A **holistic approach,** combined with a realistic phasing plan, can make decarbonization technically and economically feasible.

Planning for Resource Efficient Decarbonization

A Phased Approach to Eliminating Greenhouse Gas Emissions from Tall Buildings in Cold Climates

NEW YORK STATE | Empire Building Challenge

Strategic decarbonization planning entails balancing multiple goals

ECONOMICS
Energy and maintenance projects can save money over time.

TECH READINESS
There is lots of work to do before replacing main equipment. Take enabling steps first.

SIMPLE SOLUTIONS
What is the simplest way to design a solution?

MAINTAINABILITY
Find ways to reduce future maintenance costs by implementing decarbonization measures.

VALUES
How can decarbonization advance organizational values and goals?

RESILIENCY
Systems should be prepared for disruption and protect occupants from climate-related threats.

BUDGETS & PHASE-IN
Breaking decarbonization into incremental steps can help meet targets, within tight budgets.

EXISTING PLANS
How can an existing plan be leveraged to shift gears and implement a new trajectory? Small changes can gradually yield large results.

By phasing in solutions over a longer time horizon, and within budgets, building decarbonization is achievable and can be cost-effective.

CHECK YOUR ASSUMPTIONS.

Are any of our existing beliefs limiting your perspective? Is there another lens you could look through?

FOLLOW A CLEAR 3-STEP PROCESS.

A process is already in use that can help you trace your path to carbon neutrality.

SEE HOW OTHERS ARE DOING IT.

Learn from what others have already done to put their buildings on the trajectory to full decarbonization.

The lens you look through determines what you see.

Beware of mental traps that prevent early action.

#1

- Simple payback
- 1:1 equipment replace-ment
- My engineer says, "It can't be done."
- Electrify all at once
- Wait for better tech.
- I have "THE" solution!
- Electricity produces emissions
- Too disruptive
- Decarb is not possible

#2

- Long term capital planning
- Partial electrifi-cation and right size equipment
- Phase in measures over time
- Start with partial electrifi-cation
- Start *now* with enabling steps
- There is no 'one' sol ution! Stay "tech neutral"
- Grid is rapidly decarbo-nizing
- Decision tree, phased approac h
- Decarb is viable

Three steps to successful decarbonization planning

1

CONDITION ASSESSMENT. Conditions, requirements or events at your building or company can trigger a decarbonization effort. Look at both technical and asset baselines.

2

ENGINEERING SOLUTIONS. Take action now. Look for enabling steps and pathways to decarbonize efficiently over time, by thinking holistically.

3

CAPITAL PLANNING AND THE BUSINESS CASE. Conduct a decarbonization assessment based on a discounted cash flow model. Look at different investment scenarios, over the long term.

A Repeatable Process

Step 1: Condition Assessment

Free flow of information between **decisionmakers, real estate and technical teams** throughout the process is crucial.

REAL ESTATE/BUILDING ASSESSMENT

Asset conditions, repositioning, recapitalization, capital cycle events, tenant turnover, facade compliance, CO_2 emissions limits, investor ESG goals, etc.

TECHNOLOGY ASSESSMENT

System failure, damage from an event, end-of-useful life, wasted heat, tenant loads, indoor air quality, etc.

Integrating results from the two condition assessments will lead to a stronger, more strategic decarbonization plan.

A Repeatable Process

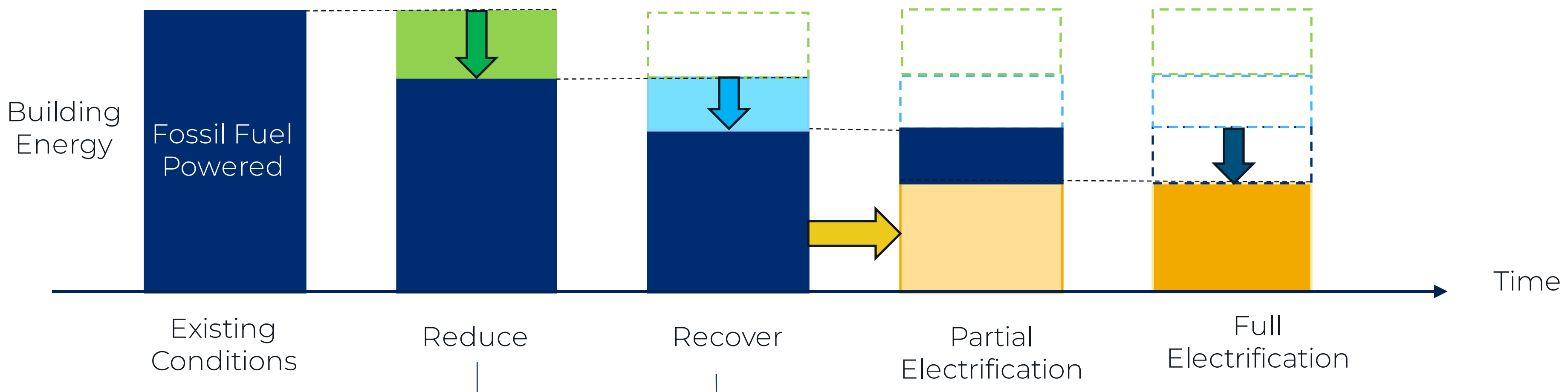
Step 2: Engineering Solutions

Apply the **Resource Efficient Decarbonization** model to help alleviate space constraints, optimize peak thermal capacity, increase operational efficiencies, **utilize waste heat, and reduce the need for oversized electric thermal energy systems**, creating retrofit cost compression. The model contains (4) steps:

1. **REDUCE** energy loads as much as possible.
2. **RECONFIGURE** systems to create thermal networks and enable low temperature distribution.
3. **RECOVER** as much heat as possible from air, water, and wastewater sources.
4. **REPLACE*** equipment incrementally over time until full decarbonization is reached.

* "All-or-Nothing" is a false assumption

Applying Resource Efficient Decarbonization (RED)



Reduce Energy Load

- Building Envelope Improvements
- Control Optimization
- Ventilation Improvements
- Dedicated Outside Air System
- Hydronic Distribution
- Lower Heating Supply Temp.
- Terminal Units Replacement

Recover Wasted Heat

- Waterside Heat Recovery
- Airside Heat Recovery
- Wastewater Heat Recovery
- Thermal Energy Networks

Partial Electrification

Replace fossil fuel inputs and prioritize the techno-economic portion of load

- Air Source Heat Pumps
- Water Source Heat Pumps
- Geothermal
- Thermal Layering

Full Electrification

In-time, replace or remove the remaining peak load equipment

- Heat Pumps
- Thermal Storage
- District Thermal Network
- Grid-interactivity

All paths to Resource Efficient Decarbonization include heat recovery and recycling.

Buildings lose heat through a variety of processes. Holistic building decarbonization requires recovering and recycling wasted heat through various interventions:

Cooling produces heat. Capture the heat and apply it to other uses, like domestic hot water.

Heat goes down the drain. Extract heat from wastewater with heat pumps and redirect it to other uses.

Think twice about ventilation. Fresh air is fundamental to healthy buildings. Be certain to recover heat and cool from exhaust air.

Save it for later. Incorporate thermal storage technology into designs to save recovered heat for when its most needed.

The way heat moves in a building is more important than how it's made.

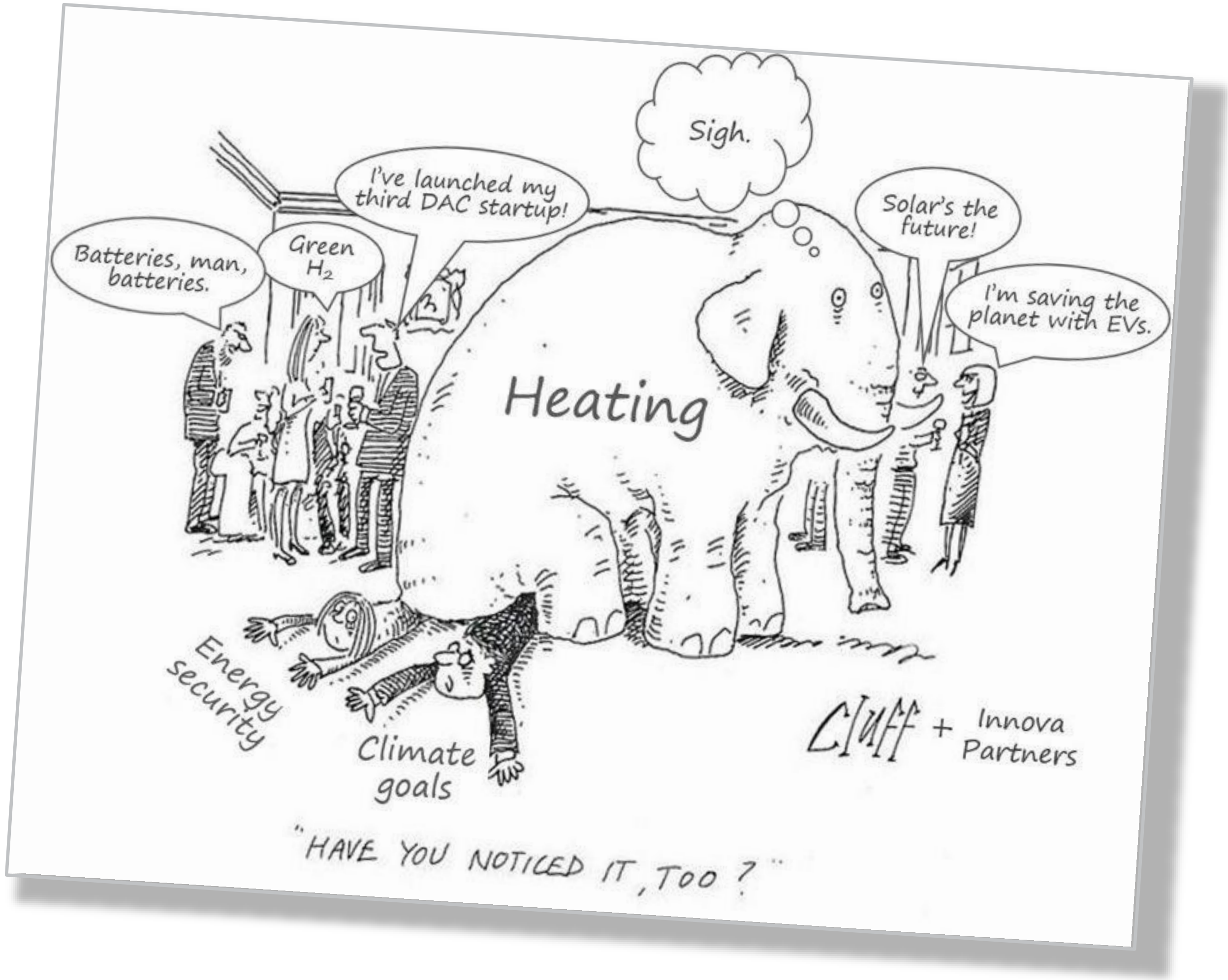
Building infrastructure must shift toward lower temperature heating distribution.

Keep your options open. Choose technology neutral distribution systems and plug in low carbon technology over time.

Steam is out. Water is in. Incrementally shift steam distribution systems to water/hydronic distribution.

Embrace low temperature heating. More efficient and enables heat pumps. Requires changing terminal units to fan coils, radiant panels or similarly performing devices.

Location is everything. Strategically relocate or add distribution infrastructure to support other goals, like heat recovery.



A Repeatable Process

Step 3: Capital Planning and the Business Case

What to do

- Define the decarbonization period (think long term)
- Start with an ideal engineering plan
- Develop multiple investment scenarios
- Evaluate NPV and conduct sensitivity analysis
- Compare to Business-As-Usual

When to do it

- Is there value to an accelerated timeline?
- How can implementation be phased to optimize resources?
- What are the capital and financial cycles of the property?

Key Strategic Decarbonization Planning Methods

Think beyond simple payback and prioritize projects.

BUSINESS-AS-USUAL

Develop a business-as-usual scenario, including information from Step 1: Condition Assessment. Include cost of offsets and reasonable assumptions about future cost of fossil fuels.

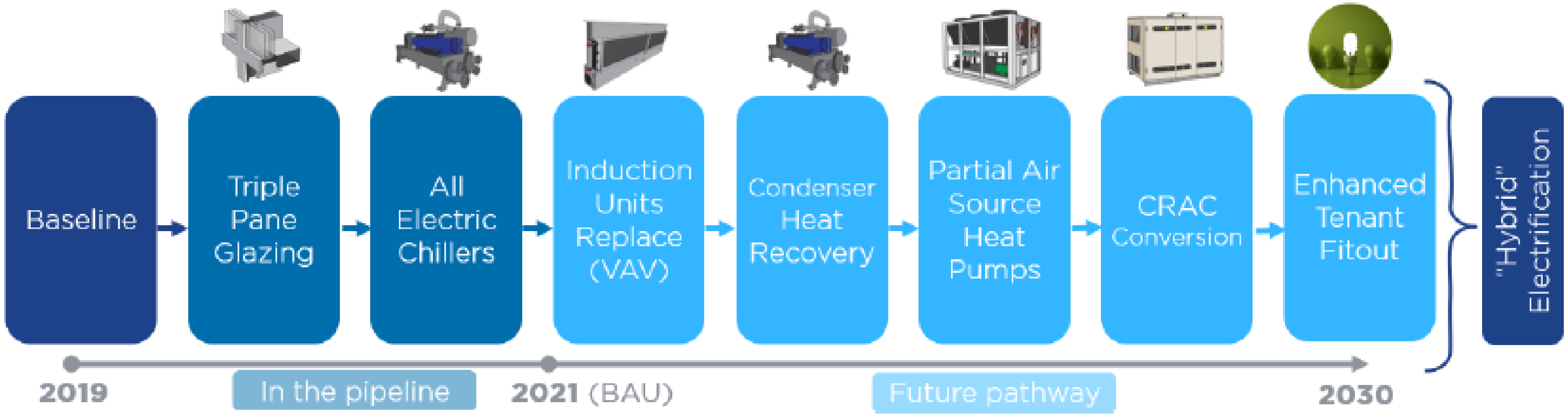
NET PRESENT VALUE

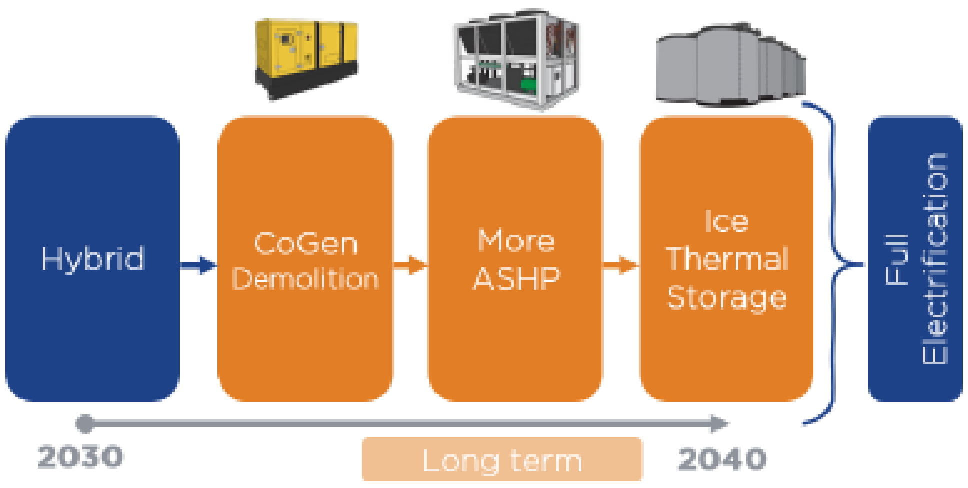
Develop a discounted cash flow model for the different investment scenarios with as much detail as possible. Assess the Net Present Value of different decarbonization pathways compared to the business-as-usual scenario. Value non-energy benefits. Attempt to quantify the value at risk by pursuing the business-as-usual path.

MARGINAL COST

Find the lowest marginal cost of decarbonization. The marginal cost of decarbonization is the incremental cost between measures or projects in the business-as-usual scenario and the selected decarbonization pathway.

