

Net-Zero/Carbon-Neutral Retrofits, 140 Kendrick St. Case Study: Tactics, Tradeoffs, and Takeaways

By Christopher Grey, RRC, REWC, PEng, and Samira Ahmadi, BEMP, LEED AP, WELL AP

This paper was presented at the 2025 IIBEC International Convention and Trade Show.

INTRODUCTION

140 Kendrick St. is a 2000s-era, 440,000 ft² (40,877 m²) workplace campus in Needham, Massachusetts, developed, owned, and managed by Boston Properties (BXP). The campus consists of several buildings, all interconnected, including Buildings A, B, and C; a mixed amenities center that connects Buildings A and B; an elevated bridge that connects Buildings A and C; and a parking garage with elevated bridges connecting to Buildings B and C (Fig. 1).

This case study will focus on 140 Kendrick St., Building A, a 106,000 ft² (9,850 m²) office building that has undergone a retrofit focused on improving overall operational efficiency and occupant comfort. Building A is the first net-zero, carbon-neutral office repositioning of this scale in Massachusetts, meaning that it is a highly energy-efficient building that produces renewable energy on site to meet building operations' energy consumption annually. The project was completed in partnership with BXP's lessee, which leased the building in 2021. The scope of the renovation project included full electrification (i.e., no fossil fuel burning systems), building enclosure improvements, advanced energy recovery systems, mechanical system modernization, and the addition of on-site renewable energy generation. The project is expected to achieve LEED v4 Gold Certification (pending) and is pursuing LEED Zero Carbon certification (pending), which will make this building the first large-scale office to achieve this rating in Massachusetts.

The project team consisted of the following:

- Building owner and developer: BXP
- Architect of record: Stantec Architecture
- Sustainability consultant: enviENERGY Studio (EES)
- Building enclosure and structural engineer: Simpson Gumpertz & Heger Inc. (SGH)

This paper will explain the process for achieving net-zero energy and carbon neutrality with an existing building for this project. It will also address challenges associated with achieving those goals and general takeaways that other project teams should consider in the future when reviewing existing buildings, with a focus on specific challenges encountered during the Building A retrofit.

Project Achievements

The key driver for the Building A retrofit was the alignment of energy savings goals of both BXP and their lessee. When redesigning the building, BXP presented the lessee with three retrofit scenarios with differing levels of sustainability ambition. The lessee selected the most ambitious option in line with LEED v4 Gold Certification and LEED Zero Carbon project targets. According to BXP, the primary goal was to create a "state-of-the-art, efficient, LEED Zero Carbon building that provides its clients with a safe, comfortable, and productive environment." The project ultimately met the following metrics:

- 40% reduction in energy use intensity (EUI)
- 1.4 MW on-site solar energy production and storage
- 1.3M kWh annual production of renewable energy
- 23.4 kg CO₂e/ft² (254.4 kg CO₂e/m²) embodied carbon savings
- 90% building heat recovered
- 38% reduction in indoor water use

Interface articles may cite trade, brand, or product names to specify or describe adequately materials, experimental procedures, and/or equipment. In no case does such identification imply recommendation or endorsement by the International Institute of Building Enclosure Consultants (IIBEC).



Figure 1. Overall view of campus. Figure credit: Nearmap.com with author markups.

NET-ZERO ENERGY AND CARBON PATHWAY

Massachusetts has set carbon neutrality goals for 2050, aligning with broader efforts to reduce greenhouse gas emissions. Meanwhile, BXP aims to reach carbon-neutral operation by 2025, requiring strategic interventions to decarbonize the built environment. Decarbonization, the process of reducing carbon emissions from buildings, is closely tied to both energy efficiency improvements (i.e., upgrading building assemblies and systems to reduce operational energy) and electrification (i.e., converting building systems to rely solely on electricity, preferably sourced from renewable energy rather than fossil fuels). Decarbonizing existing buildings can be a multiphase process, where the proposed carbon reduction measures

(CRMs) can be ranked and prioritized based on their complexity and overall impact. The building enclosure enhancement measures are often (and should be) prioritized over the electrification measures as they directly impact the heating, ventilation, and air conditioning (HVAC) equipment sizing and overall energy demand and cost. Given that electricity is often more expensive than gas in many states, including Massachusetts, upgrading the building enclosure should be prioritized. This includes measures such as improving insulation and airtightness to reduce heating and cooling loads prior to electrification, which helps avoid increased operation costs.

