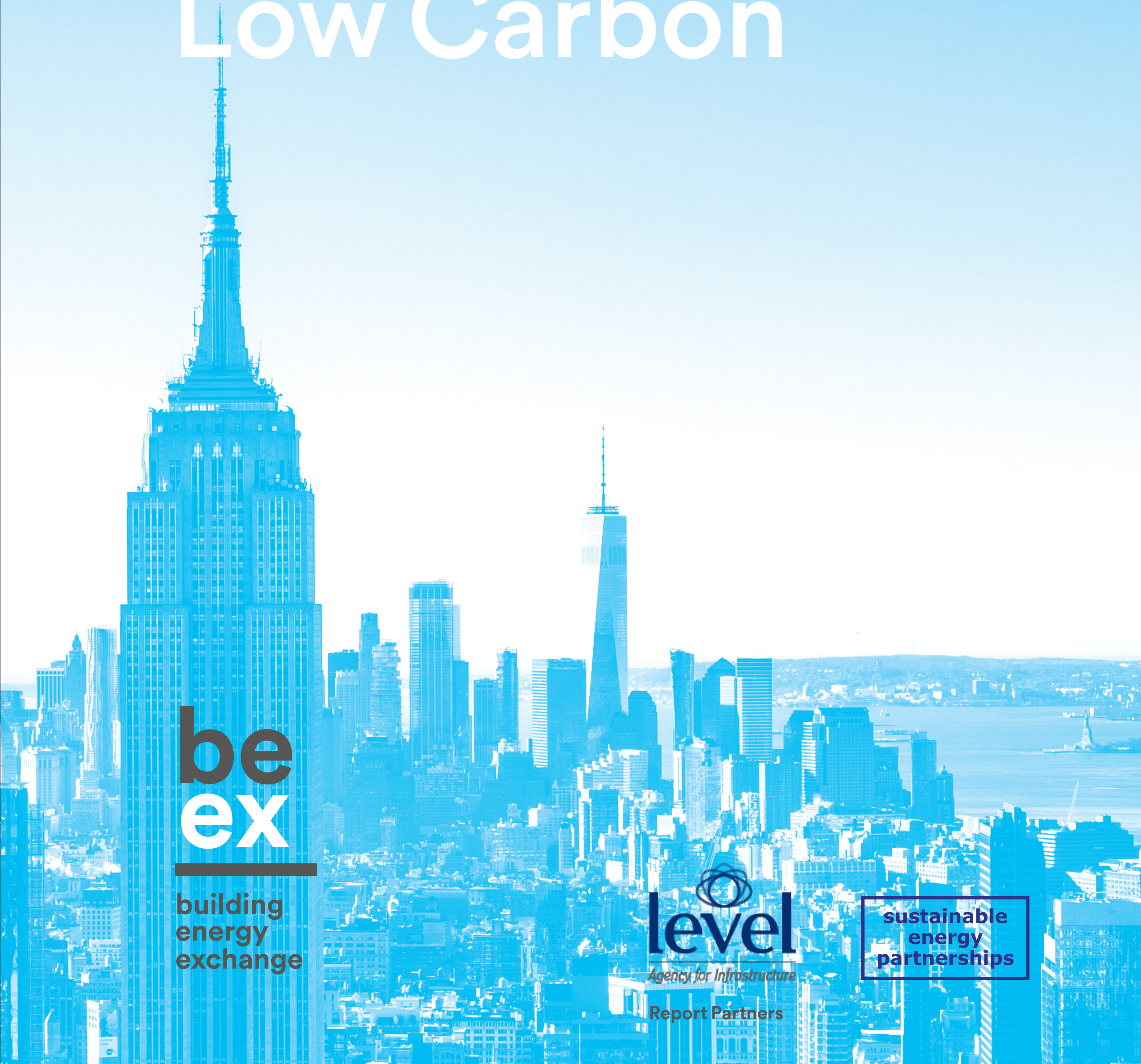
report

Office Deep Retrofit Profiles

High Rise / Low Carbon



be ex
building energy exchange

level
Agency for Infrastructure

sustainable energy partnerships

Report Partners


1. United Nations Headquarters
2. Byron Rogers Federal Building
3. 1177 West Hastings Street
4. Kyoto Station Mixed Use
5. 560 Lexington Avenue
6. Five Manhattan West
7. NEC Headquarters
8. District Center
9. Millennium Building
10. Empire State Building
11. 222 South Riverside Plaza
12. One Battery Park Plaza
13. 125 Maiden Lane
14. 1001 Pennsylvania Avenue
15. Sun Life Assurance
16. 801 Grand
17. TfL Palestra Building
18. 330 West 34th Street

contents

executive summary

New York's iconic skyline is dominated by commercial high-rise office buildings. One of the engines of its economy and the home to many of the world's leading corporate headquarters, these buildings are a foundational part of New York City's identity.

These same skyscrapers also have a fundamental role in achieving our City and State's climate action goals. This survey provides a diverse set of relevant deep energy retrofit case studies, from around the globe, which demonstrate how high-rise office buildings can achieve low carbon emission targets.

With the passage of the Climate Mobilization Act's (CMA) Local Law 97 (LL97), in April, 2019, the City's groundbreaking legislation to curb carbon emissions, many questions have arisen about the ability to transform New York's existing skyline into high performing buildings with dramatically lower carbon emissions — especially our high-rise office buildings. This research team conducted a global search for deep energy retrofits of high-rise office buildings that achieved LL97's aggressive carbon emission limits, and asked, what can we learn from them? The compendium explores key questions, including: what energy savings are achievable; what buildings systems were upgraded; what technology was deployed; what were the obstacles and opportunities; what factors motivated the project; and what are the key lessons learned?

This study's benchmark was to find deep retrofit projects of existing high-rise office buildings that resulted in annual operational carbon emissions at or below the LL97's 2030 carbon caps.[0]
To provide the most relevant examples, the authors chose to limit the examples to projects in a climate

Key Findings

- **Major building-wide renovation projects provide an effective vehicle for deep energy savings**
  Energy efficiency can be a strategic addition to major renovation projects, providing for some of the deepest savings while also significantly contributing to the overall property value creation.
- **Tenant spaces present strategic and essential savings opportunities**
  Tenant vacancy, turnover, or repositioning tends to be a time of reinvestment, and substantial energy savings can be found in addressing tenant spaces — a key component of a carbon mitigation plan.
  Tenant in place energy efficiency retrofits can be challenging, but highly effective.
- **Planning and analysis are foundational to a cost-effective deep retrofit**
  A comprehensive design and planning process is a necessary component of creating an effective deep retrofit that achieves predicted results at effective costs.
- **Only measured performance confers successful retrofit savings**
  Measured performance is hard to find, but vitally important to verify results: 'If you don't measure it, you can't manage it and you can't fix it.'
- **Changing context: The look forward may be different than the look back**
  Carbon will become a new performance metric, influencing ROI economics, technology choices, and retrofit project motivations, costs and benefits.

zone similar to New York, and, most importantly, only to include projects that had measured and verifiable pre- and post-retrofit energy data. This last requirement often proved the most challenging.

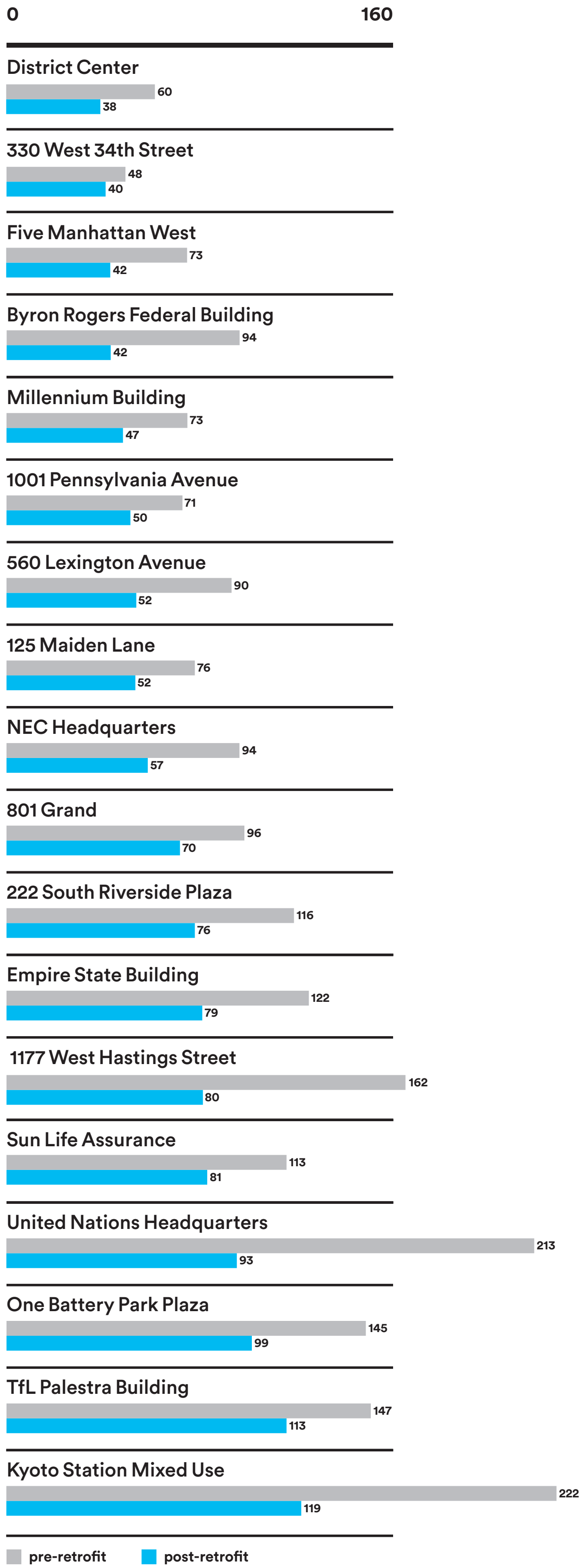
Nonetheless, this survey profiles eighteen projects that undertook a deep retrofit that resulted in often dramatic energy reduction. A complete facade reclad, a Midtown tenant repositioning, a Chicago upgrade and densification, a midwestern energy model calibration, a Japanese climate policy demonstration project, the comprehensive repositioning of NYC's most iconic tower, and many more, this diverse set of retrofit projects was able to achieve an average of a 36% reduction in their site energy intensity, with several projects cutting their energy use in half. Additionally, it is worth noting that all these projects occurred prior to, and, therefore, in the absence of, the recent aggressive climate legislation, demonstrating that low carbon high-rise office retrofits are, indeed, possible.

These profiles represent a variety of building sizes, typologies, ages, and ownership structures. Some projects were complete 'gut renovations' of empty buildings, others were incremental upgrades while the building's tenants remained in place. As detailed in the report's Technical Solutions Matrix, almost all the projects included energy efficiency upgrades to their lighting systems and controls, both favored and cost effective retrofit savings opportunities; and

Site EUI [kBtu/sf]

Post-Retrofit EUI Low to High

The bar graphs below show pre- and post-retrofit metered Site EUI for each building, ordered by lowest to highest post-retrofit Site EUI.



most found significant carbon reductions from recommissioning, upgrading, or completely replacing their cooling systems. Each retrofit had various motivating factors, summarized in the Key Results section, including complete repositioning of the property, to strategic upgrades when a tenant turned over, or at the end of life of a major piece of equipment or building system. Whether driven by a corporate Environmental, Social, and Governance (ESG) commitment, reduced operating costs, or to attract new tenants with increased comfort and quality, all the projects included a planned, intentional, and tactical deployment of energy efficiency, suffused throughout the project.

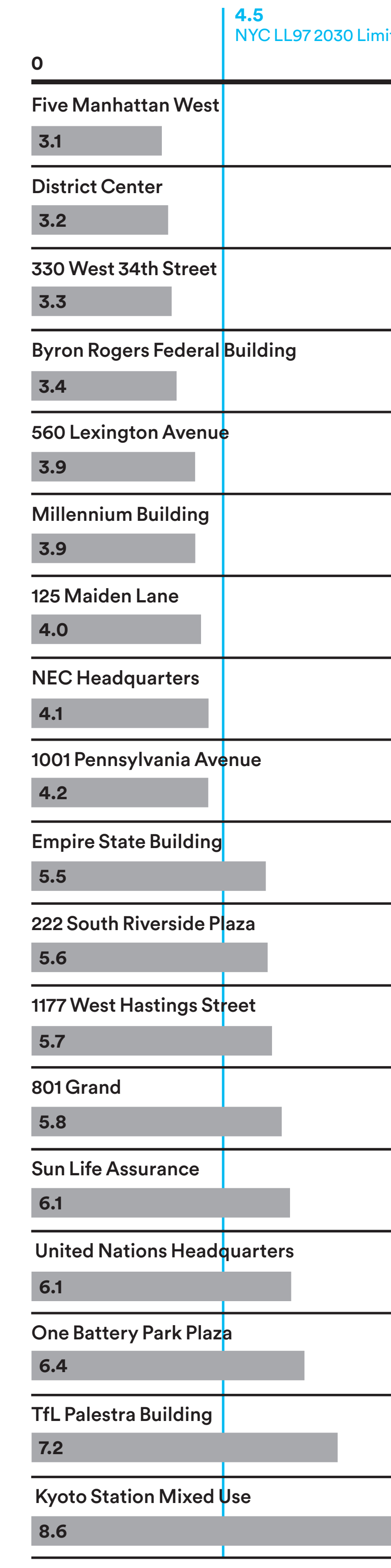
As the urgency of the global climate crisis mounts, many jurisdictions are looking to New York City's LL97 and New York State's Climate Leadership and Community Preservation Act for precedent. These aggressive laws steer a pathway to a carbon neutral economy and building sector by mid-century, and it is imperative that they succeed. This survey provides several glimmers, clues, and concrete models as to how New York's commercial high-rise office buildings can appreciably contribute to achieving these essential climate goals.

0 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.

Post-Retrofit GHGI [kg CO_2/sf]

(using NYC LL97 factors) Low to High

The bar graphs below show post-retrofit GHGI, ordered from lowest to highest.



key findings

Major building-wide renovation projects provide an effective vehicle for deep energy savings

Energy efficiency can be a strategic addition to major renovation projects, providing for some of the deepest savings while also significantly contributing to the overall property value creation.

- The deepest savings found were in retrofits that were aligned with planned major capital investments, such as the replacement of primary system equipment at the end of useful life, or holistic building renovations.
- Owners reported that the energy efficiency improvements positively impacted prospective tenants' perception of a building's quality, thus significantly contributing to attracting desirable tenants.
- Projects did not separate the costs (and overheads) for necessary capital investments versus energy efficiency measures (Byron Rogers, Five Manhattan West, Empire State Building).
- A few case studies did set aside an incremental budget for 'beyond compliance' measures, where benefits outweigh costs.
- There is potential for façade replacement, during full renovation and repositioning, that makes financial sense.

Tenant spaces present strategic and essential savings opportunities

Tenant vacancy, turnover, or repositioning tends to be a time of reinvestment, and substantial energy savings can be found in addressing tenant spaces — a key component of a carbon mitigation plan.

- Tenant equipment and behavior drives many building energy consuming systems
  - Lighting retrofits were present in nearly every case study and are more often selected and controlled by tenants
  - After-hour demands for HVAC systems
  - Occupant density
  - Cloud computing vs. on-site data centers
  - Computers, appliances, other plug loads 'unregulated' by energy code, but can be significant contributors to EUI and GHGI
- That said, the timing of this research occurred during the COVID-19 pandemic and many owners reported large office buildings without a significant drop in energy use despite being mostly unoccupied. This observation needs further study and has not yet been fully researched.
- Lease covenants, though, can reduce some tenant energy savings potential as some leases require HVAC schedules, temperature setpoints, fresh air delivery, and other factors that dictate energy consumption, regardless of actual use or occupancy.

Tenant-in-place energy efficiency retrofits can be challenging, but highly effective.

- If tenants remain in place during an energy retrofit and the building must continue to function, then energy savings opportunities are limited and significantly more challenging, yet still possible, as seen in Sun Life Assurance, 125 Maiden Lane, and 222 South Riverside.
- By installing and monitoring real-time energy management systems (EMS), building engineers were able to identify patterns of inefficiencies and operational stray in their building systems. Continual tweaking of these systems, with the help of constant feedback from EMS, over time, resulted in appreciable energy savings at the Millennium Building, TfL Palestra, and 1001 Pennsylvania.

Planning and analysis are foundational to a cost-effective deep retrofit

A comprehensive design and planning process is a necessary component of creating an effective deep retrofit that achieves predicted results at effective costs.

The design process for most deep energy retrofits in this compendium included energy modelling, multiple rounds of cost-benefit analysis, coordination with contractors, and tenant engagement that took longer and cost more than a simple, code compliant, business-as-usual design approach.

- Owners and designers of deep energy retrofits continually impressed the importance of setting out adequate time and budget for the design team to study options and design creative, yet practical, solutions.
- Retrofit projects where tenants remain in their spaces have the advantage of utilizing existing monthly energy consumption data, interval data, peak demand data, or other uniquely useful information to aid retrofit design optimization, such as calibrating energy models, right-sizing equipment, and much more (801 Grand, Kyoto Station, 222 South Riverside)
- Importance of maintenance and follow through — retro-commissioning, and continuous system optimization after ECM implementation.

Only measured performance confers successful retrofit savings

Measured performance is hard to find, but vitally important to verify results: 'If you don't measure it, you can't manage it and you can't fix it.'

Although there are 18 buildings in this compendium that range in location, height, technical solutions, occupancy type, implementation approach, EUI, GHGI, and other factors, the search went far and wide to identify even this many case studies of high-rise office buildings with metered energy data both before and after a retrofit that resulted in more than 25% energy savings.

- Benchmarking laws (including public disclosure) are critical to understanding actual post-retrofit performance
- Despite many press announcements and articles for tall building retrofits projecting deep savings, it was hard to verify actual savings after implementation
- There are likely more effective deep retrofit projects in Europe, however whole-building energy data was hard to find due to a variety of factors including limited collection of tenant energy use by owners, privacy laws and norms, and other factors
- Plenty of low rise (4-8 stories) examples in more mild climates with low EUI, low GHGI, publicly available metered data, and deep savings over 25%. A compendium of this typology could be large and wide-ranging
- Measured performance will be required for owners and operations to understand the potential impacts of LL97, and proactively avoid potential penalties.

Changing context: The look forward may be different than the look back

Carbon will become a new performance metric, influencing ROI economics, technology choices, and retrofit project motivations, costs and benefits.

These profiles are all retrofits with lessons learned looking backward. The projects represent technologies, motivations, and market conditions of the last 10 years, while the drivers for change will certainly be different in the upcoming 10 years and beyond. This new context means:

- New regulatory compliance requirements, and the potential impact of monetary fines, could significantly influence behavior, project scopes and even a project's return on investment (ROI).
- The future carbon intensity of the electric grid will influence the choice of building systems, technologies, and source energy.
- The demand for office space in the post-COVID world could shift occupancies, density, and tenant requirements; and pandemic mitigation measures are already influencing major building system modifications, including ventilation, as well as spatial requirements.
- A successful carbon trading option could impact a project's ROI, as well as introduce new incentives for exemplary efficiency projects.
- Other unforeseen changes will continue to change the decision making process of owners and tenants of office buildings.

introduction and background

Mitigating climate change is a priority for New York State, and a tremendous amount of effort is being made to this end right now, through a variety of policies and programs, especially in the building sector.

The State's Reforming the Energy Vision (REV) comprehensive energy strategy helps consumers make more informed energy choices, develops new energy products and services, and protects the environment while creating new jobs and economic opportunity throughout the State. The 2019 Climate Leadership and Community Protection Act (Climate Act, or CLCPA) establishes targets of a 100% renewable electric grid by 2040, a 40% state-wide greenhouse gas (GHG) emissions reduction by 2030, and an 85% state-wide GHG emissions reduction by 2050. The RetrofitNY program was established to mobilize the building industry to innovate and implement energy savings projects. NYSERDA is developing a Carbon Neutral Buildings Roadmap that supports increasing building energy efficiency, decarbonizing onsite energy services, utilizing clean energy from a variety of sources, and supporting real-time response to grid conditions. Finally, the Empire Building Challenge launched in 2020 will demonstrate scalable and replicable low carbon retrofit approaches for high-rise commercial and multifamily buildings across the state.

As the state's and the nation's largest municipality, New York City is also taking bold steps to mitigate climate change and reduce building-sourced GHG emissions. The City's 2009 Greener Greater Buildings Plan (GGBP) included Local Law 84 and Local Law 87, which required 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, increasing every few years. And, Local Law 97, of 2019 , the cornerstone of the 2019 Climate Mobilization Act (CMA), sets GHG Intensity (kg CO_2/sf) limits for buildings with non-trivial penalties for non-compliance. The first compliance period of LL97 is from 2024-2029, and the second compliance period is from 2030-2034. Many owners are currently weighing the cost of retrofits versus the cost of penalties, and the technical viability of achieving the mandated deep energy retrofits in LL97 is a concern to many building owners and tenants.

