

## **An all-electric Passive House renovation of a 100-year-old skyscraper: lessons learned**

*Cecil Scheib, New York University*  
*Michael Syracuse, FXCollaborative Architects*  
*Lois Arena, Steven Winter Associates*  
*Jeffrey Rios, AKF*  
*Marcin Polak, Con Ed*

### **ABSTRACT**

Rubin Hall, a landmark New York City building, was once a hotel and has been a student residence for over 50 years. At 17 stories and 156,000 square feet, its brick and masonry construction with steam heat, housing 700 residents, is typical of almost one billion square feet of pre-war multifamily construction in NYC.

The project is targeting Passive House EnerPHit certification, potentially making it the largest certified building retrofit of its type in the world. Triple-pane windows that meet landmarks preservation standards will replace steel single glazed windows, insulation will be added from the inside to the existing non insulated masonry walls, extensive air sealing throughout will be included. The renovation will add ventilation with energy recovery, reducing energy use by over 50% compared to the existing building (including adding air conditioning) while improving resiliency, indoor air quality and sound control. And an all-electric heat pump will be installed on the roof within landmarks district accepted sightlines.

The retrofit brings many challenges: mechanical and architectural, historic preservation, constructability, and cost. Because it is so representative of needed electrification and energy efficiency improvements throughout NYC's building stock, the project has been strongly supported by NYSERDA, Con Ed, AIA New York and local government. The owner believes that the total cost of ownership is lower with an EnerPHit design than with competing alternatives (including the "do nothing" or "business as usual" paths).

The session will cover the process from the pre-design study, financial analysis, and owner approval, through incentives, funding, and finally construction. It will focus on lessons learned that will benefit program designers, and aid other owners, architects, and engineers to do similar projects successfully.

### **Introduction**

With over 53,000 students, New York University is the largest private university in the United States. It is also one of the largest employers in New York City, with more than 19,000 faculty, staff, and administrators occupying about 15,000,000 owned and leased square feet in 200 buildings spread across Manhattan and Brooklyn. NYU's climate commitments include a 2007 pledge to reduce greenhouse gas emissions intensity from buildings 30% from the 2006 baseline in ten years (achieved five years early, in 2012, and updated to a net 50% reduction from the 2006 baseline by 2025) and carbon neutrality by 2040. Buildings represent over 99% of NYU's Scope 1 & 2 emissions, as well as over 2/3 of New York City's (NYC 2022), so deep

reductions are required to confront the climate challenge. Due to its setting in a highly urban, fully built-out area, full-building renovations are a key opportunity to achieving these deep reductions through completely re-envisioning base building HVAC and envelope systems.

Located in New York City's Greenwich Village at 35 Fifth Avenue, Rubin Hall was built in 1925 as a high-end hotel and apartment building frequented by members of New York's cultural elite. Along with an attached annex that was constructed in 1922, it was purchased by NYU in 1964 for use as a student residence. It was designated a historic landmark by the New York City Landmarks Preservation Commission (LPC) as part of the Greenwich Village Historic District in 1969, meaning LPC review and approval of many key design elements is required. It is built in the Neo-Federal style and as is common to many pre-war buildings in New York is supported by structural steel columns and beams with cast-in-place concrete floor slabs, with an uninsulated exterior envelope of red brick on terracotta block. It is 17 (15 floors + penthouse + cellar) stories and 156,000 square feet.

Rubin Hall houses 674 first-year students in 280 bedrooms. It is one of only two student residences in NYU's portfolio without air conditioning in student rooms, which has increasingly become problematic with recent heatwaves. There are two faculty residences in the penthouse, and a cellar with student laundry, mechanical space, and other support spaces. After renovation, the typical student floors will largely remain in their existing configuration, with bathrooms and some student rooms reconfigured for improved accessibility, and the lobby and second-floor common spaces renovated. The exterior envelope will be repaired and repointed, and all mechanical, electrical, and plumbing systems replaced. NYU formed an experienced team (architect, Passive House consultant, envelope consultant, and MEP engineer) to overcome challenges and achieve the highest level of performance feasible, with design beginning in 2019 and anticipated completion of construction in 2024.

While originally designed to best health and comfort practices at the time, the building's systems are now antiquated and inadequate to meet today's needs. Large, coal-fired steam radiators are sized to overcome heat loss through uninsulated walls, and often cause overheating. Windows provide the only ventilation in the building, causing either poor air quality when closed for comfort, or energy inefficiency when open for fresh air on hot or cold days (Flothow et al. 2015). The building is heated and cooled in three main zones. Student rooms are heated by two-pipe steam radiators fed by two scotch marine boilers. The second-floor amenity spaces are heated and cooled by hot and chilled water. Hot water is circulated through a steam to hot water heat exchanger and chilled water is circulated through an air-cooled chiller. The first-floor classrooms use a rooftop unit and variable air volume distribution for fresh air and cooling. Heating is supplied by the same steam radiators as the student rooms.

NYU has recently adopted progressive design standards for energy efficiency, including defining a minimum window performance and limiting air infiltration. New York City local laws include continually updated and increasingly stringent energy codes, fines for buildings that exceed threshold emissions, and while not applying to Rubin Hall as an existing structure, a phased-in ban on new natural gas connections. With no insulation, steam piping, limited rooftop and cellar space for mechanical equipment, no ductwork for ventilation, landmark restrictions, and no air conditioning, the challenges to renovate the building were many. At present energy and equipment costs, demonstrating a favorable business case for this deep energy retrofit required considering all benefits beyond just energy savings, including health, thermal and acoustic comfort, electrification and carbon reduction, and resiliency.

For all the challenges stated above, this renovation project poses a potential model for dramatic energy reductions, electrification, and resiliency for almost one billion square feet of similar pre-war multifamily construction across New York City (NYC 2016, 23). The project goes beyond deep energy retrofits with a goal of Passive House retrofit (EnerPHit) certification.

