summary

Strategies for a High Comfort, Low Energy Retrofit in NYC

Pursuing Passive

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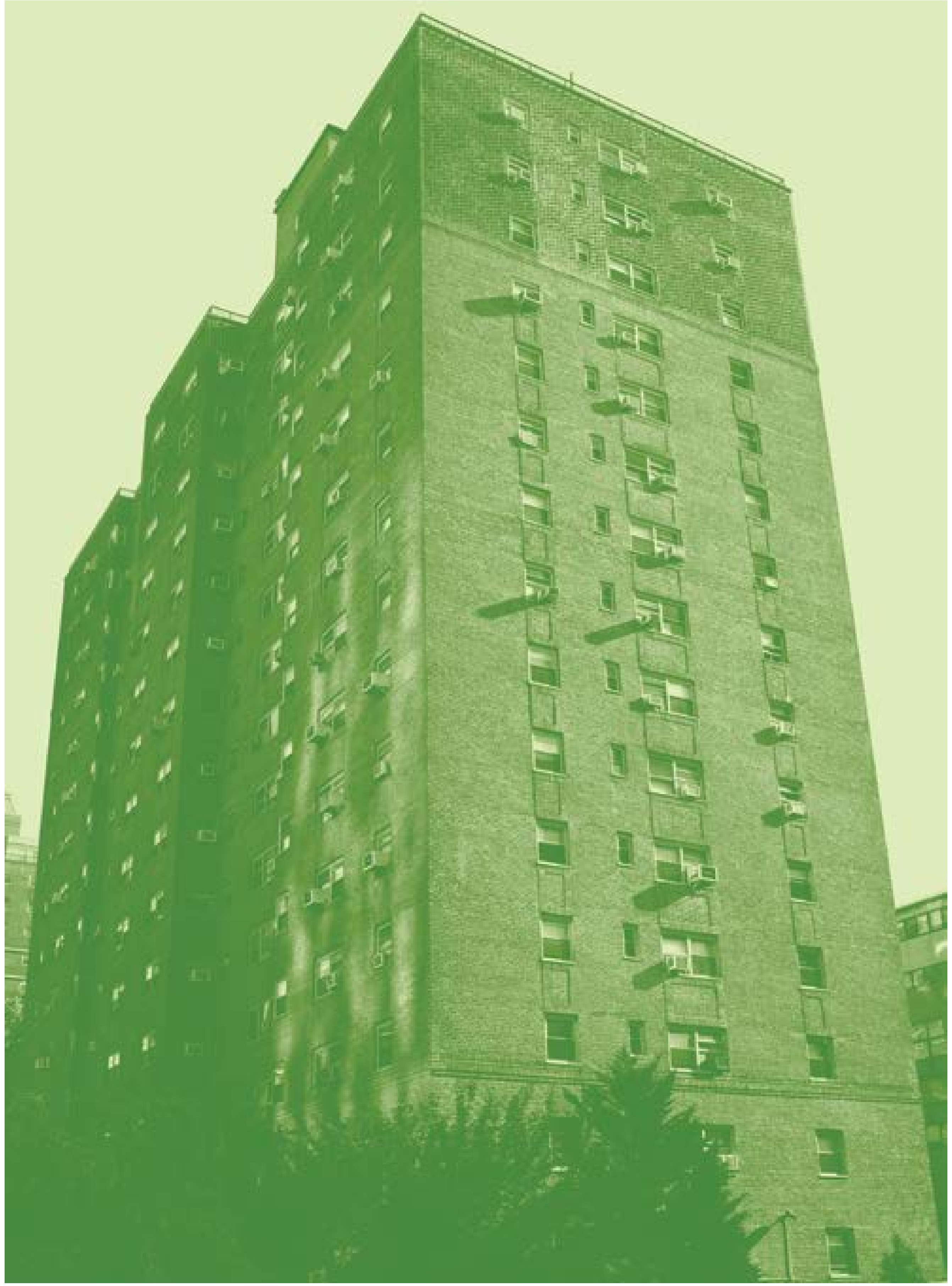


The subject building faces many challenges common to a wide variety of New York City buildings, including masonry exterior walls with no insulation, aging, windows, and merely adequate ventilation.

summary

New York City's recently passed Climate Mobilization Act highlighted the crucial role buildings have to play in our fight against global climate change, mandating that median building energy use be reduced 80% by 2050. Most buildings standing today will still be here in the mid-21st century, necessitating the identification of high performance retrofit strategies to bring these buildings in line with our emissions goals. We have selected an existing high-rise multifamily building in New York City representing a common building type to serve as a case study for this report. We determined that performing a high performance retrofit on an occupied building of this type was indeed feasible, and that doing so would also provide extensive quality of life benefits to building occupants.