New York City's 2009 Greener Greater Buildings Plan points out that the city's built square footage is highly concentrated in less than two percent of its properties — 15,000 properties over 50,000 square feet, which account for almost half of NYC's built square footage — and that 48% of New York City's total energy use comes from these properties. In order to meet the climate mitigation goals of the State and City, building owners will need to reduce their energy use and carbon emissions, especially high-rise building owners. However, while it has been widely demonstrated that it is possible to achieve very low-emission and even no net-emission, smaller buildings, in high-rise buildings, particularly in regions like that of New York, with cold winters and high heating demand, there is less experience and knowledge of achieving very low-emission large buildings.

A fair question is raised then, which is, just how feasible are deep energy retrofits of large commercial buildings? There is skepticism as to whether, specifically, the level of Greenhouse Gas Intensity (GHGI) reductions mandated by LL97 can feasibly be achieved for all buildings which are currently over the limits. High-rise commercial buildings have unique physical and economic constraints, and most existing tall, commercial buildings are currently well over the LL97 GHGI limit set for 2030. There are many well-known case studies showing the projected energy-use savings of high-rise buildings — for instance, case studies of projected savings for the Empire State Building, the UN Secretariat Building, and the Deutsche Bank Headquarters towers in Frankfurt, Germany — but even the industry casts doubt on the accuracy of modeled energy use predication — see *The World's Greenest Buildings: Promise Versus Performance in Sustainable Design* by Yudelson and Meyer, and Sidewalk Lab's *Energy Use and the Performance Gap* report.

It was somewhat discouraging to learn how difficult it was to find post-retrofit energy (or carbon) performance on high-rise building retrofits. There have been many announcements about deep retrofit projects, but we were disappointed to learn that very few of these had measured performance data publicly available to be included in this compendium.

Despite significant outreach to a variety of experts around the world, we found that the most reliable post-retrofit, whole-building energy data came from U.S. cities with mandatory building energy benchmarking with public disclosure. 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 issue is privacy; with stricter privacy protections in Europe, owners often do not have access to tenant energy consumption.

This report aims to provide a compendium that documents the proven capability of the market to deliver energy and carbon savings via high-rise commercial building retrofits. We document 18 case studies of deep energy retrofits of high-rise office buildings with metered pre- and post-retrofit energy data, presenting common technical solutions among these building retrofits.

summary list of building profiles

	Building	Location	# of Stories	Floor Area (sf)	Occupancy Type	Year(s) Renovated	Retrofit Approach	Site EUI (kBtu/sf) pre-retrofit	Site EUI (kBtu/sf) post-retrofit	Site EUI (kBtu/sf) % reduction	GHGI using NYC LL97 factors [kg CO_2/sf]
1.	United Nations Headquarters	New York, NY	39	805,000	Owner-occupied	2008 – 2015	Repositioning	213	93	56%	6.1
2.	Byron Rogers Federal Building	Denver, CO	18	494,000	Owner-occupied	2012 – 2014	Repositioning	94	42	55%	3.4
3.	1177 West Hastings Street	Vancouver, BC	26	307,000	Multi-tenant	2007 – present	Tenant Turnover, Incremental	162	80	50%	5.7
4.	Kyoto Station Mixed Use	Kyoto, Japan	15	2,520,000	Multi-tenant	2016	Energy Only Retrofit	222	119	46%	8.6
5.	560 Lexington Avenue	New York, NY	23	329,000	Multi-tenant	2010 – present	Incremental Improvements	90	52	45%	3.9
6.	Five Manhattan West	New York, NY	15	1,700,000	Multi-tenant	2015 – 2017	Repositioning	73	42	42%	3.1
7.	NEC Headquarters	Tokyo, Japan	43	1,560,000	Owner-occupied	2010 – present	Incremental Improvements	94	57	40%	4.1
8.	District Center	Washington, DC	12	908,000	Multi-tenant	2017 – 2018	Repositioning	60	38	36%	3.2
9.	Millennium Building	Washington, DC	12	240,000	Multi-tenant	2012 – present	Incremental Improvements	73	47	36%	3.9
10.	Empire State Building	New York, NY	102	2,850,000	Multi-tenant	2010 – present	Repositioning, Tenant Turnover	122	79	35%	5.5
11.	222 South Riverside Plaza	Chicago, IL	35	1,237,000	Multi-tenant	2012 and 2015 – 2018	Repositioning	116	76	35%	5.6
12.	One Battery Park Plaza	New York, NY	35	860,000	Multi-tenant	2010 – present	Incremental Improvements	145	99	33%	6.4
13.	125 Maiden Lane	New York, NY	17	316,000	Multi-tenant	2011 – 2014	Energy Only Retrofit	76	52	31%	4.0
14.	1001 Pennsylvania Avenue	Washington, DC	14	836,000	Multi-tenant	2010 – present	Energy Only, Incremental	71	50	29%	4.2
15.	Sun Life Assurance	Chicago, IL	10	140,000	Multi-tenant	2010 – 2012	Major Tenant Turnover	113	81	28%	6.1
16.	801 Grand	Des Moines, IA	44	920,000	50% Owner 50% Tenant	2013 – 2016	Major Tenant Turnover	96	70	27%	5.8
17.	TfL Palestra Building	London, UK	12	404,000	Single-tenant	2010 – present	Tenant Turnover, Incremental	147	113	23%	7.2
18.	330 West 34th Street	New York, NY	18	720,000	Multi-tenant	2016	Repositioning, Tenant Turnover	48	40	17%	3.3

1.
United Nations Headquarters

Retrofit Approach

- Repositioning
- Major tenant turnover
- Energy-only retrofit
- Incremental improvements

Retrofit Motivation

- ESG commitments
- Energy cost savings
- Property value enhancement
- Compliance or penalty avoidance

Key Figures

Pre-Retrofit Site EUI	213 kBtu/sf
Post-Retrofit Site EUI	93 kBtu/sf
% Energy Reduction	56%
Post-Retrofit GHGI (using NYC LL97 factors)	6.1 kg CO_2/sf

Location
New York, New York

Owner
United Nations

Floor Area
805,000 sf

Number of stories
39

Year built
1952

Year renovated
2008 – 2015

Occupancy
Owner-occupied

Retrofit Background

After being considered for more than a decade, in 2006, work began on the Capital Master Plan (CMP) of the United Nations Headquarters campus in NYC. Originally, five buildings were to be renovated — the Secretariat Building, the General Assembly, the Hammarskjold Library, the South Annex Building, and the Conference Building — but after a few years of progress, due to schedule and cost overruns, the South Annex Building and the Hammarskjold Library were removed from the scope of the CMP.

The Secretariat Building is the subject of this profile. Thirty-nine stories tall, with a long, narrow footprint, it was one of the first buildings of its kind to have an all-glass façade. The building is historically significant, and an architectural treasure, so its preservation was imperative during the design of the CMP renovation effort.

Description of Retrofit

The renovation of the Secretariat building was extensive. As one of the only buildings in the world where multiple heads of state regularly meet, security upgrades, including blast-resistant doors and perimeters were installed. Major meeting spaces were upgraded, and significant telecommunications capabilities introduced. During construction, Superstorm Sandy hit New York, and, as a result, critical building infrastructure received waterproofing, hardening, or was raised in elevation.

The single-most famous aspect of the renovation work on the Secretariat building was the façade reclad. Significant technical thought went into the selection and design of the new windows, which contributed to the renovated Secretariat building's LEED Platinum award.

Metered Energy Savings and Other Benefits

This project team utilized Equest for energy modeling, calibrated against energy bills. "The energy model was used extensively throughout the project as a decision-making tool. This included comparing façade options and chiller plant options and the impacts of active blind; and then reviewing the interaction of these systems together on the campus. The energy model became an invaluable decision-making tool to provide data on the impact of each of these decisions on the performance of the campus." [1.1]

Also, energy use field meters were installed and are monitored on a monthly basis and prepared in a monthly measurement & verification (M&V) report. This report is used to further calibrate the energy model.

Economic Considerations

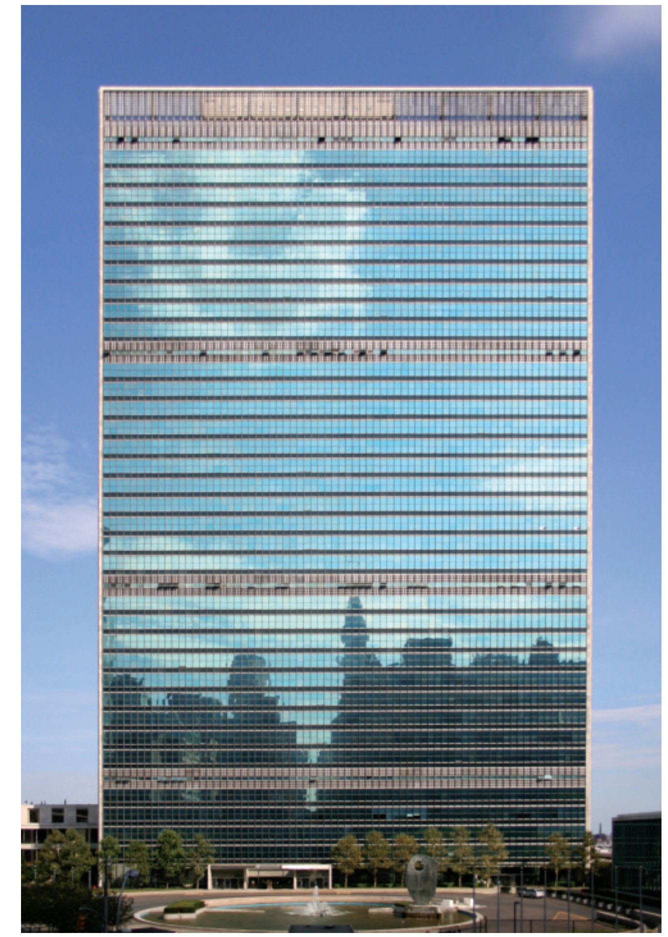
By 2006, this major renovation was sorely needed. The UN HQ campus, completed in the 1950's, was well out of code compliance, was considered a health risk to staff and visitors, had many inefficiencies, and needed to be brought up to modern security standards.

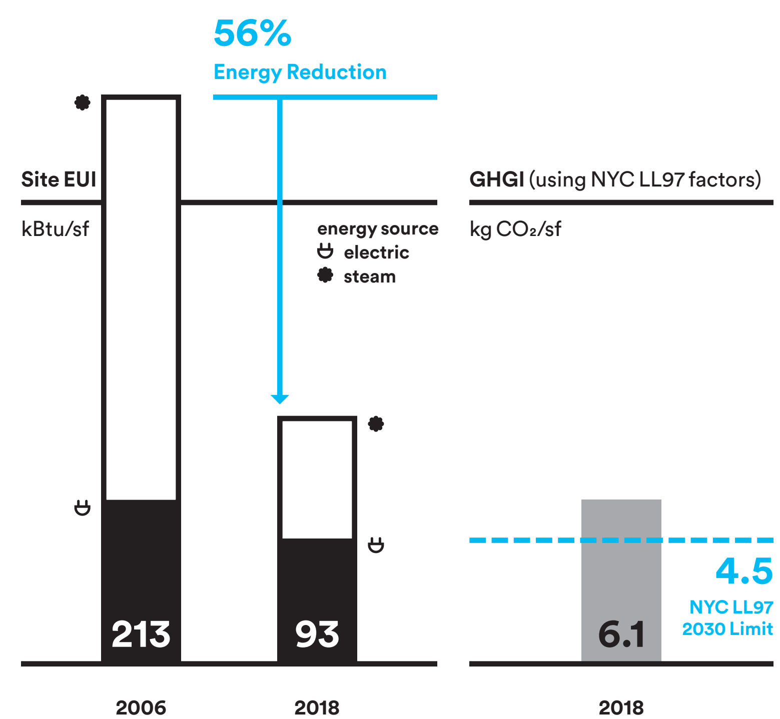
Additionally, as a leading body in the fight against climate change, the UN wanted to demonstrate its commitment to reducing greenhouse gas emissions by ensuring that its headquarters be as environmentally sustainable as possible.

Key Lessons Learned

The Secretariat Building's heating and hot water were both provided by steam, and a majority of realized energy savings came from a reduction in steam demand. Facade reclads, when properly done, can result in significant heating demand reductions.

Supporting the UN's climate goals, the United Nations Secretariat building undertook multiple capital ECM projects, including major facade work — a curtain wall reclad.





Energy Conservation Measures Overview

lighting
- Mixture of LED, fluorescent, and halogen lights
- Daylight controls
- Active blinds
- Occupancy-based controls

cooling
- Pipes for river water heat rejection upgraded
- River water intake pipes upgraded
- Chiller plant reconfiguration

heating

ventilation
- Demand ventilation
- Displacement ventilation
- Air distribution upgrades (overhead, hybrid overhead, perimeter fan coil, and chilled beam)

envelope
- Original glazed curtain wall, double-hung windows replaced with high performing, super-insulating windows

plug loads

hot water

other
- New BMS

2. Byron Rogers Federal Office Building

Retrofit Approach

- Repositioning
- Major tenant turnover
- Energy-only retrofit
- Incremental improvements

Retrofit Motivation

- ESG commitments
- Energy cost savings
- Property value enhancement
- Compliance or penalty avoidance

Key Figures

Pre-Retrofit Site EUI	94 kBtu/sf
Post-Retrofit Site EUI	42 kBtu/sf
% Energy Reduction	55%
Post-Retrofit GHGI (using NYC LL97 factors)	3.4 kg CO_2/sf

Location
Denver, Colorado

Owner
GSA

Floor area
494,000 sf

Number of stories
18

Year built
1965

Year renovated
2012 – 2014

Occupancy
Owner-occupied

Retrofit Background

The Byron Rogers Federal Office Building was a well-used 1950's high-rise office building serving 10 different federal agencies in Denver, Colorado, when this retrofit project began. There were four main drivers for the project, the first three of which were: a modernization of the office spaces and lobby, removal of asbestos fire-proofing, and seismic and Anti-terrorism Force Protection (ATFP) upgrades. The fourth goal of the project, afforded by the American Recovery & Reinvestment Act of 2009, was to achieve deep energy-use reductions well beyond GSA's standards, with the idea that the energy retrofit would be used as a test case and an example for other buildings in the GSA portfolio. Indeed, the building was featured as a prominent case study in the GSA's Green Proving Ground (GPG) program, "which leverages GSA's real estate portfolio to test innovative building technologies and to accelerate the transition between bench-scale technology and commercial viability." [2.1]

Description of Retrofit

The Byron Rogers Federal Office Building underwent a full gut renovation. Besides retaining the historic exterior features, the building interior was stripped to structural elements, which were then given seismic and ATFP upgrades. Core and shell upgrades took about two years, and tenant space fit-out for over a dozen different federal agencies took another year. Energy conservation measures were embedded throughout the building. Particularly notable was the heating and cooling system installed with the retrofit. "After capturing heat generated in the building by occupants, computers, lighting and solar gain during the day, this heat was stored in a 50,000-gallon thermal storage tank and recovered using a hybrid magnetic bearing heat-recovery chiller acting as a heat pump to utilize stored heat through the building's chilled beam system as needed. The tank was sized to accommodate the heating needs of the entire building overnight and on weekends by only operating pumps and the heat-recovery chiller to avoid operating fossil-fuel-consuming boilers during unoccupied hours." [2.1]

Metered Energy Savings and Other Benefits

In 2018, public disclosures indicate that the Byron Rogers Federal Office Building and the adjacent federal courthouse which had only window replacements (and shares a boiler and chiller plant) had an aggregate EUI of 42 kBtu/sf. With models suggesting that the building's energy fuel-mix is 10% natural gas and 90% electric, the post-retrofit GHGI for the building equals 3.4 kg CO_2/sf.

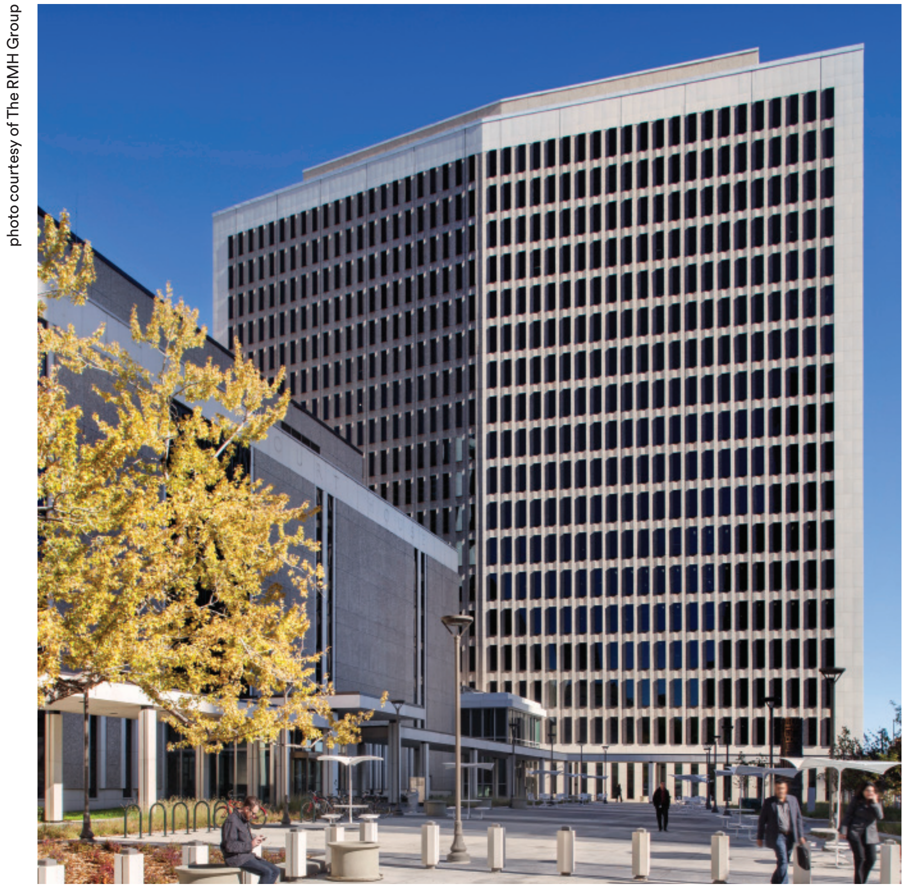
Economic Considerations

The full renovation cost $159 million in total, ($322/sf) which included all fit-out, structural, façade, HVAC, controls, lighting, and solar PV components.

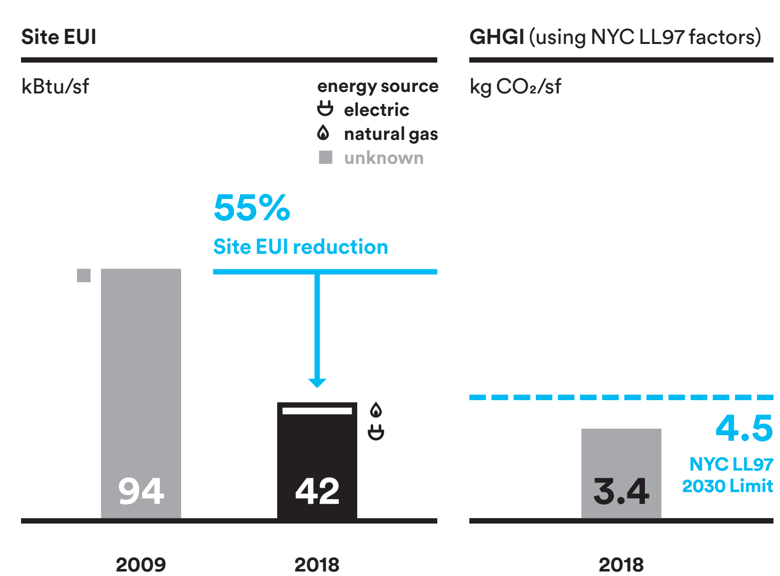
Key Lessons Learned

A full gut-renovation offers energy performance improvements beyond an energy retrofit of an occupied building. Facades, chiller plants, boilers, lighting, and controls that are 30-50 years old and at the end of their useful life will always be replaced by more efficient, higher quality modern equipment. An incremental budget set aside for ECMs beyond code compliance can take a gut renovation into the deepest retrofit savings case studies we saw in the research.

photo courtesy of The RMH Group



An 18-story 1950's office building in Denver took the opportunity of a full gut-renovation to find the deepest energy savings we found in the study (55%) and nearly eliminated the need for natural gas as the heating source.



Energy Conservation Measures Overview

lighting
- Natural daylighting
- Continuous dimming high-efficiency LED lighting
- Occupancy sensors
- Task lighting

cooling
- Air and waterside economizers
- Chilled beams
- High-efficiency magnetic bearing chiller

heating
- High-efficiency condensing boilers and thermal storage tank

ventilation
- Dedicated outside air system with heat recovery

envelope
- High-performance window replacement
- Super-insulated walls and roof with continuous air barrier

plug loads

hot water
- High-efficiency condensing boilers

other
- Power management
- Regenerative power elevators
- Solar Thermal Domestic Hot Water

3.
1177 West Hastings Street

Retrofit Approach

- Repositioning
- **Major tenant turnover**
- Energy-only retrofit
- **Incremental improvements**

Retrofit Motivation

- **ESG commitments**
- **Energy cost savings**
- Property value enhancement
- Compliance or penalty avoidance

Key Figures

Pre-Retrofit Site EUI	162 kBtu/sf
Post-Retrofit Site EUI	80 kBtu/sf
% Energy Reduction	50%
Post-Retrofit GHGI (using NYC LL97 factors)	5.7 kg CO_2/sf

Location
Vancouver, British Columbia

Owner
Golden Properties Ltd

Floor Area
307,000 sf

Number of stories
26

Year built
1968

Year renovated
2007 – present

Occupancy
Multi-tenant

Retrofit Background

1177 West Hastings Street is a 26-story, 300,000 square foot commercial office tower constructed in 1968 in Vancouver, British Columbia. Tenants are a broad mix, including insurance companies, several consulates, a ground floor bank, and a language school.