In addition to enhancing energy efficiency, it is equally important to prioritize materials with low embodied carbon (that is, the life-cycle carbon

emissions arising from the manufacturing, transportation, installation, and disposal of the material). Selecting products that contribute less embodied carbon ensures that both operational and embodied carbon are minimized, creating a more sustainable building in line with the goal of carbon neutrality.

In decarbonization projects, building energy modeling software plays a significant role; it is utilized as a critical decision-making tool to assess various CRMs. A critical component in the analysis included creating an energy model that was calibrated with utility and metered data to represent the existing building conditions (Fig. 2). The calibrated model was used as a baseline for evaluating the impact of multiple CRMs, focusing on improving the building enclosure and upgrading the HVAC system to support the project's decarbonization goals. Conducting parametric energy modeling allowed for exploration of the most effective ways to reduce the building's carbon footprint, particularly in terms of air infiltration/exfiltration and heat loss, while modernizing systems to achieve carbon neutrality.

An early goal for the project was to achieve a targeted EUI of 35 kBtu/ft² (380.4 kBtu/m²) and operational carbon neutrality with on-site renewable energy generation. This involved comprehensive renovations, including improving airtightness, adding insulation to the exterior walls and roof, and electrifying the HVAC system.

The building enclosure plays a vital role in energy efficiency and carbon reduction, particularly in office buildings. Air leakage through the building's enclosure can significantly affect energy consumption (Fig. 3). Parametric modeling of three sets of enclosure upgrades was reviewed, including adding insulation to the exterior walls and roof and improving the enclosure's airtightness. Each enclosure upgrade's impact was evaluated first on the building's existing mechanical systems and then in combination with an all-electric system. This approach helped

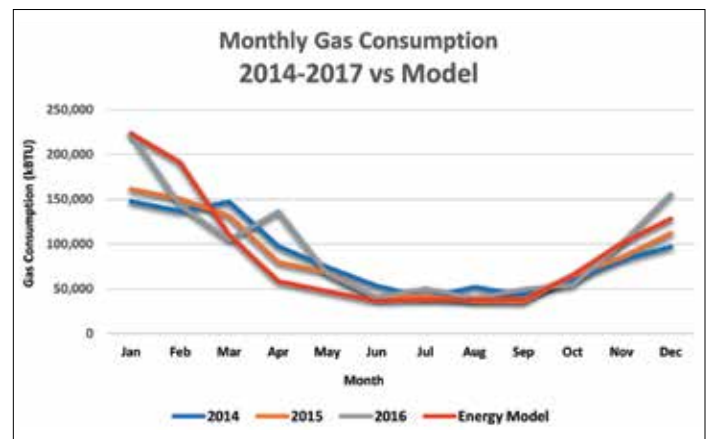
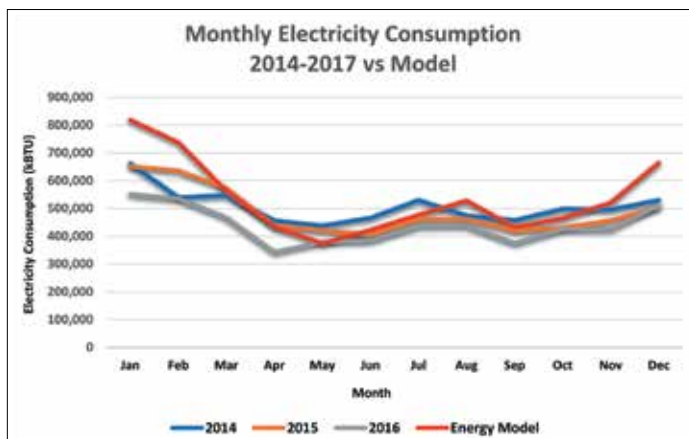


Figure 2. Utility and metered data to represent the existing conditions. Figure credit: enviENERGY Studio.