Drawing down global building energy use is essential to ensuring an equitable and sustainable future. Buildings account for 40% of global carbon emissions and an astonishing 70% of New York City's emissions. The City estimates that carbon emissions of the building sector must be reduced by at least 80% to meet our current climate action goals. The Climate Mobilization Act signalled the City's seriousness in pushing buildings to do their part in meeting our collective emissions goals. Extensive, holistic renovation of occupied buildings is expensive to owners, disruptive to occupants, and lacks a natural market to exploit due to the rarity of such work. Hitting the legislation's targets will require overcoming these challenges, disrupting a sector notoriously resistant to innovation with a radical expansion of existing building retrofits.

The diversity of New York City's building stock – in size, age, construction, etc. – complicates matters, making it difficult to scale solutions. While there are many solutions generalized for all building types, building owners require strategies more specific to their particular building before studying the feasibility of a deep retrofit. With this in mind, we have selected an existing high-rise multifamily building in New York City that represents a common building type and will serve as the case study for this report.

Having selected a building with both features and challenges common to a broad range of buildings, we have applied the standard that we feel offers the most promising mix of reliability and effectiveness: Passive House.

Passive House

Distinguishing Passive House from other standards and guidelines is its focus on occupant comfort and reliable heating and cooling savings. Passive House-certified buildings are ready for a future of electrification, high utility costs, and increasingly frequent extreme weather events. Passive House also includes a comprehensive standard explicitly for retrofits of existing buildings, called EnerPHit.

The primary retrofit components of achieving the EnerPHit standard for our subject building are relatively simple:

- Replace the windows with high performance units
- Reclad the façade with insulation and an airtight layer
- Upgrade the ventilation to a balanced system with heat recovery
- Replace the heating and cooling with a high efficiency system
- Upgrade domestic hot water and other systems

Retrofitting a high-rise, freestanding residential building to the Passive House standard presents few technical challenges and results in substantial benefits, including improved comfort, health, and asset value. That said, it also requires significant capital expense and extensive tenant engagement to complete successfully. To convince building owners to embark on such a costly and disruptive project, we must highlight benefits to building transformation beyond energy savings.

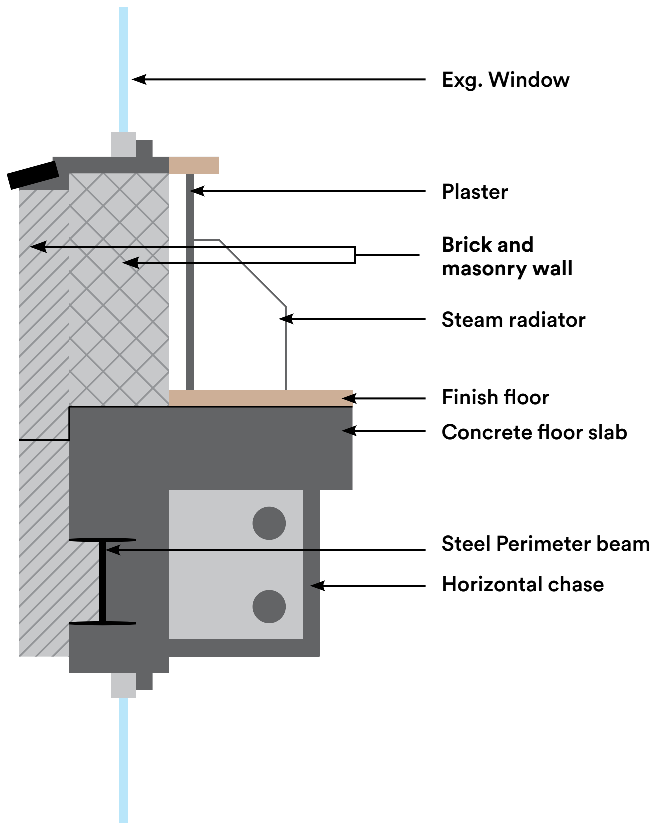
the building

The project team selected an existing building with features and challenges common to many high-rise multifamily buildings in the region.

This study describes the feasibility of upgrading an existing multifamily building in New York City to meet the Passive House standard for retrofits. The building selected for study is a 15-story, market-rate residential building on a small campus of nearly identical buildings in Brooklyn. Constructed in 1950, the building has masonry exterior walls that enclose 163 apartments across 123,000 gross square feet.

The tower is typical of a large swath of buildings in New York City (as well as many other regions) and faces many of the most common challenges encountered by anyone performing a deep retrofit of an occupied multifamily building. The owner of the property generously made drawings and other information about the building available but wished to remain unidentified in the report.