The main motivation cited for the implementation of ECM projects in this building was the ownership's commitment to reducing utility use and carbon emissions. Certification programs were used to certify work, starting with Energy Star, followed by the Canada Green Building Council's (CaGBC) Zero Carbon certification.

Description of Retrofit

More than 10 years ago the ownership team sought proposals from several engineers for building retrofit projects. Each discrete measure offered in these proposals was considered, and the ownership team created a composite master plan of retrofit measures to pursue. These measures — some large capital projects and others no- to low-cost — have been implemented incrementally since 2007. Continual adjustments and improvements, thanks to dedicated operators, have been cited as a reason for higher savings. In April 2020 for instance, the team commissioned a heat recovery plant that is expected to reduce natural gas consumption by at least 80% over the reported 2019 mid-retrofit numbers.

Major energy system upgrades occurred while tenants occupied the building. Work was therefore closely coordinated with tenants and a small construction footprint was maintained. Similarly, lighting upgrades throughout the building occurred on evenings and weekends. The ownership advises, though, that maintaining the project schedule while implementing projects in an occupied building is very challenging, and allowing for schedule flexibility is important when pursuing this approach. Nonetheless, when tenant turnover occurred, the opportunity to do full-floor tune-ups was taken.

Metered Energy Savings and Other Benefits

Generally, one project was implemented at a time, and changes in metered energy use were closely monitored to see the resultant savings of each project, and to better characterize the building. This allowed the team to optimize the design of future projects.

Economic Considerations

All projects pursued provided marginal cost savings; no projects were pursued that were not considered economically feasible. For instance, given the mild climate in Vancouver, an envelope retrofit was considered but deemed to be uneconomical. In aggregate, the projects implemented saw a 4.5-year payback period. Work was tied to incentives or financing opportunities whenever possible.

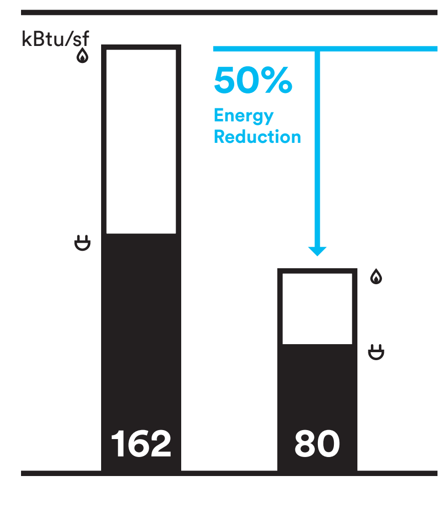
Key Lessons Learned

Deep dedication to energy efficiency is required to go beyond 10-15% savings and into deep savings beyond 30%. The dedication and commitment to results has to come from both the operating team and senior leadership. Set a goal of continuous improvement, and use each measure taken to better understand the building and optimize plans for larger capital projects. Analyzing building systems and scoping projects that are more complex — perhaps, integrating multiple systems — requires more effort than finding low hanging fruit. Furthermore, if carbon reductions are sought, simply focusing on energy conservation will not suffice as more consideration must be given to fuel sources and the mix of electricity compared to fossil fuels.

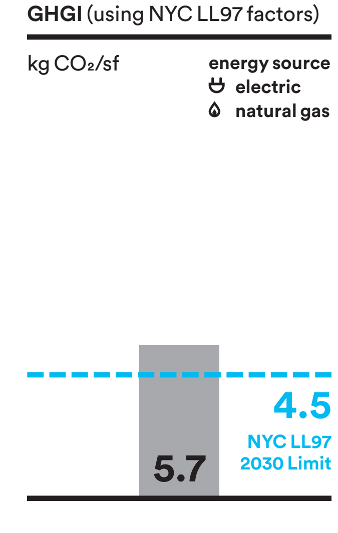
photo courtesy of Golden Properties Ltd

With owners committed to achieving a low-carbon building, this project strategically designed and implemented both large capital projects and no- to low-cost measures.

Site EUI



GHGI (using NYC LL97 factors)



Energy Conservation Measures Overview

lighting
- SMART lighting controls and custom LED fixtures with 94 CRI
- Reduced lighting schedules
- Sensors for occupancy, daylight, temperature, humidity, pressure

cooling
- VRF system in select areas
- Cooling plant modernization (VFD's on all pumps, new cooling tower, chillers and new controls)
- Reduced schedules and setpoints

heating
- Heat recovery plant utilizing waste heat via chiller heat mode
- VFDs on AHU and lower temperature heating coils

ventilation
- New dampers and controls for air economizers on all AHUs

envelope
- Façade air tightness caulking for the entire tower
- Additional insulation on roof and below grade level

plug loads
- Majority of tenant servers moved to the cloud
- Green Leadership team focus on Energy Star appliances

hot water
- Domestic hot water electrification

other
- New BMS and controls
- Regenerative drive elevators
- Submetering of electrical loads
- Mobile app integration w/ temp., occupancy, and humidity sensors

4. Kyoto Station Mixed Use

Retrofit Approach

- Repositioning
- Major tenant turnover
- **Energy-only retrofit**
- Incremental improvements

Retrofit Motivation

- **ESG commitments**
- **Energy cost savings**
- Property value enhancement
- Compliance or penalty avoidance

Key Figures

Pre-Retrofit Site EUI	222 kBtu/sf
Post-Retrofit Site EUI	119 kBtu/sf
% Energy Reduction	46%
Post-Retrofit GHGI (using NYC LL97 factors)	8.6 kg CO_2/sf

Location
Kyoto, Japan

Owner
Kyoto Station Building Development Company

Floor Area
2,520,000 sf

Number of stories
15

Year built
1997

Year renovated
2016

Occupancy
Multi-tenant

Retrofit Background

The main train station in Kyoto, Japan, was completed in 1997 as a grand architectural design with a memorable 10-story open-air concourse above the boarding platforms of Japan's famous Shinkansen bullet trains. But as the main gateway to the city in which the Kyoto Protocol was signed, the building represented a major opportunity to showcase the potential for deep energy efficiency retrofits of existing buildings.

Description of Retrofit

The renovation of the Kyoto Station primarily focused on the thermal components of the building including the heating, cooling, ventilation, and hot water systems. Limited lighting, façade, appliances, and other systems were addressed in a previous retrofit. Since the building remained in operation during the retrofit and there were no major changes to tenants, operations, or schedules, the thermal loads and daily profiles were well understood prior to the renovation. This allowed for optimal system selection and sizing to be conducted and modeled, including variable speed turbo chillers with variable speed chilled water and condensing water pumps. To replace a gas-fired steam system, a heat recovery heat pump system was selected for optimal energy utilization during the shoulder months where simultaneous heating and cooling occur. An air source heat pump was selected to provide most of the heating load. Finally, a natural gas-fired cogeneration for electricity was selected for use during the summer months which is a key feature of peak electrical demand reduction. A small solar hot water collector (50kW) supplies hot water to the hotel.

A detailed energy simulation using ACSES software helped the design and commissioning team simulate various operational states for the complex heating and cooling system design. A Commissioning Management Team commenced the commissioning process in 2010 and continued to monitor, study, and optimize the controls and systems in the building for 10 years. Ultimately a 46% reduction in whole-building energy use was achieved over the course of the extended retrofit and commissioning process.

Metered Energy Savings and Other Benefits

Energy savings from the thermal system retrofit of Kyoto Station achieved over 46% savings from 2009 to 2018.

Economic Considerations

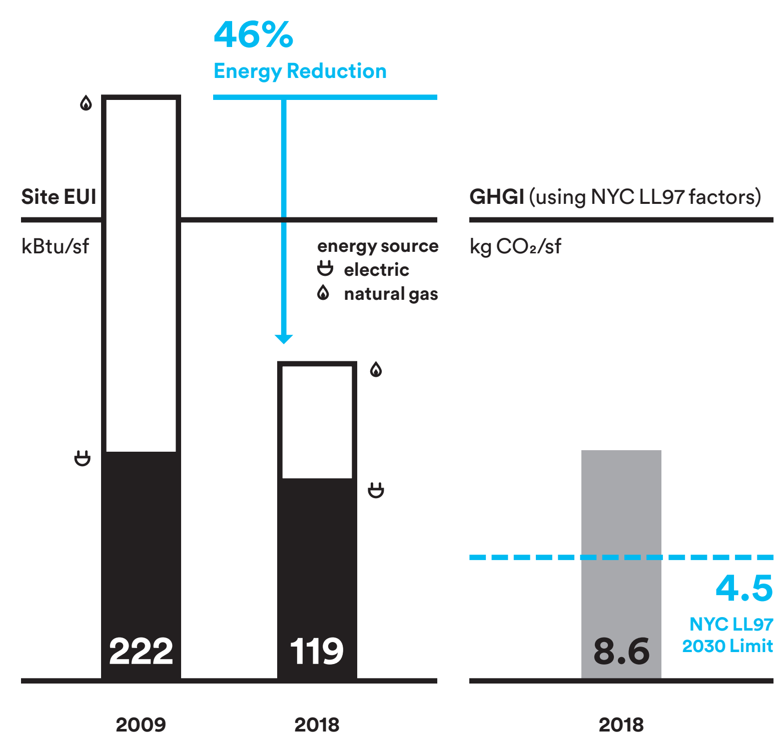
The incremental cost of the energy efficient design was $30.4M, in 2010 dollars, which resulted in a 5.7 year payback compared to operational and energy cost savings.

Key Lessons Learned

Large mixed-use buildings, because of their size and multiple uses, have the potential for highly customized and optimized heating and cooling systems. Particularly if an existing building does not change tenants or uses during the retrofit, the existing heating and cooling loads and profiles can be determined precisely, rather than estimated or calculated, which allows a lower design safety factor.

To demonstrate the potential of deep energy retrofits and the importance of reducing carbon emissions in the home of the Kyoto Protocol, this top energy consuming building underwent a dramatic deep energy retrofit and retro-commissioning.

photo courtesy of Harunori Yoshida



Energy Conservation Measures Overview

lighting
LED lighting in some areas

cooling
Upgrade to Turbo Chillers w/ VFD
Heat Recovery Heat Pump
Ground water based water source heat pump
VFD on condenser water

heating
Natural gas Cogen for HW
Air source heat pump

ventilation
Demand control ventilation

envelope

plug loads

hot water
Natural gas Cogen for hotel HW

other
50kW solar hot water for hotel HW
Cloud-based building energy management system (EMS)

5.

560 Lexington Avenue

Retrofit Approach

- Repositioning
- Major tenant turnover
- Energy-only retrofit
- **Incremental improvements**

Retrofit Motivation

- ESG commitments
- **Energy cost savings**
- Property value enhancement
- Compliance or penalty avoidance

Key Figures

Pre-Retrofit Site EUI	90 kBtu/sf
Post-Retrofit Site EUI	52 kBtu/sf
% Energy Reduction	45%
Post-Retrofit GHGI (using NYC LL97 factors)	3.9 kg CO_2/sf

Location
New York, New York

Owner
Rudin Management Company

Floor Area
329,000 sf

Number of stories
23

Year built
1980

Year renovated
2010 – present

Occupancy
Multi-tenant

Retrofit Background

560 Lexington Avenue is a Class A office building located in Midtown NYC. The building is 23 stories, a total 328,910 SF built in 1980 making the building 40 years old. The building has a central cooling and heating plant.

Description of Retrofit

Rudin Property Management has undertaken several energy conservation projects which include lighting up-grades, motor replacements, variable frequency drives (VFDs) installed on fans and pumps, new Andover BMS installation, and elevator modernization.

In 2013, 560 Lexington Avenue integrated all its critical core building systems into Di-BOSS, and later, Nantum, as the key to successful optimization.

Nantum integrated data from the building automation system (BAS), utility meters (electricity, gas, steam and water), and occupancy counts from the security turnstiles.

Additional temperature sensors were also deployed to provide increased visibility of the building's interior environments in various tenant spaces. Integrations into other siloed critical systems like elevator and fire alarm systems were implemented for additional insight into all building operations.

The strategies deployed through Nantum resulted in minimizing the energy consumption of the building without sacrificing comfort obligations. Sophisticated software algorithms would ingest the building's recent historical data and real-time data, marrying them with real-time weather data and weather forecasts, to predict building conditions and to deliver recommended actions for the building operators to streamline operations.

Metered Energy Savings and Other Benefits

Site EUI was decreased from 90 kBtu/sf to 52 kBtu/sf — a savings of 45%.

Economic Considerations

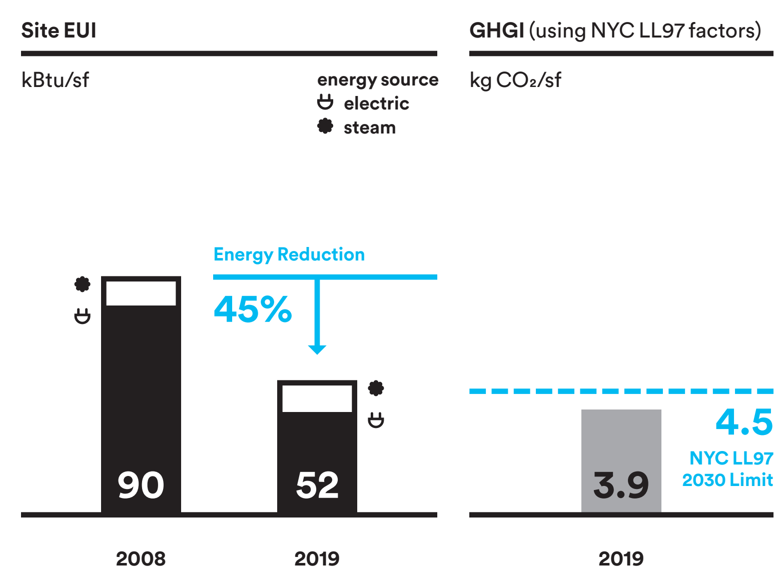
Because this project was completed while tenants occupied the building, there was no opportunity to completely renovate existing systems. As many no- to low-cost ECMs were implemented as possible, most importantly the Nantum BMS and revised setpoints and system schedules.

Key Lessons Learned

Even when tenants maintain occupancy, significant savings can be achieved over time, in this case over the course of a decade, thanks to no- to low-cost measures and the use of BMS data to perform continual optimizations. Lessons from successful ECMs were shared among building operators across similar office buildings in the Rudin portfolio. This peer network encouraged operators to try to come up with creative solutions and take deeper interest in the data provided by the Nantum BMS analysis.

photo courtesy of Rudin Management Company

Comparing energy use patterns across multiple properties in a portfolio allows building managers to share lessons learned and find benefits in healthy competition between buildings.



Energy Conservation Measures Overview

lighting
- Efficient lighting
- Dimming controls

cooling
- Replaced motors on fans, pumps, and cooling towers
- Installed VFDs

heating

ventilation

envelope

plug loads

hot water

other
- New BMS and automated controls for all mechanicals
- DiBoss/Nantum digital operating system
- Destination dispatch elevators

6. Five Manhattan West

Retrofit Approach

- Repositioning
- Major tenant turnover
- Energy-only retrofit
- Incremental improvements

Retrofit Motivation

- ESG commitments
- Energy cost savings
- Property value enhancement
- Compliance or penalty avoidance

Key Figures

Pre-Retrofit Site EUI	73 kBtu/sf
Post-Retrofit Site EUI	42 kBtu/sf
% Energy Reduction	42%
Post-Retrofit GHGI (using NYC LL97 factors)	3.1 kg CO_2/sf

Location
New York, New York

Owner
Brookfield Properties

Floor area
1,700,000 sf

Number of stories
15

Year built
1968

Year renovated
2015 – 2017

Occupancy
Multi-tenant

Retrofit Background

In 2011, Brookfield acquired this property with the strategy to give it a high-profile, wide-ranging retrofit. In 2017, Brookfield completed a comprehensive $350 million redevelopment program which included a recladding of the exterior curtain wall with insulated, low-iron, low-emissivity floor-to-ceiling glass, along with a full lobby renovation, elevator modernization and robust new infrastructure.

Description of Retrofit

The single-most notable ECM at this building was the façade reclad / new curtain wall with insulated, low-iron, low-emissivity floor-to-ceiling glass. However, all mechanical systems were replaced or refurbished as well, including the cooling tower. All equipment was fitted with variable frequency drives and hooked up to a new BMS. All new lighting was installed in public areas of the building, and all new tenant spaces resulted in new lighting throughout the entire building.

Power over Ethernet (PoE) lighting was installed in a few places, but there were two main challenges with this approach — first, generally engineers aren't very fluid with the technology, and second, laborers prefer not to do this low-voltage work.

Metered Energy Savings and Other Benefits

Over the course of the renovation and re-occupancy the building went from an EUI around 70 kBtu/sf to 42 kBtu/sf, a savings of 43% over the 3-4 year period.

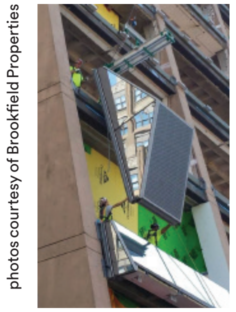
Economic Considerations

The overall renovation of the building was aimed at repositioning the property and energy efficiency was a subcomponent to the broad package of building modernization. Thus separating out the costs for energy efficiency was not a useful exercise. The façade reclad, a major cost of the renovation, was primarily done to provide better light and views for potential tenants, though it also offered improved comfort and energy savings. Other ECMs were packaged with the major HVAC system replacement and delivered much of the energy savings.

Key Lessons Learned

When thinking about a major repositioning project to create value in commercial real estate assets, energy efficiency should be part of the overall value proposition along with aesthetics, occupant comfort, controllability, health, and branding.

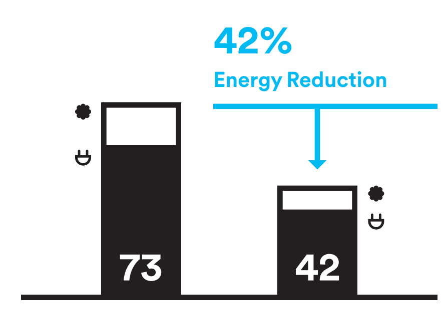
photos courtesy of Brookfield Properties



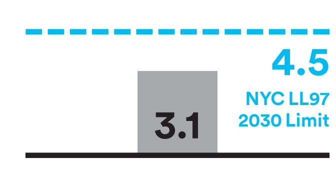

A complete facade reclad and mechanical system upgrades comprehensively repositioned this building creating enhanced property value, higher asset value, and substantial energy savings.

Site EUI
kBtu/sf

energy source
electric
steam



GHGI (using NYC LL97 factors)
kg CO_2/sf



Energy Conservation Measures Overview

lighting
All new code compliant lighting

cooling
Cooling tower replacement
New DX units throughout property

heating
Perimeter Fin Tube, Steam to Hot Water Exchangers & Fan Steam Coil

ventilation
Direct Exchange Package Unit

envelope
Facade complete recladding

plug loads

hot water
Local electric hot water heaters
Retail steam hot water heaters

other
BMS installed on majority of equipment
Regenerative Drives on Modernized Elevators

7. NEC Headquarters

Retrofit Approach

- Repositioning
- Major tenant turnover
- Energy-only retrofit
- **Incremental improvements**

Retrofit Motivation

- **ESG commitments**
- Energy cost savings
- Property value enhancement
- **Compliance or penalty avoidance**

Key Figures

Pre-Retrofit Site EUI	94 kBtu/sf
Post-Retrofit Site EUI	57 kBtu/sf
% Energy Reduction	40%
Post-Retrofit GHGI (using NYC LL97 factors)	4.1 kg CO_2/sf

Location
Tokyo, Japan

Owner
Sumitomo Mitsui Trust Bank, Limited

Floor Area
1,560,000 sf

Number of stories
43

Year built
1990

Year renovated
2010 – present

Occupancy
Owner occupied

Retrofit Background

NEC Super Tower in Shiba, Tokyo, was completed in 1990 and represented the state of the art in building technology, from earthquake resistant design, to the double skin facade, to the high efficiency central chiller and heating plant. But by 2010, when the Tokyo Carbon Cap and Trade program began and carbon reductions were required on rolling 5-year compliance periods, some of the building systems began to reach the 'end of useful life' and major capital improvement budgeting began.

A team of building operations and maintenance staff was assembled to plan a series of system upgrades and energy conservation measures that would achieve the carbon reductions required by the cap and trade system and modernize the building systems. Since the building remained under full occupancy, ECMs and equipment replacement have to be completed during off-seasons, or nights and weekends.

This series of retrofit projects was motivated by a combination of penalty avoidance, attributable to the Tokyo Carbon Cap and Trade Program, and ESG commitments, as NEC is a leading technology company and was seeking to enhance its brand.

Description of Retrofit

This project is an example of how a deep retrofit can be achieved over many years when a focus on energy efficiency is integrated into seasonal maintenance and capital projects planning. Chillers were replaced one at a time over multiple winter seasons to ensure continuous operation. Rather than replacing cooling towers and boilers with like-for-like replacements, higher performance equipment was specified, balancing additional cost with potential for energy savings.

