Hines

Smart Solutions For Decarbonizing Existing Buildings

100 Avenue of the Americas

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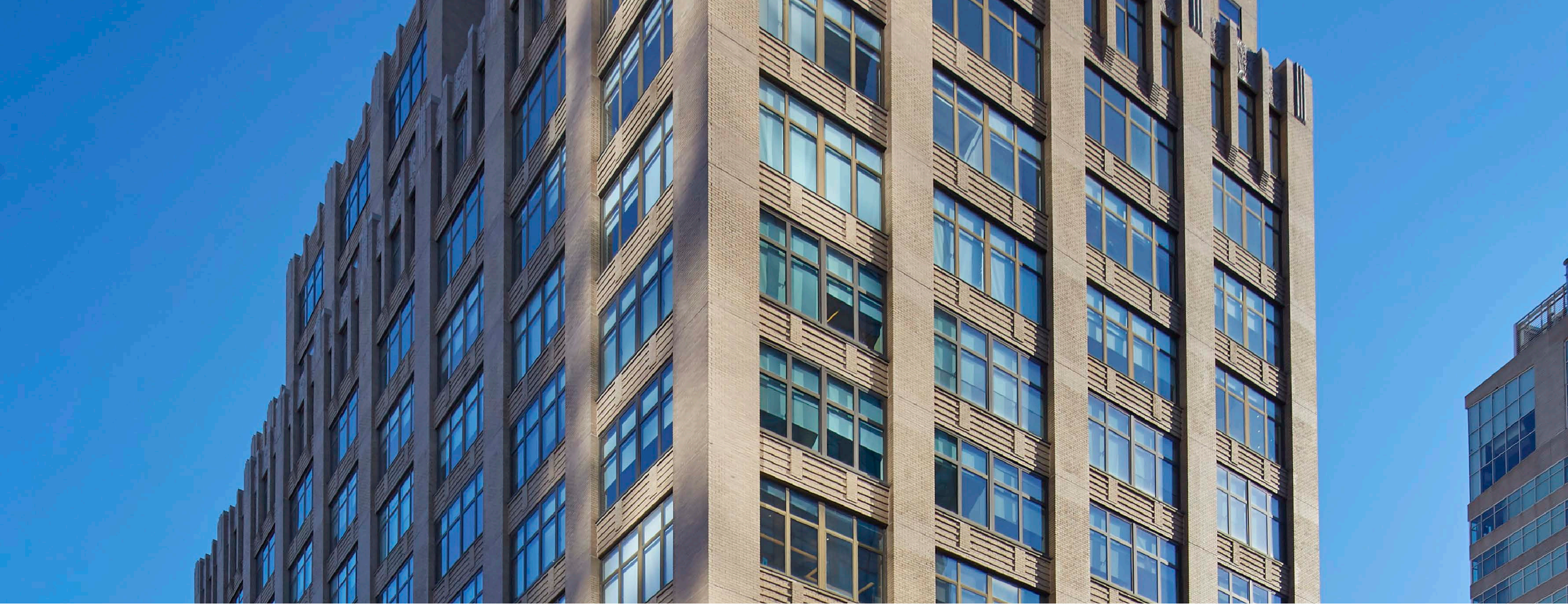


INTRODUCTION
(NYC 80X50 ROADMAP)

In 2014, New York City adopted an ambitious plan to combat climate change by reducing carbon emissions 80% by 2050.[1] While the city's 80x50 Roadmap outlined aggressive targets for transportation, waste management and energy supply, much of its success depends on greening the existing building stock. Approximately 70% of New York City's greenhouse gas emissions come from the energy used to heat, cool and power buildings.[2]

Reducing carbon emissions in the city's more than one million commercial and residential properties is no easy feat. The majority of the buildings are old. The average Midtown South commercial building is more than 90 years old, and approximately 90% of the current building stock will still be in use in 2050.[3]

Now is the time to decarbonize buildings. This is the decisive decade.

New heating and cooling technologies allow owners to condition their buildings using 90% less energy without touching the building façade. These new technologies also eliminate combustion of fossil fuels in the building, using electricity instead to provide heating. Fully electric buildings will decrease their carbon footprint as the electric grid continues to decarbonize. The greening of New York's electric grid is also an important component of the 80x50 Roadmap, and one without which decarbonization of buildings will be impossible.

NYSERDA TAPS HINES TO LEAD STUDY

Electric-powered heating and cooling systems face some challenges in the United States. Until recently, the technology to efficiently electrify heating systems, even at low ambient temperatures, had not been readily available in the U.S., and with manufacturers not seeing demand, there was little motivation to initiate the required testing and regulatory processes to bring them here. Several electric-based HVAC solutions are available only in Europe and Japan and are expected to arrive in the U.S. in the following few years. Moreover, some mechanical, electrical and plumbing (MEP) firms have been reluctant to install this unfamiliar technology in new buildings.