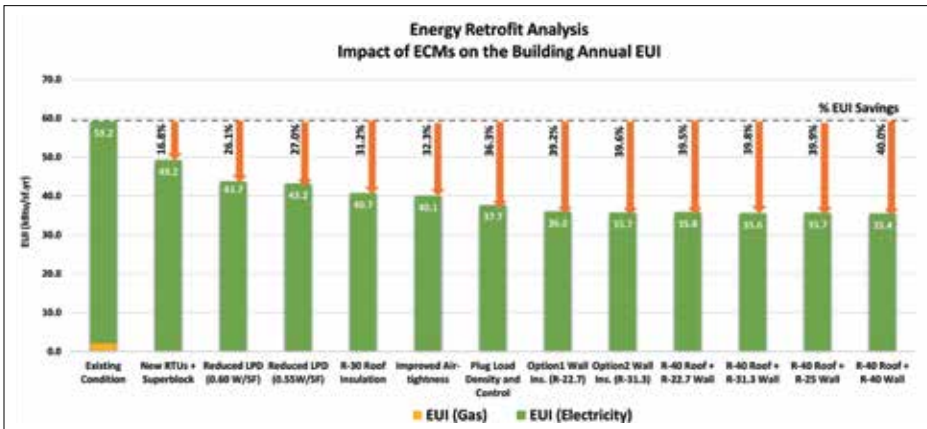


Figure 3. Overall summary of energy retrofit parametric analysis. Figure credit: enviENERGY Studio.

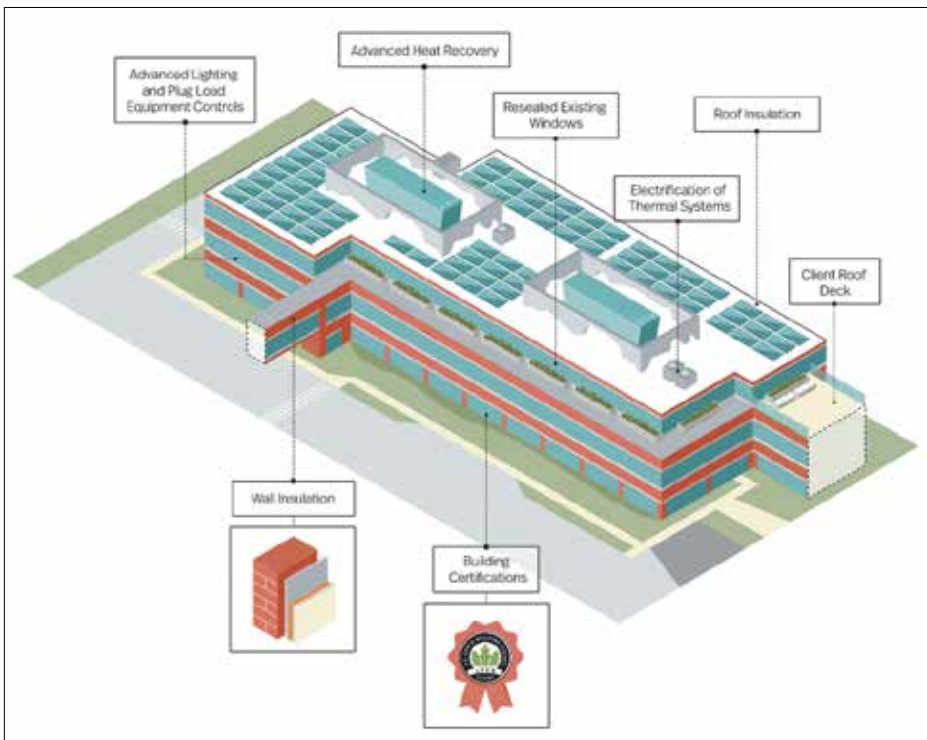


Figure 4. Building upgrade overview. Figure credit: BXP press release.

us identify the optimal balance between energy savings and carbon reduction to achieve the best outcome for the building's future (Fig. 4).

EXISTING BUILDING CONSTRUCTION CHALLENGES

A core focus of the Building A retrofit was improving the building's energy performance, primarily driven by the mechanical and enclosure systems. The main driver for compliance was to improve the mechanical system's performance by incorporating energy recovery and electrifying the building's HVAC system. While the mechanical systems constitute a large percentage of the overall building performance, the enclosure thermal and air infiltration performance also needed to be improved to reduce EUI,

as demonstrated in the parametric analysis performed at the onset of the project (Fig. 3).

The original 140 Kendrick St. complex was designed by Tsoi/Kobus & Associates Architects and constructed in 2000. The three main buildings were generally constructed around the same period and used similar enclosures and mechanical systems.

Mechanical

To decarbonize an existing building, it was crucial to electrify both the HVAC and service water heating systems while simultaneously upgrading the building enclosure. At 140 Kendrick St., the original mechanical system consists of gas-furnace and direct expansion (DX)-cooling rooftop units. These units were modernized

to energy recovery units with high-efficiency variable refrigerant flow heating and DX cooling. The zone-level conditioning remained largely intact, with series fan-powered terminal boxes featuring electric reheat in the perimeter zones and standard variable air volume boxes in the core zones. Additionally, the new ERUs are equipped with a high-efficiency Superblock heat recovery system, designed to operate at an impressive 90% effectiveness, further reducing energy consumption and improving overall sustainability.