One unique aspect of the retrofit was the research and development during the steam distribution piping insulation ECM. Disappointed by the steam pipe insulation products available on the market, NEC engineers developed a new insulation product with a hard outer cover and a variety of sizes and fittings. The product provided annual energy savings for the NEC Super Tower, and was then developed into a new product line of piping insulation sold by NEC.

As NEC business units evolve and office spaces and floors within the building are renovated to fit new work space needs, the overhead lighting is replaced with LED fixtures when the opportunity arises. So far 25% of floors have had a lighting retrofit. Stairwells and hallways have had LED lighting replacement with motion sensors.

Metered Energy Savings and Other Benefits

Energy and carbon savings at the NEC Super Tower have exceeded compliance requirements and have achieved over 40% savings over many years through an incremental retrofit approach.

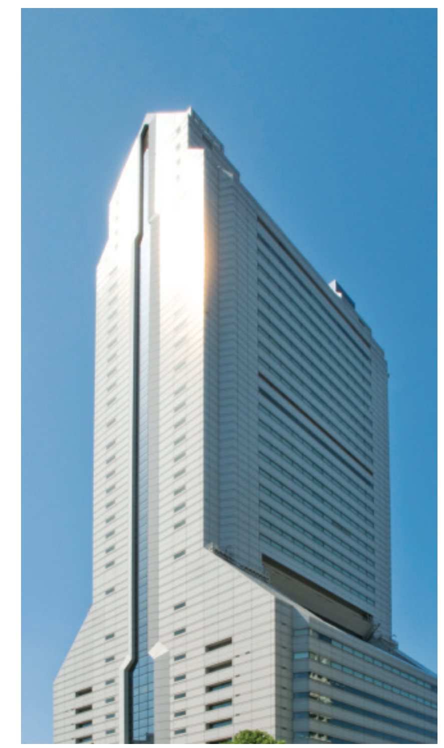
Economic Considerations

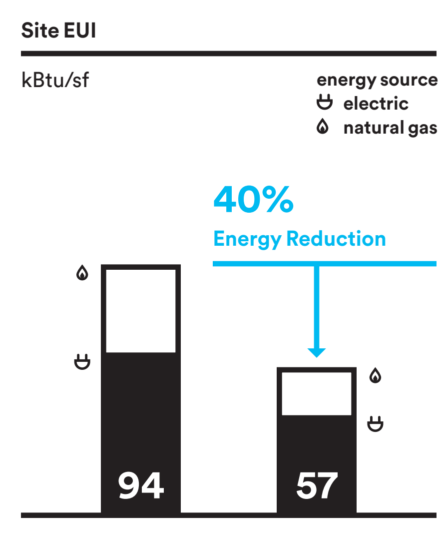
ECMs were funded through attributable savings in the annual maintenance and operations budget. There is not a separate budget for energy efficiency, rather it is integrated into regular capital expenditures and operational budget planning.

Key Lessons Learned

Deep energy reductions do not have to be a one-time major project, they can be a series of smaller projects implemented on an annual basis. Keeping a running list of potential ECMs and engaging the building maintenance and operations team on both designing and implementing the ECMs ensure buy-in from the very people who will operate and maintain the efficiency measures.

A clear example of 'Kaizen,' the Japanese concept of continual improvement, this building's maintenance team keeps a running list of potential ECMs, implementing a few energy efficiency projects every year, coincident with budget, equipment life cycles, and off-season maintenance.





Energy Conservation Measures Overview

lighting
- LED lighting in 25% of office floor area
- Occupancy sensors in stairwells
- Updated lighting schedules

cooling
- Chiller upgrade and replacement
- Cooling tower replacement
- High-efficiency cold water circulation pump

heating
- Boiler replacements with new high efficiency condensing boilers
- Steam pipe insulation

ventilation
- High-efficiency air intake and exhaust motor

envelope

plug loads

hot water

other
- High-efficiency transformer

8. District Center

Retrofit Approach

- **Repositioning**
- Major tenant turnover
- Energy-only retrofit
- Incremental improvements

Retrofit Motivation

- **ESG commitments**
- Energy cost savings
- **Property value enhancement**
- Compliance or penalty avoidance

Key Figures

Pre-Retrofit Site EUI	60 kBtu/sf
Post-Retrofit Site EUI	38 kBtu/sf
% Energy Reduction	36%
Post-Retrofit GHGI (using NYC LL97 factors)	3.2 kg CO_2/sf

Location
Washington, DC

Owner
MetLife Investment Management

Floor Area
908,000 sf

Number of stories
12

Year built
1998

Year renovated
2017 – 2018

Occupancy
Multi-tenant

Retrofit Background

MetLife Investment Management purchased the District Center in 2014 with the intention of repositioning the property. Major capital investments in the building's mechanical systems were to be made, and the building was to become one of the first investor-driven, multi-tenant smart buildings in the country, "with capability for smart tenant solutions, such as apps for personal control of lighting, HVAC, access control, and more." [8.1] MetLife committed to an integrated systems approach to "maximize return on investment and save on energy and operational costs." [8.2] JLL's Smart Buildings Team was hired to coordinate this effort.

Description of Retrofit

"MetLife leveraged efficiency leaders throughout the planning and construction process to work through technical challenges and be a model for full systems integration." [8.2]

The first phase of ECM implementation included converting the pneumatic HVAC system to direct digital controls (DDC), and updating building-wide lighting, including the installation of 32 submeters. "Built into the lighting are more than 1,000 multisensors powered by the internet of things (IoT). They track occupancy levels for code compliance, check daylighting and artificial light levels, and measure temperature and air quality." [8.3]

Next the team incorporated a Supervisory Control Management System (SCMS), which aggregates data from disparate systems into a real-time database. By analyzing this database, operational stray can be detected, diagnosed, and corrected, thereby increasing efficiency and reducing operating costs. Additionally, "because all systems have been connected to a single network, tenants will have the opportunity to support advanced workplace technologies that require interaction with previously unavailable building systems." [8.1]

Although some general contractors could struggle to properly install an integrated smart system like this one, at the District Center, the project team was able to find "installing contractors who were equally excited about the value of full systems integration and who were willing to work through a plethora of technical challenges." [8.1]

Metered Energy Savings and Other Benefits

With an emphasis on smart building technology, not only is the District Center more energy efficient, it is also now marketable in unique ways. "'For people who like to work and move around, there is a thermal map that shows the temperature gradient across a floor, so a warm-bodied person might choose to work in a colder area. The platform can expose all sorts of data that can be visualized on a screen.' Occupants can control lighting and temperature, reserve rooms and prepare them for presentations, raise and lower blinds, order food, track transportation options and much more through the smartphone app or wall-mounted screens." [8.3]

Economic Considerations

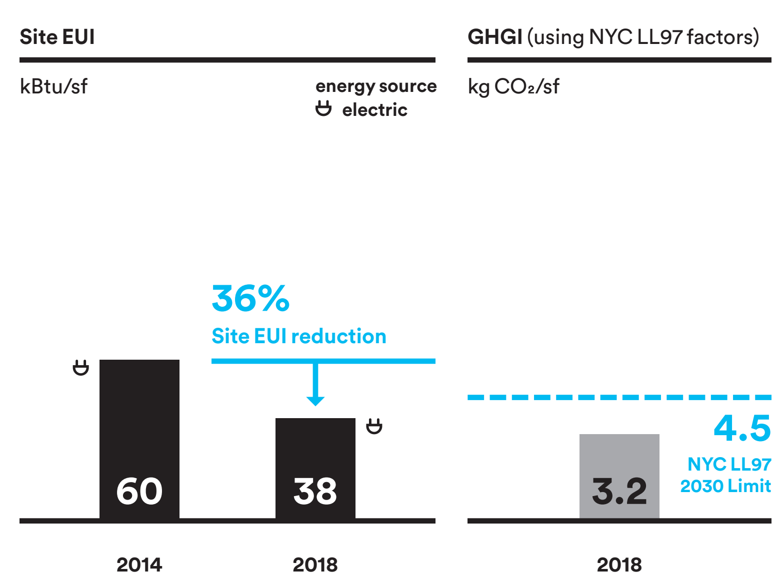
The acquisition budget for the building included replacement of several major systems. This was likely a good investment, as the 36% annual energy savings achieved at the District Center equate to more than $500,000 per year.

Key Lessons Learned

Repositionings offer an excellent opportunity to upgrade major building systems and to install updated systems controls. In addition to the benefit of enhancing tenant experience, integrated smart-building technology can be specifically leveraged to unlock further operational efficiencies.

photo courtesy of Cushman & Wakefield

After being purchased in 2014, this property underwent a major repositioning, including upgrading multiple mechanical systems; special attention was given to controls upgrades and systems integration.



Energy Conservation Measures Overview

lighting
Lighting upgrades building-wide
Motorized blinds with app control

cooling

heating

ventilation

envelope

plug loads
Remote, app-driven control for tenants

hot water

other
Conversion of pneumatic controls to DDC
Supervisory Control Management System (SCMS)

9. Millennium Building

Retrofit Approach

- Repositioning
- Major tenant turnover
- Energy-only retrofit
- **Incremental improvements**

Retrofit Motivation

- **ESG commitments**
- **Energy cost savings**
- Property value enhancement
- Compliance or penalty avoidance

Key Figures

Pre-Retrofit Site EUI 73 kBtu/sf
Post-Retrofit Site EUI 47 kBtu/sf
% Energy Reduction 36%

Post-Retrofit GHGI 3.9 kg CO_2/sf
(using NYC LL97 factors)

Location
Washington, DC

Owner
The Tower Companies

Floor Area
240,000 sf

Number of stories
12

Year built
1973 (+major renovation in 1999)

Year renovated
2012 – present

Occupancy
Multi-tenant

Retrofit Background

The Millennium Building is a class "A" commercial office building, developed in 1973 by The Tower Companies, who continues to manage the building with their in-house property management team. The property has a large lobby space, a fitness center and ground floor retail. In 1999, Tower completed a major renovation of the building and added four additional floors, which resulted in significant energy savings. In 2011, at the beginning of the analysis period for this profile, the building was already a high performer.

Description of Retrofit

In 2012, Tower installed a new building automation system (BMS) and HVAC controls, and replaced stairwell lighting with LEDs. However, the most important ECM, which helped contribute 20% energy savings in the first year alone, was the establishment of a real-time energy management system (EMS), consisting of new hardware and software. The new EMS provided engineers with energy data at 15-minute intervals, summarized in daily reports, allowing them to monitor energy usage constantly. The EMS was initially installed to educate building engineers and property managers on efficient building operations and identify potential energy savings activities. Indeed, it was discovered that substantial gains are possible when building owners operate their buildings with attention devoted to reducing the amount of energy wasted. AtSite was chosen as the initial EMS provider, and from the outset, AtSite provided a performance improvement roadmap, facilitated monthly meetings, provided analytics, charts, and metrics, and gave recommendations for improvements.

"A key element of AtSite's service was detecting and correcting operational stray. AtSite reviewed electricity usage and noticed a pattern that suggested both of the building's chillers were cycling on for a few minutes at a time, then shutting off. AtSite alerted the building engineer, and working together, the team found and corrected faulty variable-air-volume (VAV) controls that were signaling the chiller to turn on even though the building management system (BMS) called for the chiller to remain off. While this problem might have been discovered eventually without AtSite's service, it could have continued undetected for months." [9.1]

Thanks to the EMS and AtSite, the building engineers' perspectives shifted towards a focus on continuous energy efficiency improvement. Eight years later, this close coordination and culture of continuous improvement persists, with no- and low-cost ECMs being implemented and energy savings resulting every year.

Economic Considerations

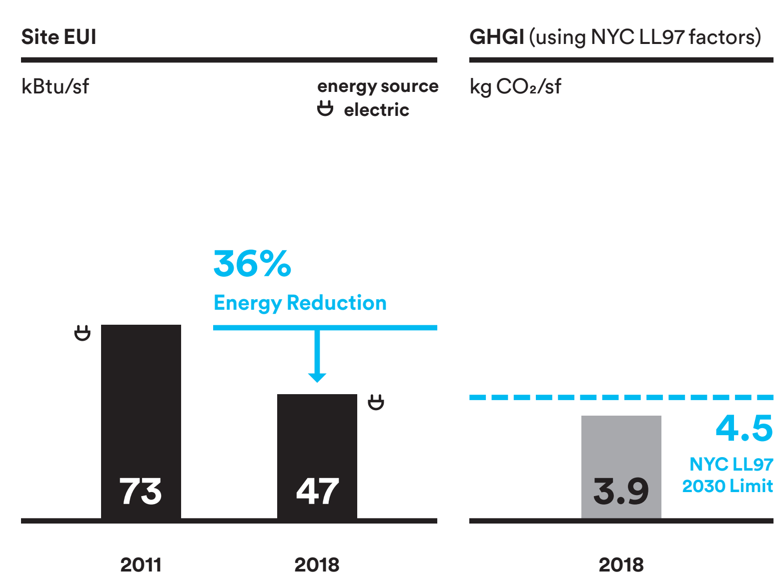
The ECMs selected for implementation in this building were often no- or low-cost, and also had the potential for quick paybacks and appreciable energy reductions and savings. Additionally, ECMs selected were often tied to local incentive programs, such as those from DC Sustainable Energy Utility.

Key Lessons Learned

This profile shows that with committed engineering, property management, and sustainability teams and strong leadership support, deep energy savings are possible without major capital investments, and even for an already high-performing building as a baseline. Additionally, energy management software (EMS), when used in tandem with a BMS, can uncover a surprising amount of no- to low-cost energy savings measures.

Implementing a real-time EMS with a goal of continuous improvement, this building achieved deep savings. This was accomplished by great communication among teams, and by implementing no- to low-cost energy conservation measures whenever possible.

photo courtesy of Ron Blunt



Energy Conservation Measures Overview

lighting
Upgraded to LED bathroom, stairwell and garage lighting

cooling
Cooling Towers were rebuilt
Adjust free cooling OA and chilled water temperatures
Increase deadband for VAV units
Chiller lockout schedule & settings

heating
Reset AHU Supply setpoints
Upgrade all internal controls to VAV boxes in ceilings throughout each floor

ventilation
Confirm all VFDs are set to auto mode and confirm speed settings
Adjust schedule for garage exhaust fans

envelope

plug loads
Plug load reduction study and advanced power strips installed on select tenant floors

hot water
Adjust schedule on hot water heater

other
Continual audit of BMS schedules and seasonal audit of setpoints
Night audits
Demand response program
Rooftop solar PV

10. Empire State Building

Retrofit Approach

- Repositioning
- Major tenant turnover
- Energy-only retrofit
- Incremental improvements

Retrofit Motivation

- ESG commitments
- Energy cost savings
- Property value enhancement
- Compliance or penalty avoidance

Key Figures

Pre-Retrofit Site EUI	122 kBtu/sf
Post-Retrofit Site EUI	79 kBtu/sf
% Energy Reduction	35%
Post-Retrofit GHGI (using NYC LL97 factors)	5.5 kg CO_2/sf

Location
New York, New York

Owner
Empire State Realty Trust (ESRT)

Floor Area
2,850,000 sf

Number of stories
102

Year built
1931

Year renovated
2010 – present

Occupancy
Multi-tenant

Retrofit Background

In 2007 ESRT began the process of a major repositioning of the Empire State Building. With building HVAC systems approaching the end of useful life, there were a wide array of investment opportunities that could improve the quality of the property and attract new high-value tenants. ESRT assembled a team including the Clinton Climate Initiative, JLL, Johnson Controls (JCI), and the Rocky Mountain Institute to analyze, develop, and publish a replicable process and create tools and resources, using the retrofit to prove the economic viability of deep energy retrofits in existing buildings.

Description of Retrofit

The total scope of the renovation included upgrades to windows, chiller plant, AHUs, central plant controls, elevators, restrooms, tenant spaces, the observatory, and the original Art Deco lobby. The existing insulated glass, double-hung windows were all given a suspended coated film and gas fill, and then reinstalled throughout the building. Additionally, over 6,000 existing radiator covers along the perimeter of the building were temporarily removed to allow for an insulated, reflective barrier to be installed in the space behind each radiator. A lighting retrofit took place in the tenant spaces, where efficient lights, photosensors, and occupancy sensors were installed. Finally, a comprehensive High Performance Design and Construction Guidelines for all tenant spaces was implemented. Heating and cooling loads were primarily reduced from the envelope, but also curbed by continuing efforts to reduce tenant lighting and equipment loads thus, the existing chillers were able to be retrofit rather than replaced — a dramatic cost savings. Of the seven chillers (7,500 tons of cooling) in the building, four electric chillers were disassembled and rebuilt with the most efficient possible performance and advanced controls, including VFDs and refrigerant. At this time, ESRT began to replace all AHUs in the building, one at a time as tenant spaces turned over, with super-efficient variable air volume units equipped with advanced controls; this work is ongoing.

Finally, direct digital controls (DDC) and tenant demand control ventilation (DCV) provided controllability to more accurately meet temperature and fresh air setpoints. Each tenant was given access to an online energy and benchmarking portal to monitor their energy use.

Metered Energy Savings and Other Benefits

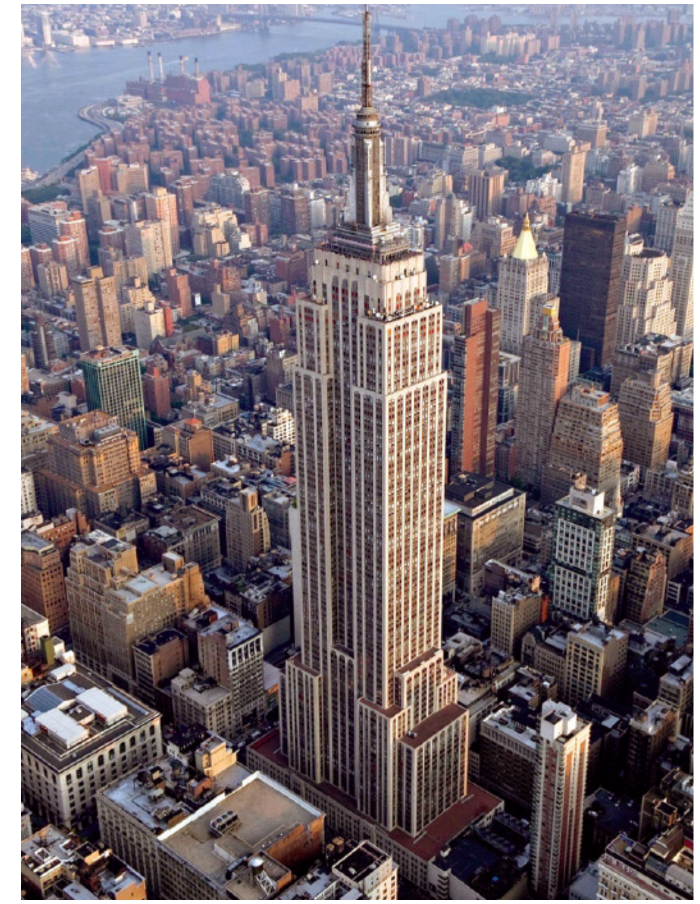
The base building ECMs are covered by an Energy Performance Contract between ESRT and JCI. All work was transparently competitively bid and JCI acted as a GC. The Empire State Building team performs IPMVP Option D Measurement & Verification. Energy savings every year, since the initial 2010 implementation, have exceeded performance savings targets.

Economic Considerations

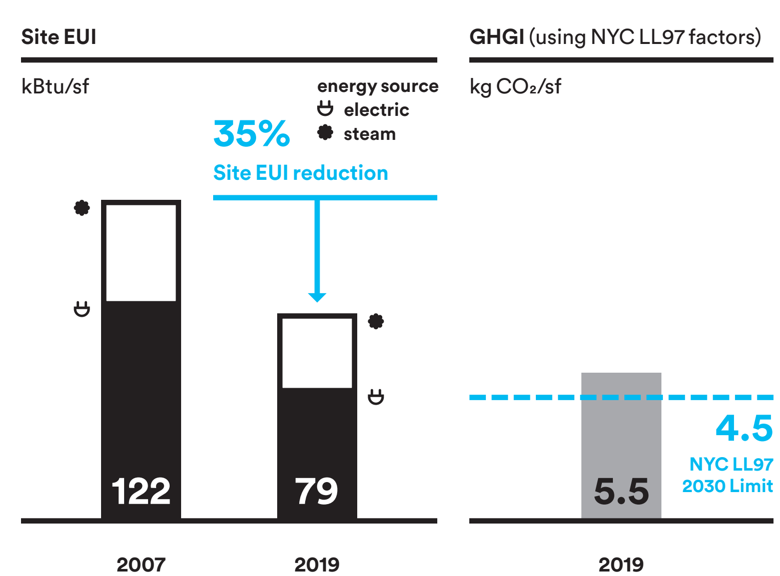
The entire renovation was a $550M project, of which approximately $106M went to replacement of building systems which impact energy usage. Through an expansive options analysis early in the design a set of ECMs with a moderate incremental cost was added to the project to enhance the comfort level of the building and achieve the deep energy savings.

Key Lessons Learned

Packaging ECMs as incremental improvements to a larger building renovation and repositioning allows project costs to be shared among many components. Envelope and HVAC improvements that reduce energy consumption have occupant comfort benefits that translate into enhanced property value.



