

Decarbonization Roadmap for Multifamily Affordable Housing



building
energy
exchange



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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

- | | | | |
|----|-----------|-----------|------------------------|
| 1. | post-1980 | mid-rise | senior rental housing |
| 2. | post-war | high-rise | mitchell-lama |
| 3. | pre-war | low-rise | rent stabilized rental |
| 4. | pre-war | low-rise | HDFC co-op |
| 5. | post-1980 | high-rise | rental |

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.

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.



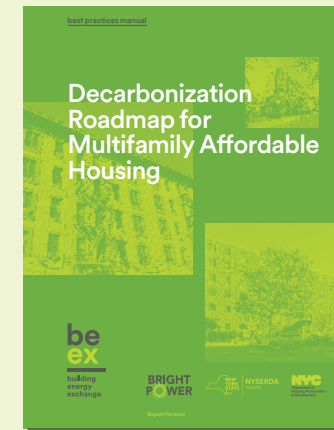
project overview

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.

tools



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.

Scenario	Low Carbon Retrofit Package	GHG Savings	No Carbon Retrofit Package	GHG Savings
Scenario 1	19%	0%	0%	0%
Scenario 2	5%	52%	5%	52%
Scenario 3	23%	30%	23%	30%
Scenario 4	1%	5%	1%	5%
Scenario 5	4%	0%	4%	0%
Scenario 6	53%	100%	53%	100%
Scenario 7	65%	100%	65%	100%

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.

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

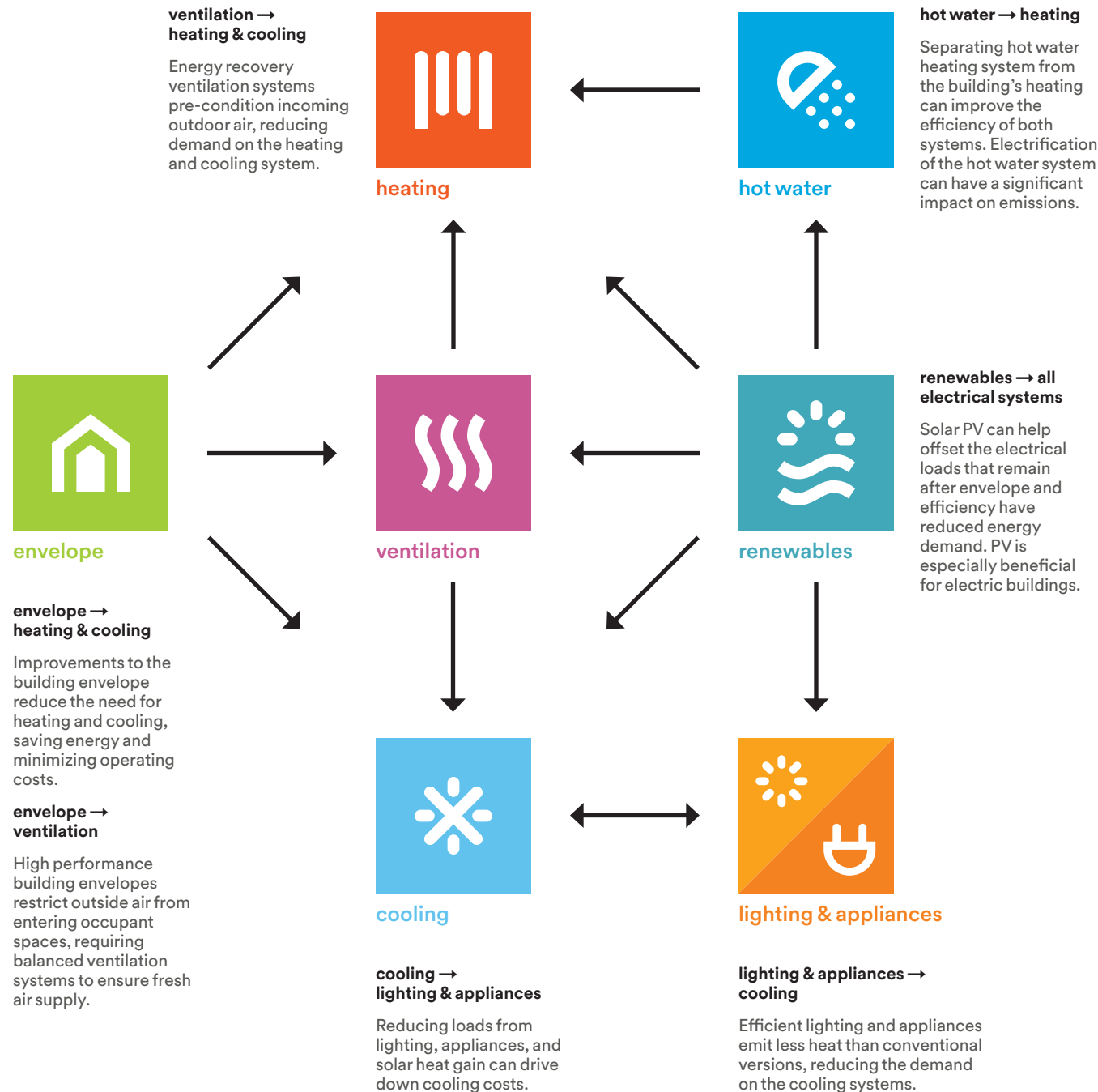
overall costs and benefits of each ECM in relation to one another. We wanted to convey that each ECM comes with its own set of costs to implement or maintain, but also its own set of unique benefits that go beyond GHG emissions reductions and include improvements to the health and comfort of a building’s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

