure that data is as accurate as possible. It would greatly benefit the City to do something similar with the Energy Audit and Retro-commissioning submissions. Improved data quality and organization of data would make analysis much easier. Additionally, by providing a standardized submittal process and an easy-to-read output from the audits, the City would empower building owners and managers to take action from their audits.

In 2016, the City Council passed a bill to expand the Energy Benchmarking Law to buildings between 25,000 and 50,000 square feet. The additional data that will result from this will give the City a more granular view of the buildings in New York City and provide these medium size buildings with more actionable information regarding their energy use and savings opportunities.

Build the Potential – 2018-2019

The NYC Retrofit Accelerator should continue building upon its early success, with targeting of deep retrofits and proof-of-concept projects to nurture market confidence in energy conservation measures. Market education must also grow in order for awareness to expand.

Since 2015, the NYC Retrofit Accelerator has been helping building owners and portfolio managers implement energy efficiency projects, developing financing avenues and producing educational events and workforce development programs. The Retrofit Accelerator focuses on helping properties that have completed energy audits and have indicators for improvement. This report aims to assist the Accelerator's efforts by identifying appropriate moments in a building's lifecycle to complete specific ECMs, as well as ways to plan for more intensive future retrofits.

High Performance

Deep energy retrofits will be crucial to meeting New York City and New York State's ambitious climate action goals.

While there are significant savings opportunities through deep retrofits, there are also a number of challenges. The tearsheets presented in this report offer guidance to building owners and managers looking to complete deep energy retrofits. Additionally, the NYC Retrofit Accelerator includes a High Performance Track to accelerate deep retrofits that greatly reduce energy use and carbon emissions. Additional research is also underway to better understand how Passive House retrofit standards, such as EnerPHit, could be implemented across New York City. The Building Energy Exchange has launched and will expand programs and trainings around High Performance Building retrofits, as well as provide guidance and produce exhibits on what High Performance Buildings can look like in New York City.

Retrofit New York

In 2017, NYSERDA launched the RetrofitNY program, a new $30 million, 10 year program aiming to develop a market for radically improving the performance of affordable multifamily buildings. The program's centerpiece is expected to be an ongoing design/build competition for fast, inexpensive, and replicable retrofits that can cut energy use by as much as 70%.

The NYC Retrofit Accelerator

The NYC Retrofit Accelerator, initially funded through mid-2018, has been extended and expanded. Since its launch in 2015, it has gathered a wealth of information about New York City's building stock and the complex group of owners, managers, tenants, and contractors that affect building performance decisions. The Retrofit Accelerator has identified significant market gaps, and its unique, personalized approach is beginning to grow the retrofit market. The Retrofit Accelerator will continue to build on this initial success and capitalize on the relationships, knowledge, and data it has already garnered. As the Retrofit Accelerator completes more projects, it is crucial that these be made into case studies that will serve as a proof-of-concept for energy efficiency retrofits. As projects are completed, it is equally important to track the ECMs implemented, document their costs, and monitor and verify their energy savings.

Resources like the *Better Steam Heat Playbook*, by BE-Ex and the Retrofit Accelerator, as well training and outreach around steam efficiency encourage upgrades in buildings that have large savings potential.

Additional campaigns to be coordinated through the Retrofit Accelerator, NYCEEC, and the City will demonstrate other high savings, quick payback opportunities, and increase awareness of efficiency opportunities among building owners and other market actors.

Beyond the building segment specific packages identified in this report, other organizations are using the growing amount of data from audits and other efficiency programs to develop standardized efficiency solutions that can be brought to scale more quickly in a large number of buildings. NRDC has developed a "concierge" approach, with a set of standardized measures that make sense in nearly all buildings, and can be offered with lower transaction costs to building owners and managers. This process will also be a key offering of the RetrofitNY initiative being rolled out by NYSERDA.

Pilot projects completed through the RetrofitNY program will be another source of case studies and provide project implementation experience that can be widely replicated.

Make The Business Case – 2020+

A profitable energy efficiency retrofit market will require educated consumers

consistently generating demand, and a broad spectrum of skilled service providers offering reliable, packaged solutions.

In the multifamily sector, energy efficiency retrofits are becoming prevalent, as more owners begin to better understand the business case. Since the implementation of the Greener, Greater Buildings plan in 2009, the energy service industry has grown and will continue to grow. As building owners, managers, and tenants become more educated around energy efficiency, opportunities open up to mature the market for how energy efficiency retrofits are initiated, financed, and delivered.

