best practices manual

# Decarbonization Roadmap for Multifamily Affordable Housing

be
ex
building
energy
exchange

BRIGHT POWER

NEW YORK STATE

NYSERDA
Supported

NYC
Department of
Housing Preservation
& Development

Report Partners

# contents

**how to use this manual**
This manual provides a decarbonization roadmap for affordable housing in New York City. Using this document, project teams can develop long term capital plans to meet New York City's increasingly stringent Local Law 97 greenhouse gas (GHG) emissions requirements. Included within is a collection of five case studies that represent theoretical Low and No Carbon retrofits of five common affordable housing typologies found in New York City. The manual outlines a step-by-step process for developing Low and No Carbon master plans. Key information regarding systems, strategies, tools, and policy considerations, as well as individual tear sheets for each case study are provided to help teams build the most impactful retrofit based on their unique project.

## tear sheets

# context

In coastal New York City, where the threat of climate change is keenly felt, there are roughly one million buildings, many of which pre-date energy codes and have poorly sealed and minimally insulated windows and walls. Since buildings account for two-thirds of all greenhouse gas emissions in the city, they are the main focus of the city's plan to combat climate change, as set forth in the landmark package of bills passed in 2019 known as the Climate Mobilization Act (CMA).

The keystone of the CMA is Local Law 97 (LL97). Under LL97, most buildings over 25,000 square feet will be required to meet new energy efficiency and GHG emissions caps starting in 2024, with increasingly rigorous emissions limits through 2050. The goal is to reduce emissions 40 percent by 2030, and 80 percent by 2050. Buildings that exceed their emissions caps will face financial penalties.

Buildings with affordable and rent-regulated housing are not exempt from LL97, but are treated differently under the law. Many of these buildings are subject to the "Prescriptive Pathway" which requires buildings to implement a suite of low-cost prescriptive energy conservation measures or voluntarily meet 2030 GHG emissions limits. Other housing, primarily large income-restricted developments, are subject to the "2035 Pathway" and will need to start meeting emissions caps in 2035. With careful planning, owners of affordable housing can strategically decarbonize their

buildings to meet LL97 compliance requirements while reducing energy costs, improving indoor air quality, and increasing residents' health, safety, and comfort.

NYC's climate plan is happening under the larger umbrella of New York State's own ambitious Climate Leadership and Community Protection Act (CLCPA). Under the CLCPA, the state commits to reducing GHG emissions 40 percent by 2030 and 85 percent by 2050 from 1990 levels. It also aims to have a clean energy grid by 2040. These state-wide targets on emissions free electricity are critical for NYC buildings to meet their own emissions goals.

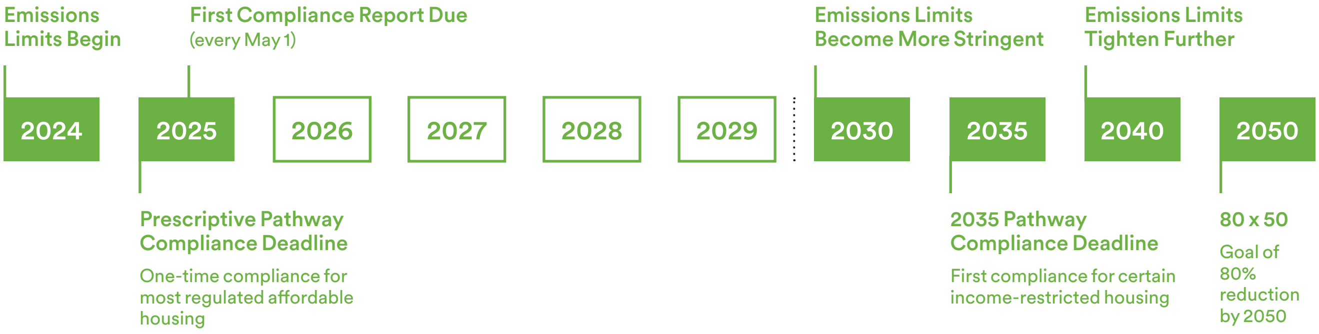
## project overview

The idea for this project was born from concerns about how affordable housing would comply with Local Law 97, and to inform strategies for affordable housing projects to meet the climate goals of both New York City and State. Specifically, the team worked to identify gaps in HPD's design and development process to determine best practices that could enable affordable housing to meet NYC's short-term and long-term decarbonization goals strategically and cost-effectively, while improving the long-term health and economic viability of the department of Housing Preservation and Development's (HPD) buildings and residents.

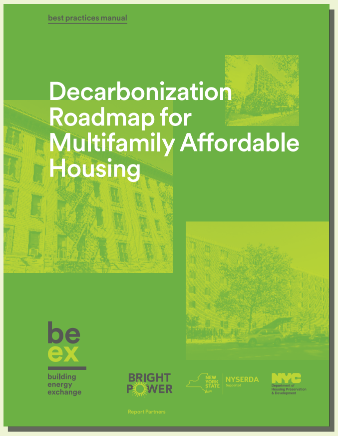
**Intent**

To inform and provide guidance around best practices for the entire ecosystem of affordable housing providers in NYC, to inform HPD's design standards, practices, and protocols, and to guide NYC's ongoing policy decisions around the decarbonization of affordable housing.

In 2021, NYC passed Local Law 154, which bans gas hookups in new buildings. The law goes into effect in December 2023 starting with smaller buildings, with a delay for most affordable housing. By the end of 2027, the law will be in effect for all buildings, including affordable housing. The city and state are also exploring legislation that will phase out fossil-fuel equipment replacements for existing buildings in the future.



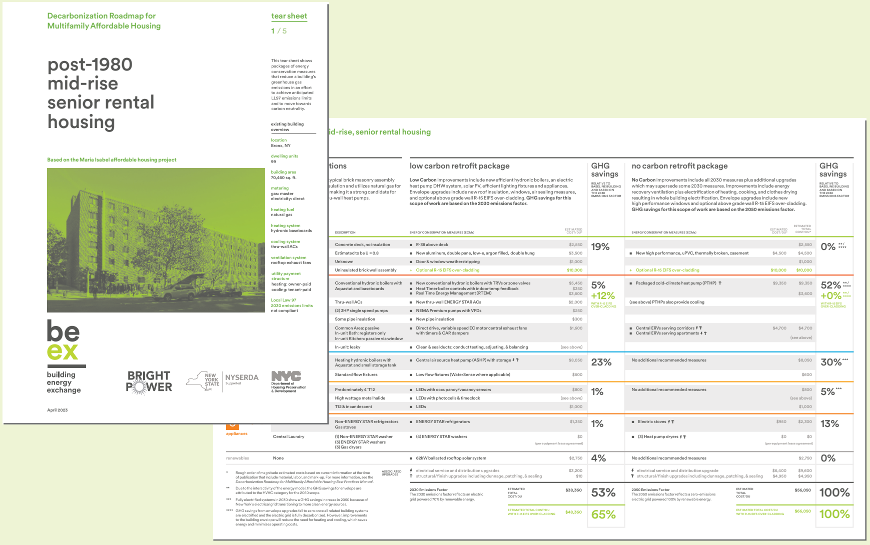
# tools



best practices manual

Decarbonization Roadmap for Multifamily Affordable Housing

building energy exchange



Decarbonization Roadmap for Multifamily Affordable Housing

tear sheet

1 / 5

post-1980 mid-rise senior rental housing

This tear sheet shows packages of energy conservation measures that reduce a building's greenhouse gas emissions in an effort to achieve anticipated LL97 emissions limits and to move towards carbon neutrality.

Based on the Maria Isabel affordable housing project

existing building overview

location
Bronx, NY

dwelling units
99

building area
70,460 sq. ft.

metering
gas: master
electricity: direct

heating fuel
natural gas

heating system
hydronic baseboards

cooling system
thru-wall ACs

ventilation system
rooftop exhaust fans

utility payment structure
heating: owner-paid
cooling: tenant-paid

Local Law 97 2030 emissions limits
not compliant

building energy exchange

April 2023

**Best Practices Manual**
The manual describes the objectives of the HPD Local Law 97 Roadmap study and outlines the key retrofit packages that were assessed for the five buildings including descriptions of the equipment and strategies included in each, and the GHG emissions limits achieved. The manual concludes with key takeaways, key challenges, and recommended next steps for affordable housing owners, developers, and policymakers.

**Tear Sheets**
The five case studies are presented in the tear sheets accompanying this manual. Each study includes: an overview of the building's base conditions, a description of two unique retrofit packages developed for that building's particular typology and equipment profile, a cost and benefit matrix, and key takeaways.

- The **Low Carbon retrofit package** provides moderate emissions reductions through key system upgrades and strategic electrification.

- The **No Carbon retrofit package** provides deep emissions reductions through more robust system upgrades and full building electrification, eliminating onsite fossil fuel use.

- Each retrofit package also includes an **optional R-15 EIFS over-cladding scope** to show how implementing more comprehensive envelope upgrades provides additional benefits and savings.

- Energy conservation measures (ECMs) comprising each retrofit package are organized by specific building system categories, including envelope, heating, cooling & ventilation, domestic hot water, lighting, appliances, and renewables.

Using the tear sheets and the Best Practices Manual as references, affordable housing stakeholders can proactively evaluate multiple retrofits based on their own projects to inform decarbonization strategies that ensure short and long-term compliance with the laws and reduce the risk of LL97 penalties where applicable.

It is important to note that every building is unique. Teams must develop and implement scopes of work that best align with individual project needs including end of system life and LL97 compliance requirements across the building's financing lifecycle.

# affordable housing typologies

The roadmap considers the most common affordable housing typologies in NYC and includes a mixture of pre-war, post-war, and post-1980 low-, mid-, and high-rise buildings as well as rentals, co-ops, and senior housing. The study covers a range of different heating system types, with the hope that building owners can find some relevant aspects to their own property.

The study was limited to buildings for which the team was able to create energy models of, and that could be accurately baselined to a standard "pre-retrofit" level of performance. For this reason, the study does not include any buildings heated by oil or electric resistance, which represent much more favorable conditions for electrification (and as such, are already required to electrify per HPD's Design Guidelines).

