playbook

Low Carbon Multifamily Retrofits

Post-1980 8+ Stories

This playbook summarizes retrofit strategies that maximize occupant comfort and energy savings through a transition from fuel to electricity-based heating, cooling and hot water systems. Aligned with typical capital improvement cycles, the recommendations will prepare buildings for increasingly stringent efficiency and carbon emissions targets through careful phasing of work across all major building components, including upgrades to exterior walls, windows, and ventilation systems.

Additional playbooks are available for these typologies.

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Steven Winter Associates, Inc.
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Photo credit: Steven Winter Associates

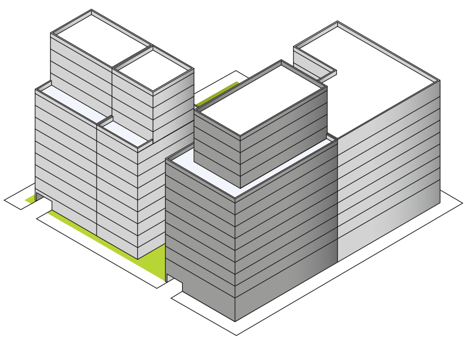
How to use this playbook

Contents:

This playbook summarizes those retrofit strategies across all major building systems and components that will maximize occupant comfort and energy savings through a transition from fuel to electricity-based heating, cooling and hot water systems. For clarity of analysis the playbook assumes an ideal phasing of strategies (page 4) but it is presumed the order of work will be based on the individual needs of the building in question, including end of system life, capital planning, and regulatory pressures. The playbook describes the primary benefits of a low carbon retrofit with details on the major system upgrades needed to access those benefits.

Post-1980 Mid to High Rise

These buildings are typically at a minimum of 8 floors in height and can be found in virtually every context–from lot line buildings like the one shown on the right, to free standing buildings on campuses like the building studied here (page 3). Many buildings of this type include mixed uses at the ground floor, such as retail (grocery stores, pharmacies, etc.) and commercial offices (Doctor's offices, etc.). Tenant amenities are common, such as laundry, gym, lounge, rooftop terrace, and storage.



The height and layout of buildings in this typology vary considerably with both simple towers and podium-tower arrangements common, both corner and mid-block.

Typical ownership challenges

- → Owners typically have limited access to capital
- → Vacancy typically low, hampering retrofit efforts
- → Tenants typically responsible for cooling costs, complicating electrification of those systems
- → In buildings with multiple uses (grocery stores, etc.) disaggregating energy use of retail tenants can be difficult if not metered, and typical leases do not envision legislation like Local Law 97

ELEMENTS	DESCRIPTION	TYPICAL ISSUES
Exterior walls	Typically steel frame and stud with some cavity insulation and punched window openings.	- Minimal interior insulation - Often no air barrier - Major thermal bridges at balconies, corners and parapet walls
Windows	Window walls with casement or slider windows common without thermal breaks, single glazing or weak double glazing common.	- Little thermal resistance - Air leakage high - Major comfort issues - Condensation risk - Windows allow significant solar heat gain
Heating	Commonly packaged terminal air conditioners (PTACs) served by steam or hot water from a central oil or gas fired boiler. Some buildings have water-source heat pumps (WSHPs) served by oil or gas fired boiler.	- High maintenance costs - Creates drafty conditions - Major thermal bridge
Cooling	PTAC units or WSHPs	- Through-wall PTACs create drafty conditions - Increases whole building U-value - Through-wall PTAC units create major thermal bridges - Noisy, inefficient - Permanent Installation - winter removal does not occur
Domestic Hot Water	Heat exchange at boiler with constant recirculation loop.	- Requires running boiler in shoulder and cooling seasons
Ventilation	Mixture of partial kitchen/ bath exhaust and natural ventilation; corridors typically have supply.	- Limited direct fresh air introduction - System is not balanced, drives infiltration from exterior and adjacent units - Exhaust or supply not often continuous

Actual Building Information

The post 1980s mid to high rise building selected for study is a 16-story, market-rate residential building on Roosevelt Island in New York City. The building has large glazing areas with perimeter columns that have interior insulation and an exterior masonry rain screen. The building is comprised of 242 apartments across roughly 242,000 gross square feet.

This building is typical of a large swath of buildings in New York City (as well as many other regions) and has many of the most common challenges that will be encountered by anyone looking to perform a deep retrofit of an occupied multifamily building.

