report

Decarbonization
Pathways for Commercial
Office Buildings

Turning Data into Action
Office Buildings

building energy exchange

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Report Partners

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Turning Data into Action
Decarbonization Pathways for Commercial Office Buildings

By implementing strategic packages of retrofit measures, office building owners can chart a clear course to higher building performance and meaningful decarbonization while preparing to meet New York's rapidly evolving climate challenges and regulations.

Meeting the Challenges of a Changing World

As the global climate crisis grows ever more urgent, New York City (NYC) is blazing a trail to curb greenhouse gas (GHG) emissions from its greatest source—existing buildings. The office buildings at the heart of the city's iconic skyline are some of the biggest emitters, with high average levels of energy use and emissions across the sector.

While building owners, operators, and tenants will face unique challenges in meeting newly enacted emissions regulations, they can seize this moment to transform NYC's office buildings for the better—not only achieving compliance, but creating healthier, higher performance workspaces that set the standard for New York's climate-ready future.

Accounting for Emissions

NYC is home to roughly one million buildings, which are the greatest contributors to citywide emissions by far. Emitting more GHG than the transportation and waste sectors combined, existing buildings account for nearly 70% of the city's GHG footprint.

About one-third of these emissions come from the commercial sector, within which office buildings account for the greatest share of GHG, energy use, and square footage.

While they vary widely by design, occupant density, and space use, on average, NYC's office buildings are 50% more energy intensive than similarly-sized multifamily buildings.

Shifting the Paradigm

Recognizing the critical need to curb building-based emissions, the New York City Council passed the 2019 Climate Mobilization Act featuring Local Law 97 (LL97), which imposes first-ever GHG emissions limits on existing large buildings. Taking effect in 2024, the limits are set to grow increasingly stringent over time. Buildings that exceed their GHG thresholds will face fines that can total millions of dollars annually.

Fortunately, most office buildings are already set to meet 2024 requirements, or will be able to achieve compliance with relatively simple efficiency upgrades or operations and maintenance improvements. In most cases, the types of measures commonly identified in energy audits—a requirement for large buildings since 2009 under NYC Local Law 87 (LL87)—will be sufficient.

In 2030, however—just six years after LL97 goes into effect—GHG emissions limits grow much tighter. To comply during this second phase, most of NYC's 550 million square feet (sf) of office space will need to undergo decarbonization retrofits at an unprecedented pace and scale.

Typical LL87 audit recommended measures alone will not suffice. To date, energy auditors have tended to recommend measures that pay back in under five years, limiting potential energy and emissions savings. In light of LL97 fines, however, the return on investment for more comprehensive retrofits has shifted significantly, making them more economical than ever before.

Additionally, LL97's focus on whole-building, site-based GHG emissions calls for decision-makers to look beyond the typical base-building efficiency improvements. Leased tenant spaces often account for more than half of an office building's energy use, and our report finds that tenant fit-outs alone can reduce building-wide emissions by as much as 20%. Even simple tenant improvements can achieve notable savings.

To meet the challenges of LL97 and the climate crisis, the building industry will need a new paradigm—one that prioritizes owner-tenant collaboration, thoughtful capital planning, and strategic implementation of deeper decarbonization measures than ever before. Fortunately, there is a wide array of well-proven, market-tested solutions to meet this need.

Leveraging the Power of Data

This report recognizes that planning for office building decarbonization requires a unique approach. To evaluate the efficacy of various retrofit solutions, our team classified NYC's office buildings into four typologies based on their primary heating and cooling systems, rather than grouping them by building age, size, or fuel-type—as is commonly done in the multifamily sector.

By analyzing publicly available NYC building data, our team identified strategic packages of retrofit measures well-suited to each of the four typologies and applicable to more than 70% of NYC's large office buildings. These retrofit packages offer options for building decision-makers to achieve moderate to deep emissions savings, and provide viable pathways to LL97 compliance for buildings at nearly any level of baseline performance.

To help decision-makers select an optimal set of these packages, our team developed four tearsheets as custom resources for each of the four office typologies. After calculating their building's current GHG emissions and the percent reduction needed to meet LL97 limits, a decision-maker can use their tearsheet to choose from three retrofit pathways, for either a modest (5–10%), medium (10–25%), or major (>25%) GHG reduction.

From there, they can follow their pathway to relevant packages of decarbonization measures, which include both base building and tenant space solutions for all major systems. Cumulatively, these packages can reduce a building's emissions by as much as 35%. By selecting a custom combination of solutions, decision-makers can gain insight into how they might develop a comprehensive, long-term capital plan for LL97 compliance.

While successful capital plans must be tailored to building specifics, many high-impact decarbonization measures are nearly universal in their applicability. These include: replacing fossil fuel systems with electric-powered equipment; deploying smart controls for major building systems; moving energy-intensive operations, like data centers, offsite when possible; and addressing issues in both base building and tenant spaces.

Taking Action

2030 is fast approaching and with it, stringent new regulations. In order to avoid hefty annual penalties for LL97 non-compliance, building owners must start planning today.

This report and accompanying tearsheets offer guidance for individuals to begin formulating comprehensive retrofit plans, enabling them to minimize costs and disruptions by phasing in projects at strategic milestones, like the time of tenant turnover or equipment replacement, rather than in response to emergencies, like equipment failure.

Armed with proven solutions and a new paradigm for action, New York's real estate community can reduce their operating costs and avoid fines, while simultaneously building healthier, higher quality workspaces and a better future for all.

Key Findings

- **Following energy audit recommendations alone will not suffice for most office buildings to meet 2030 emissions limits.**
  Building owners needing to reduce GHG emissions by more than 5–10% to avoid LL97 penalties must take a more comprehensive retrofit approach than is typically recommended in energy audits, looking beyond base building upgrades and quick paybacks, and integrating tenant space retrofits into longer-term capital plans and investments.
- **Tenant spaces are essential to achieving deep emissions reductions.**
  Decarbonizing existing office buildings will require a new paradigm of owner-tenant collaboration—one that includes new leasing models, updated fit-out requirements that leverage tenant vacancies and renewals, and optimization of tenant-controlled systems, like lighting, appliances, and information technologies.
- **Succesful decarbonization requires capital planning that aligns leasing cycle and asset planning milestones with retrofit implementation.**
  A comprehensive long-term capital plan is a crucial tool for identifying and implementing GHG emissions reduction measures. Tenant turnover, building repositioning, and equipment replacement are key opportunities to increase cost-effectiveness and reduce disruption when retrofitting both tenant and base building spaces.
- **Electrification—removing on-site fossil fuel-based systems—must be part of long-term planning.**
  To meet increasingly stringent LL97 emission limits in 2030 and beyond, most large office buildings will need to phase out fossil fuel-powered equipment, and replace it with electric heating and cooling systems to leverage the statewide increase in renewable electricity generation.
- **Non-equipment factors cannot be ignored.**
  In addition to retrofitting major building systems like heating, cooling, and ventilation, owners must also consider non-equipment factors as part of a comprehensive retrofit strategy. These include variables such as tenant space uses, occupancy intensities, and leasing cycle impacts.

In 2019, New York City passed the groundbreaking Climate Mobilization Act, featuring Local Law 97, which sets carbon emissions limits for large buildings. The City's office building sector is the largest in the country, with nearly 550 million square feet of existing space. To meet 2030 emissions limits, these office buildings will need to complete energy efficiency and decarbonization retrofits at an unprecedented pace and scale. This calls for new approaches to raise awareness around retrofit opportunities and challenges, provide guidance on cost-effective solutions, and spur building owners to action as swiftly as possible.

New York City Buildings: Shaping the Future

Buildings play a leading role in New York City's economy and climate action strategy. Office buildings are a critical part of the City's economic vibrancy and the largest portion of the commercial building sector measured by both floor area and building emissions, and dwarf the emissions reduction potential of other commercial building types.

New York City's (NYC) exceptionally diverse building stock includes everything from nineteenth century wood-framed rowhouses to twenty-first century glass spires. Covering more than 5.4 billion gross square feet (GSF), these buildings shape nearly every aspect of New Yorkers' lives, providing the places where they live, work, and play.

Ensuring that NYC's buildings are safe, healthy, and comfortable for occupants requires significant energy inputs from a combination of on-site fossil fuel combustion, grid electricity, and district steam systems.[1] Together, this energy mix makes buildings the leading source of greenhouse gas (GHG) emissions, accounting for nearly 70% of NYC's total emissions.[2]

Earlier reports by Building Energy Exchange (BE-Ex) and its partners[3] dug deeply into energy efficiency and retrofit opportunities for mid- to large-sized buildings[4] in the multifamily residential sector, which represents over 40% of NYC's total built floor area and accounts for nearly 30% of GHG emissions from buildings.[5]

This report explores similar opportunities for medium and large non-residential building types, which account for a disproportionate share of total GHG emissions. For example, the average energy use intensity (EUI) and GHG intensity—the amount of energy used, and emissions generated, respectively, per square foot per year[6]—for commercial and institutional buildings is significantly higher than it is for similarly-sized multifamily buildings. Together, NYC's commercial and institutional buildings are responsible for 40% of all citywide emissions, despite making up only 26% of the city's floor area.[7]

A Closer Look at the Commercial Sector: Opportunities for Offices

Office buildings are the largest segment of NYC's commercial building sector. Offices also represent an outsized portion of energy use and GHG across the city's entire building stock.

