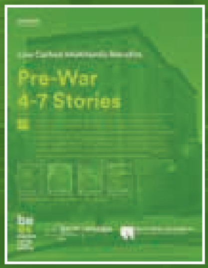
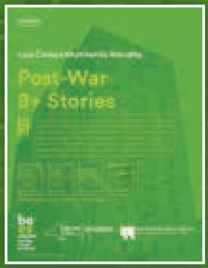
playbook

Low Carbon Multifamily Retrofits

Post-War 4-7 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.
Improving the Built Environment Since 1972

Photo credit: Steven Winter Associates

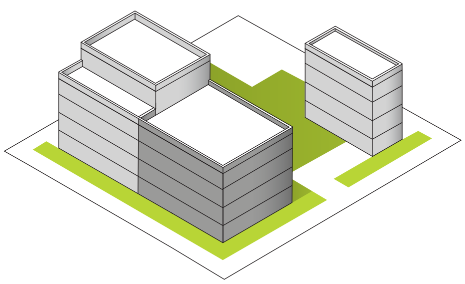
How to use this playbook

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-War Low Rise

These buildings, typically between 4 and 7 floors in height, are found in virtually every context, from lot-line to free standing buildings. Buildings of this typology rarely include mixed uses and/or tenant amenities.



Though limited in height, the layout of this typology varies considerably, with different arrangements of courtyards and street-facing facades.

Typical ownership challenges

- → Owners typically have limited access to capital
- → Vacancy is very low (hampering retrofit efforts)
- → Tenants typically responsible for cooling costs (complicating electrification of those systems)

ELEMENTS	DESCRIPTION	ISSUES
Exterior walls	Typically simple load bearing masonry with punched window openings.	- Often no insulation - Often no air barrier - Major thermal bridges at corners and parapet walls
Windows	Both wood and aluminum common, typically double-hung frames without thermal breaks, single glazing or weak double glazing common.	- Little thermal resistance - Air leakage high - Major comfort issues - Condensation risk - Absorb significant solar heat
Heating	Commonly one-pipe steam systems served by oil or gas fired boiler.	- Limited control - Overheating common - High short-term maintenance costs
Cooling	Window AC units, sporadically deployed.	- Increases whole building U-value - Creates drafty conditions - Major thermal bridge - Noisy, inefficient - Winter removal very rare
Domestic Hot Water	Heat exchange at steam boiler with constant recirculation loop.	- Requires running steam boiler in shoulder and cooling seasons
Ventilation	Mixture of partial kitchen/bath exhaust and natural ventilation.	- No direct fresh air introduction - Limited mechanical exhaust from bathrooms or kitchens

Actual Building Information

The post-war building selected for study is a 7-story, market-rate residential building in Brooklyn, New York. The building has masonry exterior walls enclosing 83 apartments across 76,113 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.