Example decarbonization roadmap: 2019 -2040

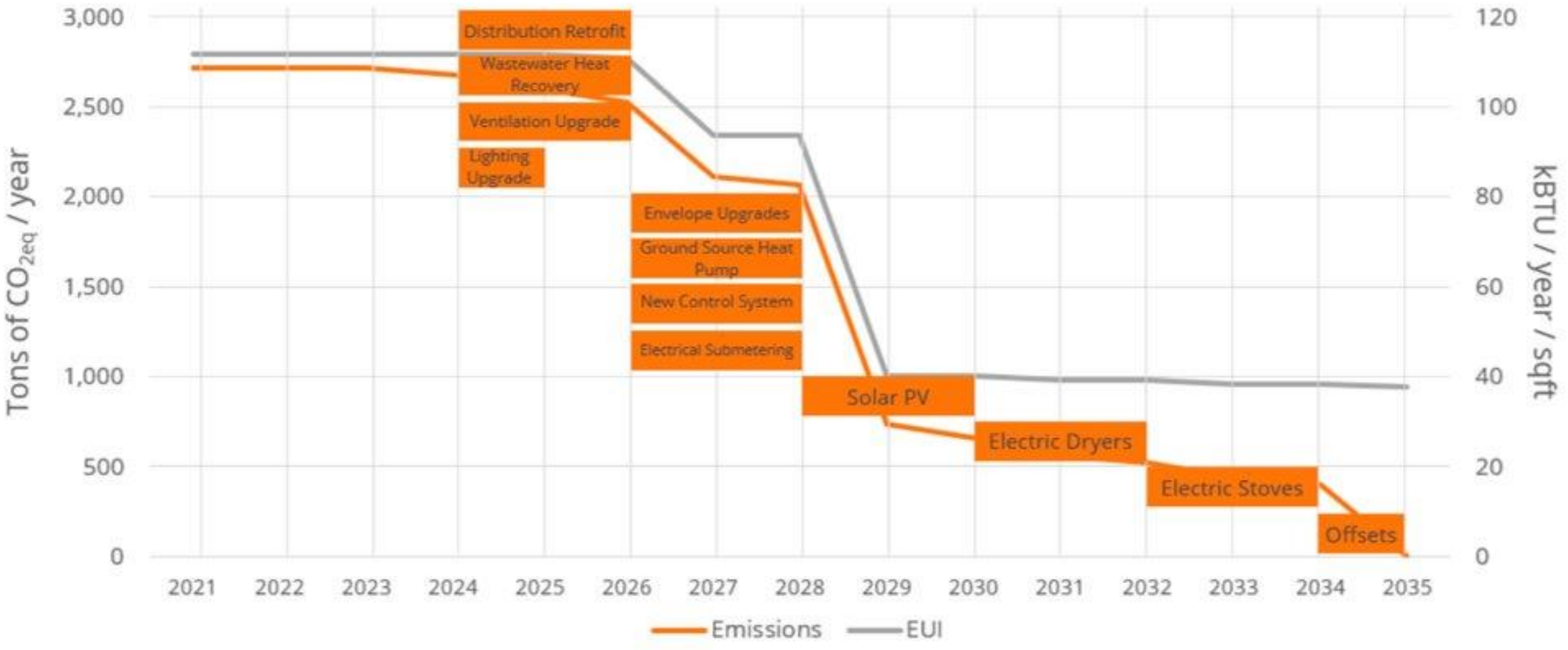




Phase 1: Hybrid electrification, with enabling steps
Phase 2: Full electrification
Decarbonization period: end date 2040
Results: 100% electric and carbon free.

Source: JB&B Deep Carbon Reduction Group.

Example phase-in plan over long time horizon

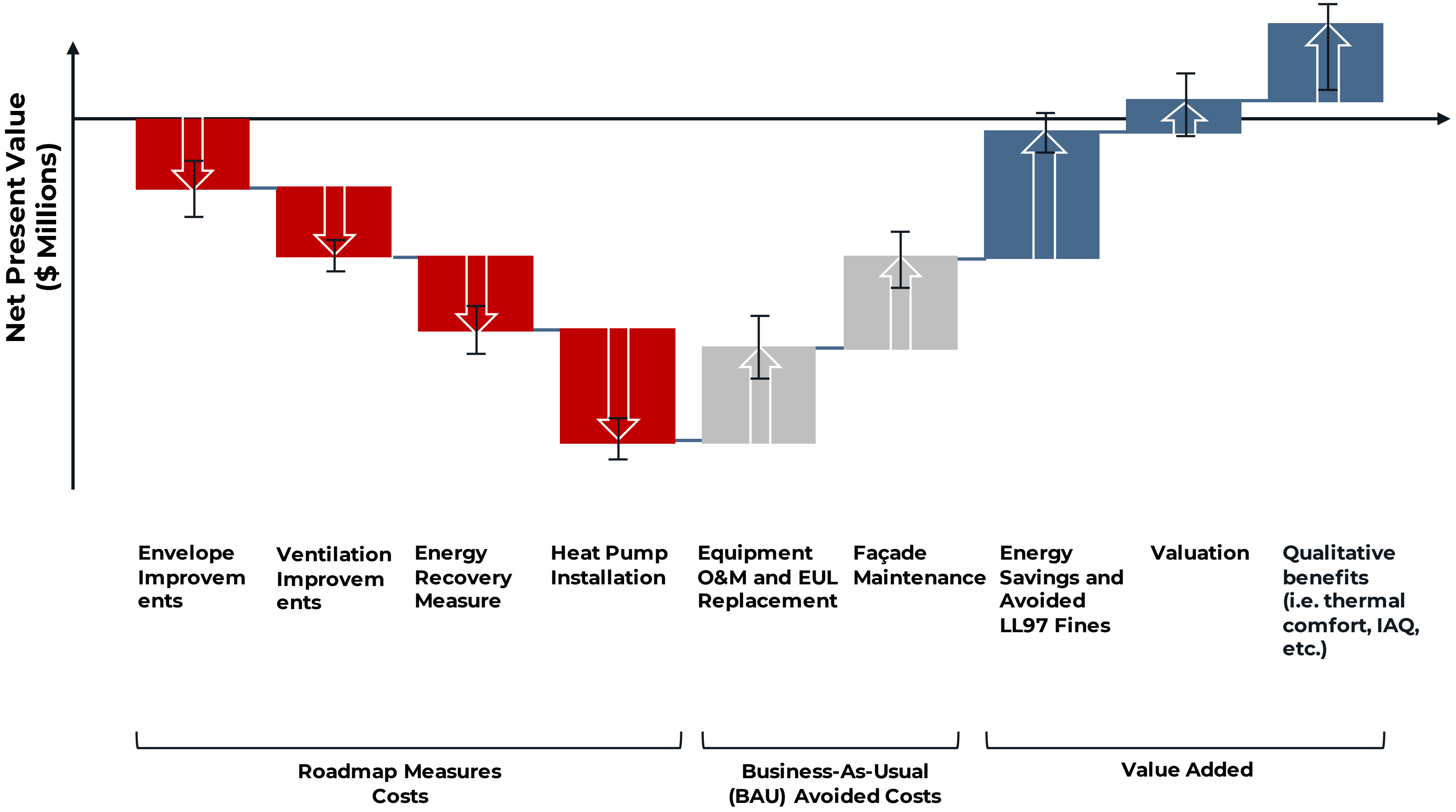


Example business case

Illustration of a discounted cash flow analysis, comparing expected costs and revenues with Business-As-Usual.

Net Present Value (NPV) is a financial calculation used to determine the value of an investment or project over a period of time by comparing the present value of its expected future cash inflows with its expected cash outflows. In other words, will the investment generate a positive or negative return after accounting for the time value of money?

Sensitivity bars representing the volatility or uncertainty of the calculation due to input variables.



About The Empire Building Challenge Program

Demonstrates strategic decarbonization planning and implementation of low carbon retrofits.

Showcases **Resource Efficient Decarbonization**: an incremental methodology, coupled with integrated design and strategic capital planning, that creates a path towards efficiently decarbonizing buildings.

Redirects focus from electricity to heat, making a case to stop wasting heat in buildings, and reusing it .

Clarifies the process to reach the lowest marginal cost of decarbonization.

Additional information: www.nyserda.ny.gov/ebc
Contact us: ebc@nyserda.ny.gov

NEW YORK STATE | Empire Building Challenge

Empire Building Challenge

GOALS

- Accelerate **investment** in decarbonization.
- Enable **replication and scale** across New York's existing large commercial and multifamily building stock.
- Drive **innovation** and market **demand**.

APPROACH

- Fund **demonstration projects** that show case cost-effective approaches to deep carbon reduction.
- Work with **portfolio** owners.
- Establish a **REPEATABLE PROCESS**.
- **Simplify** and share broadly.

FUNDING

- **$50M** in funding for technical assistance and implementation.
- **$10M** Empire Technology Prize.

Sixteen New York Portfolios

10 commercial and 6 multifamily partners overseeing
- **228 M sq. ft.**
- **70K housing units**

With public commitments to decarbonize over **125 million sq. ft.** including close to 1,500 units of affordable housing.

Empire Building Challenge
PARTNER
Reimagining Low-carbon Buildings

HUDSON SQUARE PROPERTIES
Rudin
Omni New York LLC
Jonathan Rose Companies
Silverstein Properties
Brookfield
beam LIVING
bxp
EMPIRE STATE REALTY TRUST
AMALGAMATED HOUSING COOPERATIVE
L+M Development Partners
LeFrak Organization
Durst
Equity Residential
VORNADO REALTY TRUST
TISHMAN SPEYER

16 premier sustainability and design consultants

Experience with:

- Energy modeling
- Deep energy retrofits
- Low temperature hydronic re-engineering
- Hybrid electrification
- Geothermal
- Feasibility analysis
- Decarbonization planning

Empire Building Challenge
PARTNER
Reimagining Low-carbon Buildings

EN-POWER GROUP
Cosentini A TETRA TECH COMPANY
RUHL
ryan soames engineering
JLL
JB&B
GOLDMAN COPELAND CONSULTING ENGINEERS
egg geo
Steven Winter Associates, Inc.
AKF
Brightcore BUILDING ENERGY PERFORMANCE™
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SOCOTEC
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urbs. URBAN SYSTEMS

Technical Overview Presentations

The following slides share insights into each of the Empire Building Challenge demonstration projects.

NEW YORK STATE | Empire Building Challenge

Whitney Young Manor

- Yonkers, NY
- 230,000 SF
- 195 apartments
- 2 affordable multifamily buildings built in 1974

Empire Building Challenge
PARTNER
Reimagining Low-carbon Buildings

How to leverage recapitalization to achieve carbon neutrality and transform the affordable housing sector

Project Team:

BRIGHT POWER

Omni New York LLC

Curtis + Ginsberg Architects

SHARC ENERGY

Disclaimer: The project plan outlined in this presentation is in its early design stage and can be subject to potential changes in the future.

Whitney Young Manor is an aging affordable housing complex with open balconies, inefficient electric resistance baseboard heating, electric window sleeve AC units, and a gas-powered hot water heater.

The project team believes that with care, planning, and the appropriate resources, retrofitting these residential buildings can be equitable for tenants, beneficial to the environment, and financially feasible for owners. Omni leverages the recapitalization cycle of the property to upgrade its infrastructure and include decarbonization measures to meet its climate goals.

This project prioritizes intensive load reduction through envelope improvements and hydronic distribution to improve resident comfort while reducing carbon emissions, utility spend and maintenance costs.

NYSERDA Investment	Total Project Investment
$5 Million	$12 Million

Whitney Young Manor demonstrates the benefits of over-cladding and hydronic distribution to enable heat pump technology

Envelope Improvements: Over-cladding using Exterior Insulation and Finishing System (EIFS) helps reduce heat loss and air infiltration while avoiding façade maintenance costs associated with LL11. This measure is combined with the new Dedicated Outside Air System (DOAS) to make sure adequate fresh air is injected into the building.

Hydronic Distribution: The new water-based distribution piping will enable the integration of different heating sources and allow heat sharing between end-uses, such as DHW production during cooling season. The construction team plans to pilot cross-linked polyethylene (PEX) piping to reduce cost and improve durability.

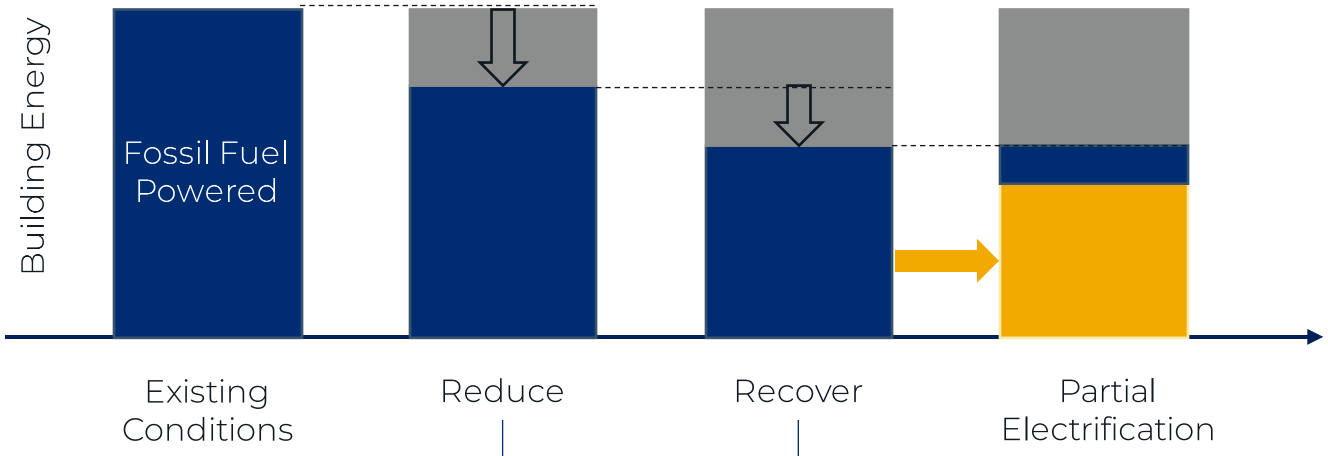
Heat Source Optionality: The project team plans to integrate different heat sources connected to the central hydronic piping. This includes centralized air source heat pumps, Wastewater Energy Transfer (WET) system and gas-fired condensing boilers as back-up.

2019 Baseline	Expected by 2035	
96 kBtu/SF/yr	**48** kBtu/SF/yr	50%
54% Natural Gas + **46%** Electricity	**25%** Natural Gas + **75%** Electricity	
1,456 tCO2e/yr	**273** tCO2e/yr	81%

Resource Efficient Decarbonization (RED):

An incremental methodology and integrated design process combined with strategic capital planning creates a path towards carbon neutral buildings.

A holistic approach and phasing can make decarbonization technically and economically feasible.



Reduce Energy Load

- **New hydronic distribution:** High efficiency water-based distribution system, lower supply temperature
- **Dedicated Outside Air System (DOAS):** decouple ventilation from heat and cooling systems
- **Envelope Improvements:** overclad, roof insulation and window replacement

Recover Wasted Heat

- **Wastewater Heat Recovery:** Recapture heat from wastewater using WSHP
- **Energy Recovery Ventilator (ERV):** Recapture heat from ventilation exhaust to condition make-up air

Partial Electrification

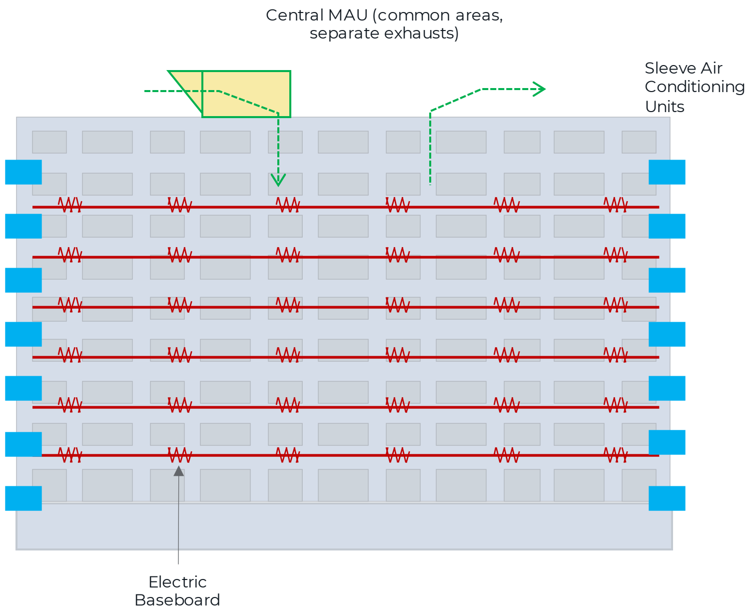
- **Central Air Source Heat Pump (ASHP):** Maintain design temperatures for the hydronic loop
- **Water Source Heat Pump (WSHP) for Domestic Hot Water (DHW):** DHW production supplied by hydronic loop
- **Back-up gas condensing boiler:** Provide supplemental heat during cold events as resiliency

Whitney Young Manor Decarbonization Plan

Heating
Cooling
Ventilation

Key Takeaways: Affordable Housing Recapitalization, Tenant Total Cost Reduction, Failing Envelope

BEFORE



2023:

Envelope Improvements
EIFS over uninsulated masonry, new windows, new roof

Dual-Temp Hydronic System
New 2-pipe hydronic piping drilled through common areas.

Central ASHP
Install 2 ASHPs to produce low temperature hot water and chilled water for in-unit FCUs

Back-up Gas Boiler
For use during power outages and extreme cold events

Fan Coils installed in units

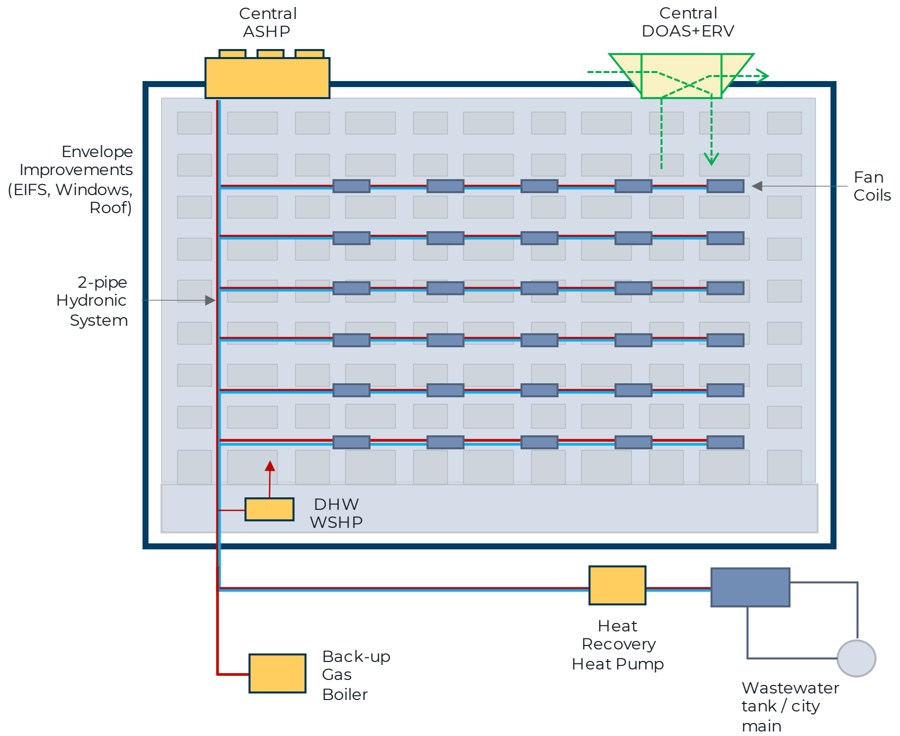
Central DOAS+ERV
Heat pump DOAS with ERV to supply tempered air to units via common areas,

WSHP for DHW
Install modular WSHPs supplied by hydronic loop

2024:

Wastewater Energy Transfer (WET) System
Install 18,000 gal sewage tank and use Sharc Energy heat pumps to recover heat and supplement central ASHPs

AFTER



The Heritage

- New York City
- 680,000 SF
- 600 apartments
- 3 mixed income multifamily buildings built in 1975

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PARTNER
Reimagining Low-carbon Buildings

Fully occupied mixed income property gets a face lift

Project Team:

L+M Fund Management

Steven Winter Associates, Inc.