Among the roughly 31,000 buildings that submitted energy and water benchmarking data for 2018, as required by NYC law,[8] the breakdown of primary building typologies was:[9]

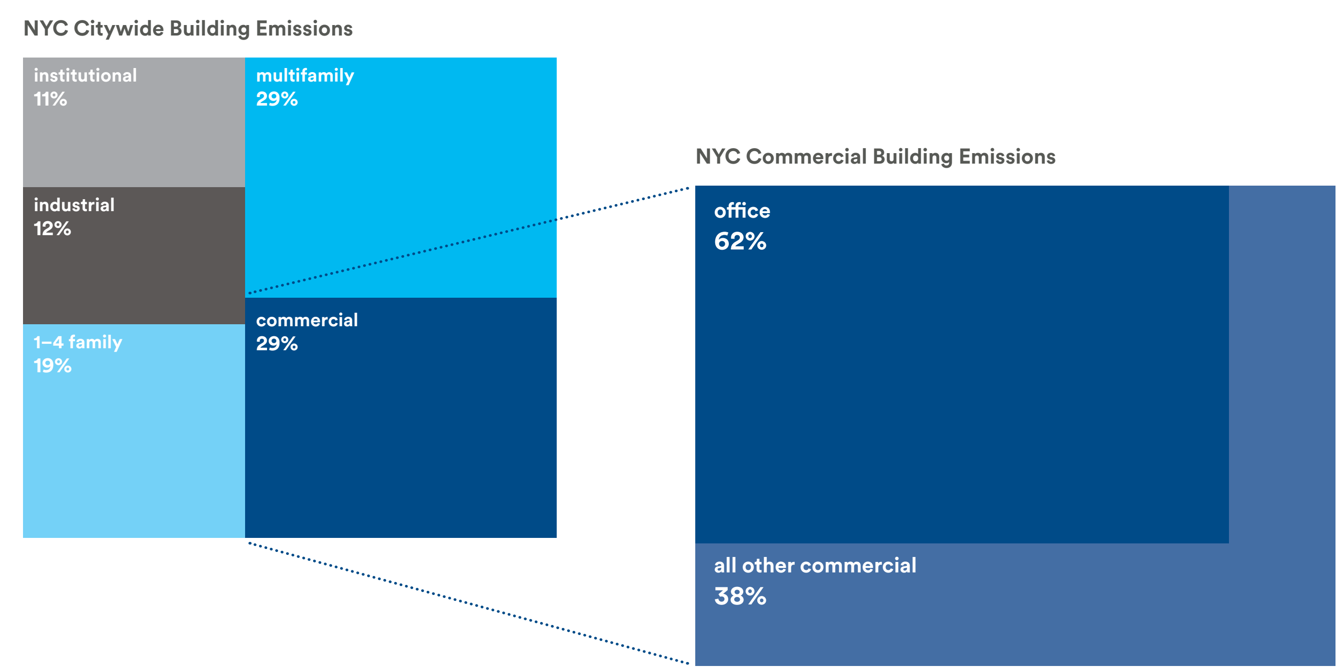
- **Multifamily:** 21,600 buildings
- **Office:** 2,700 buildings
- **Hotels:** 550 buildings

These three typologies were followed by warehouses, which feature relatively low EUI and GHG intensity. Outside of these four categories, the remaining non-residential private building typologies each had less than 100 buildings, according to 2017 benchmarking data.[10] In this report, we focus on office buildings, which account for not only the most buildings in NYC's commercial building sector, but also the greatest share of emissions, contributing 18% of citywide GHG.[11]

Office buildings are also significantly more energy intensive than multifamily buildings, with average source EUI for offices being roughly 50% higher than that of multifamily buildings.[12]

There is also a wide variance of EUI and GHG intensity among office buildings, compared to multifamily buildings, which have relatively uniform levels of energy use across the typology. Living accommodations have fairly consistent energy expenditures, even when there are different numbers of people using a given housing unit, or when units vary in size. This contrasts with non-residential buildings like offices, which feature many different

Figure 1: Commercial buildings account for nearly one-third of all emissions in NYC. Within the NYC commercial sector, office buildings contribute the vast majority of emissions.



source: BE-Ex analysis, from NYC MOS 2016 and NYC 2019 occupancy patterns and uses across buildings of the same type, or even within one building.

For example, an office building might contain mostly private offices, lightly occupied at 40 to 50 hours per week and requiring average hours of space heating and cooling to maintain occupant comfort. Another office building, however, might have financial trading floors, energy-intensive data centers, and staff working at all hours with heating and cooling required around the clock. While both are classified under the same broad "office" building category, EUI for the latter building will be much higher than that of the former. These differences in use among buildings grouped under the same category results in very different distributions of EUI within multifamily and office typologies, as shown in Figure 2.

For the purposes of this report, we analyzed buildings for which owners have self-reported their primary property type as "office" within the U.S. Environmental Protection Agency's ENERGY STAR Portfolio Manager, the platform used to submit energy benchmarking results, as required under NYC law for buildings over 25,000 square feet. Because extremely large buildings typically have a unique set of characteristics, occupancies, or mixed uses, we limited our analysis to buildings between 25,000 and 500,000 square feet.

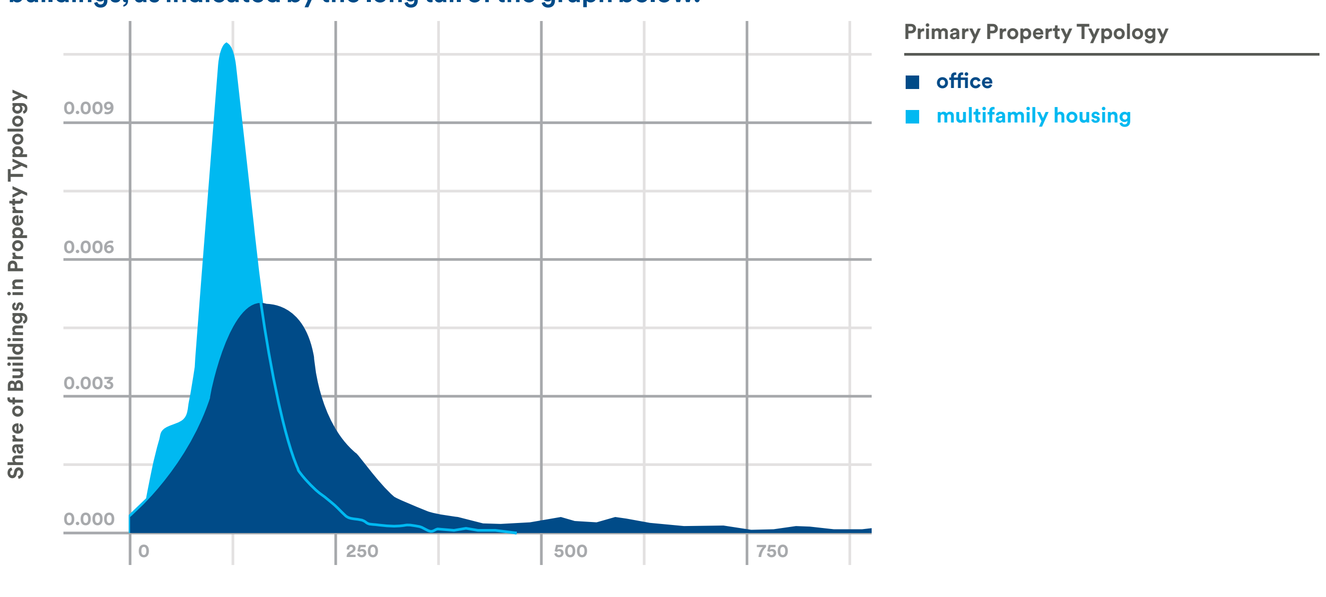
Navigating the NYC Policy Landscape

To meet the ambitious goal of achieving carbon neutrality by 2050, the NYC government passed groundbreaking climate legislation in 2019 that places limits on GHG emissions from buildings. This legislation builds upon previous NYC building energy benchmarking and auditing laws, and will require owners to implement deeper energy efficiency and emissions reduction measures in more buildings than ever before.

Passed by the New York City Council in 2009, the Greener, Greater Buildings Plan (GGBP) was the first suite of laws to address GHG emissions from NYC buildings. Originally impacting only buildings 50,000 square feet and larger, the scope was extended by new legislation in 2016 to cover all buildings 25,000 square feet and above (except for energy audit and retro-commissioning requirements, described below under Local Law 87). Buildings that must comply with these laws are often referred to as "covered buildings." The GGBP includes several laws aimed at reducing GHG emissions, including:[13]

- **Energy Benchmarking and Disclosure Law (Local Law 84):** Requires reporting and public disclosure of annual energy and water usage, beginning in 2010.
- **NYC Energy Conservation Code Law (Local Law 85):** Requires buildings to meet the most current energy code for any renovation or alteration project.
- **Energy Audit and Retro-commissioning Law (Local Law 87):** Requires an ASHRAE Level II energy audit and retro-commissioning once every ten years, starting in 2013.

Figure 2: As a set, NYC office buildings have significantly greater variance in source EUI than mutlifamily buildings, as indicated by the long tail of the graph below.



source: BE-Ex analysis, from NYC 2019

- **Lighting and Sub-metering Law (Local Law 88):** Requires commercial lighting upgrades to meet current codes and installation of sub-metering for commercial tenants over 5,000 square feet, by 2025.

In April 2019, the New York City Council passed the Climate Mobilization Act (CMA), signaling a tectonic shift in the regulatory environment for building emissions. While the GGBP created mandates for building energy use tracking and auditing—to establish comparative metrics and raise awareness of the benefits of energy efficiency—it did not include requirements for building owners to implement substantial improvements that would reduce GHG emissions. The GGBP did not even address emissions directly, focusing instead on reducing energy use.

The CMA changed that with Local Law 97 (LL97)—first-of-its-kind legislation that limits GHG emissions from existing buildings starting in 2024, with fines that can total millions of dollars each year that a covered building exceeds its limit. During the first LL97 compliance period, which runs from 2024 to 2029, GHG emission limits will impact the lowest performing 25% of covered buildings. Limits in the second compliance period, which runs from 2030-2034, will be much more stringent, impacting approximately 75% of covered buildings (based on their current GHG emissions levels), and potentially yielding a 40% reduction in citywide emissions from covered buildings, compared to 2005 levels.[14]

Many buildings may be under their emissions limits during the first compliance period, or able to achieve compliance with relatively simple improvements to building operations and maintenance. To meet more stringent targets in the second compliance period, however, these same buildings will likely require more comprehensive, costly, and disruptive energy efficiency upgrades to significantly reduce emissions and avoid fines.

While this poses a potential challenge for the industry, our analysis of NYC data suggests that most covered buildings will be able to meet 2030 limits by implementing a relatively limited number of proven measures, paired with thoughtful capital planning.

Climate Leadership and Community Protection Act
Aligning New York State and City Policies and Regulations

Beyond the NYC CMA, the Climate Leadership and Community Protection Act (CLCPA) passed by the New York State Legislature in 2019 is a landmark piece of legislation aimed at mitigating the state's contribution to climate change. Currently, greenhouse gas-emitting fossil fuel combustion accounts for 40% of New York State's electricity production.[15] This share of emissions is significantly higher in NYC, and has only increased with the recent closure of the Indian Point nuclear plants, which had been responsible for generating one quarter of the city's electricity.[16]

Under the CLCPA, New York State will add significant renewable electricity generating capacity in the form of offshore wind turbines and solar photovoltaic generation. Wind and solar are intermittent energy resources, due to their dependence on windy days and sunny skies. To manage this challenge, the CLCPA mandates the addition of significant energy storage capacity, enabling energy produced during peak production—and optimal weather—to be saved and used in times of peak demand.

The CLCPA establishes a roadmap for an aggressive transition to this renewably powered electric grid. By 2030, 70% of New York State's electricity will be produced renewably, increasing to 100% by 2040. By 2050, the state will achieve economy-wide carbon neutrality, providing New York City's buildings with the clean, renewable energy they need to lower their emissions. (See "Electricity Emissions Coefficient – LL97 After 2030," on page 16 to learn more).

