The Empire Building Challenge

Low Carbon Playbooks
Vornado Realty Trust Case Study

Empire Building Challenge

A $50 million NYSERDA investment to:

1. Accelerate private sector commitment and investment in carbon reduction, working with large portfolio owners.
2. Enable replication and scale across NY's existing large commercial/multifamily building stock.
3. Make NY a global hub for low carbon retrofits.
4. Drive innovation to meet the needs of NY's large commercial/multifamily building stock.

Low Carbon Retrofits Unlock Climate Progress

NYC: 3 billion square feet of existing office, multi-family buildings

~70% of today’s buildings constructed prior to energy code

~90% of today’s buildings will still be in operation in 2050

Buildings account for ~45% of NYS energy-related greenhouse gas emissions

Low Carbon Retrofits: Highlight on NYC Market Opportunity

The mid-range estimate of market opportunity

$20B

The annual retrofit market will expand by

13X

Number of jobs created across the NYC metro area by 2030

141K

Source: Urban Green Council, Retrofit Market Analysis 2019

Low Carbon Playbooks

In 2020, Vornado Realty Trust, The Durst Organization, Hines and Empire State Realty Trust partnered with NYSERDA to conduct in-depth analysis of their buildings.

The animating question is: **What are the retrofit pathways that transition this building to carbon neutrality and are economically and technically viable?**

Envisioning A Low Carbon PENN DISTRICT

NYSERDA Playbook Partner

VORNADO
REALTY TRUST

Who is Vornado?

Vornado Realty Trust (“Vornado”) is a fully integrated real estate investment trust, with premier office assets located in New York City, Chicago, and San Francisco.

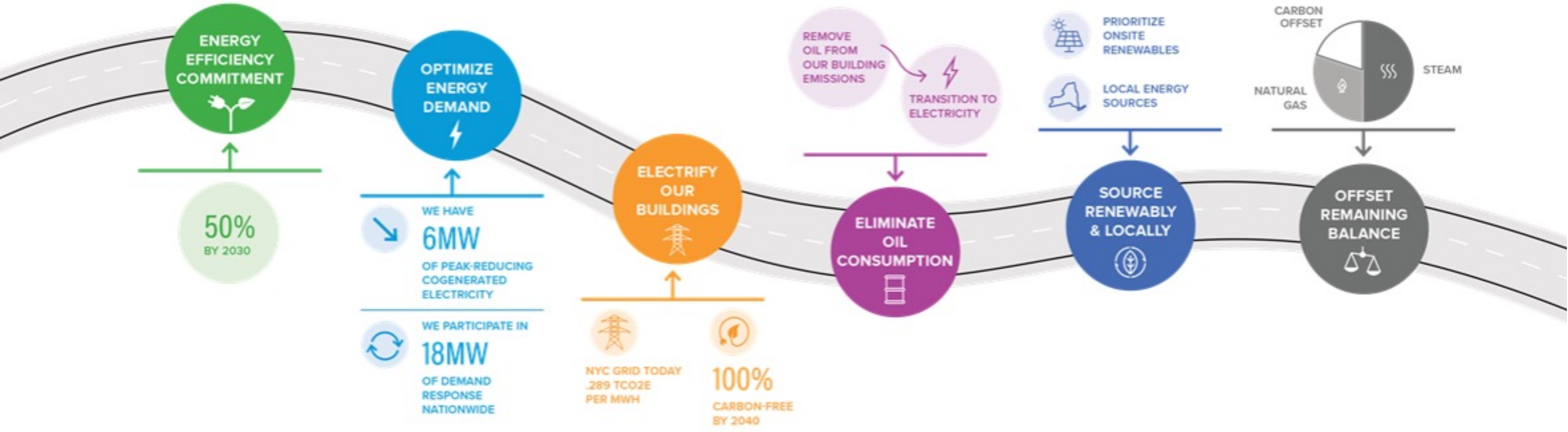
Vornado has a long history of investment in office and retail properties, which, is concentrated in the New York City market.

Vornado owns and manages over 36 million square feet of assets concentrated primarily in the New York City office market.

Vornado has been publicly traded on the New York Stock Exchange (NYSE:VNO) for over 50 years.

In April 2020, Vornado released its Vision 2030, a commitment to make its buildings carbon neutral by the year 2030.

