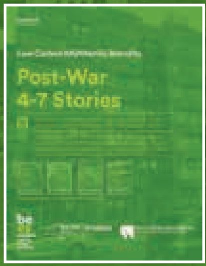
playbook

Low Carbon Multifamily Retrofits

Garden Style 1-3 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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Photo credit: Steven Winter Associates

How to use this playbook

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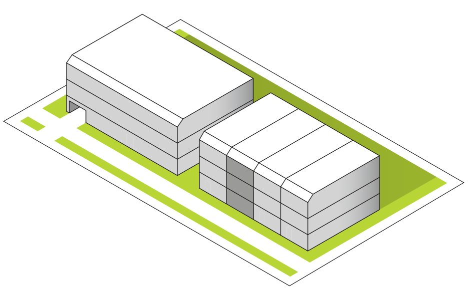
This playbook summarizes those retrofit strategies across all major building systems and components that will maximize occupant comfort and energy savings through a transition from fuel to electricity-based heating, cooling and hot water systems. For clarity of analysis the playbook assumes an ideal 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.

Garden Style 1-3 Stories Typology

These buildings are typically between 1 and 3 floors in height. They are typically set back from the lot line and freestanding. These buildings typically have ground floor entrances to all apartments with no common circulation or amenity areas for tenants. Most buildings of this typology are wood frame with some insulation in the walls and attic. Garden style buildings often exist in a campus style with multiple buildings held by the same owner on a large lot. Some campus style garden styles will have central heating and/or domestic hot water plants.



The layout of buildings in this typology is fairly consistent, with the largest variations occurring between end-units and central units that have other units on either side.

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

ELEMENTS	DESCRIPTION	TYPICAL ISSUES
Exterior walls	Typically wood framed cavity walls with punched window openings. Exterior vinyl siding and/or brick finish is typical. Shared party walls between apartments are typical.	- Minimal cavity insulation in wood frame walls - Often no air barrier - Major thermal bridges at ground connections, rim joists, corners, balconies
Windows	Both wood and aluminum common, typically double-hung frames or slider windows without thermal breaks, single glazing or double glazing common	- Little thermal resistance - Air leakage high - Major comfort issues - Condensation risk - Windows allow significant solar heat gain
Heating	Commonly hot water baseboards served by central campsus fuel fired boiler, or a fuel fired boiler in each apartment. Some apartments have electric baseboard heating only. Some apartments have central air fed by an in-unit fuel fired furnace.	- Poorly executed distribution systems - Shoulder month inefficiencies leading to overheating - Boilers frequently do not have pipe insulation, or the insulation is inadequate or compromised
Cooling	Through-wall AC units, or window AC units, or central forced air	- Through-wall AC units create drafty conditions - Increases whole building U-value - Through-wall AC units create major thermal bridges - Noisy, inefficient - Winter removal very rare
Domestic Hot Water	Commonly served by a central campus fuel-fired boiler or fuel fired boiler located in every unit. Unit fuel fired boilers may be atmospheric vented with storage. Buildings with electric heating have electric water heater storage.	- Requires running the central campus gas fired water heater or in-unit atmospheric vented gas water heaters boiler in shoulder and cooling seasons - Buildings with electric heating may also have electric water heaters with storage.
Ventilation	Mixture of partial kitchen/bath exhaust and natural ventilation; often sidewall vented and switch operated fans on the tenant meter.	- Limited direct fresh air introduction - System is not balanced, drives infiltration from exterior and adjacent units - Exhaust is intermittent

Actual Building Information

The Garden Style building selected for study is a 2-story residential building in upstate New York. The building has wood framed exterior walls with cavity insulation and a vented attic with blown-in insulation enclosing 8 apartments across roughly 12,800 gross square feet. The Garden Style building evaluated is part of a campus with seven similar buildings.

This building is typical of a large swath of buildings in New York State (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.