BUILDING SYSTEM	SYSTEM COMPONENT ¹	benefits				impacts				when to implement		
		GHG SAVINGS	COMFORT	HEALTH/IAQ	ENERGY COST SAVINGS	COSTS	LIFESPAN (YRS) ⁴	MAINTENANCE	TENANT DISRUPTION	NOW	MID-CYCLE	FUTURE REFI
 envelope	Roof Insulation	☆☆☆☆☆	low	low	\$\$\$\$\$	\$\$\$\$\$	20	medium	low	as needed	✓	✓
	Windows/Doors	☆☆☆☆☆	high	medium	\$\$\$\$\$	\$\$\$\$\$	20	medium	high	as needed	✓	✓
	Air Sealing & Weatherization ²	☆☆☆☆☆	high	medium	\$\$\$\$\$	\$\$\$\$\$	15	medium	low	✓	✓	✓
	Exterior Wall Insulation	☆☆☆☆☆	high	medium	\$\$\$\$\$	\$\$\$\$\$	20	low	medium	if feasible	■	✓
 HVAC	Heating System Upgrades ²	☆☆☆☆☆	medium	medium	\$\$\$\$\$	\$\$\$\$\$	10–20	medium	low	per HPD guidelines ⁵	✓	✓
	Electrify Heating	☆☆☆☆☆	high	high	\$\$\$\$\$	\$\$\$\$\$	15	medium	high	per HPD guidelines ⁵	■	✓
	Pipe Insulation ²	☆☆☆☆☆	medium	low	\$\$\$\$\$	\$\$\$\$\$	15	low	low	✓	✓	✓
	Ventilation Upgrades	☆☆☆☆☆	medium	high	\$/\$\$\$\$\$ (ERV)	\$\$\$\$\$	15	medium/high (ERV)	high	per HPD guidelines ⁵	■	✓
 domestic hot water	Electrify Hot Water Heating	☆☆☆☆☆	low	high	\$\$\$\$\$	\$\$\$\$\$	10	medium	low	per HPD guidelines ⁵	✓	✓
	Plumbing Fixture Upgrades	☆☆☆☆☆	low	low	\$\$\$\$\$	\$\$\$\$\$	10	low	low	✓	✓	✓
 lighting	Common Area & Exterior Upgrades ²	☆☆☆☆☆	low	medium	\$\$\$\$\$	\$\$\$\$\$	15–20	low	low	✓	■	✓
	In-Unit Upgrades	☆☆☆☆☆	low	medium	\$\$\$\$\$	\$\$\$\$\$	15–20	low	medium	✓	✓	✓
 plug loads	Appliance Upgrades	☆☆☆☆☆	low	low	\$\$\$\$\$	\$\$\$\$\$	15	low	medium	as needed	✓	✓
	Electrify Cooking	☆☆☆☆☆	medium	high	\$\$\$\$\$	\$\$\$\$\$	10	low	high	per HPD guidelines ⁵	■	✓
	Electrify Laundry	☆☆☆☆☆	low	medium	\$\$\$\$\$	\$\$\$\$\$	10	medium	low	as needed	✓	✓
 renewables	Solar PV ³	☆☆☆☆☆	low	low	\$\$\$\$\$	\$\$\$\$\$	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 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.