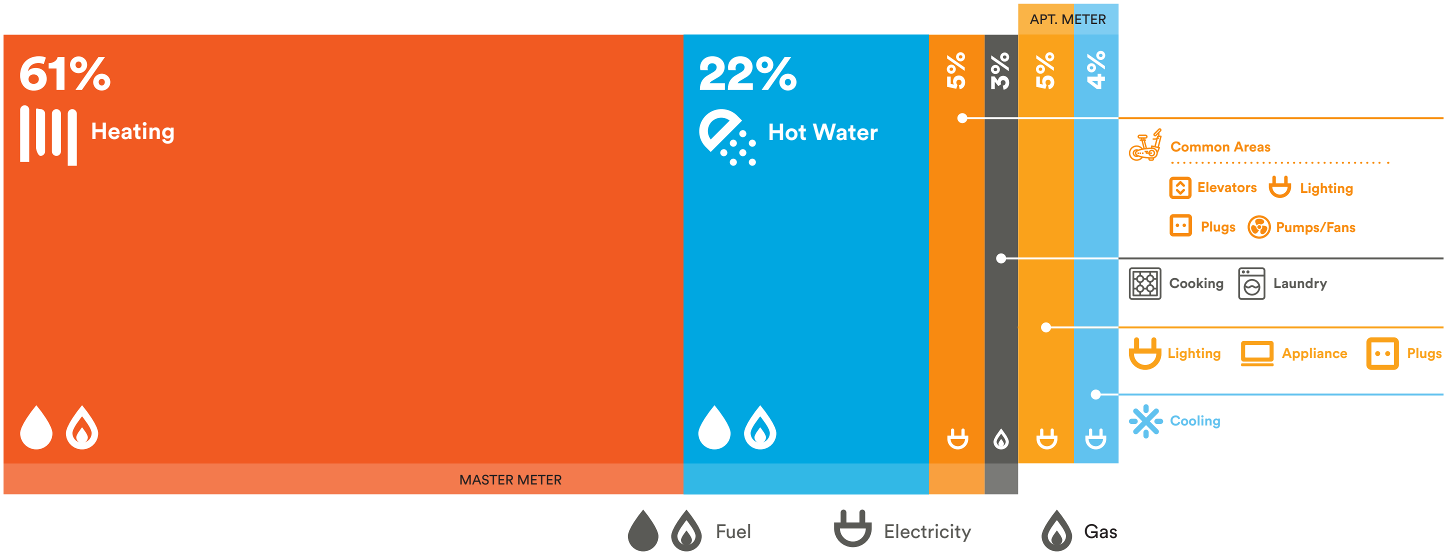
Utility Costs

Typically, the building owner pays for the utility costs of heating and hot water fuels, gas cooking and common area laundry, as well as electricity costs for all common area functions, including lighting, pumps, fans, and elevators. Tenant utility bills cover only electricity for apartment lighting, appliances, and cooling – which typically includes window AC or PTAC units. Heating and hot water boilers are typically dual fuel (oil or gas).

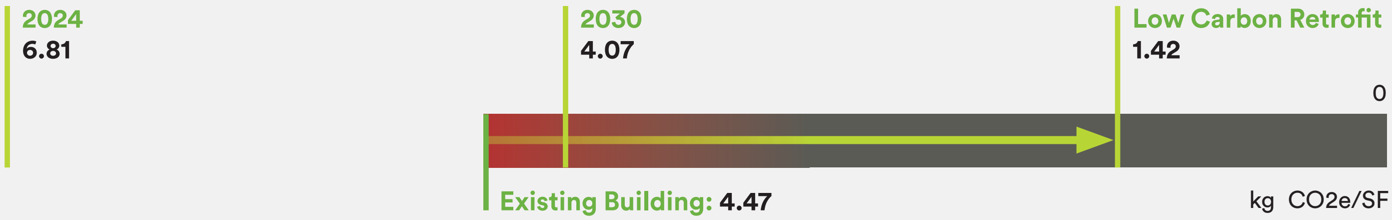
Like many buildings of the era and typology, extensive glazing is common.
Phoro Credit: Steven Winter Associates

Energy Use Analysis

Heating is by far the dominant energy end use and, therefore, retrofit measures that directly reduce heating demand—such as envelope improvements—are essential to realizing a low carbon future and avoiding penalties like those included in Local Law 97.



NYC Local Law 97 Carbon Limits



Although this particular building's carbon emissions are already in compliance with the Local Law 97 limits that begin in 2024, a fairly aggressive low carbon retrofit will be required to avoid financial penalties in 2030 and subsequent years–when these limits will be even lower.

Targets & Phasing

To meet the demands of a low carbon future we recommend that buildings pursue the Recommended Targets in the following pages and develop long term retrofit plans to coordinate the phasing and interaction of these measures over time. For more detailed retrofit planning we recommend projects use a building performance standard like EnerPHit, the Passive House standard for retrofits, as a benchmark to evaluate the total impact of various measures once enacted.

Local Regulatory Context

New York City has passed Local Law 97 which limits carbon emissions in large buildings. The first reporting period is 2024, with requirements becoming more stringent in 2030 and again in 2035. A low carbon retrofit such as recommended here puts a building in the best possible position to avoid financial penalties under Local Law 97.

Retrofit Phasing

The phasing order shown below is one of many optional pathways available. While implementing envelope measures early maximizes energy efficiency long term, many other factors may determine which measures should be completed in which order–including end of life equipment replacement, tenant disruption and access to capital.

lighting & loads

Lighting, appliance and plug load efficiency measures can be done at anytime.

See page 11

envelope

It is ideal to complete envelope measures early in the process to reduce heating & cooling demand.

See page 8

ventilation

Ventilation upgrades should follow airtightness and other envelope improvements as soon as feasible.