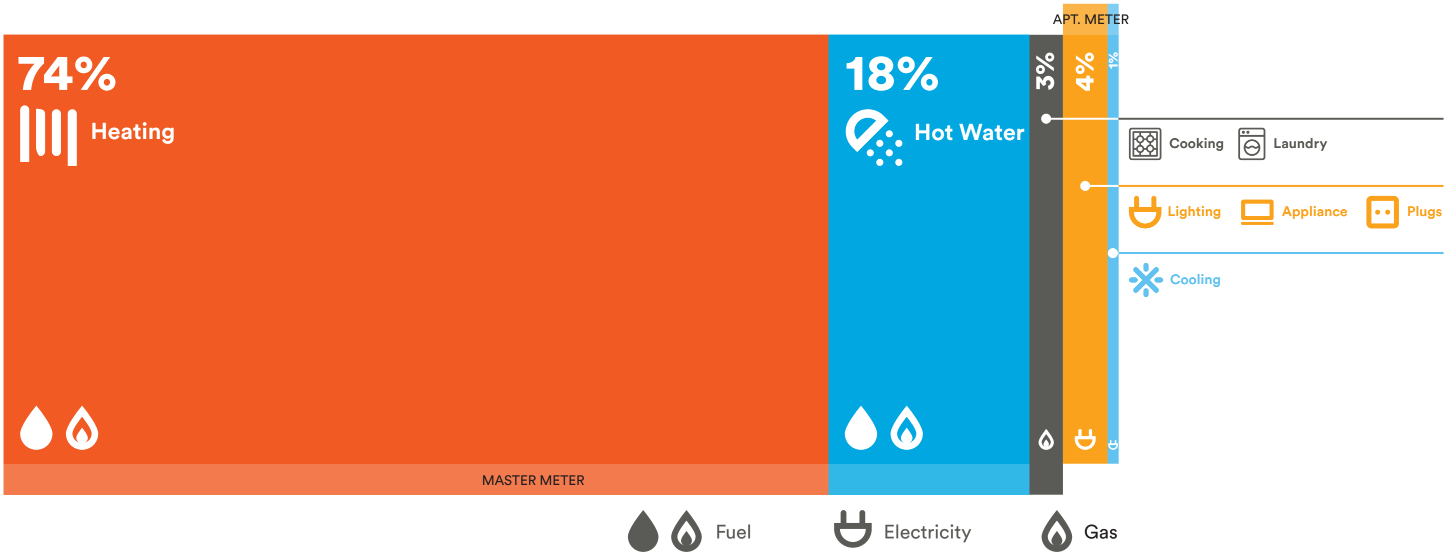
Utility Costs

With a central campus boiler the building owner pays for the utility costs of heating and hot water fuels as well as electricity costs for common area functions, including lighting, pumps, and fans. Tenant utility bills cover only electricity for apartment lighting, appli-ances, and cooling – which typically includes through wall AC, or window AC. Heating and hot water boilers are typically dual fuel (oil or gas).

Like many buildings of this era and typology, the window to wall ratio is low.
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 enve-lope improvements—are essential to realizing a low carbon future and avoiding future spikes in utility costs.



Low carbon retrofits often pose significant challenges to the financial structure of a building, with common efficiency measures leading to changes in liability for certain end-use utility charges.

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.