Vornado’s Commitment to Carbon Neutral Buildings



- Vornado has committed to making its portfolio carbon neutral through Vision 2030. The flow chart highlights six components to get there.

- Each building will employ a combination of these solutions to reach neutrality, and every building will prioritize energy efficiency.

PENN DISTRICT Development

- Neighborhood transformation to deliver world-class commercial properties in phases beginning with over 5 MM SF of in-progress development at Farley (2022), PENN 1 (2022) and PENN 2 (2023) and district-wide improvements.

- Complete modernization of all assets, place-making underway with restaurants, entertainment venues and acres of new green spaces.

- Expected to draw technology-driven tenants on the heels of landmark leasing deals at Farley, 7 West 34th Street, PENN 11, and PENN 2.

- Additional Vornado-owned new development sites in the PENN District expected to come online in later phases.

The Team

VORNADO REALTY TRUST

JB&B

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Associate Partner

Molly Dee-Ramasamy

Head of Deep Carbon
Reduction

Tyler Schott

Project Engineer

Vornado’s Sustainability Team

Sustainability is led by the SVP of Sustainability & Utilities, who reports to Vornado’s Chief Operating Officer. Vornado’s Sustainability Group includes five dedicated employees, and two employees from our BMS, LLC division.

Our team is part of the Operations division which allows us to work closely with Chief Engineers and Property Managers, to incorporate energy efficiency work seamlessly from the concept and budgeting phases through approvals and execution.

About JB&B

- Founded in 1915, JB&B has provided engineering consulting for some of the largest and most recognized buildings in the world. The firm has received many national and international engineering recognitions in its 100+ years of existence and continues to be one of the leading American Mechanical, Electrical, and Plumbing (MEP) consultants in the engineering community.

- JB&B is an active participant and partner to New York City and State in building decarbonization efforts with representation on industry committees, LL97 advisory and working groups, and CLCPA climate advisory panels.

- JB&B is a thought leader in building electrification and is working with heat pump and advanced heat recovery equipment manufacturers to drive the market toward better technologies that fit both the new and existing building markets.

PENN 1 Overview

Vornado's ongoing transformation of the midcentury PENN 1 to an office building of the future is redefining working in The PENN DISTRICT. The first three levels deliver WorkLife, an amenity ecosystem for tenants to focus on both work and self-care. The lobby offers two options for grab and go food, Office Hours and Blue Bottle, opening soon. A social stair connects the main entrance on the first level to the amenities on levels two and three. The social stair's bleacher seats and large LED panels are the perfect location for casual meetings or private events. Level two features The Landing - a soon to open full-service restaurant with private dining rooms, multiple tenant lounges for socializing and working, WorkLife WellBeing - a 35,000 SF fitness and wellness center, WorkLife Meetings - a 20,000 SF conferencing facility and WorkLife Office Suites - over 80,000 SF of adaptable workspace. The exterior building renovation is nearing completion with significant upgrades, including triple reglazing. Distinctive color change lighting in the building crown now illuminates PENN 1's place in the ever-changing skyline.

Why Focus on PENN 1?

Vornado's investment theory focuses on the repositioning of legacy assets in urban centers to make them competitive with, and as appealing as, new construction.

Reaching Vision 2030 will require solutions that are tested and validated with real properties that have barriers and challenges representative of those experienced by the whole commercial sector (technology, disruption, financing, etc.)

The transformation of the PENN District into a world-class office campus is a high visibility testbed for deep carbon reduction strategies, and approaches to electrification that have the potential to be replicated across Vornado's portfolio.

By using the PENN District as a proving ground and working with multiple partners with varying focuses, Vornado will provide a leading example for a roadmap for tall buildings in NY State.