The iconic tower undertook a comprehensive $550M repositioning that included $13M of deep energy savings from window retrofits, insulation, lighting, controls, tenant load and mechanical system upgrades.



Energy Conservation Measures Overview

lighting
Lower lighting power density in tenant spaces
Daylight dimming, occupancy/vacancy sensors and controls

cooling
Chiller plant retrofit

heating
Advanced steam controls and PRV upgrades

ventilation
New VAV AHUs
Demand control ventilation, CO_2 sensors

envelope
Window refurbishment and coatings
Radiative barrier

plug loads
High Performance Design Guidelines require efficient controlled tenant equipment

hot water
Condensate heat recovery

other
New DDC control system
Tenant Energy Management Software and Engagement Program

11. 222 South Riverside Plaza

Retrofit Approach

- Repositioning
- Major tenant turnover
- Energy-only retrofit
- Incremental improvements

Retrofit Motivation

- ESG commitments
- Energy cost savings
- Property value enhancement
- Compliance or penalty avoidance

Key Figures

Pre-Retrofit Site EUI	116 kBtu/sf
Post-Retrofit Site EUI	76 kBtu/sf
% Energy Reduction	35%
Post-Retrofit GHGI (using NYC LL97 factors)	5.6 kg CO_2/sf

Location
Chicago, Illinois

Owner
RAR2-222 South Riverside, LLC
Behringer Harvard South Riverside, LLC

Floor Area
1,237,000 sf

Number of stories
35

Year built
1971

Year renovated
2012 and 2015 – 2018

Occupancy
Multi-tenant

Retrofit Background

This building has undergone two significant retrofit efforts — a retro-commissioning project completed in 2012, by the previous owner, and an energy retrofit done in parallel with a $40 million repositioning of the property when it changed hands in 2014. Together, the two retrofit efforts have resulted in a 35% energy use reduction from 2012 to 2018. This case study will focus on the latter retrofit effort, which included a number of mechanical system upgrades plus improvements to control strategies.

Description of Retrofit

The current owner purchased this office building in 2014 with the intention to do a major repositioning, and in 2015, a $40M renovation project began. Scope included a new lobby and entrance way, upgraded corridors and restrooms, and new amenity space. From the time that the purchasing strategy was made, potential ECMs were identified and planned for implementation during the overall renovation of the property. As the renovation design was being developed, a building systems engineer was hired to "perform an energy study, create a full-building energy model, design and recommend improvements, and commission the new systems." [11.1] Mechanical system upgrades, as well as control systems, were included in the scope of the ECM work.

This major renovation took place without dislocating tenants, since the majority of the areas renovated were public spaces, such as the lobby, corridors, elevators, and front plaza. However, as air handling units (AHUs) and ventilation equipment were located throughout the building, the construction team took precise measures and completed quick installations in the tenant areas during nights and weekends. Weekly coordination meetings were held between designers, facility managers, the contractor, and sub-contractors to coordinate the project logistics.

Metered Energy Savings and Other Benefits

Since the 2015 major repositioning project, the building's energy use has been reduced by 20%. "On a peak cooling day, the high-rise core AHUs operated at 85% speed, and the low-rise core AHUs operated at 53% (compared with 100% speed and constant volume). Peak chiller operation has reduced from three chillers to two." [11.1] These savings are in addition to the 15% savings achieved between 2012 and 2014, when the previous owner completed the ComEd Retro-Commissioning Project.

In addition to energy savings, the operational life of all equipment (chillers, chilled water pumps, river water pumps, condenser water pumps, cooling tower fans, and ventilation fans) was improved; having installed variable frequency drives (VFDs) the mechanical systems will operate more efficiently, thus extending their life and reducing the frequency of required maintenance. [11.1]

Economic Considerations

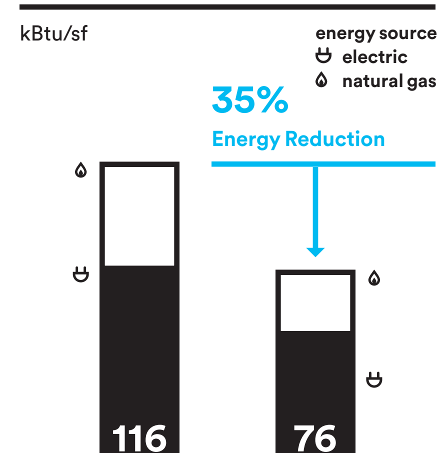
Although energy cost savings were not the motivation for this project, in 2016, before all of the ECMs were implemented, the reduction in energy use was already resulting in an annual electricity savings of $170,000.

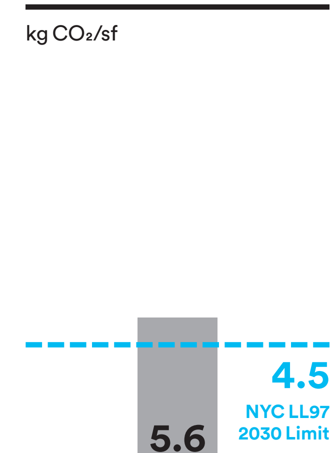
Key Lessons Learned

Including energy efficiency during capital planning for replacement of equipment at the end of useful life is key to uncovering major energy efficiency opportunities. Small incremental costs for higher performance equipment can be packaged with major capital expenditures and the overheads and project management costs can also be shared to make a modest incremental energy efficiency budget go much further.

Ownership change prompted a classic repositioning of this 35-story Chicago office tower using a combination of deep energy retrofit measures along with major upgrades to its 40-year-old mechanical systems.

photo credit: Lindsey Frey





Energy Conservation Measures Overview

lighting
Upgrades by previous owner in 2012

cooling
Chiller upgrades
VFDs added to chillers and chilled water pumps
Replace river water pumps and convert to VFDs

heating
Air ducts insulated

ventilation
VFDs on all supply and return/exhaust fans
Total air distribution system converted to VAV
AHU controls upgraded

envelope

plug loads

hot water

other
BAS system upgraded and integrated with ventilation system and river pump system
Elevator HVAC systems modernized

12. One Battery Park Plaza

Retrofit Approach

- Repositioning
- Major tenant turnover
- Energy-only retrofit
- **Incremental improvements**

Retrofit Motivation

- ESG commitments
- **Energy cost savings**
- Property value enhancement
- Compliance or penalty avoidance

Key Figures

Pre-Retrofit Site EUI	145 kBtu/sf
Post-Retrofit Site EUI	99 kBtu/sf
% Energy Reduction	33%
Post-Retrofit GHGI (using NYC LL97 factors)	6.4 kg CO_2/sf

Location
New York, New York

Owner
Rudin Management Company

Floor Area
860,000 sf

Number of stories
35

Year built
1970

Year renovated
2010 – present

Occupancy
Multi-tenant

Retrofit Background

One Battery Park Plaza is a Class A office building located in Lower Manhattan. The building is 35 stories, a total 860,000 SF built in 1970, making the building 50 years old. Floor plates in the building range from 27,000 to 29,000 square feet and offer sweeping views of New York Harbor, the Statue of Liberty, Ellis Island, Governors Island, and Battery Park. The building has a central cooling and heating plant.

Description of Retrofit

Rudin has undertaken several energy conservation projects which include lighting upgrades, motor replacements, variable frequency drive (VFD) installs on fans and pumps, a new Andover BMS installation, elevator modernization, new O/A air dampers, and retubing of chillers, condensers and evaporators.

In 2013, One Battery Park Plaza integrated all its critical core building systems into Di-BOSS, and later, Nantum, as the key to successful optimization. Nantum integrated data from the building automation system (BAS), utility meters (electricity, gas, steam and water), and occupancy counts from the security turnstiles. Additional temperature sensors were also deployed to provide increased visibility of the building's interior environments in various tenant spaces. Integrations into other siloed critical systems like elevator and fire alarm systems were implemented for additional insight into all building operations.

The strategies deployed through Nantum resulted in minimizing the energy consumption of the building without sacrificing comfort obligations. Sophisticated software algorithms would ingest the building's recent historical data and real-time data, marrying them with real-time weather data and weather forecasts, to predict building conditions and to deliver recommended actions for the building operators to streamline operations.

Metered Energy Savings and Other Benefits

Site EUI was decreased from 145 kBtu/sf to 99 kBtu/sf — a savings of 33%.

Economic Considerations

There was no specific payback threshold for this building's energy efficiency investments, as most were low to no incremental cost or were required to meet code and industry standards. Where possible rebates supported the economic justification for the ECMs implemented. Energy savings were tracked in detail year by year and an informal 'investment fund' was allocated to use savings to pay for incremental improvements and investments.

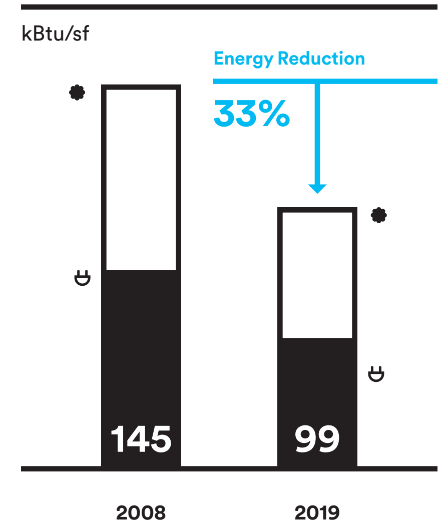
Key Lessons Learned

Seeing energy use and performance data can motivate some facilities teams. Operators of this building expressed satisfaction in operating a building as efficiently as possible utilizing the latest technologies. In turn, tenants see high-performing building systems as an indicator of a high-quality building enhancing the overall asset value.

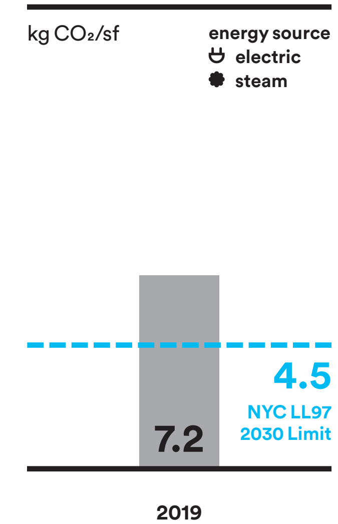
photo credit: Ryan Laber

Significant savings can be achieved from continual analysis of BMS data and incremental improvements, often at no or low-cost.

Site EUI



GHGI (using NYC LL97 factors)



Energy Conservation Measures Overview

lighting
- LED lighting

cooling
- Main cooling tower and tenant cooling tower refurbishment
- Chiller plant upgrades
- Updated chiller controls

heating

ventilation
- Replaced motors on fans, pumps, and cooling towers
- Installed VFDs on all equipment

envelope
- Window film installed on select floors

plug loads

hot water

other
- New BMS and automated controls
- DiBoss/Nantum digital operating system
- Destination dispatch and regenerative-drive elevators

13.
125 Maiden Lane

Retrofit Approach

- Repositioning
- Major tenant turnover
- **Energy-only retrofit**
- Incremental improvements

Retrofit Motivation

- ESG commitments
- **Energy cost savings**
- Property value enhancement
- Compliance or penalty avoidance

Key Figures

Pre-Retrofit Site EUI	76 kBtu/sf
Post-Retrofit Site EUI	52 kBtu/sf
% Energy Reduction	31%
Post-Retrofit GHGI (using NYC LL97 factors)	4.0 kg CO_2/sf

Location
New York, New York

Owner
Time Equities, Inc.

Floor Area
316,000 sf

Number of stories
17

Year built
1959

Year renovated
2011 – 2014

Occupancy
Multi-tenant

Retrofit Background

The owners of 125 Maiden Lane, a 17-story commercial condo in Lower Manhattan, realized that a retrofit of the building's out-of-date and inefficient systems, with a moderate capital expenditure, would result in significant energy savings. However, they did not have access to the capital needed. Through a program with NYCEEC, financing was provided for the retrofit project and a third-party energy service company, SCI Energy.

In 2011, SCIenergy provided a turn-key energy retrofit solution using a managed energy services agreement (MESA). NYCEEC credit enhanced the transaction with a $190,000 loan loss reserve, permitting a commercial loan to fund the MESA and construction to begin. A year later, Superstorm Sandy flooded all the new equipment. Because of the MESA structure, SCIenergy has an ongoing financial stake in the project, and was motivated to repair the Sandy damage with new investment. In the post-Sandy rebuild, NYCEEC provided a $2.8M loan to refinance the MESA structure and fund deeper ECMs and resiliency measures. Energy cost savings were the primary motivation for the retrofit even if the utility savings for the building would not, for the most part, be realized until the termination of the MESA. While new, energy efficient, and resilient mechanical systems have increased the building's perceived property value, this was not a primary driver for the energy retrofit.

Description of Retrofit

The main ECM of the project was a conversion from district steam heating supply to natural gas heating supply, which provided both significant cost savings as well as EUI reduction. High prices for district steam in NYC, and historically low natural gas prices, made the capital investment for a new natural gas boiler a short payback.

Other supporting ECMs included a new BMS coupled with direct digital controls (DDC). These new controls and systems allowed optimization of a variety of building mechanical components. New variable speed drives on AHU and pump motors could be optimized with better controls. This also allowed floor isolation dampers to provide ventilation to only occupied floors during out of hours occupancy.

Because only mechanical and electrical systems were replaced or modified during this project, it was decided that tenants could remain in occupancy and work would occur off-hours, during nights and weekends.

Metered Energy Savings and Other Benefits

Site EUI dropped 31%, going from 76 kBtu/sf in 2010 to 52 kBtu/sf in 2016, after the second retrofit.

Economic Considerations

The financing approach was one of the most innovative aspects of this energy retrofit as the ownership did not have to incur debt or contribute equity capital for the project. Energy cost savings would be delayed, but eventually they would be realized by the tenant-condo owners of the building. Also, under the MESA, condo owners could share in the cost savings achieved from excess efficiency generated by the ECMs.

Key Lessons Learned

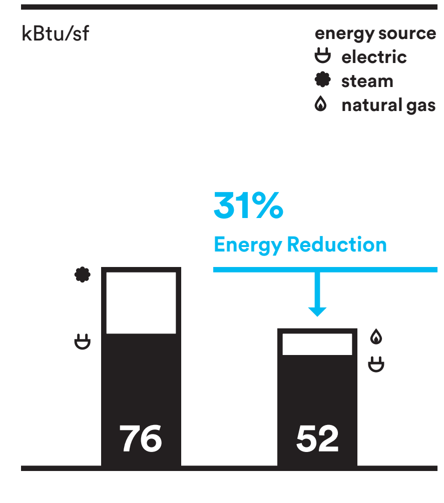
With experienced partners, an energy service agreement can be set up and financing can be obtained to implement deep energy retrofits without requiring direct capital investment from building ownership. Conversion from district steam to natural gas in NYC can have significant energy cost, EUI, and GHGI reduction potential.

photo credit: Ryan Laber

A Class B commercial condo retrofit, in Lower Manhattan, where a package of ECMs was financed by the New York City Energy Efficiency Corporations (NYCEEC) and then implemented by an ESCO, guaranteed the energy savings.

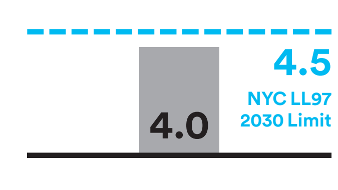
Site EUI

kBtu/sf



GHGI (using NYC LL97 factors)

kg CO_2/sf



Energy Conservation Measures Overview

- lighting
- cooling: New VFDs on air handlers and pumps
- heating: Steam to natural gas boiler conversion
- ventilation: Floor isolation dampers
- envelope
- plug loads
- hot water
- other: State of the art digital controls; New BMS

14.

1001 Pennsylvania Avenue

Retrofit Approach

- Repositioning
- Major tenant turnover
- **Energy-only retrofit**
- **Incremental improvements**

Retrofit Motivation

- **ESG commitments**
- **Energy cost savings**
- Property value enhancement
- Compliance or penalty avoidance

Key Figures

Pre-Retrofit Site EUI	71 kBtu/sf
Post-Retrofit Site EUI	50 kBtu/sf
% Energy Reduction	29 %

Post-Retrofit GHGI 4.2 kg CO_2/sf
(using NYC LL97 factors)

Location
Washington, DC

Owner
Nuveen Real Estate

Floor Area
836,000 sf

Number of stories
14

Year built
1987

Year renovated
2010 – present

Occupancy
Multi-tenant

Retrofit Background

1001 Pennsylvania Avenue NW was built in 1987 and, at 14 stories tall, is one of DC's tallest commercial buildings. The building is primarily office, but also includes about 41,000 square feet of retail space.

Around 2010, Nuveen Real Estate, the building's owner, committed to an energy reduction goal of 20% below its baseline by 2020, across its entire real estate portfolio. Although some major capital projects were implemented in support of this effort, being a portfolio-wide initiative, no- and low-cost measures were pursued whenever possible. This retrofit highlights the impact of these types of ECMs.

Description of Retrofit

Nuveen Real Estate worked very closely with its sustainability consultant and with Hines, the property manager, to identify no-and low-cost measures and a few capital investments to reduce the energy consumption of this building. Primary strategies pursued were the upgrading of HVAC controls, improving of building ventilation, and upgrading of interior and exterior lighting.

One of the most critical ECMs implemented at 1001 Pennsylvania was upgrading the building's energy management system (EMS). The EMS was paired with new central plant controls, a new central communications network system, and the conversion of the variable air volume (VAV) box controls from pneumatic to direct digital control (DDC). The updated EMS and controls apparatus allowed building engineers to continually monitor and improve building system performance.

Other ECMs included improving the efficiency of the HVAC system by installing variable frequency drives (VFDs) on the air handling unit fans, installing a plate-and-frame heat exchanger to enable free cooling during mild weather, installing high efficiency sand filtration systems in the north and south chiller plants, and replacing the damper seals on the smoke evacuation dampers.

Lighting upgrades were also implemented, and elevator systems were modernized. Finally, tenants were educated on energy-saving best practices.

Metered Energy Savings and Other Benefits

Thanks to the close work between the Nuveen ownership team and the Hines property management team, many best practices became a habit at 1001 Pennsylvania. The teams began both closely monitoring utility consumption and carefully maintaining a rigorous preventative maintenance schedule. Overall, a 29% annual energy savings was achieved, and the property's competitiveness in the DC market was improved.

Economic Considerations

When aggregated, the ECM projects implemented at 1001 Pennsylvania yielded an "overall payback period of 3.5 years and an ROI of 29%." [14.1]

Key Lessons Learned

Coordination between the ownership, property management, and sustainability experts is crucial when implementing ECMs. Low- to no-cost measures can achieve significant energy savings, and when paired strategically with capital projects, energy savings can be even higher.

Thanks to ESG commitments by ownership, this property undertook five years of sustainability-motivated ECM work, ranging from capital upgrades, to no- to low-cost measures.

photo courtesy of Nuveen Real Estate

Energy Conservation Measures Overview

lighting
- LED lighting upgrades in parking garage, stairwells, and restrooms
- T8 lamps and occupancy sensor controls in tenant spaces

cooling
- VFDs on AHU fans
- Plate-and-frame heat exchanger for free cooling
- High efficiency filtration systems
- Seals on smoke evac. dampers

heating

ventilation
- CO_2 sensors and demand controlled ventilation

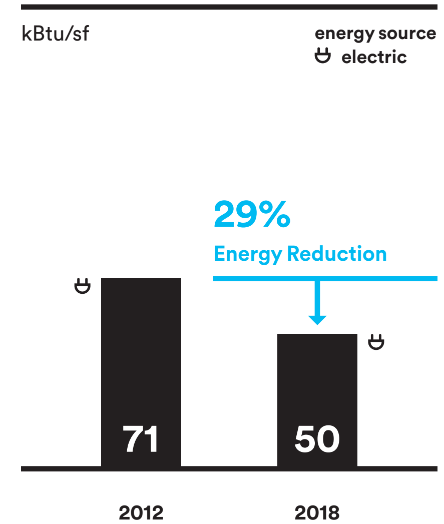
envelope
- High-performance window replacement
- Super-insulated walls and roof with continuous air barrier

plug loads

hot water

other
- Upgraded energy management system
- VAV controls from pneumatic to DDC
- Modernized elevator machine rooms

Site EUI



GHGI (using NYC LL97 factors)

15. Sun Life Assurance

Retrofit Approach

- Repositioning
- **Major tenant turnover**
- Energy-only retrofit
- Incremental improvements

Retrofit Motivation

- ESG commitments
- **Energy cost savings**
- **Property value enhancement**
- Compliance or penalty avoidance

Key Figures

Pre-Retrofit Site EUI	113 kBtu/sf
Post-Retrofit Site EUI	81 kBtu/sf
% Energy Reduction	28%
Post-Retrofit GHGI (using NYC LL97 factors)	6.1 kg CO_2/sf

Location
Chicago, Illinois

Owner
29 North Wacker LLC

Floor Area
140,000 sf

Number of stories
10

Year built
1961

Year renovated
2010 – 2012

Occupancy
Multi-tenant

Retrofit Background

This Class-B office building in downtown Chicago was only 40% occupied in 2010 and had an outdated constant air volume (CAV) system with perimeter induction and interior reheat, original air handling units, old steam fired tube boiler(s) with hot water converters, obsolete chillers, and an old BMS with predominantly pneumatic controls. Occupied tenant spaces had recently completed a fit-out and lighting upgrade, so lighting improvements were not an opportunity in about half of the building.