1 *District steam* refers to thermal energy generated at steam plants operated by Con Edison, a NYC utility, and distributed via a network of pipes to heat and cool buildings across Manhattan. Source: https://www.coned.com/en/commercial-industrial/steam)
2 Source: NYC MOS, 2016
3 Source: BE-Ex, 2015 and 2018
4 *Mid-sized buildings* refer to those 25k to 50k sq.ft, while *large* refers to those greater than 50k sq.ft.
5 Source: NYC MOS, 2016
6 EUI is a measured as kwh/sf/yr or kBtu/sf/yr, while GHG intensity is MtCO2e/sf/yr.
7 Source: NYC MOS, 2016
8 See p. 8 for more information on NYC laws impacting the building industry
9 Source: NYC, 2019
10 Source: NYC MOS, 2017
11 Source: NYC, 2019
12 EUI for the average office building is 186 kBTU/sf/yr, vs. 125 kBTU/sf/yr for multifamily.
13 NYC Local Laws are numbered by the year enacted, such that the Laws included in the GGBP are Local Law 84 of 2009, Local Law 87 of 2009, and Local Law 88 of 2009.
14 Source: NYC MOS, 2019
15 Source: EIA, 2022
16 Source: Power Trends, 2022

Meeting LL97 2030 emissions limits may be a stretch for many office building owners, who will need to go far beyond the efficiency measures identified by past energy audits and implement new technologies that may be unfamiliar. To meet this challenge and support building owners in complying with regulations, we have identified cost-effective strategies and well-proven, market-tested solutions that can reduce energy use and emissions across the covered commercial office sector.

Understanding the Performance Gap

Nearly a decade of NYC building energy benchmarking and auditing has provided a wealth of information on the energy performance and potential of NYC buildings. Taking a closer look at the data, however, we find that audit recommendations for building upgrades often fall short of achieving the level of energy and emissions reductions required to meet NYC regulations and avoid annual fines.

For the analysis in this report, we built upon methodological approaches used in the previous BE-Ex publications, *Retrofitting Affordability* and *Turning Data into Action*,[17] which leveraged publicly available NYC LL84 and LL87 datasets to identify energy efficiency opportunities for medium- to large-sized multifamily buildings.

In the time since those laws were passed and those studies were conducted, however, NYC's regulatory landscape has grown increasingly restrictive. Many LL87 audit recommendations now fall short of what may currently be needed to meet LL97 requirements. To address this shortfall, this study examines building energy efficiency and upgrade opportunities that go beyond audit recommendations—including such measures as the electrification of major thermal end-use systems—to identify cost-effective strategies that help buildings reduce energy use and emissions to required levels, and thereby avoid financial penalties.

Evaluating Opportunities

Rather than attempt to identify energy and emissions reduction opportunities for every type of covered commercial building, we focused on the most predominant type within the commercial sector—offices. Several building typologies—categorized by critical HVAC system types, helped in establishing a small number of key building types for understanding building energy and emissions reduction opportunities.

Office buildings are the largest commercial building typology in NYC, both by building count and by floor area.[18] To generate actionable recommendations for as many buildings as possible, we examined publicly available data from LL87 energy audits, including information on buildings' major heating and cooling systems, along with auditor recommended energy conservation measures (ECMs)[19] and potential energy saving estimates. We used this information to identify four specific office building typologies for analysis, based on common heating and cooling systems, as reported in audits. These four office building typologies[20] represent 71% of citywide covered office square footage:

- **Office Type 1:** Central Chiller Systems with District Steam Heating[21]
- **Office Type 2:** Packaged Cooling Systems with Steam Heating[22]
- **Office Type 3:** Decentralized Cooling Systems with Hot Water Heating[23]
- **Office Type 4:** Decentralized Cooling Systems with Steam Heating

Table 1, below, shows the breakdown of NYC offices by these four office typologies. The building typologies were based on building heating and cooling system data that is only reported in LL87. The available data allows for good representation of the different system typologies among offices for our selected building typologies.[24]

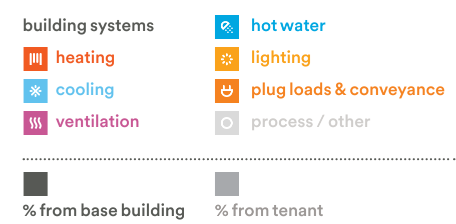
Figure 3, on the following page, provides futher detail on the level of emissions associated with each typology, showing a breakdown of GHG by end-use system.

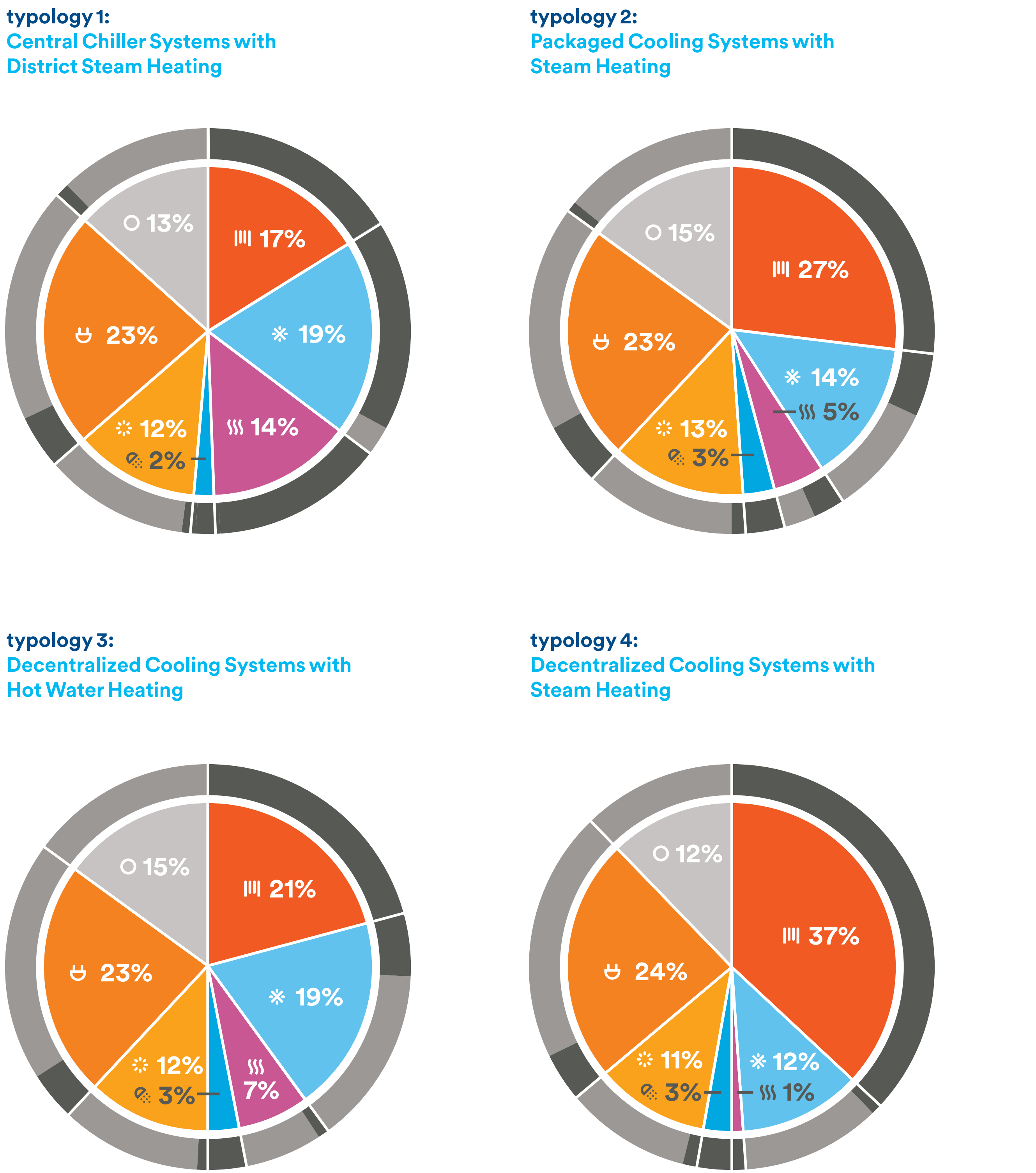
Table 1: The four office typologies selected for analysis, grouped by common heating and cooling systems.

	Office Building Type	# Buildings	% Total Buildings Count	% Total Office Gross Floor Area	% Total Office GHG Emissions
1	Central Chiller Systems with District Steam Heating	313	15%	26%	33%
2	Packaged Cooling Systems with Steam Heating	799	39%	30%	34%
3	Decentralized Cooling Systems with Hot Water Heating	102	5%	3%	4%
4	Decentralized Cooling Systems with Steam Heating	467	23%	12%	13%
	Unassigned Office (not in one of the above 4 typologies)	366	18%	29%	16%

Source: BE-Ex analysis of LL84 data, from NYC 2019.

Figure 3: Baseline whole-building GHG emissions for each typology, broken down by end-use system.





By further analyzing a combined and cleaned LL84 and LL87 dataset, we saw more clearly the gap between GHG emissions savings potential identified in audits and the reductions required by new LL97 legislation.

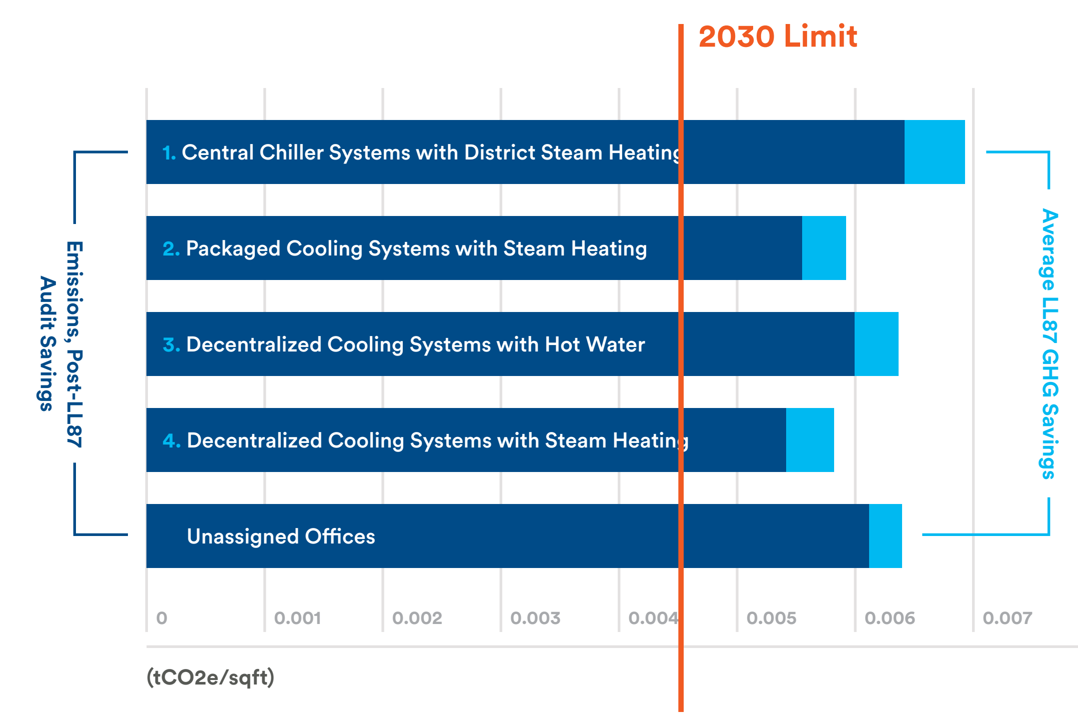
Figure 4, below, illustrates the relationship between the average emissions reduction potential identified from LL87 audit recommendations for each of our four selected office building typologies, compared with mandated LL97 2030 emissions limits. While LL87 audit recommendations provide notable GHG emissions savings, they clearly do not offer enough reductions to avoid incurring annual fines and ensure long-term LL97 compliance.