Figure 1: Existing Wall Section



The existing exterior walls contain no insulation. Steel perimeter beams at each floor aggravate the situation, providing a clear pathway for heat to escape in winter, compromising comfort and encouraging interior condensation. The study proposes that steam radiators be removed and most distribution piping abandoned.

Figure 2: Existing Building Systems Assessment

Elements	Issues	Elements	Issues
Exterior walls Simple masonry. 4" face brick bonded to 6" concrete block. Plaster interior surface.	No insulation No air barrier Major thermal bridges at perimeter floor beams High long term maintenance costs	**Cooling** Window AC units, located in most major rooms	Poor thermal performance Creates drafty conditions Major thermal bridge Noisy, inefficient
Windows Aluminum, double-hung frames (no thermal break), double-paned glazing with small metal spacers	Little thermal resistance High air leakage Major comfort issues Condensation risk Poor solar heat gain properties	**Domestic Hot Water** Heat exchange at steam boiler with constant recirculation loop	Heavy energy losses from circulation loop Requires running steam boiler in shoulder and cooling seasons
Heating Two-pipe steam system served by duel-fuel boiler in basement (serves 2 other buildings.) Includes 25 riser pairs and simple radiators in each major room.	Poor responsiveness Overheating common High short-term maintenance costs High replacement costs	**Ventilation** Exhaust only at kitchens, bathrooms and corridors. Each type collects under the roof to meet at one fan.	No direct fresh air introduction System is not balanced, drives infiltration from exterior and adjacent units Energy intensive

strategies

Envelope

A high-performance envelope constitutes the foundation of the Passive House standard, with a significant emphasis on airtightness, the right amount of insulation, and high performance windows and doors.

Airtightness

EnerPHit Criteria	1.0 ACH
Existing	5.0 ACH

Proposed
New airtight layer at façade, carefully detailed window install, correct shaft issues

Introduction of properly installed, high-performance windows will have a dramatic impact on the airtightness of the building as a whole. If an exterior-insulation-and-finish-system (EIFS) is applied to the exterior, the adhesive itself will also act as an air barrier across the opaque wall surface. In addition, remedial measures would improve airtightness of shafts, fire stairs, and existing duct risers.

Insulation

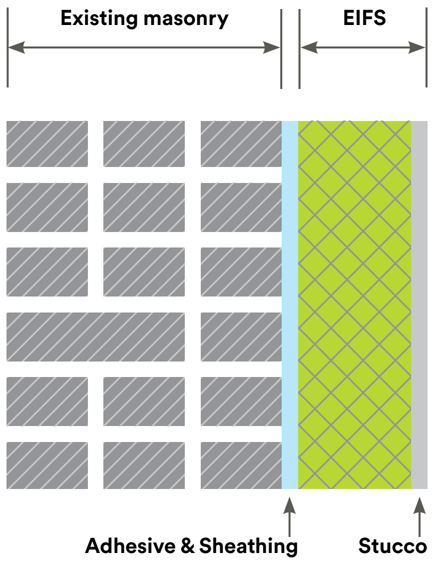
EnerPHit Target	R-10
Existing	R-2.4

Proposed
Install new exterior insulation system

EIFS: Installation of an EIFS system requires mechanically fastening a layer of exterior sheathing to existing brick, producing a clean, stable substrate. (Figure 3) The required layers of rigid insulation are then adhered directly to the sheathing without mechanical fastening. In this assembly the adhesive is actually the air barrier. A mesh-reinforced multi-layer coating resembling stucco (typically proprietary) is applied over the insulation to finish the new facade.

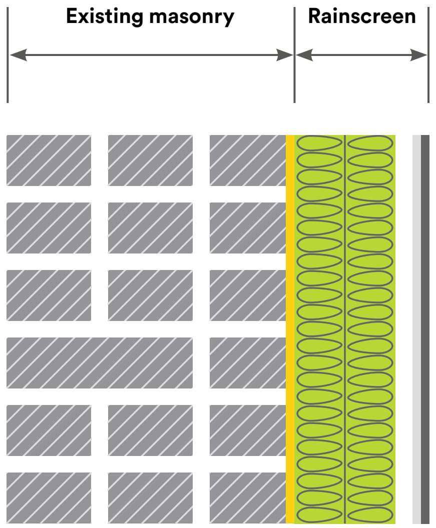
Rainscreen: These systems are more expensive than EIFS systems, but can produce an extremely durable façade with a wide variety of aesthetic options, most of which significantly increase "curb appeal". Rainscreen systems require frequent points at which the faced system connects mechanically to the existing building structure. These penetrations are costly, but also interrupt the otherwise continuous layer of exterior insulation. This requires careful detailing and may result in the need for additional R-value of insulation to compensate for the penetrations in the insulation layer (though many systems are now available that include elements with low thermal conductivity, like fiberglass). Rainscreen systems allow for the installation of façade components (insulation, air barrier, sheathing, etc.) in the correct order and in a manner allowing for easier long-term maintenance. (Figure 4) Properly constructed rainscreen systems should not suffer from moisture problems often associated with less expensive façade systems, like EIFS.