## **Energy Master Plan**

Rubin Hall's design journey began with a feasibility study in 2019 of 3 campus buildings looking at deep energy retrofit, electrification, and potential Passive House feasibility study in 2019. Energy modeling used the Passive House Planning Package (PHPP version 9.7), including inputs for project location, building geometry, envelope efficiencies, HVAC systems efficiencies, and lighting and plug loads to calculate certain energy demand metrics for the project. These metrics include the building's heating and cooling demand and the building's heating and cooling loads (before heating and cooling equipment efficiencies are factored in), compared against its source building energy demand. These four building energy demand metrics were used as the primary means of comparison for the various energy conservation measures and packages evaluated in the study. The energy model representing the as-built condition weather normalized to account for any major differences between the model's standard weather file and the actual weather during the period in which the utility bills were collected. This weather normalized model was then compared to the utility bills and calibrated further. Adjustments were made in the model to better reflect the actual DHW usage as well as the plug loads to better estimate potential savings from conservation measures in those areas.

Comparing against a "business as usual renovation", these numerous energy conservation measures (ECMs) were examined conceptually to understand their feasibility, construction cost, and their payback. NYU requested to include an analysis to determine if Passive House could be technically achieved, and if it was economically viable to do so.

Once the calibrated model was completed, potential energy savings from measures for lights and appliances were applied first. Then each ECM for the envelope and the mechanical systems was evaluated separately to determine its potential impact on the energy use of the building. Finally, all ECMs were modeled together and compared to the calibrated model to determine the total savings of the final Passive House design.

Figure 1 shows pre-retrofit energy data. The pre-retrofit, annual, whole building annual site energy use is 12,602 MMBTU.

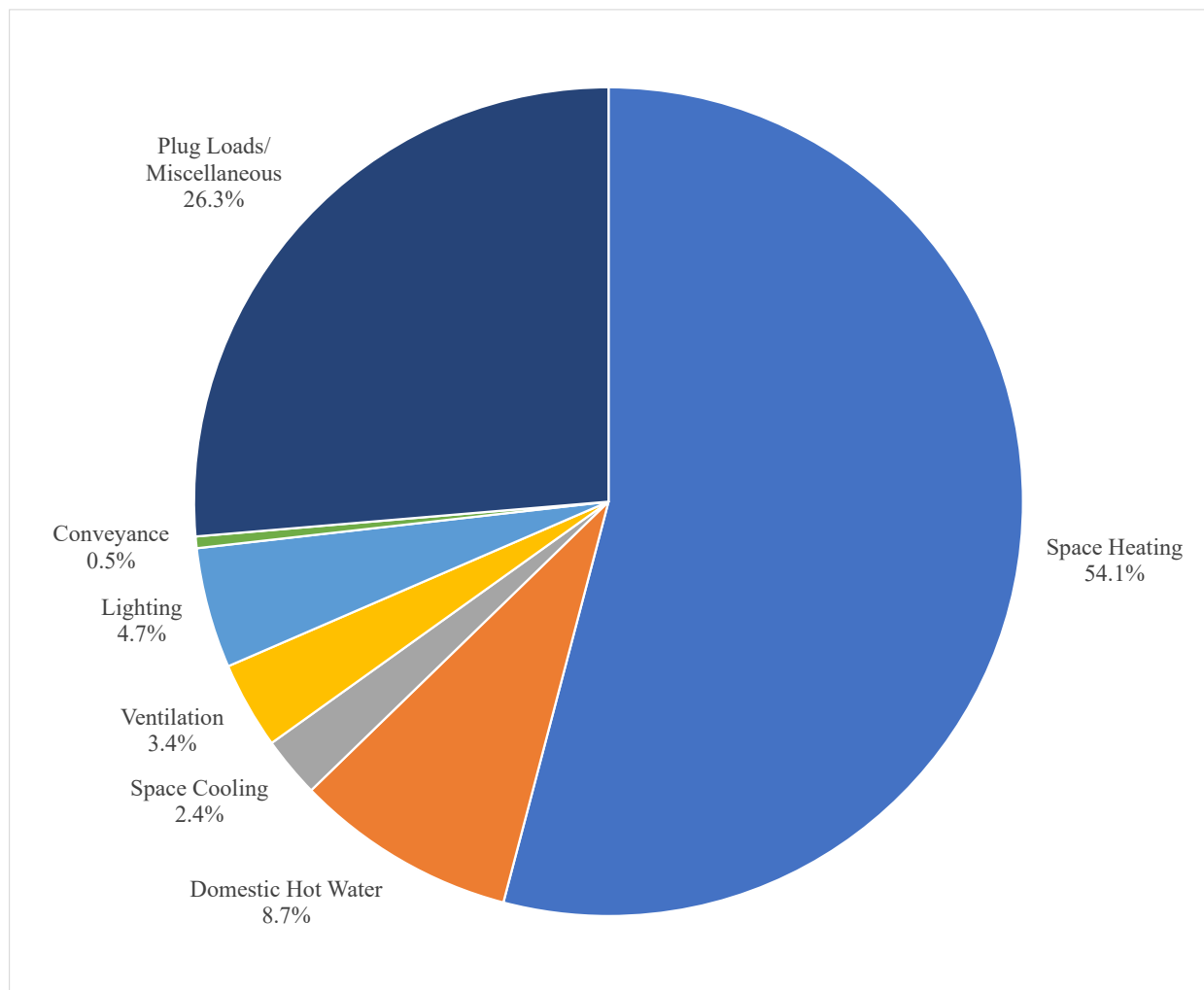


Figure 1. Pre-retrofit, annual whole building energy use data by end-use.