## post-1980 mid-rise senior rental

**year built:** 1988
**size:** 99 units · 70,460 sq. ft.
**heating system:** hydronic baseboard
**LL97 path:** Prescriptive Pathway

## pre-war low-rise HDFC co-op

**year built:** 1913
**size:** 40 units · 40,850 sq. ft.
**heating system:** one-pipe steam radiators
**LL97 path:** Prescriptive Pathway

## post-war high-rise Mitchell-Lama

**year built:** 1975
**size:** 182 units · 127,009 sq. ft.
**heating system:** two pipe steam w/baseboard
**LL97 path:** 2035 Pathway

## pre-war low-rise rent stabilized rental

**year built:** 1927
**size:** 52 units · 44,250 sq. ft
**heating system:** hydronic convectors
**LL97 path:** Prescriptive Pathway

## post-1980 high-rise rental

**year built:** 1995
**size:** 198 units · 182,828 sq. ft.
**heating system:** steam PTACs
**LL97 path:** Prescriptive Pathway

# decarbonization measures

This chart, organized by building systems, shows the energy conservation measures (ECMs) associated with each system and the associated benefits and impacts of their implementation. We compiled this matrix and added a simple ranking system of one through five—stars for GHG savings and dollar signs for cost savings—to give a high-level picture of the

| | | benefits | | | |
|---|---|---|---|---|---|
| BUILDING SYSTEM | SYSTEM COMPONENT [1] | GHG SAVINGS | COMFORT | HEALTH/IAQ | ENERGY COST SAVINGS |
| envelope | Roof Insulation | ★★☆☆☆ | low | low | $$ |
| | Windows/Doors | ★★☆☆☆ | high | medium | $$$ |
| | Air Sealing & Weatherization [2] | ★☆☆☆☆ | high | medium | $$ |
| | Exterior Wall Insulation | ★★★★☆ | high | medium | $$$$ |
| HVAC | Heating System Upgrades [2] | ★★☆☆☆ | medium | medium | $$ |
| | Electrify Heating | ★★★★★ | high | high | $ |
| | Pipe Insulation [2] | ★☆☆☆☆ | medium | low | $ |
| | Ventilation Upgrades | ★★☆☆☆ | medium | high | $ / $$<br>(ERV) |
| domestic hot water | Electrify Hot Water Heating | ★★★★☆ | low | high | $$ |
| | Plumbing Fixture Upgrades | ★★★☆☆ | low | low | $$ |
| lighting | Common Area & Exterior Upgrades [2] | ★★☆☆☆ | low | medium | $$ |
| | In-Unit Upgrades | ★★☆☆☆ | low | medium | $$ |
| plug loads | Appliance Upgrades | ★☆☆☆☆ | low | low | $ |
| | Electrify Cooking | ★★☆☆☆ | medium | high | $ |
| | Electrify Laundry | ★☆☆☆☆ | low | medium | $ |
| renewables | Solar PV [3] | ★★★☆☆ | low | low | $$$$ |

overall costs and benefits of each ECM in relation to one another. We wanted to convey that each ECM comes with its own set of costs to implement or maintain, but also its own set of unique benefits that go beyond GHG emissions reductions and include improvements to the health and comfort of a building's occupants and energy cost savings.

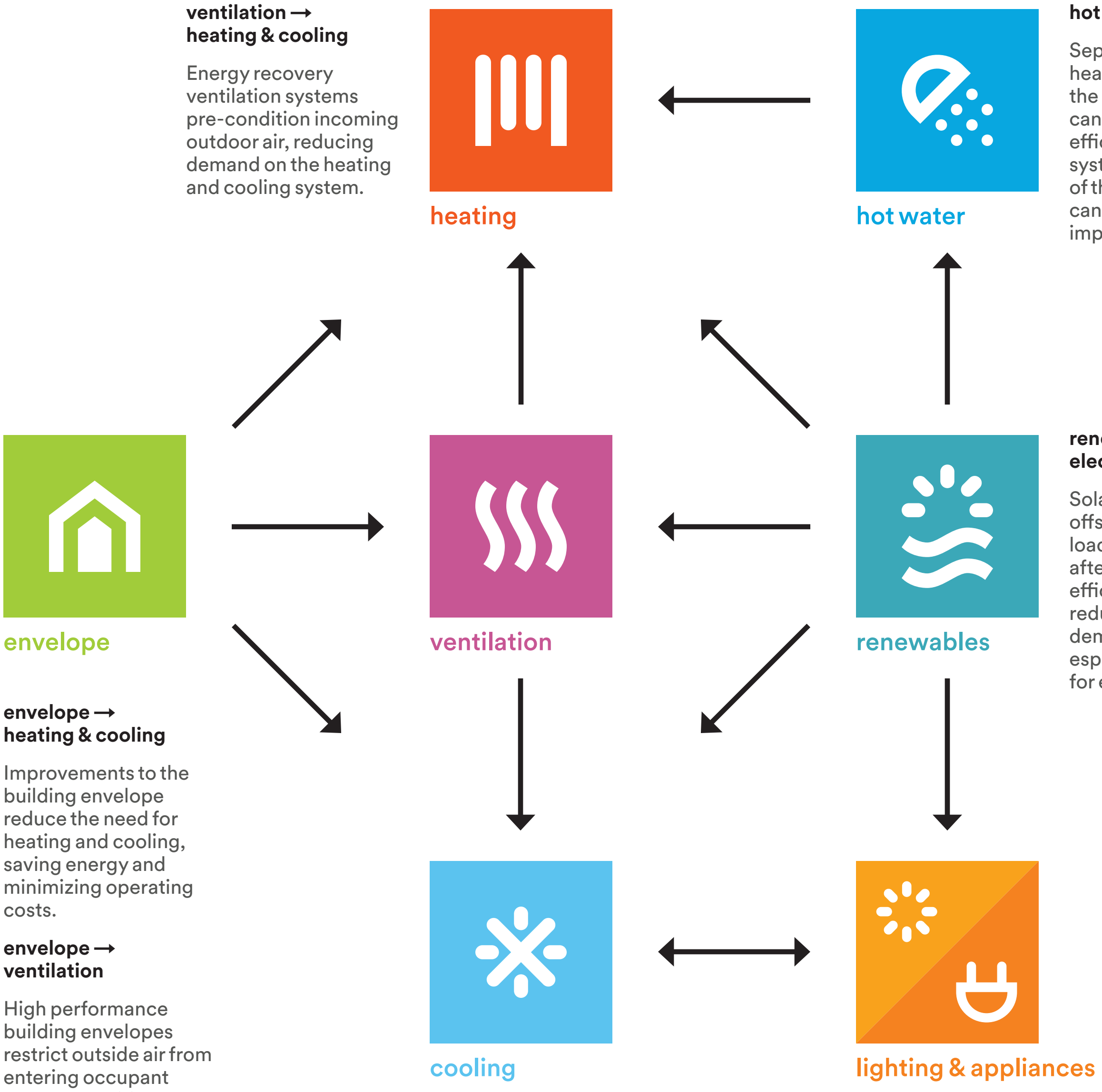
| impacts | | | | when to implement | | |
|---|---|---|---|---|---|---|
| COSTS | LIFESPAN (YRS)[4] | MAINTENANCE | TENANT DISRUPTION | NOW | MID-CYCLE | FUTURE REFI |
| **$$**$$$ | 20 | medium | low | as needed | ✓ | ✓ |
| **$$$$$** | 20 | medium | high | as needed | ✓ | ✓ |
| **$**$$$$ | 15 | medium | low | ✓ | ✓ | ✓ |
| **$$$$$** | 20 | low | medium | if feasible | ☐ | ✓ |
| **$**$$$$ | 10–20 | medium | low | per HPD guidelines[5] | ✓ | ✓ |
| **$$$$**$ | 15 | medium | high | per HPD guidelines[5] | ☐ | ✓ |
| **$**$$$$ | 15 | low | low | ✓ | ✓ | ✓ |
| **$$$**$$ | 15 | medium/ high (ERV) | high | per HPD guidelines[5] | ☐ | ✓ |
| **$$**$$$ | 10 | medium | low | per HPD guidelines[5] | ✓ | ✓ |
| **$**$$$$ | 10 | low | low | ✓ | ✓ | ✓ |
| **$$**$$$ | 15–20 | low | low | ✓ | ☐ | ✓ |
| **$**$$$$ | 15–20 | low | medium | ✓ | ✓ | ✓ |
| **$$**$$$ | 15 | low | medium | as needed | ✓ | ✓ |
| **$$$$**$ | 10 | low | high | per HPD guidelines[5] | ☐ | ✓ |
| **$$**$$$ | 10 | medium | low | as needed | ✓ | ✓ |
| **$$**$$$ | 20–25 | low | low | per HPD SWF[3] | ✓ | ✓ |

1 “Upgrades” denotes improving the efficiency of the existing system/equipment, while “Electrify” involves installing equipment that utilizes electricity, rather than fossil fuels, as a power source
2 Denotes item that is a LL97 Prescriptive Energy Conservation Measure
3 Solar is required by LL92/94 and HPD's Solar Where Feasible (SWF) Mandate
4 Lifespan is estimated following the New York State Approach for Estimating Energy Savings from Energy Efficiency Programs – Technical Resource Manual v6.1
5 “Per HPD Guidelines” are items that are required based on Rehab Classification and HPD Program

## building systems

Building systems are highly interdependent and improvements to each system should be considered holistically.

This diagram highlights the interactive relationships between different building systems examined throughout this study.



**ventilation → heating & cooling**

Energy recovery ventilation systems pre-condition incoming outdoor air, reducing demand on the heating and cooling system.

**hot water → heating**

Separating hot water heating system from the building's heating can improve the efficiency of both systems. Electrification of the hot water system can have a significant impact on emissions.

**renewables → all electrical systems**

Solar PV can help offset the electrical loads that remain after envelope and efficiency have reduced energy demand. PV is especially beneficial for electric buildings.

**envelope → heating & cooling**

Improvements to the building envelope reduce the need for heating and cooling, saving energy and minimizing operating costs.

**envelope → ventilation**

High performance building envelopes restrict outside air from entering occupant spaces, requiring balanced ventilation systems to ensure fresh air supply.

**cooling → lighting & appliances**

Reducing loads from lighting, appliances, and solar heat gain can drive down cooling costs.

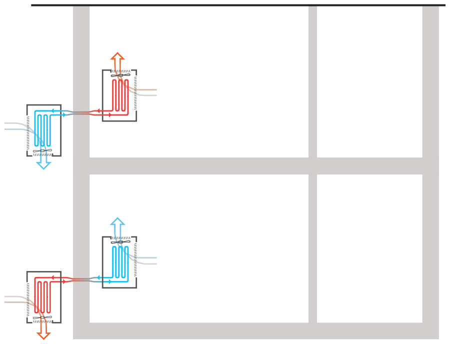
**lighting & appliances → cooling**

Efficient lighting and appliances emit less heat than conventional versions, reducing the demand on the cooling systems.