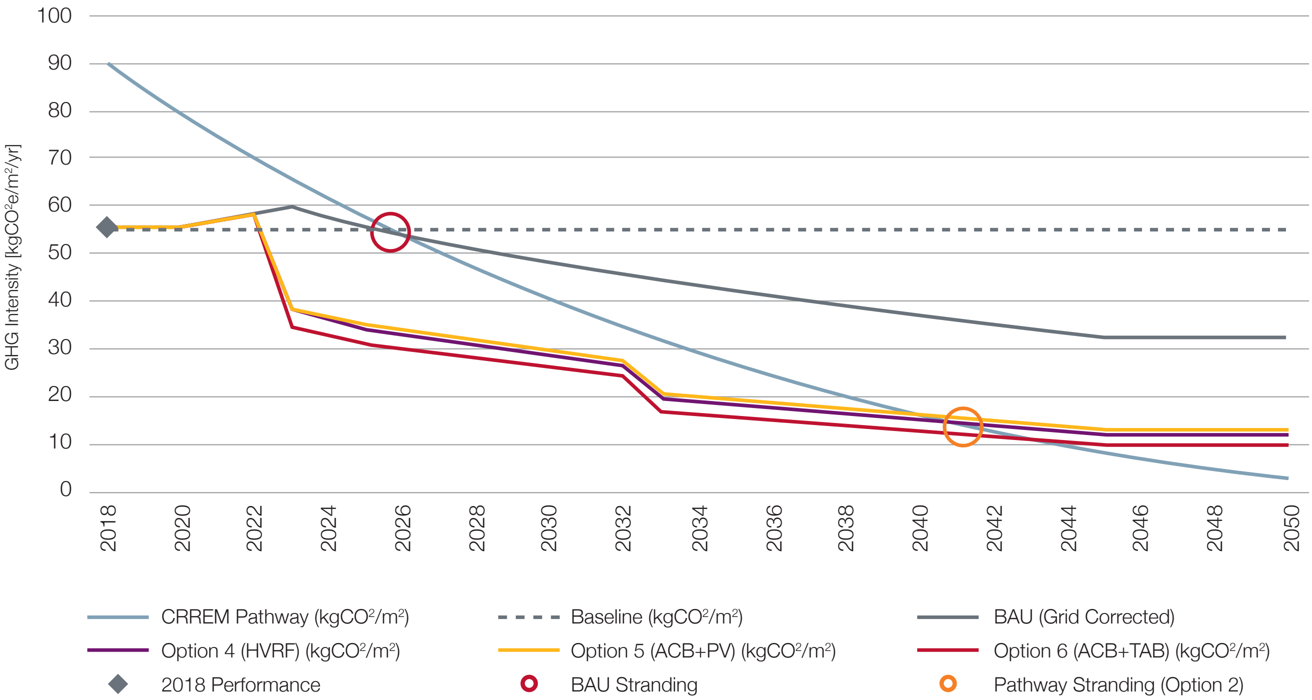
For these reasons, in 2020, the New York State Energy Research and Development Authority (NYSERDA) commissioned a study to explore whether electric-powered heating and cooling systems are feasible and, if so, how to best implement them in New York City's commercial buildings. NYSERDA commissioned Hines to lead the study. Michael Izzo, appointed to Vice President-Carbon Strategy in 2021 for the firm, assembled a team comprised of experts from Thornton Tomasetti, a multi-disciplinary engineering firm known for its advanced building simulation techniques and who managed this project; URBS | Urban Systems, a Stockholm, Sweden-based energy and finance integrator that focuses on sustainable HVAC design; van Zelm Heywood & Shadford of Hartford, Connecticut, an MEP firm which specializes in high-efficient water-based HVAC solutions; and NBI or New Buildings Institute, an organization working to improve the energy performance of commercial buildings.

MICHAEL IZZO
Hines Senior Vice President – Environmental Strategies

> **"In response to carbon reduction, we must act now and move quickly. Collaboration, co-creation and cooperation are key to finding solutions and replicating them at a large scale, which is necessary. That is what we are striving for at Hines."**

During mid-2020 and 2021, Izzo's team of developers, engineers and building scientists began exploring the use of new electric-powered heating and cooling systems. Using one of the buildings in Hudson Square Properties (HSP) portfolio, 100 Avenue of the Americas, the team set out to prove that electric-based approaches could work. This study will serve as a playbook for transforming New York's existing buildings to achieve the city's 80x50 goal.

Carbon Risk Real Estate Monitor (CRREM) Stranding Graph - Post Retrofit



Interpretation:

Installation is phased over the following years, linked to tenant lease end:

2023: Floors 1, 3, 10, 14, 15 & 16
2025: Solar PV
2033: Floors 2, 11, 21 & 17

Other options have the same implementation pathway but achieve different levels of decarbonisation.

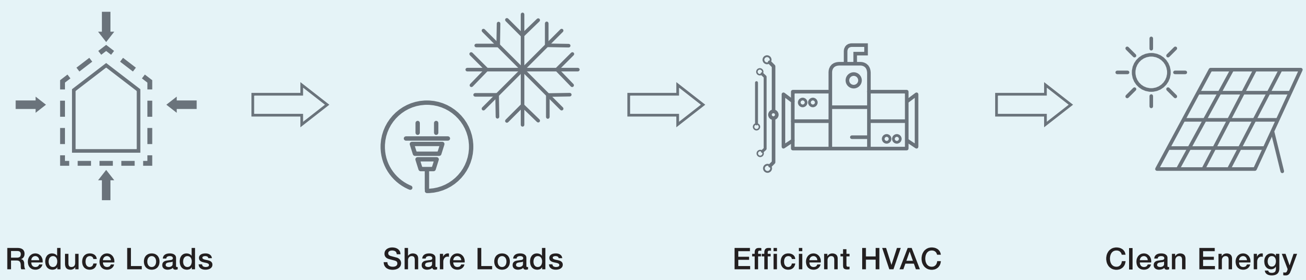
WHY 100 AVENUE OF THE AMERICAS?