Enclosure Systems

In order to meet net-zero requirements, it was critical to make upgrades to the building enclosure without major modifications to the fenestration and opaque wall cladding systems. While the building was only in service for approximately 20 years prior to the retrofit project and the enclosure systems generally appeared to be in good condition, the original construction created challenges that required review throughout the design and construction phases. The primary goals included improving thermal and whole-building airtightness performance as much as possible. The enclosure systems for the building primarily included low-slope membrane roofing, brick masonry veneer exterior walls with horizontal cast stone trim elements, and aluminum-framed fenestration systems. The project team evaluated several potential improvement scenarios for each of the systems, with some being easier to upgrade than others.

Roofing Systems

The existing roofing systems were original to construction, about 20 years old, and included about 3 in. of polyisocyanurate insulation equating to R-17. Although the goal was to reuse the existing systems, upgrading the thermal performance of the roof was a critical need to improve energy efficiency, as the roof constitutes a relatively large percentage of the enclosure for this building's geometry. Through the parametric energy modeling process, the design team established a goal of achieving R-30 (code minimum) R-40 (enhanced) with the new roof assembly. Additionally, since the project scope included adding a solar panel array across the Building A roof with a mechanical system replacement, replacing the roof was recommended so that the service lives of the systems aligned more closely. For example, the project team did not want to install a solar array with a 25- to 30-year lifespan on a 20-year-old roof and then need to remove and reinstall the solar array when the roof needed replacement in approximately 10 years.

because it satisfied several design issues for the project, including providing a high thermal performance per inch thickness, vapor barrier, and air barrier integral with the product in a single layer. Fiberglass and mineral wool were also evaluated as well as a combination of closed-cell spray foam with those products, all of which were viable options, but would require thicker wall assemblies to meet the project goal of $U-0.033$ Btu/h-ft²-F (0.187 W/m²-K), ($R-30$). Also, using fiberglass or mineral wool products required dedicated vapor barriers in the insulation, which the closed-cell spray foam did not require.

Using THERM, which is a two-dimensional heat transfer model used to assess the thermal performance of building components and connections between building components, we calculated effective wall assembly U -factors. Using closed-cell spray foam for a depth of 7½ in. (190.5 mm), an effective R -value of $U-0.032$ Btu/h-ft²-F (0.182 W/m²-K), ($R-31$), was calculated for the clear field wall, which met the project goals. In addition to the thermal and vapor performance, the closed-cell spray foam provided a dedicated air barrier across the wall assembly with an air permeance of 0.004 cfm/ft² (1.23 L*m/m²), compared to the existing building paper, which offered some resistance to moisture but generally lacked the continuous, durable properties needed to prevent air infiltration. The environmental impact of spray foam insulation was also considered, and a UL Greenguard Gold Certified product with ultra-low global warming potential was specified.

The existing 2½ in. (63.5 mm) interior stud wall was generally constructed offset from the main exterior stud wall, which reduced the assembly as we were able to insulate both stud cavities (Fig. 7). Although thermal bridging within the field of the wall was reduced with the offsetting walls, there was existing building geometry, such as an inaccessible soffit, and other conditions that could not be improved without more significant reconstruction. During the design phase, thermal derating calculations were performed to determine an effective overall opaque wall $U-0.050$ ($R-20$), including the impacts due to these larger thermal bridges, for evaluation in the parametric energy modeling.

Fenestration Systems

The existing fenestration systems consisted of aluminum thermally broken storefront systems. The intended project scope was for all existing fenestrations to remain except for localized removal and replacement at a new