## Passive House and EnerPHit

The goal of Passive House design is to reduce the overall energy consumption of a building, ensure occupant comfort by reducing cold spots and drafts, and reduce durability problems in the building envelope by eliminating thermal bridging in the facade. The EnerPHit standard is the international Passive House Institute's (PHI) standard for retrofit projects. The overarching design concepts for EnerPHit projects are essentially the same as new construction Passive House projects when compared to typical construction practices:

- Increased insulation levels continuous around the entire building
- Superior air tightness
- High-performance windows
- Balanced energy recovery ventilation with filtered supply air
- Highly efficient mechanical equipment

EnerPHit certification may be pursued using either a performance path or a component path, the latter typically used for historic buildings where the exterior façade cannot be altered. The component path sets limits for minimum efficiencies throughout the building’s components, such as above and below grade insulation, window performance, and ventilation heat recovery efficiency. These requirements are climate specific and vary slightly based on the efficiency of the rest of the building envelope, the ground conditions, and the average window size. Given these variables, the criteria for Rubin Hall are shown in Table 1.

Table 1. Rubin Hall requirements for EnerPHit component path

| Evaluation criteria for EnerPHit certification component path | Rubin Hall                             |
|---------------------------------------------------------------|----------------------------------------|
| Above grade envelope with exterior insulation                 | R-value $\geq 18.93$                   |
| Below grade envelope with exterior insulation                 | R-value $\geq 4.47$                    |
| Above grade envelope with interior insulation only            | R-value $\geq 11.36$                   |
| Below grade envelope with interior insulation only            | R-value $\geq 2.39$                    |
| Window overall U-value                                        | $\leq 0.207$ Btu/hr.ft <sup>2</sup> .F |
| Ventilation heat recovery efficiency                          | $\geq 75\%$                            |

The project is also required to meet a whole building source energy demand criterion and a whole building air tightness threshold. The source primary energy demand is also known as the Primary Energy Renewables threshold, or PER. The PER criterion was developed as a means of predicting how the building will perform in the future assuming a completely renewably powered grid with both short and long-term energy storage. The PER criterion discourages the use of fossil fuels on site and allows for projects to take credit for on-site renewable energy generation. The estimated PER thresholds for the current project design are shown in Table 2. The values shown are calculated for Passive House compliance and are based on assumptions used for certification purposes. They are not meant to be predictive of actual energy use.

Table 2. Rubin Hall Primary Energy Renewables EnerPHit thresholds

| Evaluation criteria for EnerPHit certification            | Rubin Hall                                          |
|-----------------------------------------------------------|-----------------------------------------------------|
| EnerPHit compliance path                                  | Component path                                      |
| Specific primary energy renewables (PER) demand           | 46.4 kBTU/ft <sup>2</sup> <sub>TFA</sub> ·yr        |
| Specific primary energy renewables (PER) demand threshold | $\leq 52.9$ kBTU/ft <sup>2</sup> <sub>TFA</sub> ·yr |
| Whole building air tightness                              | 1.0 ACH @ 50 Pascals                                |

ACH = air changes per hour, TFA = treated floor area

The feasibility study found that a combination of interior insulation, new triple pane windows with highly insulated frames, reduced air leakage, full electrification, introduction of energy recovery ventilation to student rooms, load reduction, and either a VRF or hydronic heating/cooling system would avoid NYC emissions fines and achieve EnerPHit criteria.

## Design

While NYU did not commit to Passive House certification at the beginning of team selection and design, the findings from the feasibility study formed the basis of owner’s

performance requirements as historical, architectural, and engineering challenges were addressed.

## **Historical Considerations**

Landmarks Preservation Commission (LPC) has established rigorous rules for the restoration and modification of historic structures to preserve their historic character. These requirements, in addition to NYU's desire to be stewards of their historic buildings and the city fabric, intersected with the design of three key high-performance elements of the retrofit: the windows, the rooftop equipment, and the exterior wall assembly.

## **Windows**

The existing windows are largely non-historic single pane, steel-framed casement windows which replaced the historic wood-framed double-hung windows in 1968 and amounted to 20% of the above-grade façade area. Triple glazing is required to meet the project target U-value of 0.18 Btu/hr-ft<sup>2</sup>-F. To satisfy air infiltration targets and reinstate the historic window configuration, simulated double hung windows are required, preferably with a tilt-in lower sash and a fixed upper sash per LPC guidelines. As a high-rise building, the durability of an aluminum framed window was required.

LPC has multiple criteria for the replacement or replication of historic windows and protocols for their approval. The criteria include configuration, geometry, operation, glass area, color, and details. For the replacement of double-hung windows, the offset of the glass planes between the top and bottom sashes is also an important criterion. While there is precedent for the approval of Passive House performance simulated double-hung wood windows on low-rise townhouse-scale buildings by LPC, there are fewer precedents for the installation of high-performance aluminum-framed windows, which tend to have wider profiles due to the need for thermal breaking and insulation inside the frame. There is no precedent for the approval of installing simulated double-hung windows with full window tilt-turn operation.

Window selection was further complicated by the large size of the majority of Rubin Hall's windows, which at 6' wide by 6' tall and create large and wide-proportioned sashes that pose a challenge for tilt-turn operation. Accessibility requirements limit the mounting height of the handle to operate the window and take into account the depth of the wall assembly and the fan coil unit below the window. The limitation of the force required to operate the handle of these large windows also required consideration. The ability to clean the exterior of the window from the interior of the building is important to eliminate the need for expensive rigging for exterior cleaning. Potential rainwater intrusion from open windows is mitigated through window selection as well.

The existing exterior wall is brick with hollow terracotta block backup. Portions of this wall have been patched and infilled with a variety of materials over the life of the building, especially the areas surrounding the windows due to their previous replacement. Because the condition at each window is thus unknown and its structural capacity is uncertain and variable from window to window, the replacement windows will be supported from steel studs inboard of and independent of the exterior wall construction. Supporting windows from separate framing will ameliorate uncertainty during the limited construction timeframe.