As the retrofit market begins to expand, entrepreneurs and service providers can use the retrofit package model to create and sell turn-key solutions to building owners and managers. These products could include packages of relevant ECMs, as well as financing and incentives to help pay for the project. By simplifying a confusing, multifaceted process into a streamlined, single-point of contact, this packaged approach could dramatically scale the market for retrofits.

The ECM packages set forth in this report are intended only as suggestions, and building owners and managers will need energy service providers to help them determine the best set of measures for their buildings, now and in the future. Service providers must be equipped with the correct skills and resources to meet the demand. Policy makers would do well to pay attention to the timelines and processes required to complete an audit and subsequent retrofit, as well as the types of measures that are most often implemented. With this knowledge, they can better address where the market is lacking, as well as support it where it is moving forward.

Going Global: International Centers of Excellence Network

The Building Energy Exchange (BE-Ex), an independent non-profit organization, will continue to play a central role in the climate action plans of both New York City and State through education, exhibits, and critical tools to advance energy efficiency in buildings. Providing an objective information hub for all industry decision-makers, including building owners and managers, architects, engineers and construction managers, this center of excellence has already attracted over 12,000 participants to more than 500 programs.

BE-Ex has been a strong partner in developing the United Nations Economic Commission for Europe's (UNECE) Framework Guidelines for Energy Efficiency Standards in Buildings. With state of the art technology, BE-Ex can live-stream events and connect with communities all over the world, and will lead UNECE's International Centers of Excellence on Energy Efficiency in Buildings alliance, an active knowledge-sharing network promoting the wide deployment of high performance buildings globally. In addition to New York, UNECE-designated Centers of Excellence are underway in Vancouver, BC and Ireland. Additional Centers are already slated for Brussels, Pittsburgh, Astana, and Kiev.

New York State's Energy Efficiency Targets

New York State is taking bold action to realize energy efficiency in its building stock, which is responsible for 59% of statewide GHG emissions. The Governor recently announced "New Efficiency: New York," an aggressive 2025 energy efficiency target designed to cut emissions and energy costs by incentivizing building developers, commercial and institutional building owners, and residential households to pursue building improvements that will reduce energy consumption by 185 TBTUs below forecasted energy use in 2025 – savings equivalent to the energy consumed by 1.8 million New York homes.[8]

Meeting the target will accelerate achievement of energy efficiency in the next seven years by more than 40% over the current path. The new energy efficiency target will not only save substantial heating fuels but will set New York State on a path to achieve annual electric efficiency savings of 3% of investor-owned utility sales in 2025. Additionally, to help build the workforce for this rapidly growing industry, NYSERDA will commit an additional $36.5 million to train over 19,500 New Yorkers for clean energy jobs.

Retrofit packages can unlock the energy savings potential of multifamily buildings, an essential part of New York City's plan to address climate change.

New York is among the leading cities developing innovative solutions to our planet's climate crisis. Lessons that we learn here are relevant to municipalities across the nation and around the world. Thanks to data collection laws passed nearly a decade ago, NYC has an increasingly clear understanding of how our buildings use energy and the significant role that buildings must play in climate mitigation. This report provides an overview of the substantial opportunities for carbon reduction in large multifamily buildings and presents user-friendly tools to help catalyze action.

Our report's retrofit packages include simple, successful measures that have big impacts, quick paybacks, and can dramatically improve the quality of our living spaces. But addressing the full scope of our climate challenges will also require accessing the deeper savings, and more profound quality of life improvements, found in the packages with greater costs and longer paybacks. Implementing and scaling these deep energy retrofits is a significant challenge, requiring public and private stakeholders to work cooperatively. Each of the packages can be used as a starting point for building owners or managers to develop long term plans to fine-tune their energy systems, and gain more room to explore financing and funding options. The City continues to develop innovative programs and regulations to help realize these potential savings, including mandating the use of building letter grades to publicly display a building's annual energy performance; a High Performance Retrofit Track within the NYC Retrofit Accelerator to support early adopters and share their lessons; and an aggressive energy code for new construction and substantial renovations.

The Building Energy Exchange is also working to accelerate the growth of the expanding Passive House movement and high performance building market with educational resources, exemplary case studies, and deep energy retrofit studies. BE-Ex is forging international alliances to share knowledge and best practices that advance the deployment of high performance buildings around the globe.