See page 9

heating

Full electrification of systems typically includes combining heating & cooling into a single heat-pump based system.

See page 10

cooling

Full electrification of systems typically includes combining heating & cooling into a single heat-pump based system.

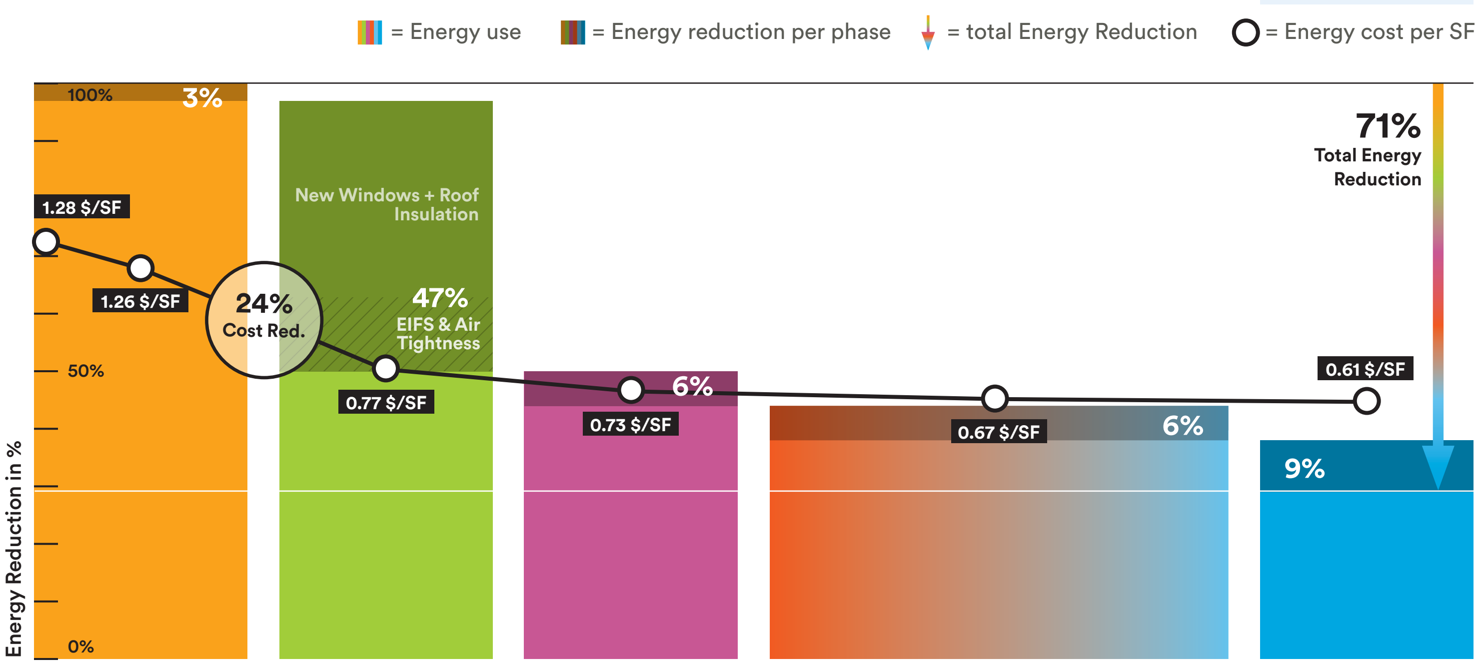
See page 10

hot water

The technology for fully electrifying large-scale hot water systems is not yet readily available in this market; however, there are options for meaningful partial electrification.

See page 11

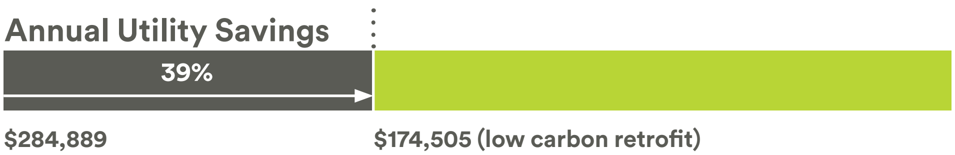
Energy & Cost Reductions by Phase



Because the building envelope plays such a critical role in heating demand and overall comfort, additional wall and roof insulation, improvements to airtightness, and the introduction of high performance windows have the greatest impact on energy use, utility cost, and carbon emission reductions.

Benefits

Most buildings are upgraded reactively, in response to a system failure or tenant turnover, and focus only on like-for-like equipment replacement. This piecemeal approach leaves significant energy and cost savings on the table, rarely improves the comfort or health of occupants, and is unlikely to align with increasingly stringent efficiency and carbon regulations. Developing a long term retrofit plan, with each phase based on the Recommended Targets listed here, can ensure that measures work in concert to produce spaces that are more comfortable, healthier, and significantly less expensive to maintain and operate.



Health

Upgrading the building envelope and ventilation systems radically improves interior air quality.