Figure 3: EIFS Detail



The proposed EIFS system would likely include a layer of sheathing fastened to the existing masonry, with the insulation adhered directly to the sheathing. The adhesive acts as an air barrier.

Figure 4: Rainscreen Detail



While more expensive, a rainscreen system provides a far more attractive and durable exterior facade that should not suffer the maintenance challenges often experienced with EIFS products.

Windows

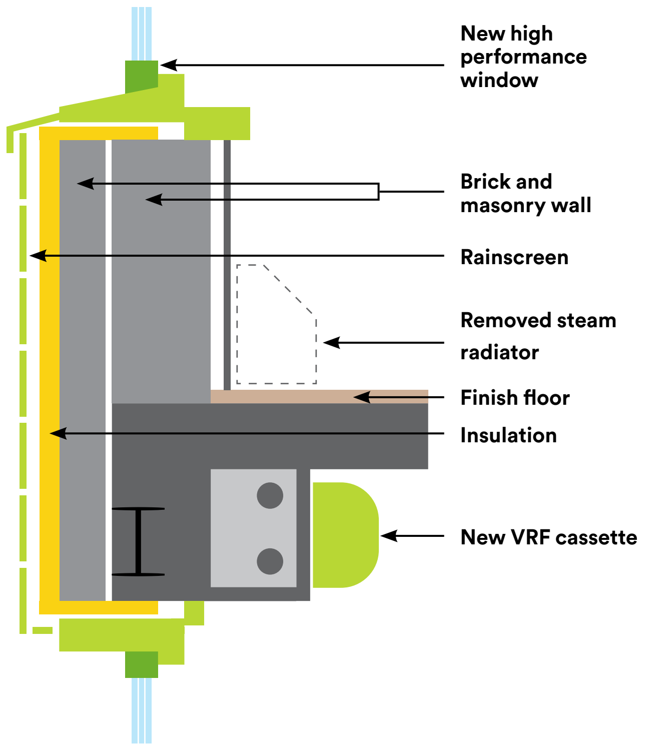
EnerPHit Target	**U=0.18**
Existing	U=0.80

Proposed
Replace existing windows with PH-certified, triple-glazed windows, with appropriate install details

Passive House requires careful selection of high-performance windows to ensure interior comfort and optimize heating and cooling demand. To maximize comfort and reduce potential for condensation, these windows often require triple-glazing. Passive House windows meet stringent standards for airtightness and thermal bridging with continuous gasketing, robust hinging and locking mechanisms, and frames that incorporate extensive thermal break materials. Window performance measures include the size of each window opening, interior conditions, and thermal bridging characteristics of the window installation.

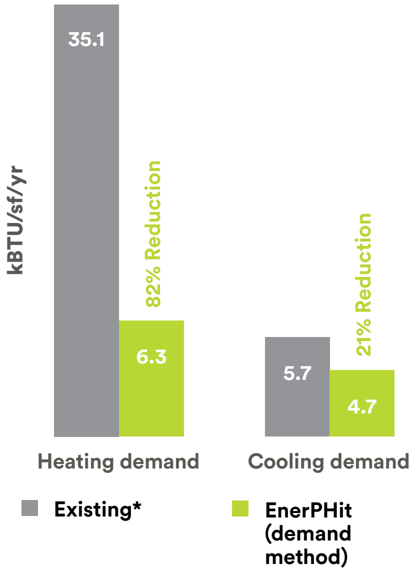
For purposes of modeling and pricing, the team selected a Passive House-certified aluminum frame window from Shuco—model AWS 90.SI+ with argon-filled, triple-glazed units that include a low-e coating. In addition to the thermal performance and comfort criteria required to meet the EnerPHit standard, New York City has structural requirements related to wind loads that typically require the use of reinforced aluminum frames.

Figure 5: Proposed Wall Section



The fully retrofitted envelope includes new recladding with sufficient insulation as well as high-performance windows, while the new VRF cassettes are installed above the window in each major room.

Figure 6: Heating and Cooling Reductions



* Based on energy modeling, calibrated to utility bills

Upgrades to the building envelope, including new exterior insulation, airtightness and high-performance windows, result in a 80+% reduction in heating demand and 20+% cooling demand.

Heating and Cooling

Once improvements to the envelope are complete, heating and cooling demand is dramatically reduced. This study assumes the steam heating and window AC cooling are replaced with a centralized Variable Refrigerant Flow (VRF) system.