Much work lies ahead if we are to meet the challenges of our climate crisis. Cities and their buildings can provide meaningful solutions that dramatically reduce harmful GHG emissions and improve health and well-being. However, there are obstacles to success and buildings are slow to change. To realize this enormous opportunity, building owners, tenants, designers, engineers, contractors, policy-makers, officials, and manufacturers must work collaboratively to turn this potential into action.

Photo credit: Simon Grim

glossary

Building Management System (BMS)
Building management systems are computer-based systems that help manage, control, and monitor building technical services and the energy consumption of devices used by that building. They provide information and tools needed to understand the energy usage of a building and to control and improve a its energy performance. These are sometimes referred to as Energy Management Systems (EMS).

Covered Buildings
Covered buildings refer to all buildings that must comply with New York City's Greener, Greater Buildings Plan. These are buildings over 50,000 square feet or multiple buildings on a single property totaling over 100,000 square feet. (This law changed in October 2016 to include properties between 25,000 and 50,000 square feet.)

Domestic Hot Water (DHW)
Domestic hot water is water used primarily for drinking, food preparation, sanitation, and personal hygiene. The three types of DHW systems available are boiler, gas, and electric.

Energy Use Intensity (EUI)
Energy Use Intensity (EUI) expresses a building's energy use as a function of its size or other characteristics. EUI is expressed as energy per square foot per year, and is calculated by dividing the total energy consumed by the building in one year (typically measured by kBtu) by the total gross floor area of the building.

EnerPHit
Achieving the Passive House Standard in refurbishments of existing buildings is not always a realistic goal, due in large part to unavoidable thermal bridges in the existing structure. Renovations according to Passive House principles are made possible by retrofitting to the EnerPHit Standard. Based on Passive House principles, the EnerPHit Standard calls for high quality, energy efficient components. Setting the EnerPHit Standard as the target ensures that both the energy demand as well as the quality of the building is future-proof.

Greener, Greater Buildings Plan (GGBP)
Green, Greater Buildings Plan (GGBP) is a comprehensive effort that targets energy efficiency in 15,000 properties over 50,000 square feet. GGBP consists of four pieces of regulation (2010 Local Laws 84, 86, 87, and 88) supplemented with job training and financing opportunities. This initiative is designed to insure that information about energy is provided to decision-makers and that the most cost-effective energy efficiency measures are pursued.

HVAC
Heating, ventilation, and air conditioning (HVAC) refers to the different systems, machines, and technologies used in indoor settings to provide air quality and thermal control (heating and cooling) services.

Local Law 84 (LL84)
Local Law 84 (LL84) requires annual benchmarking of energy and water consumption for all properties with over 50,000 square feet, or properties with multiple buildings totaling over 100,000 square feet. This law is part of the Greener, Greater Buildings Plan.

Local Law 87 (LL87)
Local Law 87 (LL87) requires an ASHRAE Level 2 energy audit and retro-commissioning of major building systems once every 10 years for all properties with over 50,000 square feet, or properties with multiple buildings totaling over 100,000 square feet. This law is part of the Greener, Greater Buildings Plan.

Local Law 88 (LL88)
Local Law 88 (LL88) applies to all properties over 50,000 square feet, or properties with multiple buildings totaling over 100,000 square feet. It requires lighting in the non-residential spaces be upgraded by 2025 to meet code, and for large commercial tenants be provided with sub-meters. This law is part of the Greener, Greater Buildings Plan.

New York City Housing Authority (NYCHA)
The New York City Housing Authority (NYCHA) is a department of the New York City Government whose mission is to provide safe, affordable housing for low- and moderate-income New Yorkers. More than 400,000 New Yorkers live in NYCHA's 334 public housing developments across the five boroughs.

Passive House
Passive House is a rigorous, voluntary standard for energy efficiency in buildings. A building constructed using passive house principles is very well insulated, virtually air-tight, and primarily heated externally via solar energy and internally from building occupants, electrical equipment, etc. Any remaining heating or cooling demand is provided by an extremely small source, and balanced fresh air is constantly supplied. This standard saves up to 90 percent of heating and cooling costs, and provides high indoor air quality.