Part of the reason why the savings potential identified in LL87 audits falls short is that audits typically focus on savings from base building systems, without identifying opportunities in tenant spaces, or for reducing tenant energy use. Most audits also only look at measures that are currently considered cost-effective, as determined by building owners. Owners often require quite a short payback period—generally within a range of five years or less.

To meet LL97 limits, deeper energy savings beyond what has historically been identified by auditors will be needed—including both with reduced tenant energy use and deeper base-building retrofit solutions. This is the focus of the recommended decarbonization pathways identified in our study, which are outlined in the next section.

17 Source: BE-Ex, 2015 and 2018
18 Source: NYC, 2019
19 Energy conservation measures (ECMs) ECMs include measures to retrofit, replace, and/or upgrade mechanical systems, building assemblies, and other components to reduce a building's energy consumption.
20 For the purposes of data analysis, "office" is defined as a building containing at least 50% of an office space use (among the three top identified space typologies) as reported in LL84 data.
21 *Central Chiller Systems* include chillers and cooling towers, regardless of fuel source. *District Steam Heating* refers to high pressure steam supplied from the Con Edison District Energy System.
22 *Packaged Cooling Systems* include DX and packaged rooftop units. *Steam Heating* includes local boilers, or the NYC district steam system operated by the utility Con Edison.
23 *Decentralized Cooling Systems* include DX units, split systems, PTACs, window A/C, and through-wall units. *Hot Water Heating* includes systems with any fuel typology.
24 See the Methodology section on page 28 for more information.

Figure 4: Although the GHG emissions reduction potential identified by LL87 audits can be notable, it typically falls short of what is needed to meet LL97 limits in 2030.



This data reflects the average building for each of the four typologies.
Source: BE-Ex analysis of 2018 LL97 data, NYC 2018.

This report endeavors to go beyond building energy audit recommendations, offering multiple savings pathways that decision-makers can select based on desired GHG savings. We identify packages of emissions reduction measures (ERMs) for each pathway that can significantly reduce emissions and move toward LL97 2030 targets.

Getting to 2030

LL97 introduces a regulatory framework around building GHG emissions for the first time, compelling building decision makers to grapple with energy efficiency upgrades through an emissions-reduction lens. Many buildings must make significant emission reductions to meet LL97 2030 limits.

Although alternative compliance measures, such as the purchase of renewable energy credits (RECs) and GHG offsets may be potential options, increasing energy efficiency, implementing strategic retrofit projects, and reducing the use of fossil fuels provides a pathway to compliance that also includes non-energy benefits, such as reduced operating costs, improved asset value, and increased health and comfort.

As previously noted, most NYC commercial office buildings are already below the limit for the law's initial compliance period, starting in 2024, which will impact only the lowest performing 25% of covered buildings. Additionally, many of the buildings with GHG emissions currently in excess of the 2024 limits may be able to implement relatively simple and low-cost improvements, including those identified in LL87 audits, to avoid penalties. However, during the law's second compliance period starting in 2030, emissions limits will become significantly more stringent, moving from a 20% to a 40% mandated reduction in citywide building-based GHG emissions, from 2005 levels.

These more aggressive limits are expected to impact nearly 75% of covered buildings. Avoiding penalties will often require much more substantial upgrades to improve building performance. Meeting the 2030 limits will be more costly—in some cases much more costly—than the relatively low-cost improvements required of most buildings for 2024 compliance. In many cases, these improvements may also be quite disruptive to tenants. With these strict requirements taking effect in less than ten years, decision-makers must start planning now to take advantage of project phasing opportunities that will allow them to minimize both cost and disruption, while maximizing emissions reduction.

Building a Decarbonization Master Plan

This report's associated tearsheets help owners identify carbon reduction pathways — including improvements to base building systems as well as tenant energy reduction measures — that can help them plan for long-term LL97 compliance.

Once a building decision-maker has calculated their property's annual GHG emissions and determined their target percent emissions reduction required for LL97 compliance, they must then develop a decarbonization master plan for long-term phasing and implementation of energy efficiency retrofits and capital improvements.There are four tearsheets accompanying this report—one for each of the office typologies identified in this report, to help owners with this process.

Figure 5, right, depicts a decision tree included in the tearsheets to assist building decision-makers in selecting a viable retrofit pathway to meet their LL97 requirements. The three pathways identified on the tearsheets are distinguished from one another by the GHG emissions percent savings range possible from building baseline.

Each savings pathway directs building decision-makers to a menu of relevant retrofit packages, or groups of emissions reduction measures (ERMs).[25] By combining packages of ERMs, building decision-makers can gain insight into how they might build out a decarbonization master plan for long-term LL97 compliance. (The "Exploring retrofit solutions" section on page 20 provides an overview of common ERMs, many of which are also recommended in the tearsheets).

Designing a Custom Pathway

How much does your building need to reduce emissions to meet 2030 limits? These pathways guide you to the opportunities for emissions reductions for your building typology, and level of reduction needed.

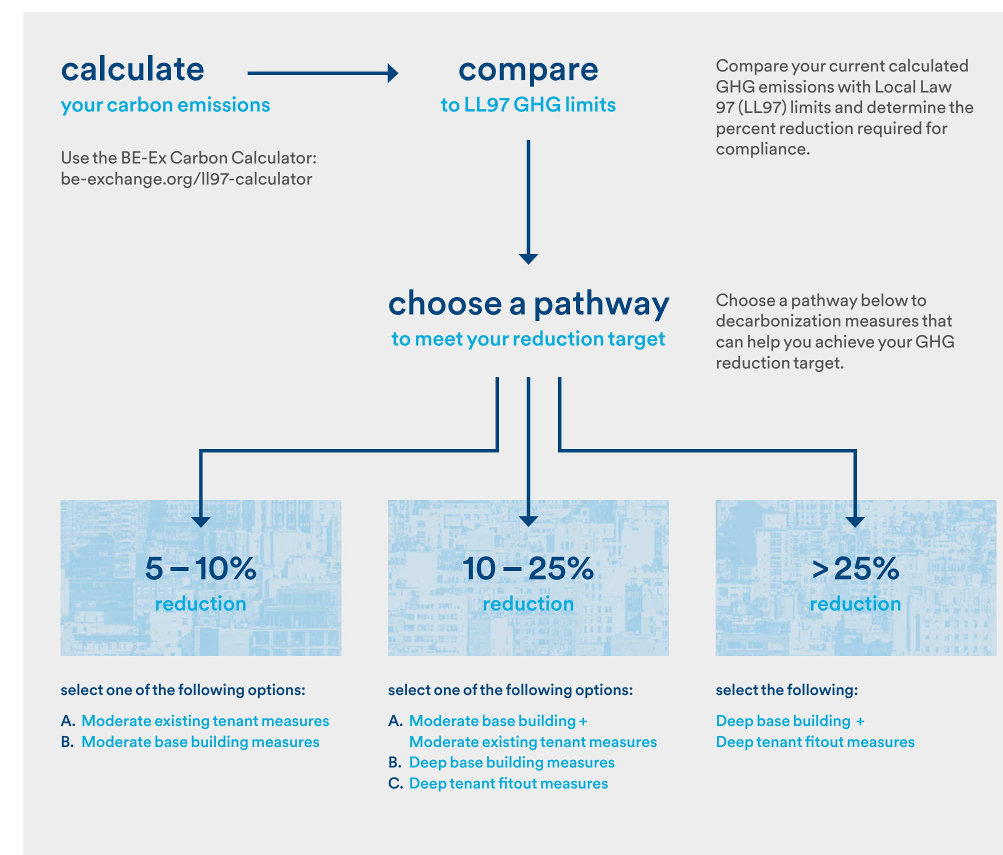
While 75% of buildings are expected to require GHG emissions reductions to avoid penalties under their 2030 limits, there is a wide range in the degree to which each building will need to reduce its emissions. Some buildings will need to reduce emissions by 5% to 10% to comply, whereas others will need to reduce by 30% or more.

As noted, the three pathways allow decision-makers to select packages of ERMs based on their GHG emissions reduction needs. Pathways group ERMs into packages configured to deliver a range of potential energy and GHG emissions savings. These packages range from operational tune-ups and low-cost retrofit measures with low to moderate savings potential, to major system upgrades and replacements, including potential electrification of heating and water heating end-uses currently using fossil fuels, that offer deeper possible savings.

The pathways are organized to help building decision-makers select energy efficiency upgrades, based initially on their emissions reduction needs relative to Local Law 97. From there, decision-makers can create a comprehensive capital improvement plan, which will likely include a combination of both moderate and deep decarbonization measures, as relevant to the specific conditions and needs of their building systems and tenants.

Figure 5:

Consult the accompanying tearsheets for help finding a viable pathway to reducing GHG emissions and complying with NYC regulations.



Modest Decarbonization Pathway ■ 5–10% emissions reduction

Packages of ERMs grouped under this pathway include relatively simple base building tune-ups and improvements, as well as ERMs that can be implemented while tenants remain in place. This pathway's recommended base building measures, in some cases combined with tenant improvement measures, offer viable options for building owners already close to meeting their LL97 emissions budgets to acheive the GHG reductions needed to comply during the first phase of the law, and to realize notable cost savings.

Figure 6, on page 18, shows a sample tearsheet for Typology 1: Central Chiller Systems with District Steam Heating. Note that implementing every ERM package on the Moderate Decarbonization menu would yield an estimated 13-17% savings, on average, well over the 5-10% target range for the Modest Decarbonization Pathway. This margin of savings provides building decision-makers the flexibility to select a custom combination of ERM packages best suited to meeting their needs, constraints, and targets.