# heating & cooling

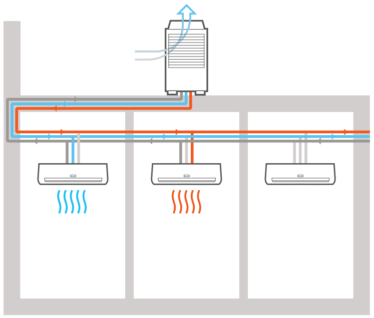
Heating and cooling often represent up to 50% of a building's total energy use and are a leading contributor to greenhouse gas (GHG) emissions. To realize a Low or No Carbon retrofit, heating and cooling systems will need to transition to electricity as a fuel source, which can be achieved with heat pumps, which can generally be categorized into the following:

split system



packaged system

central system



**Unitized Systems** involve standalone air source heat pumps that provide heating and cooling to a space, varying in size from a single room, up to an entire apartment.

- **Split systems**
  Consist of (1) outdoor unit paired with either (1) indoor unit (mini-split), or a few indoor units (multi-split). Outdoor units transfer energy to, or from, the indoor units via refrigerant.

- **Packaged Systems**
  Standalone heat pumps that fit into existing apartment penetrations, like through-wall AC sleeves. Refrigerant is contained completely within the equipment, and utilizes outdoor air to transfer energy to, or from, the room being conditioned.

**Central Systems** replace existing central heating plants, like gas boilers, and use an intermediate—water (hydronic) or refrigerant—to exchange and move energy throughout the building. Some hydronic systems could permit use of the existing terminal units such as a fin tube baseboard, but many require in-unit work to provide new terminal units to transfer energy (fan coil unit, water source heat pump, VRF air handling unit).

See *Heat Pumps for Heating and Hot Water* in the Appendix for more information about different types of heating/cooling equipment.

## considerations

### Envelope Upgrades

Heating and cooling demand can be drastically reduced, and thus drive down equipment costs, energy costs, and GHG emissions, when paired with building envelope upgrades. See the Envelope section for more information.

### Electrical Capacity & Billing

Converting to electric equipment and appliances typically requires electrical service upgrades as well as upgrades inside of apartments. This may also impact utility billing and billing arrangements (e.g., converting to electric stoves or resident-paid electric heat pumps for heating).

**Refrigerant Systems**
Refrigerant systems must be designed carefully to minimize the total piping lengths required. An effective design will reduce the potential health hazard from leaks, which also decrease indoor air quality, and increase GHG emissions.

**Proper Sizing**
Determining the appropriate capacity of space conditioning equipment is key to achieving optimal energy efficiency, GHG reductions, and occupant comfort.

### key takeaways

- Electrification of heating and cooling – particularly in conjunction with envelope upgrades — can drastically reduce a building's energy demand, operational expenditure, and improve indoor air quality.
- Installing heat pumps will likely require electrical services upgrades.
- Metering and billing arrangements must be carefully considered when electrifying heating.

## domestic hot water

Domestic hot water (DHW) systems typically represent approximately 25% of a building's total energy use. To realize a full Low or No Carbon retrofit, DHW systems will need to transition from fossil fuel-based to electricity-based systems. In addition, a building's energy use can also be reduced by completing a low flow plumbing fixture retrofit to replace all faucets and showerheads. This should always be evaluated ahead of, or in parallel with, DHW equipment replacement.

Electrification of DHW equipment can be achieved by air-to-water heat pumps (central or unitized), or a hybrid air-to-water plus water-to-water system. These systems are often paired with supplemental electrical resistance heating for backup.

**Air-to-water heat pumps (AWHP)** can be installed outside, either on the roof or on grade, and connected to storage tanks in the basement, or in other service spaces.

**A hybrid air-to-water plus water-to-water system** can be installed completely indoors, or with the air source equipment outdoors, and water source equipment inside with a storage tank in the basement or another service space.

See the *Electric Systems Matrix* in the Appendix for more information about different types of domestic hot water equipment.

image: Colmac

## considerations

Key parameters to consider when electrifying a DHW system are the size of the building, typical DHW demand, and the available indoor and outdoor space for equipment, including storage tanks. For example, a central system in a mechanical room may require ducting to the outdoors to ensure adequate air flow for DHW production during maximum demand.

Electrification of DHW does not require work inside of apartments and can be completed with, or separately, from heating and cooling electrification, depending on available capital and project phasing.

## key takeaways

- **Electrification of DHW addresses a normally energy intensive aspect of any building and can have significant impact on GHG emissions.**
- **Low flow fixtures reduce hot water use, allowing for smaller and less costly DHW equipment.**

# envelope

An improved building envelope is a critical component of every successful Low or No Carbon retrofit. The envelope is highly connected to other building systems, especially heating and cooling. Air sealing, high performance insulation and windows all provide ways to improve tenant comfort and reduce heating and cooling demand.

### Air Sealing

Air sealing is a required prescriptive energy conservation measure (ECM) of LL97 and is mandatory on all HPD rehabilitation scopes, but it should be done on all building upgrades as it is a very cost-effective method to reduce energy consumption and improve indoor air quality.

### Over-cladding/Continuous Insulation

Many old buildings lack insulation in their existing wall assembly making it especially relevant for retrofits. Exterior insulation finish systems (EIFS) or rainscreen systems are often higher performing and preferred to interior insulation. Over-cladding can be designed with cavities to accommodate ductwork, piping, and conduit, providing a path for electrifying HVAC systems in existing buildings. Over-cladding should never be installed without proper building ventilation and should be designed with future HVAC systems in mind if the project is being phased.

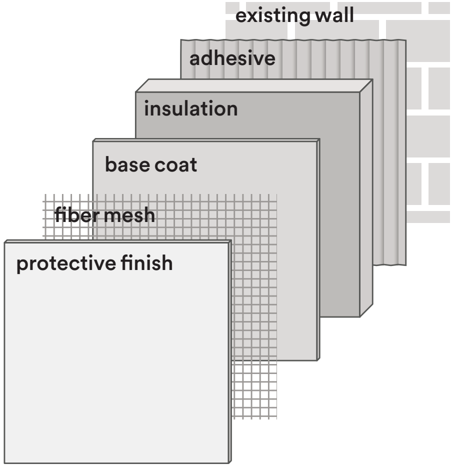


image: OCV Architects

**High Performance Windows**
High performance windows have a tremendous impact on the quality of the interior environment. They are especially necessary if a project is electrifying a building's heating systems. Double or triple pane casement style windows are recommended, if a budget allows, because the design enables a much lower air infiltration rate. Alternative window types of similar performance are available if thru-wall penetrations are required for unitized heating/cooling equipment.

### considerations

Any plan to add over-cladding must be coordinated with zoning and lot line restrictions as well as any potential oversight by local authorities such as historic preservation ordinances. Over-cladding must also be carefully coordinated with the phasing and layout of exterior refrigerant piping for HVAC systems if that is being considered.

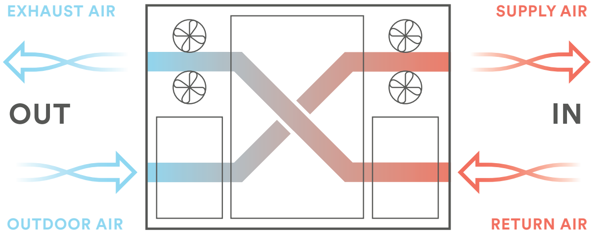
### key takeaways

- **Envelope upgrades are a key contributor to improving occupant comfort and reducing heating and cooling demand.**
- **Air sealing and high performance windows are necessary if a project is electrifying a building's heating systems.**
- **Increased wall insulation can greatly increase building performance but can be challenging: Interior insulation is difficult to implement on tenant-in-place retrofits; and exterior insulation (over-cladding) can be costly and require easements at property lines.**

## ventilation

Ventilation plays a critical role in indoor air quality and works in tandem with an airtight envelope. A proper Low or No Carbon retrofit must have balanced ventilation that delivers filtered air directly to tenant spaces, while removing stale air from kitchens, baths, and laundry rooms.

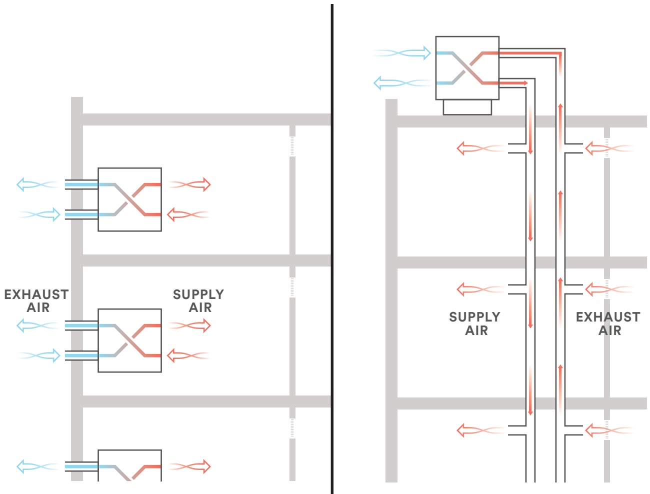
**Mechanical Ventilation**
Mechanical ventilation has been proven to improve indoor air quality but is atypical for pre-war buildings, and is often poorly functioning "exhaust only" ventilation where it does exist.



**Balanced Ventilation with ERVs**
Unlike exhaust-only systems, balanced ventilation also brings in filtered outdoor air, ideally through MERV-rated filters, to remove pollutants. Energy recovery ventilators (ERV) are a type of heat exchanger that pre-heats or pre-cools incoming outdoor air, significantly reducing the demand on heating and cooling equipment.

There are two main types of energy recovery ventilation (ERV) systems: unitized and central.

- **Unitized ERVs** are lower capacity units installed in apartments and common areas, which require multiple penetrations in the exterior walls and complicate maintenance by increasing the number of filters and units to be monitored. Building staff will need to disrupt tenant homes multiple times a year to replace filters in this setup.
- **Central ERVs** are often installed on rooftops and serve multiple floors of a building. They are easier to access and maintain but are costly and dependent on sufficient existing ducting shaft area.



unitized ERVs

central ERVs

It's important to remember that airtightness and ventilation are directly connected. Older exhaust-only ventilation systems rely on leaky exteriors and gaps between units to draw air out of the building. If the airtightness of a building is improved, existing ventilation systems could result in unhygienic or inefficient conditions. The optimal ventilation arrangement will need to be determined for each unique building.

### key takeaways

- **Installing or upgrading mechanical ventilation is critical, particularly when the building envelope is also upgraded to be more airtight.**
- **ERVs are an ideal ventilation system as they both remove stale air and provide filtered fresh air, while reducing energy use.**
- **Installing new ventilation in buildings where none exists can be costly and invasive but is critical to any Low or No Carbon retrofit and to maintain occupant health and comfort.**

## lighting & appliances

Efficiency upgrades to lighting and appliances can occur at virtually any time and are an easy strategy for reducing energy use. Replacing gas cooking appliances with electric or induction versions ensures the health and well-being of occupants and is often the last barrier to full decarbonization.