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:

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.

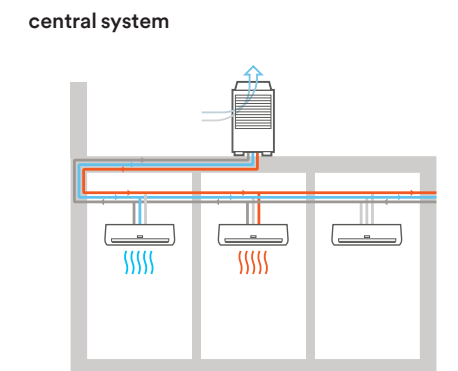
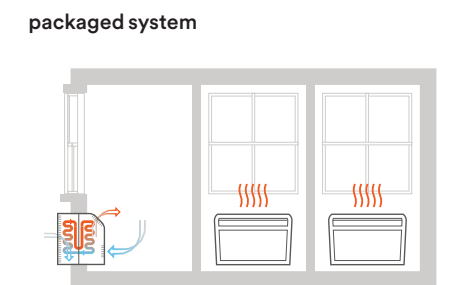
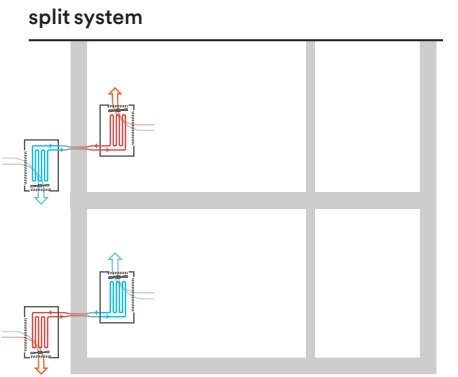
considerations

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.

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.



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

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.

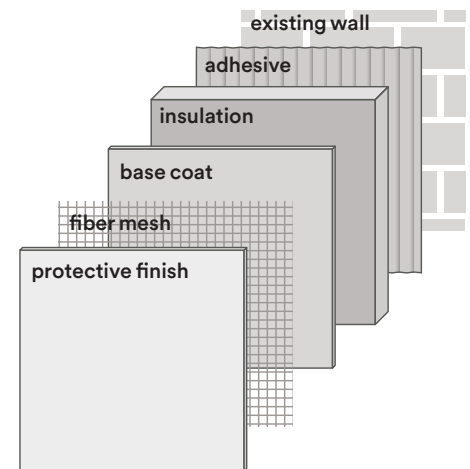
Air Sealing

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

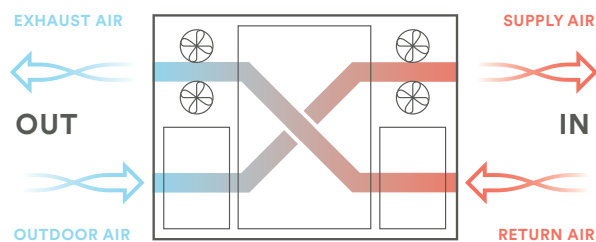
Ventilation plays a critical role in indoor air quality and works in tandem with an airtight envelope. A proper Low or No Carbon retrofit must have balanced ventilation that delivers filtered air directly to tenant spaces, while removing stale air from kitchens, baths, and laundry rooms.