Heating

EnerPHit Estimate	**4.7 kBTU/sf/yr**
Existing	5.7 kBTU/sf/yr

Proposed
Remove window AC units, install VRF system

Cooling

EnerPHit Estimate	**6.3 kBTU/sf/yr**
Existing	35.1 kBTU/sf/yr

Proposed
Remove steam radiators, install VRF system with rooftop condensers and cassettes in each major room

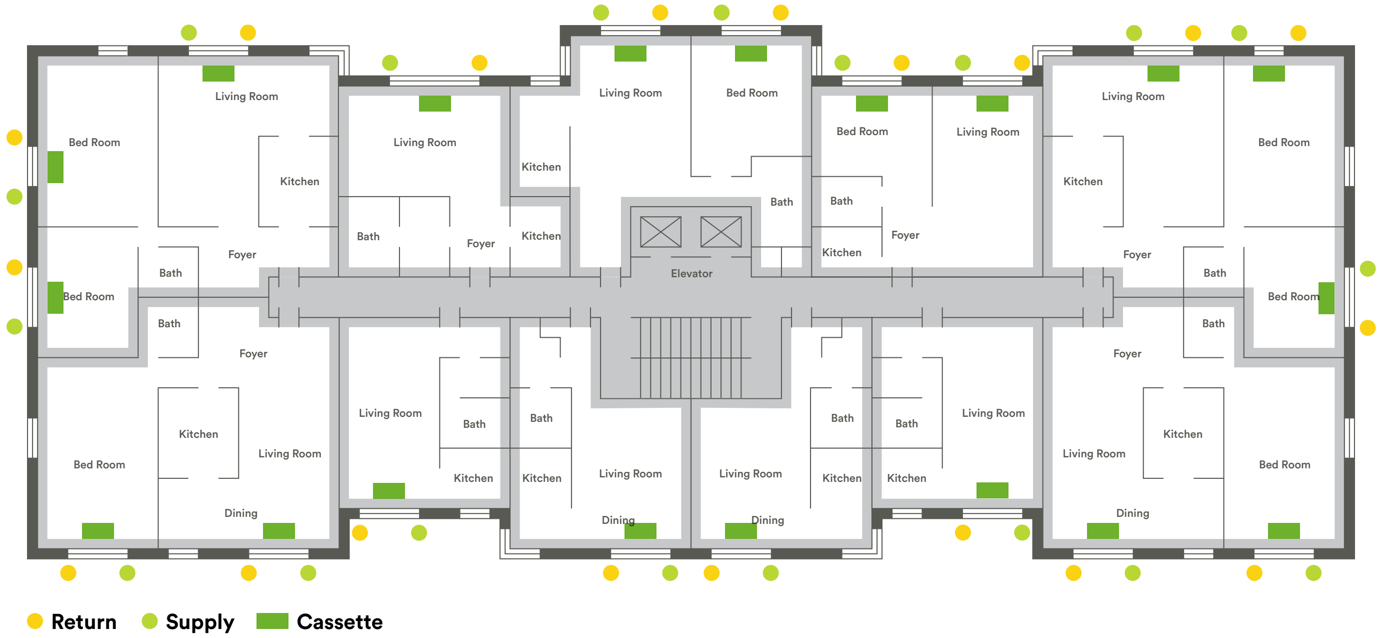
VRF

Commercialized in the 1980s, VRF systems use refrigerant as the medium for cooling and heating. A compressor and heat exchanger are located in an outdoor unit. Refrigerant is distributed throughout the building to fan-coil units (FCUs) where the refrigerant heats or cools air as needed. The ability of the system to operate at varying speeds allows for efficiency and greater control of interior temperature.

VRF systems have several benefits compared to more traditional systems, offering a much higher level of control than ducted systems, and they can be much quieter. Standard hydronic systems also provide a high level of control, but pump and fan energy to operate them can be excessive, making those systems less attractive from an energy efficiency perspective.

The most plausible VRF installation scenario involves running vertical refrigerant lines on the outside of the building with each supply/return pair of risers fed by a rooftop condensing unit. The new VRF cassettes would be located above the major windows in each apartment. (Figure 5) To avoid crossover of lines on the façade, a supply and return would run vertically on opposite sides of the windows. The primary restriction of this system is a 100 foot limit on the vertical distance between the VRF cassettes served by each riser. Due to this, each “stack” of cassettes would be divided into upper (floors 8–15) and lower (floors 1 to 7) portions with separate supply and return risers. (Figure 7) Vertical refrigerant lines would be embedded in the EIFS or rainscreen. Small penetrations through the existing masonry would be required at each cassette location to minimize interior refrigerant runs.