### LED lighting & Controls

All interior and exterior lighting should be switched to LED. Occupancy or vacancy controls should be used throughout the common areas, such as stairs and cooridors, and daylight controls should be considered for added savings and control. Exterior lighting should be controlled by an exterior photocell with a timeclock for backup.

**Cooking Appliances**
Gas stove tops are a significant contributor to poor indoor air quality and can contribute to chronic respiratory problems, especially in children. Electric cooking improves indoor air quality, eliminates the danger of gas leaks, and reduces a building's GHG emissions. Induction cooktops are significantly more efficient but also more expensive.

**Laundry Appliances**
Upgrading to more efficient ENERGY STAR washers is an easy way to reduce a building's energy demand since they are often in use. Smaller capacity electric heat pump dryers are available and commercial capacity dryers are in development.

### considerations

Replacing gas stoves will likely require an electrical service upgrade to each apartment, which can add upfront costs to the improvement, but the improved efficiency will generate operational expenditure and carbon emissions savings. Laundry appliance upgrades will likewise require electrical improvements. Careful consideration should also be paid to laundry room heating loads if heat pump dryers are removing room heat to dry clothes. Additional supplementary heat may be required.

### key takeaways

- Switching all lighting to LED and adding occupancy-based controls for common areas is a simple and easy way to reduce energy and is required by HPD.
- Replacing gas stoves with electric or induction versions greatly improves indoor air quality and eliminates the danger of gas leaks, but typically requires electrical service upgrades to each apartment.

## renewables

The use of renewables like solar can offset a portion of a building's electrical load and are heavily incentivized through federal, state, and city programs. As of 2024, solar will be mandatory, where feasible, on all roof assemblies being replaced in NYC per Local Laws 92 and 94.

Rooftop solar systems and electric battery storage are the most prevalent renewable energy options for multifamily buildings in NYC.

**Solar Photovoltaic (PV)**
A solar photovoltaic system generates electricity for use in the building or to be distributed back to the grid as in a community solar program. Often, electricity produced on-site is used to offset common

area electrical consumption like corridor and stairwell lighting, common area space lighting and plug loads. Systems can also be configured to offset dwelling unit consumption and/or to export electricity back to the grid.

### Battery Storage

Battery storage provides an opportunity for peak energy load shifting as well as storm resiliency by supplying backup power. Battery storage is currently the only option for a truly fully electrified building to also have backup or emergency power, but FDNY permitting requirements can be very challenging. Consideration of this technology should include an understanding that additional soft costs and time will be required throughout the course of the project.

## considerations

Most NYC buildings with rooftop solar PV systems only offset a portion of the annual common area electricity consumption. Some buildings may not be able to host on-site solar but can still offset residential energy use by up to 10% through the use of a community solar program.

## key takeaways

- Adding a solar PV system and a battery for backup storage can both offset a percentage of a building’s electrical load and make it more resilient against future extreme weather events.
- As of 2024, solar will be mandatory on all roof assemblies that are being replaced, per Local Laws 92 and 94.

# summary & findings

| building typology | key takeaways |
|---|---|
| **1 post-1980 mid-rise senior rental**<br><br>**LL97 path** Prescriptive Pathway<br>**existing heating system** gas-hydronic baseboards<br>**proposed heating system** Packaged cold climate heat pump (PTHP) | Simple, freestanding, low-rise buildings can be a good fit for prefabricated Deep Energy Retrofit projects like RetrofitNY, but the high costs are an impediment; whereas the Low Carbon retrofit package would comply with LL97 2030 emissions limits. Adding PTHPs into existing AC sleeves, while retaining the existing gas/hydronic heating system, can provide cooling to vulnerable seniors while enabling a future cost-effective phase-out of fossil-fuels when the building is overclad and/or the boiler is converted to a heat pump. |
| **2 post-war high-rise Mitchell-Lama**<br><br>**LL97 path** 2035 Pathway<br>**existing heating system** two-pipe steam with baseboards<br>**proposed heating system** central VRF | Many Mitchell-Lamas (ML) have poorly performing steam systems and building envelopes, so the Low Carbon retrofit package, which would meet the 2035 emissions limits, may not meet the 2040 limits, leading to penalties within a 15-year financing cycle. However, by phasing in electric heating, after 2035, penalties could be avoided. Leaving the steam system in place provides a temporary backup, until the building can be fully electrified and insulated, before the 2050 deadline. As a master-metered building, this wouldn't cause a shift in heating costs to the tenants. |
| **3 pre-war low-rise rent stabilized rental**<br><br>**LL97 path** Prescriptive Pathway<br>**existing heating system** gas-hydronic convectors<br>**proposed heating system** central ASHP & WSHP | Many low-rise rentals can electrify hydronic heating systems without significant tenant disruption. Because the Low Carbon retrofit package would comply with 2030 emissions limits, and electrifying heating will increase utility costs, these buildings should typically focus on insulation and air sealing to improve comfort and reduce utility costs. They should also consider electrifying cooking and/or installing mechanical ventilation to improve comfort and air quality in the near term and convert to electric heating when the boiler fails. |
| **4 pre-war low-rise HDFC co-op**<br><br>**LL97 path** Prescriptive Pathway<br>**existing heating system** one-pipe steam radiators<br>**proposed heating system** mini-split heat pumps | Low-rise co-ops are often a good fit for resident-paid, multi-split heat pumps because utility cost-shifting is not an issue for them; however, the Low Carbon retrofit package complies with 2030 emissions limits without electrifying heating, which would increase utility costs. Focusing on envelope improvements, ventilation, and electrification of cooking now can reduce utility costs while improving comfort and air quality. These building should develop a plan for future electrification, anticipating laws that will phase out fossil-fuel equipment. |
| **5 post-1980 high-rise rental**<br><br>**LL97 path** Prescriptive Pathway<br>**existing heating system** steam PTACs<br>**proposed heating system** packaged cold climate heat pumps (PTHPs) | The Low Carbon retrofit package for high rise buildings complies with 2030 emissions limits, because improvements to the envelope and ventilation system can significantly reduce their energy use. Replacing steam PTACs with cold-climate PTHPs is a simple future retrofit project. Over-cladding, especially if it can offset LL11 costs, can yield additional savings and allow for conversions from exhaust-only ventilation to ERVs within the cavity behind the cladding. |

|  | low carbon retrofit |  | no carbon retrofit |  |
|---|---|---|---|---|
|  | W/OUT EIFS | W/ EIFS | W/OUT EIFS | W/ EIFS |
| GHG Emissions Reductions | 53% | 65% | 100% | 100% |
| Meets 2030 GHG limits? | ✓ | ✓ | ✓ | ✓ |
| Meets 2035 GHG limits? | ✓ | ✓ | ✓ | ✓ |
| Meets 2040 GHG limits* | ✓ | ✓ | ✓ | ✓ |
| Estimated Cost per dwelling unit | $38,360 | $48,360 | $56,050 | $66,050 |
| Estimated Savings per dwelling unit Owner / Tenant | $320 / $10 | $400 / $50 | $95 / $0 | $200 / $10 |
| GHG Emissions Reductions | 46% | 54% | 100% | 100% |
| Meets 2030 GHG limits? | ✓ | ✓ | ✓ | ✓ |
| Meets 2035 GHG limits? | ✓ | ✓ | ✓ | ✓ |
| Meets 2040 GHG limits* | ☐ | ☐ | ✓ | ✓ |
| Estimated Cost per dwelling unit** | $31,560 | $48,810 | $55,010 | $72,260 |
| Estimated Savings per dwelling unit Owner / Tenant | $300 / $125 | $350 / $125 | $0 / $100 | $50 / $100 |
| GHG Emissions Reductions | 59% | 62% | 100% | 100% |
| Meets 2030 GHG limits? | ✓ | ✓ | ✓ | ✓ |
| Meets 2035 GHG limits? | ✓ | ✓ | ✓ | ✓ |
| Meets 2040 GHG limits* | ✓ | ✓ | ✓ | ✓ |
| Estimated Cost per dwelling unit** | $42,050 | $55,850 | $82,650 | $96,450 |
| Estimated Savings per dwelling unit Owner / Tenant | $425 / $10 | $450 / $25 | -$45 / $80 | $25 / $80 |
| GHG Emissions Reductions | 52% | 57% | 100% | 100% |
| Meets 2030 GHG limits? | ✓ | ✓ | ✓ | ✓ |
| Meets 2035 GHG limits? | ✓ | ✓ | ✓ | ✓ |
| Meets 2040 GHG limits* | ☐ | ☐ | ✓ | ✓ |
| Estimated Cost per dwelling unit** | $48,050 | $81,900 | $107,300 | $141,150 |
| Estimated Savings per dwelling unit Owner / Tenant | $225 / $150 | $250 / $150 | -$200 / $200 | -$125 / $200 |
| GHG Emissions Reductions | 56% | 58% | 100% | 100% |
| Meets 2030 GHG limits? | ✓ | ✓ | ✓ | ✓ |
| Meets 2035 GHG limits? | ✓ | ✓ | ✓ | ✓ |
| Meets 2040 GHG limits* | ✓ | ✓ | ✓ | ✓ |
| Estimated Cost per dwelling unit** | $26,800 | $43,600 | $74,600 | $91,400 |
| Estimated Savings per dwelling unit Owner / Tenant | $450 / $400 | $475 / $450 | $250 / $300 | $275 / $325 |

---

* Conservatively assumes grid is 50% cleaner than the 2030 grid.

** Incentives and under-writing savings are not factored into cost.

### Assessing Local Law 97 Compliance:

The Low Carbon retrofit packages outlined in this study provide emissions reductions greater than what most affordable housing projects will require to comply with LL97 emissions limits.

- **Buildings subject to the Prescriptive Pathway** will only need to meet the 2030 limits, yet the *Low Carbon* retrofit packages result in emissions reductions well below the 2040 limits.
- **Buildings subject to the 2035 Pathway** (e.g. Mitchell-Lama projects) will need to comply with emissions limits starting in 2035. This is the only case study where the *Low Carbon* retrofit pathway is not below thet 2040 cap. These project types will need to implement deeper retrofit packages or reserve funding to implement additional decarbonization measures ahead of the 2040 deadline.
- As climate laws and decarbonization goals evolve, building owners and project teams will need to reaffirm that a building remains in compliance and reassess its decarbonization retrofit plan as needed.