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.

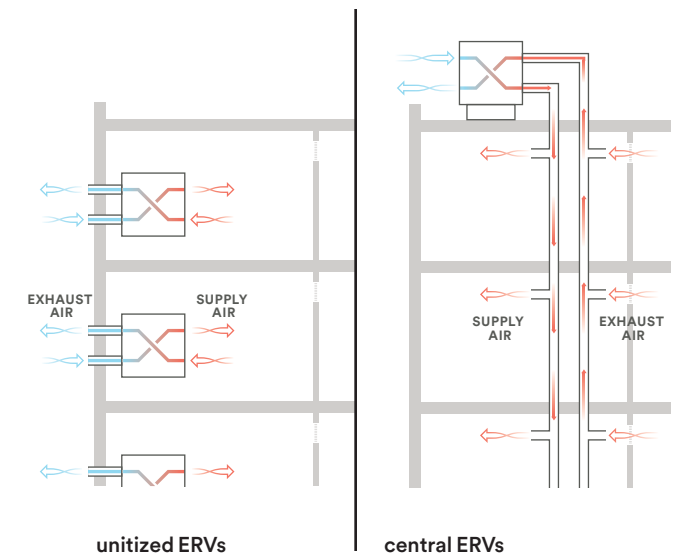
Balanced Ventilation with ERVs

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.



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 corridors, 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.

building systems



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	low carbon retrofit		no carbon retrofit		
		W/OUT EIFS	W/ EIFS	W/OUT EIFS	W/ EIFS	
1 post-1980 mid-rise senior rental  <p>LL97 path Prescriptive Pathway</p> <p>existing heating system gas-hydronic baseboards</p> <p>proposed heating system Packaged cold climate heat pump (PTHP)</p>	<p>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.</p>	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
		2 post-war high-rise Mitchell-Lama  <p>LL97 path 2035 Pathway</p> <p>existing heating system two-pipe steam with baseboards</p> <p>proposed heating system central VRF</p>	<p>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.</p>	GHG Emissions Reductions	46%	54%
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
3 pre-war low-rise rent stabilized rental  <p>LL97 path Prescriptive Pathway</p> <p>existing heating system gas-hydronic convectors</p> <p>proposed heating system central ASHP & WSHP</p>	<p>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.</p>			GHG Emissions Reductions	59%	62%
		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
		4 pre-war low-rise HDFC co-op  <p>LL97 path Prescriptive Pathway</p> <p>existing heating system one-pipe steam radiators</p> <p>proposed heating system mini-split heat pumps</p>	<p>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.</p>	GHG Emissions Reductions	52%	57%
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
5 post-1980 high-rise rental  <p>LL97 path Prescriptive Pathway</p> <p>existing heating system steam PTACs</p> <p>proposed heating system packaged cold climate heat pumps (PTHPs)</p>	<p>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.</p>			GHG Emissions Reductions	56%	58%
		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 that 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.

