report

Multifamily
Deep Retrofit Profiles

High Rise / Low Carbon Multifamily

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building
energy
exchange

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executive summary

New York City is home to over one million buildings. Buildings that provide for the engine of its economy, the stages for its culture, and the shelter for its over 8 million residents.

From single family houses, in the outer boroughs, to high-rise multifamily buildings, piercing the midtown Manhattan skyline, from pre-war affordable housing, to sleek, new, market rate high-rises, New York's residential buildings include a variety of typologies as diverse as the city itself.

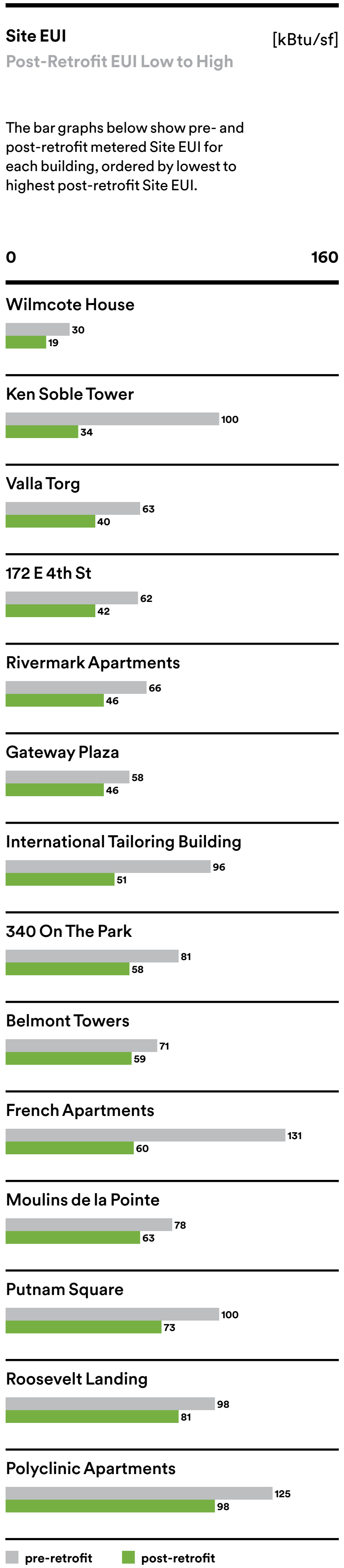
While all New York's buildings must play an essential role in effective climate action, its tall residential buildings present one of the biggest challenges. Representing approximately 15% of all of New York City greenhouse gas (GHG) emissions in 2022, New York's tall residential buildings have a predominance of natural gas and oil-powered domestic hot water and steam heating systems. Coupled with extremely low vacancy rates, the transition away from fossil fuels will be a significant and daunting challenge.

This survey provides a collection of deep retrofit profiles of fourteen tall residential buildings from around the world to demonstrate how existing high-rise multifamily buildings can achieve low carbon emission targets. As we reach the first compliance period of NYC's groundbreaking 2019 legislation to curb carbon emissions, Local Law 97 (LL97), and look, just ahead, to the law's second compliance period, in 2030, when over 60% of covered multifamily buildings will need to reduce their emissions to avoid an annual penalty, this report explored several key retrofit questions, including: what GHG reductions are achievable; what building systems were upgraded; what technology was implemented; what were the challenges and opportunities; and what are the lessons learned?

Having previously explored tall office building deep retrofit case studies, in 2020 (High Rise Low Carbon Office Deep Retrofit Profiles, August 2020), this research team turned its focus to a global search for deep retrofits of existing high-rise residential buildings that resulted in annual operational carbon emissions at or below LL97's 2030 carbon cap, limiting the search to climate zones similar to New York and only including projects with verified pre- and post-retrofit energy data. This last requirement, as with the office building survey, proved among the most challenging criteria to meet. Nonetheless, fourteen retrofit projects are presented that resulted in significant energy and GHG reductions. A major passive house renovation of an emptied tower in Ontario, new heating and controls in an affordable Manhattan rental, replacing in-apartment fan coil units with air source heat pumps while tenants remained in place, incremental improvements in a lower east side co-op over a ten year span, a completely new facade for an iconic Cambridge building, and many more, this diverse set of retrofit projects was able to achieve an average of 33% reduction in their site energy use intensity (EUI), with several cutting their energy use in half.

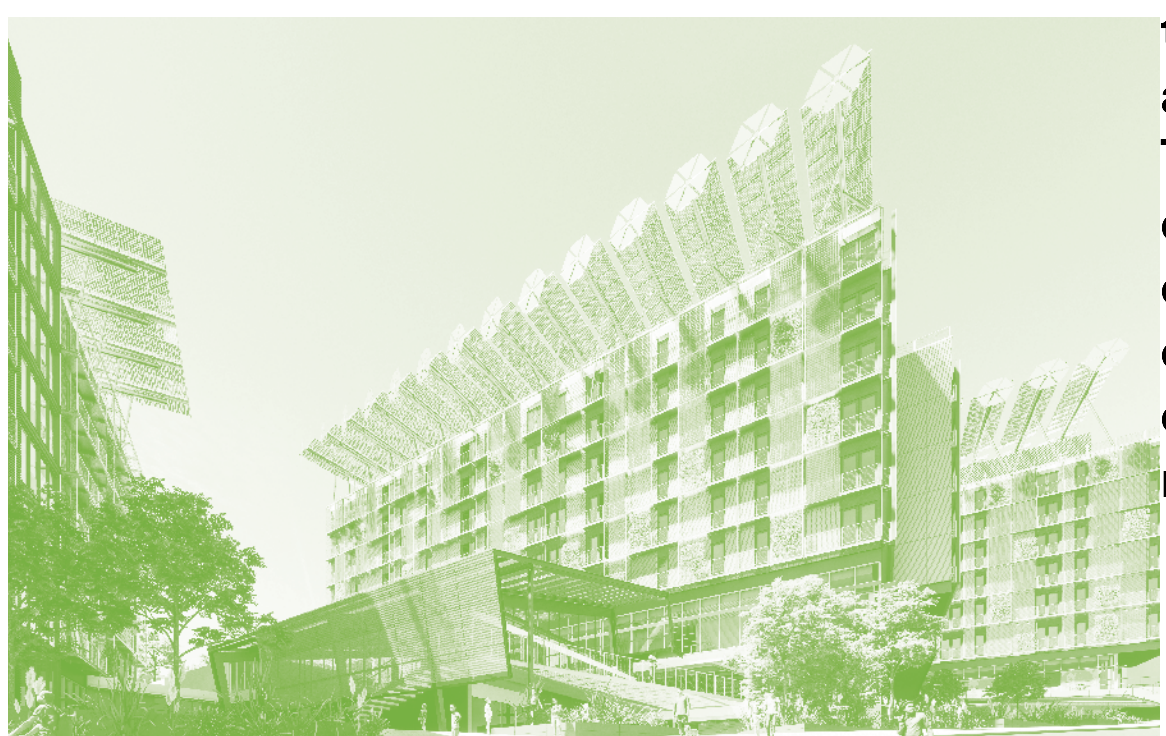
Key Findings

- **It was surprisingly difficult to find 14 tall residential buildings that had completed a deep retrofit delivering more than 20% energy savings**
  During our research, most typical retrofits showed less than 20% savings or were low-rise residential
- **Most retrofits were not part of a long-term capital plan. Rather, they were a reaction to building systems at end of useful life requiring immediate or urgent attention**
  The cost of doing nothing is not nothing
- **Deep retrofits tend to be invasive and require major system replacements, which is very challenging to do in an occupied building**
  It is much easier to renovate an empty building, but those are very rare in the residential sector
- **Residential deep retrofits completed prior to 2023 were mostly boiler replacements and facade improvements**
  Electrification is in early innings — we know the solutions for new construction, but very few tall building electrification retrofits have been completed
- **Electrification is key to deep decarbonization, but the economics of electrification need to evolve before we see conversions at scale**
  The cost of natural gas relative to electricity makes it hard for full load electrification to make economic sense as a standalone measure
- **Verified post-retrofit data is scarce**
  Validated, metered, whole-building energy data is what makes this compendium unique, but proved to be one of the biggest challenges in finding case studies



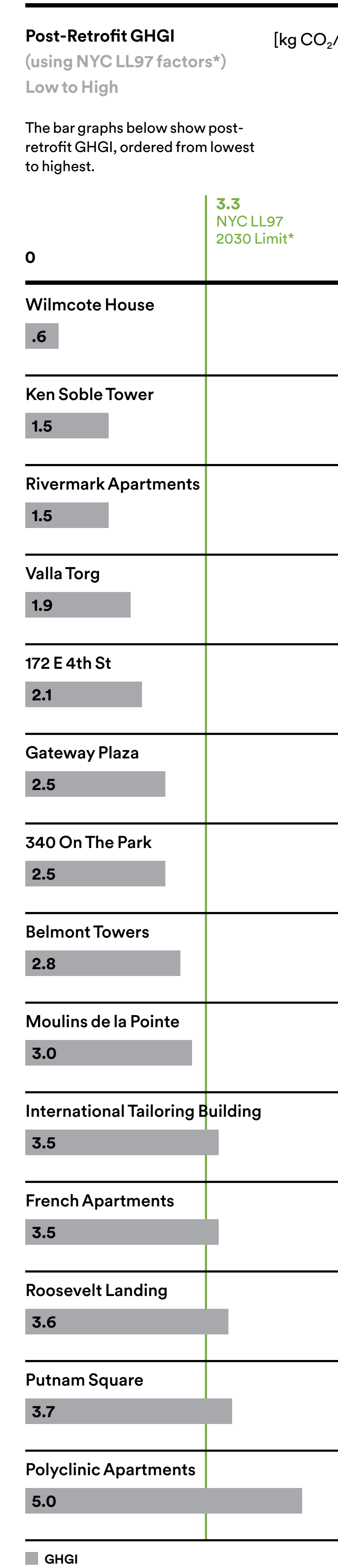
It is worth noting, as with the office profiles, most of these projects were initiated prior to, and, therefore, in the absence of the recent aggressive climate legislation, demonstrating that tall multifamily low carbon retrofits are, indeed, possible.

The profiles represent a variety of building types: affordable and market rate, rental and co-op/condo. Almost all were completed with tenants in place, and, as detailed in the report's Technical Solutions Matrix, almost all projects include an upgrade to their lighting systems; most observed significant carbon emissions reductions by making improvements to their building envelopes through air sealing, adding insulation, or window replacement projects; and many implemented improvements or replacements to their heating and domestic hot water systems. Each retrofit had various motivating factors, from complete repositioning of the property, to equipment reaching the end of useful life. Implementation approaches ranged from incremental improvements over many years to major renovations as singular projects.



As the devastating effects of the climate crisis become increasingly clear, cities around the globe are adopting building performance policies similar to New York's LL97 designed to drive emissions reductions in existing buildings. For these aggressive regulations to succeed, building stakeholders need concrete models of how to achieve compliance, as well as the right tools and resources. These case studies show examples of how New York's existing tall residential buildings can significantly reduce emissions and play an essential role in effective climate action.

* For buildings outside of NYC, the authors estimated the project's CO_2 emissions using LL97's stated carbon coefficients for the 2030 target year.



key findings

It was surprisingly difficult to find 14 tall residential buildings that had completed a deep retrofit delivering more than 20% energy savings

During our research, most typical retrofits showed less than 20% savings or were low-rise residential

- Reached out to dozens of industry leaders, researched over 60 potential case studies, could only get 14
- Older, tall residential buildings tend to have simple heating and ventilation systems with limited controls, making fine tuning and optimization difficult
- Renovating occupied buildings adds significant complexity
- Condo / Co-op Boards tend not to be building industry professionals
- Residential building owners' and managers' ability to afford professional consultants; more complex decision making process
- Major owners reported achieving more than 20% was unusual

Most retrofits were not part of a long-term capital plan, rather they were a reaction to building systems at end of useful life requiring immediate or urgent attention

The cost of doing nothing is not nothing

- A common retrofit approach was for a building to undergo major changes such as a gut renovation, window replacements, or building HVAC systems replacements during a repositioning and major re-investment project
- Other deep retrofits occurred over many years when systems failed or imminently required replacement
- In both approaches there was a consistent lack of planning for long-term decarbonization or capital investment

Deep retrofits tend to be invasive and require major system replacements, which is very challenging to do in an occupied building

It is much easier to renovate an empty building, but those are very rare in the residential sector

- Replacing radiators, windows, ventilation, cooking equipment, and other energy consuming components of residential buildings disrupts the life and home of tenants who live in the space being renovated
- The most successful and deepest retrofits in this compendium were of buildings that were undergoing repositioning, ownership changes, or were empty for some unique reason. But there were only three such examples in this compendium.

Residential deep retrofits completed prior to 2023 were mostly boiler replacements and facade improvements

Electrification is in early innings

- New, high-efficiency boilers, air sealing, and high-performance windows were the big impact measures for most of the case studies in this report
- Only two partial electrification projects in this compendium
- During our search we identified many electrification conversions in design and construction now
- Converting from fuel oil or electric resistance to heat pumps is easier
- Converting from natural gas to heat pumps is economically challenging

Electrification is key to deep decarbonization, but the economics of electrification need to evolve before we see conversions at scale

The cost of natural gas relative to electricity makes it hard for full load electrification to make economic sense as a standalone measure

- Natural gas is currently a lower cost heating source than electricity driven heat pumps
- Currently the cost of installing heat pumps in occupied apartments is much higher than replacing an existing boiler
- Incentives for electrification have the potential to scale up the implementation of electrification
- Although boilers require periodic replacement, steam radiator and hydronic heating distribution systems do not have an 'end of useful life' or a natural point where capital investments could be supplemented to spur conversions

Verified post-retrofit data is scarce

Validated, metered, whole-building energy data is what makes this compendium unique, but proved to be one of the biggest challenges in finding case studies

- Lack of data collection, and data inconsistencies persist
- The cost and effort required to gather, validate, and analyze whole-building energy use for residential buildings is expensive, and few owners can justify the cost
- Outside of the US/North America, whole-building energy data, including tenant usage, is very hard to get, mostly due to privacy laws

High Rise / Low Carbon

Sector focus:	Office	Multifamily
Date published:	2020	2024
Average energy savings %	37%	33%
Range of total energy savings %	17% – 56%	17% – 66%
Retrofit of occupied spaces:	2 of 18	13 of 14
Single retrofit project	5 of 18	11 of 14

introduction and background

Decarbonizing the multifamily residential sector is key to achieving New York State and New York City long term decarbonization goals. This compendium reviews the technologies and approaches that have proven to deliver deep energy savings in the recent past.

New York State's 2019 Climate Leadership and Community Protection Act (CLCPA) establishes targets of a 100% renewable electric grid by 2040, a 40% state-wide GHG emissions reduction by 2030, and an 85% state-wide GHG emissions reduction by 2050.

According to New York City's (NYC) 2009 Greener Greater Buildings Plan (GGBP), 48% of New York City's total building sector energy use comes from less than two percent of its properties—just 15,000 properties over 25,000 square feet—which account for almost half of NYC's built square footage. In order to meet the climate mitigation goals of the State and City, high-rise building owners will need to reduce their energy use and carbon emissions. However, while it has been widely demonstrated that it is possible to achieve very low-emission and even no-net-emission in smaller buildings, reaching such metrics in high-rise buildings is more challenging.