Built in 1930, 100 Avenue of the Americas is a 17-story masonry building representative of New York City's 132 million square feet of vintage commercial buildings. The building has an uninsulated façade, double-pane windows, and inefficient heating, cooling and ventilation systems that are prime for replacement.

The mechanical systems in 100 Avenue of the Americas are similar to those in other buildings of this vintage. Boilers burn natural gas, that create steam and is distributed to keep occupants warm in cold weather; at the same time, air conditioning units exhaust heat to the environment in an effort to keep interior rooms cool. All this energy gets pushed around by oversized belt-driven fans. So, while the systems are successful in heating and cooling the building, the equipment is energy-intensive and most of the parts are working against each other.

THE APPROACH

The team's approach centered around Izzo's philosophy of "circular systems thinking." First, reduce the demand for heating and cooling. Next, re-use the heat that is generated by the occupants, computers and lights to provide part of the heating needs of the building, instead of simply rejecting it to the environment. Third, meet any remaining needs with very efficient equipment. Last, power that equipment with clean electrical energy.



The team developed six different HVAC schemes based on this circular thinking—three for whole building renovations and three for single-floor renovations. Izzo wanted to prove that significant carbon emissions reductions could occur during natural leasing cycles of a building, or not waiting for long repositioning cycles that occur every 30 years. Improvements could happen progressively and coincide with access to capital.

The HVAC systems were designed to incorporate highly efficient heat recovery to move heat from zones that need to reject it to the zones that call for it. What little heating or cooling needs are left are provided with small heat pumps with efficiencies of 300% to 500%. Finally, the team analyzed when the building used the most energy and the costs and emissions tied to using energy during that time. This showed that using energy storage solutions to consume power during cheaper and cleaner times is achievable.

The six solutions put forward by the team are briefly described below.

Full-Building Repositioning (every 30 years)

1. **Central Air Source Heat Pump (ASHP) plant with Active Chilled Beams (ACB) distribution:** A central ASHP plant extracts heat from the cooling loop and deposits it in the heating loop as needed. The plant can move energy beyond the base needs by extracting or rejecting heat from/to outdoor air. Distribution is via highly efficient ACB.
2. **Central Water Source Heat Pump (WSHP) plant with ACB distribution:** A central WSHP plant extracts heat from the cooling loop and deposits it in the heating loop as needed. The plant can move energy beyond the base needs by extracting heat from the air with an ASHP or rejecting heat via a cooling tower. Distribution is via highly efficient ACB.
3. **Distributed water source heat pump with centralized water source heat pumps and dry coolers and distribution via ACB and Thermally Active Slab (TAS):** WSHP reject/extract heat to/from an ambient temperature condenser loop and use it to provide space conditioning via ACB and TAS. The condenser loop is balanced by a central ASHP plant.

Single-Floor Interior Renovation (every 5-10 years)

4. **Hybrid (water-distribution) Variable Refrigerant Flow (VRF):** Considered the “next generation VRF,” this is a 2-pipe heat recovery VRF system that replaces refrigerant with water between the branch circuit controller and the indoor units.
5. **4-Pipe ASHP + ACB:** Hot water and chilled water are provided by a series of “cascading” heat pumps which constantly create hot and cold water from the condenser and evaporator portions of a single heat pump unit. When simultaneous heating and cooling is required, the plant realizes “load” sharing within the equipment, using heat rejected from the chilled water loop to warm the hot water loop. (Shown in image.)

6. **2-Pipe ASHP + ACB + Thermally Active Slab:** The hot and chilled water generating equipment and terminal cooling equipment is similar to the equipment provided in the 4-pipe ASHP. This scheme incorporates a radiant floor intended to circulate ambient-temperature water between zones and passively balance slab temperatures between zones in heating and cooling. Heating or cooling loads are "topped off" with the 2-pipe ASHP when needed.

HVAC Layout Single Floor

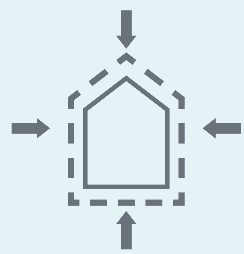
This image shows the schematic layout of Option 5, the 4-pipe air-source heat pump scheme within half of 100 Avenue of the America's 17th floorplate. The 4-pipe air-source heat pump is able to provide fully electric heating and cooling as well as exchange heat between interior and exterior zones. As an alternative, the team experimented with providing a 2-pipe air-source heat pump coupled with a thermally active slab which is able to exchange heat between zones in a similar manner.

While the three single floor proposed schemes are elegant in their simplicity, the process to arrive at them was anything but simple. Over the course of 2021, the five firms held over 100 hours of workshops and delved into a resolution of modeling and simulation rarely possible amidst the pace of the typical design and construction process. The team leveraged academic-caliber simulation tools to simulate the performance of systems just being introduced to the U.S. market with little precedent for representation in standard energy modeling programs.

Hunter Roberts Construction group provided oversight and construction estimating service to ensure these innovated systems were sound and priced appropriately. The result is a series of options that can be readily implemented in New York City's buildings, with validated results that far exceed those of standard practice.