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 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

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

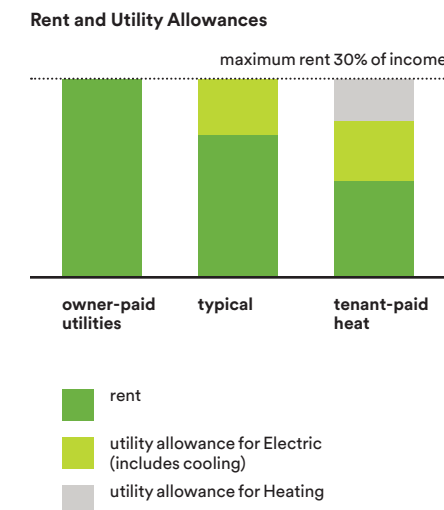
Traditionally in NYC rent-regulated housing, heating is paid by owners and cooling by residents. Tenant-paid utilities require utility allowances that ensure total housing costs are below 30% of income. Until recently, utility allowances for tenant-paid heat have been too high to underwrite—e.g. rents 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:



Heat Pump Metering/Billing Arrangements & Policy Considerations

System is on house meter	<ul style="list-style-type: none"> • Owner is more likely to invest in building/system efficiency and maintenance • Residents are less likely to conserve energy since they do not pay the utility fees • Owner is hesitant to take on cooling costs which are normally paid by residents
System is on resident’s meter*	<ul style="list-style-type: none"> • Owner is less likely to invest in building/system efficiency and maintenance • Residents are more likely to conserve energy since they pay the utility fees • Heating is not typically paid by residents in affordable housing*
System is on house meter, residents sub-metered for cooling and/or heating*	<ul style="list-style-type: none"> • Owner is likely to invest in building/system efficiency and maintenance • Residents are likely to conserve energy on utility fees they pay • Submetering adds cost and owners find it difficult to collect utility fees
Heating system is physically separate or wired separately from cooling system	<ul style="list-style-type: none"> • Owner is likely to invest in building/system efficiency and maintenance • 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 • Dual / split wiring adds cost and complexity for most air-source heat pumps

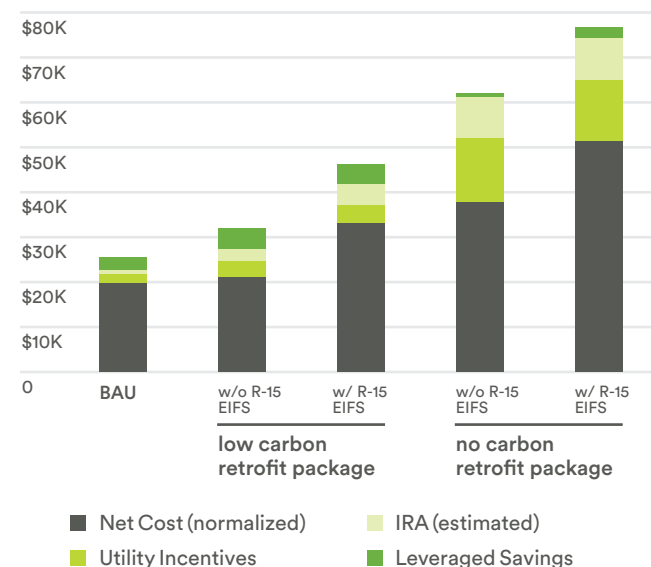
*HPD policy only allows resident paid heat in certain situations. See HPD’s Electric Heating Policy for more info.

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

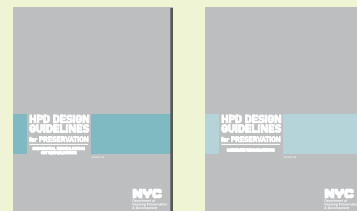
Maintenance: NYC’s local laws require ongoing (and costly) inspections and maintenance of building infrastructure. LL11 requires buildings above six stories to inspect and repair facades every 5 years and can cost hundreds of

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-hydrionic 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.