Reforming the Energy Vision (REV)
Reforming the Energy Vision (REV) is a New York State initiative designed to lead to regulatory changes that promote more efficient use of energy, deeper penetration of renewable energy resources, such as wind and solar, and wider deployment of distributed energy resources, such as micro grids, on-site power supplies, and storage.

Retro-Commissioning Measures (RCM)
Retro-commissioning is the testing and tune-up of existing building systems to confirm that they are operating as designed and as efficiently as possible. Retro-commissioning commonly identifies maintenance, calibration, and operation errors that are easily corrected and save energy and improve equipment reliability.

Source Energy vs. Site Energy
Source energy represents the total amount of raw fuel that is required to operate a building. This incorporates all transmission, delivery, and production losses. Site energy is the amount of heat and electricity consumed by a building as reflected in one's utilities bill. Site energy can be delivered to a building as primary energy (the raw fuel burned to create heat and electricity), or secondary energy (the energy product created from raw fuel).

Technical Working Group
At the beginning of 2015, the City of New York convened a Buildings Technical Working Group (TWG) that brought together dozens of leaders – including real estate professionals, architects, engineers, labor unions, academics, affordable housing experts, and environmental advocates to provide industry expertise needed to develop the right mix of policies and programs for new and existing buildings. This collaboration was crucial to placing the City on the pathway to an 80% reduction in greenhouse gas emissions by 2050.

abbreviations

BTU
British thermal unit (1 BTU)

> **KBTU**
> Kilo British thermal unit
> (1,000 BTU)
> **GBTU**
> Giga British thermal Unit
> (10^9 BTU, 10^3 KBTU)
> **TBTU**
> Tera British thermal unit (
> 10^{12} BTU, 10^9 kBTU, 10^3 GBTU)

CHP
Combined heat and power

CPC
Community Preservation Corporation

DHW
Domestic Hot Water

ECM
Energy conservation measure

EUI
Energy use intensity

GGBP
Greener, Greater Buildings Plan

HVAC
Heating, ventilation, and air conditioning

kW
Kilowatt

kWh
Kilowatt hour

MOS
Mayor's Office of Sustainability

NRDC
Natural Resources Defense Council

NYCEEC
New York City Energy Efficiency
Corporation

NYCHA
New York City Housing Authority

NYPA
New York Power Authority

NYSERDA
New York State Energy Research and
Development Authority

REV
Reforming the Energy Vision

RCM
Retro-commissioning measures

TWG
Technical Working Group

list of graphics

Figures and Tables

Sidebars

appendices

A

Existing Resources

Several programs currently exist in New York City to advance energy efficiency and reduce greenhouse gas emissions, particularly in multifamily buildings. These include:

Community Preservation Corporation (CPC)
Provides innovative capital solutions, fresh thinking, and a collaborative approach to the complex challenges faced by owners and developers of multifamily housing.

New York City Carbon Challenge Multifamily Group
A group of multifamily building owners and property managers who have committed to aggressive carbon reduction goals and to share knowledge and experiences.

New York City Department of Housing Preservation and Development Green Preservation Program
Provides financing to landlords in affordable areas for energy efficient retrofits.

New York City Energy Efficiency Corporation (NYCEEC)
Provides innovative financing for energy efficiency retrofits.

New York City Green House Website
This website, developed by the Department of Housing Preservation and Development, provides information on energy efficiency tools and financing to tenants and building owners.

New York City Retrofit Accelerator
Offers free, personalized advisory services that streamline the process of making energy efficiency improvements to buildings that will reduce operating costs, enhance tenant comfort, and improve the environment.

New York City Toilet Replacement Program
Provides rebates to multifamily buildings owners for installing low-flow toilets.

NYCHA Energy Efficiency Retrofits
To date, NYPA has financed more than 1,000 energy efficiency projects in NYCHA housing, including boiler replacement, upgraded lighting and controls, and retrofitting steam systems.

NYSERDA Multifamily Performance Program (MPP)
Provides funding for energy audits, the development of Energy Reduction Plans and the implementation of Energy Conservation Measures in multifamily properties.

Utility programs
Programs from Con Edison and National Grid providing incentives for energy efficiency retrofits in multifamily buildings.

Weather Assistance Program (WAP)
Assists income-eligible families and individuals by reducing their heating and cooling costs and addressing health and safety issues in their homes through energy-efficiency measures. This is a federally funded program, administered by the Department of Housing and Urban Development in New York.