### The electric grid must decarbonize too.

For a building to be completely emissions-free it must have no onsite fossil fuel use and the grid providing electricity must also be fossil fuel-free. How quickly the electricity grid transitions to renewable sources will affect retrofit planning since emission reductions from electrification will not be fully realized until the grid is decarbonized.

### Heat pumps may impact utility payments.

Integrating certain heat pump systems may affect utility payment structure, which may be in conflict with current utility policies for affordable housing. Choosing an appropriate system requires careful planning and consideration.

Note: All Case Studies in this study assume owner-paid heating and resident-paid cooling.

### Electrifying systems can reduce savings, despite other benefits.

Electrification can reduce potential energy cost savings or could even increase utility costs, especially if building-wide efficiency is not included. Note that for buildings converting from oil or electric-resistance heat, which are not included in this study, savings would be significantly higher.

### Retrofit Package Energy Cost Savings

The estimated annual savings per dwelling unit for each scope is:

**Low Carbon without EIFS:**
**$225 to $400**

**Low Carbon with EIFS:**
**$250 to $475**

**No Carbon without EIFS:**
**-$200 to $250**

**No Carbon w/ EIFS:**
**-$125 to $30**

### Low and No Carbon retrofits often cost more than "Business As Usual" retrofits.

Electrification is significantly more expensive than "business as usual" (BAU) fossil fuel system upgrades since associated electrical upgrades and structural work are often required to integrate electric heat pumps and appliances into older buildings.

Costs for implementing measures such as balanced ventilation and over-cladding can put the more ambitious decarbonization retrofit packages out of reach for many projects.

### Retrofit Package Costs

The average normalized* first costs for each retrofit package are:

- **BAU: $25K**
- **Low Carbon: $31K**
- **Low Carbon w/ EIFS: $46K**
- **No Carbon: $62K**
- **No Carbon w/ EIFS: $76K**

*Normalized for apartment size

## Utility Rates

Relatively high electricity rates in NYC make it difficult to justify electrification, especially for gas heated buildings. However, recent utility prices for oil and gas have increased faster than electricity rates making conversions from fossil fuels—especially oil—or electric resistance systems more economically sound.

## The Split Incentive Problem

For rental properties, a misalignment occurs where the party paying a utility fee is not the same entity that benefits from investment or conservation efforts. For instance, when owners are paying, they're more likely to invest in efficiency and maintenance efforts, but tenants are not incentivized to conserve energy. Conversely, when tenants are paying, they're more likely to conserve energy, but owners are not incentivized to invest in efficiency and maintenance efforts. The results are either better buildings or better behavior, but not both.

## Utility Policies & Cost Shifting

Traditionally in NYC rent-regulated housing, heating is paid by owners and cooling by residents. Tenant-paid utilities require utility allowances that ensure total housing costs are below 30% of income. Until recently, utility allowances for tenant-paid heat have been too high to underwrite—e.g. rents would be too low to cover expenses. In addition to accurate utility allowances, agency approval is required to shift heating costs from owner to tenants.

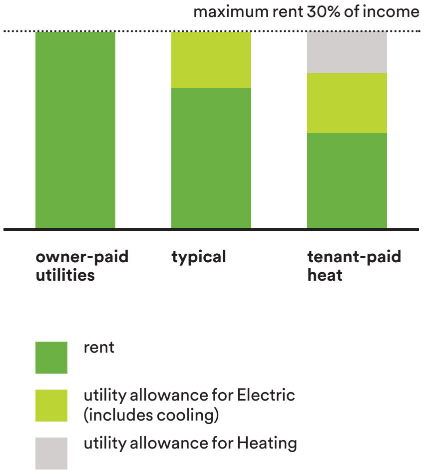
## Addressing Utility Challenges

HPD is working to overcome these barriers by (1) advocating for fair utility rates for beneficial electrification, (2) developing and piloting appropriate utility allowances for electrification, and (3) releasing an Electric Heating Policy to protect residents. Although policies still limit cost shifting, it is a step in the right direction. Refer to Resources section for HPD's Electric Heating Policy.

## Addressing Equipment Challenges

Because most heat pumps provide both heating and cooling, choosing an appropriate system and metering structure to address these challenges is critical. The chart below can help:

**Rent and Utility Allowances**



## Heat Pump Metering/Billing Arrangements & Policy Considerations

| | |
|---|---|
| System is on house meter | • Owner is more likely to invest in building/system efficiency and maintenance<br>• Residents are less likely to conserve energy since they do not pay the utility fees<br>• Owner is hesitant to take on cooling costs which are normally paid by residents |
| System is on resident's meter* | • Owner is less likely to invest in building/system efficiency and maintenance<br>• Residents are more likely to conserve energy since they pay the utility fees<br>• Heating is not typically paid by residents in affordable housing* |
| System is on house meter, residents sub-metered for cooling and/or heating* | • Owner is likely to invest in building/system efficiency and maintenance<br>• Residents are likely to conserve energy on utility fees they pay<br>• Submetering adds cost and owners find it difficult to collect utility fees |
| Heating system is physically separate or wired separately from cooling system | • Owner is likely to invest in building/system efficiency and maintenance<br>• Residents likely to install low cost, low efficiency ACs if owners do not also provide cooling. Efficiency and comfort issues likely to arise if ACs are poorly installed<br>• Dual / split wiring adds cost and complexity for most air-source heat pumps |

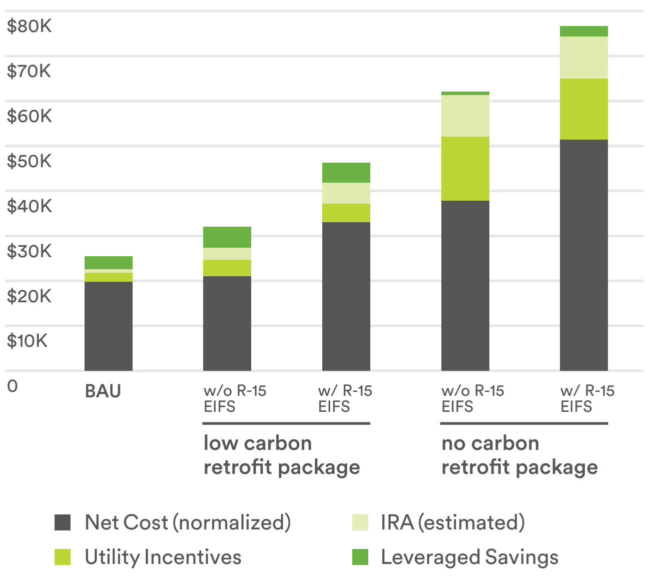
*HPD policy only allows resident paid heat in certain situations. See HPD's Electric Heating Policy for more info.

## Offsetting Costs with Incentives

Leveraging incentives and underwriting energy savings can drastically reduce incremental costs to improve the cost-effectiveness of the retrofit packages.

- Incentive programs like NYS Affordable Multifamily Energy Efficiency Program (AMEEP), Clean Heat, and Low Carbon Pathways can provide thousands of dollars/ DU for efficiency and electrification.
- The Inflation Reduction Act (IRA) includes provisions for new tax credits and efficiency/ electrification rebates.
- Every dollar of energy savings can leverage as much as $10 in additional debt to cover improvements.
- Programs like the HPD Retrofit Electrification Pilot and NYSERDA's RetrofitNY program can provide substantial funding for deep decarbonization (not shown in the chart ).

**Scope Cost Comparison: Full Cost vs. Net Cost (per apt.)**



## Offsetting Costs by Factoring in Life Cycle Considerations

**Factoring a project's current and future needs can help offset costs of deeper retrofits.**

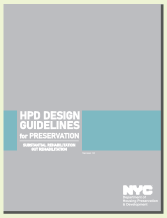
**Future Laws:** To anticipate future laws that would phase out fossil-fuel equipment, owners need to determine whether investing in fossil-fueled systems makes sense and whether a project will be at risk if a system fails and cannot be easily electrified in the future.

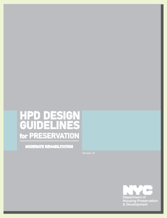
**Inspections & Building Maintenance:** NYC's local laws require ongoing (and costly) inspections and maintenance of building infrastructure. LL11 requires buildings above six stories to inspect and repair facades every 5 years and can cost hundreds of thousands of dollars per cycle. Over-cladding a building reduces these costs and can result in significant net savings over time. Local Law 152 requires gas line inspections every 5 years. Buildings can leverage the cost of gas line inspections or repairs to electrify cooking or other systems.

**Flood Risk:** Buildings in NYC's current and future flood zones face increasing risk of equipment damage during flood events. Converting a building's heating system to roof-mounted heat pumps can mitigate the risk of equipment replacement delays and costs in the case of severe flooding.

**HPD's Design Guidelines require smart investments.**

The Guidelines establish mandatory criteria to promote health, safety and efficiency for all HPD projects, including electrification where it makes the most sense. This includes electrification based on financial logic such as replacing oil-fired heating systems with heat pumps or avoiding making major investments in steam systems that can't be electrified in the future.





## Phasing Based on System Interdependencies

Despite best intentions, most projects will not be able to implement the No Carbon retrofit packages right away and will need to select a scope that is most beneficial and affordable. Understanding the interdependencies of key systems can help teams plan accordingly.

### Envelope

**Over-cladding** has a major impact on all systems: it reduces the heating and cooling loads, equipment size and utility cost. It can also provide space to run HVAC piping and ductwork. Projects that will over-clad in the future should plan for these impacts.

**Window choice** may be affected by current/ future heating equipment — e.g., a window that needs to accommodate an air conditioner now but would need to be high performance in the future.

### Ventilation

Incorporating ventilation, especially installing ERVs, is very difficult to accommodate in a retrofit. Even buildings with ventilation don't have adequate chases for ERVs. Consider how a future over-cladding project might accommodate ventilation ductwork in the future.

### Heating Systems

Projects that postpone electrification of heating systems should carefully consider other measures to ensure that decisions made today don't reduce the building's ability to cost-effectively electrify in the future.

### Electric Readiness

For buildings that aren't electrifying now, making buildings "Electric Ready" is critical to streamline future upgrades. HPD's Design Guidelines outline strategies for Electric Readiness.