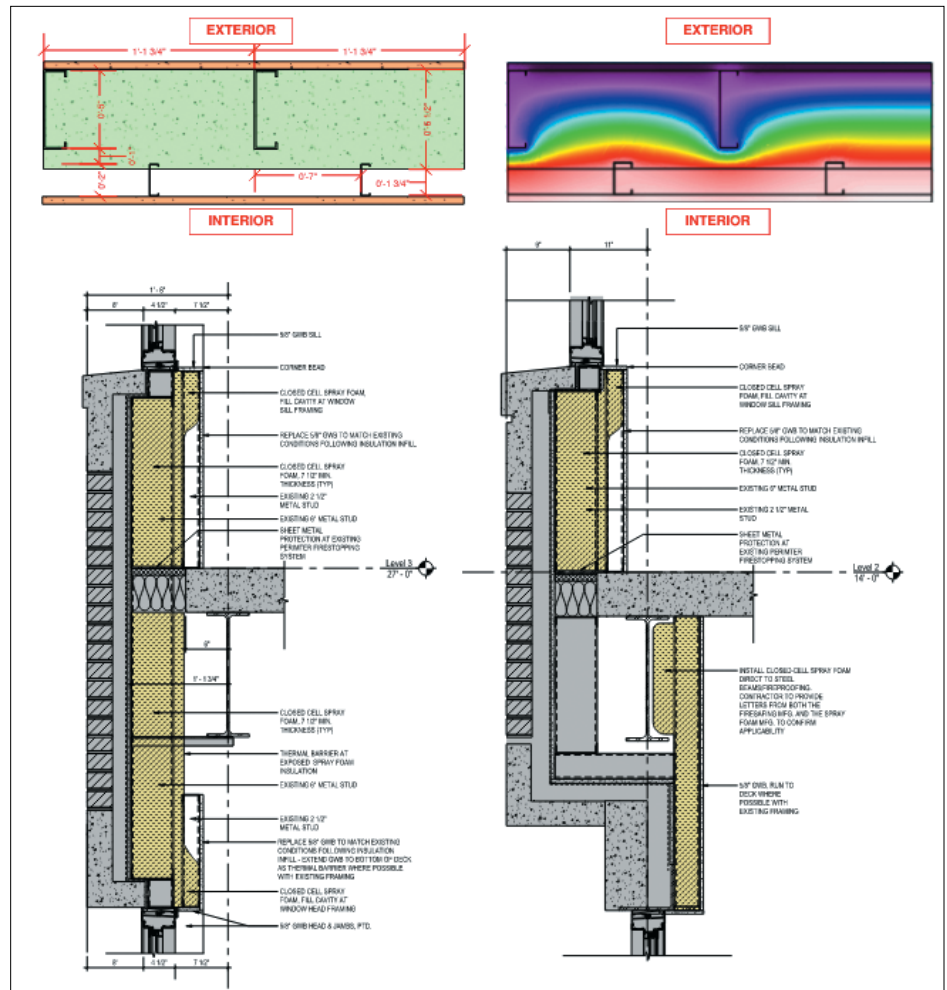


Figure 7. Opaque wall thermal analysis: retrofit wall construction and thermal bridging model (top); typical retrofit wall construction (bottom left); typical existing-to-remain thermal bridge (bottom right). Figure credit: Simpson Gumpertz & Heger Inc.

entrance to an amenity deck level. Replacing or even retrofitting triple-glazed insulated glass units into the existing systems was a financial non-starter for the project; therefore, the project team was tasked with addressing the air leakage breaches and analyzing the existing system to accurately estimate the as-built thermal performance for the energy model. Based on the original project documentation, the estimated thermal performance of the existing system was determined to be $U-0.45$ using the manufacturer's readily available literature.

From an airtightness standpoint, the fenestration systems were generally in good condition; however, several issues were observed upon demolition of the existing interior finishes that represented significant breaches in the air barrier system and needed to be addressed as part of the retrofit. These issues included a lack of interior perimeter backer rod and sealant joints between the fenestration system and the rough opening (Fig. 8), missing perimeter flashings and a lack

of integration with the adjacent brick masonry walls in localized areas, and discontinuities in the fenestration system components (Fig. 9). The project documents required new perimeter backer rod and sealant joints and newly constructed perimeter flashings installed from the interior at localized areas. Additionally, there was a provision that the contractor field survey the existing fenestrations with design team oversight and replace any missing or dislodged components and adjust any dislocated insulated glass units.

Whole-Building Airtightness

As part of our work, an initial partial-building air leakage test was performed (e.g., blower door testing) to identify a baseline enclosure air leakage rate to be used in the energy model. The overall enclosure airtightness is typically reported as the air leakage per unit of building enclosure surface area at 75 Pa (0.3 in. water column) pressure difference. Although Building A was fully unoccupied

and not that large relative to the rest of the complex, executing a whole-building air leakage test was difficult. Interior partitions and mechanical systems from the previous tenant remained in situ. Levels 1 and 2 are connected by a two-story lobby with open stairs on the north elevation. Level 2 is connected to the adjacent buildings via a bridge at the northeast corner and a hallway with locker rooms on the west elevation. Because these spaces are all interconnected, Levels 1 and 2 were difficult to isolate from the adjacent buildings. Therefore, the project team decided to isolate Level 3 and perform partial-building air testing on only the third floor. Building A contains centralized HVAC systems, as well as mechanical shafts, staircases, and elevators that connect Levels 1, 2, and 3. During testing, Level 3 was isolated by temporarily sealing elevator doors, all supply and exhaust air diffusers on the third floor, and the return air plenum at the shaft wall assembly (Fig. 10). Because supply vents were temporarily sealed, Level 3 was not conditioned to normal setpoints during testing.