As the state's and the nation's largest municipality, NYC is taking bold steps to mitigate climate change and reduce building-sourced GHG emissions. The GGBP included Local Law 84 (LL84) and Local Law 87 (LL87), which require building energy benchmarking and building energy audits and retrocommissioning, respectively. Local Law 32, the Energy Stretch Code, mandates aggressive performance targets in the energy code, which grow increasingly stringent every few years. Finally, Local Law 97 of 2019 (LL97), the cornerstone of the 2019 Climate Mobilization Act (CMA), sets GHG Intensity limits (GHGI) for buildings, with non-trivial penalties for non-compliance.

2024 marks the beginning of the first compliance period for LL97, and most properties are under the GHGI limits set for 2024-2029. Conversely, most properties surpass GHGI limits for the second compliance period, from 2030-2034. Many owners are currently weighing the cost of performing retrofits versus simply paying the penalties. Additionally, the technical viability of achieving the deep energy retrofits mandated in LL97 is a concern to many building owners and tenants.

To support these city and state decarbonization goals, the New York State Energy Research and Development Authority (NYSERDA) has developed a Carbon Neutral Buildings Roadmap that supports increasing building energy efficiency, decarbonizing onsite energy services, utilizing clean energy from a variety of sources, and enabling real-time response to grid conditions. Additionally, NYSERDA's Empire Building Challenge launched in 2020 demonstrates scalable and replicable low-carbon retrofit approaches for high-rise commercial and multifamily buildings across the state. Additionally, in 2020 NYSERDA funded the first phase of this report led by Building Energy Exchange which focused on documenting 18 high-rise office building deep retrofits.

Given this set of ambitious policies and programs aimed at reducing building emissions, how feasible are deep energy retrofits of tall residential buildings? High-rise residential buildings, in particular, have unique physical and economic constraints. There are many case studies showing the projected energy use savings of high-rise buildings, but many in the industry question the accuracy of *projected* energy savings compared to post-retrofit, metered energy savings. This compendium summarizes 14 significant examples of *realized* metered energy savings of greater than 20% in tall residential buildings from around the world.

During the research phase of this project, it was difficult to find post-retrofit energy performance data from high-rise residential building retrofits. Many organizations have announced deep retrofit projects, but very few gathered metered energy data. Although dozens of leaders in energy efficiency around the country were interviewed as part of this research, few could point to actual completed retrofit projects; Those that could cited completed energy retrofits that delivered less than 20% energy savings or were small, low-rise residential buildings.

Despite significant international outreach and research, the most reliable post-retrofit, whole-building energy data came from U.S. cities with mandatory, public-disclosure building energy benchmarking. A number of good candidate projects were identified by experts in Europe, but owners either did not have, or were not willing to share, post-retrofit performance data. One recurring issue is privacy; with stricter privacy protections in Europe, owners often do not have access to tenant energy consumption.

This report documents the proven capability of the market to deliver energy and carbon savings for high-rise residential building retrofits by sophisticated owners under the right economic conditions. Fourteen exemplary case studies of deep energy retrofits of high-rise residential buildings, with metered pre- and post-retrofit energy data, are profiled, exploring their retrofit approach and common technical solutions, motivating factors, and market conditions.

summary list of building profiles

	Building	City	# of Stories	Ownership	Affordability	# of Units	Year(s) Renovated	Renovation Approach	Site EUI (kBtu/sf) pre-retrofit	Site EUI (kBtu/sf) post-retrofit	Site EUI (kBtu/sf) % reduction	GHGI post-retrofit using NYC LL97 factors [kg CO_2/sf]
1.	Ken Soble Tower	Hamilton, ON	17	Rental	Affordable	146	2019 – 2021	Major Renovation	100	34	66%	1.5
2.	French Apartments	New York, NY	13	Rental	Affordable	174	2014	Major Renovation	131	60	54%	3.5
3.	Int'l Tailoring Building	New York, NY	13	Co-op	Market Rate	173	2023	System Replacement	96	51	47%	3.5
4.	Wilmcote House	Portsmouth, UK	11	Rental	Affordable	111	2022	Major Renovation	30	19	39%	0.6
5.	Valla Torg	Stockholm, Sweden	14	Rental	Affordable	302	2016 – 2018	Major Renovation	63	40	37%	1.9
6.	172 E 4th St	New York, NY	12	Co-op	Market Rate	102	2011	Incremental	62	42	32%	2.1
7.	Rivermark Apartments	Cambridge, MA	20	Rental	25% Affordable	300	2021	Major Renovation	66	46	30%	1.5
8.	340 On The Park	Chicago, IL	64	Condo	Market Rate	343	2016	Incremental	81	58	28%	2.5
9.	Putnam Square	Cambridge, MA	13	Rental	Affordable	94	2013 – 2015	Major Renovation	100	73	27%	3.7
10.	Polyclinic Apartments	New York, NY	10	Rental	Affordable	151	2021	Major Renovation	125	98	22%	5.0
11.	Gateway Plaza	New York, NY	34	Rental	15% Affordable	1,700	2013 – 2015	Incremental	58	46	21%	2.1
12.	Moulins de la Pointe	Paris, France	14	Condo	Affordable	41	2019	Major Renovation	78	63	19%	3.0
13.	Roosevelt Landing	Roosevelt Island, NY	20	Rental	25% Affordable	1,003	2014	Major Renovation	98	81	17%	3.6
14.	Belmont Towers	Vancouver, BC	13	Condo	Market Rate	37	2012	System Replacement	71	59	17%	2.8

1.

Ken Soble Tower

Retrofit Approach

- **Major Renovation**
- System Replacement
- Incremental

Retrofit Motivation

- End of Useful Life
- Energy Cost Savings
- **Repositioning**
- **Environmental Branding**

Key Figures

Pre-Retrofit Site EUI	100 kBtu/sf
Post-Retrofit Site EUI	34 kBtu/sf
% Energy Reduction	65%
Post-Retrofit GHGI (using NYC LL97 2030 factors)	1.5 kg CO_2/sf

Location	Hamilton, ON
Owner	City Housing Hamilton
Rental or Condo	Rental
Affordability	Affordable
Floor Area	80,000 sf
Number of Stories	18
Number of Units	146
Year built	1967
Year renovated	2019 – 2021

Pre-Retrofit	Post-Retrofit
Heating System	
Hydronic with gas fired boilers	In-unit variable air volume dampers with rooftop ASHP
DHW System	
Natural gas fired boilers	Natural gas fired condensing boilers
Air Conditioning	
None	Common area heat pump

Retrofit Background

The Ken Soble Tower project in Hamilton, Ontario truly sets out a template for implementing a Passive House retrofit alongside electrification.

Built in 1967, the building was in need of either a complete renovation or demolition. The owner, City-Housing Hamilton (CHH), decided to maintain the structure and invest in an entirely new exterior envelope and building HVAC systems. This was undertaken in an unoccupied building; all CHH tenants had been relocated to other properties in advance of the project.

Description of Retrofit

The envelope work started with replacing windows and removing balconies and their associated thermal bridging. Next, the exterior surfaces were over-cladded with a 6” EIFS product with rigid mineral wool insulation. Careful attention to air sealing between joints between walls and windows provided an overall weighted wall/window insulation value of R38.

Such a high insulation value and tight envelope dropped the building’s thermal loads so low that heating and ventilation are delivered through tempering make up air. A reheat coil at the point of delivery of make up air inside each unit is sufficient to meet each apartment’s heating load. Two Make Up Air Units (MAU) (one on the roof, and one on ground) provide heating from air source heat pumps and have heat recovery to preheat incoming fresh air. Laundry dryers were also electrified with commercial heat pump dryers.

Since the incoming power to the building was limited and not quite capable of also meeting domestic hot water demand, the hot water boilers were replaced with new, gas fired condensing boilers.

Metered Energy Savings and Other Benefits

Due to the dramatic drop in heating demand and the high Seasonal Energy Efficiency Ratio (SEER) of the air source heat pumps, the site energy demand dropped 65% and is nearly all electricity. Air quality improvements were substantial, as well as from filtered make up air and electric ranges.

Economic Considerations

As with all major renovation projects, it was difficult to specifically identify the added cost for Passive House certification and electrification. The design team indicated that, like the early days of LEED certification, they roughly estimated a 5-10% added cost to the renovation. However, they projected these additional costs would drop as the industry becomes more familiar with energy recovery ventilators (ERV), variable refrigerant flow (VRF) systems, and over-cladding.

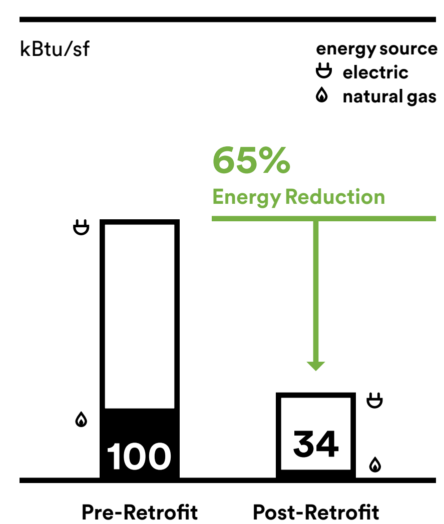
Key Lessons Learned

Being one of the first Passive House retrofits in the Toronto region, the design team, client, and contractor addressed numerous challenges, including quality-control on site, construction methods for air tightness, product availability, and conflicts with the building code. They managed through their issues and now have a demonstration project for site tours and a model approach for decarbonizing tall residential buildings.

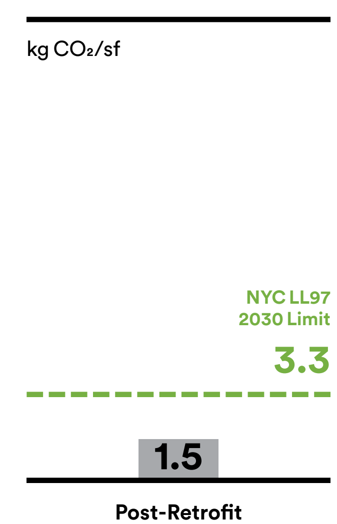
Photo credit: Codrin Talaba

Major passive house rejuvenation drives dramatic energy reduction.

Site EUI



GHGI (using NYC LL97 factors)



Energy Conservation Measures Overview

heating
- Exterior Air-Source Heat Pump, distributed forced air combined ventilation and heating (with ERV) with in-unit Variable-Air Volume Dampers for temperature control

hot water
- Natural gas fired condensing boilers

envelope
- Over-cladding with EIFS
- Triple-glazed windows and doors
- Air sealing at full envelope
- New roofing and roof insulation
- Perimeter foundation insulation

ventilation
- Centralized ERVs

lighting
- New LED lighting in hallways, common areas, and suites
- Stairwell lighting motion sensors for dimmers

plug loads
- ENERGY STAR refrigerators and dishwashers
- Induction stovetops
- Heat-pump dryers

cooling
- Partial dehumidification of ventilation air
- Ceiling fans in each suite
- Low-emissivity blinds
- Air conditioned community spaces

other

2. French Apartments

Retrofit Approach

- **Major Renovation**
- System Replacement
- Incremental

Retrofit Motivation

- **End of Useful Life**
- Energy Cost Savings
- Repositioning
- **Environmental Branding**

Key Figures

Pre-Retrofit Site EUI	131 kBtu/sf
Post-Retrofit Site EUI	68 kBtu/sf
% Energy Reduction	48%
Post-Retrofit GHGI (using NYC LL97 2030 factors)	3.5 kg CO_2/sf

Location	New York, NY
Owner	Related Companies
Rental or Condo	Rental
Affordability	Affordable
Floor Area	148,000 sf
Number of Stories	12
Number of Units	174
Year built	1929
Year renovated	2014

	Pre-Retrofit	Post-Retrofit
Heating System	2-pipe steam (natural gas)	2-pipe steam (natural gas)
DHW System	Natural gas boiler	Natural gas boiler
Air Conditioning	Thru-wall ACs	Thru-wall ACs

Retrofit Background

This is a classic example of how an over-heated, poorly-controlled NYC pre-war building can take advantage of low-cost energy efficiency measures and a scheduled boiler replacement to gain deep energy savings. The 174-unit French Apartments building, on West 30th Street, was due for scheduled refinancing in 2014. Coincidentally, the gas-fired boilers for the 2-pipe steam and domestic hot water systems were approaching the end of their useful life. An energy audit identified additional low-cost measures, so a comprehensive retrofit project was included in the refinancing package.

Description of Retrofit

TRVs were installed on all radiators throughout the building to more accurately control steam flow and temperature in apartments. A radiant barrier behind the radiator accompanied the TRVs. Air sealing and spray foam insulation reduced drafts in windows above the radiators, and storm windows were installed as well to further reduce infiltration. Like many old steam heating systems, the steam risers required balancing to more evenly distribute steam to each floor.

These low-cost energy conservation measures (ECM) reduced the peak heating demand enough to right-size new boilers to a significantly lower capacity, which, in turn, operated more efficiently. Wireless controls and additional indoor and outdoor temperature sensors increased the accuracy and efficiency of the building's heating system. The boilers were converted to have burners with micro-actuators, which allowed variable heat output rather than boilers that were either completely on or off.

A variety of ventilation system improvements included aeroseal leak sealing of ventilation ductwork, motion sensors in restrooms to control toilet exhaust, and ECM variable speed motors on exhaust duct fans. The amenity spaces, which, prior to the retrofit did not have air conditioning, were upgraded to have a high efficiency air conditioner.

Metered Energy Savings and Other Benefits

The building was a fairly high energy consumer prior to the retrofit, so the total EUI reduction of 48% was from a high baseline of 131 kBtu/sf in 2014. Prior to the retrofit, 90% of the building's energy use was in space heating and domestic hot water, so that was the focus of the efficiency efforts.

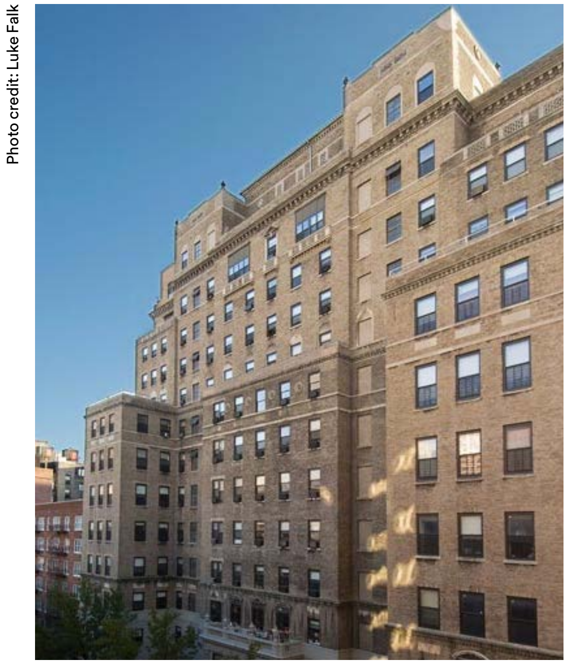
Economic Considerations

Related Companies used a scheduled refinancing to invest in energy efficiency and building systems modernization. This refinancing provided the capital for boiler replacement and energy efficiency improvements, with NYSERDA incentives to supplement and expand the list of measures implemented. U.S. Department of Housing and Urban Development incentives were explored to provide funding for a cogeneration system, but the timing did not allow that measure to be included in the retrofit.

KeyLessons Learned

Tenant education and communication required as much or more time than the technical design process on this project. Explaining to tenants that they no longer needed to open windows to avoid overheating took some time and convincing from the building's management team. A key lesson learned that was taken on to future residential retrofit projects was to communicate with tenants before, during, and after the project to ensure tenants understand the reasons for and benefits of retrofit improvements.

Photo credit: Luke Falk



Energy use from inefficient heating systems can drop nearly 50% by replacing old boilers, installing controls, sealing windows, and balancing the steam distribution network.