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

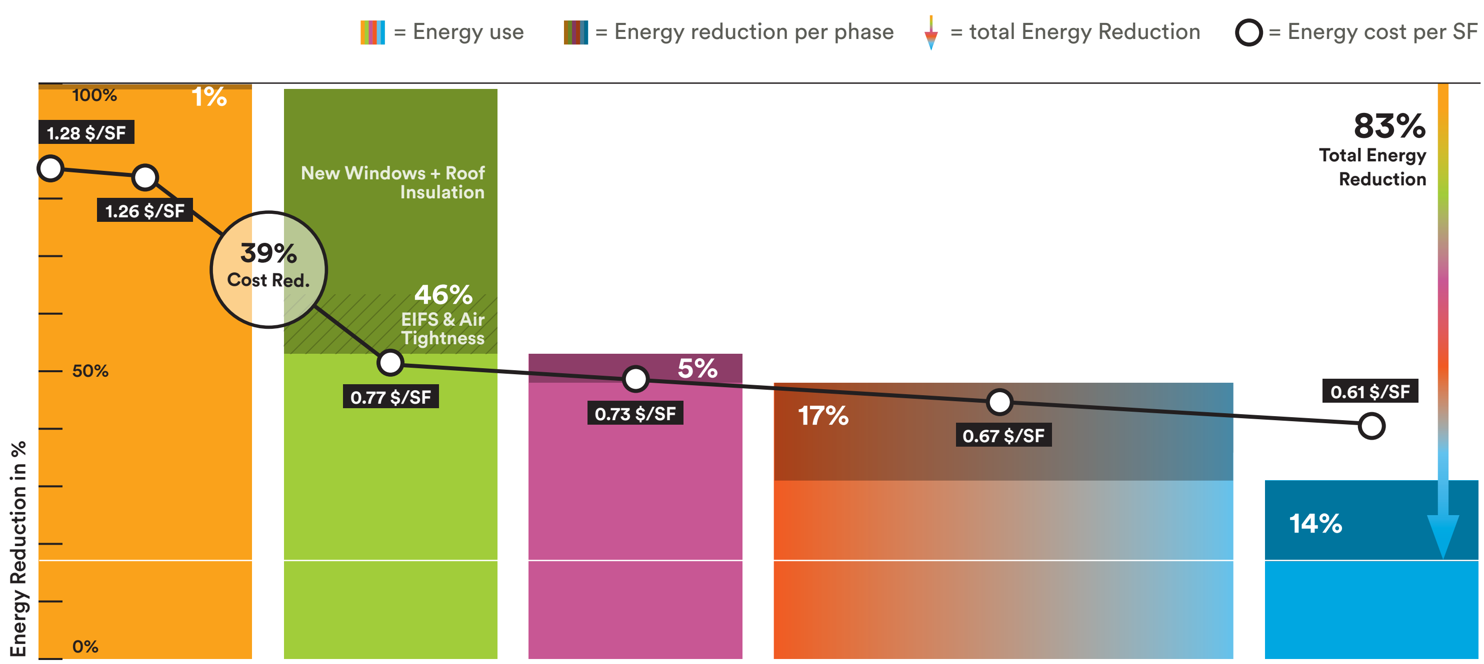
See page 10

hot water

The technology for fully electrifying hot water systems is well established for a building of this size.

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

$12,877 — $7,961 (low carbon retrofit)

Health

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

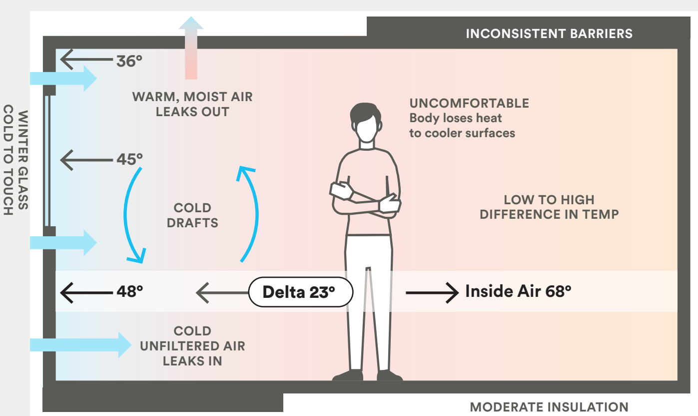
Air infiltration through leaky exterior walls and condensation at thermal bridges to the outside are among the primary vectors for poor indoor air quality. The former can be the source of moisture and myriad pollutants while the latter is the foundation of interior mold growth. In a low carbon retrofit 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

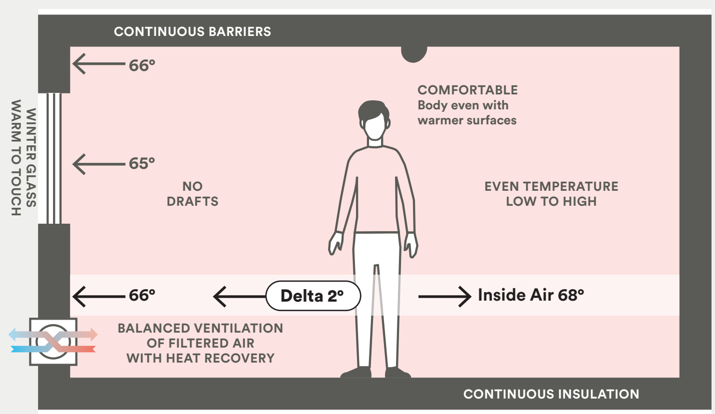
Utility cost reductions: A low carbon retrofit dramatically reduces utility bills through more efficient systems and reduction in demand for heating and cooling systems, and mitigates the impact of future utility cost increases.

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

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).