Our initial partial-building air leakage testing showed that the average air leakage rate for Level 3 was 0.61 cfm/ft² (187.77 L*m/m²) at 75 Pa of differential pressure across the building enclosure. Note that this was measured with the HVAC building enclosure penetrations temporarily sealed. It was impossible to seal all imperfections in the shaft wall construction, HVAC ductwork and some diffusers, or other miscellaneous conditions concealed by interior finishes to fully isolate Level 3 from the rest of Building A.

For reference, multiple current building codes and industry standards provide requirements and/or guidelines for whole-building airtightness of new buildings, typically reported as the air leakage per unit of building enclosure surface area at 75 Pa (0.3 in. water column) pressure difference, including the following:

- 0.40 cfm/ft² (123 L*m/m²) from American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 90.1, *Energy Standard for Sites and Buildings Except Low-Rise Residential Buildings* (optional test). The Air Barrier Association of America (ABAA) often cites this airtightness level as the maximum recommended air leakage rate.
- *AHSRAE Handbook—Fundamentals* references a 1976 study that indicates the typical leakage values for US office buildings as 0.10 cfm/ft² (30.78 L*m/m²) for tight walls,

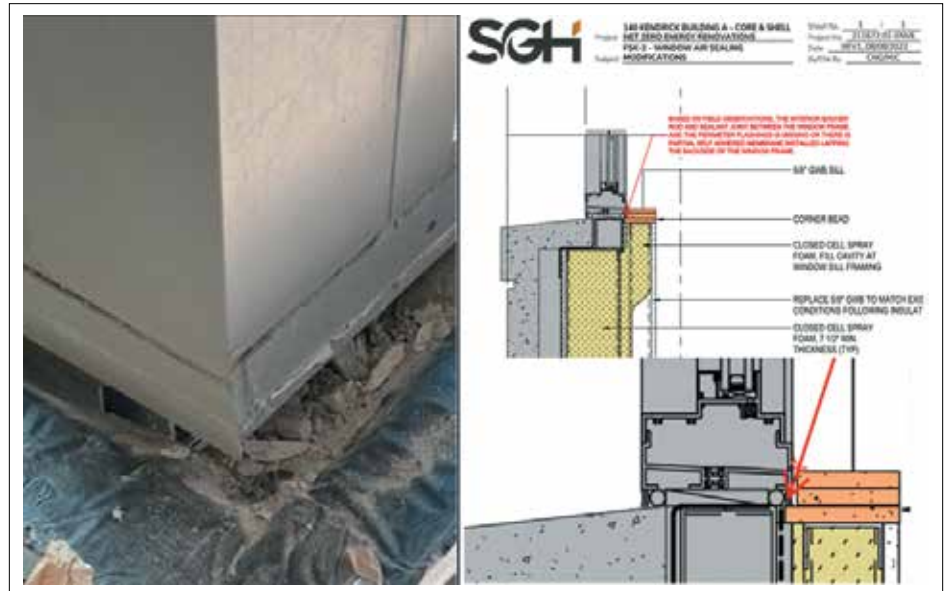


Figure 8. Fenestration issues. Missing interior backer rod and sealant perimeter joints (left) and design document showing new backer rod and sealant scope (right). Figure credit: Simpson Gumpertz & Heger Inc.