REDUCING LOADS

The team explored different strategies to reduce the heating and cooling loads of the building, including improved ventilation heat recovery and façade upgrades.

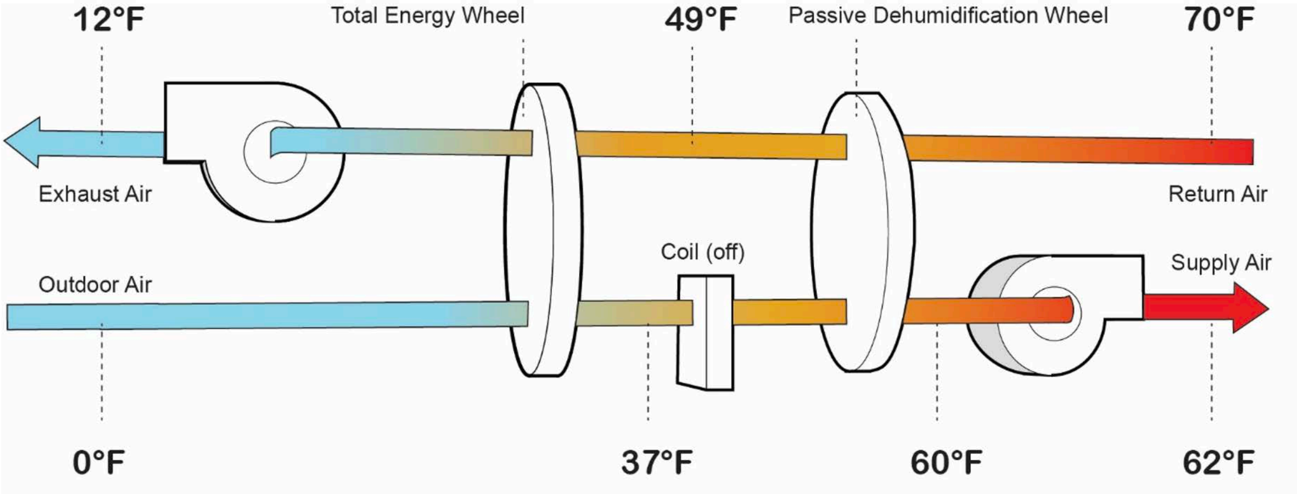


Improving the ventilation system was by far the most effective load reduction measure. Whether old or new, the majority of an office building's heating needs come from the introduction of fresh air. Even before the COVID-19 pandemic, office buildings constantly blew fresh air inside for occupant health and safety. In a post-COVID world, owners are likely to blow even more air, requiring proportionately more heating.

Each of the schemes first reduced ventilation loads by providing a Dedicated Outdoor Air System (DOAS) for fresh air, leaving heating and cooling to water-based distributions. A DOAS can provide exact amounts of outdoor air to each space, thereby reducing the ventilation load compared to traditional all-air systems. Moreover, DOAS include smaller fans and ducts (and associated higher ceiling heights) thereby reducing system first cost while increasing indoor air quality.

Next, the team incorporated heat exchangers into the DOAS, allowing the recovery of 85% of the heat that would otherwise be exhausted from the building back into the fresh air supply. These measures set the stage for the introduction of very efficient heating and cooling machines.

Reducing Loads Using Heat Exchangers

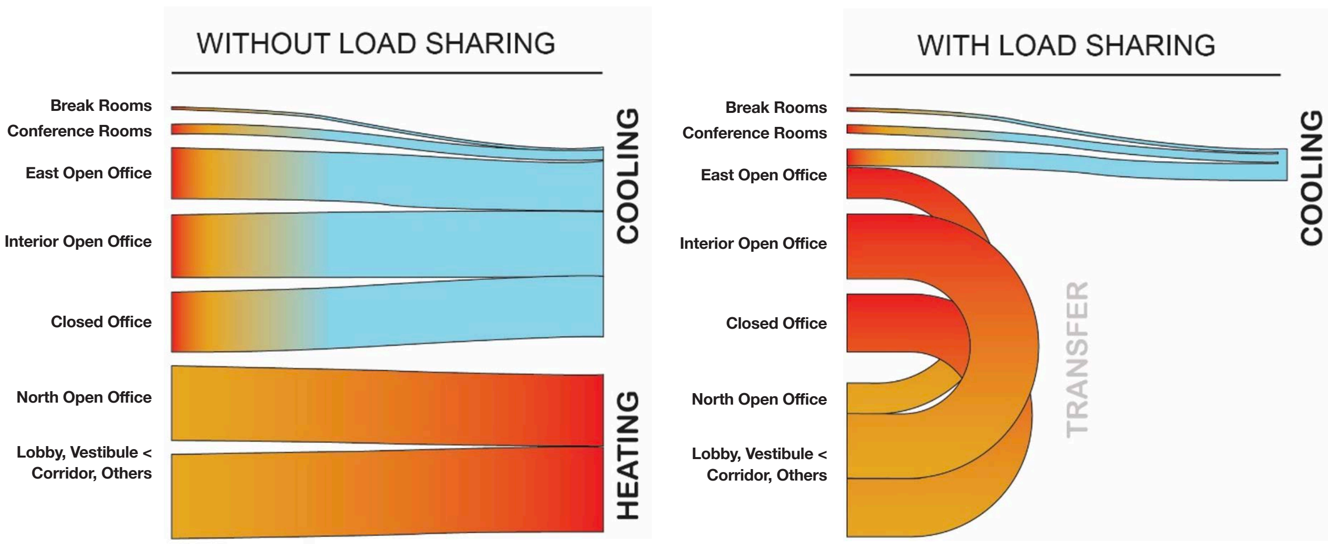


Although improving the façade showed measurable reductions in the building's heating and cooling needs, the impact on carbon emissions was minimal once high-performance HVAC was included. For the majority of New York's commercial buildings with masonry walls, like 100 Avenue of the Americas, prioritizing HVAC upgrades are a more cost-effective strategy to reduce their energy consumption and carbon footprint than façade upgrades.