Medium Decarbonization Pathway ■ 10–25% emissions reduction

To meet LL97 requirements, particularly the more stringent 2030 emissions limits, many building owners will need to reduce emissions beyond what can be achieved by ERMs recommended under past LL87 energy audits. The Medium Decarbonization Pathway combines packages of moderate decarbonization measures with packages of deep decarbonization measures. This middle pathway includes ERMs for base building and/or tenant space improvements, which can reduce emissions up to an additional 25%.

Deep decarbonization measures will typically require some degree of advanced planning, and decision-makers should take advantage of normal building operations and life cycle opportunities, like tenant fit-outs and scheduled equipment replacement, to maximize savings under this pathway.

Major Decarbonization Pathway ■ > 25% emissions reduction

Relatively few buildings will need to follow the Major Decarbonization Pathway to avoid penalties during the first two LL97 compliance periods in 2024 and 2030. However, all building decision-makers should be aware of the significant GHG emissions reduction measures that will likely be required to meet more stringent compliance periods in the future.

The packages of deep decarbonization ERMs offered under this pathway—including measures to replace some base building energy systems, as well as tenant fit-out measures—are generally quite costly. However, these packages also achieve the highest degree of emissions savings possible, making them good options when a building needs to dramatically reduce GHG.

For very deep decarbonization, some buildings will need to shift completely from fossil fuel-based heating (or other end uses) to electric-powered systems. The prospect of a near-zero-carbon electric grid that will serve NYC will drive much investment toward industry-wide building electrification, especially after 2030. (See the "Climate Leadership and Community Protection Act" text box on page 9 to learn more).

For buildings needing very deep cuts to carbon emissions, it is crucial to consider the remaining useful life of fossil fuel-based systems in the building, and to plan ahead for long-term electrification.

ERM packages included under the Major Decarbonization Pathway are best implemented when building systems are reaching the end of their useful life, during a building's financial repositioning, during tenant turnover and fit-out events, or during major tenant renovations. Additionally, deep savings in office building tenant spaces must often include moving energy-intensive IT systems to cloud-based operation, along with drastically reducing plug loads.

Electricity Emissions Coefficient — LL97 After 2030

While LL97 sets limits for building-based emissions, building owners typically only have control over the energy consumed, not the GHG emitted by their building. Recognizing this, LL97 specified GHG coefficients, or multipliers, for different fuel sources during the law's first compliance period in 2024 to 2029, but left the coefficients for subsequent periods to be determined by NYC Department of Buildings (DOB) rulemaking.

As noted earlier, under the CLCPA, New York's electricity grid is expected to dramatically decarbonize within the next two decades, with a legally binding target of 70% renewable electricity statewide by 2030 and a fully decarbonized, 100% renewable electric system by 2040. Because of this, it is highly likely that the carbon content of NYC electricity will be significantly lower by 2030.

As our team conducted analysis for this report in 2021 and 2022, we anticipated that the 2030 LL97 electricity coefficient might be lower than what had been prescribed for 2024. However, based on the degree of uncertainty around LL97 rulemaking, we chose to use the electricity GHG coefficient established for 2024-2029 in our analysis of the potential benefits of implementing decarbonization measures during subsequent compliance periods.

In October 2022, DOB issued proposed LL97 rules–including a new GHG conversion coefficient for electricity from 2030 to 2034–and finalized the rules in December 2022. The prescribed electricity coefficient is indeed significantly lower for the second compliance period than it is for the first. This will impact how many buildings are affected by GHG intensity limits in 2030 and beyond, as well as the potential impacts of various retrofit measures.

Strategic Decarbonization Assessment

NYC LL87 audit requirements were developed a decade in advance of LL97, and were not intended to provide the deep decarbonization analysis needed today.

The Strategic Decarbonization Assessment (SDA) –originally called the Strategic Energy Assessment and developed as a next generation energy audit for a San Francisco regulation similar to NYC LL87– is a tool that combines the requirements of an ASHRAE Standard 211 Level 2 Energy Audit with a partial property conditions assessment report and discounted cashflow analysis. The SDA offers the real estate industry a way to plan for decarbonization that is similar to how owners already plan for other capital needs investments.

As part of New York's Empire Building Challenge (see page 31 for details), the SDA tool was recently customized for use with large NYC buildings, and is being considered for additional uses by NYSERDA and other entities.

Considerations for All Pathways

Creating a pathway to LL97 compliance will require a new level of cooperation between building owners and their tenants, as well as consideration of each building's unique features.

Tenants in leased office spaces typically consume more than half of the building's energy.[26] This means that tenant spaces represent substantial opportunities to reduce a building's overall energy consumption and emissions. Without specifically addressing tenant energy use, it will be nearly impossible for most commercial buildings to attain the deep, long-term GHG reductions called for in this groundbreaking legislation.

Over a decade ago, as part of the GGBP, New York City passed legislation to help advance tenant energy efficiency, including Local Laws 85 (LL85) and 88 (LL88) of 2009. LL85 requires buildings to meet the most current energy code for any renovation or alteration project, eliminating compliance exceptions for partial building renovations (i.e., the majority of tenant improvement projects). LL88 further requires large non-residential buildings to upgrade lighting to meet current NYC Energy Conservation Code standards, and to install electrical sub-meters for each large non-residential tenant space and provide monthly energy statements.

Taken together, these laws have spurred dramatic reductions in tenant, and, consequently, whole-building energy use. Building owners have reported up to 30% building reductions just by their largest tenants upgrading lighting and renovating their spaces to current codes.

But there is much more work to be done. Opportunities to save energy are available throughout the lifecycle of a commercial office tenant's leasing cycle, from pre-lease activities—including site selection and project

Figure 6: This figure depicts a sample tearsheet for office buildings with central chiller systems and district steam heating. By combining recommended packages of ERMs for each end-use system, decision-makers can create and customize a viable pathway to meet their emissions reduction targets.

Building owners needing only a 5–10% reduction in GHG emissions under the Modest Pathway can forge a relatively simple path to LL97 compliance by implementing a combination of base building and tenant improvement measures.

Building owners pursuing a 10–25% reduction in GHG emissions under the Medium Pathway can select from these deep decarbonization packages and/or combine them with items on the moderate decarbonization menu,to the left, to develop a viable pathway to savings. Owners pursuing >25% reduction under the Major Decarbonization Pathway are advised to consider all deep savings measures.

Central Chiller Systems with District Steam Heating

building emissions by system

This shows the breakdown of GHG emissions by end-use system, as well as bar charts depicting base building vs. tenant usage for each system.

retrofit packages

moderate decarbonization

The potential GHG savings percentages listed below reflect estimated base building and/or tenant space emissions savings from baseline whole-building emissions. The total savings range for moderate decarbonization measures includes the combined savings from both base building measures and existing tenant measures.

retrofit packages

deep decarbonization

Achieving deeper GHG savings for buildings more than 25% over emissions limits will require significant investment, often including electrification solutions (⚡) for heating, cooling, and hot water. A detailed engineering analysis is needed to determine the best measures for each building.♦ GHG savings listed below are from baseline whole-building emissions.

Building system	%GHG (whole building)	Base building / Tenant	Moderate: base building measures — Emissions reduction measures (ERMs)	Potential GHG savings (whole building)	Moderate: existing tenant measures — Emissions reduction measures (ERMs)	Potential GHG savings (whole building)	Deep: base building measures — Emissions reduction measures (ERMs)	Potential GHG savings (whole building)	Deep: tenant fitout measures — Emissions reduction measures (ERMs)	Potential GHG savings (whole building)
heating	17%	100% base building / 0% tenant	Repair/replace steam traps and control valves Install TRVs Install or Upgrade EMS/BMS & other controls Upgrade zone controls Insulate pipes Install heat recovery	2.0%			⚡ Convert to water source heat pump or other electrification option, as appropriate Upgrade window glazing	6.0%	⚡ Convert to water source heat pump or other electrification option, as appropriate	*
cooling	19%	90% base building / 10% tenant	Install economizers Adjust setpoints and setbacks Install demand controlled ventilation Install VAV and thermostats in tenant spaces Map tenant BMS into base building system Reset chilled water differential pressure setpoint	6.0%	Optimize server room cooling Optimize setpoints and schedules Calibrate sensors and controls Clean coils	<0.5%	⚡ Convert to water source heat pump or other electrification option, as appropriate Upgrade window glazing	3.5%	⚡ Convert to water source heat pump or other electrification option, as appropriate	0.5%
ventilation	14%	100% base building / 0% tenant	Install VFDs on AHUs Convert CV system to VAV type system Install demand controlled ventilation Install exhaust fan timers Upgrade fans/air handlers	1.5%	Optimize VAV static pressure reset schedule Install demand controlled ventilation Install VFDs on AHUs	*	Install dedicated outside air system (DOAS) Install demand controlled ventilation	3.5%	Install dedicated outside air system (DOAS) Install demand controlled ventilation	*
hot water	2%	100% base building / 0% tenant	Install DHW controls Install low-flow aerators Install low-flow showerheads Insulate DHW tank	0.5%			⚡ Convert to water source heat pump for DHW	0.5%	⚡ Conver to electric point-of-use DHW, where applicable	*
lighting	12%	10% base building / 90% tenant	Install occupancy/vacancy sensors and timers Upgrade lighting to LEDs Upgrade to bi-level lighting fixtures in stairwells Delamp overlit spaces	<0.5%	Install occupancy/vacancy sensors and timers Upgrade lighting to LEDs Upgrade to bi-level lighting fixtures in stairwells Delamp overlit spaces	1.5%	Install occupancy/vacancy sensors and timers Upgrade lighting to LEDs Upgrade to bi-level lighting fixtures in stairwells Delamp overlit spaces	<0.5%	Install new LED lighting systems Install advanced daylighting & occupancy controls	6.0%
plug loads & conveyance	23%	20% base building / 80% tenant	Install plug load controls/timers Add elevator regenerative drives Upgrade elevator and escalator motors	0.5%	Install plug load controls/timers Use ENERGY STAR appliances Utilize sleep modes on IT equipment Move onsite IT to cloud, when possible	3.5%	Install plug load controls/timers Add elevator regenerative drives Upgrade elevator and escalator motors	0.5%	Install plug load controls/timers Utilize sleep modes on IT equipment Use ENERGY STAR appliances Move onsite IT (e.g. server rooms) to cloud	8.5%
process / other	13%	4% base building / 96% tenant	GHG savings from base building measures	9–11%	GHG savings from existing tenant measures	4–6%	GHG savings from base building measures	13–15%	GHG savings from new tenant measures	14–16%
GHG breakdown		56% base building / 44% tenant	total savings from moderate decarbonization measures	13–17%			total savings from deep decarbonization measures	27–31%		

* For end uses where there are measures listed but no savings shown, the whole-building GHG savings is counted in the base building column for that end use. The transition to all-electric equipment will shift some energy loads between base building and tenant systems, which is not estimated in this table.