After extensive market research, there were limited available options that meet the required criteria. The team worked closely with Wausau and Schuco to modify their window products to meet the project needs. Wausau's applicable hardware is limited due to the large size and weight of the window and ultimately could not replicate the historic configuration closely enough - and modifications to do so diminished the thermal performance to the point that it no longer met the Passive House comfort criteria. Schuco was already in the process of developing a product in response to the need for double-glazed high-performance windows in historic configurations but had not yet had the opportunity to implement it on a project. The team collaborated with Schuco to further push the product that they are developing to include triple glazing and to increase the size of the sash to meet the large openings on Rubin Hall. This resulted in a full-window tilt-turn operation which opens as a casement window (after releasing a custodial lock) for cleaning from the interior for the typical window. While the offset glazing planes between the simulated top and bottom sashes replicated the historic configuration, the flat frame surrounding them is all on one plane and did not. Thus, additional trim will be added to the sash to create a change of plane in the metal framing as well, to replicate the historic window more closely. Similarly, trim will be extended from the fixed frame into the opening to diminish the apparent width of the operable sash and bring it closer to historic proportions.

## **Rooftop Equipment**

Selecting and placing the rooftop mechanical equipment required careful coordination between the architect, mechanical engineer, acoustic consultant, structural engineer, and historic preservationist. All services, including outside air supply and exhaust, will be routed through existing shafts that were previously used for plumbing risers and as an exhaust plenum, eliminating the need for new shafts which would require significant structural reinforcement and consume valuable floor area. This is especially notable because of Rubin Hall's limited shaft space due to its previous lack of air conditioning. The location of the distributed existing shafts as they extended to the roof influenced the location of the rooftop equipment.

Rubin Hall does not have an architecturally distinctive pitched roof. Rather, it consists of a series of stepped roof levels, utilitarian bulkheads, a penthouse, and a former water tank house. The penthouse on which much of the mechanical equipment is located is of lighter-weight steel framing than the remainder of the building below. The penthouse roof structure will require reinforcement from the interior to support the new equipment through the addition of new plates welded to existing members or new structural members, in addition to dunnage framing above. Structural thermal breaks will be used at mechanical supports.

To preserve the historic characteristics of the neighborhood, visibility from the public way was considered in the placement of the new equipment. LPC has limitations for the visibility of equipment that is approvable at the staff level. Due to the extensive constraints, some equipment was more visible than the staff-approvable threshold and required approval at a public hearing. A scaffolding mockup was built to represent the mass of the rooftop equipment to allow the public and LPC Commissioners to visualize it.

## Exterior wall assembly

The historic nature of the building required that improvement to the façade occur on the interior. Probes of the existing wall and a mockup of the exterior wall assembly showed that in addition to the predominant wall construction of 4" of brick and 8" of hollow terracotta, there were many exceptions due to previous renovations and repairs, including portions of solid brick, terracotta, plaster, and paper-faced drywall. Additionally, the plaster easily crumbled and released from the substrate when it was disturbed. During the probes, the team collected brick samples and conducted lab testing to understand its porosity. That information fed into thermal analysis to understand the freeze-thaw cycling of the brick under the existing and proposed conditions.

Indicative of many existing buildings, the poor performance of the non-insulated existing concrete slab edges buried in the existing wall is a limiting factor in the overall envelope performance. The slab edge makes up 10% of the exterior vertical, above-grade surfaces.

While additional insulation is important, reducing air infiltration is paramount in controlling the mechanical loads. The existing plaster could not be relied on as an air barrier because it is in poor condition. To avoid costly patching of the plaster, control unknown patching scope that could increase uncontrollably during construction as it crumbled, and to ensure the integrity of the air barrier, a continuous ¼" thick fiberglass-faced gypsum board will be attached directly to the plaster to stabilize it and act as the primary air barrier.

The existing loose cinder fill topping on the floor slab does not permit a continuous air barrier transition from the wall to the floor. Thus, the cinder fill will be removed adjacent to the exterior wall, infilled with a smooth cementitious topping slab, and a transition membrane installed between the wall and the smooth topping slab surface. Similarly, new gypsum board will be applied to the deteriorated plaster at the ceiling to stabilize it and to provide a smooth surface for the transition membrane to be attached to. Vertical connections to interior walls will be sealed with the transition membrane.

Interior to the fiberglass-faced gypsum board, +/- 4" (2" - 3" continuous and 1 ⅝" between studs) of open-cell spray foam insulation is designed with a variable permanence vapor retarder on the stud face. Gypsum board will be installed as the finished surface. Different wall configurations were considered, but given the varied existing wall conditions, the open-cell spray foam insulation was the conservative approach and reduced the risk of trapped moisture. The insulation type and thickness were selected to meet comfort and thermal performance required by Passive House as well as to prevent thermal cycling failure in the brick. Electrical back boxes will be installed on interior walls and all mechanical piping installed interior to the full exterior wall assembly to ensure a continuous seal.

Below grade, a similar assembly will be installed at the interior of the foundation wall. An existing non-conditioned vault extends under the sidewalk and is outside of the exterior envelope. Access doors connecting these spaces will be gasketed and sealed.

## Mechanical Systems

The baseline mechanical systems for the student rooms at Rubin Hall consist of a two-pipe steam distribution system. There is no cooling in the existing student rooms. For the first and second floor offices and classrooms, cooling is provided via a rooftop unit and a few mini-

split heat pumps. The ventilation in the existing building is mostly exhaust. The domestic water heating is a centralized recirculation system using the same boilers as the heating system. Hot water consumption is assumed at five gallons per student per day for showering and general use. No cooking or dishwashing hot water is included as there are no kitchens in the rooms.