Inglese Architecture + Engineering

Cosentini A TETRA TECH COMPANY

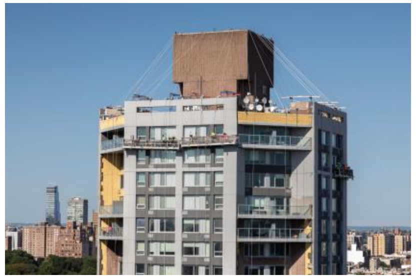
sto

DEXTALL Prefabricated Exterior Walls

ICE AIR World Class Comfort®

Disclaimer: The project plan outlined in this presentation is in its early design stage and can be subject to potential changes in the future.

The Heritage is a 3-building mixed-use development with 600 mixed-income residential units located in Manhattan's East Harlem neighborhood on the northeast corner of Central Park. These buildings have an aging infrastructure with poor insulation, and high utility bills due to inefficient electric resistance heating baseboards and gas-fired domestic hot water heaters.

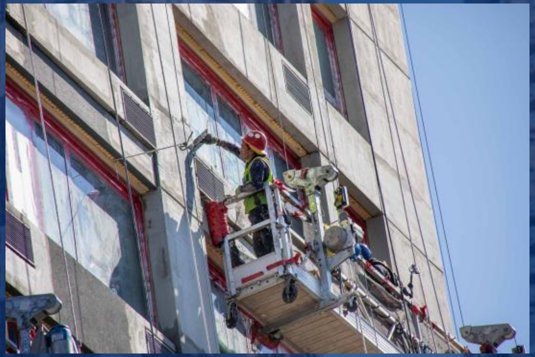


L+M takes advantage of the recapitalization cycle of the Heritage to upgrade its infrastructure and include decarbonization measures to meet its climate goals while improving tenant comfort.

The outdated design and age of the property made it an ideal candidate for a deep carbon reduction project, focused on envelope improvements, high efficiency heat pumps, and an integrated design approach to minimize tenant disruption.

NYSERDA Investment	Private Investment
$5 Million	$14 Million

The Heritage demonstrates how a well-planned façade upgrade enables decarbonization with less tenant disruption



Re-skin the exterior: improving the building envelope and reduce energy load

Re-cladding of the 3 buildings is estimated to avoid $10 million of LL11 compliance costs between now and 2046. One portion of the project is using pre-fabricated external wall panels from Dextall to minimize installation time and therefore tenant disruption.

Heat Pump Technology: take advantage of higher efficiency

Replacing apartment electric resistance heating baseboards and sleeve air conditioning units with modular Packaged Terminal Heat Pumps (PTHP), and installing CO_2-based heat pumps for Domestic Hot Water (DHW) production will significantly increase system efficiency and reduce energy use and costs. The PTHP installation work is coordinated with the panelized external wall system to integrate necessary electrical upgrades and condensate lines and minimize installation time as a result.

2019 Baseline	Expected by 2030	
77 kBtu/SF/yr	**45** kBtu/SF/yr	↓ 42%
35% Natural Gas + **65%** Electricity	**100%** Electricity	
3,414 tCO2e/yr	**1,072** tCO2e/yr	↓ 69%
$34,424 /year of LL97 fines starting in 2030	**$0** LL97 fines starting in 2030	

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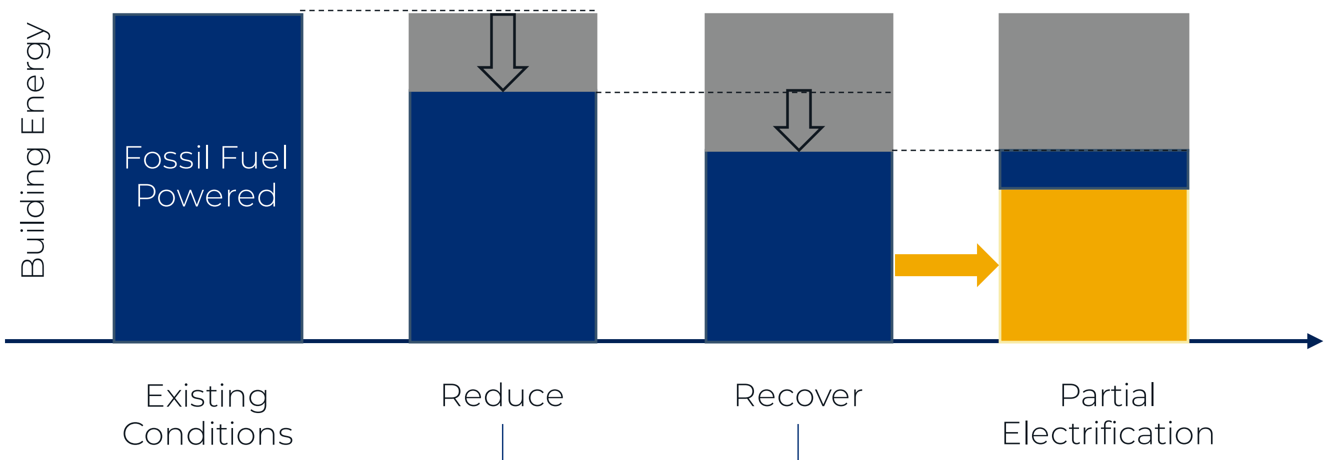
An incremental methodology and integrated design process combined with strategic capital planning creates a path towards carbon neutral buildings.

A holistic approach and phasing can make decarbonization technically and economically feasible.



Reduce Energy Load

- **Envelope Improvement:** Install exterior wall and roof insulation (overclad and panelized EIFS), and replace windows
- **Heat Pumps:** Replace electric baseboard heating with Package Terminal Heat Pumps (PTHPs) for apartments and install VRF system for common areas
- **Submetering and Control Optimization**

Recover Wasted Heat

- **Energy Recovery Ventilator (ERV):** install ERV unit into exhaust risers to recapture exhaust heat and preheat fresh air

Partial Electrification

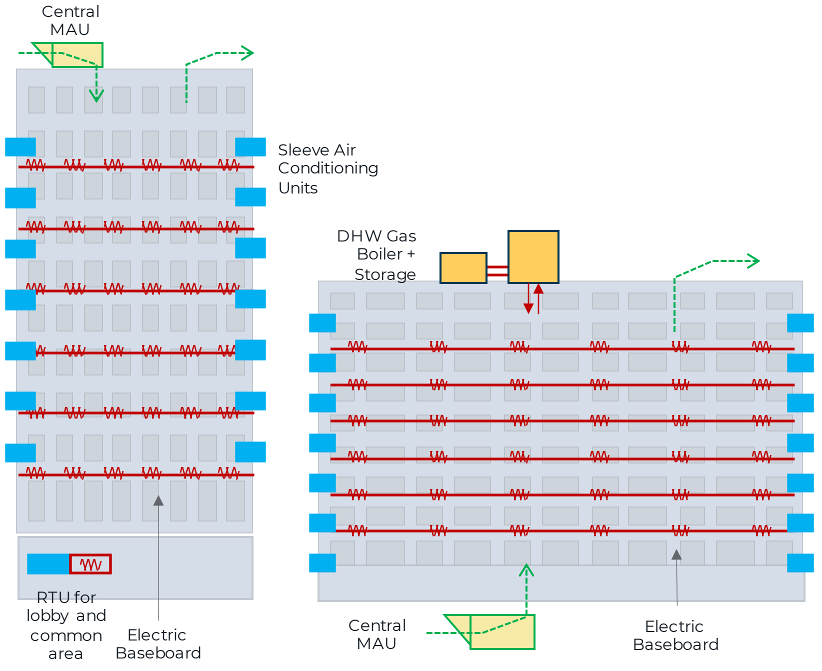
- **Domestic Hot Water:** CO_2 Air Source Heat Pump (ASHP) for DHW production
- **Laundry appliance**

The Heritage Decarbonization Plan

Heating
Cooling
Ventilation

Key Takeaways: Affordable Housing Recapitalization, Tenant Total Cost Reduction, Failing Envelope

BEFORE



Two Towers **1660 Madison Ave**

Two Towers (1295 & 1309 Fifth Ave):

2022:

- **Install VRF Heat Pump Unit for Lobby and Common Area**
- **Exterior Insulation**
  EIFS overclad from Sto Corporation
- **Submetering and Controls Upgrades**

1660 Madison Ave:

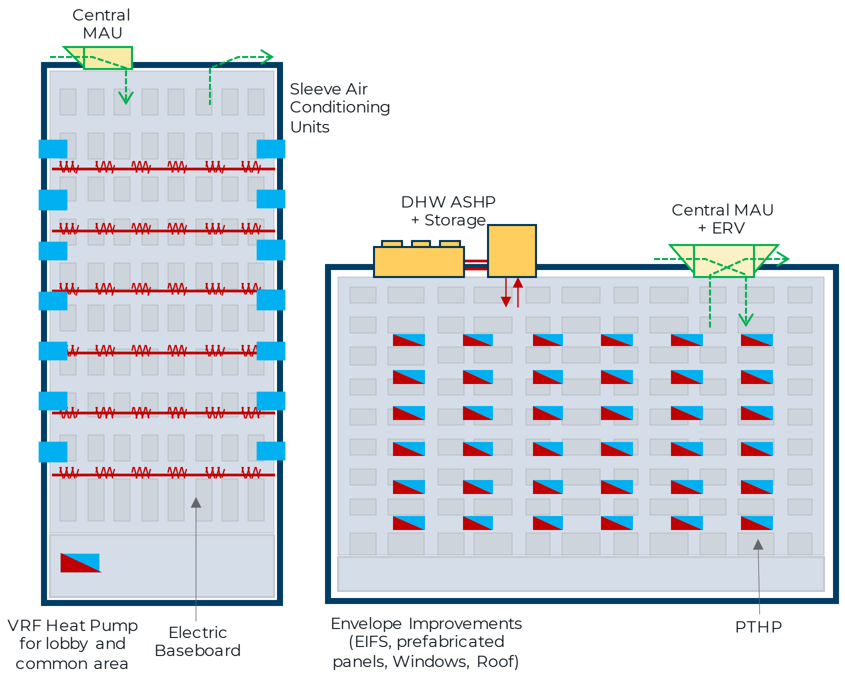
2023:

- **Exterior Insulation & High-Performance Windows**
  Unitized prefabricated ext. wall (Dextall), windows, roof
- **Packaged Terminal Heat Pumps**
  Decentralized IceAir PTHP (no backup resistance heat), integrated with Dextall wall panels (electrical upgrades + condensate drainage)

2024:

- **Energy Recovery Ventilation (ERV)**
  Adding ERV to rooftop fresh air unit
- **Domestic Hot Water (DHW) Electrification**
  CO_2 ASHP for DHW
- **Laundry appliance electrification**
- **Submetering and Controls Upgrades**

AFTER



Two Towers **1660 Madison Ave**

The Towers

- Bronx, NY
- 425,000 SF
- 2 affordable multifamily building built in 1968 and 1971
- 20 stories
- 316 apartments

Empire Building Challenge
PARTNER
Reimagining Low-carbon Buildings

Making clean energy from dirty water to eliminate carbon emissions.

AMALGAMATED HOUSING COOPERATIVE

Project Team:

EN-POWER GROUP

egg geo

Amalgamated Housing Corporation (AHC) is the oldest limited equity co-operative in the United States. The Towers are two of 13-buildings that together comprise this multifamily campus located in the Bronx. Many of systems at the property, including the piping distribution system, are beyond useful life and in extremely poor condition, causing leaks and requiring constant repairs and maintenance. The campus uses a central gas-powered boiler plant to produce steam for heating, cooling and domestic hot water.

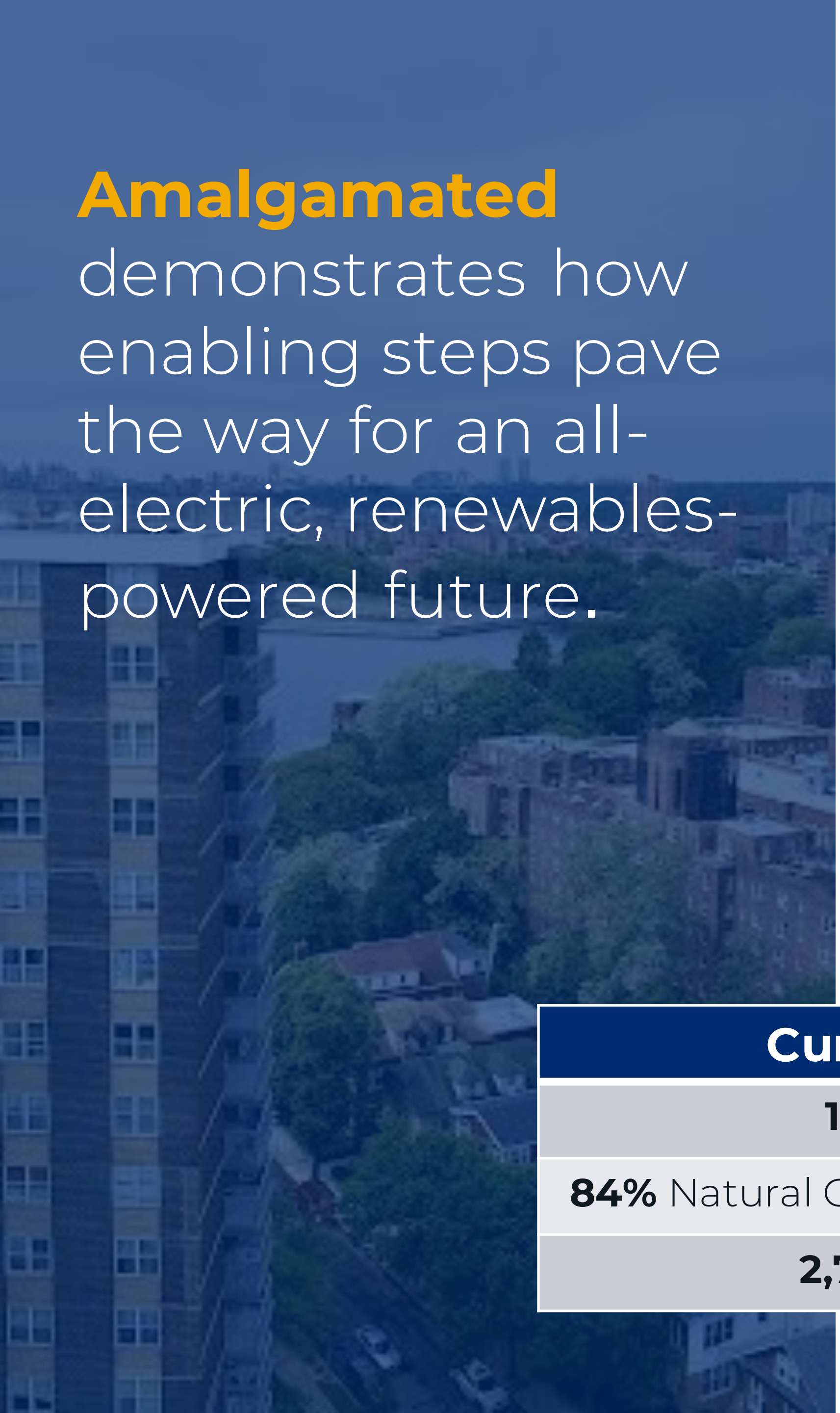
As part of its recapitalization cycle, the property is embarking on a decarbonization journey which will include a comprehensive retrofit of the heating, cooling and domestic hot water systems, a façade upgrade, and on-site renewable generation in the form of geothermal and solar PV.

This project will increase thermal comfort and secure utility affordability for its low-and-moderate income residents, as well as enhance the energy efficiency and climate resilience of the property.

From the full carbon neutrality roadmap, the Empire Building Challenge is funding the first two enabling measures: hydronic system retrofit and wastewater heat recovery.

NYSERDA Investment	EBC Funded Measures Private Investment	Full Roadmap Private Investment
$3 Million	**$16.6 Million**	**$27 Million**

Disclaimer: The project plan outlined in this presentation is in its early design stage and can be subject to potential changes in the future.



Amalgamated demonstrates how enabling steps pave the way for an all-electric, renewables-powered future.

Enabling step: New hydronic piping

Replace the dual temperature hydronic system with new piping supplying both heating hot water and chilled water simultaneously to provide heating or cooling year-round improving tenant comfort. The measure includes new fan coil units with more efficient motors and designed for low temperature heating hot water to reduce the load on the buildings and facilitate heat pump technology integration.

Integrate different heat sources:

Wastewater heat recovery: Recapture heat from wastewater lines (sinks, showers, toilets) using a wastewater energy transfer (WET) system.

Geothermal System: Drill boreholes on property land and install ground source heat pumps (GSHP) to meet the remaining energy loads of the buildings.

This system will use the wastewater and boreholes as heat sinks in cooling mode.