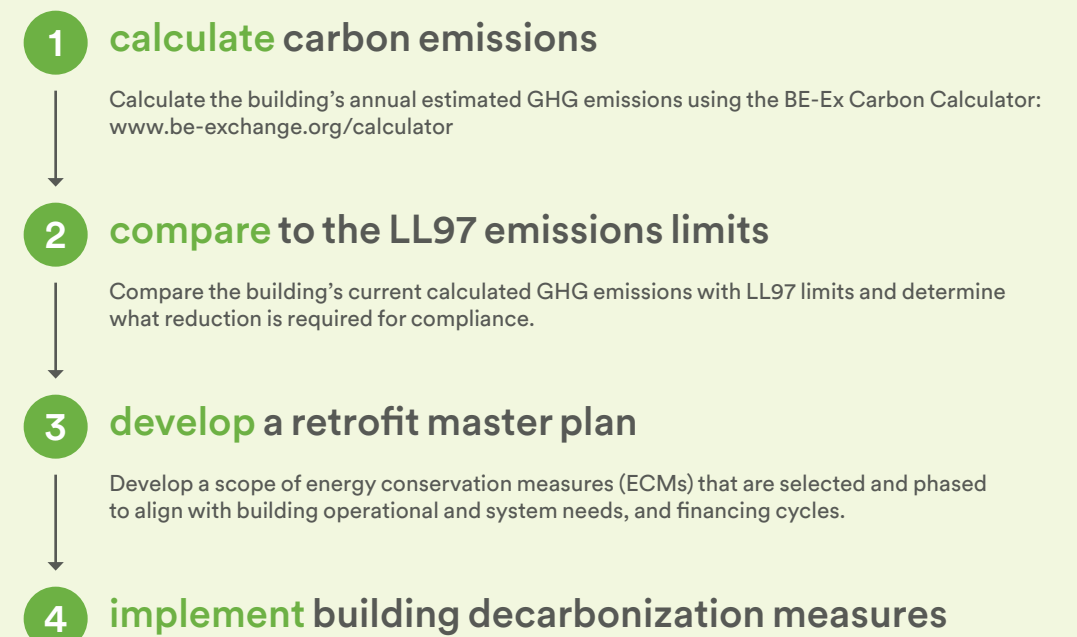
taking action

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



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)
Large rooftop compressor feeds multiple apartments



system type
central

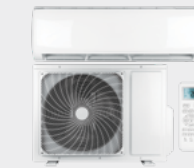
who pays heating/cooling?
owner / owner
owner / resident
(via sub-metering)

cost
\$\$\$\$\$

tearsheet
post-war high-rise
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
Outside compressor serves multiple rooms in a single apartment



system type
unitized

who pays heating/cooling?
resident / resident
owner / owner
owner / resident
(via sub-metering or dual wiring)

cost
\$\$\$-\$\$\$\$

tearsheet
pre-war low-rise
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
Through-wall unit heats and cools a single room



system type
unitized

who pays heating/cooling?
resident / resident
owner / owner
owner / resident
(via dual wiring)

cost
\$\$\$-\$\$\$\$

tearsheet
post-1980 mid-rise
senior rental housing &
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
Heat pump replaces gas boiler on hydronic system



system type
central

who pays heating/cooling?
owner / owner

cost
\$\$\$-\$\$\$\$

tearsheet
pre-war low-rise
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)
Outdoor compressor pulls heat from surrounding air to warm water in a storage tank



system type
central

who pays hot water?
owner

cost
\$\$\$\$

tearsheet
All but
pre-war low-rise
rent stabilized rental

Applicable to multifamily buildings. Storage required to meet variable load. Outdoor units scale based on building size.

ASHP + WSHP Hybrid System
Outdoor compressor pulls heat from surrounding air to warm water in a storage tank



system type
central

who pays hot water?
owner

cost
\$\$\$\$\$

tearsheet
pre-war low-rise
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.

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 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.

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.

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.

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.

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

Based on the Maria Isabel affordable housing project

be ex building energy exchange

BRIGHT POWER

NEW YORK STATE NYSEDA

NYC Department of Housing Preservation & Development

April 2023

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.