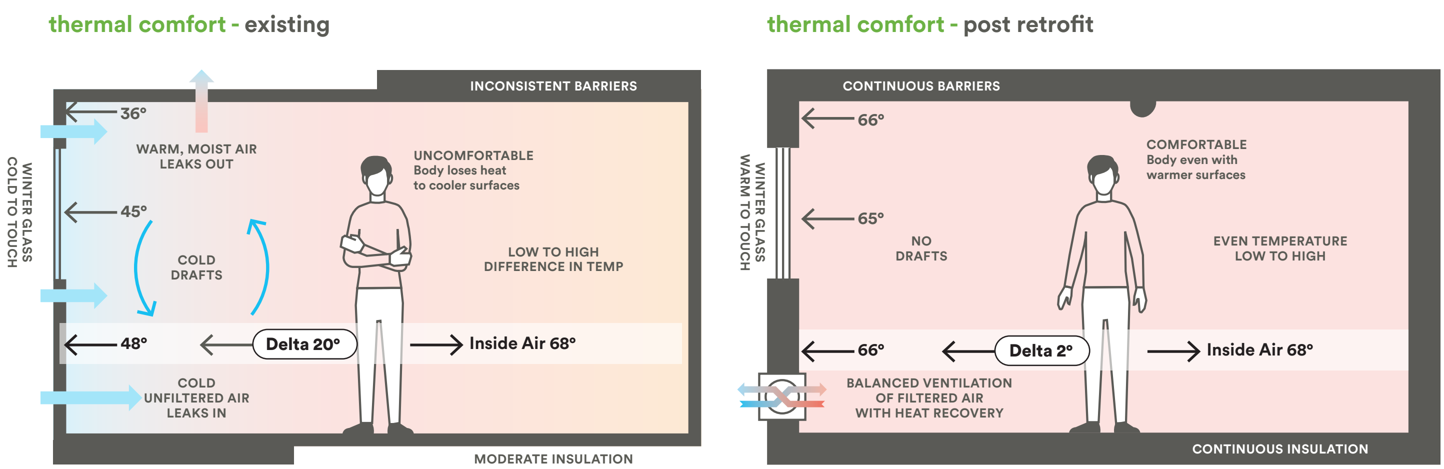
Air infiltration through leaky exterior walls and condensation at thermal bridges to the outside are among the primary vectors for poor indoor air quality. The former can be the source of moisture and myriad pollutants while the latter is the foundation of interior mold growth. In a low carbon retrofit improved airtightness and reduced thermal bridging work together with a balanced, highly filtered ventilation system to provide ample fresh air while reducing pollutants, resulting in a far healthier building interior.

Operating Cost Savings

Utility cost reductions: A low carbon retrofit dramatically reduces utility bills through more efficient systems and reduction in demand for heating and cooling systems, and mitigates the impact of future utility cost increases.

Facade inspection savings: Many buildings of this era and style spend considerable sums on inspection and repair of their aging facades. Properly designed recladding systems should not require significant maintenance for decades. In some cases buildings have significant condensation and mold issues related to poor exterior wall construction. Recladding projects can mitigate the repairs these issues necessitate.

Gas System inspection savings: Local Law 152 of NYC mandates extensive inspections of gas systems every five years. Buildings in NYC that fully decarbonize through switching their gas-based systems like heating, hot water and cooking to electricity-based systems will avoid the considerable costs associated with these inspections and any subsequent repairs.



Insulating the exterior walls and installing high-performance windows ensures that the inside surface temperature of the exterior walls remains warmer throughout winter and, most importantly, closer to the interior air temperature. Research indicates that comfort is significantly compromised when this difference is greater than 7 degrees F. We estimate the existing building suffers from a difference nearly 3x this figure.
Graphic credit: Building Energy Exchange

Thermal Comfort

Far more comfortable interiors are one of the primary advantages of pursuing a holistic low carbon retrofit.

The difference between air temperature and the surface temperature of exterior walls and windows is a major driver of interior comfort. The diagram above outlines this relationship under the existing building conditions (left) and the conditions once envelope and ventilation improvements are complete (right).

Post-war 1980 Mid & High Rise Efficiency Package

The options for improvement listed here will maximize occupant comfort and energy savings through a transition from fuel to electricity-based heating, cooling and hot water systems. Aligned with typical capital improvement cycles, these strategies will prepare buildings for increasingly stringent efficiency and carbon emissions targets.

Retrofit Strategies	Benefits				Costs
	Energy Savings	Comfort	Health/IAQ	Maintenance	
ROOF					
→ Insulate Roof	★★	★	★	LOW	$
EXTERIOR WALL					
→ Add Interior insulation	★★★	★★★	★★	LOW	$$$$
→ Add Exterior Insulation	★★★★★	★★★★★	★★★★	LOW	$$$$
WINDOWS					
→ Replace Existing Windows with High Performance Windows	★★★★	★★★★	★★★	MEDIUM	$$$$$
Air Tightness					
→ Ensure Air Sealing as part of Exterior Wall & Window Upgrades	★★★★	★★★★	★★★	LOW	$$
→ Packaged Terminal Heat Pumps	★★★★	★★★	★★	HIGH	$$$$
→ Centralized Energy Recovery Ventilation System	★★	★★	★★★★★	MEDIUM	$$$$$
→ Air to Water Heat Pump Water Heaters	★★★★	★	★	MEDIUM	$$$$
LIGHTING					
→ High Efficiency Common Area Lighting	★★★	★★	★	LOW	$
PLUG LOAD					
→ High Efficiency Appliances and Smart Systems	★★	★★	★★	MEDIUM	$$
PHOTOVOLTAIC					
→ Install Solar PV Array	★	★	★	LOW	$$

