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

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

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.

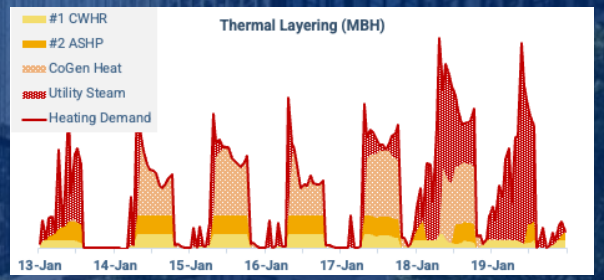
To enable phase-out of the cogeneration plant, Vornado plans to advance a series of heat recovery and thermal storage solutions that will position PENN 1 for carbon neutrality by 2040.

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:

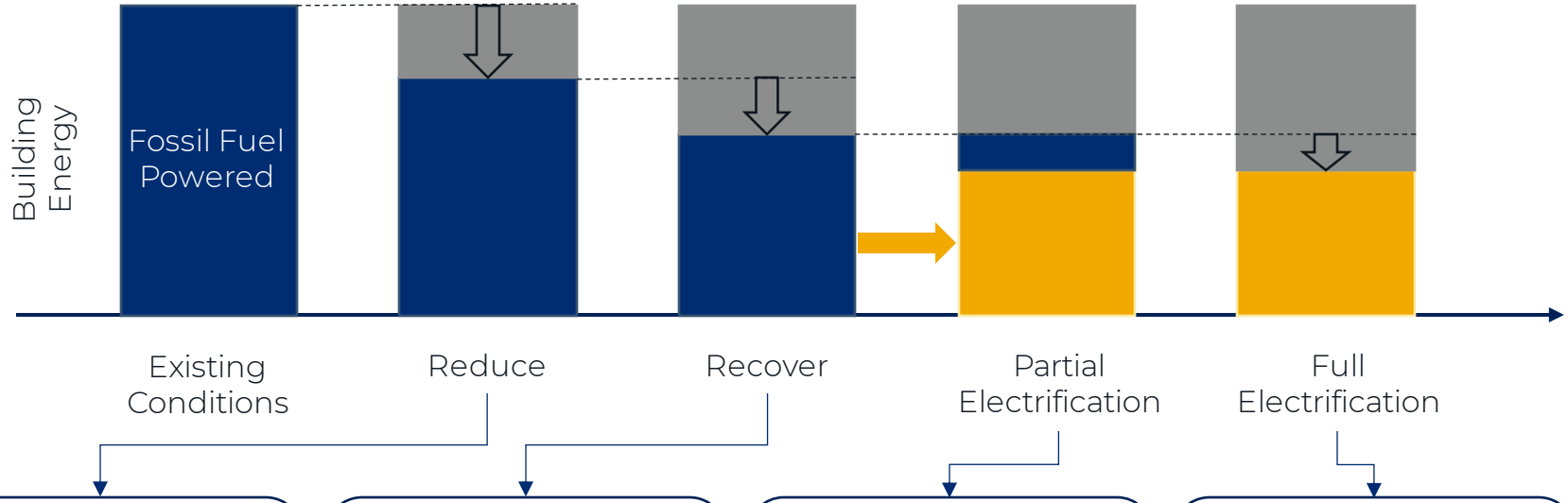
Heating loads are sequenced and prioritized to first engage low-carbon resources to meet the building's heating demand, and then use next-available or higher carbon thermal resources to come online. For example, first use low carbon electric thermal resources, then heat from the Cogen, and finally utility 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.



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:

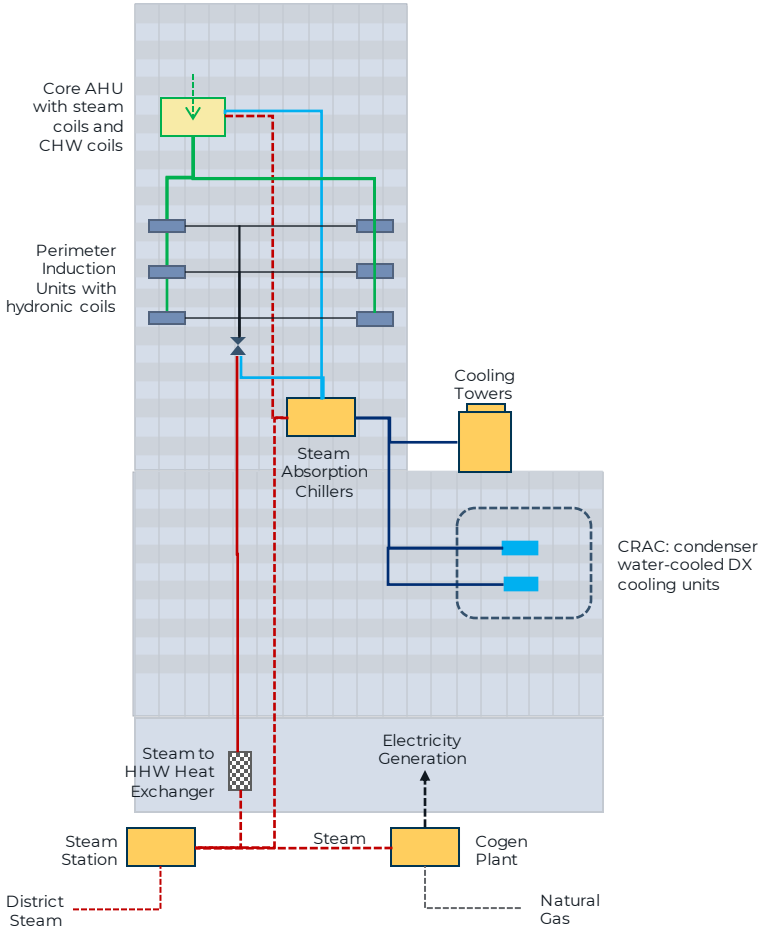
- **Cogen Decommissioning:** Retire cogeneration plant and eliminate on-site fossil fuel usage, keep district steam as back-up
- **Ice Thermal Storage:** Install ice storage to enable full-building electrification by shifting and support heating and cooling peaks and empower grid flexibility
- **More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