Garden Style 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
		EnergySavings	Comfort	Health/IAQ	Maintenance	
envelope	ROOF					
	→ Insulate Roof	★★★★★	★★★★	★★★	LOW	$$
	EXTERIOR WALL					
	→ Add Interior insulation	★★★	★★★★	★★	LOW	$$$$$
	→ Add Exterior Insulation	★★★★★	★★★★★	★★★★	LOW	$$$$
	WINDOWS					
	→ Replace Existing Windows with High Performance Windows	★★★	★★★★★	★★★	MEDIUM	$$$$
	Air Tightness					
	→ Ensure Air Sealing as part of Exterior Wall and Window Upgrades	★★★★	★★★★	★★★	LOW	$$
heating / cooling	→ Mini-Split Heat Pumps	★★★★	★★★	★★★	HIGH	$$$$
ventilation	→ Decentralized Energy Recovery Ventilation System	★★	★	★★★★★	HIGH	$$$$$
hot water	→ Air to Water Heat Pump Water Heaters	★★★★	★	★	MEDIUM	$$$
lighting & loads	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		✓	✓	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 and Window Upgrades	✓	✓	✓	MEDIUM	LOW
→ Mini-Split Heat Pumps		✓	✓	HIGH	LOW
→ Decentralized Energy Recovery Ventilation System	✓	✓	✓	HIGH	MEDIUM
→ Air to Water Heat Pump Water Heaters	✓	✓	✓	MEDIUM	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 of a wood frame building involves detailing at each step of an envelope retrofit, from the windows and doors themselves, to their installation, to the creation of a continuous air barrier within the existing wall and roof assemblies. Most often the air barrier must be located on the exterior side of the structrural sheathing. Special attention should be directed to improve the airtightness of the roof to wall connection in wood frame buildings.

Insulation

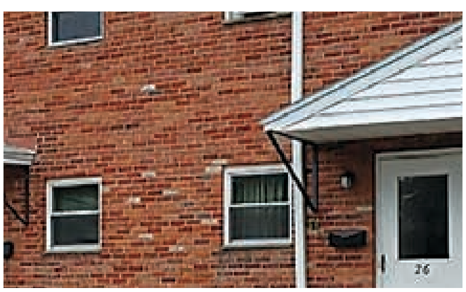
Insulation is the primary method of separating the interior environment from the exterior and is especially critical for retrofits of buildings with no insulation in their existing wall assembly.

Improving wall cavity insulation is only possible when units are not occupied, and on its own does provide the high R-values, durability, and occupant comfort sought here. Cavity insulation should be supplemented with continuous exterior insulation, most commonly through EIFS, the most cost-effective option.

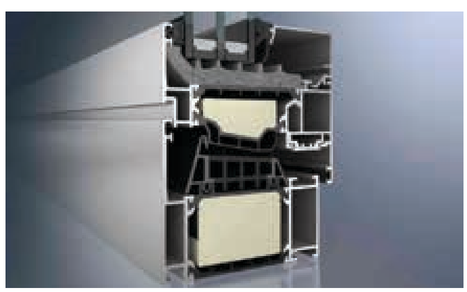
Windows

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, with triple-glazing often recommended. Passive House certified windows are typically preferred, with awning, tilt-turn, and casement style windows preferred over more traditional double-hung or sliding windows.



Existing Window: Although the frames of high performance windows are typically larger than the existing, the retrofit would allow for the elimination of window AC units, thus increasing the actual daylight area of the windows. 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

- **Add Interior Insulation to Underside of Roof Sheathing**
- **Roof Insulation:** *Minimum of R-40*
- **Add Exterior Insulation over a full depth of wood frame cavity insulation:** *Minimum of R-10 Continuous Exterior insulation*
- **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-valve:** *0.062 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.

Special attention should be directed to improve the airtightness of the roof to wall connection in wood frame buildings. Large roof overhangs that contain soffit vents for a vented attic are an area of high air infiltration that can be difficult to air seal. Air sealing at these critical connections can be addressed by converting vented attics to conditioned attics, including the original soffit vent within the new continuous air barrier system, and moving the insulation/ thermal boundary to the underside of the roof sheathing.

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 and baths.

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

- **Decentralized 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

Decentralized ventilation: 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. Appropritately sized transfer area should be provided with door undercuts or transfer grills so that all rooms will receveive fresh air.

Special Considerations

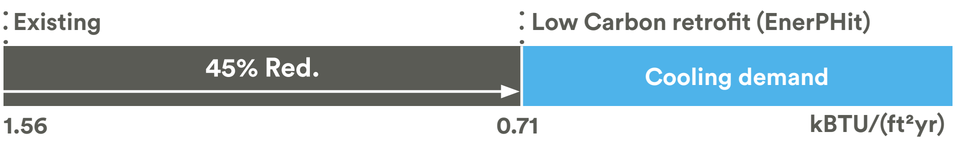
Phasing: Airtightness and ventilation are directly connected. Older exhaust-only ventilation systems rely on leaky exteriors and gaps between units to draw air out of the building. If the airtightness of a building has been dramatically improved, existing ventilation systems must be carefully analyzed 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. This study describes the primary options for providing heating and cooling, with an emphasis on air-source mini-split heat pumps.