Retrofit Strategies	Touchpoints			Impacts	
	Anytime	Refi/Major	Tenant Turnover	Tenant Disruption	Appearance Impact
ROOF					
→ Insulate Roof	✓	✓	✓	MEDIUM	LOW
EXTERIOR WALL					
→ Add Interior insulation		✓	✓	HIGH	LOW
→ Add Exterior Insulation	✓	✓		MEDIUM	HIGH
WINDOWS					
→ Replace Existing Windows with High Performance Windows		✓	✓	HIGH	MEDIUM
Air Tightness					
→ Ensure Air Sealing as part of Exterior Wall & Window Upgrades	✓	✓	✓	MEDIUM	LOW
→ Packaged Terminal Heat Pumps		✓	✓	MEDIUM	LOW
→ Centralized Energy Recovery Ventilation System		✓		HIGH	LOW
→ Air to Water Heat Pump Water Heaters	✓	✓		LOW	MEDIUM
LIGHTING					
→ High Efficiency Common Area Lighting	✓	✓		LOW	LOW
PLUG LOAD					
→ High Efficiency Appliances and Smart Systems	✓	✓		MEDIUM	LOW
PHOTOVOLTAIC					
→ Install Solar PV Array	✓	✓		LOW	MEDIUM

Envelope Upgrades

A high-performing envelope constitutes the foundation of a low carbon retrofit, with significant emphasis on airtightness, the right amount of insulation, and high-performance windows and doors to dramatically improve comfort and reduce heating and cooling demand.

Airtightness

Whole building airtightness positively impacts energy use and interior air quality while enabling highly efficient ventilation.

Proper airtightness involves each step of an envelope retrofit, from the windows and doors themselves, to their installation, to the creation of an air control layer within any new insulation assembly. Remedial measures should also be implemented to improve airtightness of shafts, fire stairs, bulkheads, and duct risers.

Insulation

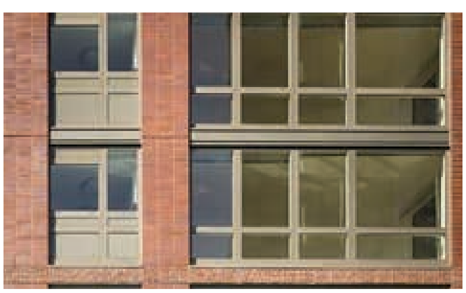
Insulation is the primary method of separating the interior environment from the exterior and is especially critical for retrofits of buildings with no insulation in their existing wall assembly.

Although exterior applications of insulation provide much better performance, interior applications of insulation will often be required when the exterior facades are historic, have complicated features like balconies, or when facades are along lot lines. For buildings with limited opaque wall area it is often more effective to improve the glazing systems than to focus on improving wall insulation.

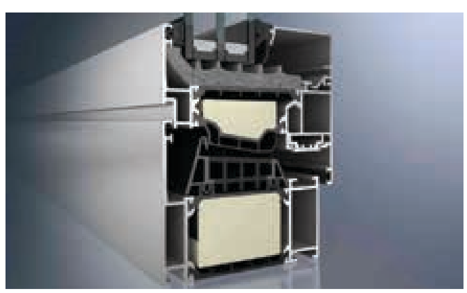
Windows

Few elements impact the quality of the interior environment as much as high-performance windows.

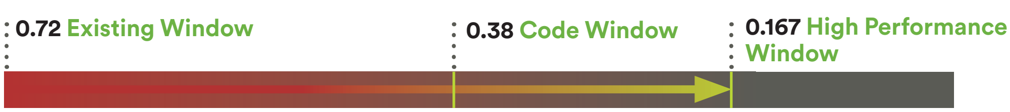
Low carbon retrofits require careful selection of high-performance windows to ensure interior comfort and optimize heating and cooling demand. To maximize comfort and reduce the potential for condensation, triple-glazing is often recommended. Passive House certified windows are typically preferred as they meet stringent standards for airtightness and thermal bridging. Awning, tilt-turn, and casement style windows are preferred over more traditional double-hung or sliding windows because they have a far lower air infiltration rate with improved locking mechanisms and gaskets that also extend their useful life.