## Example Phased Scenarios

The following scenarios demonstrate how different buildings may consider phasing based on LL97 requirements, heating system type, or other capital needs:

| | What to do now: | What to do next: | What to do at refinancing: |
|---|---|---|---|
| Project subject to the 2035 Pathway where electrification isn't financially viable | Implement a Low Carbon Retrofit Package | Phase in or partially electrify heating ahead of the 2040 compliance deadline | Insulate and ventilate building, and decommission (remove) existing fossil fuel system before 2050 compliance deadline. |
| Buildings with oil or electric resistance heat | Implement a No Carbon Retrofit Package | Replace electric equipment in kind as needed | Replace systems as needed and overclad if economics allow |
| Buildings with gas-hydronic heating where electrification isn't financially viable | Implement a Low Carbon Retrofit Package | If boiler fails, replace with minimally disruptive central heat pump to comply with new laws | Insulate building & add ventilation |
| Buildings needing significant facade work, e.g. to comply with LL11 | Implement a Low Carbon w/ EIFS Retrofit Package | Maintain boiler until refinancing | At system end of life: Refinance and electrify heating system |

# looking forward

## Innovation is key to scaling up decarbonization and is already underway to respond to Local Law 97's market signals.

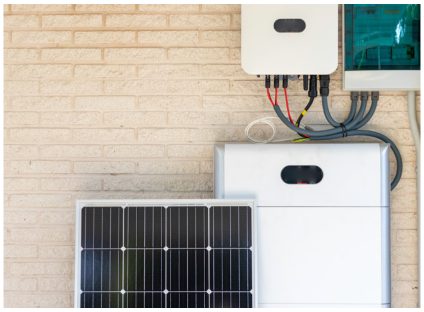
**Some of the most promising innovations include:**

### Better Hardware

- NYCHA's Clean Heat for All Challenge leveraged its scale to push the market to create an affordable cold climate heat pump that can be easily installed through a window opening without requiring electrical upgrades or condensate drainage, which greatly reduces installation costs. Although promising, the system is not yet on the market, and currently is set up for tenant-paid heating.
- Several start-ups are experimenting with induction stoves with battery backup that can be plugged into a regular 110V outlet, reducing the need for costly electrical upgrades.
- Solar energy storage increases energy resilience and is critical for full building electrification, but in NYC there are challenges in getting batteries approved. Emerging technology and policy changes will be needed to enable this critical resource.

### Better Software

Smart building systems and controls that automate processes and track actionable information can have significant impact on energy use, GHG emissions, and occupant comfort, and enable buildings to avoid high electricity demand costs.



left image: Jordan Bonomo

### Integrated Solutions

NYSERDA's RetrofitNY program is modeled on EnergieSprong, a highly successful program in the Netherlands that relies on a "one-stop shop" prefabricated approach to deep energy retrofits that can be installed with minimal disturbance to residents.

### Innovation in policy and financing will also be a critical tool to scaling up equitable decarbonization.

**Incentives as a Source**
There has been great interest in moving toward more integrated incentive delivery approach so that incentives can be consolidated and recognized as construction source financing—including through programs like HPD's Retrofit Electrification Pilot and HCR's Clean Energy Initiative.

**Equitable utility rates and protections to support beneficial electrification**
New York State has publicly announced intentions to cap electric bills at 6% of income and is advocating for electric rates that favor high-efficiency electric heating.

**Cooling as a right**
In the age of climate change, air conditioning may be a necessity for human survival. Cooling is already required per HPD's New Construction Design Guidelines and there is increasing support for laws to ensure that cooling is mandatory.

In addition to meeting New York's ambitious climate goals, building decarbonization has many benefits. For example, implementing a Low or No Carbon retrofit that pairs system upgrades and electrification not only reduces GHG emissions, it:

- improves local air quality and reduces health risks, like asthma
- contributes to the safety and comfort of residents
- reduces operational costs for owners and residents
- increases the resiliency of the building and the electric grid

In order to avert the most harrowing dangers of a changing climate, New York City must reduce the GHG emissions from all of its buildings, including those in the affordable housing sector. This undertaking presents an enormous challenge, but also an incredible opportunity. With the resources from this project, affordable housing project teams will not only be able to reduce their building's emissions and meet regulatory requirements, but also improve their residents' lives and ensure a more resilient and equitable future.

### Roadmap for Decarbonization

1. **calculate carbon emissions**

   Calculate the building's annual estimated GHG emissions using the BE-Ex Carbon Calculator: www.be-exchange.org/calculator

2. **compare to the LL97 emissions limits**

   Compare the building's current calculated GHG emissions with LL97 limits and determine what reduction is required for compliance.

3. **develop a retrofit master plan**

   Develop a scope of energy conservation measures (ECMs) that are selected and phased to align with building operational and system needs, and financing cycles.

4. **implement building decarbonization measures**

# methodology

The following provides insight into the methodology behind the data provided in this Best Practices Manual and its accompanying Tear Sheets.

## Energy Modeling

All energy modeling for the project was completed with Trane Trace 700 version 6.3.5 using typical metrological year weather data (TMY3) for John F. Kennedy (JFK) Airport.

A baseline building energy model was generated for each building and calibrated to whole building weather normalized annual utility consumption data based on at least a 12-month period. Any residential space energy consumption correlated with a commercial space utility meter was estimated based on the space type.

## HVAC specifications

Energy modeling of all heating, cooling, and DHW equipment is based on equipment capacities and performance data published by manufacturers and compared with published Air conditioning, Heating, and Refrigeration Institute (AHRI) performance data if available. Coefficient of Performance (COP) is the typical heating performance metric, while Energy Efficiency Ratio (EER) is the typical cooling performance metric. Any equipment (heating or DHW) with electric resistance heating was modeled as backup or supplemental capacity based on the intended system operation.

## Basis of Design (BOD) Equipment

**Heating and Cooling**

- Unitized package heat pumps:
  - Ephoca HPAC 2.0 cold climate unitized heat pump with electric resistance supplemental/back-up heating, without energy recovery ventilation
  - Ice Air RSXC series packaged terminal heat pumps (PTHP) with electric resistance backup/supplemental heating capacity
- Central VRF with heat recovery: Daikin VRV IV series
- Hybrid air source and water source heat pump system: Aermec NYK series air source heat pumps + Aermec WWB series water source heat pumps
- Mini-split VRF system: Daikin RXSQ series

**Domestic Hot Water**

- Air to water heat pump: Colmac CxV series or Aermec NYK series
- Water to water heat pump: Colmac CxW series

## Utility Rates

**Residential**
Utility rate analysis was completed using an all-in "blended" rate for electricity and gas, to account for seasonal average costs, demand charges, taxes, and other fees. A 3% gas and electric rate escalation was used for the economic analysis.

**Electricity**
Typical electricity service class (SC) classifications for the studied multifamily buildings:

- SC2 General – Small: Applicable for light, heat, power sources that do not exceed 10kW
- SC9 General – Large: Applicable for light, heat, power sources that exceed 10kW

Electricity rates used for this analysis:

- All-in electricity rate – owner paid meter: $0.21/kWh
- All-in electricity rate – tenant paid meter: $0.24/kWh

**Natural Gas**
The blended rate used for the analysis is $1.30 per therm.

## Key Assumptions

Local Law 97 end use emissions factors and emissions cap factors will remain similar to what is proposed in this analysis through 2050, based on all information known at the time of this study.

The electricity grid will decarbonize in alignment with the New York State 80 x 50 goals set forth in the Climate Leadership and Community Protection Act (CLCPA).

## Emissions factors

| **Multifamily Housing** (R-2 zoning) | **Emissions cap factor** (mtCO2e/sq.ft.) |
|---|---|
| 2024 – 2029 | 0.00675 |
| 2030 – 2034 | 0.00334664 |
| 2035 – 2039 | 0.002692183 |
| 2040 – 2049 | 0.002052731 |
| 2050 | 0 |

Per proposed Local Law 97 rule subsection 103-14.c.3

| | **Electricity** (mtCO2e/kWh) | **Natural Gas** (mtCO2e/kBtu) | **#2 Oil** (mtCO2e/kBtu) |
|---|---|---|---|
| 2024 – 2029 emissions factor[1] | 0.000288962 | 0.00005311 | 0.00007421 |
| 2030 – 2034 emissions factor[2] | 0.000145 | 0.00005311 | 0.00007421 |
| 2050 emissions factor[2] | 0.00 | -- | -- |

1. Per Local Law 97 subsection 28-320.3.1.1
2. Per proposed Local Law 97 rule subsection 103-14.d.3.ii

# heat pumps for heating and hot water

| | system description | | | takeaways /comments |
|---|---|---|---|---|
| heating systems | **Central Variable Refrigerant Flow (VRF)**<br>Large rooftop compressor feeds multiple apartments<br> | system type<br>**central**<br>cost<br>**$$$$$** | who pays heating/cooling?<br>**owner / owner**<br>**owner / resident**<br>(via sub-metering)<br>tearsheet<br>**post-war high-rise**<br>**Mitchell-Lama** | Allows for long refrigerant runs, but leaks can be hard to find if they occur. Length between indoor & outdoor units must be considered during design. For systems without heat recovery, zoning the system based on different loads (e.g. south vs. north) is important. |
| | **Mini/Multi-Split Heat Pump**<br>Outside compressor serves multiple rooms in a single apartment<br> | system type<br>**unitized**<br>cost<br>**$$$–$$$$** | who pays heating/cooling?<br>**resident / resident**<br>**owner / owner**<br>**owner / resident**<br>(via sub-metering or dual wiring)<br>tearsheet<br>**pre-war low-rise**<br>**rent stabilized rental** | Simpler than VRF. Typically best for smaller/shorter buildings (less than 5 stories). Potentially more cost effective than packaged heat pumps for larger apartments. And if one unit goes out, only one apartment loses heat. |
| | **Packaged Cold-Climate Heat Pump**<br>Through-wall unit heats and cools a single room<br> | system type<br>**unitized**<br>cost<br>**$$$–$$$$** | who pays heating/cooling?<br>**resident / resident**<br>**owner / owner**<br>**owner / resident**<br>(via dual wiring)<br>tearsheet<br>**post-1980 mid-rise**<br>**senior rental housing &**<br>**post-1980 high-rise rental** | Refrigerant contained within unit. Requires a wall sleeve, penetration through the façade, or a costly window adaptor. May be undersized for large rooms. Dual wiring is available for this equipment. |
| | **Central Water Source Heat Pump**<br>Heat pump replaces gas boiler on hydronic system<br> | system type<br>**central**<br>cost<br>**$$$–$$$$** | who pays heating/cooling?<br>**owner / owner**<br>tearsheet<br>**pre-war low-rise**<br>**HDFC co-op** | Refrigerant contained within equipment. Possible to integrate into existing hydronic distribution. Only some equipment permits central cooling. Best for Electric-Ready alternative. Distribution is via water rather than refrigerant. |
| hot water systems | **Air Source Heat Pump (ASHP)**<br>Outdoor compressor pulls heat from surrounding air to warm water in a storage tank<br> | system type<br>**central**<br>cost<br>**$$$$** | who pays hot water?<br>**owner**<br>tearsheet<br>**All but**<br>**pre-war low-rise**<br>**rent stabilized rental** | Applicable to multifamily buildings. Storage required to meet variable load. Outdoor units scale based on building size. |
| | **ASHP + WSHP Hybrid System**<br>Outdoor compressor pulls heat from surrounding air to warm water in a storage tank<br> | system type<br>**central**<br>cost<br>**$$$$$** | who pays hot water?<br>**owner**<br>tearsheet<br>**pre-war low-rise**<br>**rent stabilized rental** | Hybrid DHW production can reduce total space required for equipment and achieve increased system efficiencies. Includes air to water and water to water heat pumps. |

# how to use the tear sheets

The tear sheets accompanying this manual depict five common New York City affordable housing typologies based on age, size, and rental/ownership structure. For each typology, two scopes of work — a Low Carbon and No Carbon retrofit package — were created to represent viable retrofit pathways that achieve moderate and deep GHG emissions reductions, respectively.