♦ Emissions reductions are shown using the electricity carbon coefficient specified in Local Law 97 for the 2024-2029 compliance period; it is likely that the final electricity coefficient for 2030-2034 will be lower, resulting in bigger GHG reductions.

planning—to new space fit-outs and renovations, as well as during occupancy and at lease renewal.

It is also crucial to note that every office building has unique features and different baseline levels of energy consumption and emissions. As such, not every retrofit measure will apply to every situation. Suggested ERMs for each building typology and decarbonization pathway are representative, and not necessarily applicable to every building.

Building decision-makers must consider their specific building systems and equipment conditions when evaluating potential ERM packages. It is also important that they work with a qualified service provider in developing a comprehensive decarbonization plan and scope of work appropriate for their building.

25 ERMs are specific improvements and upgrades to building systems, such as heating, cooling, lighting, etc., that reduce building-based GHG emissions.
26 Energy use in interior offices and leased space accounts for between 40-60% of end use in a typical commercial office building.

While each building decision-maker must develop a long-term capital plan unique to their goals and building conditions, many impactful decarbonization solutions are applicable to nearly all large office buildings. These include shifting from fossil fuel-based systems to electric-powered equipment, installing comprehensive controls, and addressing opportunities in both base-building and tenant-spaces.

Getting to Know Your Building Systems

This section provides a summary of some of the most common and impactful solutions for reducing energy use and GHG emissions in commercial office buildings.

Consult this report's tearsheets to learn more about how measures can be packaged together to create viable pathways to building decarbonization. Be sure to work with a qualified service provider to determine the best strategies and solutions for your building.

heating

Boiler Plant Replacement or Upgrades

Heating solutions may include replacing primary boilers, often at the end of their useful life. While moderate energy and emissions savings can be achieved with higher efficiency boilers and improved controls, converting to electric-powered systems, like heat pumps, will be necessary to acheive the deeper reductions required for compliance with LL97 in 2030 and beyond.

- Replace boilers with high efficiency condensing boiler and thermal storage tank
- Install heat recovery plants utilizing waste heat via chiller heat mode
- Convert to heat pump or other electrification option
- Retro-commission (RCx) gas cold-climate heat pumps (CCHP) to optimize use of low temperature hot water

Distribution system improvements

For steam and hot water heating distribution systems, improvements include measures to reduce heat loss and upgrade valves and perimeter units. For air-based heating systems, improvements include installing variable frequency drives (VFDs) on air handling units (AHUs), increasing airflow control through dampers, and insulating ductwork.

- Insulate steam or hot water distribution pipes
- Install advanced steam controls and upgrade thermostatic radiator valves (TRVs)
- Replace steam traps
- Install new actuators and VFD motors
- Install perimeter fin tube, steam to hot water exchangers & fan steam coil
- Upgrade all internal controls to variable air volume (VAV) boxes in ceilings throughout each floor
- Insulate air ducts

cooling

Cooling Plant Replacement or Upgrades

Most retrofit plans should include improvements to primary cooling plant equipment. Building owners should consider the following equipment options, keeping in mind that, as with heating systems, they must ultimately convert to electric-powered systems to achieve deeper decarbonization:

- Variable speed screw chillers
- Variable speed turbo chillers
- Magnetic bearing chillers
- Direct expansion (DX) units
- Heat recovery heat pumps
- Well-water source heat pumps

Lower-cost solutions include:

- Retrofit and retrocommision (RCx) chiller plant
- Refurbish or replace cooling towers at end of useful life
- Install air and waterside economizers
- Convert to active chilled beams and variable air volume (VAV) systems

Motor Improvements

Replacing constant speed motors with VFD motors enables pumps to reduce their electrical draw for non-peak conditions and reduces energy consumption. Consider VFD upgrades for the following:

- Chillers & chilled water pumps
- DX unit motors
- Condenser water pumps
- AHUs & pumps

Controls Upgrades

Most tall office buildings have some form of BMS that allows fine-grained control of many setpoints related to cooling energy efficiency. A common no-cost energy savings strategy includes:

- Reduce setpoint temperatures
- Refine operating schedules

Other controls-related options include:

- Increase deadband for VAV units
- Increase outdoor air free cooling
- Increase chilled water temperatures
- Adjust chiller lockout settings
- Charge tenants for overtime HVAC use

Other Innovative Measures

Cooling systems typically have the widest variety of unique efficiency solutions, which are often customized to meet a building's specific conditions. Some innovative, yet less commonly deployed solutions are:

- Install plate-and-frame heat exchanger for free cooling
- Install river water heat rejection system
- Install smoke evacuation damper seals
- Relocate servers to optimize cooling
- Install variable refrigerant flow (VRF) systems for lobby and lower-level tenants
- Install thermal/ice storage

ventilation

Air Handling System Replacement or Upgrades

Air handling units (AHUs) are often replaced when equipment is past its useful life. Many measures deal with retrofitting controls and drives on AHU fan motors and converting constant air volume (CAV) systems to variable air volume (VAV) systems. Other measures for central systems include installing isolation dampers and converting to displacement ventilation. Upgrading to energy recovery ventilation systems (ERVs) can achieve some of the most significant reductions in energy use and GHG emissions.

- Convert total air distribution system to VAV
- Install ERVs
- Install displacement ventilation
- Upgrade air distribution (overhead, hybrid overhead, perimeter fan coil, and chilled beam)
- Install VFDs on all supply and return/exhaust fans
- Upgrade AHU controls
- Install VFDs on new air handlers with fan array
- Set VFDs to auto mode and confirm speed settings
- Reduce static pressure
- Install floor isolation dampers

Demand Controlled Ventilation

Reducing fresh air supply based on occupancy is a relatively common measure. This includes installing either an occupancy sensor or CO2 sensor plus controls to reduce outside air supply volumes.

- Install demand controlled ventilation controls and CO2 sensors
- Reduce ventilation rates on nights and weekends
- Install fresh air controls with presence detectors, enabling shutdown for unoccupied areas
- Instal carbon monoxide (CO) controls on garage ventilation

Outside Air Economizer

Free cooling from 100% outside air or increased supply of outside air during shoulder seasons provides some energy and emissions savings, particularly in all-air systems. Consider installing the following equipment options:

- Dedicated outside air system with heat recovery
- Free cooling coils in each DX unit
- Plate-and-frame heat exchanger for free cooling
- New dampers and controls for air economizers on all AHUs

hot water

Hot Water Heater Replacement

Replacing old, inefficient hot water heaters with new high efficiency equipment can achieve a certain level of energy and emissions savings in domestic hot water systems (DHW). However, acheiving the level of reduction needed for long-term LL97 compliance will require converting to all-electric systems, like heat pumps. Building owners should consider installing the following:

- High-efficiency condensing boilers
- New DHW tanks
- Heat exchangers to optimize low temp hot water from cold climate heat pump
- Retail steam hot water heaters

Electrification of Hot Water Generation

Shifting from central hot water generation and storage to point-of-use hot water heaters reduces heat loss during storage and distribution. These savings can be substantial, particularly for buildings with low hot water demand and/or high peak, low volume, like tall office buildings.

- New electric domestic hot water tanks
- Local electric hot water heaters
- Electrical point of use hot water heaters for hand washing and low-flow fixtures

Other Innovative Hot Water Measures

Additional options include:

- Install condensate heat recovery
- Optimize hot water heater temperature setpoint and schedule for bathrooms, fitness centers, and kitchens

lighting

Reduced Lighting Power Density

Most comprehensive retrofit plans will include some form of lighting fixture or lamp replacements, such as with LEDs and dimmable ballasts. New technologies for lamps and fixtures provide higher efficacy, reducing overall energy use and emissions while improving lighting quality. New codes limiting lighting power density may require many of the following measures:

- Upgrade to code compliant lighting
- Lower lighting power density in tenant spaces
- Upgrade to LED lighting in parking garage, stairwells, and restrooms
- Upgrade lighting upgrade to LED fixtures and vacancy sensors on floors with new tenant fit outs
- Select LED fixtures with continuous dimming
- Utilize task lighting
- Utilize lighting override controls

Daylighting Systems

This group of measures includes strategies to reduce energy consumption and emissions by harnessing natural daylight to replace electric lighting. Daylighting measures include installing and using the following:

- Daylight sensors and controls
- Active blinds with controls
- Lighting dimming controls
- Light shelves
- Reflective paints and finishes

Occupancy Sensors

Another common lighting measure is using motion sensors to monitor occupancy and switch off lighting in unoccupied spaces. More advanced examples include occupancy sensors networked to a BMS to directly control overhead lighting. Simple examples are direct switches of lighting in stairwells or parking areas. Consider installing:

- Occupancy sensors
- Occupancy-based lighting controls
- Occupancy sensors in stairwells
- Bi-level lighting

Reduced Lighting Schedules

Reducing the number of hours that overhead lights are on is a simple and effective no-cost measure. It requires lighting to be controlled by a BMS, which is most common in large, tall office buildings.

plug loads & conveyance

ENERGY STAR Appliances

ENERGY STAR-rated appliances can use ten to twenty percent less energy than standard appliances. Some owners and/or tenants may implement policies or lease clauses requiring appliances to meet ENERGY STAR standards, in addition to complying with NYC Energy Efficiency Code.

Data Servers

A major energy user in tenant spaces has been data servers and increased computation needs over the past few decades. With the rise of cloud computing and remote servers, however, that energy consumption can be moved to remote locations to reduce the energy load on the building.

Other Plug Load Measures

Other creative approaches include:

- Complete a plug load reduction study
- Install advanced power strips on select tenant floors
- Provide remote, app-driven tenant controls
- Develop Green Leadership teams to partner with tenant services on purchasing from ENERGY STAR appliance and computer vendors for new tenants and existing tenants on replacement cycles.

Regenerative Elevators

In high-rise buildings, elevator demands add a small percentage to base building energy use and emissions. Installing regenerative drive motors and destination dispatch controls can reduce energy use at a small premium, either when elevators are replaced at their end of useful life or during a building-wide repositioning. Consider the following measures:

- Install regenerative drives on modernized elevators
- Uprade to destination dispatch
- Install VFDs on motors
- Replace older Gen Set elevator systems

other ERMs

Control System Upgrades or Replacement

Control technologies have advanced so rapidly that nearly all buildings can achieve savings by installing a new BMS or upgrading an existing one, and modernizing programming and controls. A BMS increases controllability and saves energy by reducing airflows, temperature setpoints, lighting levels, and other systems during times of vacancy or favorable weather conditions. BMS systems should be connected to all major equipment. Options include:

- Convert pneumatic controls to direct digital controls (DDC)
- Install a Supervisory Control Management System (SCMS)
- Convert to a cloud-based building energy management system (EMS) with real- time energy management (RTEM)
- Use a Tenant Energy Management Software and Engagement Program
- Install a building automation system (BAS)

Phasing Out Fossil Fuel Equipment in NYC Buidlings

Passed in 2021 and ramping up over a period of five years, NYC Local Law 154 (LL154) prohibits new construction and gut renovation projects of a certain size from installing fossil-fuel burning equipment and appliances.