Current Baseline	Expected by 2035	
111.6 kBtu/SF/yr	**32.5** kBtu/SF/yr	↓ 71%
84% Natural Gas + **14%** Electricity + **2%** Oil	**100%** Electricity	
2,771 Ton CO2e/yr	**202** Ton CO2e/yr	↓ 93%

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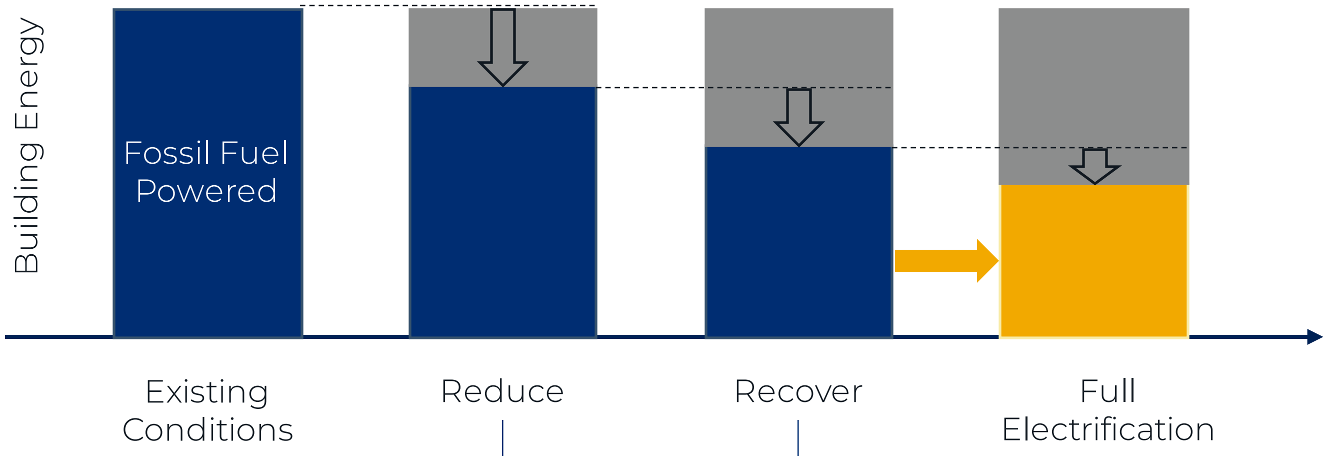
A holistic approach and phasing can make decarbonization technically and economically feasible.



Reduce Energy Load

- **New hydronic distribution:** Replace existing infrastructure that is beyond EUL and install dual-temperature 2-pipe hydronic system (in-series configuration allowing the benefits of 4-pipe system), with new FCUs in apartments. Designed with lower heating supply temperature
- **Envelope Improvements**: roof insulation, window replacement and air sealing walls
- **Ventilation Maintenance**: balancing and sealing of ventilation system to reduce exhaust air
- **Controls Upgrades**: Install modern control system to automate and optimize new heat pump systems

Recover Wasted Heat

- **Wastewater Heat Recovery:** Recapture heat from wastewater using WSHPs to produce heating, cooling and DHW. Use wastewater as heat sink in cooling mode to enable removal of old cooling towers.

Full Electrification

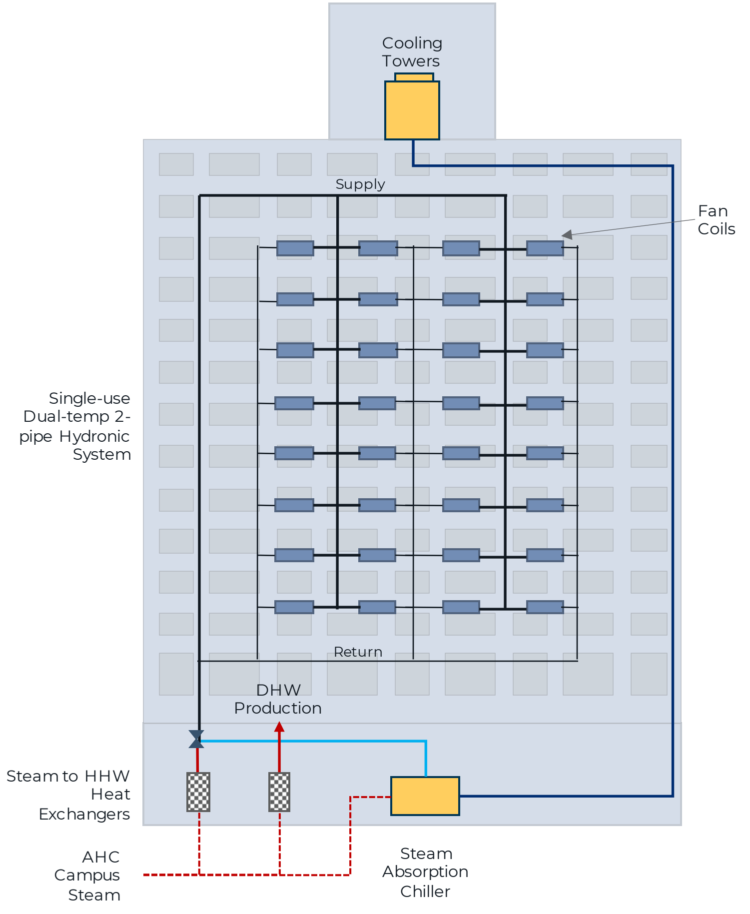
- **Ground Source Heat Pumps**: Drill boreholes on property land and install WSHPs to produce heating, cooling and DHW. Use boreholes as heat sink in cooling mode
- **Solar PV:** Install solar PV system on rooftop
- **Electrify Appliances:** install electric dryers and cooking equipment

The Towers Decarbonization Plan

Heating
Cooling
Ventilation

Key Takeaways: Affordable housing recapitalization, Tenant total cost reduction, Failing distribution infrastructures, Eliminate fossil fuel usage, Improve comfort, Resilient systems

BEFORE



2024:

Retrofit Dual-Temp Hydronic System
Existing distribution system and terminal units beyond EUL. Install new dual-use dual-temp 2-pipe hydronic piping, designed for simultaneous heating and cooling, with new FCUs in apartments.

Wastewater Energy Transfer (WET) System
Install sewage tank and use Sharc Energy heat pumps to produce heating, cooling and DHW

Ventilation System Maintenance
Cleaning and balancing of existing ventilation system

2026:

Envelope Improvements
Insulate roofs, replace windows and air seal walls.

Geothermal System
Drill geothermal boreholes on property land and install ground source heat pumps to produce heating, cooling and DHW

Submetering and Controls Upgrades

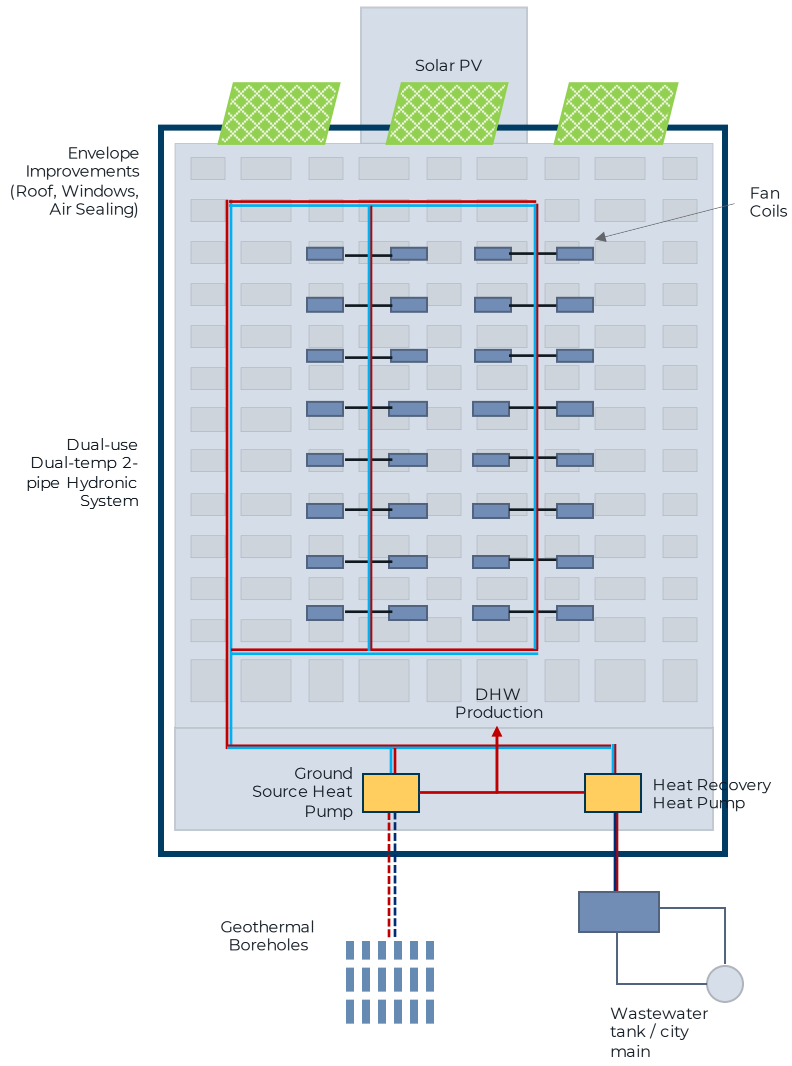
2028:

Solar PV
Take advantage of rooftop space to install solar PV system for clean electricity generation

2030+:

Laundry and cooking appliance electrification

AFTER



Empire State Building

- New York City
- 2.85 million SF
- 102 stories commercial
- office building built in 1931

Empire Building Challenge
PARTNER
Reimagining Low-carbon Buildings

New York City icon reaches for Net Zero by 2030

Project Team:

EMPIRE STATE REALTY TRUST

BURO HAPPOLD

LUTHIN ASSOCIATES

Quest energy group

Disclaimer: The project plan outlined in this presentation is in its early design stage and can be subject to potential changes in the future.

The **Empire State Building** has been an integral part of the NYC skyline since 1931. The 102-story art deco structure is heated by district steam.

Following up on a deep energy retrofit initiated in 2009, Empire State Realty Trust (ESRT) has taken a step further with *ESB 2.0*, a 21st century plan to bring the iconic building to Net Zero.

Through this plan, ESRT will prove the technical and economic business case for investing in deep energy retrofits and share findings to drive market change within the high-rise office building landscape.

The phased approach strategically deploys energy conservation measures through 2035. ESRT will optimize existing systems, maximize energy recovery and enable heat pump integration to decrease steam and electricity consumption.

NYSERDA Investment	Private Investment
$5 Million	$40 Million +

Empire State Building will demonstrate phased decarbonization in a fully occupied landmarked building

Learn more about the Empire State Building project

- ESB: Energy Efficiency and Sustainability
- ESRT Shares New Guide in Empire Building Playbook
- Empire Building Playbook: ESRT Case Study
- How the Empire State Building Became a Green Icon

Optimization: ensure existing systems are operating automatically and efficiently

By enabling automation of heating and cooling systems, upgrading to high performance sequences of operation, and integrating zones throughout the building onto the base building BMS, the functionality and efficiency of current systems are maximized, and simultaneous heating and cooling is eliminated.

Heat Recovery: recaptures thermal energy that would otherwise be wasted

Water source heat pump(s) will recover heat from the condenser water loop to displace steam usage and energy recovery ventilators (ERVs) will retain and utilize heat from the building's exhaust ventilation system.

Heat Pump Integration: install new centralized hydronic heating loop to enable the use of heat pump technology

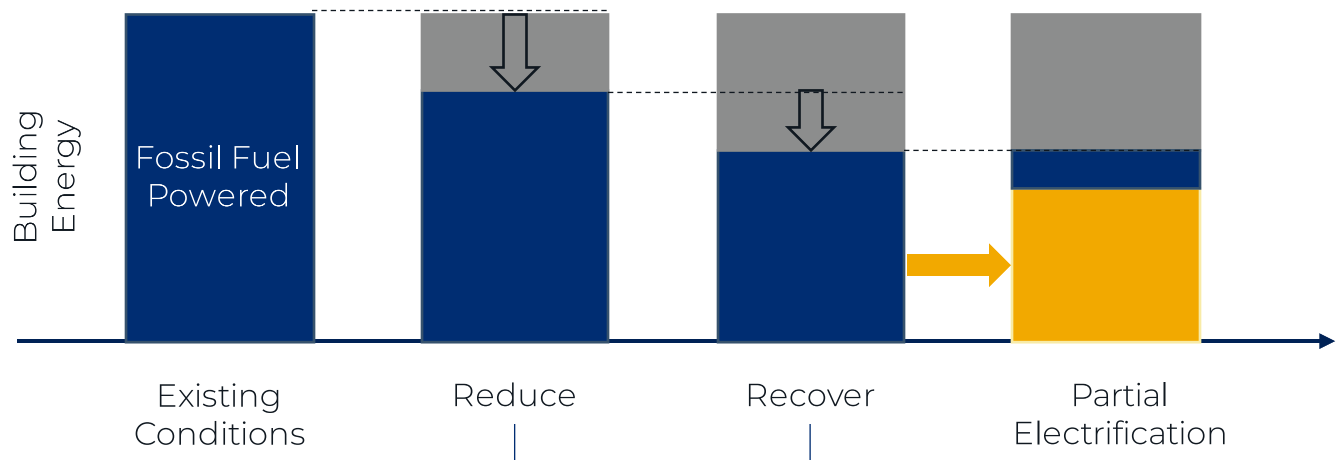
The team is replacing steam coils in core air handling units with low temperature hot water coils supplied by air source heat pumps.

2019 Baseline	Expected by 2035	
84 kBtu/SF/yr	**50** kBtu/SF/yr	↓ 40%
35% District Steam + **63%** Electricity	**16%** District Steam + **82%** Electricity	
15,640 tCO2e/yr	**3,986** tCO2e/yr	↓ 75%
$933,000 /year of LL97 fines starting in 2035	**$0** LL97 fines starting in 2035	

Resource Efficient Decarbonization (RED):

An incremental methodology and integrated design process combined with strategic capital planning creates a path towards carbon neutral buildings.

A holistic approach and phasing can make decarbonization technically and economically feasible.



Reduce Energy Load

- **Cooling plant optimization:** connect the chilled water zones with heat exchangers to share load, optimize shoulder season usage, and increase resiliency
- **Retail Loop Condenser Water Control:** retro commission the CW loop to enable heating mode on existing tenant WSHPs
- **Air Source Domestic Hot Water Heaters Pilot:** replace existing electric water heaters with ASHP
- **Steam System Optimization and Improvements**
- **Airside Sequence of Operations:** implement high performance sequence of operations to enable static pressure and temperature resets and eliminate simultaneous heating and cooling.

Recover Wasted Heat

- **Energy Recovery Ventilator (ERV) Pilot:** install ERVs in tenant MERs to recover heat from AHU exhaust, temper incoming outdoor air, and address freeze risk
- **1st Floor Lobby Reheat via Waterside Heat Recovery:** Replace lobby AHU steam coils with hydronic heating coils supplied by WSHP that recover heat from the building condenser water loop to enable electrified heating and reheat. Recover heat from the steam condensate system to provide resiliency during the heating season.

Partial Electrification

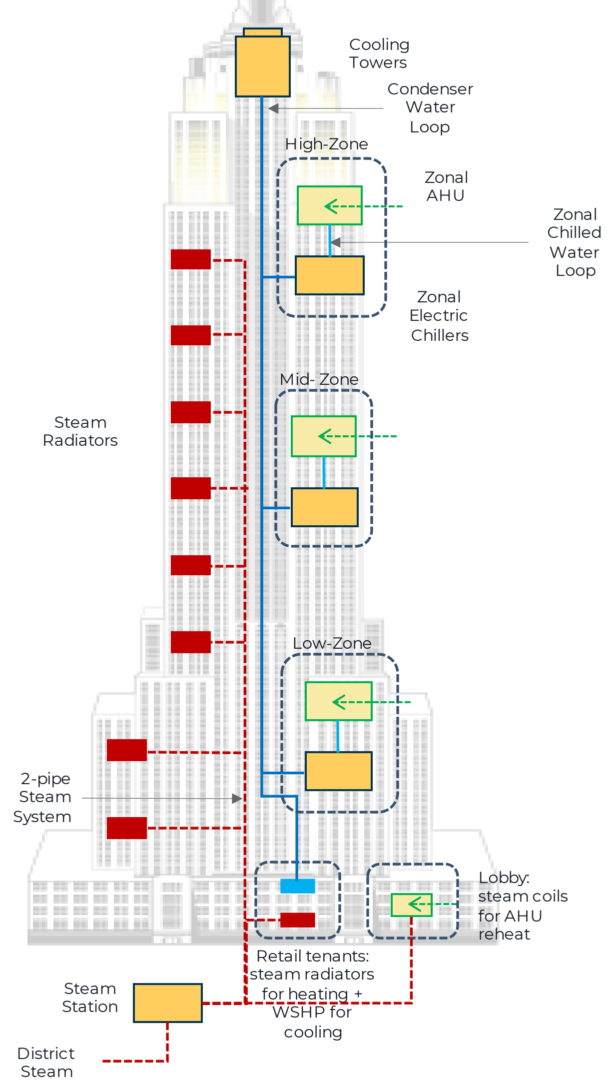
- **Steam Phase-Out Enabling Step:** Eliminate steam usage for airside heating with new low temp. HHW riser (120F) supplied by central ASHP

Empire State Building Decarbonization Plan

Heating
Cooling
Ventilation

Key Takeaways: Reduce district steam usage, decouple core ventilation heating load and perimeter heating, optimize operation of cooling plant, enable heat recovery

BEFORE



2022:

Central Cooling Plant Optimization
Connect the chilled water zones with HX to share load and optimize shoulder season usage

1st Floor Lobby Reheat via Waterside Heat Recovery
Replace AHU steam coils with hydronic supplied by WSHP

Retail Loop Condenser Water Control
3-port valve to independently control the retail loop from the building condenser loop and enable heating mode on tenant WSHPs

2023:

Steam Phase-Out Enabling Step: Hydronic Riser + ASHP
Eliminate steam usage for airside heating: new low temp. HHW riser (120F) supplied by central ASHP + replace zonal AHU steam coils with hydronic coils

Steam System Optimization and Improvements
Automating start-up practices, convert medium-pressure to low-pressure steam, etc.