This project was spurred by a variety of motivations. Value creation through modernizing building systems was meant to attract new tenants. Energy savings on owner-controlled base building systems were also a motivation. Finally, the increase in tenant comfort and indoor air quality was deemed necessary for leasing goals.

Description of Retrofit

This retrofit included the renovation of leased spaces during tenant turnover for about half of the floors, and the upgrade of major building systems at the end of their useful life. The retrofit was designed to be minimally intrusive to existing tenants and to reuse as much existing ductwork and perimeter dual temperature piping as possible, particularly in occupied spaces. Work in tenant spaces to replace perimeter units and to install variable air volume (VAV) components was conducted at night and on weekends in order to provide continuous service to the building's tenants.

A new chiller plant, cooling tower, and pumps accounted for a majority of the overall energy savings. Additional ECMs included variable frequency drives (VFDs) on new air handlers, a new condensing boiler, heating distribution conversion from steam to hot water, active chilled beams, and additional insulation where possible in non-vision glazing. A modern direct digital control (DDC) system provided dramatically improved control and monitoring of building systems.

Metered Energy Savings and Other Benefits

EUI went from 113 kBtu/sf, in 2009, to 81 kBtu/sf, in 2013, when the building was fully occupied — a 28% reduction. Tenants also received better temperature and fresh air control, resulting in improved comfort.

Economic Considerations

Renovation costs are confidential, but this project is an example of a typical Class B renovation under tight budget constraints.

Most of the 28% energy savings was realized in the central systems controlled and paid for by the owner, including the cooling plant, central ventilation, and central boiler. Therefore the life cycle cost benefits accrued to the owner, who invested in improved systems to attract new tenants.

Modernized HVAC, lighting, and controls were a selling point to prospective tenants and helped accelerate leasing of the property.

Key Lessons Learned

The design team considered a wide variety of innovative solutions during the concept phase and carefully analyzed and considered the costs and benefits of a range of options. Low cost retrofit projects tend to have compressed design and implementation schedules which often do not allow options or innovations that lead to deep energy savings.

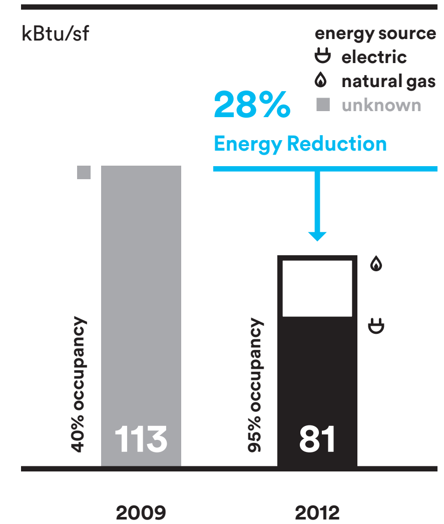
One key to a cost effective approach in an existing building retrofit is to analyze what infrastructure can be reused without compromising the goals of the project.

It is possible to conduct perimeter heating/cooling unit replacement in occupied tenant spaces with minimal intrusion on tenants.

photo courtesy of Elara Engineering

This 10-story Class B Chicago office building increased occupancy from 40% to 95%, while reducing EUI from 113 to 81 kBtu/sf, through smart upgrades that minimized existing tenant disruption.

Site EUI



GHGI (using NYC LL97 factors)

Energy Conservation Measures Overview

lighting
- Lighting upgrade to T-8, T-5 and LED fixtures on floors with new tenant fit outs

cooling
- New variable speed screw chiller
- New chilled water and condenser water pumps
- Convert constant volume induction to VAV

heating
- Steam to natural gas boiler conversion

ventilation
- VFDs on new air handlers with fan array
- CO control on garage ventilation

envelope
- Additional insulation on exterior walls

plug loads

hot water
- Electrical point of use hot water heaters for hand washing and low-flow fixtures

other
- New DDC controls with BACnet
- Replaced domestic water pumps

16.
801 Grand

Retrofit Approach

- Repositioning
- **Major tenant turnover**
- Energy-only retrofit
- Incremental improvements

Retrofit Motivation

- **ESG commitments**
- **Energy cost savings**
- **Property value enhancement**
- Compliance or penalty avoidance

Key Figures

Pre-Retrofit Site EUI	96 kBtu/sf
Post-Retrofit Site EUI	70 kBtu/sf
% Energy Reduction	27%
Post-Retrofit GHGI (using NYC LL97 factors)	5.8 kg CO_2/sf

Location
Des Moines, Iowa

Owner
Principal Financial Group (PFG)

Floor Area
920,000 sf

Number of stories
44

Year built
1989

Year renovated
2013 – 2016

Occupancy
50% Owner occupied;
50% Multi-tenant

Retrofit Background

801 Grand is the tallest building in Iowa, with Principal Financial Group being the owner and occupying about half of the floor area. Retail and restaurants occupy the podium levels, along with a very small parking garage (parking area excluded from floor area reported above), and a restaurant occupies the top floor. The building is all-electric with electric resistance heating due to the low cost of electricity and relatively low heating demand. With all-air variable air volume (VAV), central chillers, and rooftop cooling towers, the HVAC systems were fairly typical for a high rise office.

In 2012, Principal Financial Group, who at the time occupied 25 floors, intended to relocate some of their office operations out of 801 Grand. Therefore, a strategic opportunity to perform a major retrofit presented itself. The owner engaged JLL as a project manager and established two goals: achieve LEED-EB O&M and improve indoor environmental quality, particularly as it related to cold air infiltration during the winter months. The overall hope was to reduce operational costs and to improve the quality office space about to be put on the market.

Description of Retrofit

The first activity that JLL undertook was the hiring of Grumman/Butkus Associates (G/BA) to perform a Level 3 energy audit and an airflow model. The Level 3 energy audit was calibrated using five existing electric meters and additional data loggers. G/BA also provided an airflow model of the building's major air pathways using CONTAM software — a multi-zone indoor air quality and ventilation analysis computer program provided by NIST. Crucially, the CONTAM model helped determine that HVAC-based countermeasures to infiltration would not be required if physical barriers were deployed.

Based on the findings of these models, developing the scope of the retrofit work concentrated on achieving more air-tightness in the building, upgrading the HVAC system, installing new light fixtures, and better calibrating the operation of the building systems with building occupancy. Although upgrades were made, the primary HVAC equipment (four AHUs, two chillers, cooling towers, and associated pumps) was not replaced.

Metered Energy Savings and Other Benefits

The project was successful in substantially increasing energy efficiency and air-tightness of the building. Site EUI fell from 96 to 70 kBtu/sf, for a savings of 27% which supported the targeted LEED-EB O&M certification.

Economic Considerations

About a dozen no- to low-cost measures were implemented, resulting in $224,515 in annual savings with payback less than one year. Seven capital projects remain on the table for future implementation and would result in a modeled 8% additional energy use reduction as part of infrastructure replacement projects.

Key Lessons Learned

CONTAM pressure/infiltration modeling is cited as a key driver of success during this project, as it led the team to pursue crucial insulation and infiltration reduction/mitigation measures. Because of this, more expensive HVAC improvements were able to be foregone.

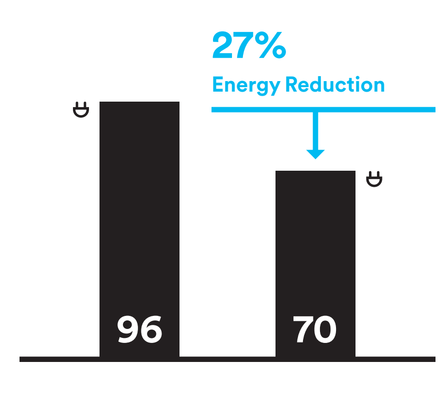
Using interval data from electric meters and a pressure/infiltration model, engineers were able to precisely calibrate and utilize an energy model to realize 27% energy savings through strategic low-cost or no-cost measures for the tallest building in Iowa.

photo courtesy of JLL

Site EUI

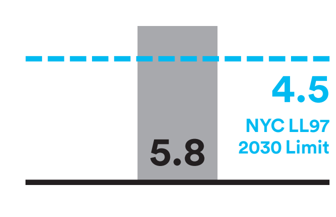
kBtu/sf

energy source
electric



GHGI (using NYC LL97 factors)

kg CO_2/sf



Energy Conservation Measures Overview

lighting
- LED lighting and new lighting controls
- Lighting override controls
- Lobby and parking garage re-lamping

cooling
- Setpoint temperatures reduced
- Cooling tower refurbishment

heating

ventilation
- AHU control upgrade
- Reduced ventilation nights and weekends
- AHU VFDs and static pressure reduction

envelope
- Passive stack effect mitigation
- Infiltration reduction projects (high speed garage doors, vestibules at the skyway, weatherization, etc.)

plug loads

hot water

other

17.

TfL Palestra Building

Retrofit Approach

- Repositioning
- Major tenant turnover
- Energy-only retrofit
- Incremental improvements

Retrofit Motivation

- ESG commitments
- Energy cost savings
- Property value enhancement
- Compliance or penalty avoidance

Key Figures

Pre-Retrofit Site EUI	147 kBtu/sf
Post-Retrofit Site EUI	113 kBtu/sf
% Energy Reduction	23%
Post-Retrofit GHGI (using NYC LL97 factors)	7.2 kg CO_2/sf

Location
London, England

Owner
Blackfriars Investments Limited

Floor Area
404,000 sf

Number of stories
12

Year built
2006

Year renovated
2010 – present

Occupancy
Single-tenant

Retrofit Background

The Palestra building was completed in 2006 as a speculative commercial property. The building was designed and constructed to be a high energy performer — earning a Very Good sustainability rating from the Building Research Establishment Environmental Assessment Method (BREEAM). The building included a "gas-powered tri-generation combined cooling, heating and power (CCHP) system; a solar PV installation on the roof; micro wind turbines; efficient T5 lighting; rainwater harvesting; and a hydrogen fuel cell." [17.1]

Transport for London (TfL) became the primary lessee in 2008, and in 2013, when the London Development Agency vacated two floors, TfL occupied the entire Palestra building. Much of the energy retrofit measures were driven by TfL.

Description of Retrofit

Following its initial occupancy in 2008, in tandem with ongoing fit-out work, TfL first worked to advance the building BREEAM rating from Very Good to Excellent. "During this phase of work, almost all of the original building services plant was retained, but much was upgraded or improved." [17.2] Work included a more efficient chiller system, building management system (BMS), daylight controls, and efficient computer systems. TfL also required that a traffic and bus control center on the second floor, which requires 24-hour operation, be installed.

"In 2013, when TfL became the sole occupant of the building, it reconfigured building electrical infrastructure to allow for additional control rooms. It also commissioned Verco to investigate why the original trigeneration CCHP was not operating as originally anticipated." [17.1] This study identified improvements that could be made to the hot water system and to the tri-generation CCHP system, which, as a result, was temporarily shut off.

"In 2015, TfL appointed E.ON to carry out an energy performance contract, through the Greater London Authority's RE:FIT program. E.ON's solution guaranteed significant utility cost savings and an 8% reduction in CO_2 emissions." [17.1] A selling point was that the building could be renovated while still occupied and operational. TfL has worked closely with the E.ON and Palestra teams each year to make further improvements.

Metered Energy Savings and Other Benefits

In addition to the energy and carbon savings achieved, occupants enjoyed a longer-lasting supply of hot water in the shower room and improved temperature management on office floors.

Economic Considerations

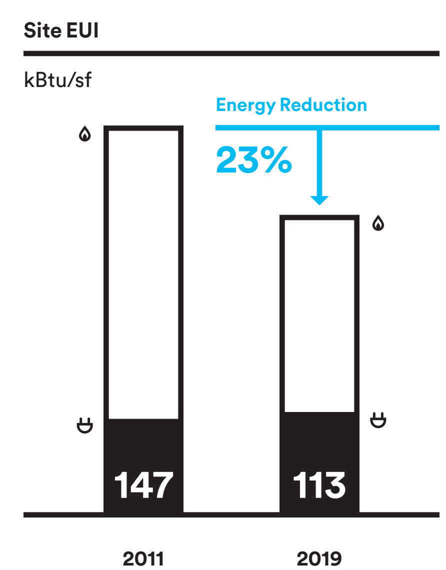
The total project costs for the scope of work that has been completed since 2013, when TfL became the sole occupier of the building, including the energy performance contract with E.ON and BMS upgrades, is $2,000,000. E.ON had guaranteed annual savings of $140,000, but actual savings in the first year of full implementation have been $550,000.

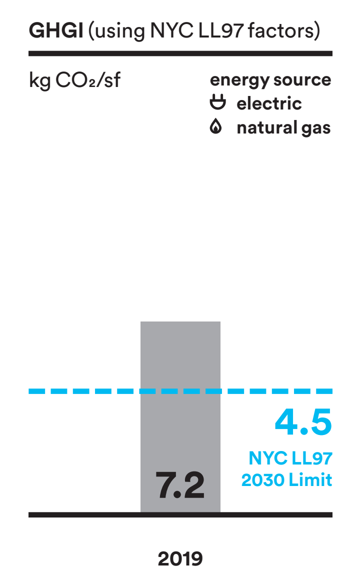
Key Lessons Learned

This project demonstrates the potential for deep energy savings when an owner and tenant work closely together with shared goals. Comfort, carbon emissions reduction, energy cost savings, and optimal working environment were shared objectives for this retrofit and were all achieved over the retrofit and retro-commissioning process. Continued fine-tuning, each year, has resulted in appreciable savings.

photo courtesy of Transport for London

Already designed with cutting-edge sustainability features and recognized as a high-performing building, TfL utilized an energy performance contract to achieve even further system optimization, motivated by ESG goals.





Energy Conservation Measures Overview

lighting
Daylight sensors to control lighting

cooling
New electric driven chillers
RCx of existing absorption chiller
relocate servers to optimal location for cooling

heating
RCx of gas CCHP to optimize use of low temp. hot water

ventilation
Fresh air controls with presence detectors enabling shutdown when areas are unoccupied

envelope

plug loads

hot water
New DHW tanks and heat exchangers to optimize low temp hot water from CCHP

other
New BMS to replace existing BMS
roof and ground floor vegetation

18.
330 West 34th Street

Retrofit Approach

- **Repositioning**
- **Major tenant turnover**
- Energy-only retrofit
- Incremental improvements

Retrofit Motivation

- **ESG commitments**
- Energy cost savings
- **Property value enhancement**
- Compliance or penalty avoidance

Key Figures

Pre-Retrofit Site EUI	48 kBtu/sf
Post-Retrofit Site EUI	40 kBtu/sf
% Energy Reduction	17%
Post-Retrofit GHGI (using NYC LL97 factors)	3.3 kg CO_2/sf

Location
New York, New York

Owner
Vornado Realty Trust

Floor Area
720,000 sf

Number of stories
18

Year built
1925

Year renovated
2016

Retrofit Background

This retrofit was a comprehensive renovation in an effort to reposition an aging 18-story commercial office property in Midtown Manhattan. Before this retrofit project, the largest tenant in 330 West 34th Street was the traffic division of the New York Police Department with a nine-to-five schedule. Following the property's repositioning the property is now fully occupied and leased to higher occupant density and tenants with longer hours, including a global construction company, marketing firm, a retail corporate headquarters, and similar professional tenants.
In addition to a transformation of the tenant roster, the building added considerably to its occupant density, with over 3,500 full time employees on a normal business day.

Description of Retrofit

Nearly the entire building was included in the scope of this repositioning, so energy systems were impacted across the board. Tenant spaces were fit out and brought up to code with a focus on lighting replacements which reduced lighting power density dramatically. A fairly simple floor-by-floor HVAC approach was implemented with new DX units on every floor. The new BMS and DX units allowed better control and sequence of operations responding to static pressure sensors. New dampers on new mechanical rooms on each floor allowed better temperature and ventilation control. Demand control ventilation from CO_2 sensors in conference rooms allowed reduced fresh air requirements and reduced heating and cooling loads.

Metered Energy Savings and Other Benefits

Site EUI decreased from 48 kBtu/sf to 40 kBtu/sf, a savings of 17% annually.

Economic Considerations

Separate costs or budgets for energy efficiency were not broken down for this renovation, rather they were embedded in the approach and specifications by the owner. Based on previous studies the owner has developed energy efficient design standards such as regenerative elevator, lighting, and controls. Also standard energy efficient fit-out design standards for tenants were part of a green lease and incentive program by the owner.

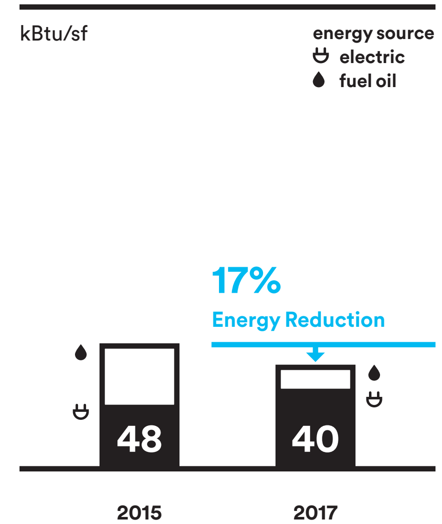
Key Lessons Learned

Even when not the explicit goal, a major repositioning and bringing tenant fit-out up to current code represents a big opportunity for energy conservation measures. Bringing an older building with outdated systems up to date with contemporary lighting, controls, and appliances offers major energy savings.

A strategic, major repositioning included significant energy conservation measures, whether motivated by energy goals or not.

photo courtesy of Vornado Realty Trust

Site EUI



GHGI (using NYC LL97 factors)

Energy Conservation Measures Overview

lighting
Base building lighting retrofit with LED bulbs and occupancy sensors
Tenant spaces lighting replaced to meet NYC Energy Efficiency Code

cooling
New floor-by-floor tenant DX units
Replaced HVAC in common areas

heating

ventilation
'Free cooling' coils in DX units

envelope
Selective replacement of some windows from single-pane to double-pane

plug loads
Appliances and plug loads in tenant spaces compliant with NYC Energy Efficiency Code
Cloud computing to limit data center space and energy use

hot water
New electric DHW tanks

other
Destination-dispatch regenerative drive elevators

technical solutions matrix

Category	Solution	1. UN HQ	2. Byron Rogers Federal Building	3. 1177 West Hastings Street	4. Kyoto Station Mixed Use	5. 560 Lexington	6. Five Manhattan West	7. NEC HQ	8. District Center	9. Millennium Building	10. Empire State Building	11. 222 South Riverside Plaza	12. One Battery Park Plaza	13. 125 Maiden Lane	14. 1001 Pennsylvania	15. Sun Life Assurance	16. 801 Grand	17. TfL Palestra Building	18. 330 West 34th Street
lighting	Reduced lighting power density	●	●	●	●	●	●	●	●	●	●	●	●	○	●	●	●	○	●
	Daylight sensors and controls	●	●	●	○	●	○	○	●	○	●	○	○	○	○	○	○	●	○
	Occupancy sensors	●	●	●	○	○	○	●	○	○	○	○	○	○	●	○	○	○	●
	Reduced lighting schedules	○	○	●	○	○	○	●	○	○	○	○	○	○	○	○	●	○	○
cooling	Cooling plant replacement or upgrade	●	●	●	●	●	●	●	○	●	●	○	○	○	●	●	○	●	●
	VFDs on motors for pumps, fans, etc.	○	●	●	●	●	●	○	○	○	○	●	●	●	●	●	●	○	○
	Reduced schedules and setpoint temps	○	○	●	○	○	○	●	○	●	○	○	●	○	○	○	○	○	○
	Other innovative cooling ECMs	●	●	○	●	○	○	●	○	●	○	●	○	○	●	●	○	●	○
heating	Boiler plant replacement or upgrade	○	●	●	●	○	○	●	○	○	○	○	○	●	○	●	○	●	○
	Distribution system improvements	○	○	●	○	○	●	●	○	●	●	●	○	○	○	●	○	○	○
ventilation	AHU replacement or upgrade	○	○	○	○	○	●	○	○	●	●	●	○	●	○	●	●	○	○
	Demand control ventilation	●	○	○	●	○	○	○	○	●	●	○	○	○	●	●	○	○	○
	Outside air economizer	○	●	●	○	○	○	○	○	○	○	○	○	○	○	○	●	●	●
envelope	Façade reclad or window replacement	●	●	○	○	○	●	○	○	○	●	○	●	○	●	○	○	○	●
	Air tightness improvements	○	○	●	○	○	○	○	○	○	○	○	○	○	○	○	●	○	○
	Additional insulation	○	●	●	○	○	○	○	○	○	●	○	○	○	●	●	○	○	○
plug loads	Energy Star appliances, new computers	○	○	○	○	○	○	○	○	○	●	○	○	○	○	○	○	○	●
	Cloud-based computing (no servers)	○	○	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	●
	Other plug load ECMs	○	○	●	○	○	○	○	●	●	○	○	○	○	○	○	○	○	○
hot water	Hot water heater replacement	○	●	○	●	○	○	○	○	○	○	○	○	○	○	○	○	●	○
	Electrification of hot water generation	○	○	●	○	○	●	○	○	○	○	○	○	○	○	●	○	○	●
	Other hot water ECMs	○	○	○	○	○	○	○	○	●	●	○	○	○	○	○	○	○	○
other	Upgraded or new BMS and controls	●	●	●	●	●	●	○	●	●	●	●	●	●	●	●	○	●	○
	Regenerative drive elevators	○	●	●	○	●	●	○	○	○	○	●	●	○	●	○	○	○	●
	On-site renewables	○	●	○	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	Other ECMs	○	○	●	●	○	○	●	○	●	●	○	○	○	○	○	○	●	○

solutions summary

lighting

Reduced lighting power density

Most buildings in this survey included some form of lighting fixtures or lamp replacements which included LED lighting, T5 or T8 lamps, task lighting, or dimmable ballasts. New technologies for lamps and fixtures provide higher efficacy which allows an overall reduction in energy use with better light temperature and increased lumens. New codes limiting lighting power density require many of these lighting ECMs.