SHARING LOADS

New York's office buildings already generate most of the heat they need; they just do not use it. Rooms near the middle of an office floor (like medium to high density office and conference rooms) need cooling year-round. With no walls to the outdoors, heat from lights, people and equipment is constantly pumped out by the air conditioning system. Rather than sending it outdoors, Izzo's team redirected it to rooms that need heat in winter, like open offices near the edge of the building or conference rooms supplied with high volumes of outdoor air.

February 16th 24-Hour Thermal Loads



The three single floor systems put forward by the team balance themselves by "sharing the load" in the building by using heat pumps to transfer heat from spaces in cooling to spaces in heating. This load sharing effectively reduces or eliminates additional energy use. In addition, one of the schemes uses the thermal mass of the floor slab to transfer heat between zones. Two of these systems use a central heat pump to move heat between the cooling and heating water loops, while the TAS option relies on the concrete floor itself for load transfer.

HIGH-EFFICIENCY EQUIPMENT

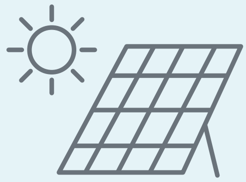
The three single floor systems incorporate heat pump technology to inject and/or reject heat. Heat pumps are particularly efficient when compared to gas or electric boilers, as they can provide more heating than the electrical energy they use to do so. Heating coefficient of performances (COPs), for an ASHP is around three or four, while traditional boilers have a COP under one.

For the particular case of the TAS scheme (Option 6), the temperatures of the water in the slab and the condenser loop were selected to maximize the COP at which the ASHP and WSHP operate.

Finally, the high chilled water temperature used in the ACBs also helps to operate the heat pumps more efficiently.

REDUCING GRID DEMAND

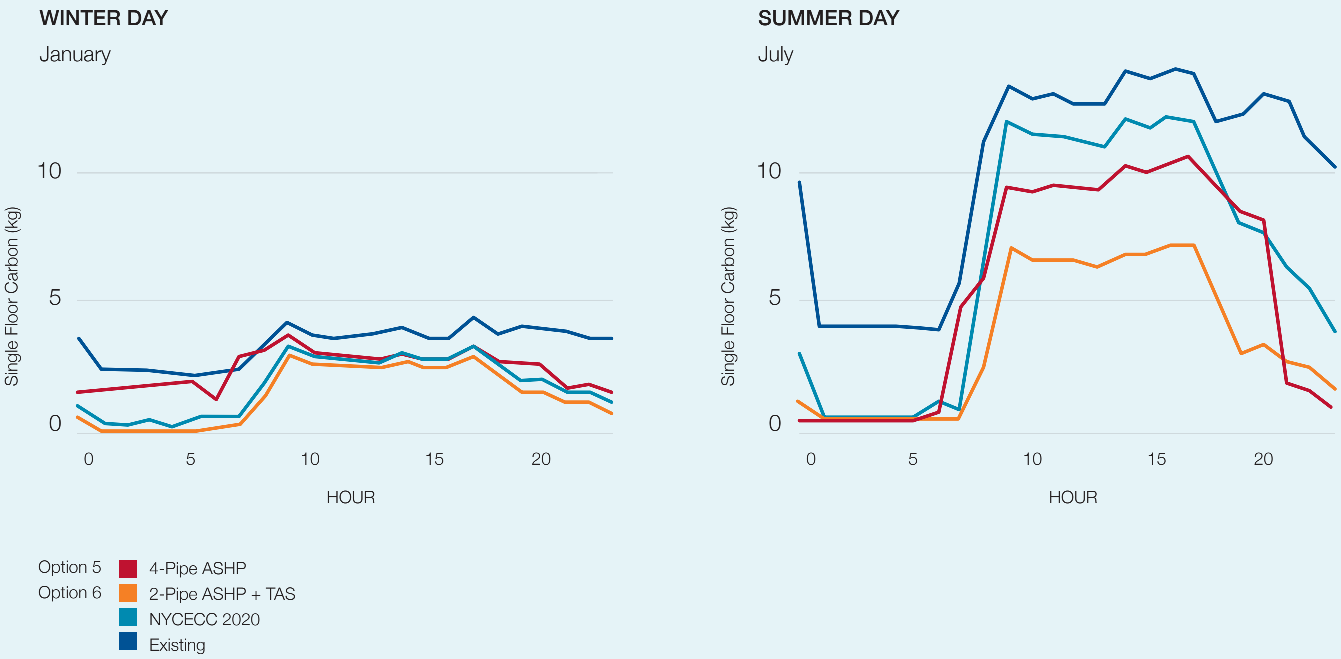
As more projects turn to electric heat, there is growing concern over potential strains on the city's electricity grid. Utilizing a building's preexisting heat sources presents an important mitigation strategy to this effect. By using heat from people, lights and equipment, buildings no longer call upon electrical infrastructure to warm up. Furthermore, the high cooling efficiencies of these systems will reduce peak summertime demands.