Table 3. Rubin Hall energy needs, pre-retrofit (energy baseline)

|                       |                                |
|-----------------------|--------------------------------|
| Heating demand*       | 39.6 kBtu/ft <sup>2</sup> /yr  |
| Cooling demand*       | 9.7 kBtu/ft <sup>2</sup> /yr   |
| Source primary energy | 154.5 kBtu/ft <sup>2</sup> /yr |

\*Heating and cooling demand are neither site nor source energy. This the amount of energy that needs to be added or removed from the building over the course of one year to maintain a certain setpoint regardless of the type of HVAC systems. The pre-retrofit building does not provide cooling to student spaces.

To minimize operational emissions and eliminate fossil fuels in accordance with NYU's climate goals, heat pumps were considered as the base of the proposed mechanical systems. Heat pump technology has been common for many years, but low ambient temperature heat pumps that can heat during the coldest days of the year were uncommon. Within the last 5 – 10 years heat pump technology has seen a major improvement, and the number of available products and competitors has grown significantly and continues to grow and improve. The project team evaluated the emissions impact as well as the first cost, space requirements, maintenance, acoustic and student life impacts of a traditional boiler system relative to fossil fuel free heat pump solutions. These options were evaluated by NYU, and due to maintenance concerns about refrigerant leakage in a VRF distribution system within the building, an air-to-water heat pump system was chosen. The system minimizes maintenance and HVAC noise in the student rooms and results in fossil fuel free system that can be an example for all-electric buildings in the future. The heat pumps provide hot and chilled water to fan coils located at each student room. In addition to local space conditioning provided by the fan coils, the project also provided ventilation air (pre-conditioned by all electric VRF heat pumps) to each space, using dedicated outside air units (DOAS) with energy recovery, located at the roof. This mechanically provided ventilation air helped to meet LEED and Passive House requirements, and provides the students with healthier, cleaner air, with filtered and treated ventilation provided 24/7. The DOAS units were selected with a sensible effectiveness that meets EnerPHit requirements.

In a dense student residence like Rubin Hall, domestic water heating can account for more than 10% of the annual energy consumption and resulting carbon emissions. During early design discussions both point-of-use heaters and centralized air-to-water heat pumps were discussed, but both had design challenges. The selection of the air-to-water heat pump as the space heating and cooling system created an opportunity. The design uses the hot/chilled water loop from the HVAC heat pumps as the water source side for domestic water-to-water heat pumps, and the HVAC heat pumps are sized to cover both the HVAC and domestic source loads. This will allow efficient heating of the domestic hot water while locating all the domestic systems within the building with the primary heating and storage equipment to be located within the cellar. Due to Landmark requirements and limited roof space, locating the domestic heating systems inside the building is another benefit of this strategy.

The conventional baseline HVAC solution would have been to install water source heat pumps in each residential unit, a condenser water loop throughout the building, a boiler in the

cellar, and cooling towers on the roof. This traditional design was investigated early in the process and one of the benefits of the cooling towers scheme is that it required about half the roof area compared to the all-electric heat pump option, although it is significantly taller and more visible than the all-electric option. Due to the constraints inherent to putting any mechanical equipment on the roof of this existing structure, this proved to be one of the bigger design challenges to the all-electric heat pump option that was ultimately chosen. While challenging, the result shows that it is possible for pre-war buildings of this scale to convert conventional boiler systems to an efficient all-electric solution.

## Energy Model Results

The baseline energy model for LEEDv4 and the utility (Con Ed) Clean Heat program are based on different modeling methodologies, but the results are very similar. The energy model geometry is based on the existing building plans, and envelope performance values and HVAC design from the construction documents. All other inputs are based on industry standards, the applicable energy code, or the ASHRAE 90.1 User Manual. Modeled overall LEEDv4 design energy consumption is shown in Table 4, and by end-use in Figure 2. An interesting result of the deep-energy retrofit is that “miscellaneous equipment” – mostly networking equipment for the building’s Ethernet and wireless networks – has become one of the largest loads.

Estimating peak electrical usage is important both for impacts on the local grid as well as cost implications for utility demand charges. The model predicts that the electrical winter peak (heating mode) will be about 387 kW (for a day with -4F outdoor temperature, using the TMY3 data; more typical winter peaks are modeled at about 330 kW). The summer peak (cooling mode) in the model is about 311 kW. Due to the higher lift required of the heat pumps in winter compared to summer, the winter peak is comparable but higher. The post-renovation electrical peak usage will be higher than either winter or summer peaks in the existing building (around 220 kW) since the current condition does not include air conditioning and uses fossil fuels for heating.