Existing Window: The existing windows contain louvers for PTACs. Although the window system should be upgraded to improve performance, the PTAC louver areas should be maintained for the installation of PTHPs. Photo Credit: Steven Winter Associates



Proposed Window: Passive House certified windows benefit from generous thermal breaks within the frame, typically include triple glazing, and, perhaps most importantly, include gasketing and hardware that ensure airtightness. Photo Credit: Shuco



Window U-value (measure heat loss through window, lower is better)

RECOMMENDED TARGETS

- **Roof Insulation:** *Minimum of R-30, or local code minimum.*
- **Add Interior Insulation :** *Minimum of R-20*
- **Add Exterior Insulation :** *Minimum of R-10*
- **Replace Existing Windows with High Performance Windows:** *Recommended U value = 0.167 Btu/hr.ft².F*
- **Reduce Air Leakage:** *Recommended airtightness = 1.0 ACH*
- **Whole Building U-value:** *0.091 Btu/ hr.ft².F*

Whole Envelope Performance

Building owners pursuing a low carbon retrofit can follow the Recommended Targets for individual element listed here, or they can model the performance of the entire exterior assembly to meet a whole building U-value. With this latter method an owner can trade higher performance in one area, say additional insulation, with slightly lower performance in another area, such as windows, while remaining confident of meeting their whole building carbon emissions goals.

Special Considerations

Any plan to add insulation to the exterior of a building must be carefully coordinated with any zoning or lot line restrictions, as well as any potential oversight by local authorities such as historic preservation ordinances.

If considering exterior refrigerant piping for heating and cooling systems both the phasing and layout of the piping must be carefully coordinated with any recladding systems.

Ventilation

A properly implemented low carbon retrofit requires balanced ventilation that delivers filtered supply air directly to habitable spaces, while stale air is removed from kitchens, baths and laundries.

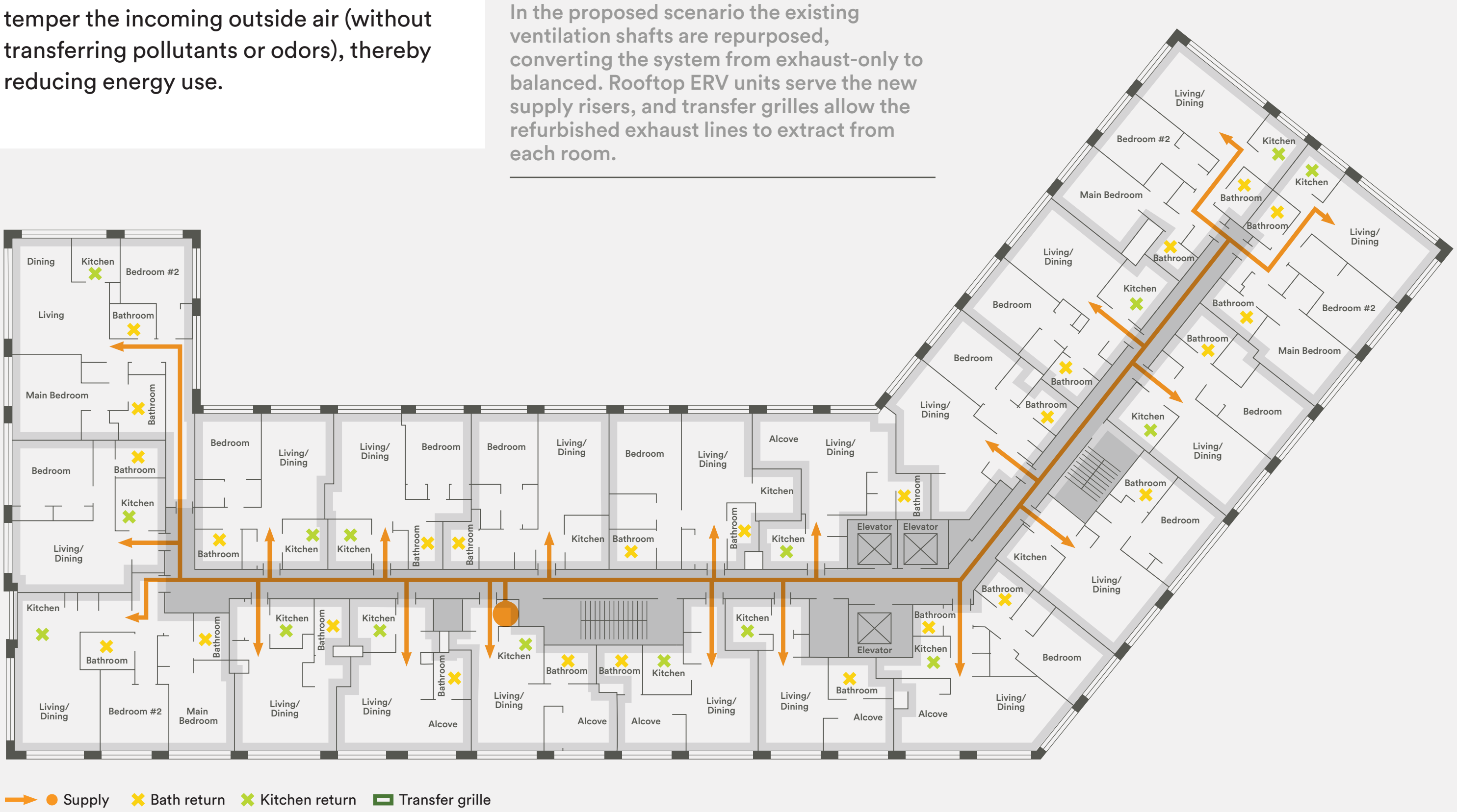
Balanced ventilation works in tandem with an airtight envelope to ensure the system draws little air via infiltration from the exterior or from adjacent apartments. In addition, an energy recovery system captures heat that would otherwise be exhausted to the outdoors and uses it to temper the incoming outside air (without transferring pollutants or odors), thereby reducing energy use.