Figure 7: Centralized VRF, Option 3: Risers on the Exterior



The preferred VRF option limits interior construction by placing the new refrigerant lines on the outside of the existing masonry walls and directly accessing the new cassettes over each window.

Ventilation

Ventilation represents an underappreciated component of interior space quality. The need for balanced and properly filtered fresh air receives far less attention than heating and cooling systems but has just as significant an impact on the comfort and health of occupants.

EnerPHit Criteria	**75% efficient (energy recovery), humidity control**
Existing	**No heat recovery, no humidity control**
Proposed	
Convert existing exhaust system to balanced system utilizing rooftop energy recovery ventilation units	

The Passive House standard requires balanced ventilation that delivers properly filtered supply air directly to habitable spaces, while stale air is removed from kitchens, baths and laundries. This approach is made possible in part by the airtight envelope, which ensures the balanced ventilation, draws little air via infiltration from the exterior or adjacent apartments.

This study explored a centralized scheme in which existing ventilation shafts are repurposed and the system is converted from exhaust only. This arrangement results in the fewest number of ventilators, preserving valuable floor area and easing maintenance requirements. (Figure 8)

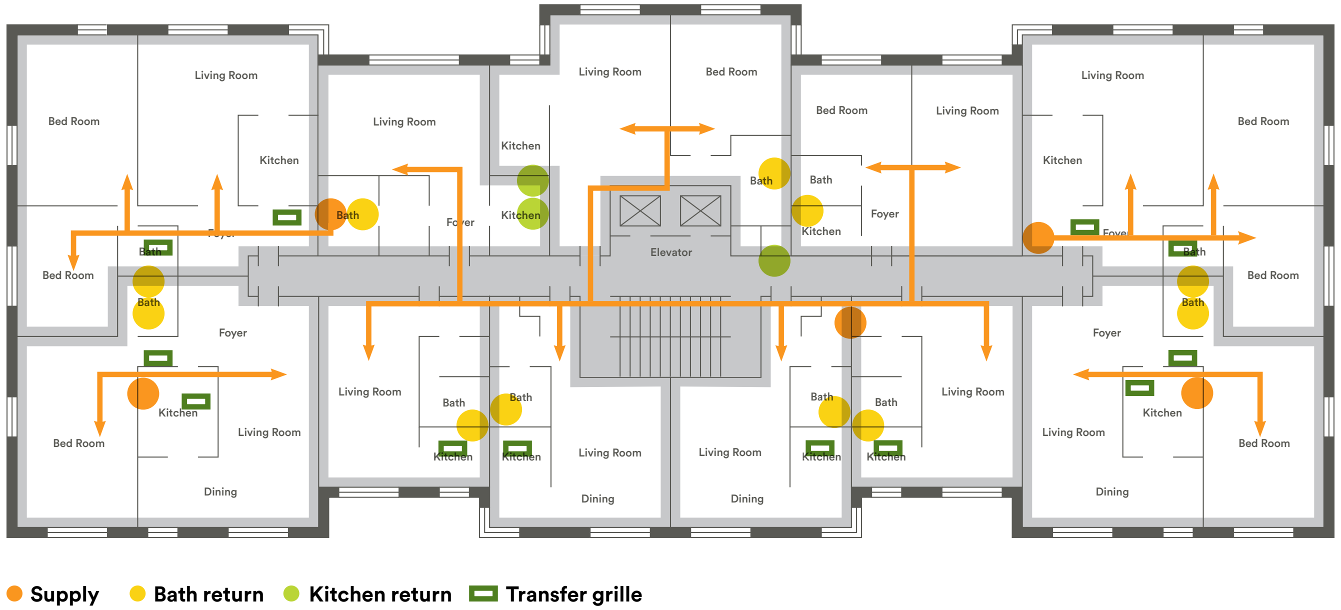
Domestic Hot Water

The study assumes that the existing steam heat exchanger for domestic hot water (DHW) is replaced with a high efficiency gas-fired boiler connected to the existing distribution system.

EnerPHit Estimate	**6.8 kBTU/sf/yr**
Existing	**14.1 kBTU/sf/yr**
Proposed	
Replace existing steam heat exchanger with high efficiency boiler	

While other options do exist for DHW, including air to water heat pumps (AWHP), in this climate they are not currently a standalone option for buildings of this scale. AWHPs have a lower output than boilers, and units available in the US cannot meet the simultaneous demands of a building this large. As carbon intensity of the grid decreases, however, AWHPs' carbon reduction potential grows, and it is anticipated that systems capable of servicing buildings of this scale will be developed for the US and other markets.