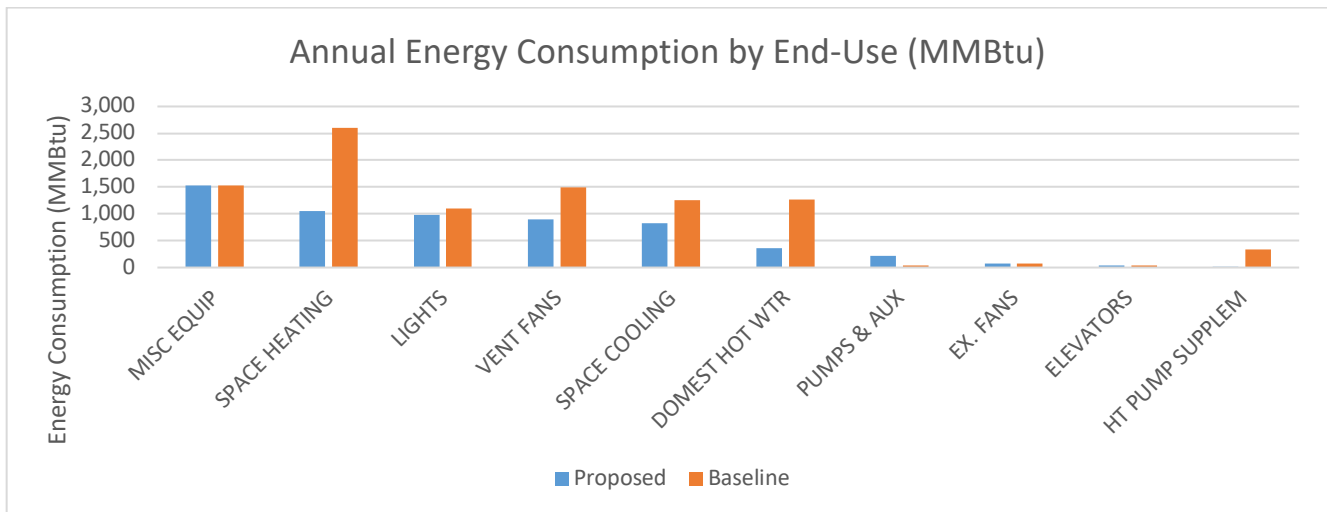
In comparison to Figure 1, showing existing whole building site energy use of approximately 12,602 MMBTU/year, the proposed design according to the LEEDv4 model (Table 4) shows more than a 52% projected reduction in site energy usage from existing conditions.

Table 4: LEEDv4 model

|                 | Total annual energy consumption (MMBTU) | Total annual energy cost | Total electricity (kWh) | Total natural gas* (therm) | Total savings (MMBTU) | Site EUI (kBtu/ft <sup>2</sup> /yr) |
|-----------------|-----------------------------------------|--------------------------|-------------------------|----------------------------|-----------------------|-------------------------------------|
| Proposed design | 5,994                                   | \$248,023                | 1,680,932               | 2,571                      | 3,726                 | 39                                  |
| Baseline design | 9,720                                   | \$433,915                | 2,599,245               | 8,491                      | 0                     | 63                                  |

\* Natural gas serving existing rooftop unit for ground-floor classrooms not part of project scope  
LEED Summary: 42.8% cost savings against modeled baseline design, qualifying for projected 16 LEED points.

Figure 2: Proposed design energy by end-use



## City, State and Utility Context and Support

On July 18, 2019, New York State enacted the Climate Leadership and Community Protection Act (Climate Act), requiring the State to reduce greenhouse gas emissions 40% by 2030, from 1990 levels. An additional emissions reduction limit of 80% by 2050 was enacted by New York City through its Climate Mobilization Act. The CLCPA requires that New York State have a net-zero carbon economy by 2050, including 70% renewable energy by 2030 and decarbonization of the electric sector by 2040. This State commitment to renewable energy from the grid is a critical part of NYU's choice to focus on all-electric solutions towards its 2040 carbon neutrality goal. In alignment with its Carbon Neutral Buildings Roadmap, NYSERDA competitively awarded the Rubin retrofit with a \$2M grant from the Carbon Neutral Community Economic Development Program for the design and construction of the highly efficient, all-electric project.

The NYS Clean Heat program is one of the initiatives developed by the state to meet the 2050 targets and place New York on a path toward carbon neutrality. The program offers a range of incentives to make heat pumps more affordable and accessible to residents, small businesses, and both commercial and multifamily building owners. The Con Ed Clean Heat Program, launched in 2020, is focused on New York City's buildings. New York City's buildings account for approximately 67% of the city's 50 million tons of carbon dioxide annual emissions. The program includes incentives to advance the adoption of efficient electric heat pump systems designed for space and water heating. Central to the program are the incentives supporting customer adoption of eligible heat pump technologies -- both cold climate air source and ground source systems. The Clean Heat Program also includes support for training and qualification of contractors, processes to assure quality installations, and education to help customers better understand and operate systems optimally.

Electrification is a crucial part of the solution, but deep efficiency and load reduction are closely intertwined together. The Clean Heat Program encourages and recognizes the benefits and value of significant building envelope upgrades to enhance thermal comfort and decrease equipment capacity, even before installing heat pumps. It is critical for customers to engage with utilities early on to develop actionable strategies that meet their objectives while identifying

areas where energy use can be better optimized. Early engagement increases the probability of a project to maximize the incentives to lower first and lifecycle costs.

The project team expects the proposed building envelope upgrades to reduce the building heating load by more than 30%. These envelope upgrades and heat pumps systems could lead to a significant incentive, based on an estimated reduction in site energy consumption and incentive level of \$400 per saved MMBTU. The actual incentive offer level will be confirmed after the design is finalized and the existing baseline conditions are verified.

## **New York City Emissions Regulations and Compliance**

New York City's caps on building emissions as set under the 2019 Climate Mobilization Act. Caps are set according to the building occupancy use classifications defined in the building code, such as Residential, Mercantile, Institution, and so forth, with a limited number of subcategories of use types of those major classification groups. Each use type is assigned an annual per-square-foot predetermined greenhouse gas emission allowance for a given compliance period. The initial two compliance periods, 2024-2029 and 2030-2034, have emissions intensity allowances set by law, with the later compliance period more stringent (lower emissions intensity allowances); emissions intensity allowances for later compliance periods will be set by NYC government in the future. The law requires buildings to pay a fine equal to the difference between the building emissions threshold for a given year and the reported building emissions for the same year, multiplied by \$268.

These caps apply to Rubin Hall, with 145,018 square feet counted as R-2 Residential and 10,219 square feet as E Educational. Total emissions thresholds (multiplying the allowance of emissions per square foot by the square feet in the building of the relevant use category) are 1,056 MTCO<sub>2</sub>e/year for the first compliance period 2024-2029, and 625 MTCO<sub>2</sub>e/year for the second compliance period 2030-2034. The proposed design with estimated emissions of 499 MTCO<sub>2</sub>e/year currently meets both the 2024-2029 and 2030-2034 thresholds, resulting in no anticipated fines.