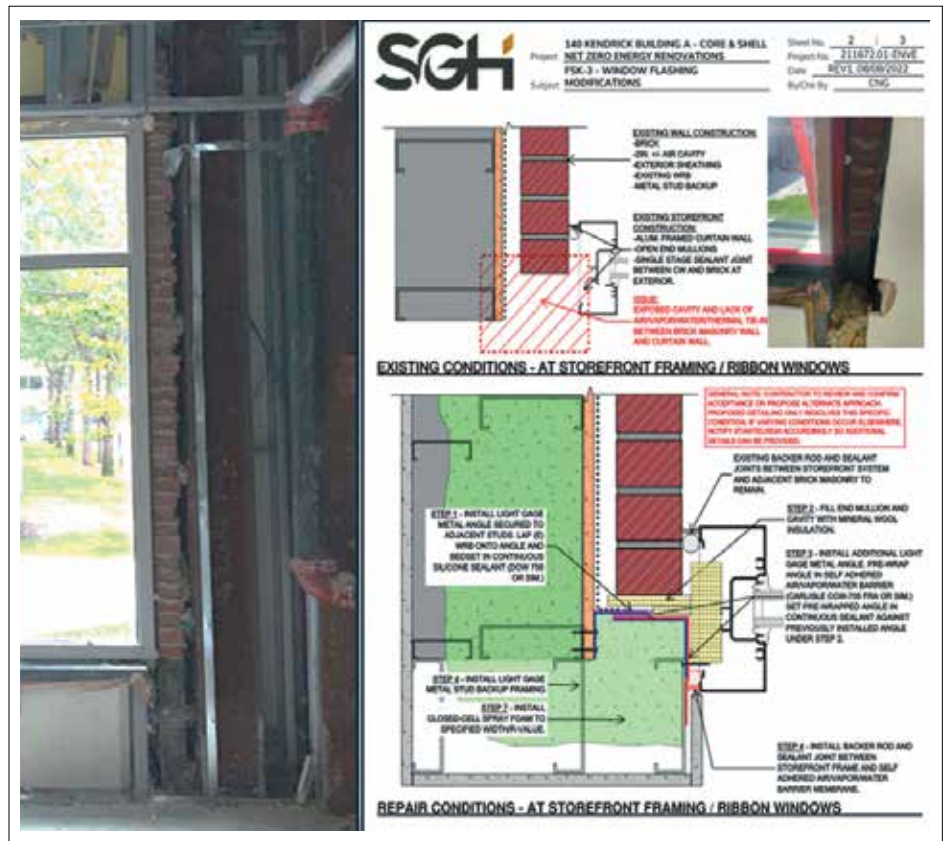


Figure 9. Fenestration issues. Missing flashings between masonry wall and fenestration systems (left) and retrofit flashings (right). Figure credit: Simpson Gumpertz & Heger Inc.

- 0.30 cfm/ft² (92.34 L*m/m²) for average walls, and 0.60 cfm/ft² (184.70 L*m/m²) for leaky walls.
- 0.25 cfm/ft² (76.96 L*m/m²) from the US Army Corps of Engineers, *International Green*

Construction Code/ASHRAE Standard 189.1 and GSA PBS-P100 Tier 1.

- 0.10 cfm/ft² (30.78 L*m/m²) for GSA PBS-P100 Tier 3 and State of Utah High Performance Structures.



Figure 10. Whole-building airtightness testing issues: typical blower door fan setup at stairwell shaft (left) and large connecting plenums above suspended ceiling spanning multiple floors (right). Figure credit: Simpson Gumpertz & Heger Inc.

It is important to note that these reference standards are intended for new buildings, not necessarily existing buildings. As buildings age and are subjected to weather, seals and other items contributing to airtightness may begin to deteriorate, causing increased air leakage over time. In addition, this building was designed and constructed before air barriers became a prescriptive building code requirement in Massachusetts circa 2001; the existing exterior wall system does not include a dedicated air barrier layer as is now required by code. Despite the lack of a dedicated air barrier, the measured leakage rate falls within the range of what we would expect for a typical office building at the time of original construction. In the design phase energy modeling, the project team conservatively assumed the measured value of 0.61 cfm/ft² (187.77 L*m/m²) in the existing condition and utility and metered calibrated models. In the final proposed case, an improved value of 0.40 cfm/ft² (123.13 L*m/m²) (approximately a 35% reduction) was assumed, which aligns with the ASHRAE Standard 90.1 values. The project team felt that this would be a conservative and improved rate since a dedicated air barrier was being added as part of this work. Due to the issues encountered and lack of confidence in the measured air leakage during the initial partial test, the project team

opted to exclude retesting post-retrofit. The use of the closed-cell spray foam, installation of window perimeter flashing and seals, and repair of voids in the exterior wall construction all contributed to significantly reducing air leakage, likely beyond the assumed 0.40 cfm/ft² (123.13 L*m/m²) value.