Of the three single floor schemes, the radiant slab approach presented additional opportunities for peak demand reduction. While two of the strategies primarily relied on central heating and cooling machines to transfer energy, a third radiant slab option utilized the building's massive structure to store and release heat throughout the day. While the amount of energy used in this scheme was similar to the other two options, the radiant slab scheme demonstrated the potential for significant carbon savings as the building could draw energy from the grid when renewables were most available and "ride out" times when they were not. While this scheme presented the added cost and architectural challenges of introducing an additional 3" topping slab to an existing floor plate, the "peak" cost savings and carbon emissions reductions could justify the premiums in certain building typologies and situations.

Daily Carbon Summary Single Floor

These charts show the single floor average carbon emissions for a day in Winter and Summer. The values shown are an average of all days in the month. The graphs use predicted emissions factors from the year 2030.

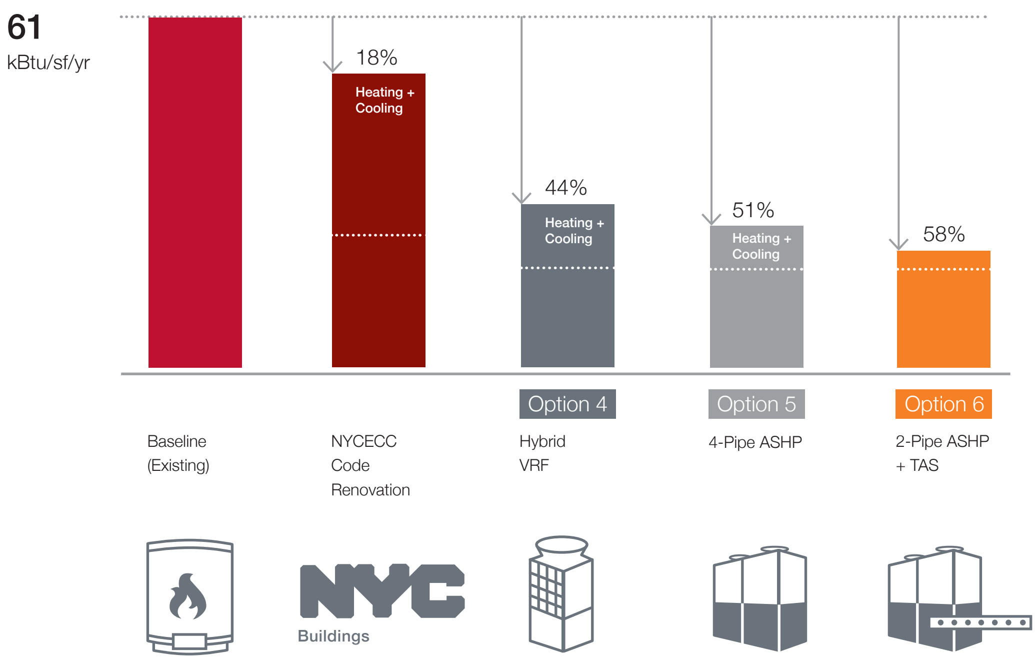


THE RESULTS

The results for all of the single floor options were better than expected: Load sharing is not only possible but could virtually eliminate the need for gas heating in New York's buildings, making decarbonization possible. Unlike combustion or electric resistance, the systems output more useful energy than they use, and the resulting energy use intensity (EUI) is as low as today's best-in-class new construction buildings or Nearly Zero Energy Buildings. And perhaps most importantly for large-scale market adoption, two out of the three options studied presented a comparable or incremental added cost than their standard practice counterparts.

Annual Energy End-Use Single Floor

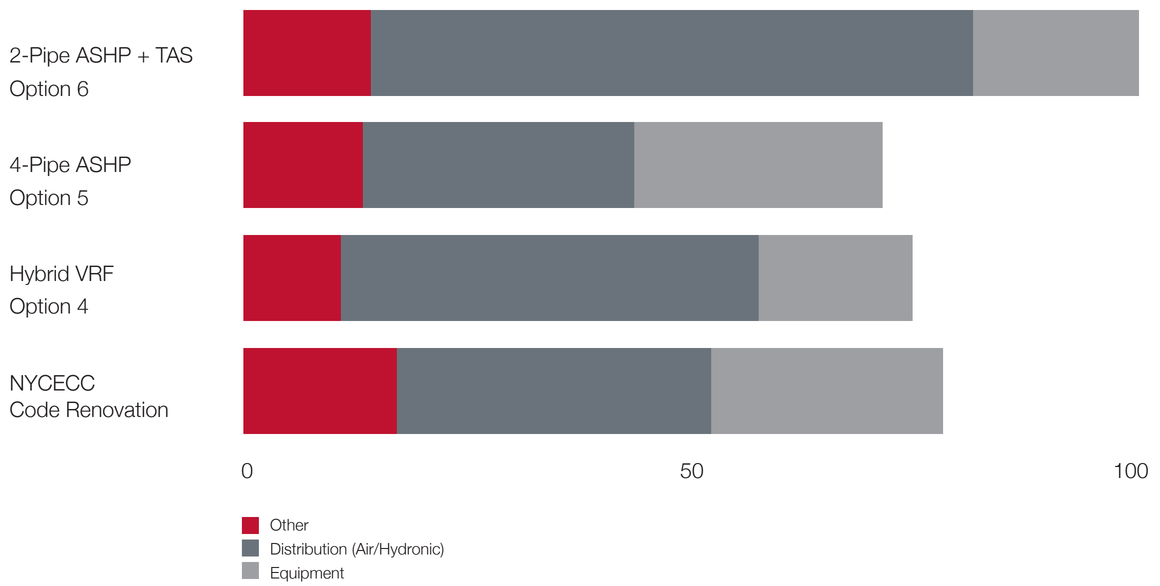
This chart shows the single floor average carbon emissions for a day in Winter and Summer. The values shown are an average of all days in the month. The graphs use predicted emissions factors from the year 2030.