## **Challenges and Lessons Learned**

At the time of writing, project work is planned to begin in Spring 2023, with completion anticipated for Fall 2024. In addition to its low-energy and all-electric design, NYU hopes Rubin Hall will then receive EnerPHit certification. However, the path from conceiving of a Passive House retrofit project to implementing one was neither straight nor clear. Hopefully, sharing some of the bumps in the road encountered along the way will be helpful to others.

The NYC building code does not require ventilation air be supplied to residential rooms, allowing the opening of windows by occupants to suffice, and the building did not have ventilation supplied in its existing condition. Adding this ventilation as a prerequisite for LEED (the NYU standard for new construction and major renovations, targeting Silver minimum certification) and Passive House, as well as for student health and comfort (both in terms of supplying filtered air to rooms, as well as the benefit of keeping windows closed under all weather conditions) was a major cost driver for this project. NYU students are exposed to high levels of ambient and street noise on 5<sup>th</sup> Avenue in Manhattan, but if windows must be opened for ventilation, the sound (and energy) performance enhancements of high-quality windows will

be bypassed. The existence of shafts that could be reused for supply air to floors was thus instrumental to the LEED and Passive House certification; without the ability to include floor-by-floor, wall-hung outdoor units, and cost prohibition on adding shafts throughout the 17-story structure, it's unclear how outdoor air could otherwise have been provided. Adding ventilation was a major cost for this project.

Having the time to perform a comprehensive energy and Passive House feasibility study, completed well before team selection or design kickoff, was pivotal to NYU investigation of Passive House during design. In fact, much of the energy study team was hired for project design. While the study was both detailed and thoughtful, it was a conceptual study. Very detailed analysis was required in many areas, such as in the engineering of windows to understand hardware possibilities, different options for insulation at different parts of the building, and sizing for landmarks review, which was not covered in the pre-design study. Although the results were therefore approximations, they were pivotal in setting the course toward the final scope, and overall costs and benefits remained directionally and fairly proportionally correct throughout various stages of design. NYU would recommend pre-design studies of this type for similar projects.

After team selection, the Passive House approach helped to galvanize the team around a big picture, which made decision-making around any given component a frame of reference, and reasons to keep things in the project as a comprehensive package – momentum that began with the study kickoff years before construction. It took significant time and research to solve all of the challenges raised by Passive House, and the lesson is to start early and assume complexity when dealing with an adaptive reuse project.

While considering HVAC options, especially roof mounted ASHP vs VRF, there was considerable hesitation towards VRF within student rooms. VRF is used on the rooftop for the DOAS, but the perception that maintenance or leaks could leave residents without heat for an unspecified period was a major concern. There was higher comfort with water as an energy transport medium as it was believed that leaks would be easier to discover and fix.

Scheduling full-building blower door testing in an occupied large residential apartment building is quite difficult. The tests require every interior hallway door in the building to be open and every exterior window closed. To maintain the accuracy of the test as well as alleviate concerns of the security of student belongings if their doors must be left open for a multiple hour test, tests are scheduled for unoccupied periods. The final, full-building performance test can be completed at the end of construction and before re-occupancy. A baseline test will be completed after the building is emptied of residents and just before interior work begins. A test of two mockup rooms was conducted while the building was unoccupied during Covid; in retrospect, we should have tested the whole building at that time. Lesson learned: grab your chances for blower door testing when you can.

Covid and supply chain issues continue to present ongoing challenges in cost estimation and benefit-cost analysis, as prices (especially for imported equipment or materials) can rise quite quickly. A combination of rising prices and equipment capacity recalculations resulted in a tripling of the projected price for the water-to-water heat pumps for domestic hot water for the building.

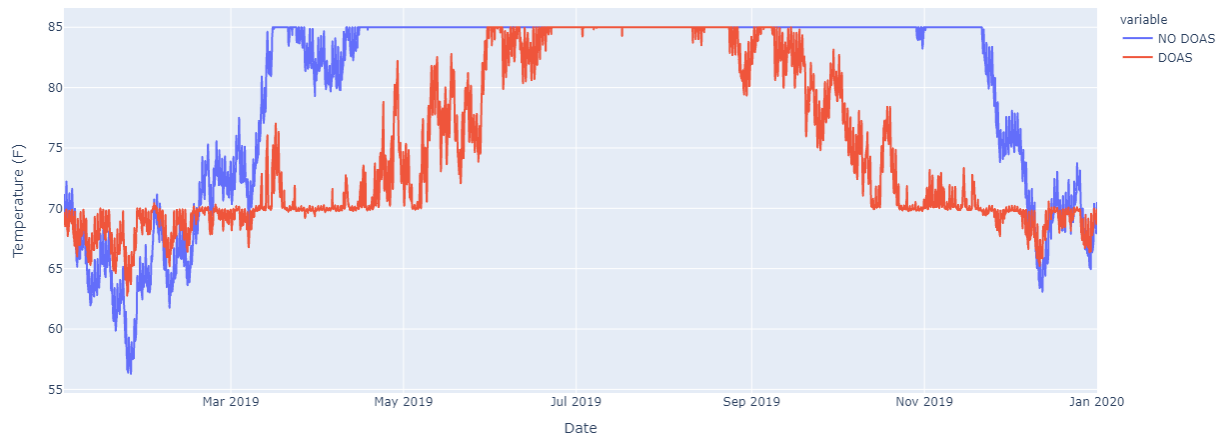
A challenge that many others may face is the costs and increased complexity for Passive House certification above a code-minimum or even high-performing project. Modern codes are quite stringent so the additional savings available to go from a compliant project to a Passive

House project are not large. In addition, the project is pursuing the EnerPHit component path (as opposed to the performance path), as hitting the defined EnerPHit energy targets is not possible due to existing conditions, such as thermal bridges at slab edges, some of which cannot be addressed due to landmarks concerns. Thus, thermal comfort criteria turned out to be very important because thermal comfort, and not strictly energy efficiency, is the Passive House requirement that drove triple glazing and the best window frames. These thermal comfort standards, along with quieter rooms from better windows, air sealing, and improved air quality from supplying filtered outdoor air, support cognitive function that supports NYU's academic mission. Meeting these thresholds were important markers that signal success.