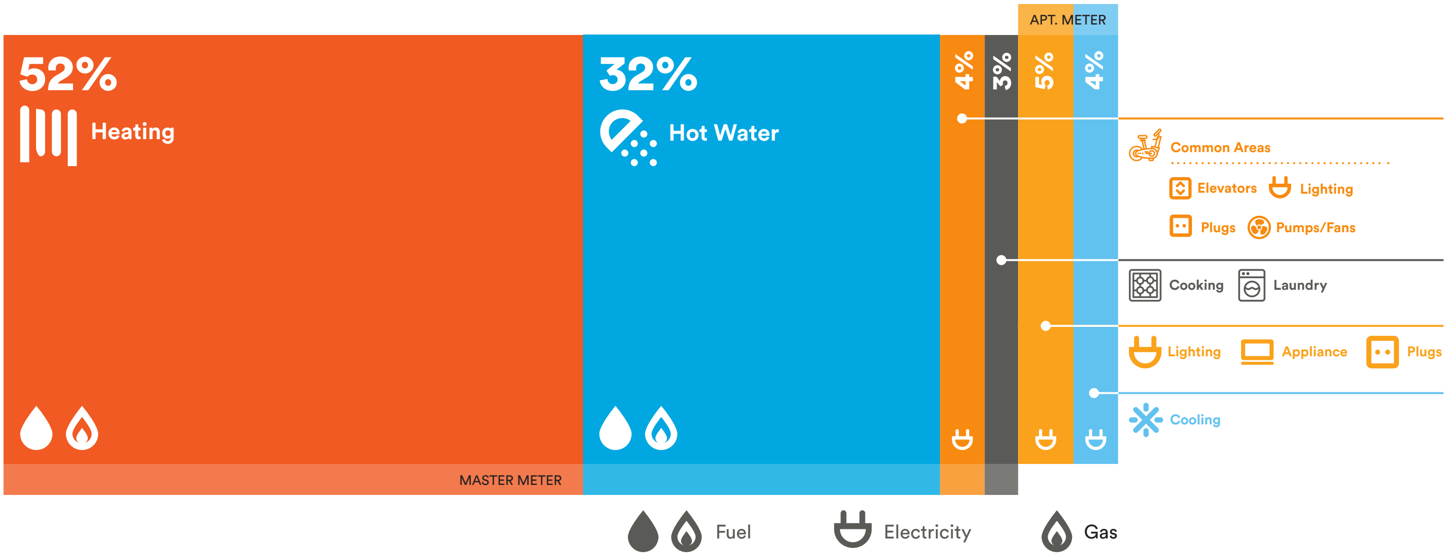
Utility Costs

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 Through-wall AC units. Heating and hot water boilers are typically dual fuel (oil or gas).

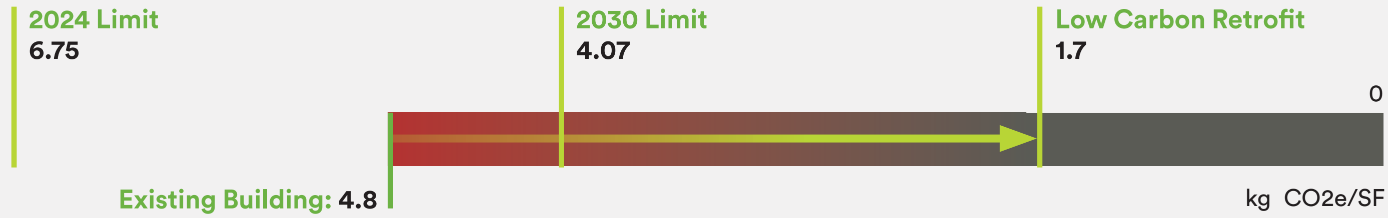
The study building includes common features like low performance glazing systems and balconies. Photo credit: Steven Winter Associates

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

Upgrading to high-performance casement windows will require coordination with window AC units.