Energy Conservation Measures Overview

heating
- New gas fired boilers with modulating burners
- New wireless controllers on boilers
- TRVs on radiators
- Steam riser balancing

hot water
- Low-flow fixtures
- VFDs on circulation pump motors

envelope
- New low-e storm windows
- Radiant barrier behind radiators
- Air sealing and spray foam insulation

ventilation
- Aeroseal ductwork sealing
- Timers to reduce exhaust fans overnight
- Motion sensors for toilet exhaust
- VFDs on exhaust fan motors

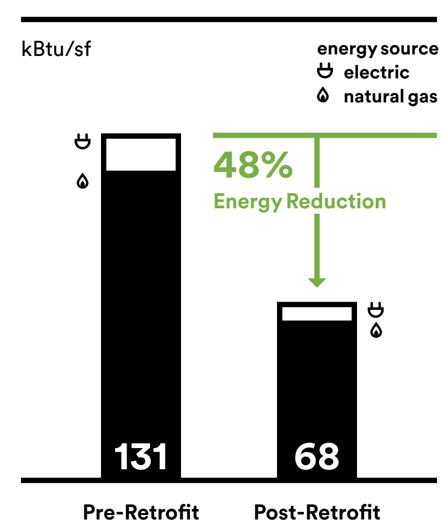
lighting
- LED lighting throughout common areas

plug loads

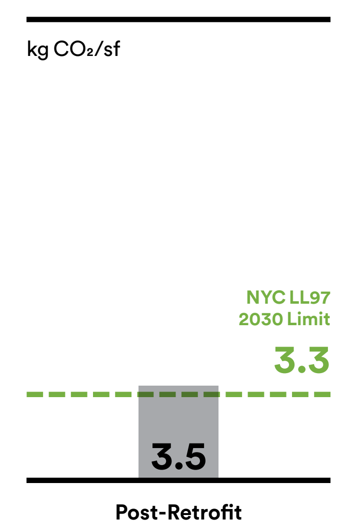
cooling
- VRF air conditioning in community spaces

other

Site EUI



GHGI (using NYC LL97 factors)



3. International Tailoring Company Building

Retrofit Approach

- Major Renovation
- **System Replacement**
- Incremental

Retrofit Motivation

- **End of Useful Life**
- Energy Cost Savings
- Repositioning
- Environmental Branding

Key Figures

Pre-Retrofit Site EUI	96 kBtu/sf
Post-Retrofit Site EUI	51 kBtu/sf
% Energy Reduction	47%
Post-Retrofit GHGI (using NYC LL97 2030 factors)	3.5 kg CO_2/sf

Location	New York, NY
Owner	Co-op
Rental or Condo	Co-op
Affordability	Market Rate
Floor Area	185,000 sf
Number of Stories	13
Number of Units	173
Year built	1921
Year renovated	2023

Pre-Retrofit	Post-Retrofit
Heating System	
Fan coil units	In-unit heat pumps
DHW System	
Natural gas boiler	Natural gas condensing boiler
Air Conditioning	
Fan coil units	In-unit heat pumps

Retrofit Background

This 1920s manufacturing building was converted to a residential co-op in the 1980s. The 2-pipe fan coil unit heating and cooling systems were at the end of their useful life and did not meet the comfort standards of a luxury apartment building in the 2020s. Through an innovative process, Ecosystem Energy Services designed an HVAC system that utilized waste heat, improved temperature control, and substantially electrified the building's space heating, cooling, and hot water generation.

Description of Retrofit

This retrofit replaced fan coil units in apartments with new heat pumps connected to a new hydronic loop. In the summer, the apartments in cooling mode reject heat to the hydronic loop; in the winter apartments in heating mode draw heat from the hydronic loop. During the summer when all heat pumps are in cooling mode, the hydronic loop becomes the heat source for domestic hot water. Due to spatial and budget constraints, the building needed to remain within its existing electrical capacity. As roof area was limited for Air to Water Heat Pumps (AWHP), the heating capacity of the AWHP provides about one third of the peak heating demand. Despite providing only a third of peak load, the system reduces annual natural gas consumption by over 80%.

Ecosystem Energy Services provided full turnkey project delivery, including design, construction management, and commissioning services. The approach was to install the heat pumps in half a floor at a time over the course of one week. The first day included preparation and an exhaustive effort to hermetically seal off the work area. Fan coils were removed, and the change-over to heat pumps was completed on the second through fourth days. The last day was a thorough clean up to return the apartment to its previous condition.

Metered Energy Savings and Other Benefits

Pre-retrofit EUI hovered around 95 to 100 kBtu/sf, with a typical ratio of 2/3 natural gas and 1/3 electricity. The efficiency measures from the retrofit reduced electricity use, while electrification of cooling and most of the heating increased electricity use, resulting in roughly the same electricity EUI of 26 kBtu/sf. Conversely, natural gas EUI dropped dramatically, as gas was no longer used for absorption chillers or most of the heating demand. Post-retrofit, whole-building EUI dropped to 51 kBtu/sf, amounting to a 47% net savings.

Economic Considerations

The co-op board realized their absorption chillers/heaters were approaching the end of their useful life and began setting aside reserves for five years before this project was implemented. Through a unique approach, Ecosystem Energy Services provided a preliminary assessment at no charge to the co-op board. Later, the cost of their detailed feasibility study and design documentation was included in the overall cost of the project and only charged if the board decided not to move forward with the project. NYSERDA's Low Carbon Pathways program provided $250,000 to the project, while the Con Edison Clean Heat Program provided $1.6M, which provided nearly 20% of total project cost.

KeyLessons Learned

Substantial electrification is a practical step that can be implemented today and set a building on a path to long-term decarbonization and, ultimately, full electrification. This project's unique, integrated approach of design, project management, general contracting, and commissioning all by Ecosystem Energy Services was critical to the success of project delivery.

Photo credit: Ecosystem Energy Services

> "Retrofits of large apartment buildings that remain occupied during construction is like changing the engine of a plane when it is in flight."
>
> — Eric Einstein, Co-op Board President

Energy Conservation Measures Overview

heating
- Heat pumps in apartments replace fan coil units
- New ASHP for heating supply
- New gas condensing boilers
- Smart thermostats

hot water
- Pre-heat DHW from hydronic loop in summer

envelope

ventilation
- New dedicated outdoor air system (DOAS)

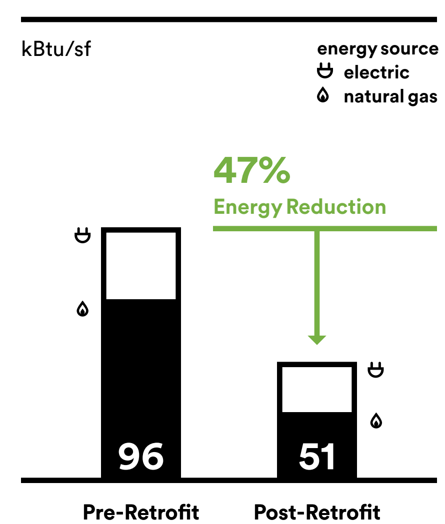
lighting

plug loads

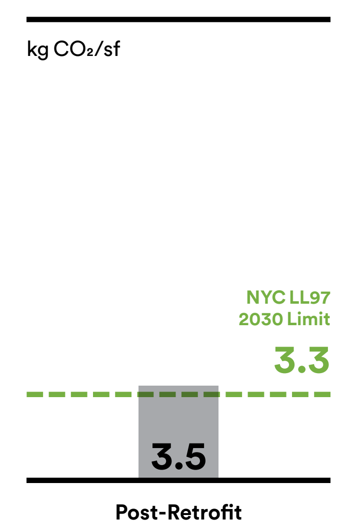
cooling
- Decommissioned absorption chillers
- New water cooled cooling tower

other

Site EUI



GHGI (using NYC LL97 factors)



4. Wilmcote House

Retrofit Approach

- **Major Renovation**
- System Replacement
- Incremental

Retrofit Motivation

- **End of Useful Life**
- **Energy Cost Savings**
- Repositioning
- Environmental Branding

Key Figures

Pre-Retrofit Site EUI	24 kBtu/sf
Post-Retrofit Site EUI	15 kBtu/sf
% Energy Reduction	39%

Post-Retrofit GHGI **0.6 kg CO_2/sf**
(using NYC LL97 2030 factors)

Location	Portsmouth, UK
Owner	Portsmouth City Council
Rental or Condo	Rental
Affordability	Affordable
Floor Area	135,000 sf
Number of Stories	11
Number of Units	111
Year built	1968
Year renovated	2018

Pre-Retrofit	Post-Retrofit
Heating System	
Electric baseboard	Electric baseboard
DHW System	
In-unit electric tank	In-unit electric tank
Air Conditioning	
None	In-unit electric tank

Retrofit Background

Built in 1968, its original structure consisted of large, poorly insulated pre-cast concrete panels with inefficient windows and extensive thermal bridges, leading to high heat losses, internal condensation, mold growth, and low internal comfort levels. Due to its large panel system structure, natural gas was removed shortly after its original construction, and instead electric storage heaters were included in each maisonette, with electricity meters paid directly by each tenant. Unfortunately, after 50 years, the windows and facades were leaky, and the walls were poorly insulated, causing high electricity bills in the winter. Some low-income tenants experienced energy poverty and were unable to afford maintaining World Health Organization safe temperatures in their homes. Thus, a major envelope retrofit designed to EnerPhit/Passivhaus standards was developed and completed in 2018.

Description of Retrofit

This retrofit was predominantly an envelope upgrade with accompanying ventilation and space heating improvements. Firstly, the exterior concrete walls received extensive re-cladding which provided insulation, air tightness, and protected the aging concrete structure. The roof also received over 12” of additional insulation along with new waterproofing and drainage details. Most importantly, the balconies and walkways were enclosed, and a continuous thermal envelope was created through the new exterior cladding and new windows enclosing the balconies, living rooms, and walkways. This strategy significantly reduced the area of thermal envelope, contributed to eliminate any thermal bridging, and created additional useful floor area.

Building the envelope to Passive House [LP1] standards required mechanical ventilation to provide adequate fresh air to the maisonettes. Small heat recovery ventilators (HRV) were installed in each unit, extracting air from bathrooms and delivering filtered, tempered air to living areas. Small electric resistance heaters in the living areas replaced electric storage heaters in every room.

Metered Energy Savings and Other Benefits

The pre-retrofit electricity EUI of 24 kBtu/sf in 2013 is deceptively low because tenants were simply not heating their units to comfortable temperatures due to the high cost. The envelope retrofit allowed tenants to bring their units up to typical warm temperatures in the winter while still reducing the whole-building electricity EUI by 39% to 15 kBtu/sf.

Economic Considerations

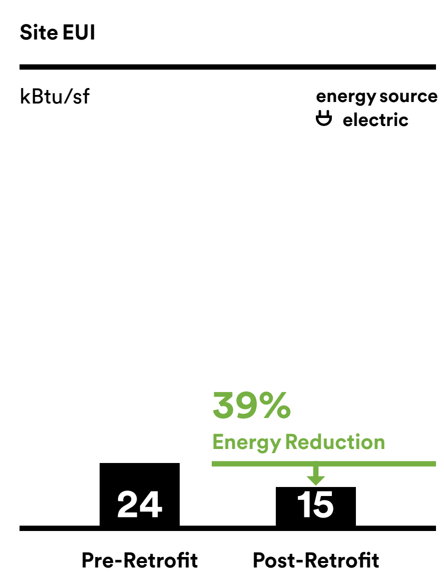
The total retrofit project cost of £13M (US$17M) was higher than a typical envelope retrofit due to the structural repairs required for the 1960s concrete structure and additional steel columns required to enclose walkways and balconies. But the impact on the lives of residents is significant, as they are now able to heat their homes adequately and much more affordably, bringing them out of energy poverty.

KeyLessons Learned

Despite the perception of electric resistance heating being inefficient and costly, this project demonstrates the potential for a highly insulated, airtight envelope with heat recovery ventilation to require very little heating and be “all-electric” while maintaining low electricity bills. With such a low heating demand, a very simple heating system of electric resistance makes sense rather than pumping water through buildings in hydronic loops, especially considering the rapid decarbonization of the electricity grid in the UK.

Photo credit: Loreana Padron, ECD Architects

Passive House renovation drives down heating loads from leaky, uncomfortable, starting points.



Energy Conservation Measures Overview

heating
New electric resistance heating to boost HRVs

hot water
New electric resistance hot water tanks

envelope
Additional exterior wall and roof insulation
New triple glazed windows
Air sealing around windows and doors

ventilation
Heat recovery ventilators in each unit

lighting
New LED lighting in apartments and communal areas

plug loads

cooling

other

5. Valla Torg

Retrofit Approach

- **Major Renovation**
- System Replacement
- Incremental

Retrofit Motivation

- **End of Useful Life**
- Energy Cost Savings
- **Repositioning**
- Environmental Branding

Key Figures

Pre-Retrofit Site EUI	**63 kBtu/sf**
Post-Retrofit Site EUI	**401 kBtu/sf**
% Energy Reduction	**36%**
Post-Retrofit GHGI	**1.9 kg CO_2/sf**

(using NYC LL97 2030 factors)

Location	**Stockholm, Sweden**
Owner	**Stockholmshem**
Rental or Condo	**Rental**
Affordability	**Affordable**
Floor Area	**210,000 sf**
Number of Stories	**14**
Number of Units	**302**
Year built	**1961**
Year renovated	**2016 – 2018**

Pre-Retrofit	**Post-Retrofit**
Heating System	
Hydronic radiators	Hydronic radiators
DHW System	
District hot water	District hot water
Air Conditioning	
None	None

Retrofit Background

Through the Grow Smarter (growsmarter.eu) program, the affordable housing developer and manager, Stockholmshem, chose the 302-unit Valla Torg housing complex to undertake a major renovation in 2016–2018. This post-war, 1960s era housing development is typical throughout Europe. So, by focusing on energy efficiency and indoor environmental quality during the modernization, this project became a demonstration of best practices for energy retrofits in residential buildings and a template for the developer to repeat across their portfolio.

Description of Retrofit

Major envelope improvements led this retrofit. Old windows with a U-value of R3 were replaced with new R8 windows, and were installed with careful attention to air tightness and air sealing around the frames. Exterior walls received an additional 3” of exterior insulation, while roof areas received an additional 12” of insulation. Ventilation systems went from mechanical ventilation without heat recovery to a trickle vent under each window that drew fresh air past radiators to immediately heat intake air. Toilet and kitchen exhaust risers flowed to an exhaust air heat pump, which extracted heat from exhaust air and provided a heat source for the domestic hot water heat pump. A total of 80kW of rooftop solar photovoltaic panels were installed on various rooftops around the complex. Many other small ECMs were installed as well, including wastewater drain heat recovery to preheat domestic hot water, hot water distribution piping insulation, modern thermostats controlling radiators in each unit, and LED lighting in hallways and elevators.

A complex shifting of tenants into unoccupied units temporarily was a way to keep tenants in the complex while their unit was under renovation for a few weeks. Checkerboarding tenants out of their apartments into temporary apartments required substantial scheduling but was required to gain approval from tenants to have access to their units.

Metered Energy Savings and Other Benefits

Significant heating savings were achieved through the replacement of the windows, air tightness, heat recovery ventilation, and additional insulation. District hot water EUI dropped from 35 to 16 kBtu/sf, a dramatic drop demonstrating the potential for improvement in the aging housing stock in Sweden. Electricity savings from LED lighting were minor, but the 80kW solar array did reduce the electricity EUI from 28 to 25 kBtu/sf. Total Site EUI reduced 36%, of which most of the savings went to reducing the building owner’s heating bill. But tenants received the benefit of having more comfortable apartments and better air quality in their homes.