**Building typology** is based on age, size, and rental/ownership structure.

**Baseline building conditions** describe the system components comprising the existing building.

The **Low Carbon retrofit package** provides moderate emissions reductions through key system upgrades and strategic electrification.

Decarbonization Roadmap for
Multifamily Affordable Housing

tear sheet

1 / 5

post-1980
mid-rise
senior rental
housing

This tear sheet shows packages of energy conservation measures that reduce a building's greenhouse gas emissions in an effort to achieve anticipated LL97 emissions limits and to move towards carbon neutrality.

Based on the Maria Isabel affordable housing project

**existing building overview**

location
Bronx, NY

dwelling units
99

building area
70,460 sq. ft.

metering
gas: master
electricity: direct

heating fuel
natural gas

heating system
hydronic baseboards

cooling system
thru-wall ACs

ventilation system
rooftop exhaust fans

utility payment structure
heating: owner-paid
cooling: tenant-paid

Local Law 97 2030 emissions limits
not compliant

building energy exchange

April 2023

typology: post-1980, mid-rise, senior rental housing

**baseline building conditions**

This post-1980s mid-rise building has a typical brick masonry assembly with minimal detailing and no interior insulation and utilizes natural gas for heating plus thru-wall A/Cs for cooling, making it a strong candidate for insulated over-cladding and unitized thru-wall heat pumps.

**low carbon retrofit package**

**Low Carbon** improvements include new efficient hydronic bo
heat pump DHW system, solar PV, efficient lighting fixtures an
Envelope upgrades include new roof insulation, windows, air s
and optional above grade wall R-15 EIFS over-cladding. **GHG s**
**scope of work are based on the 2030 emissions factor.**

| BUILDING SYSTEM | % OF GHG EMISSIONS | SYSTEM COMPONENTS | DESCRIPTION | ENERGY CONSERVATION MEASURES (ECMs) |
|---|---|---|---|---|
| envelope | n/a | Roof Insulation | Concrete deck, no insulation | ■ R-38 above deck |
| | | Windows/Glazing | Estimated to be U = 0.8 | ■ New aluminum, double pane, low-e, argon filled, double hung |
| | | Air Sealing & Weatherization | Unknown | ■ Door & window weatherstripping |
| | | Above Grade Walls | Uninsulated brick wall assembly | + Optional R-15 EIFS over-cladding |
| heating<br>cooling<br>ventilation | 49% | Heating | Conventional hydronic boilers with Aquastat and baseboards | ■ New conventional hydronic boilers with TRVs or zone valves<br>■ Heat Timer boiler controls with indoor temp feedback<br>■ Real Time Energy Management (RTEM) |
| | | Cooling | Thru-wall ACs | ■ New thru-wall ENERGY STAR ACs |
| | | Pumps | (2) 3HP single speed pumps | ■ NEMA Premium pumps with VFDs |
| | | Pipe Insulation | Some pipe insulation | ■ New pipe insulation |
| | | Ventilation | Common Area: passive<br>In-unit Bath: registers only<br>In-unit Kitchen: passive via window | ■ Direct drive, variable speed EC motor central exhaust fans with timers & CAR dampers |
| | | Ductwork | In-unit: leaky | ■ Clean & seal ducts; conduct testing, adjusting, & balancing |
| domestic hot water | 26% | DHW | Heating hydronic boilers with Aquastat and small storage tank | ■ Central air source heat pump (ASHP) with storage ⚡ T |
| | | Plumbing Fixtures | Standard flow fixtures | ■ Low flow fixtures (WaterSense where applicable) |
| lighting | 9% | Common Area | Predominately 4' T12 | ■ LEDs with occupancy/vacancy sensors |
| | | Exterior | High wattage metal halide | ■ LEDs with photocells & timeclock |
| | | In-unit | T12 & incandescent | ■ LEDs |
| appliances | 16% | Appliances | Non-ENERGY STAR refrigerators<br>Gas stoves | ■ ENERGY STAR refrigerators |
| | | Central Laundry | (1) Non-ENERGY STAR washer<br>(3) ENERGY STAR washers<br>(3) Gas dryers | ■ (4) ENERGY STAR washers |
| renewables | | None | | ■ 62kW ballasted rooftop solar system |

ASSOCIATED UPGRADES
⚡ electrical service and distribution upgrades
T structural/finish upgrades including dunnage, patching, & sealin

**2030 Emissions Factor**
The 2030 emissions factor reflects an electric grid powered 70% by renewable energy.

ESTIMATED TOTAL COST/DU

ESTIMATED TOTAL CO
WITH R-15 EIFS OVER-

* Rough order of magnitude estimated costs based on current information at the time of publication that include material, labor, and mark-up. For more information, see the *Decarbonization Roadmap for Multifamily Affordable Housing Best Practices Manual*.

** Due to the interactivity of the energy model, the GHG savings for envelope are attributed to the HVAC category for the 2050 scope.

*** Fully electrified systems in 2030 show a GHG savings increase in 2050 because of New York's electrical grid transitioning to more clean energy sources.

**** GHG savings from envelope upgrades fall to zero once all related building systems are electrified and the electric grid is fully decarbonized. However, improvements to the building envelope will reduce the need for heating and cooling, which saves energy and minimizes operating costs.

**Existing building overview** provides a more detailed snapshot of the baseline building conditions.

**Percentage of GHG emissions** for the baseline building shows the portion of total emissions attributed to each building system.

**ECMs** are organized by specific building system categories.

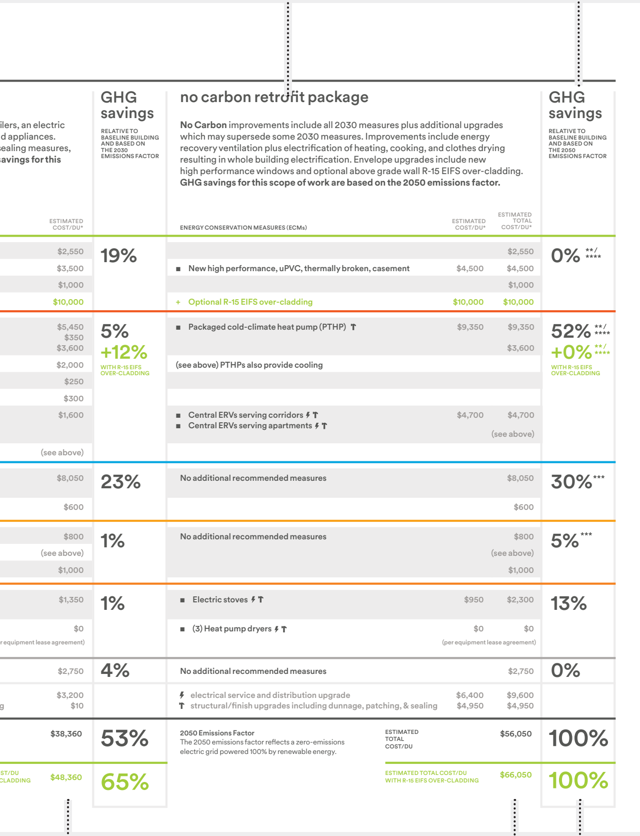
Building industry stakeholders can use these tear sheets to assess example measures that comprise a retrofit package and to understand the relative impacts — such as greenhouse gas (GHG) savings, cost, and energy cost savings — of implementing system upgrades and electrification. This information can help project teams as they develop a decarbonization roadmap and retrofit packages to help ensure that their building will comply with LL97 requirements.

The **No Carbon retrofit package** provides deep emissions reductions through more robust system upgrades and full building electrification, eliminating onsite fossil fuel use.

**GHG savings** show the percentage reduction associated with implementing the ECMs within each building system category.

**Decarbonization Roadmap** diagram lists key steps to developing a decarbonization retrofit plan.

**Key Takeaways** provide insight and rationale into the retrofit packages developed for that specific building typology.

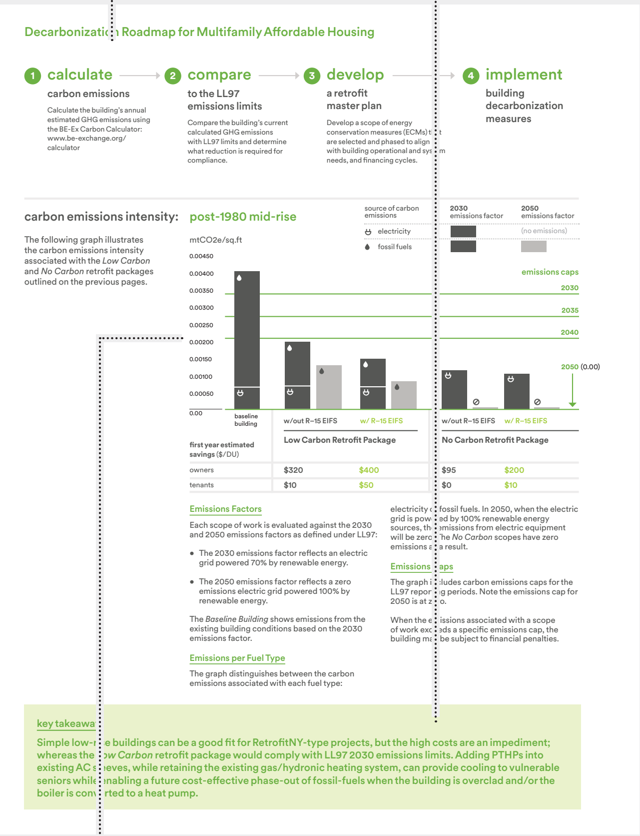


ilers, an electric
d appliances.
ealing measures,
avings for this

## no carbon retrofit package

**No Carbon** improvements include all 2030 measures plus additional upgrades which may supersede some 2030 measures. Improvements include energy recovery ventilation plus electrification of heating, cooking, and clothes drying resulting in whole building electrification. Envelope upgrades include new high performance windows and optional above grade wall R-15 EIFS over-cladding. **GHG savings for this scope of work are based on the 2050 emissions factor.**