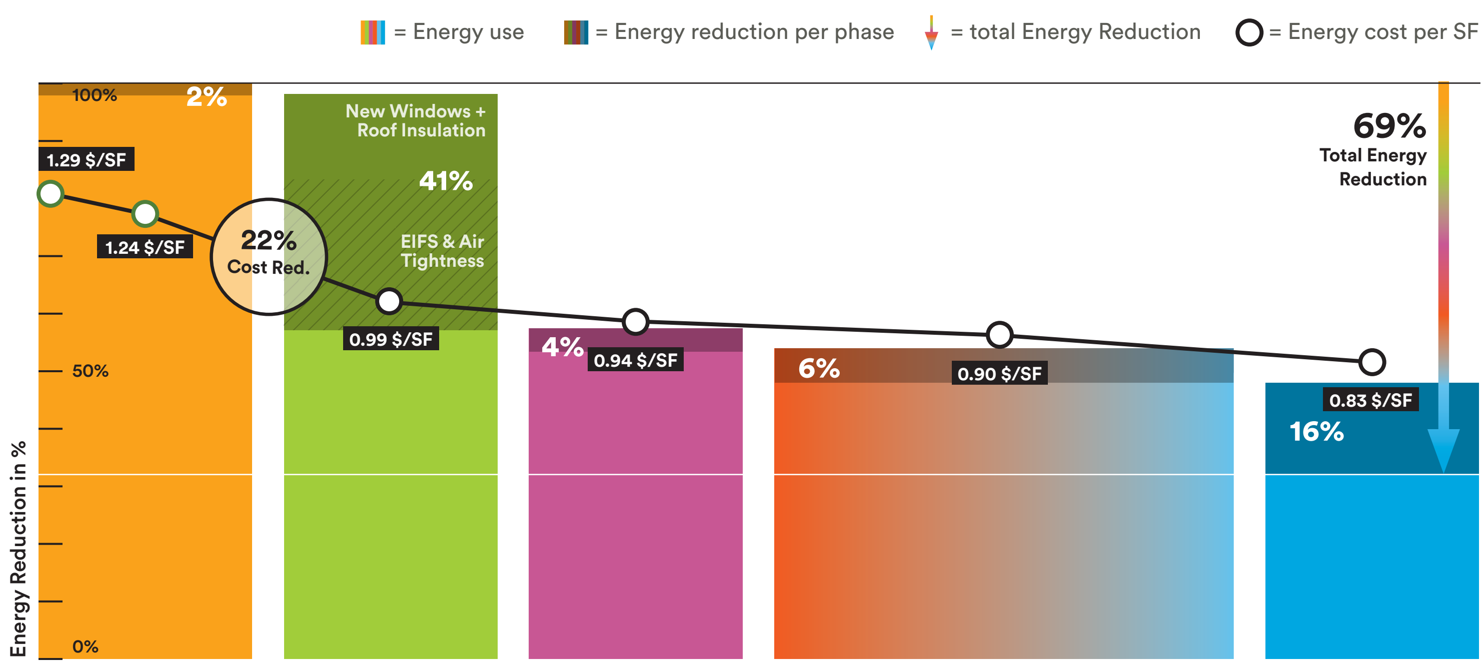
See page 10

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.

Annual Utility Savings

$98,097 **$63,267 (low carbont retrofit)**

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.

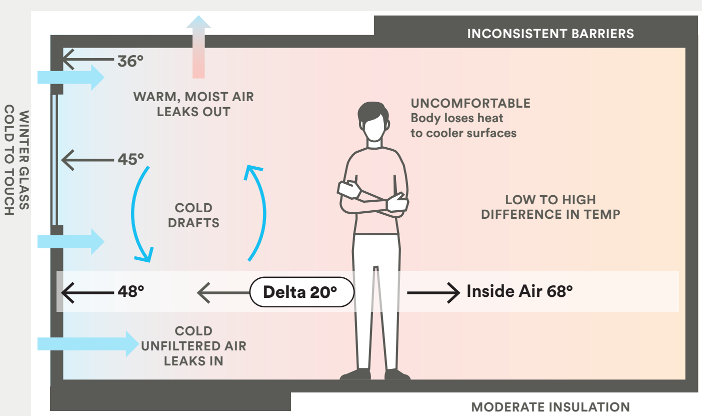
Gas System inspection savings: Local Law 152 of NYC mandates extensive inspections of gas systems every five years. Buildings in NYC that fully decarbonize through switching their gas-based systems like heating, hot water and cooking to electricity-based systems will avoid the considerable costs associated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

Health

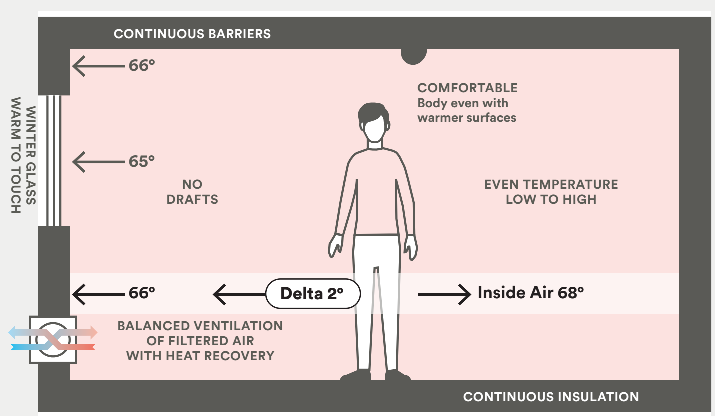
Upgrading the building envelope and ventilation systems radically improves interior air quality.