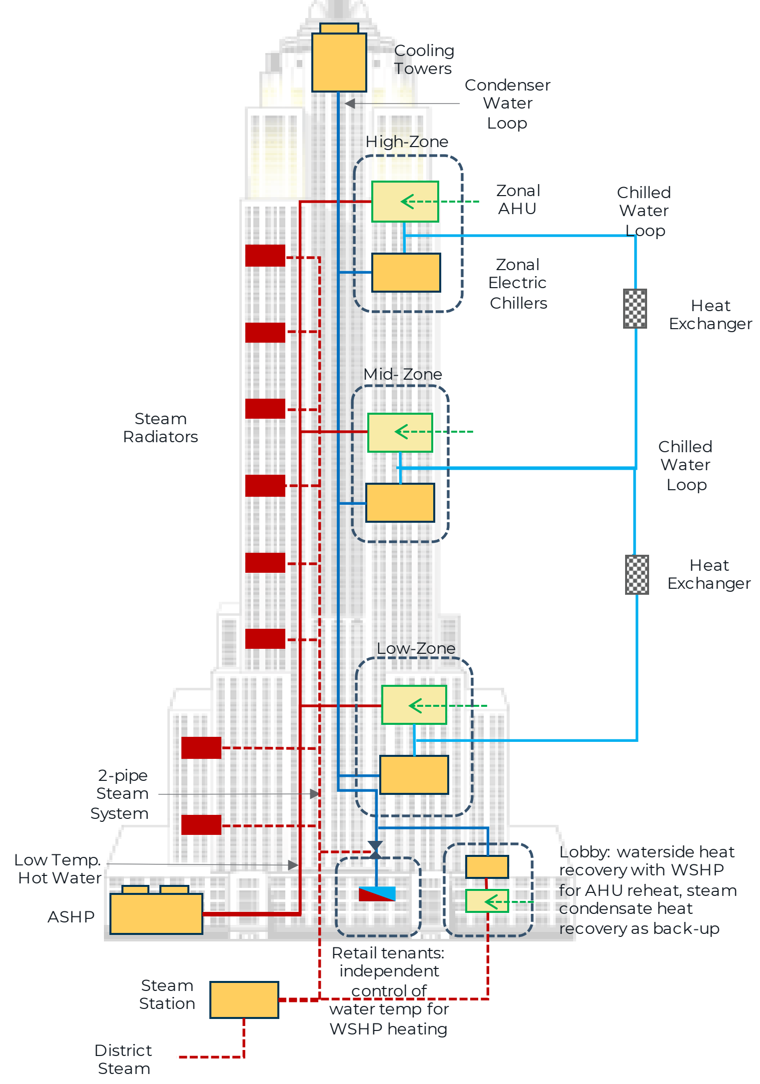
2024:

Energy Recovery Ventilator (ERV) Pilot
ERV on floor outdoor AHU for select floors

Air Source Domestic Hot Water Heaters Pilot
Convert existing electric water heaters to ASHP

Airside Sequence of Operations
Implement static pressure and temperature resets; Optimize chilled water dT

AFTER



345 Hudson Street

- New York City
- 857,000 GSF
- 17 stories commercial
- office building built in 1931

Empire Building Challenge
PARTNER
Reimagining Low-carbon Buildings

Nordic design principles applied to New York real estate

Hudson Square Partnership:

Hines · TRINITY CHURCH WALL STREET · NORGES BANK INVESTMENT MANAGEMENT

Project Team:

urbs. URBAN SYSTEMS · ENERGY MACHINES · JBB

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345 Hudson is a commercial office building with a mid-tier energy rating of 75 kBtu/SF, an ageing heating system burning natural gas and recurring carbon emissions fines starting in 2035.

The Hudson Square partnership is committed to future-proof its flagship property by upgrading its building infrastructure while meeting the legislative climate goals and stay competitive in the commercial office market.

The HSP team brought together a consortium of global solution providers and engineering expertise to develop a long-term retrofit plan to minimize energy usage and carbon emissions.

The 345 Hudson EBC project provides a roadmap for sustainable practices by applying the Nordic design principles of holistic energy recycling and electrification.

As part of the overall decarbonization roadmap, the Empire Building Challenge is funding the measures to be implemented before 2025

NYSERDA Investment	EBC Funded Measure Private Investment
$5 Million	$30 Million +

345 Hudson will demonstrate the power of thermal networking and electrification

Learn more about the 345 Hudson project

- High Rise / Low Carbon Partner Profile: 345 Hudson
- Empire Building Playbook: HSP Case Study

Thermal Networks: enable heat sharing between spaces

Developing a hydronic loop operating at ambient temperatures by converting the existing condenser water riser. The ambient loop enables future optionality with the integration of different heat sources and takes advantage of simultaneous heating and cooling opportunities between spaces and floors to reuse otherwise wasted heat.

Water Source Heat Pump by Energy Machines

Electrification: take advantage of high coefficient of performance

Leverage the high efficiency of heat pump technologies, enable grid interactivity, and take advantage of future low-carbon electricity production planned by the state.

Current Baseline	Potential by 2030*	
75 kBtu/SF/yr	**38** kBtu/SF/yr	↓ 50%
24% Natural Gas + **76%** Electricity	**100%** Electricity	
4,999 Ton CO2e/yr	**1,500** Ton CO2e/yr	↓ 70%
$204,000 /year of LL97 fines starting in 2030	**$0** LL97 fines through 2030	

* These potential results are based on the best-case scenario but are dependent on tenant plug loads and tenant equipment fit-outs.

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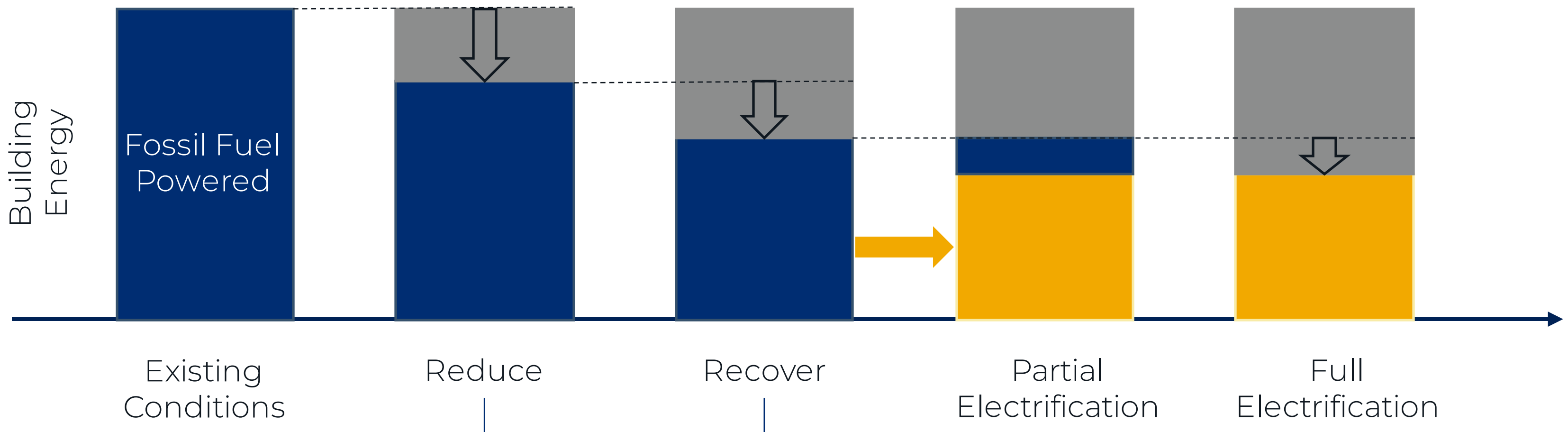
A holistic approach and phasing can make decarbonization technically and economically feasible.



Reduce Energy Load and Recover Wasted Heat

- **Ambient Loop Hydronic Spine:** high efficiency water-based distribution system, lower supply temperature and heat sharing between floors/zones
- **Dedicated Outside Air System (DOAS) with Energy Recovery Ventilator (ERV):** decouple ventilation from heat and cooling systems, and recapture exhaust air energy to reheat fresh air with 85% recovery
- **Tenant Conversion:** install floor-by-floor WSHPs and convert to hydronic low temperature heating and high temperature cooling
- **Window replacement** (provisional): reduce air infiltration

Partial Electrification: right-size heat pump

- **Central ASHP + Adiabatic Dry Cooler:** heat supply and heat rejection, maintain design temperatures for ambient loop

Full Electrification: replace/remove peak load equipment

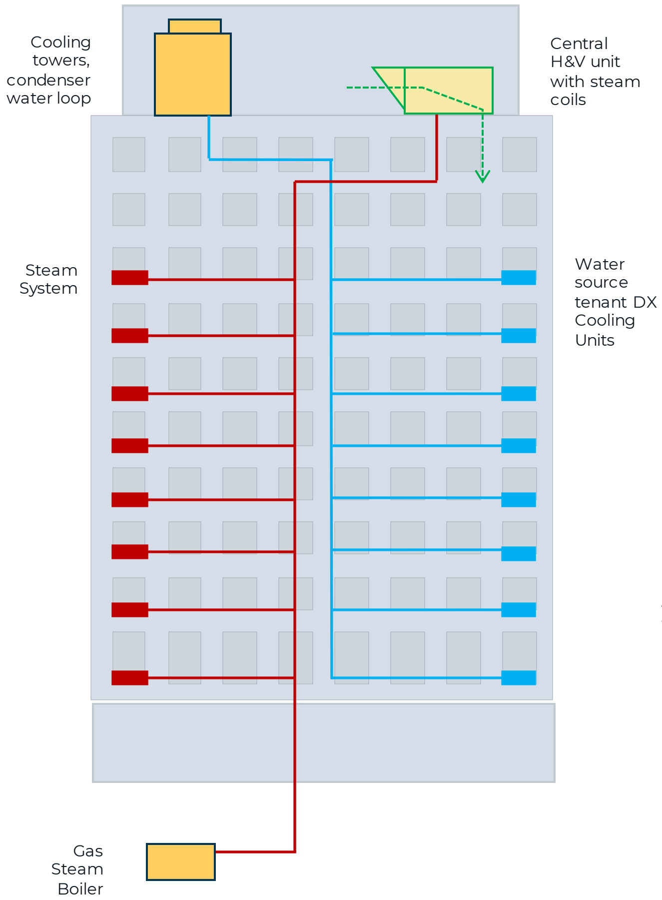
- **Thermal Storage** (provisional): leverage storage for peak load
- **Thermal network connection to neighboring building:** heat sharing capability and leverage geothermal pills in property next door
- **Decommission natural gas boilers**

345 Hudson Decarbonization Plan

Heating
Cooling
Ventilation

Key Takeaways: Eliminate on-site fossil fuel usage, phased-in implementation based on tenant turnover, lower distribution temperatures, minimize wasted heat, heat sharing

BEFORE



2022: **Install Ambient Loop Hydronic Spine**
Convert existing condenser water loop.

2023: **Tenant Conversion Phase 1**
Remove steam radiators and water source DX cooling units
Install 4-pipe hydronic, WSHP, fan-coil, radiant options

Install Central ASHP and Adiabatic Dry Cooler
Central plant to maintain design temp. for hydronic loop

2024: **Install Central DOAS+ERV**
Fresh air supply with minimum 85% heat recovery

Provisional: **Thermal network connection to neighbor**
new building with geothermal piles

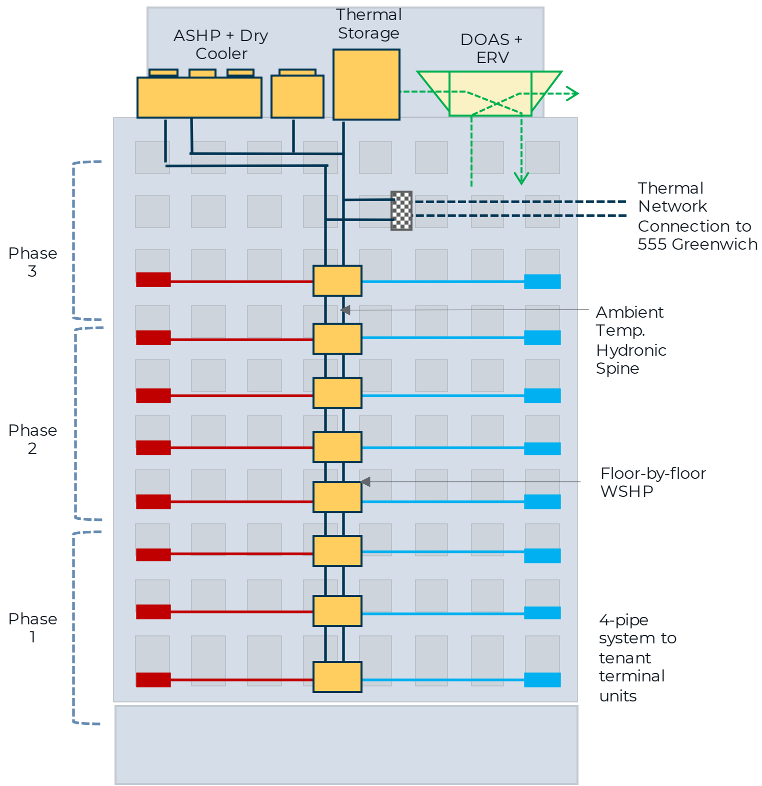
2025: Provisional: Install rooftop **Thermal Storage**
to supplement central plant

Provisional: **Envelope Improvements**
Replace windows to improve air infiltration and reduce load

2027: **Tenant Conversion Phase 2**
Phase-in tenant floor work based on tenant turnover lease

2029: **Tenant Conversion Phase 3**

AFTER



601 Lexington

- New York City
- 1.5 million SF
- 59 stories commercial
- Office building built in 1977

Empire Building Challenge
PARTNER
Reimagining Low-carbon Buildings

Iconic midtown office tower modernizes by recycling heat

Project Team:

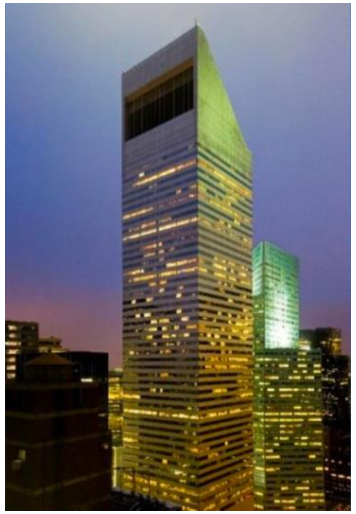
bxp

NORGES BANK INVESTMENT MANAGEMENT

JB&B

Disclaimer: The project plan outlined in this presentation is in its early design stage and can be subject to potential changes in the future.

601 Lexington Avenue anchors BXP's Midtown Manhattan campus, and the skyline itself, with a globally recognized silhouette. The premier workplace building, with ground floor retail, was constructed in 1977. The building's infrastructure is typical of NYC commercial high-rises of its vintage. Heating is achieved with district steam and cooling is achieved by way of a central plant featuring electric chillers and rooftop cooling towers.



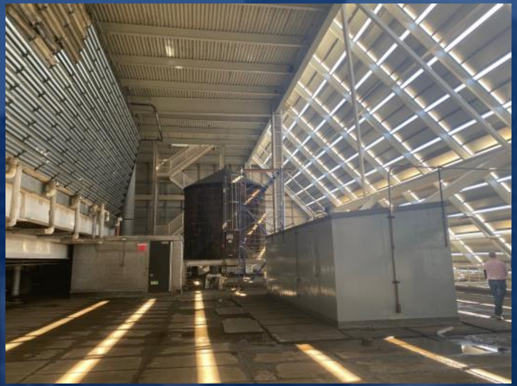
BXP strives to improve energy efficiency and has been minimizing the use of district steam at the property since 2010. This projects demonstrates a replicable decarbonization solution in existing commercial high-rise buildings and joins a list of energy conservation measures already deployed at the property.

This project will deploy existing technology in a novel way, creating a thermal network that recovers and utilizes heat which would otherwise be rejected by the cooling towers.

The Empire Building Challenge is funding the demonstration of condenser water heat recovery.

NYSERDA Investment	EBC Funded Measure Private Investment
$1.1 Million	**$2.5 Million**

BXP deploys existing technology in a novel way to create a thermal network to re-use heat that would otherwise be discarded.



Condenser Water Heat Recovery and Automated Bypass:

The building condenser water system carries heat from tenant supplemental systems to the cooling towers, where it is rejected to the atmosphere. Much of this heat is constant in commercial office buildings and available year-round for recovery. In the proposed measure, water-to-water heat pumps (WSHPs) will be installed. They will replace the function of the cooling towers during the heating season and will reclaim heat from the condenser water loop for beneficial use. An automated bypass valve will divert condenser water from the cooling towers, retaining as much heat in the building as possible for recovery by the WSHPs. The heat recovered will be reused in the building's heating systems and will significantly offset reliance on fossil fuel-based steam.

These measures will reduce annual steam consumption by an estimated 30%.

Potential Future Electrification:

In addition to the WSHPs, air source heat pumps (ASHPs) will be installed to produce low-temperature hot water to cover some of the remaining heating loads. The project team plans to investigate ASHP infrastructure within the physical space constraints of this occupied building to minimize reliance on steam heating.