RECOMMENDED TARGETS

- **Centralized Energy Recovery Ventilation (ERV) System**
  Sensible Heat Factor: 80%
  Max fan power: 0.76 W/cfm

Floor Plan: Centralized Ventilation

In the proposed scenario the existing ventilation shafts are repurposed, converting the system from exhaust-only to balanced. Rooftop ERV units serve the new supply risers, and transfer grilles allow the refurbished exhaust lines to extract from each room.



Ventilation Options

Ventilation systems should serve every unit and typically have exhaust grills in each kitchen and bath and supply grill in each living area and bedroom. Depending on the system chosen, ERVs can incorporate the ability to control humidity as well as a method to boost supplied air temperature.

Centralized Ventilation: Typically, existing ventilation shafts are repurposed and the system converted from exhaust only to balanced (see diagram this page). This arrangement is dependent on sufficient existing shaft area, but results in the fewest number of ventilators, preserving valuable floor area and easing maintenance.

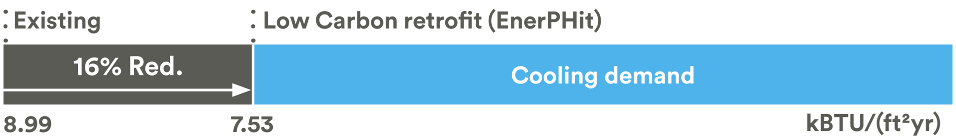
Special Considerations

Phasing: 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 has been dramatically improved, existing ventilation systems must be carefully analyzed to avoid unhygienic or innefficient conditions. Internal investigation will be required to determine optimal ventilation arrangement for each building. For the subject building, decentralized systems are also an option but require multiple penetrations in the exterior wall and complicated maintenance by increasing the number of filters and units to be monitored. Maintenance is often a concern with decentralized systems because the filters in each ERV need to be replaced or cleaned at least twice a year.

Heating & Cooling Upgrades

Once improvements to the envelope are complete, heating and cooling demand is dramatically reduced. This study describes the primary options for providing heating and cooling, with an emphasis on Packaged Terminal Heat Pumps (PTHPs).

Packaged Terminal Heat Pump (PTHP) systems offer higher efficiencies over the existing heating and cooling system, which are typically Packaged Terminal Air Conditioner (PTAC) units for this building type. While PTAC units are already fully electric, they rely on low-efficiency electric resistance to provide heating. Some PTHPs also include back-up electric resistance for colder days, but newer PTHP models are entering the market that are capable of operating as a heat pump even at low temperatures. PTHP units are relatively low in cost when compared to other heat pump systems, and also have lower labor costs for installation when compared to systems that require refrigerant lines throughout the building.

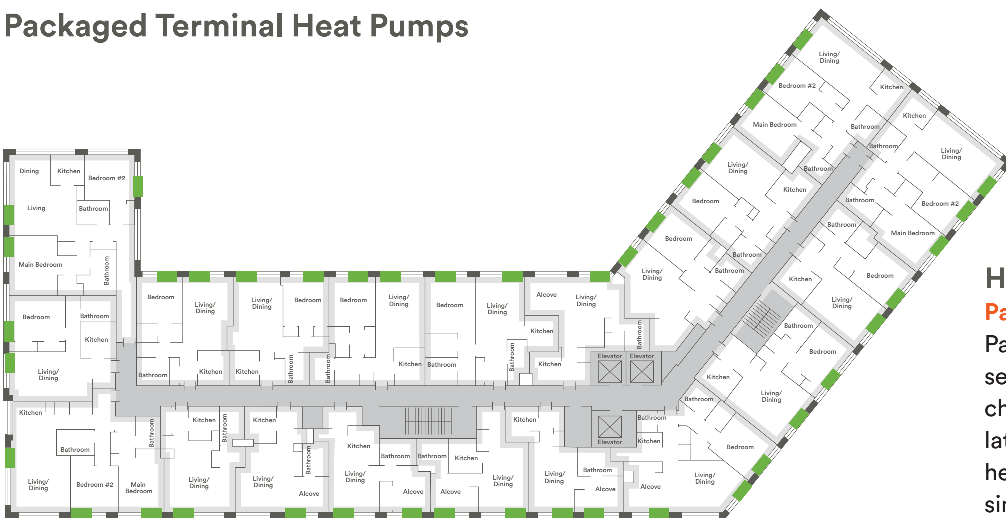


Although a high performance envelope does not reduce the cooling demand nearly as much as the dramatic reductions in heating demand, a 20% reduction in cooling demand remains extremely important as that reduction will occur during periods of peak demand for electricity—periods when utility costs and carbon penalties are likely to be highest in the future.