* Cross referenced to options on page 8/9

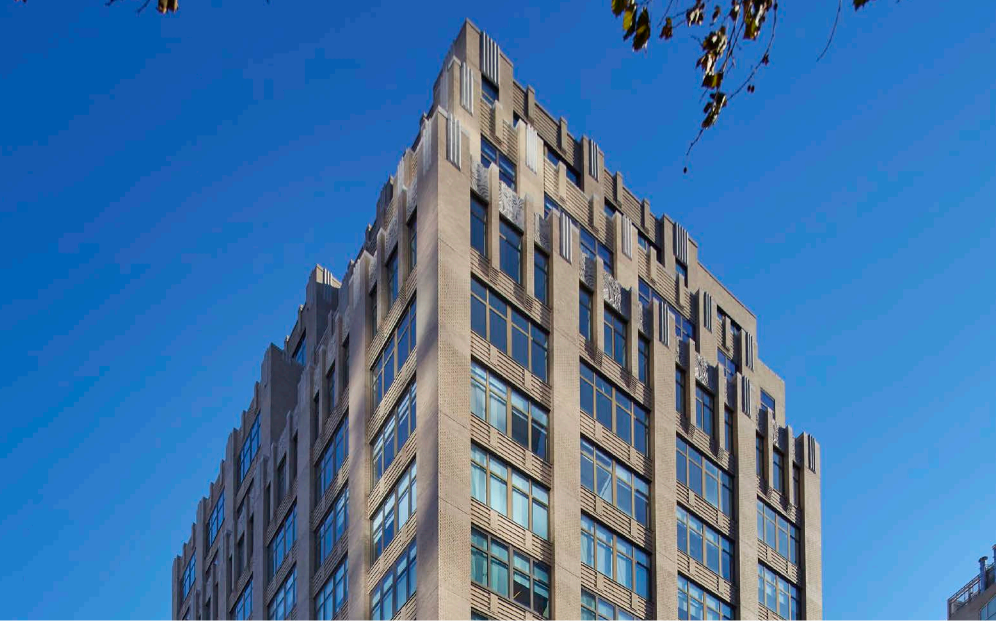
Installing new heat pump equipment was less expensive than a code renovation that used the existing boiler. The cost of a new air-handler and associated VAV ductwork offset the savings from using the existing heating equipment. Both the hybrid VRF and 4-pipe ASHP options cost less day 1. The labor associated with the in-floor radiant system produced a significant premium over the alternatives studied.

HVAC Components ($/sf)



Equally important for market adoption, the solutions presented minimal disruption to operations and could be implemented at a variety of scales. While standard window upgrades and air-sealing measures could reduce systems size, low-energy results were not dependent on over cladding or façade replacement. The schemes also worked equally well whether implemented on a floor-by-floor basis or when applied to an entire building repositioning.

Substantial energy savings were possible, implementation was virtually identical to standard HVAC retrofits, and the cost premium of these electric-based systems is effectively zero. It is estimated that full-floor tenants vacate spaces up to every 10 years and these solutions suggest that there should be ample opportunities for upgrades before the city's 2050 deadline to achieve carbon neutrality.




IN SUMMARY

Using 100 Avenue of the Americas as a prototype, the team was able to demonstrate how it is possible to retrofit New York City's aging commercial buildings to use almost no energy for heating at minimal first cost, without touching the building façade. What little energy the buildings will use can be supplied by a grid that is forecasted to be 100% renewable by 2040.

The study identified a few relatively easy steps New York City's aging commercial buildings can take to be more efficient and sustainable:

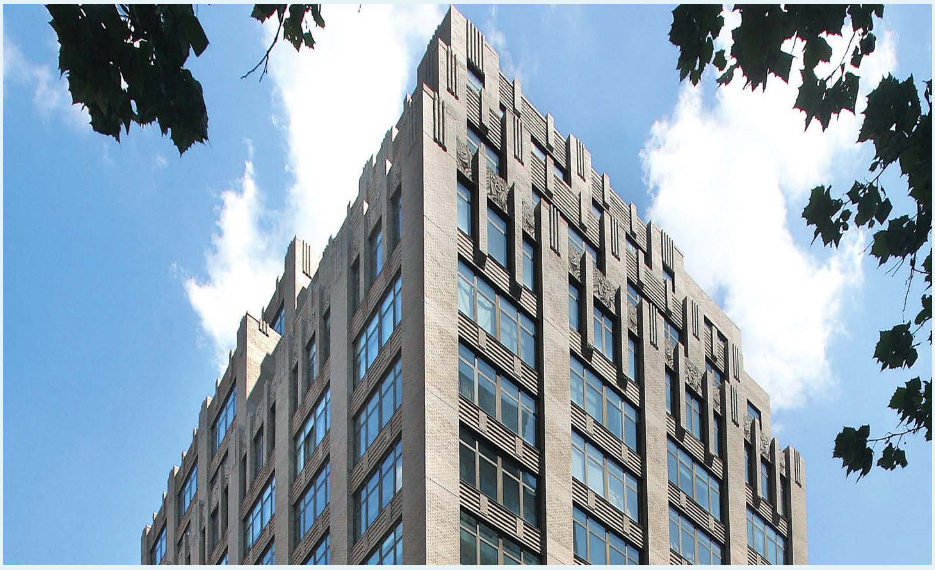
- Choose systems that can re-use heat generated from people, lighting and equipment as its primary heating source.
- Utilize heat pumps to satisfy remaining heating loads in buildings and fully eliminate the use of fossil fuel combustion.
- Leverage DOAS heat recovery ventilation to reduce conditioning loads.
- Supply heating and cooling to spaces using hydronic distribution systems rather than air.
- If needed, perform renovations on a floor-by-floor basis, which may present budgetary benefits, schedule flexibility and minimal disruption to existing tenants.
- Separate fresh air delivery from heating and cooling systems by using a dedicated outdoor air supply.
- Recycle existing sources of heat within the building during cold weather and hot weather (for domestic hot water) rather than rejecting it to the atmosphere.

If we can drastically reduce carbon emissions while making buildings more efficient for minimal to no cost, why wouldn't we?

THE TEAM

About Hines

Hines is a privately owned global real estate investment firm founded in 1957 with a presence in 383 cities in 30 countries. Hines oversees investment assets under management totaling approximately $94.6 billion[1]. In addition, Hines provides third-party property-level services to 440 properties totaling 100 million square feet. Historically, Hines has developed, redeveloped or acquired approximately 1,836 properties, totaling over 681 million square feet. The firm currently has more than 197 developments underway around the world. With extensive experience in investments across the risk spectrum and all property types, and a foundational commitment to ESG, Hines is one of the largest and most-respected real estate organizations in the world. Visit www.hines.com for more information. [1]Includes both the global Hines organization as well as RIA AUM as of June 31, 2023.



Data as of June 30, 2023

1. Includes both the global Hines organization and RIA AUM as of June 30, 2023.

383 cities
in 30 countries

$94.6 billion[1]
assets under management

440
properties totaling
100 million
square feet

THIRD-PARTY PROPERTY-LEVEL SERVICES

1,836
properties, totaling over
681 million
square feet

DEVELOPED, REDEVELOPED OR ACQUIRED

197
developments

About Hudson Square Properties (HSP)

HSP was established in 2015 comprising of a joint venture between Trinity Church Wall Street (long-time landowner in lower Manhattan), Norges Bank (central bank of Norway) and Hines (global real estate investment, development and management firm). Together HSP owns 12 buildings totaling six million square feet in the Hudson Square, Soho, West Village and Tribeca districts. These buildings were predominantly constructed in the 1920's and 30's purposed for manufacturing which have since been converted to commercial office.

Trinity Church Wall Street has played a prominent role in lower Manhattan for more than 300 years. Its history in the Hudson Square neighborhood dates to the generous land grant given to the church by Queen Anne in 1705. Today, Trinity owns 14 acres in the neighborhood, property that continues to provide resources for the church's mission and ministries in New York City and around the world. Social justice along with diversity and inclusion are just a few of the foundational core values Trinity is committed to.

Norges Bank Investment Management is one of the world's largest funds, with holdings in around 9,000 companies worldwide, and hundreds of buildings in some of the world's leading cities in Europe, Asia and the Americas. Current real estate assets under management in NY include HSP and an additional five properties which equal 4.7 million square feet, these assets are located in Herald Square, Times Square, Grand Central, and Park Avenue. Norges is committed to managing the properties they own in an environmentally sustainable manner and work closely with their partners to ensure their portfolio is managed to a high standard. Implementation of sustainability plans is a fundamental component of their business and includes consistent demonstration of improvement relative to internationally recognized standards.

About Thornton Tomasetti

Thornton Tomasetti applies engineering and scientific principles to solve the world's challenges – starting with yours. An independent organization of creative thinkers and innovative doers collaborating from offices worldwide, our mission is to bring our clients' ideas to life and, in the process, lay the groundwork for a better, more resilient future. For more information, visit www.ThorntonTomasetti.com or connect with us on LinkedIn, Twitter, Instagram, Facebook, Vimeo and YouTube.

About URBS

urbs is a true systems integrator that delivers concept-to-completion sustainable solutions to green the built environment, using bottom-up and circular principles to drive environmental, economic and social impact.

Endnotes

1. https://www1.nyc.gov/site/sustainability/codes/energy-benchmarking.page#:~:text=New%20York%20City%20Energy%20Water,on%20energy%20and%20water%20management
2. https://www1.nyc.gov/assets/sustainability/downloads/pdf/publications/New%20York%20City's%20Roadmap%20to%2080%20x%2050_Final.pdf
3. https://www1.nyc.gov/assets/sustainability/downloads/pdf/publications/New%20York%20City%27s%20Roadmap%20to%2080%20x%2050_Final.pdf