These building types are typically heated with ducted forced-air furnaces, hydronic baseboards, or electric baseboards, and cooled with window or through-wall AC units. Mini-split heat pump systems can provide both heating and cooling, offering higher efficiencies, improved comfort, and more control for occupants. A passage for refigerant piping must be found to connect the indoor and outdoor units of the system. In a retrofit applicaton, ductless mini-split systems are often preferred over ducted systems because interior disruption is typically reduced.



A high performance envelope produces dramatic reductions in both heating and cooling demand.

RECOMMENDED TARGETS

- **Decentralized mini-split heat pumps:**
  Cold climate system:
  Min. efficiency: → Heating: 3.3 COP @ 47°F
  → Cooling: 4.4 COP

Mini-Split Heat Pumps

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. Refrigerant lines for the mini-splits can run within the joist depth or be concealed within soffits.

Mini-split heat pump system will utilize interior wall mounted cassettes to deliver both heating and cooling. A unit similar to the one shown here would be installed in each major room, replacing any baseboard heating and window AC units.

Mini-split layout options and special considerations

→ "Cold-climate" mini-split heat pumps operate efficiently without reliance on back-up heating, even when the temperature drops below 20 degrees-Fahrenheit.

→ Mount outdoor units of mini-splits on an exterior wall, roof, or ground, making sure that they are above the snow line or anywhere that can obstruct proper airflow. The outdoor units should not be arranged so that defrosted condensation can drip from one outdoor unit down to another, which can cause ice buildup and affect mini-split performance.

→ Most low carbon retrofits result in combining the heating and cooling systems, originally separate, into a single system. In many cases, this impacts the responsibility for paying the relevant utility costs. This work may also require electrical upgrades to power the new systems. The layout options should be coordinated with ventilation system layouts as well.

Domestic Hot Water

hot water

To realize the full benefits of decarbonization, domestic hot water (DHW) systems should transition from fossil fuel based systems to electricity based systems. There are small heat pump hot water systems available in the market for in-unit use when considering replacement in smaller buildings. For these buildings, full electrification of DHW is possible. However, for buildings with centralized DHW systems, options in the market today are limited by size and application. Buildings can offset a portion of their DHW usage with heat pumps, while still retaining 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 system options:

Air-to-water heat pumps (AWHP) for in-unit DHW systems

- → Install smaller-scale air-to-water heat pumps (AWHP) in each dwelling unit.
- → Equipment options: There are multiple small-scale AWHPs available today for in-unit DHW applications. These units can produce high temperature hot water in all cold climate conditions expected in New York.
- → One of the more promising recent developments has been the introduction of CO2-based heat pumps that utilize a “split-system” arrangement with an outdoor compressor, improving efficiency. These split systems alleviate potential comfort issues related to indoor AWHPs, which draw heat from interior spaces and may create colder areas in apartments.

Air-to-water heat pumps (AWHP) for centralized DHW systems

- → 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 new heat pump system may need to work alongside another system to "boost" the water temperature. This "boost" system may be the existing fuel-based system or a direct electric heater.

RECOMMENDED TARGETS

- **Air to Water Heat Pump for Centralized Systems :** *Min. COP: 2.2*
- **Air to Water Heat Pump for In-Unit Systems:** *Min. COP: 2.2*

Preparing now for future DHW electrification:

- → A benefit of smaller buildings is the potential to install equipment that uses natural refrigerants, which means they have extremely low greenhouse gas impact compared to the larger-scale AWHPs.

Special Considerations

→For split hot water heat pumps, ensure that the outdoor units are above the snow line or anywhere that can obstruct proper airflow. The outdoor units should not be arranged so that defrosted condensation can drip from one outdoor unit down to another, which can cause ice buildup and affect performance.

→A benefit of smaller buildings is the potential to install equipment that uses refrigerants with extremely low greenhouse gas impact compared to the larger-scale AWHPs.

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 this includes the reduction of gas leaks and fire, as well as reduced risk of carbon monoxide poisoning.

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 lighting 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 highly efficient, available at reasonable costs and provide a cooking experience similar to gas stoves. They should be a focus of anyone looking to improve the overall performance of their building.

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

- Post 1980 Mid High 8+ Stories
https://be-exchange.org/report/lowcarbonmultifamily-post80-highoc

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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