Removing the heavy oil boilers also contributes to environmental justice and health by reducing unhealthy particulates from combustion, which disproportionately disadvantaged communities, particularly those in Environmental Justice Areas identified by New York City (NYC 2021).

Building resiliency will be greatly enhanced by the renovation. Previously, heating was provided by heavy oil boilers located below grade in the basement. Should surface flooding (or, were the building to be located in a coastal flooding zone, as so many multifamily buildings in the New York City archipelago are) disable the boiler, residents would be unable to stay in the building after a severe weather event. Post-retrofit, the equipment is on the roof, with little flood risk. In the case of a grid outage of electricity (in which case, even natural gas or fuel oil fired boilers are generally unable to operate), the building will hold its temperature significantly longer due to the insulation, high-performance glazing, and air sealing incorporated into the project. This will enable students to shelter in place for days or potentially weeks, even in extreme weather, without reaching dangerous indoor temperatures, reducing the desperate need for temporary shelters for climate refugees during a Superstorm Sandy-type blackout (Urban Green Council 2013). The project incorporates a natural gas backup generator that will enable heating, elevators, and other key building systems to remain operational in case of a grid outage. With the improved envelope performance and emergency generator powered ventilation air from the DOAS, the student rooms are expected to not drop below 64F across an average weather year, with only the DOAS air supplied (Figure 3). This is meant to represent minimum space temperature only, and is capped at 85F with the assumption that the operable windows can be used to alleviate higher temperatures in the event of a long term power outage.

Figure 3: Modeled indoor temperatures during a power outage, with only DOAS supplied air and no primary zone heating or cooling.



Despite the many additional expenses from adding ventilation, insulation, upgrading windows, and selecting electric instead of gas-fired heating and hot water equipment, NYU found the 30-year total cost of ownership to be lower for this project than the traditional base case of ventilation via open windows, natural gas fired domestic water heaters, condensing boilers, and a cooling tower, and water distribution with local fan coils or water source heat pumps. This is both because of savings from reduced energy cost over time, avoiding fines under NYC emissions regulations, avoided future cost to remove fossil fuels from the building and electrify building systems between now and 2040 towards NYU's carbon neutral goal, and the availability of NYSERDA and Con Ed incentives for the all-electric, Passive House, and deep energy retrofit nature of the project. It would have been less expensive over 30 years to electrify the building without adding ventilation, although it would not have been possible to certify the project under LEED or EnerPHit requirements. The path chosen allows the project to meet NYU LEED certification standards and achieve Passive House certification for, reduce energy costs and reduce GHG emissions, install heat recovery on ventilation, and contribute to student health, thermal comfort, and improved sound control.

## Acknowledgements

The authors would like to thank Jena Rimkus, Elizabeth Himmel, and Daniel Piselli from FXCollaborative, Dylan Martello from Steven Winter Associates, Tim Hanna and Patrick Krystniack from AKF, and Vicki Kuo from Con Ed for their contributions to this paper.

NYU would like to thank NYSERDA and Con Ed for their generous financial support of this project in support of New York State, New York City, and utility climate goals.

## References

- Flothow, J., J. Block, N. Ceci, H. Nolen, and M. Zuluaga. 2015. *Clanging Pipes and Open Windows: Upgrading NYC Steam Systems for the 21<sup>st</sup> Century*. New York, NY: Energy Efficiency for All.  
[assets.ctfassets.net/ntcn17sslow9/73gDFE9yMk45H4mEezo18y/e5a8dac4f08dc8dba727f387e2a11d71/EEFA-Upgrading\\_NYC\\_Steam\\_Systems.pdf](https://assets.ctfassets.net/ntcn17sslow9/73gDFE9yMk45H4mEezo18y/e5a8dac4f08dc8dba727f387e2a11d71/EEFA-Upgrading_NYC_Steam_Systems.pdf)

NYC (New York City). 2016. *One City Built to Last: Technical Working Group Report: Transforming New York City Buildings for a Low-Carbon Future*.  
[www1.nyc.gov/assets/sustainability/downloads/pdf/publications/TWGreport\\_04212016.pdf](http://www1.nyc.gov/assets/sustainability/downloads/pdf/publications/TWGreport_04212016.pdf)

NYC (New York City). 2021. *Environmental Justice*. Accessed March 2022.  
[www1.nyc.gov/site/sustainability/our-programs/new-york-citys-environmental-justice-for-all-report.page](http://www1.nyc.gov/site/sustainability/our-programs/new-york-citys-environmental-justice-for-all-report.page)

NYC (New York City). 2022. *GHG Inventory*. Accessed March 2022.  
[www1.nyc.gov/site/sustainability/reports-and-data/ghg-inventory.page](http://www1.nyc.gov/site/sustainability/reports-and-data/ghg-inventory.page)

Urban Green Council. 2013. *Baby It's Cold Inside*.  
[www.urbangreencouncil.org/sites/default/files/2013\\_baby\\_its\\_cold\\_inside\\_report.pdf](http://www.urbangreencouncil.org/sites/default/files/2013_baby_its_cold_inside_report.pdf)