While this new law currently applies to only a subset of NYC buildings, it is accelerating New York's transition to an all-electric, clean-energy future, and points the way to a new paradigm for the building industry.

Although meeting emissions limits for the second compliance period of NYC LL97 will not be easy, our report finds that it is achievable for most office buildings.

Reducing GHG emissions by 25% or more will likely require significant shifts in the ways that many building decision-makers approach building upgrades—including electrification of major fossil-fuel powered systems, closer collaboration with tenants, and long-term planning to implement retrofit projects at key moments in time, such as major capital events.

Although NYC's ten year old Greener, Greater Buildings legislation has facilitated unprecedented insight into the city's building stock and energy consumption patterns, it has stopped short of mandating that building owners act on this information or implement upgrade measures identified in their energy audits. As the climate crisis has come into sharper focus, it has become clear that more direct action is needed to realize the significant GHG reduction potential of building efficiency measures—a realization that provided one of the underlying arguments for passing the Climate Mobilization Act and LL97.

Despite the significant effort and cost that will be required to dramatically reduce GHG emissions and achieve NYC's ambitious 2030 climate action goals, building owners stand to reap major benefits. These include reduced operating costs and utility expenses, as well as an edge in an increasingly competitive real estate market. Building stakeholders and commercial tenants, along with their boards and customers, are raising expectations for climate action and are making Environmental, Social, and Governance (ESG) commitments that address the impacts of their office footprints.

Furthermore, in a post-COVID world, tenants increasingly are demanding healthier and more comfortable spaces—attributes that typically go hand in hand with high performance, low-carbon buildings. As building codes and performance standards continue to grow tighter, not only in NYC but in cities around the globe, implementing deep decarbonization measures today will enable building decision-makers to effectively future-proof their investments.

This report and associated tearsheets demonstrate that each of the four office building typologies analyzed—and each individual building within those typologies—will need to develop its own pathway, select specific packages of emissions reduction measures, and create a long-term capital plan appropriate to their unique needs and constraints, in order to reduce carbon emissions to the degree required by NYC law. However, this report also reveals that many of the most impactful measures are applicable to the majority of buildings. These measures include replacing onsite fossil-fuel burning systems with electric-powered equipment, installing automated controls to manage lighting, plug loads, and HVAC equipment, and moving energy-intensive business operations—like onsite management of IT and data centers—to the cloud.

Despite uncertainty that may persist in the regulatory landscape in NYC and beyond—including details of energy codes and climate policies that may evolve over time—it remains clear that market demand and local, state, and federal regulations are all moving towards deep decarbonization of the built environment. This report offers guidance for office building decision-makers to start taking action to meet these demands, begin realizing the benefits of high performance upgrades, and lead the industry in building a safer, healthier, and more sustainable future for all.

New York City and State have enacted groundbreaking legislation to advance building decarbonization and clean energy generation. This is just the beginning of a global trend toward building performance standards as a crucial tool to curb emissions and fight climate change.

Scaling and growing confidence in the building decarbonization retrofit market will require a coordinated, industry-wide effort. We believe that a successful path forward should include targeted campaigns, activities to stimulate and curate a portfolio of successful case studies, and international partnerships that provide proof of financially viable decarbonization solutions, moving energy efficiency optimization to standard practice.

To accelerate the decarbonization of office buildings, we believe that the following steps will be needed:

Case Studies

Identify, track, document, and publicize the energy cost savings, as well as implementation costs, of successful energy efficiency retrofit projects from diverse office building typologies, to transfer knowledge and inspire confidence in results. Develop a follow-up to High Rise | Low Carbon Office Deep Retrofit Profiles, expanding the data base and solution set of implemented and measured results.

Training & Education

Increase outreach and education to all building stakeholders to spread awareness and understanding of retrofit best practices and benefits, including topics on high performance buildings, deep decarbonization retrofits, leased spaces, and tall buildings.

Technical Research

Continue to study retrofit pathways for deep decarbonization, along with pilot project results from a variety of building types. This research should inform the development of sensible solutions for transitioning to all-electric heating, cooling, and ventilation systems, as well as capital plans that can achieve significant energy and emissions savings.

Exemplary Building Competitions

Effectively message and broadly convey the lessons learned from public-private building decarbonization competitions like New York's Empire Building Challenge, Empire Technology Prize, and Buildings of Excellence, to a wide cohort of building decision-makers.

Solutions and Partnerships

Expand awareness and expertise by sharing best practices among international building stakeholders and policymakers, and increase opportunities for international partnerships that can accelerate local adoption of global solutions.

A Timeline for Action

2024

Most large office buildings will be below NYC LL97 GHG emissions limits in 2024, or able to comply with relatively simple efficiency upgrades and operations and maintenance improvements, such as those identified by NYC's Energy Audit and Retro-commissioning Law (LL87).

Continuous commissioning and effective, modern operations and maintenance will be essential to reducing and keeping emissions in check.

2030 to 2034

Most large office buildings will need to complete moderate or deep decarbonization retrofits to comply with LL97 in 2030. Owners should develop long-term capital plans that match their emissions reduction goals, and include upgrade measures for both base-building and tenant systems.

More case study examples will be needed to help building decision-makers better understand and visualize effective decarbonization measures and implementation. Innovative approaches for transitioning off of on-site fossil fuel use must vetted and well communicated to become standard industry practice.

2035 and Beyond

Anticipating New York State's mandated shift to a 100% renewable electric grid, building decision-makers should begin making long-term plans to replace on-site fossil fuel systems with electric-powered equipment.

To ensure resiliency and operational continuity, the building industry will also need to address barriers to on-site energy storage, ease regulatory friction, and develop effective turn-key solutions for the market.

Another priority should be advancing and scaling up thermal network technologies at the building, block, and community levels, in order to efficiently move surplus heat to where it is needed, when it is needed.

Data Segmentation and Cleansing Methodology Overview

The overall goal of this analysis was to identify and segment a limited number of building typologies that would collectively encompass the largest portion of the office building stock in New York City, by floor area and greenhouse gas (GHG) emissions. The publicly available NYC Local Law 84 (LL84) energy benchmarking dataset was leveraged to quantify the gross square footage (GSF), count, and total GHG emissions of office buildings in New York City between 25,000 sf and 1 million sf. The publicly available Local Law 87 (LL87) energy audit dataset was leveraged to identify the most common building systems in those office buildings, and then segment out four typologies, based on major heating and cooling systems, for further analysis. The analysis required examining data for every individual building from both datasets, and then cleansing the LL84 data and LL87 data to filter for buildings that are included in both datasets, to verify that whole building energy use and GHG emissions data energy use data reported in LL87 audit reports is indeed for the whole building.

Local Law 84 Data Cleansing

To cleanse the LL84 dataset, the team started with data from 2018, which included 25,245 submissions. They then completed the following steps:

1. Removed buildings with no office space typologies (Office, Financial Office, Medical Office, and Veterinary Office) in the following columns: Primary Property Type—Self Selected; Primary Property Type—Portfolio Manager Calculated; Largest Property Use Type; 2nd Largest Property Use Type; and 3rd Largest Property Use Type.
2. Removed properties with less than 50k sf and properties with more than 1M sf.
3. Removed properties with EUI >1000 or <5 [kwh/sf/yr].
4. Removed properties with no electricity use.
5. Removed properties with estimated energy values.
6. Removed properties with less than 12 full calendar months of data.
7. Removed properties with district chilled water > 0.
8. Removed duplicate property IDs, leaving the most recent submission.
9. Removed properties with duplicate Building-Block-Lot (BBL) and Building Identification Number (BIN), leaving the most recent submission

Following this data cleansing process, the team was left with a total of 2,257 submissions.

Local Law 87 Data Cleansing

To cleanse the LL87 dataset, the team started with data from 2013 to 2018, which included 7,083 submissions. They then completed the following steps:

1. Removed properties with less than 50% office square footage. Acceptable office space typologies were: Financial Office, Office, Medical Office, and Veterinary Office. Following this step, 773 submissions remained.
2. Removed buildings below 50,000 sf, leaving 769 remaining.
3. Removed buildings over 1M sf, leaving 712 remaining.
4. Removed buildings without a BBL match between LL84 and LL87 data sets, leaving 583 remaining.
5. Removed duplicate BBLs and kept the most recent submission, leaving 566 remaining.
6. Removed buildings where the space type reported in LL84 and LL87 data did not match, leaving 546 remaining.
7. Remove buildings with site EUI below 5 or above 1000 [kwh/sf/yr], leaving 479 remaining.
8. Remove buildings with a total site EUI discrepancy of 50% or more between LL84 and LL87 data (to account for false reporting), leaving 354 remaining.
9. Remove buildings with a discrepancy of 20% or more in GFA between LL84 and LL87 data, leaving 320 remaining.

After completing this data cleansing process, the team segmented the remaining 320 office properties into four building typologies, based on primary heating and cooling systems, in order to then calculate end use energy breakdowns, as well as Energy Conservation Measure (ECM) savings. This left the team with a total of 263 buildings across the four chosen typologies.

ECM Data Cleansing

To accurately calculate potential savings that can be achieved by implementing LL87 energy audit recommended ECMs, the team began by examining LL87 ECM submissions from 2013-2018, which included 47,924 ECM recommendations.

The team then took the following steps to cleanse the data:

1. Filtered to select office property type.
2. Removed duplicate submissions.
3. Removed ECMs with data type issues (e.g., text listed in an important numerical column).
4. Removed ECMs with missing energy savings.
5. Removed ECMs with missing cost savings.
6. Removed ECMs where the total energy savings are higher than the total building energy consumption.
7. Removed ECMs where the energy savings = 0.
8. Removed ECMs where the cost savings = 0.
9. Removed ECMs where the energy savings are negative.
10. Removed ECMs where the cost savings are negative.
11. Removed ECMs where the calculated total savings differ from the self-reported total savings by more than 30% (this is to catch ECMs where the individual fuel savings were reported in units other than kBtu as units were not provided in the LL87 data).
12. Remove any ECMs from properties that did not pass the LL87 data cleansing process.

Following this process, the team was left with a dataset of 2,507 total ECMs, from which they could calculate savings by end use system.