B

Methodology

Methodology of Benchmarking Law and the Energy Audit Law Cleaning and Analysis for Turning Data into Action.

The data cleaning and analysis described below is specific to the scope of the Retrofitting Affordability report. Our efforts were focused solely on the fields relevant to this study (those relating to location, age, area, building type, primary heating fuel, and energy conservation measures). For any further analysis beyond this scope, further cleaning is needed.

Tools & Datasets
The cleaning and analysis was performed using Python programming in the Pandas library, a standard library for manipulating large datasets that contain both numerical and text information. Python was chosen for this analysis because it has a repeatable methodology that could be employed on subsequent annual dataset submissions. Both Pandas and Python are freely available.

The datasets were received from the New York City Mayor's Office of Sustainability (MOS). Two datasets were used for this analysis, the Benchmarking Law (Local Law 84, LL84) data from 2014 and the Energy Audit Law (Local Law 87, LL87) data from 2013 and 2014. The LL84 dataset used contained 13,052 benchmarking submissions. The LL87 dataset used contained 2,532 energy audits submitted to the City in 2013 and 2014. It also contained 333 "early submission" audits, but these were not used due to their different report formats. Both the LL84 and the LL87 datasets required substantial data cleaning, and efforts focused solely on the fields relevant to this study. Additional cleaning is needed to include any further fields for any other analysis.

Energy Audit Law (Local Law 87) Data Cleaning
For the initial exploration and subsequent analysis the following fields were corrected for misspelling, spurious whitespace and variations in capitalization, and corrections were performed using find/replace or in some cases regular expression matching:

- Borough
- Early compliance
- Gross floor area
- Central distribution type
- Number of above grade floors
- Measure name × 25 fields
- Category × 25 fields

In addition, many of the LL87 ECMs are named 'Other.' Many of these measures (385 out of 1215) were able to be re-labeled with their appropriate measure name based on the description field.

Duplicate entries were then removed. There were 111 perfect duplicates of every field. 41 entries with duplicate BBL (Borough, Block, Lot) and BINs (Building Identification Numbers) were removed, keeping only the most recent entry. This may have eliminated some properties with reasonable data, but it was not possible to investigate these further within the scope of this study. There were also several audits (39) where the sum of the savings from each of the ECMs was greater than the total predicted savings, in some cases by more than an order of magnitude. These audits were removed from the analysis. Additionally, there were a number of ECMs (~200 out of ~40,000) for which the Simple Payback differed by more than 20% from the calculated payback (based on the Total Implementation Cost and Annual Cost Savings). These were removed from the analysis.

Benchmarking Law (Local Law 84) Data Cleaning
The LL84 dataset fields required no specific spelling or whitespace fixes due to these data being sourced from the Portfolio Manager submissions, which enforces dropdown selection and field entry restrictions. The authors and other leading auditor companies

highly recommend a similar system be developed for LL87 data going forward.

The LL84 dataset, however, does suffer from some other data quality issues, stemming from the more diverse group of people who enter this information. This study followed similar data cleaning procedures to previous studies that included:

- Removal of non-NYC zipcodes (104 sites)
- Removal of sites where the "Property Floor Area" was missing or zero. (24 sites)
- Removal of sites where the Source EUI was greater than 1000 or less than 5. (1,048 sites)
- Removal of duplicated BBL submissions. This may have eliminated some properties with reasonable data but it was not possible to investigate these further within the scope of this study. (618 sites)
- Removal of sites with EUIs in the 1st and 99th percentile. The cutoffs calculated were 1st : 26.17BTU/sqft year, 99th : 303.4 kBTU/sqft/year for Multifamily properties. (196 sites)
- These steps removed 1,990 properties, resulting in 11,062 properties remaining.
- Only multifamily properties were considered in this study, these were determined from the "Primary Property Type - Self Selected" field. This left 8,324 multifamily properties
- In cases where properties did not have the 'Multifamily Housing - Maximum Number of Floors' field complete, this was retrieved from the PLUTO dataset. For properties with mutliple BBLs, the highest number of floors was used.
- Properties that did not contain the required fields for labeling were eliminated from the analysis (105 sites). This left a total of 8,219 LL84 properties still under consideration.

Comparing the Two Labeled Data Sets

In order to extrapolate from the findings in the LL87 dataset to the LL84 dataset it was necessary to confirm that the labeled datasets contained no large systematic discrepancies.