- All new code compliant lighting
- Lower lighting power density in tenant spaces
- LED lighting upgrades in parking garage, stairwells, and restrooms
- Lighting upgrade to T-8. T-5 and LED fixtures on floors with new tenant fit outs
- Continuous dimming high-efficiency LED lighting
- Task lighting
- Base building lighting retrofit with LED bulbs and occupancy sensors
- Tenant spaces lighting replaced to meet NYC Energy Efficiency Code
- Lighting override controls

Daylight sensors, dimming, active blinds

This group of ECMs includes a variety of strategies to reduce energy consumption through the harnessing of natural daylight to replace overhead powered lighting including: light shelves, reflective ceilings, daylight sensors, daylight dimming, or daylight switching. Active blinds are included here as some reflect light up to ceilings though some are controlled to reduce solar gain rather than reduce lighting energy.

- Natural daylighting
- Motorized blinds with app control
- Daylight dimming, occupancy/vacancy sensors and controls
- Daylight sensors and controls
- Active blinds

Occupancy sensors

Another common lighting ECM included motion sensors to monitor occupancy and switch off lighting in unoccupied spaces. More advanced examples in this compendium included occupancy sensors networked to BMS to directly control overhead lighting, temperature setpoints, and ventilation. Simple examples of occupancy controls were direct switches of lighting in stairwells or parking areas.

- Occupancy sensors
- Occupancy-based lighting controls
- Occupancy sensors in stairwells

Reduced lighting schedules

A couple buildings implemented the no-cost control ECM of simply reducing the number of hours overhead lights were on. This required lighting controlled by a BMS which is more common in large, tall office buildings than other building typologies.

- Reduced lighting schedules

cooling

Cooling plant replacement or upgrade

Nearly as frequent as the lighting replacement ECM, most buildings in this survey conducted some type of improvement to primary cooling plant equipment. Examples of cooling plant replacement with new high efficiency equipment included: variable speed screw chillers, turbo chillers with VFDs, or high-efficiency magnetic bearing chiller, heat recovery heat pump, or new DX units. Lower-cost solutions included replacing chilled water and condenser water pumps or replacing cooling towers at the end of their useful life.

- Chiller plant retrofit
- High-efficiency magnetic bearing chiller
- New variable speed screw chiller
- Chiller upgrade to Turbo Chillers with VFD
- Heat Recovery Heat Pump
- Well water based water source heat pump
- New DX units throughout property
- Retro-commissioning of existing absorption chiller
- New chilled water and condenser water pumps
- Cooling tower replacement
- Cooling tower refurbishment
- Chilled beams
- Air and waterside economizers
- Constant volume induction converted to active chilled beams and VAV

VFDs on motors in AHUs, cooling towers, pumps

Replacing old constant speed motors with variable frequency drive motors and associated controls allows pumps to reduce their electrical draw for non-peak operational conditions and reducing energy consumption. Common motors for VFD replacement included water pump motors, air handling fan motors, chillers, and dx units.

- VFDs added to chillers and chilled water pumps
- Refurbished DX units with new motors and VFD
- Replace river water pumps and convert to VFDs
- VFD on condenser water
- VFDs on air handlers and pumps

Reduced setpoint temps and schedules

Most tall office buildings have some form of BMS which allows fine-grained control of many setpoints related to cooling energy efficiency. Many of the buildings in this compendium found no-cost energy savings through reducing cooling setpoints and refining operating schedules. A number of owners included overtime charges for HVAC use which discouraged cooling energy consumption. Other control-related cooling

ECMs included increased deadband, adjustments to chilled water supply temperatures, chiller lockout schedule adjustments, and increased outdoor air free cooling.

- Setpoint temperatures reduced
- Increase deadband for VAV units
- Adjust free cooling OA and chilled water temperatures
- Chiller lockout schedule and settings

Other innovative cooling ECMs

Cooling systems had the widest variety of innovative and unique energy efficiency solutions that were customized to the specific conditions of the mechanical cooling systems in the buildings in this study. The following ECMs were unique to only one or two buildings so are listed here for brevity: chilled beams, river water heat rejection upgrades, plate-and-frame heat exchanger for free cooling, damper seals on smoke dampers, retro-commissioning of existing absorption chiller, relocate servers to optimal location for cooling, VRF system for lobby and lower level tenants, air and waterside economizers, and VAV terminals to replace constant volume induction units.

- Pipes for river water heat rejection upgraded
- Tenants charged for overtime HVAC use
- Damper seals on the smoke evacuation dampers
- Relocate servers to optimal location for cooling
- VRF system for lobby and lower level tenants

heating

Boiler plant replacement or upgrade

This ECM included replacement of primary boilers often at the end of their useful life. There were a couple conversions from district steam to natural gas for primary heating source and a couple examples of natural gas fired combined heat and power (CHP) plant installations or improvements. Energy savings were achieved through higher conversion efficiency boilers and improved controls.

- Boiler replacements with new high efficiency condensing boilers
- High-efficiency condensing boilers and thermal storage tank
- Replaced old steam-to-water conversion for perimeter heating to new natural gas condensing boilers
- Natural gas cogen for hot water
- Steam to natural gas boiler conversion
- RCx of gas CCHP to optimize use of low temperature hot water
- Heat recovery plant utilizing waste heat via chiller heat mode
- Air-source heat pumps

Distribution system improvements

For steam and hot water heating distribution systems this category included insulation of distribution hot water or steam pipes, replacement of valves, and new perimeter units. For air-based heating systems improvements included VFDs on AHUs, increased airflow control through dampers, and insulating ductwork.

- Steam or hot water distribution pipe insulation
- Advanced steam controls and PRV upgrades
- New actuators, VFD motors, steam trap replacement
- Perimeter Fin Tube, Steam to Hot Water Exchangers & Fan Steam Coil
- Upgrade all internal controls to VAV boxes in ceilings throughout each floor
- Air ducts insulated

ventilation

Air handling system replacement or upgrade

A wide variety of energy efficiency measures dealt with air handling equipment. Often AHUs were replaced if older existing equipment was past its useful life. Many ECMs dealt with retrofitting new controls and VFDs on AHU fan motors and often converting constant volume systems to VAV systems. Other central system measures included isolation dampers and conversion to displacement ventilation,

- New VAV AHUs
- Total air distribution system converted to VAV
- Displacement ventilation
- Air distribution upgrades (overhead, hybrid overhead, perimeter fan coil, and chilled beam)
- VFDs on all supply and return/exhaust fans
- AHU controls upgraded
- VFDs on new air handlers with fan array
- AHU VFDs and static pressure reduction
- Floor isolation dampers
- VFDs set to auto mode and confirm speed settings

Demand control ventilation

Reducing fresh air demand supply to unoccupied spaces was another common energy conservation measure in the retrofits in this study. This included either an occupancy sensor or CO_2 sensor and controls to reduce outside air supply volumes.

- Demand control ventilation and CO_2 sensors
- Reduced ventilation nights and weekends
- Fresh air controls with presence detectors enabling shutdown when areas are unoccupied
- Carbon Monoxide control on garage ventilation

Outside air economizer

Free cooling from 100% outside air or increased supply of outside air during shoulder seasons provided some energy savings, particularly in all-air systems.

- Dedicated outside air system with heat recovery
- Free cooling coils in each DX unit
- Plate-and-frame heat exchanger for free cooling
- New dampers and controls for air economizers on all AHUs

envelope

Façade recladding or window replacement

A few buildings in this study undertook a complete facade replacement if the building envelope was past its useful life or significantly out of date. Other more modest approaches included simply replacing windows or a selection of windows with products with higher insulation values, solar performance, and air tightness.

- Facade complete recladding
- High-performance window replacement
- Window refurbishment and coatings
- Original glazed curtain wall, double-hung windows replaced with high performing, super-insulating windows
- Selective replacement of some windows from single-pane to double-pane

Air tightness improvements

A simple low-cost measure for buildings with older facades was to reduce air leakage through weather stripping, caulking, gaskets, and other retrofit measures that kept windows in place.

- Weather stripping replaced and new gaskets installed
- Passive stack effect mitigation
- Façade air tightness caulking for the entire tower

Additional insulation

On complete facade recladding or roof replacement projects, a low-cost ECM was to increase insulation on exterior walls and roof surfaces. This included bringing insulation values up to code or even beyond code.

- Super-insulated walls and roof with continuous air barrier
- Radiative barrier
- Additional insulation on exterior walls
- Additional insulation on roof and below grade level

plug loads

Energy Star appliances

Some owners and tenants initiated policies or lease clauses requiring Energy Star appliances or appliances that comply with NYC Energy Efficiency Code.

- New Energy Star appliances
- Appliances and plug loads in tenant spaces compliant with NYC Energy Efficiency Code

No data servers in building

A major energy user within tenant spaces has been data servers and increased computation needs over the past decades. But with the rise of cloud computing and remote servers, that energy consumption has been moved to remote locations outside the footprint of some buildings in this study.

- No data servers in building — all cloud computing
- Cloud computing to limit data center space and energy use
- Majority of tenant servers moved to the cloud

Other plug load ECMs

Other creative approaches to reducing energy consumption from plug loads included monitoring systems, plug load reduction studies, design guidelines for plug loads, and Green Leadership programs.

- Plug load reduction study and advanced power strips installed on select tenant floors
- Remote, app-driven control for tenants
- High Performance Design Guidelines require efficient controlled tenant equipment
- Green Leadership team partners with tenant services team to purchase from SMART suppliers that provide Energy Star appliances and computers for new tenants and for existing tenants on replacement cycles

hot water

Hot water heater replacement

A few buildings in the study found energy savings through replacement of old, inefficient hot water heaters to new high efficiency condensing boilers. Some fuel switching from district steam to natural gas was also identified, though that may have had more of a positive impact on energy cost than on energy or carbon intensity.

- High-efficiency condensing boilers
- Natural gas cogen for hotel HW
- New DHW tanks and heat exchangers to optimize low temp hot water from CCHP
- Retail steam hot water heaters

Electrification of hot water generation

Interestingly a number of buildings elected to shift from central hot water generation and storage to point-of-use hot water heaters. For office buildings with low demand for hot water this reduced heat loss during storage and distribution which can be substantial for high peak, low volume buildings like tall office buildings.

- New electric domestic hot water tanks
- Local electric hot water heaters
- Electrical point of use hot water heaters for hand washing and low-flow fixtures

Other hot water ECMs

Some innovative ideas implemented for hot water generation included condensate heat recovery and hot water heater setpoint temperature schedule optimization.

- Condensate heat recovery
- Adjust schedule on hot water heater that serves bathrooms, fitness center, and kitchens

other ecms

Upgraded or new control system

Control technologies have advanced so much in the past decades that nearly all buildings in this study found energy savings through installing a completely new building management system or upgrading an existing BMS. With increased controllability energy savings can be achieved through reducing airflows, setpoints, lighting, and other systems during unoccupied or favorable weather conditions.

- New BMS installed on majority of equipment
- Upgrade of existing BMS programming and modernized controls
- Conversion of pneumatic controls to DDC
- Supervisory Control Management System (SCMS)
- Cloud-based building energy management system (EMS), some more advanced than others, with the most advanced offering real-time energy management (RTEM) capabilities
- Tenant Energy Management Software and Engagement Program
- BAS system upgraded and integrated with ventilation system and river pump system

Renewable energy

Due to the limited roof space availability only a few of the tall office buildings in this study utilized on-site renewable energy generation technologies such as solar photovoltaic or solar hot water panels.

- Solar thermal domestic hot water
- Rooftop solar PV
- Solar hot water for hotel hot water

Regenerative elevators

Tall buildings' elevator demands inherently add a small percentage of base building energy consumption to all tall buildings compared to low-rise buildings. But regenerative drive motors and destination dispatch can reduce elevator energy consumption at a small premium when elevators are replaced at the end of their useful life or during a building-wide repositioning.

- Regenerative drives on modernized elevators
- Destination-dispatch regenerative drive elevators

Other ECMs

Some ECMs did not fall into typical categories or were uniquely suited to a single property, but should still be highlighted as potential ECMs. These included: replacement of domestic water pumps, continual audits and optimization of various schedules and controls, green roofs, submetering, and Demand Response Programs.

- Replaced domestic water pumps
- Continual audit of BMS settings to align HVAC schedules with lease requirements
- Seasonal audits to adjust BMS setpoints for weather changes
- Night Audits to ensure lights are off, sensors are working, equipment is only being used as needed, etc.
- Demand Response Program
- Roof and ground floor vegetation
- Native plant species green roof
- Submetering of electrical loads, lighting, plug load, mechanical equipment, and emergency generator
- Integration with mobile app and dashboard with occupancy, DLH, and temperature and humidity sensors

Glossary of Terms and Abbreviations

AHU	Air handling unit
BAS	Building automation system
BMS	Building management system
CAV	Constant air volume
CCHP	Combined cooling, heating, and power system
CHP	Combined heat and power
CO	Carbon monoxide
DCV	Demand control ventilation
DDC	Direct digital control
DHW	Domestic hot water
DX unit	Direct expansion air conditioning unit
ECM	Energy conservation measure
EMS	Energy management system
ERV	Energy recovery ventilation
ESCO	Energy service company
ESG	Environment, social, governance
EUI	Energy use intensity
GHGI	Greenhouse gas intensity
HRV	Heat recovery ventilation
HW	Hot water
LEDs	Light-emitting diode lights
M&V	Measurement & verification
MESA	Managed energy services agreement
OA	Outdoor air
PRV	Pressure reducing valves
RCx	Retrocommissioning
RTEM	Real-time energy management system
SCMS	Supervisory control management system
Solar PV	Solar photovoltaic system
VAV	Variable air volume
VFD	Variable frequency drive

conclusions and path forward

New York City's LL97 sets ambitious GHG emissions targets, and a large number of its high rises are over the limits and will require significant reductions, particularly to reach the 2030 limits. Many questions have arisen about the ability to transform New York's existing skyline into high performing buildings with dramatically lower carbon emissions — especially high-rise office buildings.

This survey profiles a diverse set of eighteen projects that undertook a deep retrofit resulting in significant energy reduction — an average of a 37% reduction in their site energy intensity. Even though the projects occurred prior to recent aggressive City and State climate legislation, these case studies demonstrate that it's possible to implement a deep retrofit that meets or betters the aggressive 2030 emissions limits of LL97, sometimes even by a substantial amount.

As noted earlier, we identified several key findings in this report that bear repeating:

- **Major building-wide renovation projects provide an effective vehicle for deep energy savings**
  Energy efficiency can be a strategic addition to major renovation projects, providing for some of the deepest savings while also significantly contributing to the overall property value creation.

- **Tenant spaces present strategic and essential savings opportunities**
  Tenant vacancy, turnover, or repositioning tends to be a time of reinvestment, and substantial energy savings can be found in addressing tenant spaces — a key component of a carbon mitigation plan.

  Tenant in place energy efficiency retrofits can be challenging, but highly effective.

- **Planning and analysis are foundational to a cost-effective deep retrofit**
  A comprehensive design and planning process is a necessary component of creating an effective deep retrofit that achieves predicted results at effective costs.

- **Only measured performance confers successful retrofit savings**

  Measured performance is hard to find, but vitally important to verify results: 'If you don't measure it, you can't manage it and you can't fix it.'

- **Changing context: The look forward may be different than the look back**

  Carbon will become a new performance metric, influencing ROI economics, technology choices, and retrofit project motivations, costs and benefits.

The Path Forward

Building retrofits have many motivations, and are often complicated, multiyear projects. Nonetheless, they are an essential part of achieving our city and state's climate goals. This report identifies several central issues as part of the path forward to help accelerate and scale high-rise office deep retrofit projects.

A Critical Opportunity: Tenant turnovers and leases

Substantial energy and emissions reductions can be found in addressing tenant spaces. Virtually all of the non-owner-occupied building projects took advantage of lease changes, or a building repositioning to attract a new or different kind of tenant, to make major changes within tenant spaces (or the building systems serving those spaces). These tenant-related retrofits often realized significant savings.

Key points that were observed in the case study projects:

- Tenant equipment and behavior drives many building energy consuming systems
- Lighting retrofits were present in nearly every case study and are more often selected and controlled by tenants
- Equipment can be changed or improved that allow for more efficient delivery of after-hour demands for HVAC systems, providing the comfort conditions only where needed instead of throughout the whole space
- Occupant density drives energy consumption; there has been a major recent trend for space "densification," resulting in much higher energy use intensity in a given space (though likely to reverse in the near term due to COVID health concerns). Efficient tenant space design can dramatically reduce the energy and emissions growth from densification in many cases
- Cloud computing vs. on-site data centers is an increasingly important opportunity. Moving data centers out of tenant spaces into the cloud has been demonstrated to result in quite significant savings, and off-site cloud servers typically operate much more efficiently
- Many tenant energy loads, including computers, appliances, and other plug loads 'unregulated' by energy code, can be significant contributors to EUI and GHGI; effective tenant space design and engagement can reduce these loads significantly.

The bottom line: to meet NYC LL97's emissions limits, there will need to be much more effort from building owners and their tenants to collaborate on energy reductions, or they will need to sort out contractually how to split fines if the building is over the limits.

Looking Forward: Carbon will be the new metric

This report includes only high-rise, deep retrofit projects that have already been completed and have at least a full year of post-retrofit energy performance data (in many cases, several years of post-retrofit data). These profiles are all retrofits with lessons learned looking backward at technologies, motivations, and market conditions of the last 10 years, while the drivers for change will certainly be different in future decades.

Looking ahead to retrofits being planned and implemented now, there is a new regulatory paradigm that is shifting to measured energy and carbon performance. New York City's Local Law 97 of 2019, the centerpiece of the City's world leading Climate Mobilization Act, establishes GHG Intensity limits starting in 2024, and getting dramatically more stringent in 2030 and beyond, with very significant financial penalties when those limits are exceeded. Other building performance standards adopted in leading jurisdictions in the US and other countries are also driving new attention to measured building performance.

Regulatory compliance with these new carbon emissions limits, including the changing carbon intensity of the electric grid, compels building owners to look very differently at building retrofits. With carbon as the metric, a different set of technologies must be considered.

Faced with significant penalties if a building does not meet stringent emission limits, owners will be much more focused on improved energy and carbon performance, and reducing GHG emissions. Instead of just considering projected energy savings from modeling, there are likely to be new contractual models that deliver carbon savings to avoid the penalties. There is also the potential for monetization of GHG reductions with the trading system envisioned in LL97 — the legislation requires a study and implementation plan for a trading system that would allow for some buildings to purchase "emissions reductions credits" from other buildings, where they can be delivered at a lower cost. This system could provide a new revenue stream for the most forward thinking owners who can execute lower cost retrofits that perform below their respective LL97 limits, thus providing a monetizable carbon credit.

A carbon metric results in major changes looking forward:

- Carbon reductions will be a different lens to look through than energy cost
- Expectations of a very clean electric grid can dramatically influence heating decarbonization decisions
- Building ROI considerations and retrofit economics will change:
  - Project paybacks shorten when large potential penalties are taken into account

- There may be new potential revenue streams from trading when buildings can be made to operate under the emissions limits

New Initiatives: Scaling change

In order to better understand how to deliver very low-carbon high-rise buildings, a number of planning efforts are now underway:

The NY State Empire Building Challenge ■ As announced in Governor Cuomo's 2020 State of the State, NYSERDA is launching the Empire Building Challenge, which plans to leverage $50 million in State funds to create public-private partnerships with leading real estate owners, occupants, and solution providers to:

- Develop and demonstrate low-carbon retrofit approaches that can be replicated across the State's existing high-rise commercial office and multifamily buildings.
- Recruit best-in-class equipment manufacturers, solution providers, and other businesses to invest in business development, innovation, and product development to overcome the barriers preventing existing high-rise buildings in NYS from achieving carbon neutrality.
- Establish New York City as a hub for successful retrofits that create jobs and local economic development while reducing greenhouse gas emissions.

Carbon Neutral Buildings Roadmap ■ NYSERDA is also leading development of a Carbon Neutral Buildings Roadmap to chart the course for the buildings sector to reach carbon neutrality by 2050, as required by the NY State Climate Leadership and Community Protection Act (CLCPA). Some building typologies have an easier path to carbon neutrality, and it is widely acknowledged that high-rise buildings present some of the most vexing challenges. Documenting more, and deeper, retrofits, like those identified in this report, will help guide what is possible as part of that statewide roadmap.

Building Electrification Roadmap ■ To reach carbon neutrality it is necessary to phase out burning fossil fuel and begin a massive shift to electric heat and other end uses currently served by on site fuel combustion (or use of fossil driven district energy systems like the ConEd district steam system). In order to understand the more near term challenges to converting from traditional fossil fuel based heating and hot water systems, NYSERDA, in collaboration with the NY State Department of Public Service, is preparing a Statewide Building Electrification Roadmap that will identify challenges and barriers to building electrification in the near term, to chart the course for the building sector to reach carbon neutrality.