Current Baseline	Expected by 2035	
86.3 kBtu/SF/yr	**73.6** kBtu/SF/yr	↓ 15%
69% Electricity + **31%** District Steam	**88%** Electricity + **12%** District Steam	
3,920 tCO_2e/yr	**2,899** tCO_2e/yr	↓ 26%

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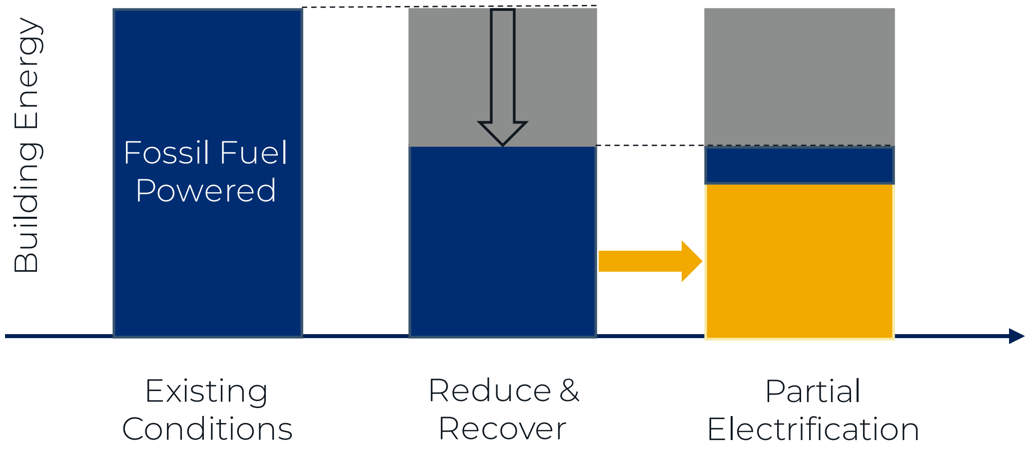


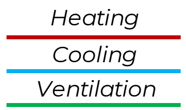
Recover Wasted Heat: EBC funded measure 2024

- **Condenser Water Heat Recovery:** Install WSHPs to capture waste heat from the condenser water loop. The recovered heat will be reused into the building's perimeter heating loop, reducing district steam usage.

Partial Electrification: Potential Future Measures 2034

- **Hydronic Coils for Ventilation Preheat:** Low temperature hot water for preheating ventilation air at select AHUs
- **Air Source Heat Pumps:** Use ASHP to produce low temperature hot water to serve partial heating loads

601 Lexington Decarbonization Plan



Key Takeaways: Recycle waste heat from the condenser loop and minimize reliance on district steam. Provide a replicable model for waterside heat recovery industry-wide and integrate air-side heat recovery, where possible.

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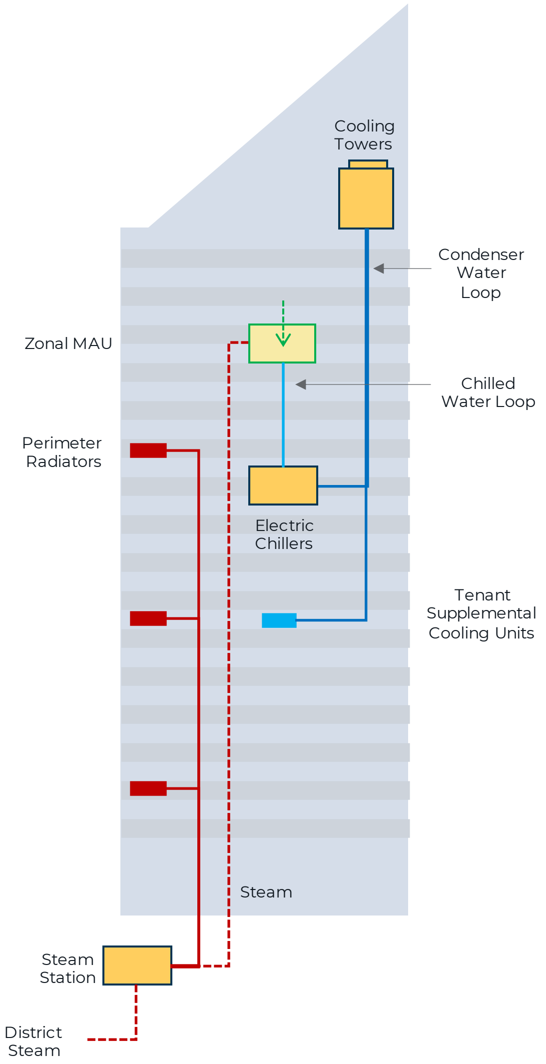


2024:

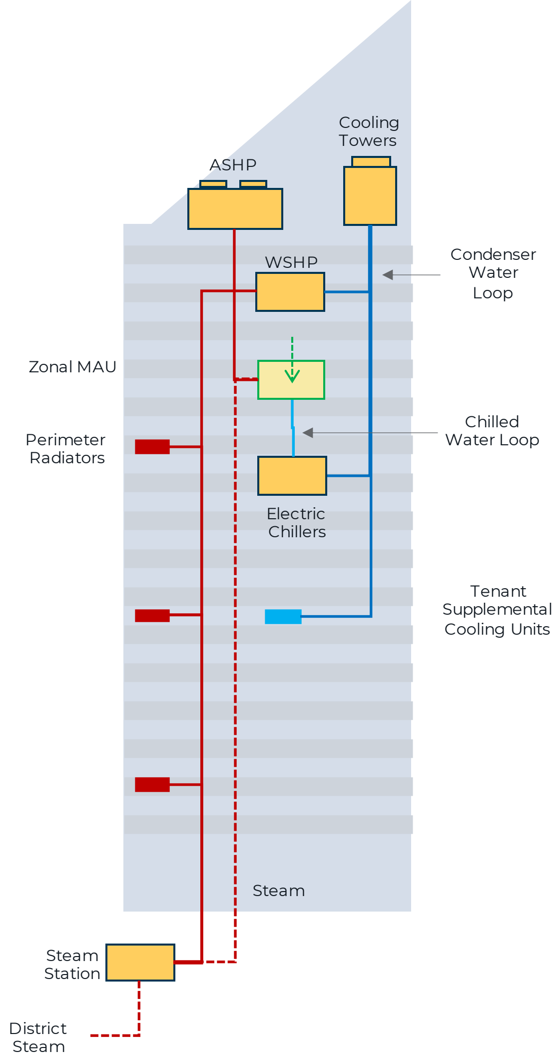
Condenser Water Heat Recovery
Install WSHP to reclaim heat for re-use in the building's perimeter heating systems. An automated cooling tower bypass valve will retain heat in the building, maximizing heat available for recovery during the heating season.

2034-2035:

Hydronic Coils for Ventilation Preheat
Install hydronic coils in select AHUs to supply low temperature hot water for preheating ventilation air, keep steam coils as back-up

Heating and DHW Electrification: Air Source Heat Pumps
Install air source heat pumps. These will reclaim heat from the atmosphere, to produce hot water for the remaining heating loads.

AFTER



660 Fifth Ave.

- New York City
- 1.4 million SF
- 41 stories commercial
- office building built in 1957

Empire Building Challenge
PARTNER
Reimagining Low-carbon Buildings

Modern heat recycling and fresh air systems help meet accelerated climate goals

Project Team:

Brookfield Properties

Cosentini
A TETRA TECH COMPANY

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660 Fifth Ave is a 42-story commercial office building located in Midtown Manhattan that is currently undergoing a full redevelopment to modernize the building.

Brookfield Properties is leveraging the redevelopment of this property to integrate decarbonization solutions that will upgrade its internal systems, reducing its reliance on fossil fuels and positioning it for full decarbonization by 2035.

The decarbonization plan for this property utilizes a variety of solutions that will cut energy use, recycle heat that would otherwise be wasted, and electrify existing building systems.

As part of the overall carbon neutrality roadmap, the Empire Building Challenge is funding the measures starting implementation in 2023 and 2024, including: lower distribution temperatures, thermal network expansion and waterside heat recovery.

NYSERDA Investment	EBC Funded Measures Private Investment
$3 Million	**$6.7 Million**

Brookfield demonstrates a multi-faceted, strategic approach to decarbonization of a high-rise office building

Energy Load Reduction:

Brookfield is incorporating several measures to immediately reduce the building's steam demand and enable strategic implementation of low carbon heating solutions. These include:

- Replace single pane windows with an insulated curtain wall.
- Replace steam turbine chillers with electric chillers.
- Install a full energy recovery dedicated outdoor air system (DOAS), which separates the building's ventilation system from the heating system, allowing each to operate independently.
- Optimize the existing hydronic system to lower heating hot water supply temperatures and enable integration of air source heat pumps in the future.

Maximize Heat Recovery:

This project utilizes water source heat pumps in a variety of heat recovery and reuse applications to dramatically reduce steam use throughout the building. The team looks to maximize heat recovery by integrating retail and tenant supplemental cooling loops to the main condenser water loop.

Current Baseline	Expected by 2035	
119.5 kBtu/SF/yr	**47.9** kBtu/SF/yr	↓ 60%
62% Electricity + **38%** District Steam	**94%** Electricity + **6%** District Steam	
12,508 Ton CO2e/yr	**3,059** Ton CO2e/yr	↓ 76%
$340,000 /year of LL97 fines starting in 2030	**$0** LL97 fines starting in 2030	

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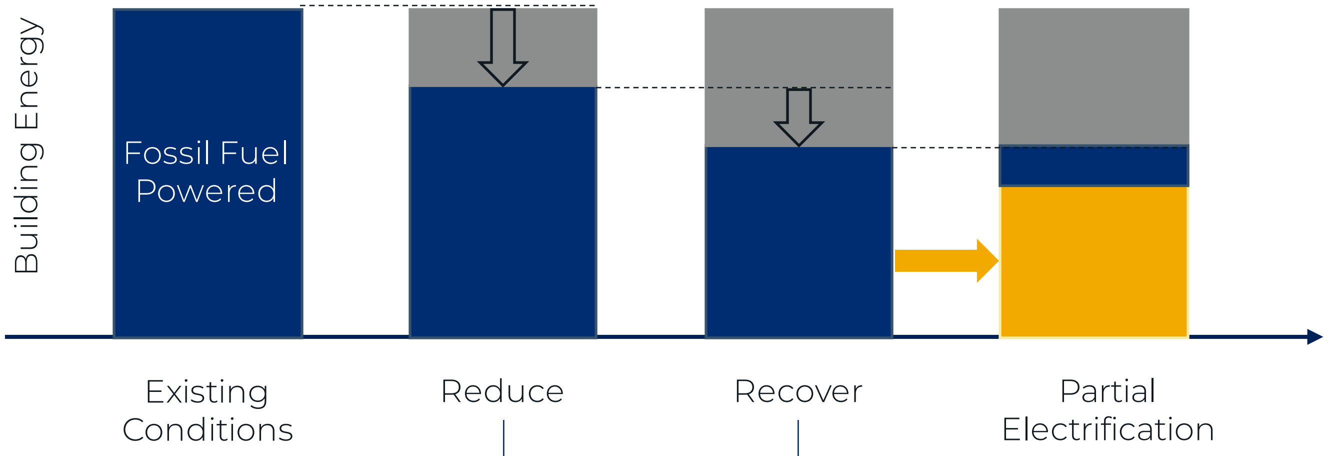


Reduce Energy Load

- **New Façade:** install new insulated curtain walls
- **Lower Heating Distribution Temperatures:** reduce heating hot water supply temperatures to 120-130F

Recover Wasted Heat

- **Thermal Network Expansion:** connect retail tenant condenser water loop to main condenser water loop to maximize waterside heat recovery
- **Waterside Heat Recovery:** recapture heat from condenser water loop using WSHPs (Lobby, Garage, DHW production)
- **Energy Recovery DOAS:** recapture heat from ventilation exhaust to condition make-up air, energy recovery units replacing high-pressure induction system

Partial Electrification

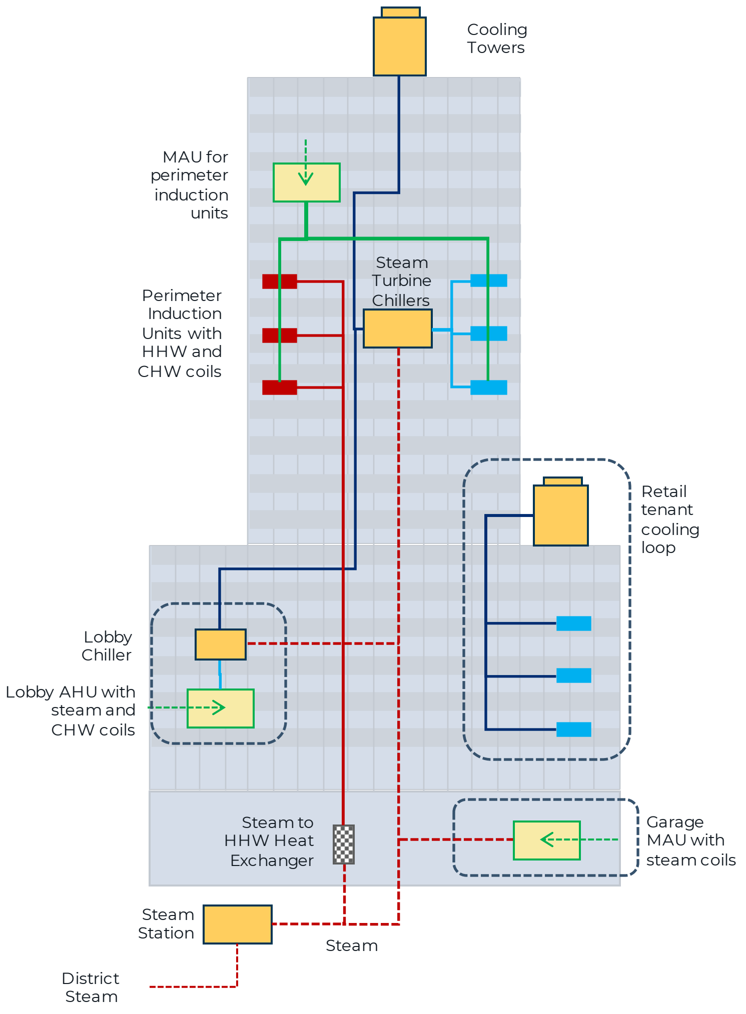
- **Electric Chillers**: replace steam turbine chillers to electric chillers
- **Air Source Heat Pumps:** ASHP to provide supplemental heating and cooling

660 Fifth Ave Decarbonization Plan

Heating
Cooling
Ventilation

Key Takeaways: Building Redevelopment, Reduce district steam usage, Maximize waterside heat recovery, Lower heating hot water temp., DOAS with ERV, Remove perimeter induction units

BEFORE



2022:

Envelope Improvements
Replace single pane windows with no wall insulation with insulated curtain wall

Install DOAS+ERV
Replace Make-up Air Unit (MAU) supplying high pressure perimeter induction units with energy recovery DOAS with heating/cooling coils

Perimeter Terminal Units
Replace high pressure perimeter induction units with fin-tube radiators

Electric Chillers
Replace steam turbine chillers with electric chillers

2023:

Lower Distribution Temperatures
Reducing heating hot water supply temperature to 120-130F

Thermal Network Expansion
Connect retail tenants to main condenser water loop to maximize waterside heat recovery

Lobby Heat Pump Chiller
Replace lobby chiller with WSHP to supply heating and cooling reusing hydronic coils in lobby AHU

Garage Ventilation Heat Pump
Install water source VRF heat pump to provide minimum heating, replacing steam coils in the garage MAU

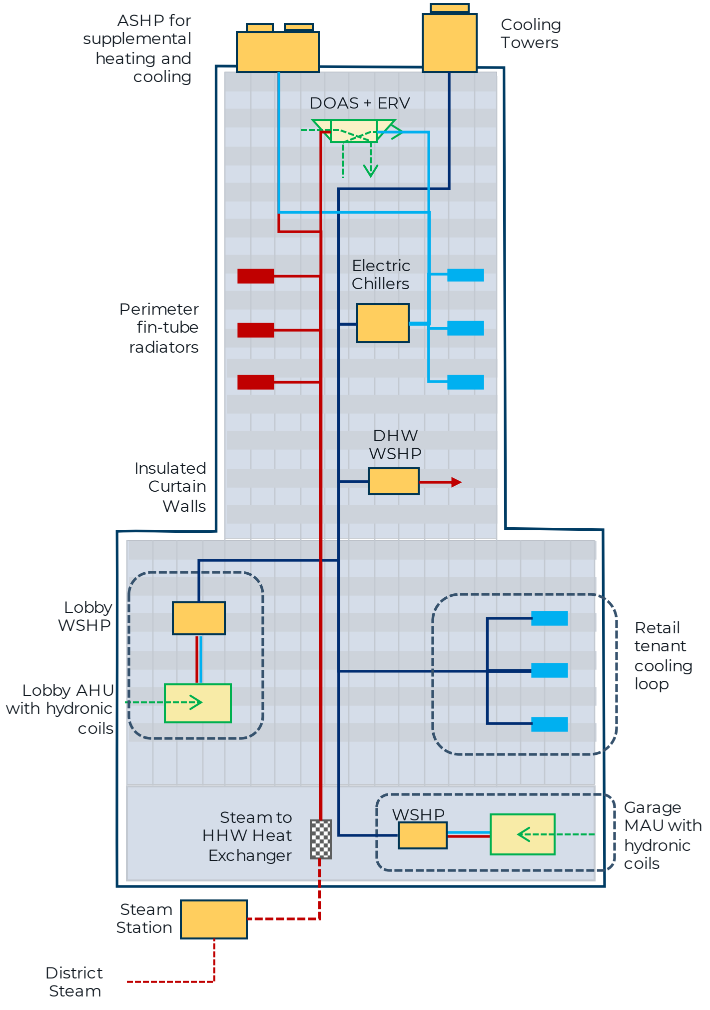
2024:

Domestic Hot Water WSHP
Waterside heat recovery using WSHPs to produce DHW

2026:

Air Source Heat Pumps
Install ASHPs to provide supplemental heating and cooling

AFTER



Lefrak City Plaza

59-17
Junction Boulevard

- Queens, NY
- 396,000 SF
- 20 stories commercial
- office building built in 1970

Empire Building Challenge
PARTNER
Reimagining Low-carbon Buildings

Leveraging end-of-life building upgrades to support decarbonization and ensure climate resiliency.