RECOMMENDED TARGETS

- **Decentralized PTHPs:**
  Cold climate system:
  Min. efficiency: → Heating: 3.2 COP @ 47°F
  → Cooling: 4.4 COP

Packaged Terminal Heat Pumps



Packaged Terminal Heat Pump

Each room heater can be replaced with the packaged heat pump solution when necessary, so this retrofit can be phased to coincide with normal equipment replacement cycles.
Phoro Credit: Steven Winter Associates

Heating & Cooling Options

Packaged Terminal Heat Pumps (PTHPs)

Packaged heat pumps are factory assembled and leak-tested, so there is little chance of refrigerant leakage due to installation quality compared to split- or central heat pump systems. Installation is also simplified since there is no requirement for field leak testing, which requires a return visit by the installer.

The retrofit will likely require some amount of envelope modification to fit the new equipment. The envelope work can be coordinated with other required façade work. Air sealing around the PTHPs units is extremely important if the existing conditions lack insulation. Address condensate and defrost as well.

Labor for wall opening modifications is the only source of additional cost, making this technology the least expensive option for electrification of fossil fuel systems.

Domestic Hot Water

hot water

To realize the full benefits of decarbonization, domestic hot water systems should transition from fossil fuel based systems to electricity based systems. Currently, heat pump hot water systems are limited in size and application for large buildings. However, there are options on the market today that can allow a building to offset a portion of its DHW usage with heat pumps, while still retaining its existing fuel-based system to serve the remaining load. Options to get started now are listed below, along with ways to prepare your building for when more large-capacity heat pump systems are available.

Domestic Hot Water electrification options:

Air-to-water heat pumps (AWHP)

→ Install an air-to-water heat pump (AWHP) plant outside, either on the roof or at grade, and connect to storage tanks in the basement or other service space.

→ Equipment options: As there are a limited number of products that can produce sufficient hot water on the coldest days, the system will need to work in conjunction with a fossil fuel based system or a second "boost" stage, which could be a water-to-water heat pump or a direct electric heater.

RECOMMENDED TARGETS

- **Air to Water Heat Pump: Min. COP: > 2.2**

Preparing now for future DHW electrification:

→ Install a small heat pump plant to offset a portion (~30%) of the DHW load now. This will save carbon and give the owner/operator a chance to become familiar with the technology while leaving the fuel-based plant in place.

-Leave spare electric capacity and breakers so additional equipment and controls can be added in the future without significant electrical work.

-Leave valved off and capped piping to allow for easier heat pump connections in the future.

Lighting/Plugs/Cooking

Efficiency upgrades to lighting, appliances and equipment can occur at virtually any time and are a good place to begin if new to energy conservation. Switching cooking appliances from gas to electricity (induction) is required to reach full decarbonization and to ensure the health and well being of occupants.

Lighting and plug load recommendations

→ Use LEDs in all hard-wired fixtures and lamps.

→ Use ENERGY STAR® appliances, including refrigerators, dishwashers, and laundry equipment.

→ Install occupancy sensors, daylighting sensors, and timers were appropriate and allowed (all common areas, fire stairs in some jurisdictions).

→ Use smart plugs to reduce equipment loads when the spaces are unoccupied and/or install systems that allow remote operation.

MINIMAL THRESHOLD

- **High Efficiency Common Area:** *50% Reduction in W/SF*
- **High Efficiency Appliances and Smart Systems:** *55% Reduction in plug loads*

Induction Cooking

Gas stovetops are a significant contributor to air quality problems in residences and often the final barrier for buildings that wish to fully decarbonize their systems. Induction cooking appliances are available at reasonable costs and should be a focus of anyone looking to improve the overall performance of their building.

Electric stoves and cooktops also reduce the risk of gas leaks and fire, as well as carbon monoxide poisoning..

BEEx: the building energy exchange connects New York City real estate and design communities to energy and lighting efficiency solutions through exhibitions, education, technology demonstrations, and research. We identify opportunities, navigate barriers to adoption, broker relationships, and showcase best practices online and at our resource center in Manhattan.

Resources

Other Playbooks in Series :

- Post-War 8+ Stories
https://be-exchange.org/report/lowcarbonmultifamily-postwar-high

- Pre-War 4-7 Stories
https://be-exchange.org/report/lowcarbonmultifamily-prewar-low

- Post-War 4-7 Stories
https://be-exchange.org/report/lowcarbonmultifamily-postwar-low

- Garden Style 1-3 Stories
https://be-exchange.org/report/lowcarbonmultifamily-garden

BEEX Tech Primers

The following primers directly relevant to this typology are listed below and found here: be-exchange.org/tech-primers

- VRF Systems
- Energy Recovery Ventilators
- Roof Insulation
- Wall Insulation
- High Performance Ventilators
- DHW: Air to Water Heat Pumps
- DHW: Point of Use
- LED Lighting Retrofits
- Plug Loads and Tenant Energy Use Reduction

Contributors

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