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.

thermal comfort - existing



thermal comfort - post retrofit



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 Low Rise Efficiency Packages

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	
envelope	**ROOF**					
	→ Insulate Roof	★★	★	★	LOW	$
	EXTERIOR WALL					
	→ Add Interior insulation	★★	★★★	★	LOW	$$$
	→ Add Exterior Insulation	★★★★★	★★★★	★★★	LOW	$$$$
	WINDOWS					
	→ Replace Existing Windows with High Performance Windows	★★★★	★★★★★	★★★	LOW	$$$$$
	Air Tightness					
	→ Ensure Air Sealing as part of Exterior Wall & Window Upgrades	★★★★	★★★★	★★★	LOW	$$
heating	→ Building-Wide VRF System	★★★★★	★★★★	★★★	HIGH	$$$$$
cooling	→ Mini-Split Heat Pumps	★★★★	★★★	★★★	HIGH	$$$$
	→ Building-Wide Hydronic Loop with Hybrid Acs	★★★★	★★★★	★★★	HIGH	$$$$$
ventilation	→ Decentralized Energy Recovery Ventilation System	★★	★	★★★★★	HIGH	$$$$$
hot water	→ Air to Water Heat Pump Water Heaters	★★★★	★	★★	MEDIUM	$$$
	→ Water to Water Heat Pump Water Heaters	★★★★	★	★★	MEDIUM	$$$$
lighting & loads	**LIGHTING**					
	→ High Efficiency Common Area Lighting	★★	★★	★	LOW	$
	PLUG LOAD					
	→ High Efficiency Appliances and Smart Systems	★★	★★	★★	LOW	$$
solar	**PHOTOVOLTAIC**					
	→ Install Solar PV Array	★	★	★	LOW	$

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

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

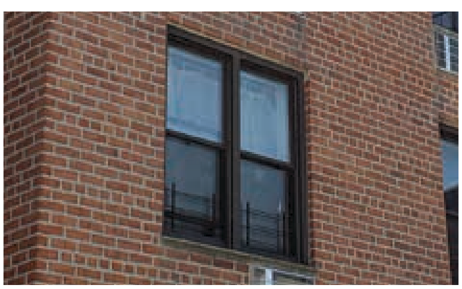
Insulation is the primary method of separating the interior environment from the exterior and is especially critical for retrofits of buildings with no insulation in their existing wall assembly.

Although exterior applications of insulation provide a 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.

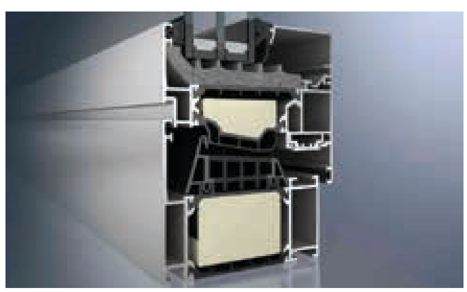
Windows

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

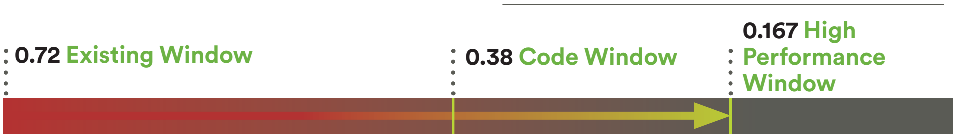
Low carbon retrofits require careful selection of high-performance windows to ensure interior comfort and optimize heating and cooling demand. To maximize comfort and reduce the potential for condensation, triple-glazing is often recommended. Passive House certified windows are typically preferred as 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 infiltrtation rate with improved locking mechanisms and gaskets that also extend their useful life.



Existing Window: Most windows of this period have limited thermal breaks and poor airtightness, contributing to comfort problems year round. 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:** *0.084 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 specifications 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 against 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