| ESTIMATED COST/DU* | GHG savings RELATIVE TO BASELINE BUILDING AND BASED ON THE 2030 EMISSIONS FACTOR | ENERGY CONSERVATION MEASURES (ECMs) | ESTIMATED COST/DU* | ESTIMATED TOTAL COST/DU* | GHG savings RELATIVE TO BASELINE BUILDING AND BASED ON THE 2050 EMISSIONS FACTOR |
|---|---|---|---|---|---|
| $2,550 | 19% | | | $2,550 | 0% **/**** |
| $3,500 | | ■ New high performance, uPVC, thermally broken, casement | $4,500 | $4,500 | |
| $1,000 | | | | $1,000 | |
| $10,000 | | + Optional R-15 EIFS over-cladding | $10,000 | $10,000 | |
| $5,450<br>$350<br>$3,600 | 5%<br>+12% WITH R-15 EIFS OVER-CLADDING | ■ Packaged cold-climate heat pump (PTHP) ⊤ | $9,350 | $9,350<br>$3,600 | 52% **/****<br>+0% **/**** WITH R-15 EIFS OVER-CLADDING |
| $2,000 | | (see above) PTHPs also provide cooling | | | |
| $250 | | | | | |
| $300 | | | | | |
| $1,600 | | ■ Central ERVs serving corridors ⚡ ⊤<br>■ Central ERVs serving apartments ⚡ ⊤ | $4,700 | $4,700<br>(see above) | |
| (see above) | | | | | |
| $8,050 | 23% | No additional recommended measures | | $8,050 | 30%*** |
| $600 | | | | $600 | |
| $800 | 1% | No additional recommended measures | | $800 | 5%*** |
| (see above) | | | | (see above) | |
| $1,000 | | | | $1,000 | |
| $1,350 | 1% | ■ Electric stoves ⚡ ⊤ | $950 | $2,300 | 13% |
| $0<br>r equipment lease agreement) | | ■ (3) Heat pump dryers ⚡ ⊤ | $0 | $0<br>(per equipment lease agreement) | |
| $2,750 | 4% | No additional recommended measures | | $2,750 | 0% |
| g $3,200<br>$10 | | ⚡ electrical service and distribution upgrade<br>⊤ structural/finish upgrades including dunnage, patching, & sealing | $6,400<br>$4,950 | $9,600<br>$4,950 | |
| $38,360 | 53% | **2050 Emissions Factor**<br>The 2050 emissions factor reflects a zero-emissions electric grid powered 100% by renewable energy. | ESTIMATED TOTAL COST/DU | $56,050 | 100% |
| ST/DU CLADDING $48,360 | 65% | | ESTIMATED TOTAL COST/DU WITH R-15 EIFS OVER-CLADDING | $66,050 | 100% |



Decarbonization Roadmap for Multifamily Affordable Housing

1 **calculate** carbon emissions

Calculate the building's annual estimated GHG emissions using the BE-Ex Carbon Calculator: www.be-exchange.org/calculator

2 **compare** to the LL97 emissions limits

Compare the building's current calculated GHG emissions with LL97 limits and determine what reduction is required for compliance.

3 **develop** a retrofit master plan

Develop a scope of energy conservation measures (ECMs) that are selected and phased to align with building operational and system needs, and financing cycles.

4 **implement** building decarbonization measures

**carbon emissions intensity:** post-1980 mid-rise

The following graph illustrates the carbon emissions intensity associated with the *Low Carbon* and *No Carbon* retrofit packages outlined on the previous pages.

| first year estimated savings ($/DU) | w/out R–15 EIFS | w/ R–15 EIFS | w/out R–15 EIFS | w/ R–15 EIFS |
|---|---|---|---|---|
| owners | $320 | $400 | $95 | $200 |
| tenants | $10 | $50 | $0 | $10 |

**Emissions Factors**

Each scope of work is evaluated against the 2030 and 2050 emissions factors as defined under LL97:

- The 2030 emissions factor reflects an electric grid powered 70% by renewable energy.
- The 2050 emissions factor reflects a zero emissions electric grid powered 100% by renewable energy.

The *Baseline Building* shows emissions from the existing building conditions based on the 2030 emissions factor.

**Emissions per Fuel Type**

The graph distinguishes between the carbon emissions associated with each fuel type: electricity or fossil fuels. In 2050, when the electric grid is powered by 100% renewable energy sources, the emissions from electric equipment will be zero. The *No Carbon* scopes have zero emissions as a result.

**Emissions Caps**

The graph includes carbon emissions caps for the LL97 reporting periods. Note the emissions cap for 2050 is at zero.

When the emissions associated with a scope of work exceeds a specific emissions cap, the building may be subject to financial penalties.

key takeawa

Simple low-rise buildings can be a good fit for RetrofitNY-type projects, but the high costs are an impediment; whereas the *Low Carbon* retrofit package would comply with LL97 2030 emissions limits. Adding PTHPs into existing AC sleeves, while retaining the existing gas/hydronic heating system, can provide cooling to vulnerable seniors while enabling a future cost-effective phase-out of fossil-fuels when the building is overclad and/or the boiler is converted to a heat pump.

**Estimated cost per dwelling unit** for individual ECMs and the total scope of work show the price associated with implementing each retrofit package.

**Total GHG savings** shows the percentage reduction of the baseline building emissions that results from implementing each retrofit package including the additional savings from the optional R-15 EIFS over-cladding.

**Carbon Emissions Intensity** graph depicts the emissions per square foot of the baseline building, the Low Carbon, and No Carbon retrofit packages.

Both retrofit packages are evaluated using the 2030 and 2050 emissions factors to show how emissions will reduce over time as the grid transitions towards clean energy sources.

**LL97 emission caps** are indicated in the graph to show how emissions from each scope of work compares to the increasingly stringent limits.

## additional resources

**BE-Ex**

Tech Primers
https://be-exchange.org/tech-primers

Pursuing Passive
https://be-exchange.org/report/pursuing-passive

Multifamily Passive House: Connecting Performance to Financing
https://be-exchange.org/report/multifamily-passive-house-connecting-performance-to-financing

Multifamily Retrofits Playbooks
https://be-exchange.org/lowcarbonmultifamily-main

Carbon Calculator
https://be-exchange.org/ll97-calculator

**NYC Housing Preservation and Development (HPD)**

Design Guidelines
https://www.nyc.gov/site/hpd/services-and-information/preservation-design.page

Retrofit Electrification Pilot
https://www.nyc.gov/site/hpd/services-and-information/hpd-nyserda-retrofit-electrification-pilot.page

Electric Heating Policy
https://www.nyc.gov/site/hpd/services-and-information/hpd-heating-policy.page

Understanding LL97
https://www.nyc.gov/site/hpd/services-and-information/ll97-guidance-for-affordable-housing.page

Sustainability Web Page
https://www.nyc.gov/site/hpd/services-and-information/sustainability.page

Solar Where Feasible
https://www.nyc.gov/site/hpd/services-and-information/solar-where-feasible.page

**New York State Energy Research and Development Authority**

Low Carbon Pathways Program
https://www.nyserda.ny.gov/All-Programs/Multifamily-Buildings-Low-Carbon-Pathways-Program

Retrofit NY
https://www.nyserda.ny.gov/retrofitny

Flexible Technical Assistance Program
https://www.nyserda.ny.gov/All-Programs/FlexTech-Program

**Con Edison**

Clean Heat Program
https://www.coned.com/en/our-energy-future/electric-heating-and-cooling-equipment

## credits

**Project Team**

Jennifer Leone, NYC Housing Preservation & Development
David Sachs, Bright Power
James Henshaw, Bright Power
Richard Yancey, Building Energy Exchange
Katie Schwamb, Building Energy Exchange
Grennan Milliken, Building Energy Exchange

**Special Thanks**

Acacia Network
Hudson Valley Property Group
Workforce Housing Advisors
PRC – Property Resources Corporation
Settlement Housing Fund

**Design**

Might Could

**Project Sponsor**

NEW YORK STATE
NYSERDA
Supported

**Disclaimer**

While every effort has been made to contain correct information, neither Building Energy Exchange nor the authors make any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. None of the parties involved in the funding or the creation of this study assume any liability or responsibility to the user or any third party for the accuracy, completeness, or use or reliance on any information contained in the report, or for any injuries, losses or damages arising from such use or reliance. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by Building Energy Exchange. The views and opinions of authors expressed herein do not necessarily state or reflect those of the Building Energy Exchange Board. As a condition of use, the user pledges not to sue and agrees to waive and release Building Energy Exchange, its members, its funders, and its contractors from any and all claims, demands, and causes of action for any injuries, losses or damages that the user may now or hereafter have a right to assert against such parties as a result of the use of, or reliance on, the report.

April 2023
be-exchange.org

# list of abbreviations

| acronym | description |
|---|---|
| AC | Air Conditioner |
| AHU | Air Handling Unit |
| ASHP | Air Source Heat Pump |
| BOD | Basis of Design |
| CAR | Constant Airflow Regulator damper |
| CFL | Compact Fluorescent Lightbulb |
| CLCPA | Climate Leadership and Community Protection Act |
| CMA | Climate Mobilization Act |
| COP | Coefficient of Performance |
| CO2 | Carbon Dioxide |
| DHW | Domestic Hot Water |
| DU | Dwelling Unit |
| EC | Electronically Commutated motor |
| ECM | Energy Conservation Measure |
| EER | Energy Efficiency Ratio |
| EIFS | Exterior Insulation Finishing Systems |
| ERV | Energy Recovery Ventilation |
| FISP | Façade Inspection Safety Program |
| GHG | Greenhouse Gas |
| HP | Horsepower |
| HVAC | Heating, Ventilation, and Cooling systems |
| IRA | Inflation Reduction Act |
| LED | Light-Emitting Diode light |
| LL97 | Local Law 97 (of 2019) – Building Emissions Limits |
| ML | Mitchell-Lama |
| PTAC | Packaged Terminal Air Conditioner |
| PTHP | Packaged Terminal Heat Pump |
| RTEM | Real Time Energy Management |
| SC | Service Class |
| Solar PV | Solar Photovoltaic system |
| SWF | Solar Where Feasible |
| TMY | Typical Meteorological Year |
| TRV | Thermostatic Radiator Valve |
| uPVC | Unplasticized Polyvinyl Chloride |
| VFD | Variable Frequency Drive |
| VRF | Variable Refrigerant Flow |
| WSHP | Water Source Heat Pump |

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**