Project Team:

LeFrak Commercial

Steven Winter Associates, Inc.

ryan soames engineering

Disclaimer: The project plan outlined in this presentation is in its early design stage and can be subject to potential changes in the future.

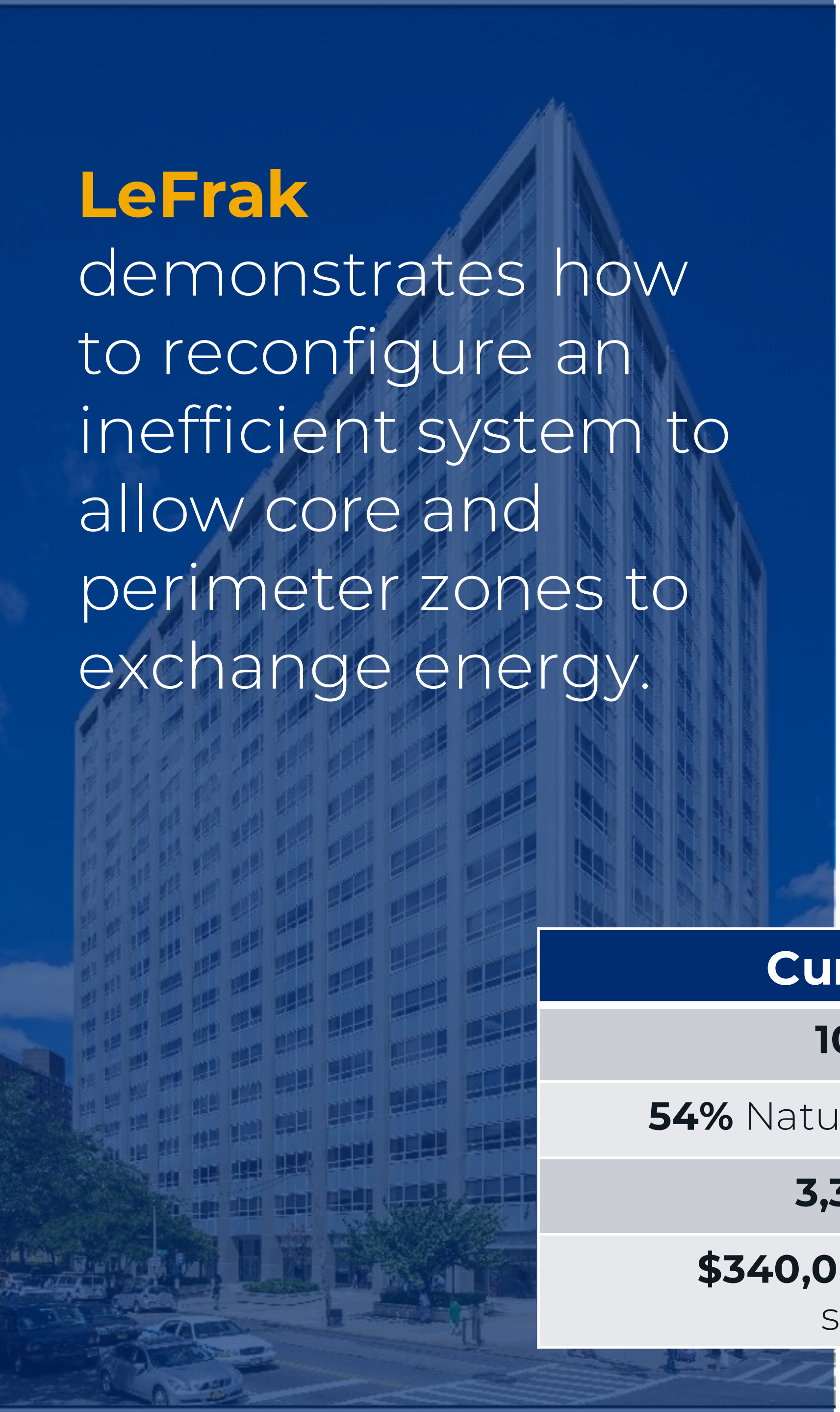
59-17 Junction Boulevard is a commercial office building located in Queens, New York. The building is heated and cooled by a dual temperature 2-pipe hydronic system and a central plant that has reached the end of its useful life, due in part to damage sustained during Hurricane Ida in 2021.

LeFrak will leverage these necessary upgrades to install modern, low-carbon solutions that will bring the property to carbon neutrality by 2035, and safeguard critical building systems from future climate events.

The decarbonization approach employed by the project team involves electrifying the central plant, incorporating heat recovery measures to utilize heat that would otherwise be wasted, and transition thermal loads away from inefficient steam usage. It will do so with limited disruption to its anchor tenant which occupies the entire building.

As part of the overall decarbonization roadmap, the Empire Building Challenge is funding the enabling steps for heat recovery, involving hydronic piping work to separate core and perimeter loops.

NYSERDA Investment	EBC Funded Measure Private Investment
$3 Million	$6.7 Million



LeFrak demonstrates how to reconfigure an inefficient system to allow core and perimeter zones to exchange energy.

Thermal zoning and enabling heat recovery:

The existing, inefficient 2-pipe system, which only allows the building to be in heating or cooling mode, will be re-pipped to create two separate hydronic zones. This will allow the newly independent core and perimeter zones of the building to exchange heat as needed.

This piping work will incorporate heat exchangers to possibly connect with adjacent buildings also owned by LeFrak that are mostly residential and create a community thermal network to share loads.

Electrification:

Beginning in 2023, the existing fossil fuel driven plant will be decommissioned, and a new plant that enables decarbonization will be installed, including modular electric chillers with heating and cooling capabilities.

Current Baseline	Expected by 2035	
103.5 kBtu/SF/yr	**51.3** kBtu/SF/yr	↓ 50%
54% Natural Gas + **46%** Electricity	**100%** Electricity	
3,330 Ton CO2e/yr	**358** Ton CO2e/yr	↓ 89%
$340,000 /year of LL97 fines starting in 2030	**$0** LL97 fines starting in 2030	

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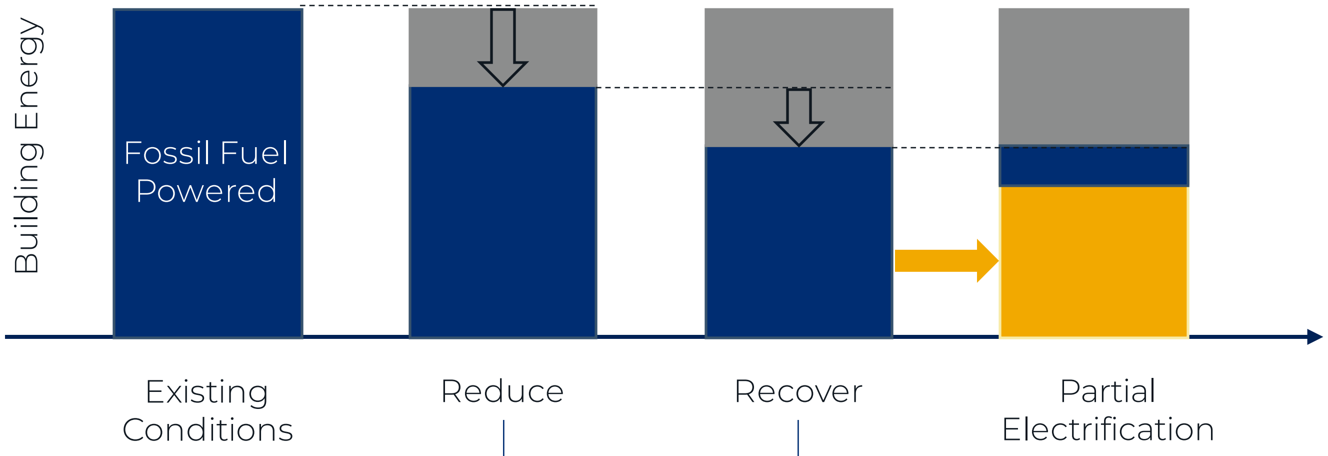


Reduce Energy Load

- **Building Management System (BMS):** Install new BMS for better integrated control of HVAC equipment and lower distribution temperature

Recover Wasted Heat

- **Enabling Heat Recovery:** New piping work to separate core and perimeter hydronic systems and operate them independently. Install heat exchangers to facilitate heat recovery between core and perimeter using electric modular chillers
- **Heat Recovery Ventilation:** Install Energy Recovery Ventilators (ERV) to recapture wasted heat and pre-condition fresh air.

Partial Electrification

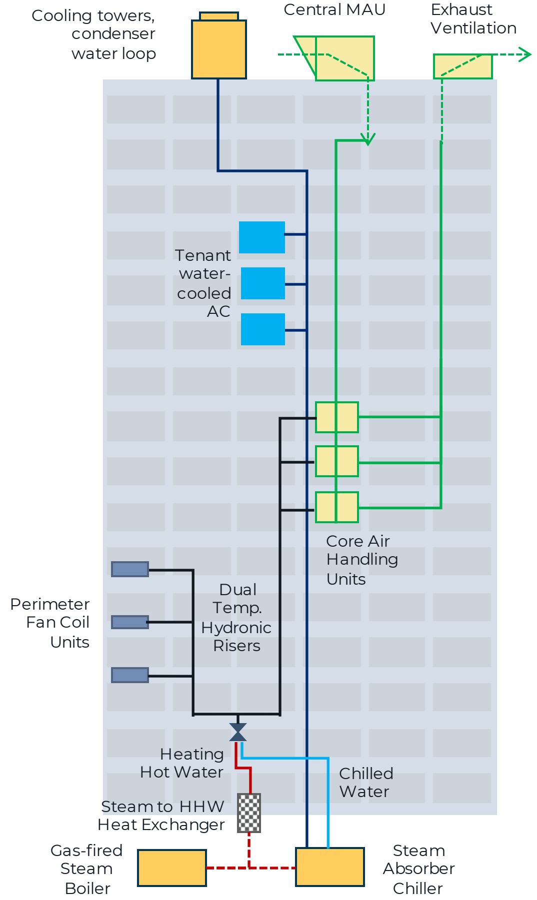
- **Electric Chillers**: Replace existing fuel fired steam absorption chillers with electric modular chillers that can provide heat recovery
- **Thermal Network Connection:** Install heat exchangers and auxiliary connection to allow a future connection to a campus-wide thermal energy network.

LeFrak City Plaza Decarbonization Plan

Heating
Cooling
Ventilation

Key Takeaways: Re-piping to enable heat recovery, Heat Recovery Chillers, Elimination of Steam Boilers and absorber chillers, Thermal Energy Network connection, Building Management System (BMS)

BEFORE



2024:

Electric Modular Chillers and BMS
Replace damaged steam chillers with electric modular chillers for electric cooling and enable waterside heat recovery. This is a first step toward eliminating on-site natural gas use. A new BMS system will allow better, integrated control of HVAC systems.

Enabling Heat Recovery
New piping work to separate core and perimeter hydronic systems and operate them independently. Install heat exchangers to facilitate heat recovery between core and perimeter using electric modular chillers

2024-2025:

Enabling Thermal Energy Network Connection
The heat recovery chiller plant will have an auxiliary connection and heat exchanger allowing a future connection to a campus-wide thermal energy network.

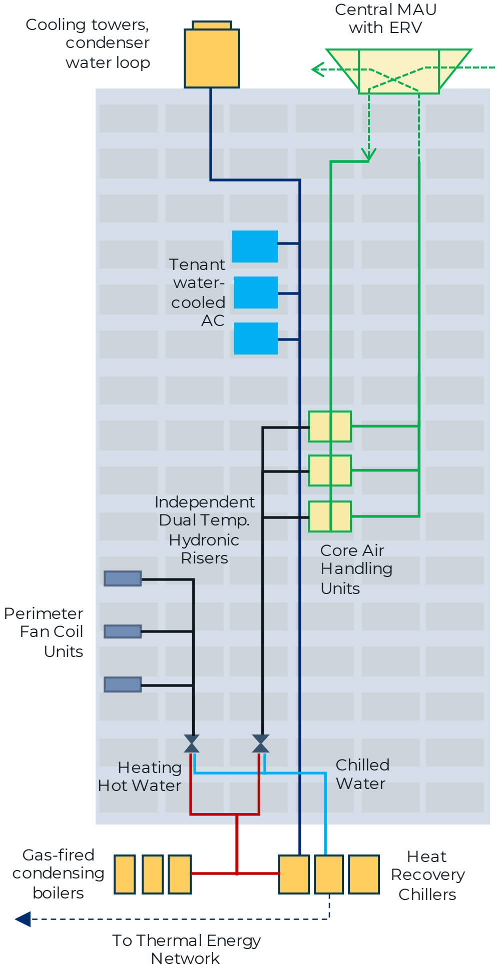
2025:

Electric Capacity
Expand electrical capacity and provide backup generation for resiliency. The measure will allow additional, layered heat generation needed to meet peak heating loads.

2026+:

Heat Recovery Ventilation
Extract additional heat and cool from outgoing exhaust and redirect back into the building.

AFTER



520 Madison Avenue

- New York City
- 1,000,000 SF
- 43 stories commercial
- office building built in 1982

Empire Building Challenge
PARTNER
Reimagining Low-carbon Buildings

Tishman Speyer to drill for geothermal energy below Madison Avenue

Project Team:

TISHMAN SPEYER

JB&B

Brightcore BUILDING ENERGY PERFORMANCE™

520 Madison Avenue is a class A commercial office building located in Midtown Manhattan with ground floor retail and restaurant spaces. The energy profile of this property is strong, with an 87.4 EUI and energy grade of *A* based on 2019 baseline.

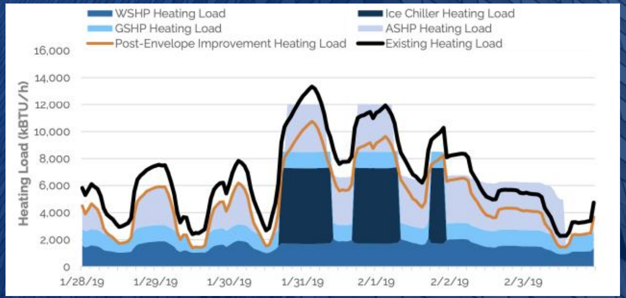
Tishman Speyer is planning a lobby upgrade and restaurant renovation for the building and is leveraging these improvements to simultaneously upgrade the building systems. These upgrades will help position the property to reach carbon neutrality by 2035.

This project will involve reduction of energy loads, recovery and reuse of heat that would conventionally be wasted, and development of an urban geothermal system. The European geothermal drilling technology slated for this project has never been implemented in New York City for a building of this size. In doing so Tishman Speyer sets a strong precedent for scalability and replication of this solution throughout the high-rise office building market.

NYSERDA Investment	Roadmap Phase 1 Private Investment
$3 Million	$22.2 Million

Disclaimer: The project plan outlined in this presentation is in its early design stage and can be subject to potential changes in the future.

Tishman Speyer demonstrates how to strategically reduce loads, recover heat, and electrify equipment over time



Enabling Steps:

The project team's vision for decarbonizing 520 Madison requires enabling steps to significantly reduce heating loads and facilitate heat pump integration. This is achieved via envelope improvements, waterside heat recovery, ventilation upgrades and lower heating hot water supply temperatures.

Electrification:

Heat pumps will be deployed in various applications throughout the building to electrify onsite heating loads. This includes water source heat pumps (WSHPs) for heat recovery, ice heating and geothermal (ground source heat pumps or GSHPs) combined with air source heat pumps (ASHPs) for the remaining heating load.

Thermal Layering:

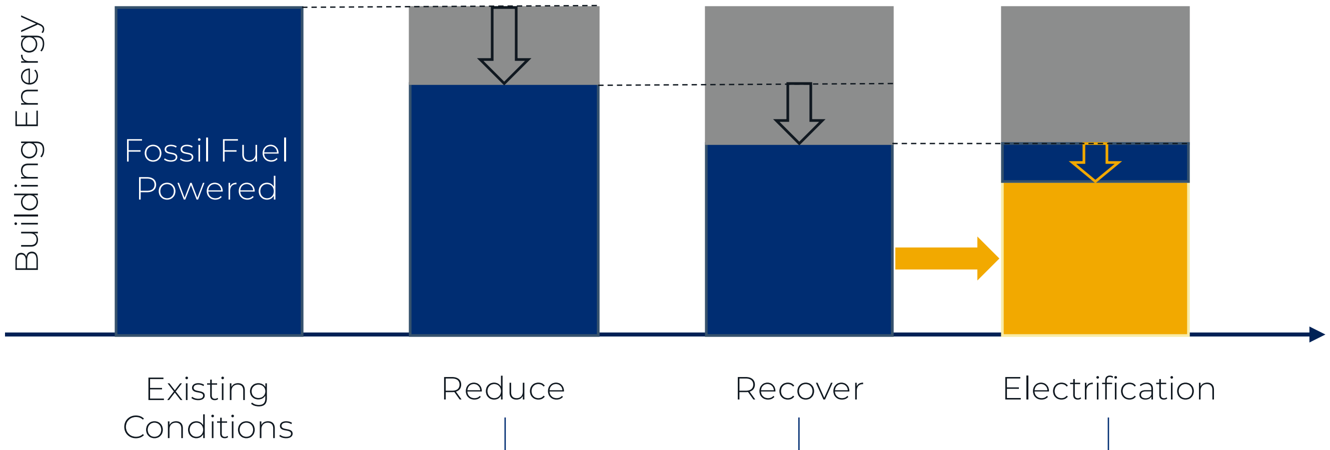
The decarbonization approach for this project utilizes thermal layering, in which multiple heat sources overlap to meet operational energy needs in the building while minimizing the use of fossil fuels and carbon emissions.