Upon inspection, there is reasonably good agreement between the two sets. A Pearsons's Chi-squared test was performed on each group to test the null hypothesis that these two sets were drawn from the same population of buildings. The height distribution shows reasonably good agreement between the two sets ($p = 0.098$), and does not reject the null hypothesis. However, both the building age ($p = 0.00002$) and the heating fuel ($p = 0.000$) do reject the null hypothesis, implying the differences shown in those charts are statistically significant.

This likely has the biggest impact on the All Electric group where the methodology for determining heating fuel in the LL84 dataset may be slightly biased towards labeling Electricity. As such, the analysis may over-estimate the impact of ECMs in All Electric buildings. However, given that these are a relatively small group, this does not invalidate the overall analysis.

The other noticeable trend is that LL87 reported a lower percentage of Post-1980 buildings.

Estimation of Impact

In order to estimate the energy savings potential of the New York City multifamily building stock of properties over 50,000 SF, the authors took the following steps.

- Labeled every valid LL87 property with the above segment labels.
- Grouped similar measures together (e.g. Upgrade Chiller and Replace Chiller)
- Calculated the average percentage site energy savings of each Measure Type and Segment combination.
- Eliminated any measures that were recommended in less than 5% of audits in a particular segment, or, for more heavily populated segments, less than 4 times (no measures that appeared four times or more in a particular segment were eliminated). Measures that projected over 20% savings for that single measure were also eliminated (this only eliminated three examples).
- Calculated the frequency of recommendation of each Measure Type by Segment.
- Combined those two values to determine the real energy savings potential expectation value for that Measure/Segment combination.
- Multiplied that expectation value by the total encompassed site energy for each segment to determine the energy savings potential for that Measure/ Segment combination if it were applied to the LL84 building stock.
- Determined the site to source conversion factor and site to carbon conversion factor for each LL84 segment type and applied those factors to the site energy savings potential to determine the source and carbon savings potentials.
- Aggregated all the potential savings by segment.
- Scaled up the results from the total number of labelled LL84 properties to the total number of multifamily buildings on the covered building list, to determine the citywide savings potential.

A slightly different methodology was employed for estimating the source energy savings potential for cogeneration and steam-to-gas conversion measures. Since the fuel types that are switched have very different source-to-site conversion factors, these ECMs should have a negative site energy savings and positive source energy savings. For these measures, the source energy savings was calculated as the sum of the energy savings from each individual fuel type, after converting those to source energy. Therefore, any ECM which did not include information on the energy saved for the relevant fuel types was omitted from the analysis. The source energy savings for each ECM was then used similarly to the site energy savings as described above, to get the percentage savings impact, the energy savings expectation value and finally the total source energy impact for each measure/ segment combination.

Though many assumptions were made to estimate the theoretical impact of LL87 measures, the authors believe these assumptions are defensible. The source energy estimate of 215.7 million GJ for all large multifamily buildings is in close agreement to 187.5 million GJ, the number reported in the 2012 Inventory of Greenhouse Gas Emissions for "Residential Large." This check gives confidence to the methodology.

The general assumptions made to facilitate the above are:

- The frequency a measure is recommended in LL87 for a given segment will remain valid for the same segment in the LL84 set.
- The average percent savings for a given measure in LL87 for a given segment will remain valid for the same segment in the LL84 set.

The LL87 dataset is a little less than 20% of the LL84 properties, which is a reasonable sampling level to make assumptions about the relationship between LL84 and LL87 datasets.

- The analysis assumes the fuel mix in each individual LL84 segment is indicative of the fuel mix in the LL87 segments, which allows the use of the same site to source and site to carbon conversions. This assumption is due to the very poor data quality in the individual fuel totals in the LL87 data for both the measure impact and the overall building energy. A more rigorous data collection scheme for LL87 would remove the need for this assumption.

- Finally, the distribution of buildings by segment in the LL84 set is assumed to be indicative of the distribution of all multifamily buildings over 50,000 SF. This seems a reasonable assumption given that the LL84 labeled set is sampling 8,219/9,761 or about 84% of all potential buildings.

As future years of LL87 data are submitted, it will be possible to assess the validity of these assumptions and update the projected energy and carbon savings potential appropriately. Each year 10% more of the NYC building stock will be sampled, resulting in a high percent coverage of the LL87 data.

C

Greenhouse Gas and Source Energy Conversions

Discussing the impacts of different greenhouse gas coefficients on estimating emissions.