Economic Considerations

Partial funding for this renovation came from European Commission grants through the GrowSmarter program. Long-term tenants were concerned that investment in the complex would result in higher rental rates. Coming to an agreement between tenants and the owner, Stockholmshem, delayed the project, but an agreement was finally reached, and the project was implemented.

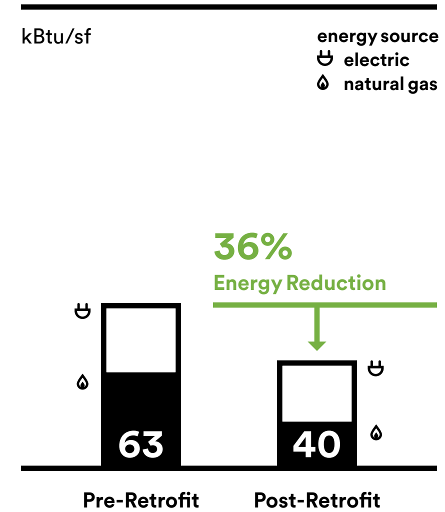
KeyLessons Learned

Working with tenants to schedule major renovations within their units proved the most challenging aspect of the project; far more difficult than the technical and construction aspects. The funding support from the GrowSmarter initiative allowed this project to implement a deep energy saving retrofit.

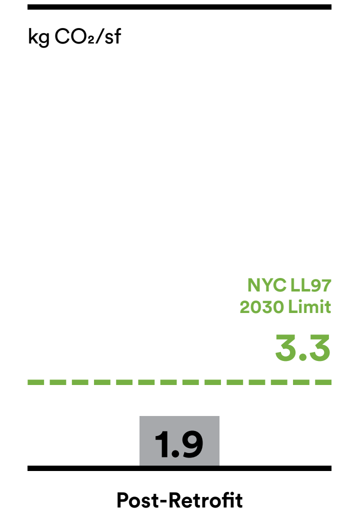
Photo credit: Will DiMaggio

Nordic solutions for a deep energy retrofit of a housing complex.

Site EUI



GHGI (using NYC LL97 factors)



Energy Conservation Measures Overview

heating
New radiators below windows

hot water
Exhaust air heat recovery for domestic hot water
Hot water piping insulation

envelope
New double glazed windows
Exterior wall over-cladding with additional 3” rigid insulation
New roof with additional 12” rigid insulation

ventilation
Exhaust air heat recovery for domestic hot water

lighting
LED lighting in hallways and elevators

plug loads

cooling

other
80kW of rooftop solar photovoltaics
Shower drain heat recovery

6.
172 E4th St

Retrofit Approach

- Major Renovation
- System Replacement
- Incremental

Retrofit Motivation

- End of Useful Life
- Energy Cost Savings
- Repositioning
- Environmental Branding

Key Figures

Pre-Retrofit Site EUI	62 kBtu/sf
Post-Retrofit Site EUI	42 kBtu/sf
% Energy Reduction	32%
Post-Retrofit GHGI (using NYC LL97 2030 factors)	2.1 kg CO_2/sf

Location	New York, NY
Owner	Co-op
Rental or Condo	Co-op
Affordability	Market Rate
Floor Area	126,000 sf
Number of Stories	12
Number of Units	102
Year built	1929
Year renovated	2001 – 2011

	Pre-Retrofit	Post-Retrofit
Heating System	2-pipe steam (fuel oil)	2-pipe steam (natural gas)
DHW System	Fuel oil boiler	Natural gas boiler
Air Conditioning	Window ACs	Window ACs

Retrofit Background

This retrofit project has been a 20-year endeavor by an active and financially disciplined co-op board. Built in 1929, this 12-story, 102-unit co-op was a classic pre-war NYC apartment building with clanging radiators and no air conditioning. A fuel oil-fired boiler generated steam for a two-pipe steam heating system and heated water for domestic hot water. Operable windows provided ventilation and relief from the overheated apartments most of the winter.

Description of Retrofit

In 2001, the building's co-op board president began a retrofit journey with a mindset of long-term investment rather than the previous approach of as minimal investment as possible. The first seemingly small step was to replace old, rusted radiator valves with new TRVs at each radiator. Each TRV was connected to an early version of building automation to control sections of the building based on indoor and outdoor temperature. The work at this time was steam balancing: the removal of individual steam traps and installation of orifice plates at the valve junction. Pressure release valves were installed at the top of all risers and a master vent was installed in the basement. The removal of the steam traps also eliminated the knocking associated with steam radiators. The TRV's and computerized thermostat system were installed in 2010.

In 2011, the old fuel oil-fired boiler failed, forcing the issue of a boiler upgrade. At the time, switching fuel to a new, high efficiency natural gas boiler made sense financially and environmentally.

Over the following decade, a slow and steady stream of energy efficiency investments continued the building's retrofit process. Variable Frequency Drive (VFD) motors were installed on water pumps to pressurize hot and cold-water lines up the building. LED lights replaced fluorescent and incandescent lights in stairwells and hallways. Windows were sealed to reduce air leakage in the winter.

Metered Energy Savings and Other Benefits

Eliminating overheating of apartments and replacing the old, inefficient fuel oil boiler led to much of the 35% EUI savings. A post-retrofit EUI of 42 kBtu/sf is quite low and is a testament to simple building systems such as natural ventilation and window air conditioners that can deliver efficiency through simplicity. The investments over the past 20 years have put this building in compliance with NYC LL97 through both the 2024-2029 and 2030–2034 compliance periods.

Economic Considerations

By building financial reserves each year, this co-op board demonstrated how continual investment in energy efficiency can drive down operational costs. No incentives were utilized for this project, partially because the board did not have the industry expertise to seek and receive rebates or grants. However, the building is currently studying how incentives from NYSERDA for decarbonization studies, or rebates for efficient appliances, could help them continue their journey.

KeyLessons Learned

Replacing old radiator valves to TRVs is an easy, low-cost, non-intrusive retrofit option that all buildings with two-pipe steam heating systems should implement. Space heating tends to be the highest energy cost for residential buildings, so those systems should be the first place to look for savings.

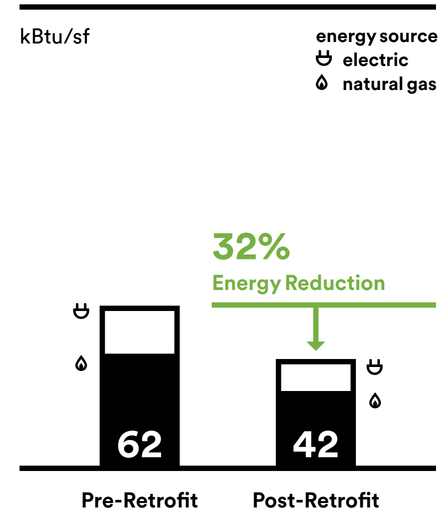
Boards of co-op buildings represent shares in a company that owns the entire building. The board needs to demonstrate common value for all cooperative shareowners, so that mindset lends itself to improving base building systems, such as heating and hot water.

Photo credit: if Needed

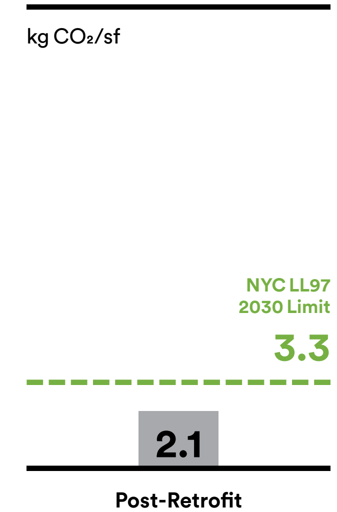
"The cost of doing nothing is not nothing."

—Lane Burt

Site EUI



GHGI (using NYC LL97 factors)



Energy Conservation Measures Overview

heating
- TRVs on radiators
- Automated thermostatic control in common areas
- Replace fuel oil boiler with natural gas boiler

hot water
- VFDs on DHW circulation pumps

envelope
- Window replacement throughout
- Air sealing around windows

ventilation
- Ductwork air sealing

lighting
- LED lighting throughout common areas

plug loads

cooling

other

7.

Rivermark Apartments

Retrofit Approach

- **Major Renovation**
- System Replacement
- Incremental

Retrofit Motivation

- **End of Useful Life**
- Energy Cost Savings
- **Repositioning**
- Environmental Branding

Key Figures

Pre-Retrofit Site EUI	66 kBtu/sf
Post-Retrofit Site EUI	46 kBtu/sf
% Energy Reduction	29%
Post-Retrofit GHGI (using NYC LL97 2030 factors)	2.2 kg CO_2/sf

Location	Cambridge, MA
Owner	Homeowners Rehab Inc
Rental or Condo	Rental
Affordability	70% Affordable
Floor Area	430,000 sf
Number of Stories	19
Number of Units	300
Year built	1978
Year renovated	2021 – 2023

	Pre-Retrofit	Post-Retrofit
Heating System	Hydronic, gas fired boilers	Hydronic, gas fired condensing boilers
DHW System	Natural gas fired boilers	Natural gas fired condensing boilers
Air Conditioning	None	In-unit A/C

Retrofit Background

Homeowners Rehab Inc (HRI) acquired this large property in 1997 in order to maintain the over 200 affordable housing units in the property. Over 25 years later HRI finally completed the upgrades to the facade, and the apartments that had been desperately needed. First, legal issues delayed the project, then putting financing together took another 10 years. Then, construction of the occupied building took nearly three years itself.

Description of Retrofit

The custom unitized panels that overclad the block and concrete facade give a fresh and modern look to this prominent building along Memorial Drive and the Charles River in Cambridge, MA. Light blue unitized windows and balcony doors also contribute to this building looking brand new despite being nearly 50 years old. The additional insulation in the over-cladding and the new, double glazed windows provide a dramatically lower heating and cooling demand for this large building. Thus, smaller condensing boilers provide peak heating demand. A new, natural gas fired cogeneration system provides base heating load and domestic hot water generation, as well as electricity for common areas.

A few smaller elements of the renovation were upgraded for energy efficiency and to support the Enterprise Green Communities certification. LED lighting was installed in the hallways, community room, gym, activity room, and computer lab. ENERGY STAR certified appliances were part of the kitchen upgrade package. New mechanical ventilation and air conditioning provide better indoor air quality and lower electricity bills for tenants.

Metered Energy Savings and Other Benefits

Most energy savings came from reduced heating demand bringing the natural gas EUI down from 39 kBtu/sf to 24 kBtu/sf. There were electricity savings from the cogen system and improved lighting and appliances, but much of that was offset by adding air conditioning and increasing ventilation rates. Therefore, the electricity EUI went down only slightly from 27 to 22 kBtu/sf.

Tenants reported being more comfortable with the airtight envelope and additional insulation. Air quality also improved with filtered ducted fresh air to the units. The building looks nicer overall, with the brick colored panelized facade and blue tinted windows — a dramatic improvement from the concrete and block colors from the 1970s.

Economic Considerations

Securing funding for the more than $15M project took many years, but finally came through in 2019. Most of the project cost went to the exterior insulated over-cladding panels and windows. About a third of the project cost was for air conditioning equipment and a new cooling tower. The incremental cost of LED lighting and ENERGY STAR appliances were minor, yet they were wrapped into the financing package.

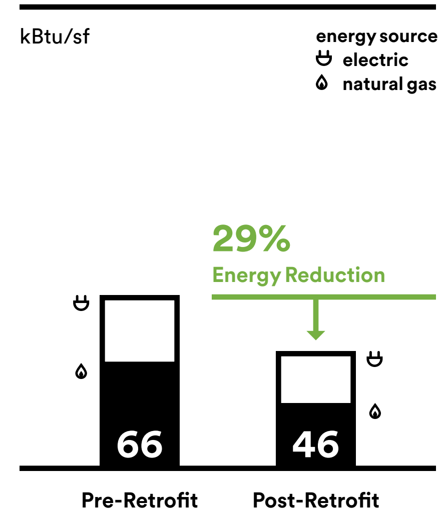
Key Lessons Learned

This major investment was a model for modernizing affordable housing in the high cost neighborhood of Cambridge, MA.

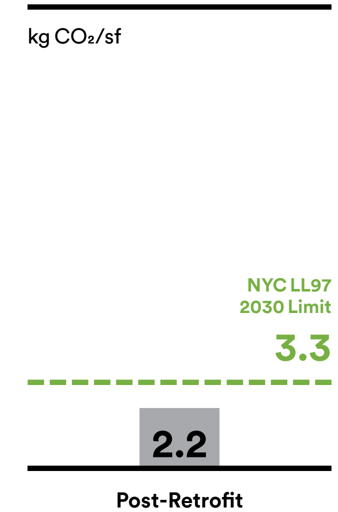
photo courtesy of Nuveen Real Estate

Years in the making, this major undertaking to put a new envelope on an iconic building in Cambridge was finally completed in 2023.

Site EUI



GHGI (using NYC LL97 factors)



Energy Conservation Measures Overview

heating
New condensing boiler

hot water
Cogeneration

envelope
Over-cladding with custom unitized panels
New double-glazed windows
Air sealing around windows

ventilation

lighting
LED lighting in hallways and common areas
Stairwell lighting motion sensors for dimmers

plug loads
ENERGY STAR refrigerators and dishwashers

cooling
New heat pumps for common areas and commercial areas

other

8.

340 On the Park

Retrofit Approach

- Major Renovation
- System Replacement
- **Incremental**

Retrofit Motivation

- End of Useful Life
- **Energy Cost Savings**
- Repositioning
- **Environmental Branding**

Key Figures

Pre-Retrofit Site EUI	81 kBtu/sf
Post-Retrofit Site EUI	58 kBtu/sf
% Energy Reduction	28%
Post-Retrofit GHGI (using NYC LL97 2030 factors)	2.5 kg CO_2/sf

Location	Chicago, IL
Owner	Condo
Rental or Condo	Condo
Affordability	Market Rate
Floor Area	800,000 sf
Number of Stories	64
Number of Units	343
Year built	2007
Year renovated	2016

	Pre-Retrofit	Post-Retrofit
Heating System	Electric baseboard	Electric baseboard
DHW System	Natural gas boilers	Natural gas tankless boilers
Air Conditioning	District cooling to fan coil units	Rooftop chillers to fan coil units

Retrofit Background

This 65-story tower recently built in 2007 was the tallest, all-residential building for a few years and the first LEED Silver building in Chicago. Originally, the building was connected to Chicago's district chilled water network, the largest in North America. About five years after it was completed, a retro commissioning (RCx) study by ComEd, a local RCx agent, identified a few no-cost measures to optimize controls, setpoints, and economizers. Then, as the second of two 5-year contracts for chilled water service was due to expire, the building took a closer look at the chilled water supply and decided to invest in their own chilled water plant on the roof, an acrobatic installation indeed. Five years after that, another handful of no-cost energy efficiency measures were identified through a RCx process in 2021.

Description of Retrofit

The first tranche of RCx identified no-cost measures in 2012 such as: reducing simultaneous heating and cooling in MAUs by disabling reheat in summer, optimizing pumping of hot water and chilled water distribution pumps, disabling pool heating in summer, and enabling economizer mode for common area AHUs. About 10 years after the building was completed, a few major investments took place. The domestic hot water boiler was replaced with a tankless hot water system. The investment in two 500-ton screw chillers and water-cooled cooling towers was completed in 2017. In 2019, a corridor and stairwell lighting upgrade consisted of replacing over 700 plug-in compact fluorescent lamps (26W) with LED lamps (9W). Then, the most recent RCx identified no-cost measures, such as reducing make up air overnight, fixing preheat controls, resetting cooling coil temperatures, and reducing humidifier schedules. Over the past few years the number of electric vehicles in the building has increased so much as to require a third party vendor, EverCharge, to bring in additional power supply and dynamic EV charging stations to power 48 charging stations in the building's parking garage.