Closing

As this report is being finalized, in the summer of 2020, the landscape is very different from when it began. Demand for office space in the post-COVID world, and other unforeseen changes, will dramatically influence the decision-making process of owners and tenants of office buildings.

Additionally, the timing of this research occurred during the COVID-19 pandemic and many owners reported large office buildings without a significant drop in energy use despite being mostly unoccupied. This observation has not yet been fully researched and needs further study.

While this study has intentionally focused specifically on high-rise office buildings, a similar survey is needed to understand successful deep retrofits of high-rise multifamily buildings. Given the prevalence of large, high-rise multifamily buildings covered by LL97, and the many NYC stakeholders considering how to bring them down to the new GHG intensity limits, a similar global review of high-rise residential buildings would provide for an understanding of current practice and document what is working.

Finally, in the course of this research, the authors identified a number of "buildings to watch" (see left), where a promising deep retrofit project is underway but not yet complete, or not yet fully occupied with a year of measured energy data. A follow up to this survey, in two to three years, which includes several retrofits resulting from LL97 early actions, as well as key high potential projects outside of NYC, would be essential to better understand how the state of the retrofit market is evolving and the levers that can continue to accelerate and scale its progress.

Buildings to Watch

New York, New York:
Citigroup Headquarters
1333 Broadway
Empire State Building "2.0"
1100 Avenue of the Americas
660 5th Avenue
Rockefeller Center
1270 Avenue of the Americas
825 3rd Avenue
75 Rockefeller Plaza

Indianapolis, Indiana:
99 High Street

Boston, Massachusetts:
Regions Tower

Looking ahead to retrofits being planned and implemented now, there is a new regulatory paradigm that is shifting to measured energy and carbon performance.

Regulatory compliance with these new carbon emissions limits compels building owners to look very differently at building retrofits.

With carbon as the metric, a different set of technologies must be considered.

methodology and approach

In preparing this report, the first task was to create a long list of buildings that had the potential to be featured in this compendium. A set of technical criteria that all buildings would have to meet for consideration was established, and is listed here:

- Buildings' primary use must be office.
- Buildings must be 10 stories or taller, and ideally over 15 stories tall.
- Buildings may be from geographically diverse locations, but must have a climate comparable to that of New York City.
- Buildings must have metered energy data from both before and after the energy retrofit. Ideally, this data would be publicly available, reported in a disclosure program or somewhere similar.
- Buildings must have deep energy savings due to a retrofit project or process, with savings of at least 20%, but ideally with savings greater than 30%.

Using this set of criteria, a list of candidate buildings was assembled using public disclosure data from New York City, Boston, Chicago, DC, Philadelphia, and Minneapolis. 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); buildings which were featured in other institutional databases such as the US Department of Energy's Better Buildings Initiative database, the European Commission-supported Construction21 database, and the Rocky Mountain Institute's Retrofit Depot; and finally, buildings which were featured in various publications such as High Performing Buildings Magazine, the Tokyo 30 Low Carbon Buildings Report, and Racine's Exemplary Buildings: Success Stories from Brussels. 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 commercial real estate, building systems engineering, and green buildings circles. 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 high-rise office buildings, but all but one lacked accessible metered energy data, likely due to privacy customs in Europe. The well-known, retrofitted Deutsche Bank Headquarter towers in Frankfurt, Germany, was one such example. The team was also referred to a number of buildings that are currently undergoing or have recently undergone a retrofit. These buildings didn't yet have available post-retrofit energy data, but are included in the "Buildings to Watch" list on page 56.

Once this subset of buildings meeting the technical criteria was established, practical considerations were then taken into account. 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. Analyzing disclosure data from Philadelphia, four high-rise commercial office buildings were identified — all built by 1983 — that met the NYC LL97 2024 limit for GHGI — 4.5 kg CO_2/sf. It's very likely that these buildings' energy use has been reduced since their opening, but the team was not able to arrange interviews for these buildings. Therefore, this study should not at all be considered a comprehensive survey of high rise commercial buildings that have undergone deep energy retrofits. Indeed, as discussed in the introduction, our goal was to identify 15–20 representative buildings meeting the profile criteria. Finally, in three 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 18 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 energy conservation measures (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. Greenhouse Gas Intensity (GHGI) was calculated using carbon intensity factors as stated in NYC Local Law 97 legislation 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.

After the team assembled retrofit information for each building, a building profile was prepared and sent to the interviewees for each building for their review. Nearly all comments on the subject matter of the profiles were accepted by the team before publishing this report.

Finally, it's important to note that, at the mid-point of this project, the team conducted three workshops via videoconference with community stakeholders. The goal of these workshops were two-fold. The first goal 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. The three workshops were organized by categories of attendees — the first workshop was held with technical experts and building systems engineers in attendance, the second workshop was held with government and non-profit policy makers in attendance, and the third workshop was held with commercial real estate owner representation in attendance. Overall, 19 stakeholders attended the workshops, a list of whom is included in the Credits and Thanks section of this report. The workshops included 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.

Fuel Type	Carbon intensity factor
Electricity	0.084 kg CO_2/kBtu
Natural Gas	0.053 kg CO_2/kBtu
Fuel Oil	0.073 kg CO_2/kBtu
District Steam	0.046 kg CO_2/kBtu

project references

1. United Nations Headquarters
Publications
Seventeenth annual progress report on the implementation of the capital master plan. Item 136 of the provisional agenda, 74th session. August 8, 2019. Report of the Secretary-General. United Nations General Assembly.

Assessing the Carbon-Saving Value of Retrofitting versus Demolition and New Construction at the United Nations Headquarters. December 6, 2016. Syska Hennessy Group, and Vidaris, Inc. <https://www.vidaris.com/uploads/files/assessing-the-carbon-saving-value-of-retrofitting-versus-demolition-and-new-construction-at-the-united-nations-headquarters-199.pdf>.

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United Nations Renovations: Original Scope Reduced and Project Over Budget, but Lessons Learned Could Improve Future Projects. Report to the Chairman, Committee on Foreign Relations, United States Senate. GAO-15-414. May, 2015. United States Government Accountability Office (GAO). <https://www.gao.gov/assets/680/670218.pdf>.

United Nations Headquarters Campus Renovation of Facades. Heintges & Associates. April 27, 2017. Docomomo. <https://docomomo-us.org/news/united-nations-headquarters-campus-renovation-of-facades>.

Energy Data
Pre- and Post-retrofit energy data* taken from Table 2, Seventeenth annual progress report on the implementation of the capital master plan. Item 136 of the provisional agenda, 74th session. August 8, 2019. Report of the Secretary-General. United Nations General Assembly.

*Energy data is aggregated for the entire campus — the Secretariat Building (805,225 sf), the General Assembly (251,560 sf), Basements + Parking (1,231,300 sf), Hammarskjold Library (60,000 sf), South Annex Building (20,000 sf), and the Conference Building (224,000 sf). The Secretariat Building is the subject of this profile.

2. Byron Rogers Fed. Building
Interviewees and Reviewers
Bill Green, The RMH Group
Andrew Olsen, GSA Region 8
Bryan Zach, GSA Region 8
Richard Stebbins, GSA Region 8
Tyler Cooper, GSA Region 8

Publications
[2.1]Matthew Bartels and Michelle Swanson, "From Retro," for High Performing Buildings Magazine (HPBM), ASHRAE, Summer 2016. <https://www.hpbmagazine.org/byron-g-rogers-federal-building-denver-colo/>.

Case Study. The Retrofit Depot. Rocky Mountain Institute. <https://rmi.org/wp-content/uploads/2017/04/Buildings_ByronRogers_CaseStudy_2009.pdf>.

Energy Data Source*
Pre-Retrofit**: HPBM Magazine

Post-Retrofit**: Energize Denver dataset, City of Denver, Colorado <www.EnergizeDenver.org>. 2018.

*The EUIs reported have been calculated jointly for the Byron Rogers Federal Office Building (FOB) and adjacent Byron Rogers Courthouse, which share a central plant. The post-retrofit EUI of the FOB alone is estimated to be in the mid 30s.

**Pre-Retrofit GHGI is calculated based on an estimated fuel mix; post-retrofit fuel mix is estimated.

3. 1177 West Hastings Street
Interviewees and Reviewers
Alex Lau, Golden Properties Ltd
Kenric Lee, Golden Properties Ltd

Energy data source
Pre- and Post-Retrofit energy data provided by Golden Properties Ltd*

Post-Retrofit data was given from July 2019 to June 2020, which likely includes some reduction due to Covid-associated closures.

4. Kyoto Station Mixed Use
Interviewees and Reviewers
Kazuhiro Otaka, Engineering Department, Nikken Sekki
Harunori Yoshida, Kyoto University

Publications
Harunori Yoshida, Kyoto University, and Naomiki Matsushita, Cx Planning, "Existing Building Commissioning of Kyoto Station Building" presentation for Building Commission Association Conference, Nashville, Tennessee, 2018.

Harunori Yoshida, Kyoto University, and Naomiki Matsushita, Cx Planning, "Seminar 10 — Cutting-Edge Japanese Technologies SHASE Award for Renovation Project in 2019" presentation for Building Commission Association, Orlando, Florida, 2020.

"Kyoto Station Building Heat Source / Air Conditioning Equipment Renovation Commissioning Project" for 7th Air Conditioning and Sanitation Society Special Award "Renewal Award" by Kyoto Station Building Development Co., Ltd., Kenken Design Co., Ltd., and Sand Thermal Engineering Co., Ltd., for Building Commission Association, NPO, October, 2018.

James Scott Brew and Tomoaki Ushio, "Kyoto Station Undergoes Radical Energy Retrofit," for High Performing Buildings Magazine (HPBM), ASHRAE, Summer 2020. <https://www.hpbmagazine.org/kyoto-station-kyoto-japan/>.

Energy Data Source
Pre- and Post-Retrofit energy data provided by Harunori Yoshida, Kyoto University

5. 560 Lexington Avenue
Interviewees and Reviewers
Gene Boniberger, Rudin Property Management

Thomas Fletcher, Rudin Property Management

Eugene Hennessy, Rudin Property Management

Luis Rios, Rudin Property Management

Energy data source
Pre- and Post-Retrofit energy data provided by Rudin Property Management

6. Five Manhattan West
Interviewees and Reviewers
Daniel Kindbergh, Brookfield Properties
Sabrina Kanner, Brookfield Properties

Energy Data Source
Pre- and Post-Retrofit energy data provided by Brookfield Properties

7. NEC Headquarters
Interviewees and Reviewers
NEC Building Facilities
Satoshi Chida, Tokyo Metropolitan Government
Yuko Nishida, Renewable Energy Institute

Energy Data Source
Pre- and Post-Retrofit energy data provided by NEC Building Facilities

8. District Center
Publications
[8.1]"MetLife District Center," Better Buildings, U.S. Department of Energy. <https://betterbuildingssolutioncenter.energy.gov/showcase-projects/metlife-district-center>.

"Metlife Investment Management's District Center Recognized For Sustainability Leadership," Better Buildings, U.S. Department of Energy. January 23, 2020. <https://betterbuildingssolutioncenter.energy.gov/beat-blog/metlife-investment-management%E2%80%99s-district-center-recognized-sustainability-leadership>.

"MetLife Investment Management," Better Buildings, U.S. Department of Energy. <https://betterbuildingssolutioncenter.energy.gov/partners/metlife-investment-management>.

"555 12th Street Repositioning," Smith Group. <https://www.smithgroup.com/projects/555-12th-street-repositioning>.

[8.2]"MetLife Recognized for Energy Efficiency Leadership," Facility Executive. January 23, 2020. <https://facilityexecutive.com/2020/01/metlife-investment-management-recognized-energy-efficiency-leadership/>.

[8.3]Trey Barrineau, "District Center: A Downtown D.C. Office Reborn as a Smart Building," for Development Magazine, NAIOP, Winter 2019/2020. <https://www.naiop.org/en/Research-and-Publications/Magazine/2019/Winter-2019-2020/Business-Trends/District-Center-A-Downtown-DC-Office-Reborn-as-a-Smart-Building>.

Energy Data Source
Pre- and Post-Retrofit energy data taken from DC Building Energy Benchmarks (2014 and 2018 respectively).

9. Millennium Building
Interviewees and Reviewers
Eugenia Gregorio, Gregorio Sustainability, LLC, formerly of The Tower Companies

Publications
The Millennium Building. Better Buildings Initiative. US Department of Energy (DOE). <https://betterbuildingssolutioncenter.energy.gov/showcase-projects/tower-companies-millennium-building>

"The Millennium Building Wins 'Outstanding Building Of The Year (Toby)' Earth Award" Press Release by The Tower Companies. May 2, 2016. <https://towercompanies.com/wp-content/uploads/2016/05/Press-Release-Millennium-Building-wins-a-TOBY-Award.pdf>.

Alexandrea Harry. Increasing Tenant Engagement Through Plug Load Management. Institute for Market Transformation (IMT). 2016. <https://www.imt.org/resources/increasing-tenant-engagement-through-plug-load-management/>.

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"Bright Future For Nation's Capitol Office Building Launches Largest Solar Array Of Its Kind" Press Release by The Tower Companies. January 20, 2015. <https://towercompanies.com/wp-content/uploads/2016/01/1909-K-Solar-Press-Release-DE-Solar.pdf>.

Energy data source
Pre- and Post-Retrofit energy data taken from DC Building Energy Benchmarks (2011 and 2018 respectively).

10. Empire State Building
Interviewees and Reviewers
Dana Schneider, Empire State Realty Trust

Publications
Dana Schneider and Paul Rode, "Energy Renaissance," for High Performing Buildings Magazine (HPBM), ASHRAE, Spring 2010. <https://www.hpbmagazine.org/content/uploads/2020/04/10Sp-Empire-State-Building-New-York-NY.pdf>.

"Empire State Building Case Study Cost-Effective Greenhouse Gas Reductions via Whole-Building Retrofits: Process, Outcomes, and What is Needed Next," by JLL, Clinton Climate Initiative, Rocky Mountain Institute, and Johnson Controls. <https://www.esbnyc.com/about/sustainability>.

Eric Harrington and Cara Carmichael, "Project Case Study: Empire State Building," for RetroFit: a Rocky Mountain Institute Initiative, 2009. <https://rmi.org/wp-content/uploads/2017/04/Buildings_Retrofit_EmpireStateBuilding_CaseStudy_2009.pdf>.

Amy Cortese, "Makeover on 34th Street," in New York Times, October 4, 2008. <https://www.nytimes.com/2008/10/05/realestate/commercial/05sqft.html>.

Energy Data Source
Pre- and Post-Retrofit energy data provided by Empire State Realty Trust

11. 222 South Riverside Plaza
Interviewees and Reviewers
Mike Murphy, Grumman/Butkus Associates
Fiona Martin McCarthy, Grumman/Butkus Associates
David Eldridge, Grumman/Butkus Associates

Publications
City of Chicago, Retrofit Chicago website. "Fifth Third Center — 20% Energy Reduction Achieved in 2016 and 35% Energy Reduction Achieved in 2018!" <https://www.chicago.gov/city/en/sites/retrofitchicago/home/participants/fifth-third-center.html>.

Sudo, Chuck. "Nikki Kern Talks About The Renovations At 222 South Riverside," 16 June 2016, Bisnow Chicago. <https://www.bisnow.com/chicago/news/office/inside-jlls-40m-renovations-at-222-south-riverside-61462>.

222 South Riverside Plaza | JLL website. Renovations page. <http://www.222sriverside.com/renovations.html>.

[11.1]Illinois ASHRAE. Technical Awards 2016, Group Poster: JLL and Grumman/Butkus Associates. "222 South Riverside Plaza: Mechanical Value-Add Improvements." <https://illinoisashrae.org/downloads/Tech_Awards_Docs_2016/group_poster_1.pdf>.

Energy data source
Pre- and Post-retrofit energy data are from Chicago's public benchmarking data and from the Retrofit Chicago website.

*Pre-retrofit fuel mix is estimated.

12. One Battery Park Plaza
Interviewees and Reviewers
Gene Boniberger, Rudin Management Company
Thomas Fletcher, Rudin Management Company
Eugene Hennessy, Rudin Management Company
Luis Rios, Rudin Management Company

Energy data source
Pre- and Post-Retrofit energy data provided by Rudin Management Company

13. 125 Maiden Lane
Interviewees and Reviewers
Sean Neill, (formerly) Transcend Equity Development
Patrick O'Donnell, NYCEEC

Publications
Deal Spotlight: 125 Maiden Lane" by NYCEEC, March 2016

"Case Study: 125 Maiden Lane" by SCI Energy

Energy Data Source
Pre-Retrofit energy data private

Post-Retrofit energy data from NYC LL84 Disclosures (2016)

14. 1001 Pennsylvania Avenue
Publications
[14.1]"1001 Pennsylvania Avenue," Better Buildings, U.S. Department of Energy. <https://betterbuildingssolutioncenter.energy.gov/showcase-projects/1001-pennsylvania-avenue>.

"Nuveen Real Estate," Better Buildings, U.S. Department of Energy. <https://betterbuildingssolutioncenter.energy.gov/partners/nuveen-real-estate>.

"1001 Pennsylvania Avenue NW," Hartman-Cox Architects. <https://www.hartmancox.com/1001-pennsylvania-plaza>.

"1001 Pennsylvania Avenue." Hines. <https://www.hines.com/properties/1001-pennsylvania-avenue-washington>.

Energy Data Source
Pre- and Post-Retrofit energy data taken from DC Building Energy Benchmarks*

*Pre-Retrofit data is taken from a 2012 entry, and Post-Retrofit data is taken from a 2018 entry that excludes retail areas; we assume the 2012 entry excludes retail also, although this is not explicitly stated. The 2018 reported GFA is used to calculate intensities for both pre- and post-retrofit conditions.

15. Sun Life Assurance
Interviewees and Reviewers
Don Mclauchlan, Elara Engineering
Matt Swanson, Elara Engineering

Publications
ASHRAE 2012 Excellence in Engineering Illinois Award and Technology Award at ASHRAE Society Level, by Elara Engineering

Energy Data Source
Pre- and Post-Retrofit energy data taken from ASHRAE Technology Award profile*

*Pre-Retrofit GHGI is calculated based on an estimated fuel mix; post-retrofit fuel mix is estimated.

16. 801 Grand
Interviewees and Reviewers
David Eldridge, Grumman/Butkus Associates

Publications
David Eldridge, "Leveling Up: Using Measurement & Verification to Improve an Office Building," for High Performing Buildings Magazine (HPBM), ASHRAE, Fall 2019. <https://www.hpbmagazine-digital.org/hpbmagazine/fall_2019/MobilePagedArticle.action?articleId=1517660#articleId1517660>.

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Energy Data Source
Pre- and Post-Retrofit energy data from HPBM (2010 and 2016 respectively)

17. TfL Palestra Building
Interviewees and Reviewers
Colin Grenville, Erebus Environment Limited
Quinten Babcock, Transport for London

Publications
[17.1]TfL Partnership with E.ON Transforms Performance at Palestra. Better Buildings Partnership (UK BBP). December 4, 2019. <https://www.betterbuildingspartnership.co.uk/tfl-partnership-eon-transforms-performance-palestra>.

[17.2]Palestra Project Details. Buro Happold. <https://www.burohappold.com/projects/palestra/#>.

TfL Palestra Building Fitout. Pringle | Richards | Sharratt | Architects. <http://www.prsarchitects.com/projects/workplace/tfl-palestra-building-fitout>.

Optimizing Energy Efficiency of the Palestra Building. Becca Allen. Spring 2006. The Pennsylvania State University. <https://www.engr.psu.edu/ae/thesis/portfolios/2006/rsa126/Final%20Report/Allen-Thesis%20Full%20Report.pdf>.

Energy Data Source
Pre- and Post-Retrofit energy data taken from the UK's Real Estate Environmental Benchmark (REEB) (2011 and 2019 respectively, although retrofit activities began in 2010)

18. 330 West 34th Street
Interviewees and Reviewers
Dan Egan, Vornado Realty Trust

Energy Data Source
Pre- and Post-Retrofit energy data provided by Vornado Realty Trust

about this report

Client Team

Michael Reed, New York Energy Research and Development Authority (NYSERDA)

Project Team

Byron Stigge, Level Infrastructure
Ryan Laber, Level Infrastructure
Richard Yancey, Building Energy Exchange
Yetsuh Frank, Building Energy Exchange
Adam Hinge, Sustainable Energy Partnerships

Workshop Attendees

Mark Chambers, NYC Mayor's Office of Sustainability
Aaron Ordower, NYC Mayor's Office of Sustainability
Gina Bocra, NYC Dept. of Buildings
Ian Graham, NYC Dept. of Buildings
Donna DeCostanzo, Natural Resources Defense Council
Lindsay Robbins, Natural Resources Defense Council
Chris Corcoran, NYSERDA
Dan Egan, Vornado Realty Trust
JP Flaherty, Tishman Speyer
Sydney Mainster, The Durst Organization
Charlotte Matthews, Sidewalk Labs
Zach Steinberg, Real Estate Board of New York
Dan Kindbergh, Brookfield
Sabrina Kanner, Brookfield
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