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

BUILDING SYSTEM	% OF GHG EMISSIONS	SYSTEM COMPONENTS	DESCRIPTION	ENERGY CONSERVATION MEASURES (ECMs)	ESTIMATED TOTAL COST/DPW	GHG SAVINGS	ESTIMATED TOTAL COST/DPW	GHG SAVINGS
envelope	n/a	Roof Insulation, Windows/Glazing, Air Sealing & Weatherization, Above Grade Walls	Concrete deck, no insulation; Estimated to be U = 0.8; Unknown; Uninsulated brick wall assembly	R-38 above deck; New aluminum, double pane, low-e, argon filled, double hung; Door & window weatherstripping; Optional R-15 EIFS over-cladding	\$2,500, \$5,500, \$1,000, \$10,000	19%	\$2,500, \$4,500, \$1,000, \$10,000	0%
heating	49%	Heating	Conventional hydronic boilers with Aquastat and baseboards	New conventional hydronic boilers with TRVs or zone valves; Heat Timer boiler controls with indoor temp feedback Real Time Energy Management (RTM)	\$6,450, \$300, \$3,600	5%	\$9,350, \$3,600	52%
cooling	26%	Cooling, Pumps, Pipe Insulation, Ventilation	Thru-wall ACs; (2) SHP single speed pumps; Some pipe insulation; Common Area: passive in-unit Bath registers only; In-unit Kitchen: passive via window	New thru-wall ENERGY STAR ACs; NEMA Premium pumps with VFDs; New pipe insulation; Direct drive, variable speed EC motor central exhaust fans with timers & CAR dampers	\$2,000, \$250, \$300, \$1,600	+12%	\$3,600, \$4,700, \$4,700	+0%
ventilation	26%	Ductwork	In-unit leaky	Clean & seal ducts; conduct testing, adjusting, & balancing	\$600	23%	\$600	30%
DHW	9%	Plumbing Fixtures	Heating hydronic boilers with Aquastat and small storage tank; Standard flow fixtures	Central air source heat pump (ASHP) with storage tank; Low flow fixtures (WaterSense where applicable)	\$8,050, \$600	23%	\$8,050, \$600	30%
lighting	9%	Common Area, Exterior, In-unit	Predominately 4' T12; High wattage metal halide; T12 & incandescent	LEDs with occupancy/vacancy sensors; LEDs with photocells & timedlock; LEDs	\$800, \$10,000, \$1,000	1%	\$800, \$10,000	5%
appliances	16%	Appliances	Non-ENERGY STAR refrigerators; Gas stoves; Central Laundry	ENERGY STAR refrigerators; ENERGY STAR refrigerators; (1) Non-ENERGY STAR washer (3) ENERGY STAR washers (3) Gas dryers	\$1,350, \$0, \$0	1%	\$2,300, \$0, \$0	13%
renewables	None	None	None	62kW ballasted rooftop solar system	\$2,750	4%	\$2,750	0%
				electrical service and distribution upgrades; structural/finish upgrades including damage, patching, & sealing	\$3,200, \$10		\$6,400, \$4,950	
				2030 Emissions Factor	\$38,360	53%	\$66,050	100%
				2050 Emissions Factor	\$48,360	65%	\$66,050	100%

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.

Decarbonization Roadmap for Multifamily Affordable Housing

- calculate carbon emissions
- compare to the LL97 emissions limits
- develop a retrofit master plan
- implement building decarbonization measures

carbon emissions intensity: post-1980 mid-rise

first year estimated savings (\$/DPW)

owners	\$320	\$400
tenants	\$10	\$50

emissions caps

2030 emissions factor: 0.0000 (no emissions)

2050 emissions factor: 0.0000 (no emissions)

key takeaways

- Simple low-cost retrofits can be a good fit for retrofit-type projects, but the high costs are an impediment.
- Low Carbon retrofit packages would comply with LL97 2030 emissions limits. Adding PTHPs into existing AC systems, 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 com...

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>

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<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>

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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
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Con Edison

Clean Heat Program
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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

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