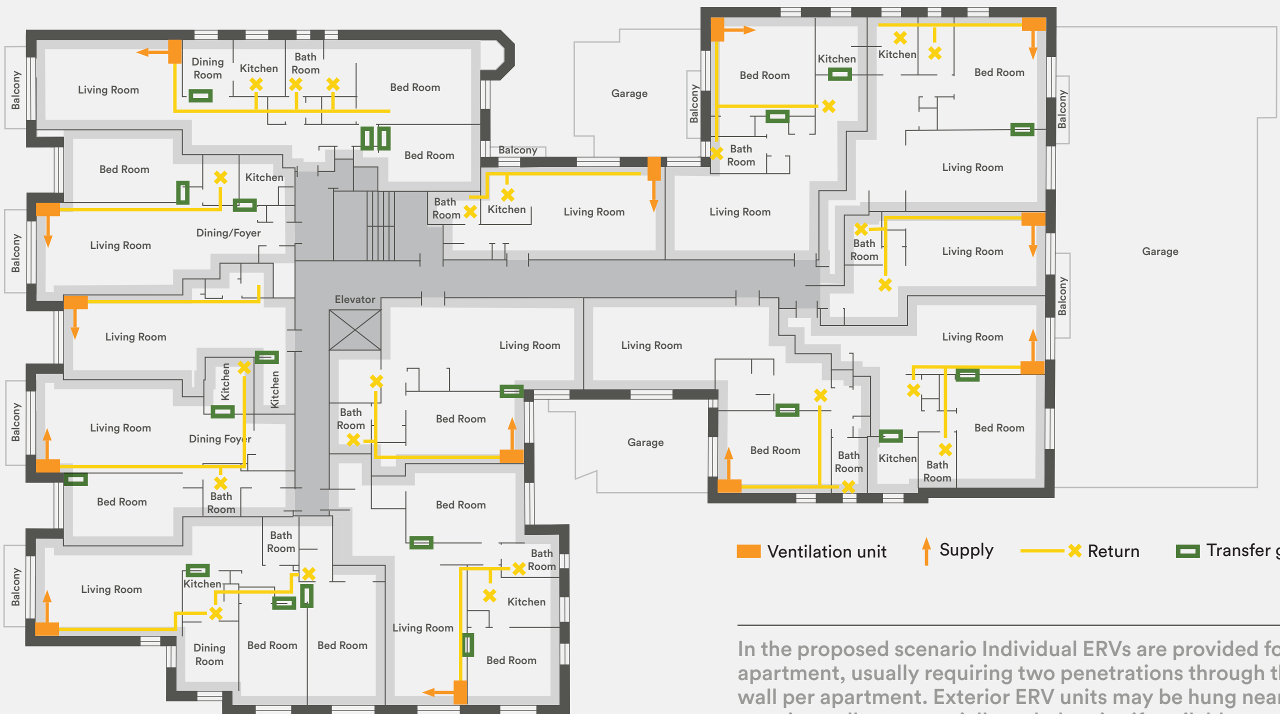
A properly implemented low carbon retrofit requires balanced ventilation that delivers properly filtered supply air directly to habitable spaces, while stale air is removed from kitchens, baths and laundries.

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 transfering pollutants or odors), thereby reducing energy use.

RECOMMENDED TARGETS

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

Floor Plan: Decentralized Ventilation



In the proposed scenario Individual ERVs are provided for each apartment, usually requiring two penetrations through the exterior wall per apartment. Exterior ERV units may be hung near the ceiling or exterior wall, or potentially on balconies if available.

Ventilation Options

Ventilation systems should serve every apartment and typically have exhaust grills in each kitchen and bath and supply grills at 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. Appropriately sized transfer area should be provided with door undercuts or transfer grills so that all rooms will receveive fresh air.

Decentralized ventilation: Individual ERVs are provided for each apartment, usually requiring two penetrations through the exterior wall per apartment. Exterior units may be hung near the ceiling or exterior wall, or potentially on balconies if available.

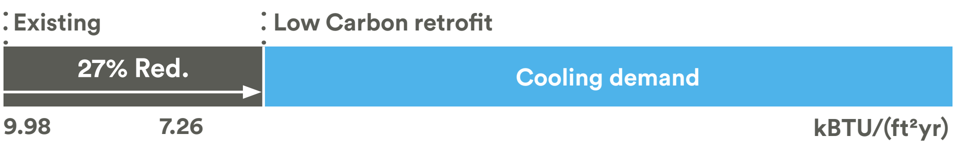
Special Considerations

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 inefficient conditions.
Internal investigation will be required to determine optimal ventilation arrangement for each building. For the subject building a decentralized ventilation systems is recommended because vertical ventilation shafts were not appropriate for re-purposing. Decentralized ERVs require multiple penetrations in the exterior wall. Maintenance is required for each ERV in a decentralized systems - filters in each ERV need to be replaced or cleaned 2-3 times per year, and exterior grills should be cleaned every year.