Since the launch of PlaNYC in 2007, the City has been preparing annual Greenhouse Gas Emissions (GHG) Inventories, with advances in the methodologies each year. New York City's emissions calculation methodology differs from the standardized reporting developed by the US Environmental Protection Agency (EPA) used in reporting building energy performance through the Energy Star Portfolio Manager system. All of the Benchmarking Law reporting and data analysis in the annual Benchmarking Reports by the City (done through the Portfolio Manager system) uses the EPA methodology for data analysis, which reports total direct and indirect greenhouse gases emitted due to energy used by the property in metric tons of carbon dioxide equivalent (mtCO2e). The Energy Star carbon coefficient is based on NYC's EPA Emissions & Generation Resource integrated Databasesub-region.

The different methodology used in the annual NYC GHG inventory reports accounts more accurately for usage within the five boroughs of NYC alone, and also includes more recent electricity generation data, including electricity imported into New York City. Similarly, NYC calculates the emissions factors for district steam on a local basis, different from EPA's national methodology. A detailed description of the emissions calculations methodology is provided in the Appendices of each year's NYC GHG Inventory report.

Because *Turning Data into Action* relies heavily on the LL84 data compiled by the City, it uses the EPA Energy Star emissions and source energy conversion factors ("source" energy is the amount of energy needed to create all the energy consumed on the site, and takes into account, for example, energy lost due to the generation and transmission of electricity). The variations between the EPA methodology and the NYC factors are relatively minor: the electricity emissions factors vary by less than 3% between the two methodologies, while the site/source energy calculations differ by less than 7%. As such, this report stays consistent with all the LL84 reporting, but has a small discrepancy with the larger, city scale NYC GHG Inventory.

D

Data Challenges – Collecting Quality Audits

This report incorporates the second year of LL87 data but many of the first year challenges remain. NYC is working to improve the quality of the data.

In the case of this study, the two primary data sets are from the Benchmarking Law (Local Law 84) data and the Energy Audit Law (Local Law 87) data. The Benchmarking Law dataset is significantly larger, which means that it would take many more poor quality data points to affect the overall quality of the analysis. Also, now that Benchmarking Law data has been submitted for several years, some of the original data quality issues have been corrected through education of both the submitters and the recipients of the data. The Energy Audit Law data analyzed here is the second year of submitted data, and thus there are still data quality issues within the relatively small data set. As a result, our team exercised significant caution in the analysis of this report. Several Local Law 87 data issues are outlined below:

Data Standardization

The Energy Audit Law (Local Law 87) requires buildings to perform an energy audit and organize a separate retrocommissioning process. This mandate results in two sets of information, Energy Conservation Measures (ECMs, from the audits) and Retro-Commissioning Measures (RCMs), compiled into a single report. Missing from this analysis is the energy, cost and GHG savings impact of the required retrocommissioning measures.

There also appears to be disagreement between auditors as to whether certain measures belonged in the ECM or the RCM categories; therefore measure recommendation tallies may be inaccurate, making even a simple count of a particular measure difficult.

City Expectations

While the City provided more specific guidance on the RCMs to be included in LL87, the energy audit recommendations were left to the professional discretion of the auditor. Two engineers asked to solve a fairly open-ended problem (e.g. "how would you make this better?") will give very different answers, and this holds true for the individuals performing the Energy Audit Law work: lighting experts are more likely to find lighting measures, heating experts are more likely to find heating measures, etc. As a result, there is no clear threshold of whether a set of recommendations is comprehensive enough to satisfy the law. Particularly in situations where the building owner looks at the Energy Audit Law as just another compliance requirement, there is very little motivation for the auditor to do any more than the bare minimum.

Training and Experience Level of Auditors

There was general concern among the authors and the advisory committee that the range of experience among energy auditors might lead to wide variation in the quality of ECM recommendations. A deeper concern, shared by members of this group, is that the skill level and knowledge of some individuals performing LL87 audits is questionable, meaning that some recommended measures are limited and/or inappropriate. Furthermore, in order to maximize the benefit of LL87 for the city, and achieve projected savings, it is vital that complete recommendations are made. For example, a heating control system (EMS) should be upgraded in conjunction with balancing the heating system, but this type of thorough recommendation was often not seen clearly in LL87 data, raising the potential for projects to fall short of projected savings.

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