EARLY GOALS AND FINAL DECISIONS

Setting early goals is critical for decarbonization and net-zero carbon projects as it establishes a clear vision and roadmap for achieving sustainability targets. It also allows project teams to align on objectives such as EUI targets, carbon reduction strategies, and key performance indicators. An early goal for the 140 Kendrick St. project was to achieve a targeted EUI of 35 kBtu/ft² (380 kBtu/m²) and to achieve an operational carbon neutrality with on-site renewable energy generation. This involved comprehensive renovations, including building enclosure upgrades and electrification of the HVAC system.

To achieve these goals, an early energy modeling and parametric analysis were integrated in the design process and used a tool to help the project team with making informed choices, optimizing building systems, and avoiding costly retrofits or redesigns later in the project. It also helped with stakeholder


engagement, as early goals provide a clear framework for discussions with tenants and investors, ensuring all parties are aligned with the project's sustainability objectives from day one.

During the decision-making phase, the project team performed an iterative energy modeling strategy and assessed the impact of several CRMs on the existing and improved conditions. The outcome of these analyses was that all proposed CRMs were necessary for achieving the building carbon neutrality goals with the exception of the window replacement measure. The energy audit and analyses showed that the existing windows were in good condition and replacing them with code-compliant windows would not have had a significant impact on the building operation. 140 Kendrick St. has been occupied and operational for almost a year and has been going through a retro commissioning process. The on-site renewable energy production exceeds the project energy consumption, and therefore, the project is on track to achieve its carbon neutrality goals.

CONCLUSIONS

The 140 Kendrick St., Building A, project was a renovation of an existing building to a net-zero-energy and carbon-neutral office

located in Needham, Massachusetts. The energy retrofit included full electrification, building enclosure improvements, and HVAC modernization including advanced heat recovery system and on-site renewable energy generation.

The project team conducted a series of energy modeling runs and investigated pathways for the project to achieve net-zero-energy and carbon-neutrality status. The impact of several energy conservation measures on the building's overall energy use, cost, and GHG emissions was evaluated and presented to the design team during the schematic design and design development phases. This project, like all decarbonization studies conducted by our teams, highlights the importance of early involvement and goal setting, and utilizing energy modeling as a decision-making tool. Engaging stakeholders early on allows for a clear definition of objectives, while setting ambitious yet achievable goals provide a strategic framework for the project. Early iterative energy modeling was essential for evaluating various scenarios, optimizing system performance, and ensuring that each decision contributed to reducing the building's carbon footprint efficiently and cost-effectively. 

REFERENCE

Boston Properties Case Study Archives (2024). *Pioneering Net-Zero Redevelopment of an Existing Building*, Boston Properties website, https://www.bxp.com/wp-content/uploads/2023/08/140-Kendrick_BXP_Final_08.16.23.pdf.

ABOUT THE AUTHORS



CHRISTOPHER GREY,
RRC, REWC, PENG

Christopher Grey is an Associate Principal in Simpson Gumpertz & Heger Inc.'s (SGH) Building Technology Division in Boston, Massachusetts. He is experienced in investigating, rehabilitating, and designing a wide range of building enclosure systems, from historic structures to contemporary high-rise buildings. His practice focuses on enclosure consulting for new construction and existing building retrofits specializing in energy performance analysis, performance testing, and the design and coordination of unitized curtainwall and prefabricated megapanel enclosure systems. Grey holds a Bachelor of Science in civil engineering and a Master of Science in civil engineering, structural focus, from Virginia Tech. He is a certified sUAS Level I Thermographer and a contributing member of the FGIA/AAMA, serving on several industry-standard task groups.



SAMIRA AHMADI,
BEMP, LEED AP,
WELL AP

Samira Ahmadi is the Founding Principal of enviENERGY Studio LLC and has more than 14 years of experience in energy modeling and sustainability consulting. Her practice focuses on sustainability and energy performance analyses for new construction and existing building retrofit projects that aim for sustainability certifications, energy upgrades, decarbonization, enhanced occupant health and comfort, and post-occupancy evaluation, measurement, and verification. Ahmadi holds a Master of Science in building performance and diagnostics from Carnegie Mellon University, a Bachelor of Science in architectural engineering, and a Master of Architecture from the University of Texas at San Antonio. She is a member of the BAC Board of Trustees and has previously served on the US Green Building Council Massachusetts Chapter Board of Directors.

Please address reader comments to chamaker@iibec.org, including "Letter to Editor" in the subject line, or IIBEC, *IIBEC Interface Journal*, 434 Fayetteville St., Suite 2400, Raleigh, NC 27601