Figure 8: Floor Plan: Central 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 reufrbished exhaust lines to extract from each room.

benefits

The building industry typically views individual elements of energy efficiency projects as distinct entities that must prove their worth in simple payback terms without reliance on other measures. This approach severely limits the industry's ability to improve the building stock and prepare for the future, with a dire impact on efforts to reduce carbon emissions. Passive House benefits derive from several highly interdependent measures that in concert produce comfortable buildings that use limited energy. Taken together, these benefits have potential to reposition a building, in investment terms, from Class B, or even C, to Class A.

Thermal Comfort: Improving interior comfort is one of the primary advantages to pursuing Passive House certification. Most standard buildings suffer from a host of issues that degrade interior comfort, chiefly poor thermal performance of exterior walls and windows.

Understanding the importance of insulation, airtightness, and high-performance windows is critical in achieving thermal comfort. The difference between interior air temperature and surface temperature of exterior walls and windows drives three major components of interior comfort: drafts, radiant temperature, and condensation. When the difference in these temperatures is large enough, the warm interior hits the cold surface, cools, and then falls toward the floor, creating a dramatic internal draft—air movement that occupants experience as a chill, even if the ambient air temperature remains constant. Warm objects radiate heat towards cold ones, and this remains true if the objects are humans and exterior walls. If the exterior walls and windows are significantly colder than the ambient air temperature, humans feel chilled near the exterior walls and windows.

On a winter day, the existing building produces highly uncomfortable conditions near the exterior walls, with a difference between air and surface temperatures of more than 20 degrees, almost three times the recommended delta, certain to produce significant drafts and radiant chills for anyone near the walls or windows. Passive House is a completely different story, with the exterior insulation and a high-performance windows providing a comfortable interior that will not produce internal drafts or radiant chills. An upgraded envelope offers a clear and dramatic impact on comfort.

Health: Air infiltration and condensation are among the primary vectors for poor indoor air quality. The former can be the source of moisture and myriad pollutants (including carcinogens like PM 2.5) while the latter is the foundation of interior mold growth. Additionally, the balanced, highly filtered ventilation system in a Passive House building provides ample amounts of fresh air. This mixture of reduced pollutants and increased fresh air can provide a far healthier building interior than typical.

Energy Cost Savings: In addition to the raw utility savings outlined in Figure 40, the reduced energy use of Passive House-certified buildings also shields building owners and tenants from the risk of utility cost fluctuations. In the

Figure 9: Annual Energy Cost Savings by Phase

		Electricity			Gas			
		kBTU/SF/YR	kWh/YR	$/YR*	kBTU/SF/YR	therms/YR	$/YR**	total ($)
Existing Utility Costs		11	396429	$79,286	64.29	79077	$83,031	$162,316
Utility Cost Savings by Phases								
1	Windows	0	0	$0	10.23	12583	$13,212	$13,212
2	Ventilation	-0.68	-24507	$4,901	6.51	8007	$8,408	$3,506
3	Ext. Insul.	0.21	7568	$1,514	24.36	29963	$31,461	$32,975
4	VRF	0.82	29552	$5,910	7.13	8770	$9,208	$15,119
5	DHW	0.15	5406	$1,081	3.25	3998	$4,197	$5,279
6	Plugs/Appliances	1.94	69916	$13,983	0	0	$0	$13,983
Totals		2.44		$17,587	51.48		$66,486	$84,073
*	Cost kWh	$0.20						
**	Cost therms	$1.05						

near future it is likely that utilities will charge more for energy delivered in peak periods and that energy will be more expensive than in prior years. Passive House-certified buildings mitigate both factors.

Net Costs: Figure 11 displays conservative cost estimates of each phase of proposed work. Estimates include costs to furnish and install all required components of each phase, including general conditions such as scaffolding and protection, together with on-site staff. Also factored into overall costs are the following cost drivers:

Insurance	4%
Overhead	2%
Fee	8%
Contingency	10%

The table includes costs for each retrofit phase, if delivered separately, along with costs of business-as-usual (BAU) upgrades that the building might reasonably expect to perform over time.

Phasing

Year 0: Envelope 1: Windows + Roof Insulation

Year 4: Ventilation System (Balanced ERV system + exhaust)