Metered Energy Savings and Other Benefits

Over the 10 years of energy efficiency investments, the building reduced total site energy consumption by 28%. Natural gas EUI was reduced from 16 kBtu/sf/yr to 10 kBtu/sf/yr, which is low for Chicago because gas is used only for hot water and heat for MAU. Space heating for apartments is delivered through electric baseboard heating, partly because electricity cost is only $0.08/kWh and partly to allow heating costs to be paid directly by each apartment owner.

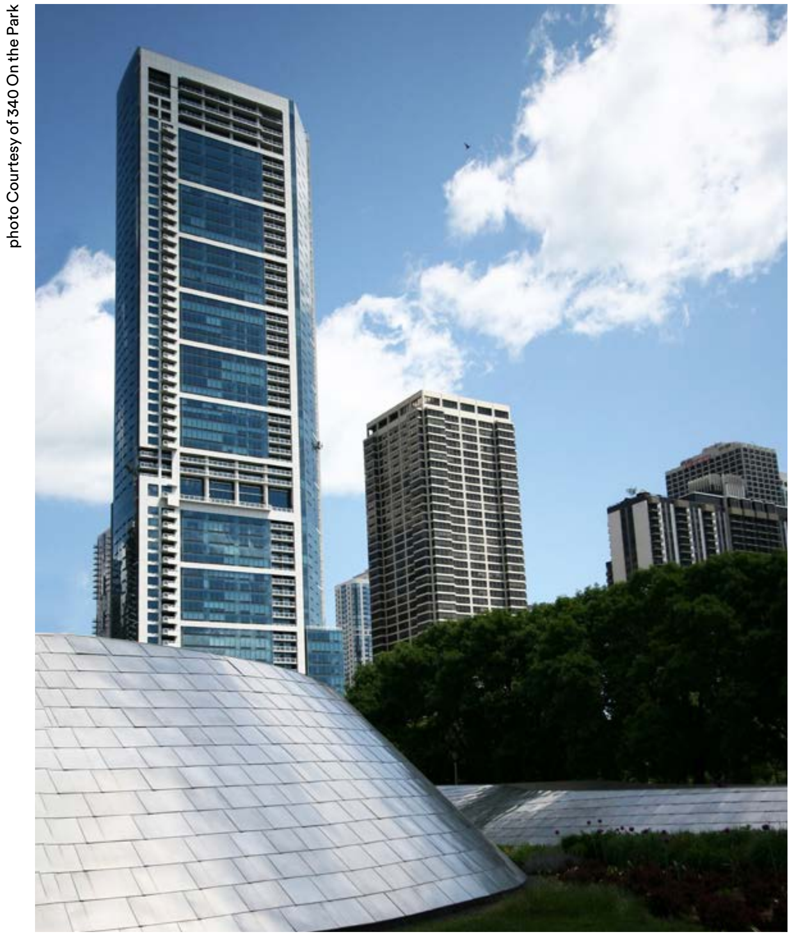
Economic Considerations

The switch to a rooftop chilled water plant provided minor energy savings due to the economies of scale and efficiencies of the district chilled water system. But the shift dropped the chilled water bill from nearly $500,000/yr to less than $200,000/yr. Utilizing condo board funds as collateral, the building was able to secure a low, 2.5% interest loan for the chilled water plant construction. The loan was paid back in less than six years by allocating cost savings to loan payments, so now the condo association sees significantly lower annual operating costs.

KeyLessons Learned

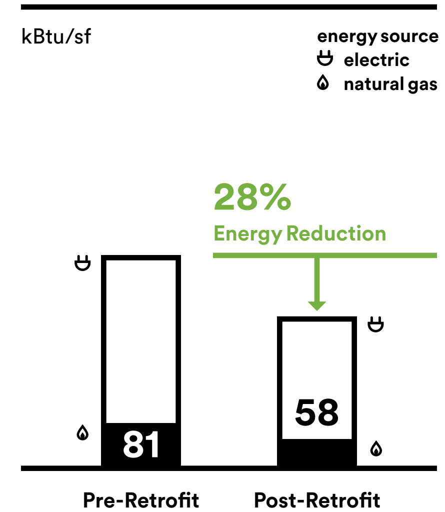
Being the first LEED Silver building in Chicago in 2007 instilled a mindset of energy efficiency and leadership in the condo board and generally in the owners. Such a mindset facilitated the RCx every five years and gained approval from 70% of the owners for the chilled water plant investment. Achieving energy savings requires effort, and having a positive mindset is the first step in the process.

photo Courtesy of 340 On the Park

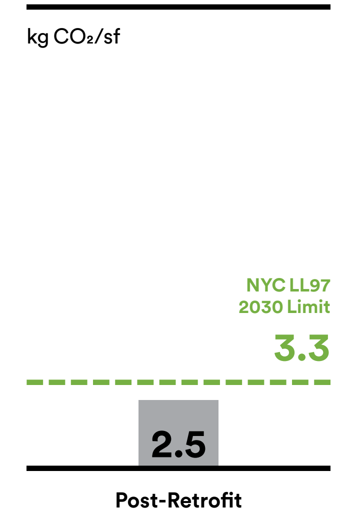


Take a close look at building systems every five years and you're bound to find 5–10% percent energy savings each time.

Site EUI



GHGI (using NYC LL97 factors)



Energy Conservation Measures Overview

heating

hot water
- Tankless (instant) hot water replaced DHW tank boiler

envelope

ventilation
- Balanced make-up air and reduced overall flow rate

lighting
- Stairwell and hallway relamping to LED

plug loads

cooling
- New chillers and cooling towers replaced district chilled water
- VFDs on CHW distribution
- Free cooling heat exchangers
- EcoBee smart thermostat

other
- 75 EV chargers with smart charging controller

9.
Putnam Square

Retrofit Approach

- Major Renovation
- System Replacement
- Incremental

Retrofit Motivation

- End of Useful Life
- Energy Cost Savings
- Repositioning
- Environmental Branding

Key Figures

Pre-Retrofit Site EUI	100 kBtu/sf
Post-Retrofit Site EUI	77 kBtu/sf
% Energy Reduction	23%
Post-Retrofit GHGI (using NYC LL97 2030 factors)	3.7 kg CO_2/sf

Location	Cambridge, MA
Owner	Homeowners Rehab Inc
Rental or Condo	Rental
Affordability	Affordable
Floor Area	71,000 sf
Number of Stories	14
Number of Units	94
Year built	1982
Year renovated	2015

	Pre-Retrofit	Post-Retrofit
Heating System	Hydronic with gas boilers	Hydronic with gas condensing boilers
DHW System	Natural gas boilers	Natural gas condensing boilers
Air Conditioning	Thru-wall ACs	Thru-wall ACs, VRF in common spaces

Retrofit Background

This renovation was part of an acquisition to preserve the building as an affordable residential building for seniors. New kitchens and appliances were installed in each unit to update kitchens that were decades old. Integral to the preservation process was an investment to modernize the facade and building systems to allow the building to operate efficiently for decades into the future.

Description of Retrofit

This is a classic example of a renovation to modernize an aging building that also included incremental funding for energy efficiency and higher specification equipment. A new, high efficiency condensing boiler replaced an old gas fired boiler. During installation of new, double pane windows careful attention was paid to air sealing around the window opening. LED lighting replaced old incandescent stairwell lighting. A VRF was installed in the first floor community room to provide both heating and cooling in the communal space.

Metered Energy Savings and Other Benefits

Although not a super-low energy building, this building went from a Site EUI of 100 kBtu/sf to 77 kBtu/sf, a 23% savings. Natural gas savings was due to a higher efficiency boiler and tighter, more insulated windows. Electricity savings was due to low energy lighting, and reduced air conditioning loads.

Economic Considerations

Total project cost was around $5M, a majority of which was for the new boiler and new windows. Funding for the acquisition and modernization upgrades came from the Massachusetts 40T program that preserves affordable housing in the region.

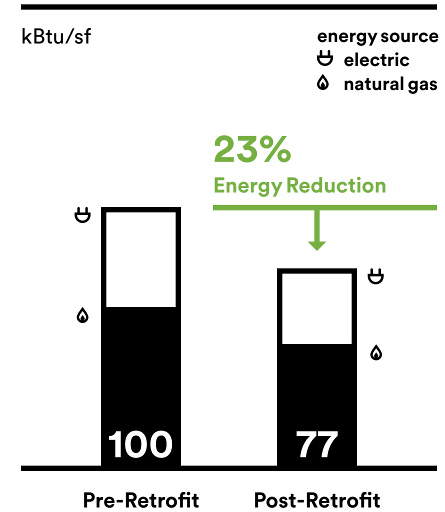
KeyLessons Learned

Extensive communication with residents allowed this project to run smoothly. With careful planning and execution, a major renovation can be completed in an occupied building in a straight-forward manner.

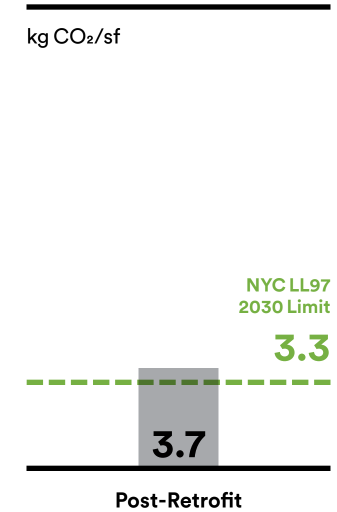
Photo credit: Will Monson, HRI

Some retrofits can be straightforward!

Site EUI



GHGI (using NYC LL97 factors)



Energy Conservation Measures Overview

heating
New condensing boiler

hot water

envelope
New double-glazed fiberglass windows
Air sealing around windows

ventilation

lighting
LED lighting in hallways and stairwells

plug loads
New kitchens and ENERGY STAR appliances

cooling
New VRF for air conditioning in community room

other

10. Polyclinic Apartments

Retrofit Approach

- Major Renovation
- System Replacement
- Incremental

Retrofit Motivation

- End of Useful Life
- Energy Cost Savings
- Repositioning
- Environmental Branding

Key Figures

Pre-Retrofit Site EUI 125 kBtu/sf
Post-Retrofit Site EUI 98 kBtu/sf
% Energy Reduction 21%

Post-Retrofit GHGI 5.0 kg CO_2/sf
(using NYC LL97 2030 factors)

Location	New York, NY
Owner	Standard Communities
Rental or Condo	Rental
Affordability	Affordable
Floor Area	150,000 sf
Number of Stories	13
Number of Units	151
Year built	1930 converted 1979
Year renovated	2021

Pre-Retrofit	Post-Retrofit
Heating System	
2-pipe steam	2-pipe steam
DHW System	
Natural gas boiler	Natural gas boiler
Air Conditioning	
Window ACs	Window ACs

Retrofit Background

In 2020, Standard Communities hired Bright Power to perform a RCx and audit report for NYC's LL97 compliance. The outcome of this report showed that the 2-pipe steam heating system had issues stemming from the building's conversion from a hospital to a 151-unit multifamily residential building in 1979. This, in addition to the system being over 40 years old, explained the frequent tenant complaints about overheating in some areas of the building and underheating in others.

As an affordable rental property, the building would be subject to the LL97 Prescriptive Pathway in 2024. In anticipation of these compliance requirements as well as looking for energy cost savings, Standard decided to implement most of the ECMs recommended in the LL87 audit report in 2021.

Description of Retrofit

This retrofit consisted of a series of comprehensive, low-cost measures across the steam radiator system, ventilation system, and domestic hot water system. TRVs were installed on all radiators to control steam flow and reduce overheating. Orifice plates were also installed to eliminate steam traps which frequently failed. A new controller was added to the boiler, which allowed remote control and monitoring and improved efficiency. Insulation was added to both steam and condensate piping where possible.

Other low-cost measures included sealing ventilation ductwork to reduce leakage and exhaust fan time-of-day timers to reduce energy at night. Common area lighting energy use was reduced by nearly 50% by a re-lamping effort throughout common areas. Metering water use and billing for water helped to reduce water demand, and, in particular, hot water demand and low flow fixtures reduced energy use to generate hot water.

Metered Energy Savings and Other Benefits

The bulk of the energy savings were from the steam system optimization and balancing. Natural gas EUI went from 103 kBtu/sf to 80 kBtu/sf, a 23% drop. Electricity use was a smaller portion of the total energy use in the building, with an EUI reduction from 23 kBtu/sf to 19 kBtu/sf. In addition to energy use and energy cost savings, there was a focus on improving air quality with improved ventilation and filtration of outside air. The timing of this project during the height of the COVID-19 pandemic pushed the issue of health and air filtration to be of high importance.

Economic Considerations

With a total project cost of $375,000, this project is an example of a retrofit achieving deep energy savings with very low capital investment. The project used $128,000 of incentives through Con Edison's Affordable Multifamily Energy Efficiency Program (AMEEP). Utilizing both the program's prescriptive measures list as well as custom measures, the project had less than a 5-year payback.

The primary motivation of the project was to improve building efficiency and the energy grade poster at the front door, in addition to compliance with the LL 97 Prescriptive Path.

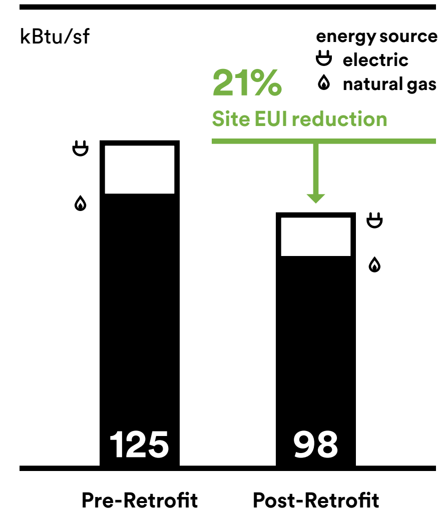
KeyLessons Learned

Overheating and poorly balanced steam radiator heating systems are typical in large NYC residential buildings. This case study informed the Prescriptive Pathway for affordable housing in LL 97 by demonstrating the types of low cost measures that can reduce energy use and improve comfort without a large capital investment. These types of measures are an important first step that a building can take toward a longer path to full decarbonization.

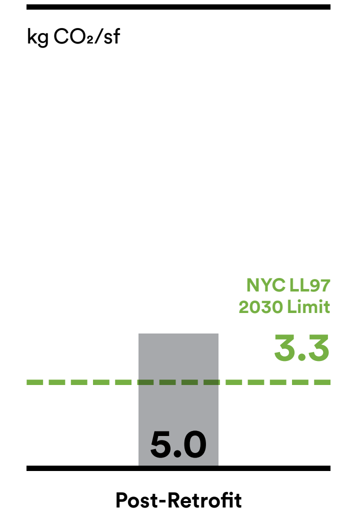
Photo credit: Bright Power

Taking the early steps on a longer decarbonization journey.