Heating & Cooling Upgrades

Once improvements to the envelope are complete, heating and cooling demand is dramatically reduced.

VRF systems offer significant improvements over existing heating and cooling systems although the refrigerants come with a risk of leakage and regulatory phase outs. Maximum refrigerant quantity restrictions often require the use of several smaller VRF systems in a large building. Mini-split heat pumps are a good alternative for buildings 7 stories and under. "Cold-climate" mini-split heat pumps operate efficiently without reliance on back-up heating, even when the temperature drops below 20 degrees F.



Although a high performance envelope does not reduce the cooling demand nearly as much as heating demand, a 20-30% reduction in cooling demand remains extremely important as that reduction will occur during periods of peak demand for electricity—when utility costs and carbon penalties are likely to be highest.

Centralized VRF: Risers on the Interior

This preferred VRF layout requires interior construction, removing existing steam risers and locating new refrigerant risers in their place. Most sets of risers serve two cassettes on each floor.

Similar to "mini-split" systems, VRF systems utilize interior cassettes to deliver heating and cooling. A unit similar to the one shown here would sit above the window in each major room, replacing the steam radiators and window AC units.

RECOMMENDED TARGETS

- **Building-Wide VRF System:**
  Cold climate system:
  Min. efficiency: → Heating: 3.3 COP @ 47°F
  → Cooling: 4.4 COP
- **Mini-split heat pumps:**
  Cold climate system:
  →Heating: 3.3 COP @ 47°F
  →Cooling: 4.4 COP
- **Building-Wide Hydronic Loop + Hybrid ACs: Fed by AWHPs:**
  AWHP - Cold climate system:
  Min. efficiency: → Heating: 2.3 COP
  → Cooling: 2.2 COP

Special Considerations

Most low carbon retrofits result in combining the heating and cooling systems, originally separate, into a single system. This work will typically require electrical upgrades and often results in switching the utility costs for heating from the owner to the tenant.

Heating & Cooling Options

Building-wide VRF System

Providing both heating and cooling through a building-wide VRF system is among the most effective means of tempering interior conditions efficiently. Common layout options include:

→ Replace Steam Risers: Refrigerant risers can often be run in the same location as removed steam risers, though this entails significant disruption in each apartment.

→ New Interior Chase: Provide a new vertical chase in a central location for refrigerant risers. Cassettes typically located near unit entrance.

→ Exterior Risers: Placing refrigerant lines on the exterior minimizes interior disruption but requires some form of recladding due to lot lines, balconies and building geometry.

Mini-Split Heat Pumps

Mini-split heat pump systems provide both heating and cooling, offering higher efficiencies, improved comfort, and more control. A passage for refrigerant piping must be found to connect the indoor and outdoor units. In a retrofit application, ductless mini-split systems are often preferred over ducted to reduce disruption.

Domestic Hot Water

hot water

To realize the full benefits of a green grid, and to avoid penalties associated with stringent carbon reduction requirements, 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. Today buildings should consider offsetting a portion of its DHW usage with heat pumps, while still retaining its existing fuel-based system to serve the remaining load.

Domestic Hot Water electrification system options:

Air-to-water heat pumps (AWHP) for buildings with VRF heating/cooling

→ If VRF system is used for heating/cooling, 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.

Water-to-water heat pumps (WWHP) for buildings with hydronic heating/cooling

→ If hydronic system is used for heating/cooling, install a water-to-water heat pump (WWHP) and storage tank for DHW in the basement or other service space. WWHPs pulls heat from the hydronic loop for DHW, providing beneficial cooling in the warm season.

→ Equipment options: Unlike AWHPs which require outdoor placement, WWHPs can be installed indoors.

RECOMMENDED TARGETS

- **Air to Water Heat Pump: Min. COP > 2.2**
- **Water to Water Heat Pump: Min. COP >3.1.**

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 appliance 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 recommendation

→ 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 where 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 1980-Mid High 8+ Stories
https://be-exchange.org/report/lowcarbonmultifamily-post80-high

- 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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