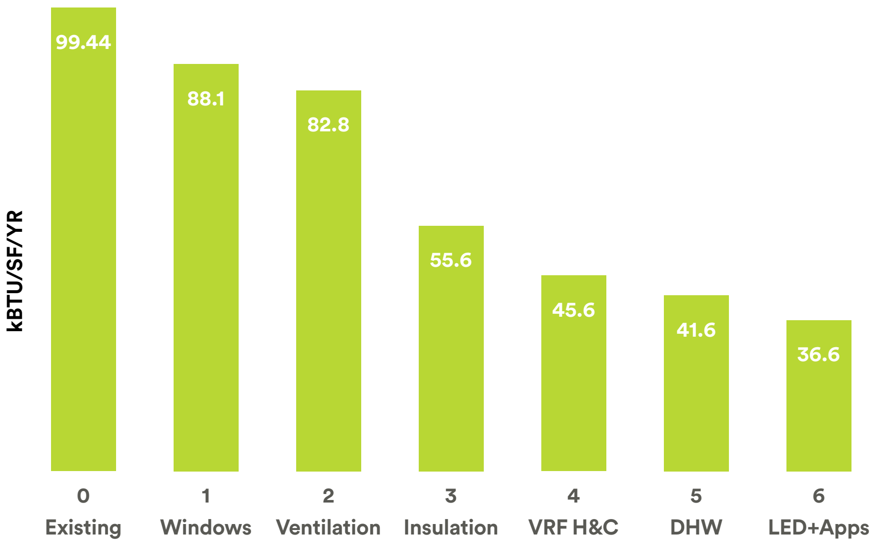
Year 8: Envelope 2: Wall Insulation & Airtightness

Year 12: Replace Heating/Cooling systems with VRF system

Year 16: Replace Domestic Hot Water boiler with high efficiency version

Anytime: Upgrade lighting to LED, upgrade elevators, install energy efficient appliances

Figure 10: Energy Reductions by Retrofit Phase



The fully completed retrofit is estimated to reduce total building energy use by 63%, with more than 60% of those reductions the result of new exterior insulation and high-performance windows.

Figure 11: Retrofit Construction Costs by Phase

Phase Est.	Cost ($)	Business As Usual Cost
Windows/Roof Insulation	$4,494,000	-$652,000
Ventilation (balanced ERV + exhaust refurb)	$1,447,000	-$324,000
Insulation + Airtightness + Rain Screen	$3,719,000	-$1,150,000
Install VRF system (remove steam/PTACS)	$3,071,000	-$1,261,000
Replace DHW boiler	$250,000	-$250,000
Total costs, multiple phases	$11,790,000	-$3,636,000
General Conditions reduced (if single phase project)	$1,655,000	
Total costs, single phase	$10,135,000	
Net total single phase (total costs–BAU costs)	-$6,498,000	

Phasing the retrofit delays the full benefits of the retrofit while adding $1.6M to the $10.1M cost of doing the work in a single phase. If the business as usual costs of equipment upgrades are deducted, the net cost of the retrofit is $6.5M, less than 8% of the current market value of the building.

conclusions

A substantial percentage of our existing building stock must undergo deep, holistic retrofits if we are going to meet our climate action goals and avoid the most disastrous impacts of global climate change. The challenges of climate change can seem overwhelming in scale and complexity, but the responses required can be broken into a series of small actions. What must each city do? Each building? What are the steps that building should take? Implementing the answers to these questions is the surest path to a sustainable future and the subject of this report.

There are, of course, many different pathways to producing highly efficient buildings. We selected the Passive House pathway for this report because of its focus on comfortable, healthy spaces and its strong track record of delivering significant heating and cooling energy savings. The costs are substantial, but the benefits are extensive and result in a radically transformed building of significantly higher value that will allow our community to meet its climate action goals. Inaction is not an option.

New York City and State are both demonstrating clear national leadership on this issue by working on programs that incentivize deep retrofits of buildings. Chief among these available resources are:

- NYSERDA’s RetrofitNY program
- Property assessed clean energy (PACE) financing, introduced in the Climate Moblizaiton Act
- NYC Retrofit Accelerator’s High Performance Retrofit Track

Many of the recommendations within this report align with the mission of these programs.

Moving forward, we will need to incentivize the more effective delivery of retrofitted systems, whether this means creating a strong market demand for modular recladding systems or ensuring that efficient equipment such as the high performance packaged heating and cooling units discussed earlier in this report are available here. We will also need to identify mechanisms that connect the broader societal benefits of deep retrofits with the costs to individual building owners. This might involve property tax relief or PACE programs, or some mixture of these in combination with other initiatives.

It is clear from our analysis that it is feasible to transform an occupied building of this type to meet the demands of our coming century, while providing a living environment of far higher quality than most of us currently enjoy. Our task is to ensure a sustainable, equitable future for our communities. This study finds that buildings can definitely play a leading role in ensuring such a future. Now we need to determine the most effective means of grasping this opportunity.

be-ex: the building energy exchange is an international center of excellence dedicated to reducing the effects of climate change by improving the built environment. We accelerate the transition to healthy, comfortable, and energy efficient buildings by serving as a resource and trusted expert to the building industry.

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Additional Information

This is an abbreviated version of a full length report, which can be found on the report project page: https://be-exchange.org/report/pursuing-passive/

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