Site EUI



GHGI (using NYC LL97 factors)



Energy Conservation Measures Overview

heating
- TRVs on radiators
- Orifice plates on radiators
- New controllers on boilers
- Insulation on steam and condensate piping

hot water
- New water meters
- Low flow fixtures

envelope

ventilation
- Exhaust fan timer to reduce overnight ventilation rates
- Constant Air Regulator (CAR) dampers

lighting
- LED lighting throughout common areas

plug loads

cooling

other

11.
Gateway Plaza

Retrofit Approach

- Major Renovation
- System Replacement
- **Incremental**

Retrofit Motivation

- **End of Useful Life**
- **Energy Cost Savings**
- Repositioning
- **Environmental Branding**

Key Figures

Pre-Retrofit Site EUI	58 kBtu/sf
Post-Retrofit Site EUI	46 kBtu/sf
% Energy Reduction	20%
Post-Retrofit GHGI (using NYC LL97 2030 factors)	2.1 kg CO_2/sf

Location	New York, NY
Owner	LeFrak
Rental or Condo	Rental
Affordability	15% Affordable
Floor Area	1,700,000 sf
Number of Stories	34
Number of Units	1,700
Year built	1983
Year renovated	2013 – 2025

Pre-Retrofit	Post-Retrofit
Heating System	
Electric PTACs with electric resistance	Electric PTACs with heat pumps
DHW System	
Natural gas boilers (atmospheric)	Natural gas boilers (condensing)
Air Conditioning	
PTACs	PTACs

Retrofit Background

Gateway Plaza, one of the first buildings to be built on the reclaimed land of Battery Park City in 1983, required a variety of upgrades to meet the residential market standards of the 2010's. The 1,700-unit complex provides predominantly market rate rental apartments on the waterfront site within walking distance to NYC's Financial District. Around 300 units have been maintained as income-restricted, affordable, residential units.Tenants began expressing concerns about comfort, air quality, and high energy costs stemming from leaky windows and Packaged Terminal Air Conditioner (PTAC) electric resistance heating. In response, the ownership and management team, led by LeFrak, took a long term approach to upkeep and investments, using this modernization effort to improve the facade, ventilation, and heating & cooling systems to contemporary standards.

Description of Retrofit

Replacing windows and PTACs drove the original need for this retrofit project, as both were more than 30 years old and well past their useful life. Beyond that, an expansive effort was undertaken to add additional energy efficiency upgrades which would improve comfort, air quality, and operational costs for tenants.

New windows with tighter air sealing and higher R-values allowed a specification of heat-pump PTACs to replace electric resistance heating. Central building systems saw upgrades as well. Natural gas-fired condensing boilers replaced old domestic hot water boilers. Hallway and stairwell lighting were replaced with fluorescent fixtures. All constant speed motors for water pumps and fans were replaced by variable frequency drive (VFD) motors.

Implementing window replacements and new PTACs required coordination with tenants living in the units. This project demonstrates it is possible to undertake such an ambitious retrofit, but it also underlines the impact on construction schedule, as the whole-building retrofit took nearly three years to complete.

Metered Energy Savings and Other Benefits

Tenants saw most of the building-wide Site EUI savings of 20%, in addition to thermal comfort improvements from better windows and ventilation systems. Tenants reported fewer complaints of high electricity bills or cold, drafty apartments.

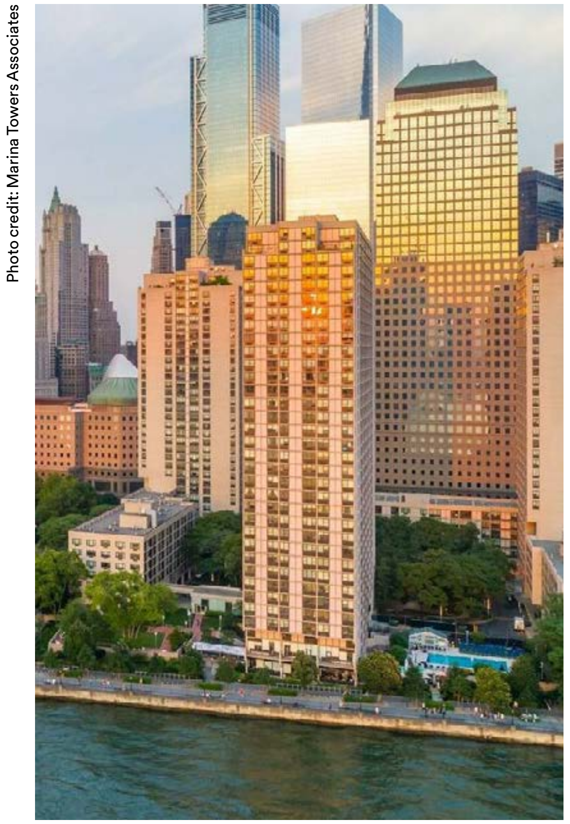
Economic Considerations

The economic drivers of this case study were primarily a response to meeting market demands set by new residential buildings in Battery Park City with LEED Gold and Platinum certifications. Owners invested in energy efficiency upgrades that reduced tenant energy costs. Typically, this split incentive discourages owners from energy efficiency retrofits, but this ownership group saw a longer term economic outlook with benefits of increased rental rates and higher occupancy rates. Many NYSERDA incentives were utilized, including energy efficiency studies during the design process, grants, and rebates for higher performance equipment.

KeyLessons Learned

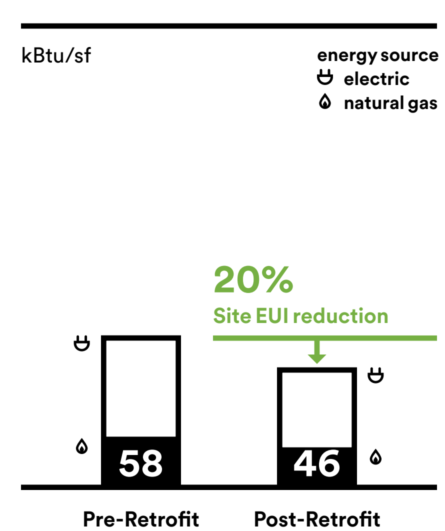
Sometimes, investments to upgrade building systems evolve from broader market conditions and tenant requests rather than simple payback or short-term financial considerations. This project responded to tenant complaints and a need to market a healthier, greener residential product.

Photo credit: Marina Towers Associates



Improving tenant satisfaction and cutting energy use with updated building technologies.

Site EUI



GHGI (using NYC LL97 factors)

Energy Conservation Measures Overview

heating
- New PTACs with heat pumps to replace resistance heating

hot water
- New condensing boiler with modulating controls
- Air Source Heat Pump for partial DHW load
- VFDs on DHW circulation pumps

envelope
- Window replacement throughout
- Air sealing around windows

ventilation
- Ductwork air sealing

lighting
- LED lighting throughout common areas

plug loads

cooling

other

12.

Moulins de la Pointe

Retrofit Approach

- **Major Renovation**
- System Replacement
- Incremental

Retrofit Motivation

- End of Useful Life
- **Energy Cost Savings**
- Repositioning
- Environmental Branding

Key Figures

Pre-Retrofit Site EUI	78 kBtu/sf
Post-Retrofit Site EUI	63 kBtu/sf
% Energy Reduction	19%
Post-Retrofit GHGI (using NYC LL97 2030 factors)	3.0 kg CO_2/sf

Location	Paris, France
Owner	Condo Assocation
Rental or Condo	Condo
Affordability	Affordable
Floor Area	30,500 sf
Number of Stories	11
Number of Units	41
Year built	1963
Year renovated	2017

	Pre-Retrofit	Post-Retrofit
Heating System	Hydronic radiators and natural gas boiler	Hydronic radiators and natural gas boiler
DHW System	Natural gas boiler	Natural gas boiler
Air Conditioning	None	None

Retrofit Background

France has nearly 10 million housing units in 740,000 condominiums, of which 40% are classified as “Energy strainers” according to a recent national survey. As renovations of these low-performing buildings are growing, information on best practices would prove to be valuable to the engineers, architects, and contractors to deliver the greatest possible energy savings. To raise awareness of best practices in energy renovations of residential condominiums, France established the Rénovons Collectif program to contribute to the development of skills and the organization of the professional sector in energy renovations.

Rénovons Collectif commissioned Enertech to perform a detailed study of the real performance of 50 residential retrofit projects across France. For each building, they collected pre-retrofit and post-retrofit energy use, tenant satisfaction, and detailed building systems information. This allowed a comprehensive view of residential retrofits of all types, sizes, and locations. The results and observations of this study are intended to improve energy renovation projects, by providing recommendations to professionals working in the sector.

Description of Retrofit

This is an envelope retrofit complimented with boiler upgrade and heating system balancing. The building, originally built in 1963, had very little wall and roof insulation. Some windows had been replaced with double glazed PVC windows in the 1990s, but many original single pane windows remained. Adding exterior insulation and replacing some windows was an obvious project to tenants who were used to living in drafty apartments all winter.

An aging gas fired boiler was upgraded with new burners and controls, but not completely replaced. The domestic hot water system also received benefits from the improved boiler as well as modest pipe insulation.

Metered Energy Savings and Other Benefits

Even though the hydronic radiators were not improved, this project achieved a 19% Site EUI reduction from the dramatically improved envelope and upgraded boiler. All of the energy savings were a result of reduced heating demand, and electricity consumption slightly increased due to fan energy from adding mechanical ventilation.

Economic Considerations

The total project cost was $540,000, with a third of the cost funded through public sector subsidy support. About $10,000 of ‘Energy Savings Certificates’ also contributed to the cost of the project. Lowering heating costs to low-income tenants by 20% was a significant benefit to residents, so they were pleased to receive the renovation and accept the temporary disruption to their homes.

KeyLessons Learned

Over-cladding projects should consider the entire envelope including wall insulation, windows, air sealing, roof insulation, and ground floor insulation. Complete insulation guarantees comfort and energy performance, while missing one of the envelope elements lets heat out and drafts in.

Photo credit: if Needed

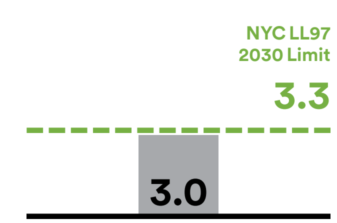
A comprehensive envelope retrofit delivers substantial energy savings.

Site EUI

kBtu/sf

GHGI (using NYC LL97 factors)

kg CO_2/sf



Energy Conservation Measures Overview

heating
- Boiler upgrade and controls
- Hydronic system balancing

hot water
- System balancing and pipe insulation

envelope
- Additional exterior insulation on walls, roof, and lowest floor
- Double glazed windows to replace single pane windows
- Air sealing around windows

ventilation
- New constant volume toilet exhaust with HRV

lighting

plug loads

cooling

other

13.

Roosevelt Landing

Retrofit Approach

- **Major Renovation**
- System Replacement
- Incremental

Retrofit Motivation

- **End of Useful Life**
- **Energy Cost Savings**
- Repositioning
- Environmental Branding

Key Figures

Pre-Retrofit Site EUI	98 kBtu/sf
Post-Retrofit Site EUI	81 kBtu/sf
% Energy Reduction	17%
Post-Retrofit GHGI (using NYC LL97 2030 factors)	3.6 kg CO_2/sf

Location	New York, NY
Owner	Urban America
Rental or Condo	Rental
Affordability	50% Affordable
Floor Area	1,008,000 sf
Number of Stories	20
Number of Units	1,003
Year built	1969
Year renovated	2013

	Pre-Retrofit	Post-Retrofit
Heating System	Electric baseboard heating	Electric baseboard heating
DHW System	Natural gas boilers	Natural gas cogen and boilers
Air Conditioning	Thru-wall ACs	Thru-wall ACs

Retrofit Background

In 2013, this 1,003-unit, former Mitchell Lama building was retrofitted by then-owners, Urban America. With five buildings and over 1M SF, the old, oversized domestic hot water boilers were operating inefficiently and impacting the owner's bottom line. Such a large residential building demands a significant domestic hot water load, justifying a technical study for a more efficient boiler plant, including a cogeneration system. This study then led to further investigation into overall building energy efficiency measures across the envelope and other building systems.

Description of Retrofit

The main component of this retrofit was to replace four old, 5,250 MBH domestic hot water boilers with a cogeneration system and new smaller boilers. The three 100kW gas-fired cogeneration units were sized to meet the base load of the domestic hot water system. Five new, 1,350 MBH gas-fired condensing boilers would serve the morning and evening peak loads. Based on hourly data of actual hot water load in the building, the overall capacity of the new boiler plant was reduced to less than half of its original capacity.

Other low-cost ECMs were included in this retrofit to harvest low-hanging efficiency measures. Air sealing at the slab edge reduced infiltration. Additional insulation was installed at the slab edge to reduce thermal bridging. Sensors were installed on windows to switch off electric baseboard heating when windows were open. Timers were installed on the toilet exhaust fans to reduce the flow and energy use overnight. CFL bulbs were given to residents to replace incandescent bulbs.

Metered Energy Savings and Other Benefits

Energy modeling during the technical studies projected a 9% reduction in Site EUI. However, the actual metered energy savings amounted to 17%, nearly double the projected estimate. Most of the savings came from reduced electricity EUI from 75 kBtu/sf to 64 kBtu/sf, since the cogeneration system offset a constant 300kW of electrical demand 24/7 throughout the year. Despite the highly optimized new boiler plant, the cogeneration system does consume a significant amount of natural gas, so natural gas EUI went down only slightly from 23 to 17 kBtu/sf.

Economic Considerations

Typically, projected savings of only 9% would not justify the time nor effort for such a major boiler replacement and energy retrofit, which had a total project cost of $8M. But since the cogeneration system burned low-cost natural gas and offset high-cost electricity, the energy cost savings were significantly more than 9%. Furthermore, there were a variety of incentives for the installation of cogeneration systems from NYSERDA, Con Edison, and ARRA funding, which totaled $1.2M, over 15% of the project budget.

This project also utilized a creative financing solution through New York City Energy Efficiency Corporation (NYCEEC). NYCEEC provided $4.5M of low-interest debt financing, and NYSERDA also provided $500,000 in low-interest financing. After grants and debt totalled $6.2M, $1.8M — just over 20% of total project cost — for equity capital was required from the building owner.

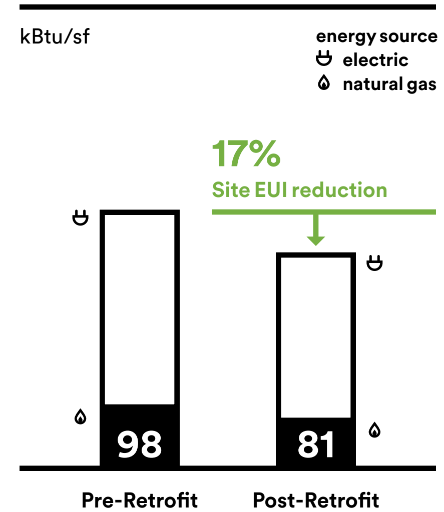
KeyLessons Learned

The owners of this property expressed that their main lesson was to utilize as many incentives and low-interest financing vehicles as possible, as fast as possible to gain as much energy and cost savings as they could. Finding technically feasible and financially viable retrofits is possible with a creative engineering and a creative financing approach.

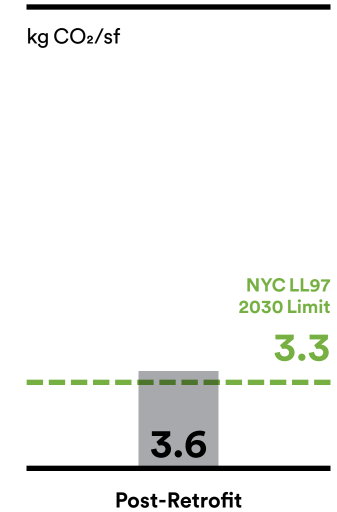
Photo credit: Flickr user Huanhai Cheng

Envelope upgrades, smart controls, and domestic hot water renovation with cogeneration improve tenant comfort and reduce costs through incentives and creative financing.