End Use Breakdown Methodology (Energy & GHG)

To calculate the end-use breakdown (EUB) by building typology, we utilized the set of 263 buildings that passed the LL87 cleansing above. To calculate the GHG associated with each EUB category, we calculated the GHG emissions per EUB category for each property. To do that, we took used the follow steps and assumptions:

1. Multiplied each EUB category's consumption by the relevant GHG emissions factor
2. GHG emissions factor was based on the assumed primary fuel type for that building and EUB category.
3. The space heating and domestic hot water factors were based on the primary heating fuel type defined for the building
4. The space cooling factor was based on the primary cooling fuel type defined for the building, and the other categories used the electricity emissions factor.
5. The emissions factors used were the ones outlined in Local Law 97.

Savings Potential by End Use Category for Each Typology (Energy & GHG)

To calculate the ECM savings potential by end use category, we started with the ECM dataset as defined in the ECM Cleansing Methodology above. This left us with 2,507 ECMs from which to calculate potential savings across 263 properties. We then used the following steps and assumptions:

1. Filter out ECMs where the energy savings are greater than the reported end-use-breakdown category, leaving us with 2,225 remaining ECMs.
2. Calculate the GHG savings for each ECM by multiplying the individual fuel type savings by the GHG emissions factor for that fuel type as defined by Local Law 97.
3. Sum the total savings for each of the four office typologies by ECM category (this is different than the EUB categories, LL87 does not have you specify which EUB category your savings came from).
4. Use the total savings by ECM category to calculate the total savings by EUB category using the following methodology:
a. For each ECM category that applies to only one EUB category, add the summed value for that ECM category to the EUB category sum
b. For each ECM category that applies to more than one EUB category, split the ECM savings into the respective EUB category, weighting the savings by the EUB consumption. For example, if an ECM category applies to space heating and space cooling, and 2x the energy is used for heating vs cooling, assign 2/3 of the savings to space heating and 1/3 to space cooling.
5. Copy the total consumption (energy & GHG) by EUB category for each typology as calculated in the previous section.
6. Calculate the post-savings consumption as total consumption minus estimated savings.
7. Calculate the savings as a percentage of the total consumption as the estimated savings for that category divided by the total consumption for that typology.
8. Finally, we calculate the savings as a percentage of the EUB category as the estimated savings for that category divided by the total consumption for that category.

Citywide Extrapolation of Typologies and GHG Savings

Finally, to estimate the citywide savings potential for the identified energy reduction measures for the four typologies we extrapolated our findings from the cleansed LL87 data and applied them to the LL84 data set of building between 25,000sf and 1 million square feet.

The proportional count, total area, GHG emissions and GHG savings for each typology within the cleansed LL87 data was applied to the universe of office buildings between 25,000sf and 1 million square feet from the 2018 LL84 data set.

Building Typology Assignment
Buildings were assigned to one of four typologies based on their primary heating system, primary heating fuel, primary cooling system, and whether they have centralized or decentralized cooling. Please see the table below for a list of systems included in each typology.

Office Building Typology	Building Count After Cleansing	Heating Systems	Heating Fuel	Cooling Systems	Centralized or Decentralized
1. Central Chiller Systems with District Steam Heating	49	• District Steam	• District Steam	• Chillers, including: Absorption, Centrifugal, Reciprocating, Screw Driven, Electric	• Centralized
2. Decentralized Cooling Systems with Steam Heating	125	• Steam Boiler • District Steam	• District Steam • Dual Fuel • Natural Gas • Oil • Electric • Propane • Unknown	• Packaged Rooftop Units • DX Units • Unknown	• Decentralized • Unknown
3. Decentralized Cooling Systems with Hot Water Heating	16	Hot Water Boiler	• District Steam • Dual Fuel • Natural Gas • Oil • Electric • Propane • Unknown	• Ductless Mini-Split Systems • Multi-Split Systems • Single-Split Systems • Split System Central Air • PTAC • Through-Wall A/C • Window A/C	• Decentralized
4. Packaged Cooling Systems with Steam Heating	73	Steam Boiler	• District Steam • Dual Fuel • Natural Gas • Oil • Electric • Propane • Unknown	• Single-Split Systems • Ductless Mini-Split Systems • Multi-Split Systems • Split System Central Air	• Centralized or Decentralized
Not assigned	57				

Heating Fuel and System Assignment
Heating fuel typologies were simplified from the list provided in the LL87 submissions to the list below, using the following mapping:

Simplified Fuel Categories Used for Analysis	Original Lookups in LL87 dataset
District Steam	• District Steam • Misspelled variants
Dual Fuel	• Dual Fuel • Misspelled variants
Electric	• Electric
Natural Gas	• Firm Gas • Natural Gas • Misspelled variants
Oil	• #2 Oil • Oil #2 • #4 Oil • #4 Fuel Oil • #6 Oil • Oil
Propane	• Propane
Unknown	• N/A • Blank entries • Unrelated numerical entries

The primary heating system was simplified from the list provided in LL87 submissions to the list below through a manual process:

Heating Systems
Combined Heat and Power
Electric Resistance
Furnace
Steam, including: • District Steam • Steam Boiler
Heat Pumps, including: • Air Source • Water Source
Hot Water Boiler (Hydronic)
Gas-Fired Units, including: • Rooftop Units • Terminal Units
Unknown

Equipment Assignment
The centralized vs decentralized cooling was determined from the primary cooling system using the following mapping:

Centralized	Decentralized
Chillers, including: • Absorption • Centrifugal • Reciprocating • Screw Driven • Scroll	**A/C systems, including:** • PTAC • Through-Wall A/C • Window A/C
Electric Chiller	**DX Units** **Split Systems, including:** • Ductless mini-split • Multi-split • Single split • Split system central air **Packaged Rooftop Units**

additional resources

Education & Training

In addition to the Building Energy Exchange, the following organizations provide education and training on a variety of building energy efficiency upgrades and decarbonization strategies. A variety of courses are available for building owners, designers, managers, operators, and staff in New York City and online:

32BJ Training Fund: The 32BJ Training Fund is a joint labor-management partnership that offers training to eligible participants at no cost. 32BJ provides training on a range of topics. www.training.32bjfunds.com

City University of New York, Building Performance Lab (CUNY BPL): CUNY BPL promotes high-performance building operations for existing commercial and public real estate. CUNY BPL offers building energy efficiency and operations & maintenance trainings. www.cunybpltraining.org

Solar One: Solar One, NYC's Green Energy Education Center, offers trainings through its Green Workforce Training Program. www.solar1.org

Additional Education & Training Resources: Relevant resources may also be available through: Building Performance Institute (BPI); the New York State Energy Research and Development Authority (NYSERDA); the Passive House Network (PHN); and Urban Green Council (UGC).

Financing

Financing and incentives from may be available to help defray the costs of building decarbonization measures. The following is a short list of resources:

New York City Energy Efficiency Corporation (NYCEEC) & Commercial Property Assessed Clean Energy (C-PACE): NYCEEC, a non-profit finance company, provides loans for energy efficiency and clean energy projects in the Northeast and Mideast. NYCEEC administers NYC's C-PACE program, a financing tool offering building owners up to 100% funding for energy efficiency and renewable energy projects. The C-PACE loan model requires little to no upfront cost and has lower interest rates and longer loan terms than standard financing tools. www.nyceec.com

Utilities: In New York, Con Edison and National Grid provide incentives and rebates for a wide variety of energy efficiency and renewable energy projects. Visit their websites to learn about current offerings.
www.coned.com/energyefficiency
www.nationalgridus.com/services-rebates

New York State Energy Research and Development Authority (NYSERDA)

NYSERDA has many programs that support energy efficiency in buildings. In addition to rebates, incentives, and technical assistance for efficiency projects, NYSERDA also provides support for a variety of energy efficiency and clean energy training programs. www.nyserda.ny.gov

The Empire Building Challenge

NYSERDA's Empire Building Challenge (EBC) is a $50 million investment by New York State to demonstrate different pathways for achieving carbon neutrality in tall buildings. Through the establishment of a private-public partnership with leading real estate owners and their engineering experts, exciting approaches to cold climate decarbonization are being tested in the New York market. With the potential to replicate these solutions across the 130 million square feet of real estate controlled by the first cohort of EBC partners and beyond, the impact of each project will accelerate New York's progress toward the Climate Leadership and Community Protection Act's goal of reducing greenhouse gas emissions 85% by 2050. Launched in the Governor's State of the State Address in January 2020, the EBC program began through a solicitation seeking applications from the largest real estate firms in NY. Nearly 40 major real estate owners responded, including the largest owners in NY and several multinational owners with high-rise properties around the US and the globe. By the end of 2020, an initial cohort of ten real estate portfolio owners were selected who collectively control around 130 million sf and have made public commitments to carbon neutrality by 2035. The selected partners received technical assistance funding to develop building decarbonization roadmaps to prepare for the retrofit project funding portion of the Challenge, with that solicitation launched during Climate Week NY in September 2021.

In early 2022 $20 million in NYSERDA funding was announced for the first four real estate partners' initial low carbon retrofit demonstration projects which will serve as models of urban sustainability for cold climates. These buildings are demonstrating deep decarbonization strategies and solutions that will be a model for other owners who need to significantly reduce emissions to meet LL97's requirements. NYSERDA will seek additional real estate partners, along with additional funding, in future rounds.

More information is available at www.nyserda.ny.gov/All-Programs/Empire-Building-Challenge

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Might Could

Disclaimer

Glossary of Key Terms and Abbreviations

AHU	Air handling unit
BAS	Building automation system
BMS	Building management system
CAV	Constant air volume
CCHP	Combined cooling, heating, and power system
CHP	Combined heat and power
CLCPA	Climate Leadership & Community Protection Act
CO	Carbon monoxide
CO2	Carbon dioxide
DCV	Demand control ventilation
DDC	Direct digital control
DHW	Domestic hot water
DX unit	Direct expansion air conditioning unit
ECM	Energy conservation measure
EMS	Energy management system
ERM	Emissions reduction measure
ERV	Energy recovery ventilation
ESG	Environment, social, and governance
EUI	Energy use intensity
GHGI	Greenhouse gas intensity
HVAC	Heating, ventilation, and cooling systems
HW	Hot water
LEDs	Light-emitting diode lights
M&V	Measurement & verification
PRV	Pressure reducing valve
RCx	Retrocommissioning
RTEM	Real-time energy management system
SCMS	Supervisory control management system
Solar PV	Solar photovoltaic system
TRV	Thermostatic radiator valve
VAV	Variable air volume
VFD	Variable frequency drive
VRF	Variable refrigerant flow

The **Building Energy Exchange** is a center of excellence dedicated to reducing the effects of climate change by improving the built environment. BE-Ex accelerates the transition to healthy, comfortable, and energy efficient buildings by serving as a resources and trusted expert to the building industry.

be-exchange.org