2019 Baseline	Expected by 2030	
87.4 kBtu/SF/yr	**28** kBtu/SF/yr	↓ 23%
3% Natural Gas + **67%** Electricity + **30%** District Steam	**5%** Natural Gas + **95%** Electricity	
2,294 tCO2e/yr	**1,166** tCO2e/yr	↓ 49%

Resource Efficient Decarbonization (RED):

An incremental methodology and integrated design process combined with strategic capital planning creates a path towards carbon neutral buildings.

A holistic approach and phasing can make decarbonization technically and economically feasible.



Phase 1:

- **New Hydronic Distribution:** to serve new system while transitioning to low supply temperature and enable heat pump integration
- **Façade efficiency upgrades** to bottom portion of tower

Phase 2:

- **Dedicated Outside Air System (DOAS):** decouple ventilation from heat and cooling systems using terminal DOAS delivery and central DOAHU
- **Envelope upgrades** to top portion of tower

Phase 1:

- **Condenser Water Heat Recovery:** piping work and Water Source Heat Pumps (WSHPs) to recapture heat from cooling systems
- **Geothermal:** UrbanGeo drilling and ground sources heat pumps

Phase 2:

- **Thermal Network Expansion:** interconnecting central plant components allows for deeper heat recovery and storage
- **Energy Recovery Ventilator:** expanded DOAHU continues air side heat recovery expansion

Phase 1 – Partial Electrification:

- **WSHPs:** for UrbanGeo and condenser water loop heat recovery
- **Domestic Hot Water (DHW):** point of use electric water heaters to reduce district steam use

Phase 2 – Full Electrification:

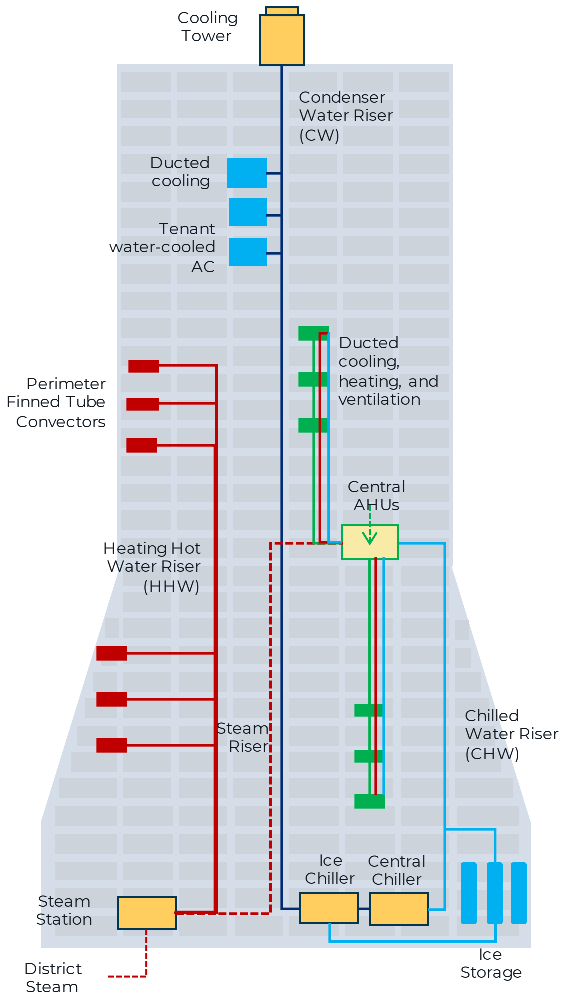
- **Air Source Heat Pump:** integrate ASHPs
- **Ice Heating:** install ice storage and use WSHPs to store and extract heat
- **Thermal Layering:** a multi-source approach using advanced controls to combine and integrate multiple equipment to meet load

520 Madison Decarbonization Plan

Heating
Cooling
Ventilation

Key Takeaways: Façade improvements, urban geothermal drilling, heat recovery, low temperature heating hot water, DOAS, distributed electric DHW, ice heating and ASHPs

BEFORE



2023: **Domestic Hot Water**
Install point-of-use electric DHW heaters to replace central system

2024: **Condenser Water Heat Recovery**
Install WSHPs to extract wasted heat from the condenser water loop and serve perimeter heating loop.

2024-2025: ***UrbanGeo* Geothermal Drilling**
Use ground floor vacancy to drill a geothermal borefield beneath the existing building footprint using *UrbanGeo* technology.

2025: **Ground Source Heat Pump**
Install water source heat pumps for the geothermal borefield.

2025-2030: **Envelope Improvements**
Install new windows and improve air leakage.

2026+: **Central DOAS+ERV**
Install new central DOAS with ERV to condition fresh air.

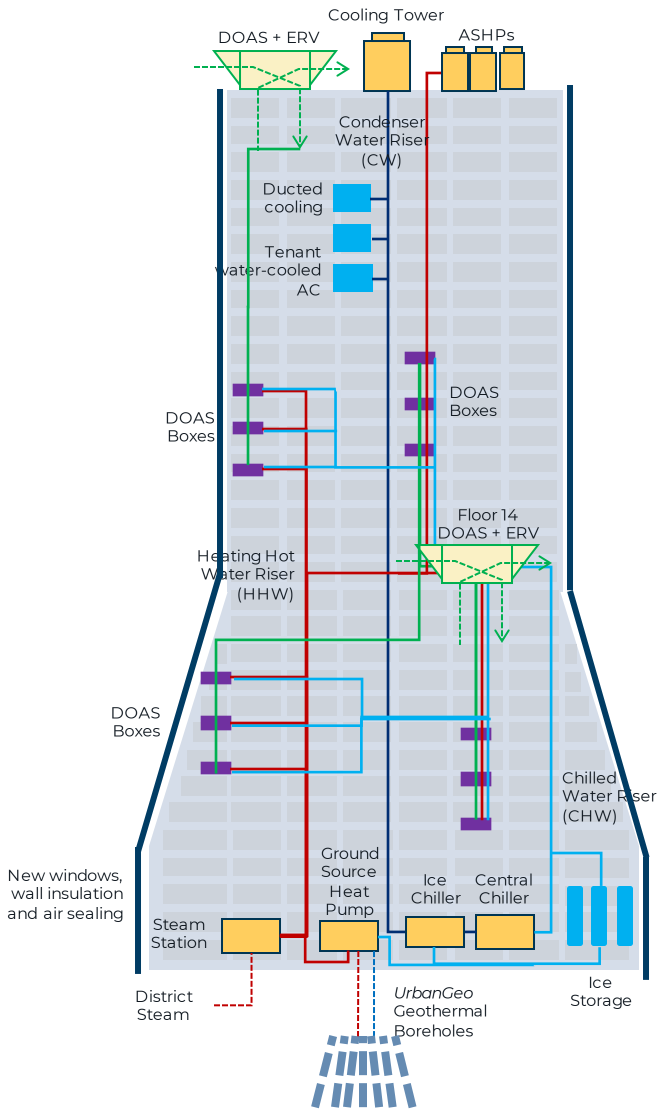
2026-2035: **Tenant Fit-out: Terminal Unit DOAS Boxes**
Replace terminal units with DOAS boxes to accommodate low temp. heating hot water and incorporate conditioned air.

2028+: **Air Source Heat Pumps**
Addition of ASHP capacity to serve low temperature HHW.

Ice Heating
Reuse ice storage tanks and WSHP to enable ice heating.

Thermal Layering
Combine multiple heating sources (Geothermal, ASHPs, Heat Recovery, Ice Heating, Steam) and optimize deployment.

AFTER



PENN 1

- New York City
- 2.5 million SF
- 57 stories commercial
- office building built in 1972

Empire Building Challenge
PARTNER
Reimagining Low-carbon Buildings

Innovating with existing technology that is scalable, practical and affordable.

Project Team: VORNADO REALTY TRUST; JBB

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PENN 1 is a commercial office building located in Midtown Manhattan that houses commercial office and retail spaces. The building is heated and cooled by district steam that is supplemented by the existing cogeneration plant.

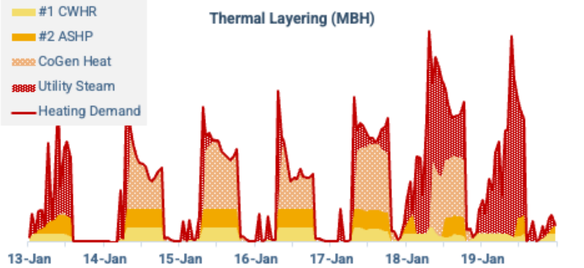
To enable phase-out of the cogeneration plant, Vornado plans to advance a series of heat recovery and thermal storage solutions that will position PENN 1 for carbon neutrality by 2040.

The decarbonization approach at Penn One integrates an innovative thermal dispatch model, which allows the building to intelligently prioritize low-carbon thermal resources for operational building needs ahead of those that are more carbon intensive. This thermal layering strategy, enabled by electrification of heating loads and heat recovery measures, will reduce energy use by 22% and carbon emissions by 38% by 2030.

From this decarbonization roadmap, the Empire Building Challenge is funding one measure to demonstrate condenser water heat recovery.

NYSERDA Investment	EBC Funded Measure Private Investment
$1 Million	$3 Million

Vornado demonstrates creative decarbonization with advanced heat recovery solutions and thermal layering.



Advanced Waterside Heat Recovery:

This tactic will use water-source heat pumps (WSHP) to utilize heat from the condenser water system to supplement heating hot water for the building's hydronic system. The WSHP method creates a "heat-lifting" machine that will raise the temperature of hot water to match the building's existing supply – usefully extracting heat that would be otherwise be wasted and reducing steam heat emissions.

Thermal Layering:

Heating loads are sequenced and prioritized to first engage low-carbon resources to meet the building's heating demand, and then use next-available or higher carbon thermal resources to come online. For example, first use low carbon electric thermal resources, then heat from the Cogen, and finally utility steam to meet remaining demand. When the ASHPs are installed, they will be dispatched second, as another low carbon alternative. This approach makes it possible to meet peak heating loads during extreme cold events with relative ease and low carbon emissions.

Current Baseline	Expected by 2035	
167 kBtu/SF/yr	**49** kBtu/SF/yr	↓ 71%
31% Electricity + **14%** District Steam + **55%** Natural Gas	**100%** Electricity	
18,750 tCO2e/yr	**1,638** tCO2e/yr	↓ 91%
$790,000 /year of LL97 fines starting in 2030	**$0** LL97 fines starting in 2035	

Resource Efficient Decarbonization (RED):

An incremental methodology and integrated design process combined with strategic capital planning creates a path towards carbon neutral buildings.

A holistic approach and phasing can make decarbonization technically and economically feasible.

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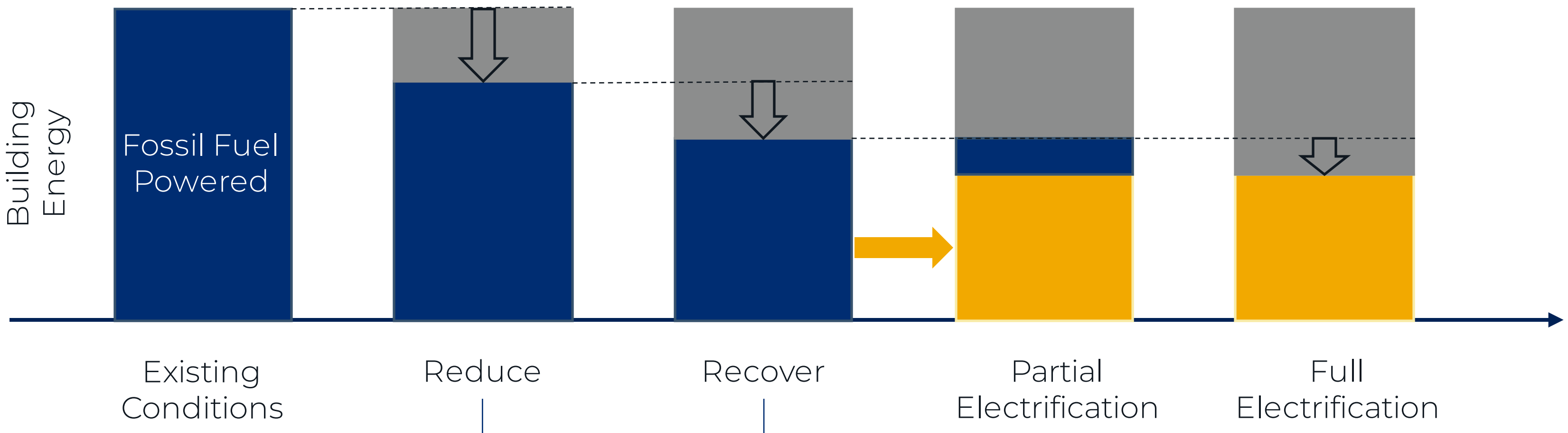


Reduce Energy Load

- **Envelope Improvement:** Triple pane glazing **Induction Units Replacement:** replace constant volume perimeter induction units with VAV units
- **Enhance Tenant Fit-out:** Install high-efficiency equipment and engage with tenants to ensure best-in-class fit-out during turnover

Recover Wasted Heat

- **Condenser Water Heat Recovery:** Install WSHPs to recapture wasted heat from the condenser water loop
- **Computer Room Air Conditioning (CRAC) Conversion:** Convert existing condenser water-cooled DX units to chilled water-cooled unit to maximize heat recovery and improve cooling efficiency

Partial Electrification:

- **Electric Chillers:** Replace steam absorption chillers to electric chillers
- **Partial Air Source Heat Pumps:** Install ASHPs to partially cover heating load served by the secondary hot water loop

Full Electrification:

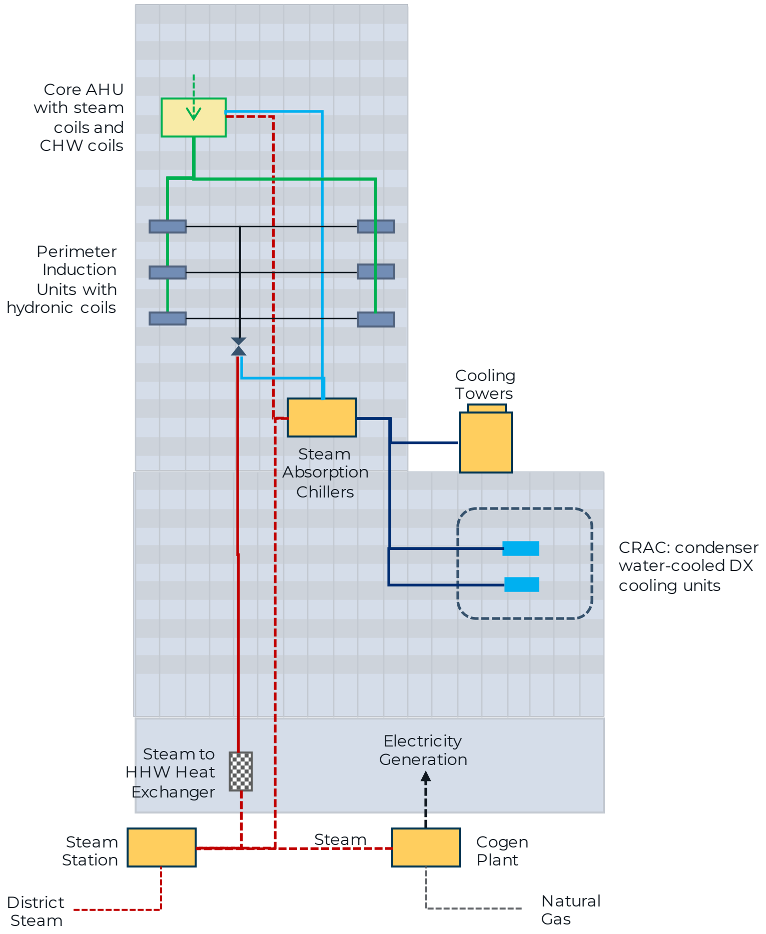
- **Cogen Decommissioning:** Retire cogeneration plant and eliminate on-site fossil fuel usage, keep district steam as back-up
- **Ice Thermal Storage:** Install ice storage to enable full-building electrification by shifting and support heating and cooling peaks and empower grid flexibility
- **More ASHPs:** Install ASHPs to cover remaining heating load

Penn One Decarbonization Plan

Heating
Cooling
Ventilation

Key Takeaways: Minimize district steam usage, maximize waterside heat recovery, integrate air source heat pumps where possible

BEFORE



2022: **Envelope Improvements**
Replace existing curtain wall glazing with triple pane

Electric Chillers
Replace steam absorption chillers with electric chillers

Induction Unit Replacement
Replace constant volume induction units with Variable Air Volume (VAV) units

2023: **Condenser Water Heat Recovery**
Install WSHPs to reclaim rejected heat

2024: **Partial Air Source Heat Pumps**
Install ASHPs to electrify heating and inject to secondary HHW

2025: **Computer Room Air Conditioning (CRAC) Conversion**
Convert existing condenser water-cooled DX units to chilled water-cooled units. Maximize heat recovery

Enhanced Tenant Fit-out
Engage tenants during turnover to ensure best-in-class fit-out

2029: **Cogen Decommissioning**
Retire cogeneration plant and eliminate on-site fossil-fuel usage, keep district steam as back-up

2030+: **More Air Source Heat Pumps**
Install ASHPs to electrify the remaining heating load

Ice Storage System
Install ice storage to support peak demand

AFTER