Site EUI



GHGI (using NYC LL97 factors)



Energy Conservation Measures Overview

heating
Window sensors to turn off heat when window is open

hot water
Cogeneration for base DHW load
New DHW condensing boilers

envelope
Air sealing at floor slab
Additional insulation at floor slab

ventilation
Timers on toilet exhaust

lighting
CFL bulb replaced incandescent bulbs

plug loads

cooling

other

14.

Belmont Towers

Retrofit Approach

- Major Renovation
- **System Replacement**
- Incremental

Retrofit Motivation

- **End of Useful Life**
- Energy Cost Savings
- **Repositioning**
- Environmental Branding

Key Figures

Pre-Retrofit Site EUI	71 kBtu/sf
Post-Retrofit Site EUI	59 kBtu/sf
% Energy Reduction	17%
Post-Retrofit GHGI (using NYC LL97 2030 factors)	2.8 kg CO_2/sf

Location	Vancouver, BC
Owner	Condo
Rental or Condo	Condo
Affordability	Market Rate
Floor Area	45,000 sf
Number of Stories	13
Number of Units	37
Year built	1982
Year renovated	2012

	Pre-Retrofit	Post-Retrofit
Heating System	Electric baseboard heating	Electric baseboard heating
DHW System	Natural gas boilers	Natural gas boilers
Air Conditioning	none	none

Retrofit Background

The owners of the condos in this 13-story senior living tower in Vancouver felt they needed to make some improvements to their building and its systems to keep up with local market trends and protect their real estate value. They created a working group of knowledgeable and engaged residents to guide the project and communicate with residents. Since the project predominantly included exterior work, the residents were able to remain in place during construction.

Description of Retrofit

This retrofit was nearly all enclosure work. The core of the project was new, triple glazed fiberglass windows. A variety of window options including aluminum, internal gases, and various coatings were studied through energy modeling and cost modeling. The fiberglass, double glazed option proved to be the most optimal for cost and energy savings goals. Exterior wall insulation and over-cladding were also added to the exterior envelope. Careful attention was paid to a rigorous air tightness campaign at the joints between the over-cladding and the window openings. Since only exterior work was done, there was less disruption to occupants, yet each suite did require work over two days to remove old windows and install new windows.

A second phase was also studied to include in-suite HRV and central heat recovery ventilation units to provide conditioned corridor ventilation, but this has not yet been approved or funded.

Metered Energy Savings and Other Benefits

Electric baseboards provide heat for the apartment units, and there is no air conditioning in the units. So, most of the energy savings from an improved envelope were seen in the electricity EUI dropping from 38 to 26 kBtu/sf, almost all from reduced space heating demand. Natural gas provides heat for the domestic hot water boiler, fireplaces, and hallway ventilation heating, none of which were impacted by the retrofit.

The modeled energy savings showed a 20% site EUI reduction, but metered energy savings fell just shy at 17%. This shows the importance of the building envelope to overall energy performance and demonstrates that envelope work alone can save around 20% of energy use. Condo owners appreciated this reduction in their monthly electricity costs, but they also greatly appreciated the improved thermal comfort and lack of drafts, which are key issues to seniors.

Economic Considerations

As with most design processes, some components of the proposed design did not meet payback constraints that the ownership group required. The cost benefit model developed by RDH did justify triple glazed windows when incentives from the local gas utility were included. Also, HRVs were proposed to improve ventilation rates, but they were postponed to Phase 2, as they did not fit within the Phase 1 budget.

KeyLessons Learned

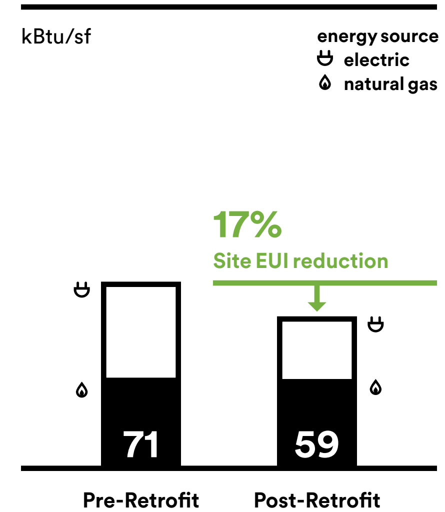
Because of the improvements to thermal bridging, air tightness, and overall insulation values of the new envelope, residents began seeing condensation on the exterior surfaces of windows some mornings and expressed concerns. The RDH team explained that some mornings after clear nights with a lot of black sky radiation would make the exterior surface of the windows quite cold and condenses moist air when relative humidity is high. Previously the glass would be warmer because of heat loss from the warm apartments inside and the exterior surface would not drop below the dew point.

Photo credit: Paul Grdina Photography

Envelope improvements alone reduced energy use by 17% and are keeping the feet warm in this senior living facility.

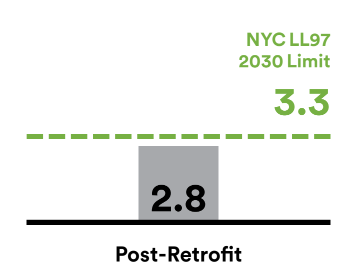
Site EUI

kBtu/sf



GHGI (using NYC LL97 factors)

kg CO_2/sf



Energy Conservation Measures Overview

heating

hot water

envelope

- New double-glazed fiberglass windows
- Over-cladding ext. wall insulation
- Air barrier system, liquid applied
- Air sealing around windows

ventilation

lighting

plug loads

cooling

other

technical solutions matrix

Category	Solution	1. Ken Soble Tower	2. French Apartments	3. Int'l Tailoring Bldg	4. Wilmcote House	5. Valla Torg	6. 172 E 4th St	7. Rivermark Apartments	8. 340 On The Park	9. Putnam Square	10. Polyclinic Apartments	11. Gateway Plaza	12. Moulins de la Pointe	13. Roosevelt Landing	14. Belmont Towers
heating	Boiler replacement: high efficiency, or oil to gas		●	●			●	●		●					
	Boiler control improvements		●							●	●		●		
	Steam riser balancing or TRVs		●							●	●		●		
	Electrification of space heating	●		●	●							●			
hot water	Hot water boiler replacement	●	●	●	●							●		●	
	High efficiency water fixtures		●								●			●	
	DHW distribution improvements	●	●		●	●					●	●	●		
	Air source heat pump for DHW			●		●						●			
envelope	Window replacement	●			●	●	●	●		●		●	●		●
	Air sealing around windows	●	●		●	●	●	●		●		●	●	●	●
	Over-cladding additional insulation exterior	●			●	●		●					●	●	●
	Additional thermal barrier on interior surface		●			●									
ventilation	Air sealing ductwork		●				●				●	●			
	Heat recovery on exhaust air ERVs	●		●	●	●							●		
	Reduced ventilation schedules overnight		●						●		●		●	●	
	Motion sensors on toilet exhaust		●												
lighting	LED lamp replacement in common areas	●	●		●	●	●	●	●	●	●	●		●	
	Motion sensors / smart lighting	●						●							
plug loads	ENERGY STAR appliances (replacement)	●						●		●					
	Gas to electric cooking	●													
	Heat pump dryers	●													
cooling	Building-wide central chillers, water cooled			●					●						
	VRF air conditioning in common areas	●	●					●		●					
	Ceiling fans	●													
other	Photovoltaics on rooftop					●									
	Instant DHW or Cogen for DHW							●	●						
	EV charging stations								●						

solutions summary

heating

Boiler replacement: high efficency, or oil to gas

This was a common ECM for deep retrofits which includes replacement of boilers at the end of their useful life. Most of the examples are replacing an old, inefficient, natural gas boiler with a higher efficiency or condensing natural gas boiler. There were also a couple conversions from fuel oil to natural gas as the primary heating source. Energy savings were achieved through higher conversion efficiency boilers and right-sizing replacement boilers.

- **Replace old natural gas boiler with new, high efficiency condensing boiler**
- **Replace fuel oil boiler with natural gas boiler**

Boiler control improvements

During the replacement of an old boiler, or simply upgrading an existing boiler, this ECM includes a variety of boiler control improvements to improve efficiency. Modernizing controls often replaces boilers with only full ON or completely OFF based on outside air temperature.

- **Micro-actuators on burners to modulate flame**
- **Outdoor and indoor temperature sensors**
- **Remote control and motoring of boiler**

System balancing or Thermostatic Radiator Valves (TRV)

Historically radiator valves were manual valves that allow tenants to turn up or down the flow of steam to each radiator. But they tend to have limited effectiveness and they seize up over time. This ECM involves replacing old manual valves with new valves that modulate based on room temperature. This significantly reduces overheating and wasted energy from opening windows.

- **Steam riser balancing**
- **Install TRVs on all radiators and remove manual valves**
- **Automated thermostatic control in common areas**
- **Install orifice plates on radiators**
- **Insulation on steam and condensate piping**
- **New radiators below windows**

Electrification of space heating

Long term decarbonization typically requires converting all on-site fossil fuel combustion for space heating to electricity-driven heat sources. This includes installation of air source heat pumps, VRF systems, heat pumps and hydronic loops, or PTACs with electric resistance or with heat pump heating mode.

- **Air source heat pumps for space heating**
- **VRF for heating and cooling**
- **Heat pumps and hydronic loop**
- **New electric resistance heating to boost HRVs**
- **PTACs to replace electric resistance**

hot water

Hot water boiler replacement

A few buildings in the study found energy savings through replacement of old, inefficient hot water heaters to new, high efficiency condensing boilers. Two projects electrified hot water generation through air source heat pumps, but most simply replaced old, gas boilers with new, condensing hot water boilers.

- **High efficiency condensing boilers**
- **Natural gas fired cogen as DHW boiler**
- **Natural gas fired on-demand hot water boilers**

High efficiency water fixtures

Reducing the amount of hot water used in showers, sinks, and appliances directly corresponds to a reduction in energy required to heat hot water. This low-cost measure is particularly effective in older buildings with fixtures and appliances that were installed prior to ENERGY STAR or code maximums on water fixture flow rates.

- **Low-flow showerheads**
- **Low-flow sink faucets**
- **ENERGY STAR certified appliances**
- **New water meters for each unit**

DHW distribution improvements

This ECM includes simply adding insulation to domestic hot water circulation pipes. This is a low cost measure, but tends to occur on major renovation projects when walls are opened and hot water piping is exposed. Common motors for VFD replacement include domestic hot water circulation pump motors, or hydronic loop circulation pump motors.

- **Insulation on DHW circulation pipes**
- **VFDs on DHW circulation pumps**
- **VFDs on hydronic loop circulation pumps**
- **Shower drain heat recovery**

Air source heat pump (ASHP) for DHW

Although there are many technical approaches to electrifying DHW generation, the only measures implemented in the case studies in this report were installation of air source heat pumps. All three projects that implemented ASHPs for DHW were all partial electrification of DHW generation as morning peak loads were too high to be met with ASHPs.

- **Air source heat pumps for DHW generation**
- **Pre-heat DHW from hydronic loop in summer**

envelope

Window replacement

Although most examples of window replacement in this compendium were driven by the need to replace old, leaky windows, they did represent a major common theme in residential retrofits that achieved deep savings.

- **New double or triple pane windows or doors**
- **Low-e storm windows**

Air sealing around windows

All projects that installed new windows also included air sealing around windows as a complimentary ECM. Even some projects removed windows trim to spray in foam around the gaps between windows and frames.

- **Spray foam insulations around windows**

Over cladding additional insulation exterior

Not a common ECM, but one that made a lot of sense for case studies in the colder climates and were built 30–50 years ago with minimal insulation. Some projects installed a complete additional continuous envelope around the existing exterior walls, while others simply addressed critical thermal bridges at slab edges or balconies.

- **Over-cladding with Mineral Wool EIFS**
- **New roofing and roof insulation**
- **Perimeter foundation insulation and waterproofing**
- **Removal of thermal bridges**

Additional thermal performance on interior walls

Only a couple of projects improved the thermal performance of the exterior walls by adding radiant barriers behind radiators to reflect radiant heat back into the room rather than outward away from heated space.

- **Radiant barrier behind radiators**

ventilation

Heat recovery on exhaust air

As envelopes become tighter and allow much less air to leak in, mechanical ventilation becomes more important for air quality in apartments. Various ECMs can help reduce the energy required to temper outside air or capture heat from exhaust air.

- **Heat Recovery Ventilators (HRVs)**
- **New dedicated outdoor air system (DOAS)**
- **Constant Air Regulator (CAR) dampers**

Reduced schedule

Some jurisdictions allow toilet exhaust fans to be reduced overnight or based on occupancy. Reducing far speed or turning off toilet exhaust fans overnight significantly reduces exhaust air rates and the corresponding treated fresh air requirement.

- **Timers to reduce exhaust fan speeds overnight**

Motion sensors controlling exhaust volumes

Some jurisdictions allow toilet exhaust fans to be reduced overnight or based on occupancy. Simply connecting the toilet exhaust fan to a motion sensor significantly reduces exhaust air rates and the corresponding treated fresh air requirement.

- **Motion sensors for toilet exhaust**

Sealing ductwork

As the importance and volume of mechanical ventilation increases, so does the need to reduces losses in supply and exhaust ductwork. Tightly sealing ducts through products like aeroseal were common in case studies in the compendium.

- **Aeroseal ductwork sealing**

lighting

LED lamp replacement in common areas

The most common ECM in this compendium was the relamping of hallway and stairwell lighting. This may be due to the timing of this study as most buildings installed LED lighting in common areas between 2015 and 2024 as the technology became mainstream during this time period and incentives supported this switch.

- **New LED lighting in hallways, common areas, and suites**

Motion sensors / smart lighting

Motion sensors make sense in stairwells that require 24-hour lighting, but are rarely used. With the cost of sensors and the ability of LED lights to dim without impact to bulb longevity, this small ECM was coupled with LED lighting switch on many buildings in this report.

- **Stairwell lighting motion sensors for dimmers**

plug loads

ENERGY STAR appliances

ENERGY STAR appliances are common as most high quality driers, dishwashers, and refrigerators come standard with the certification. New approaches to electrical driers include heat pumps to generate heat for driers.

- **ENERGY STAR refrigerators and dishwashers**
- **Heat pump dryers**

Gas to electric cooking

Slowly induction cooking has become more popular as an electriciation approach in kitchens as the health impacts of natural gas ovens and stoves are studied and publicized. Only one project (Ken Soble Tower) took the shift from gas ranges to induction ranges.

- **Induction stovetops**

cooling

Building-wide central chillers, water cooled

Only one project in the compendium (340 on the Park) installed central chillers with water cooled cooling towers as part of an energy retrofit.

- **New chillers and cooling towers replaced district chilled water**
- **New water cooled cooling tower**

VRF air conditioning in common areas

Quite a few of the affordable housing case studies did not have air conditioning in common areas, but as part of the modernization and retrofit air conditioning was installed in these spaces. A simple approach is a VRF when a podium rooftop or small outdoor space is available near the community room.

- **VRF air conditioning in community spaces**

Passive cooling techniques

A couple projects in climates slightly north of New York utilized more passive approaches to cooling including ceiling fans and low-emissivity blinds. Smart thermostats that automatically reduce heating setpoints overnight or can be controlled remotely are effective passive strategies as well.

- **Ceiling fans in living rooms and bedrooms**
- **Low-emissivity blinds**
- **EcoBee smart thermostat**

other ecms

Photovoltaics on rooftop

Only one project in this compendium installed photovoltaic panels on the rooftop as part of the energy retrofit project (Valla Torg).

- **Rooftop solar photovoltaics**

Instant DHW or Cogen for DHW

There are a few unique approaches to domestic hot water generation including instant DHW generation (gas fired), and gas fired cogeneration. Both approaches reduce waste through boiler tank losses and flue gas losses.

- **Natural gas fired turbines with flue gas heat capture for cogeneration**
- **Tankless instant hot water boilers**

EV charging stations

Only one project in this compendium installed EV chargers in the parking area (340 on the Park). Although not strictly a building decarbonization ECM, we included this as an innovative and important contribution to transportation decarbonization.

- **EV chargers with smart charging controller**

Glossary of Terms and Abbreviations

ASHP	Air Source Heat Pump
CHP	Combined Heat and Power
DHW	Domestic Hot Water
ECM	Energy Conservation Measure
ERV	Energy Recovery Ventilation
EUI	Energy Use Intensity
GHGI	Greenhouse Gas Intensity
HRV	Heat Recovery Ventilation
LED	Light Emitting Diode
PTAC	Packaged Terminal Air Conditioner
RCx	Retro-Commissioning
TRV	Thermostatic Radiator Valve
VFD	Variable Frequency Drive
VRF	Variable Refrigerant Flow

conclusions and path forward

Deep decarbonization of tall multifamily buildings is an increasingly high priority for building owners due to coming LL97 GHG limits and potential penalties. While there are many examples and case studies of low-rise building deep retrofits, there are not enough examples of tall building deep energy or decarbonization retrofits.

This survey profiles a diverse set of fourteen multifamily buildings that undertook a deep retrofit resulting in significant energy reduction—an average of 33% reduction in their site energy use intensity. Even though most all the projects began prior to the recent City and State climate legislation, these case studies do demonstrate that it's possible to cost effectively implement a deep retrofit that meets the aggressive 2030 GHG limits of NYC's LL97.

This report set out to identify case studies of deep energy or carbon retrofits of tall multifamily buildings, to demonstrate what is possible for meeting New York City LL 97 targets. We expected it to be relatively easy to find a large selection of case studies based on various press announcements about different retrofit projects, but in reality, with our stated goal of only highlighting projects with measured pre- and post-retrofit energy performance data, it was a challenge to get to the 14 projects that we have presented.

It was very surprising after reaching out to dozens of experts around the world that very few projects could provide information about projects that met our criteria: multifamily residential buildings at least eight stories tall, with pre- and post-retrofit whole-building data showing at least 20% energy or GHG reduction. We were especially surprised that some leading multifamily building owners noted how unusual it is to achieve 20% energy reduction. As with our earlier report compiling tall office building deep retrofit case studies, we found that outside of the growing number of U.S. cities where there are benchmarking and disclosure laws, it is extremely difficult to find whole building energy performance data that includes tenant energy use.

Most of the projects that we identified were improvements to the existing building space heating and domestic hot water systems and equipment, some with building envelope improvements, but only two included electrification of heating and DHW that will be required to get to 2050 LL97 targets. In the cases where we saw building envelope improvements, the main motivation was not deep energy savings, but driven more by the need to replace old, leaky windows.

We are in early days with tall multifamily building electrification retrofits — there are projects now getting started, but not yet complete, or without a year of post-retrofit measured data. For new construction electrification seems viable, but it is very challenging for building retrofits, particularly in buildings with natural gas as the current fuel for space heating and cooking, the economics are extremely difficult. Additionally, in buildings with natural gas as fuel for domestic hot water the technical aspects still present a challenge (this compendium shows no examples of electrification of hot water in these 14 case studies).

At the time of this report, the long term full decarbonization solutions for retrofits that are financially viable, have yet to fully emerge. That said, there are some exemplary projects included in this survey, and several more underway that deserve a closer look and may become models for what New York buildings need to do to meet coming LL97 limits.

Path Forward

Looking forward, to truly scale and drive tall multifamily building deep energy retrofits there are three significant problem areas to address: planning, occupancy, and economics; and several new, promising initiatives to keep under observation.

Planning. Very few of the projects profiled were implementing a strategic long term capital plan. Forward planning must become more pervasive to achieve the most cost-effective deep savings, optimize timing of system replacement and coordinate capital planning and asset management.

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NYSERDA's *Empire Building Challenge* has identified the need for building teams to develop a decarbonization roadmap that can optimize asset value and emissions reduction, while providing flexibility as circumstances evolve, with an approached named Resource Efficiency Decarbonization. This strategy, essential to tall buildings, is presented, along with curated planning tools and case studies, in the recently launched Retrofit Playbook for Large Buildings (retrofitplaybook.org).

Occupancy. Low occupancy rates of most New York residential buildings make them particularly challenging to retrofit and renovate. Furthermore, most NYC multifamily buildings are heated by high temperature steam systems with centralized fossil fuel powered boilers. Currently replacing these systems requires invasive and economically prohibitive work in tenant apartments. In short, new solutions are needed, and two New York State programs are working to address this need:

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Clean Heat for All is challenging manufacturers to develop a packaged cold climate heat pump that can be installed through an existing window opening to provide heating and cooling on a room-by-room basis. Avoiding disruptive in-unit retrofitting of existing steam heating systems or costly electrical upgrades, these solutions could provide a promising alternative.

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The $10m *Empire Technology Prize* is challenging solutions providers to develop fully functional prototypes of heating or distribution systems that can be installed in a manner that does not displace occupants and works with existing infrastructure in tall buildings, including steam and high temperature hot water heat pumps leveraging both air and water heat source.

Economics. Currently, the project economics of deep energy retrofits, especially in tall residential buildings, is very challenging. Fully decarbonizing major building systems often requires a prohibitive combination of completely replacing building wide heating systems, while switching from less expensive to operate gas equipment to (currently) more costly all electric systems. Therefore, there often isn't a resulting operational savings that might help to finance or defray the high upfront construction costs. Furthermore, current business as usual underwriting standards have yet to recognize the increased asset value and operational savings of high-performance buildings. Several initiatives and new federal and state programs seek to address this financing gap.

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Future Housing's *Underwriting Standards for Low-Carbon Housing*, a collaboration of Bright Power and Building Energy Exchange, is developing a database of measured energy performance data from low-carbon multifamily properties, which will guide the creation of utility cost benchmarks that can be used for underwriting low-carbon multifamily buildings.

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NYS's *Climate Friendly Homes Fund*, through the Community Preservation Corporation, is leveraging $250M to electrify 10,000 affordable homes, incentivizing electrifying heating and hot water systems and making envelop and ventilation upgrades.

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The Inflation Reduction Act's $27B *Greenhouse Gas Reduction Fund* is designed to seed a national network of nonprofit financial institutions financing tens of thousands of clean energy and energy efficiency projects and create residential solar programs, with an emphasis on low-income and disadvantaged communities.

With new climate regulations now reaching their compliance periods, and an increasing array of new incentives, financing, and promising new technology solutions on the horizon, many deep retrofit and electrification projects being planned, designed and beginning to start construction. Looking forward, it will be essential to track and better understand how the state of the retrofit market is evolving and what technologies, best practices, financing, and incentives can continue to effectively scale its progress.

methodology and approach

The initial task for this research was to develop the selection criteria for the target case studies and to create a long list of buildings that had the potential to be featured in this compendium. The technical criteria was established as:

- Primary use must be residential
- 8 stories or taller, and ideally over 15 stories if possible
- Publicly available metered energy data from both before and after the energy retrofit
- Energy savings achieving at least 20%, but ideally with savings greater than 30%
- From geographically diverse locations, but in a climate comparable to that of New York City
- An even mix of Affordable and Market Rate buildings
- An even mix of Rental, Co-op, and Condo ownership

Using this set of criteria, a list of candidate buildings was assembled by searching datasets and websites. Institutional databases such as the Passive House database, U.S. Department of Energy's Better Buildings Initiative database, Rocky Mountain Institute's Retrofit Depot; and finally, buildings which were featured in various publications such as High Performing Buildings Magazine, Passive House Buildings Magazine, and ASHRAE/ACEEE Summer Study papers. Public disclosure data from New York City, Boston, Chicago, D.C., Philadelphia, and Minneapolis was used to try to identify buildings with reduced EUI over time. Additionally, consideration was given to buildings which had been recognized for their energy savings by certification programs like LEED O&M, Green Globes, and EnerPHit; buildings which had been recognized by award programs such as the ASHRAE Technology Awards, the AIA's Committee on the Environment Top Ten Awards, and the Contest on Usage & Efficiency in Buildings (CUBE). The sources listed here are representative but not at all exhaustive.

The most fruitful resource used to find candidate buildings with deep energy retrofits, though, was the professional networks of the study team participants. The team reached out to many individuals in residential real estate, building systems engineering, and green building leadership organizations. After following many leads, a small subset of buildings was established, with all meeting the study's technical criteria established above. It is worth noting that the team was referred to a large number of European Passive House buildings, but locating metered energy data and a contact who worked on the project proved difficult. The team was also referred to a number of buildings that are currently undergoing or have recently undergone a retrofit. These buildings did not yet have available post-retrofit energy data, but are included in the "Buildings to Watch" list in the Conclusion.

Once the Long List of buildings meeting the technical criteria was established, practical considerations were then taken into account to filter down to a Short List. For each building, the study team endeavored to interview an owner, engineering consultant, or someone directly familiar with the building and the retrofit process. This was not always possible. For instance, after analyzing public energy disclosure data from various cities, it seemed that a decent number of buildings had reduced their energy use appreciably over a number of years, however, our team was not able to find contacts for many of these buildings. Therefore, this study should not at all be considered a comprehensive survey of high-rise residential buildings that have undergone deep energy retrofits. Indeed, as discussed in the introduction, our goal was to identify 14 representative buildings meeting the profile criteria. Finally, in two instances, the team relied on case studies or publications profiling a building, rather than on a direct interview.

After the process of filtering down potential buildings, the team arrived at the final list of 14 buildings included in this report. At this point, interviews were conducted. For each building, the team interviewed those people indicated in the References section and asked questions about the building's history, the building's ownership, the building's tenants, the motivation and approach to each retrofit, economic considerations for each retrofit, the ECMs included in each retrofit, and the key lessons learned during the retrofit. These interviews, along with any publications detailing the buildings and retrofit processes form the basis for the profiles of each building. Then, for each building, an energy analysis and data validation process was conducted. Many buildings' analyses rely on publicly disclosed benchmark data. In some cases, energy data was sourced from previous publications. If an owner wanted to provide energy data, the team used this energy data, rather than publicly disclosed data, even if there were discrepancies between the two sources. Whenever available, energy usage included in the report is presented with its constituent fuel mixes, but this information was not always available. Energy usage was converted to Site EUI in kBtu/ sf for all buildings. GHGI was calculated using carbon intensity factors as stated in NYC LL 97 rulemaking for 2030 and summarized in the table below. In some cases, GHGI was based on an estimated fuel mix, in which case, a note is included in the References section.

At the mid-point of this project, the team conducted a Stakeholder Workshop with building owners, technical consultants, NYC Buildings Department staff, and LL97 policymakers. The goal of the workshops was to share the progress that had been made to date, namely, the establishment of criteria for selecting buildings, initial resources and contacts consulted, a short-list of candidate buildings for inclusion in the report, and preliminary key findings. The second goal of the workshop was to solicit feedback from the stakeholders. The team wanted to understand if the stakeholders found the case studies and associated findings helpful, if the stakeholders felt, in the initial body of work, there were any discrepancies with their own experiences, and if the stakeholders felt the team had missed any important resources or retrofit projects. Overall, 13 stakeholders attended the workshop, a list of whom is included in the Credits and Thanks section of this report. The workshops concluded that the team was in the process of creating a relevant and compelling report, and many of the key insights gained during the workshops are reflected in the contents of this report.

Finally, the team assembled energy data and detailed retrofit information for all 14 buildings and a building profile was prepared. A draft was sent to the interviewees for each building for their review. Comments on the facts and descriptions in the profiles were integrated into the profiles by the team. The team deliberated on Key Findings and report messaging and wrote up the research conclusions. The graphic design team layed out the report and consolidated the content into easily readable text and graphics. Approvals were gained by NYSERDA and Building Energy Exchange leadership prior to final publication.

Fuel Type	Carbon Intensity Factors based on LL97 2030 factors
Electricity	0.042 kg CO_2/kBtu
Natural Gas	0.053 kg CO_2/kBtu
Fuel Oil	0.073 kg CO_2/kBtu
District Steam	0.043 kg CO_2/kBtu

project references

1. **Ken Soble Tower**
Interviewees and Reviewers
Graeme Stewart, ERA Architects
Mikael Sydor, ERA Architects

Publications
Ken Soble Tower EnerPhit, Passive House Buildings Magazine, Summer 2020

Energy Data Source
Pre- and Post-Retrofit data provided by Mikael Sydor, ERA Architects

2. **French Apartments**
Interviewees and Reviewers
Paul Rode, Tishman Speyer
Luke Falk, Related Properties
Geoff Hurst, Related Properties

Publications
Building Energy Exchange Energy Retrofit Profile, Dec 2016

Energy Data Source
Pre- and Post-Retrofit energy data downloaded from LL84 Benchmarking public data sets from CY2014 and CY2022

3. Int'l Tailoring Bldg
Interviewees and Reviewers
Jaime Pereira, Ecosystem Energy Services
Ben Milbank, Ecosystem Energy Services
Rick Kinsinger, Ecosystem Energy Services

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A case study for future-proofing a multifamily building with clean energy solutions, NYSERDA website, Feb 2024

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4. Wilmcote House
Interviewees and Reviewers
Loreana Padron, ECD Architects

Energy Data Source
Pre- and Post-Retrofit data provided by Loreana Padron, ECD Architects

5. Valla Torg
Interviewees and Reviewers
Harry Matero, Engie (formerly Skanska)

Energy Data Source
Pre- and Post-Retrofit data provided by Harry Matero

6. 172 E 4th St
Interviewees and Reviewers
Thom Ostrowski, 172 E4th St Co-op Board President

Energy Data Source
Pre- and Post-Retrofit energy data downloaded from LL84 Benchmarking public data sets from CY2014 and CY2022

7. Rivermark Apartments
Interviewees and Reviewers
Will Monson, Homeowners Rehab Inc

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An Affordable Housing Complex in Massachusetts Sets a National Precedent for Sustainable Investment in Large-scale Housing Communities, Retrofit Magazine article Dec 18, 2023

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8. 340 On The Park
Interviewees and Reviewers
Amy Eickhoff, 340 On The Park

Energy Data Source
Pre- and Post-Retrofit data provided by Amy Eickhoff, 340 On The Park

9. Putnam Square
Interviewees and Reviewers
Will Monson, Homeowners Rehab Inc

Energy Data Source
Pre- and Post-Retrofit data provided by Will Monson, HRI.

10. Polyclinic Apartments
Interviewees and Reviewers
Rohan Kulkarni, Bright Power
Dave Sachs, AKF (formerly Bright Power)

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Standard Communities Undertakes Substantial Energy Efficiency Upgrades at 151—Unit 100% Affordable Community in Manhattan, Standard Communities website, published Nov 2021

Energy Data Source
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11. Gateway Plaza
Interviewees and Reviewers
Jared Rodriguez, Emergent Urban Concepts (formerly LeFrak)

Energy Data Source
Pre- and Post-Retrofit energy data provided by Jared Rodriguez via ESPM Portfolio Manager download

12. Moulins de la pointe
Interviewees and Reviewers
Thierry Rieser, Enertech Group
Damien Jannot, Enertech Group

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Study on the Energy Performance of Renovated Condominiums, Enertech, Dec 2023

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Interviewees and Reviewers
Brittany Coughlin, RDH

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Special Thanks to

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This report made possible with the generous support of

New York State Energy Research and Development Authority

NEW YORK STATE | NYSERDA Supported

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