PENN 1 Building Energy Attributes

Façade: Curtain wall of steel and glass, currently undergoing upgrade to triple-pane reglazing

Heating Input: District steam, Natural gas-fired Cogeneration waste heat (steam)

Heating: Steam coils AHU, Steam-to-hot water perimeter induction unit

Cooling Input: Electric grid, Cogen waste heat (steam), District Steam

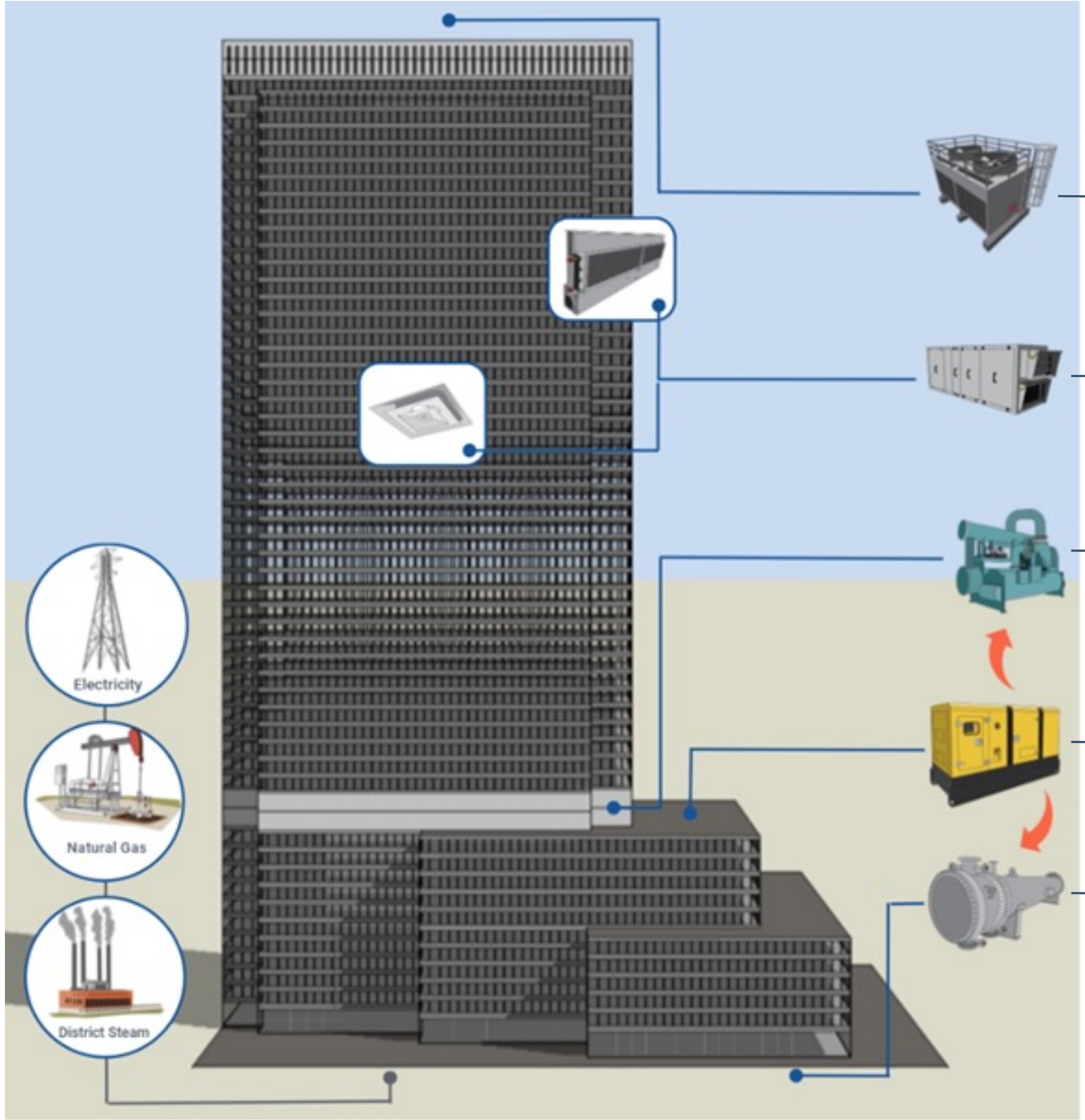
Cooling: Two (2) new 1,800 Ton electric centrifugal chillers with a legacy 3,200 Ton steam turbine. Chilled water coil AHUs and perimeter induction units.

Air Distribution: Centralized constant air volume system serving interior zones and the perimeter induction units

Ventilation: Intake dampers on the centralized AHUs

Domestic Hot Water: Steam-to-hot water heat exchangers

PENN 1 Building Energy Attributes



Heat Rejection (Waste Heat)
Open Cell Cooling Towers

Air Distribution
Constant Volume Centralized AHUs w/ Perimeter Induction

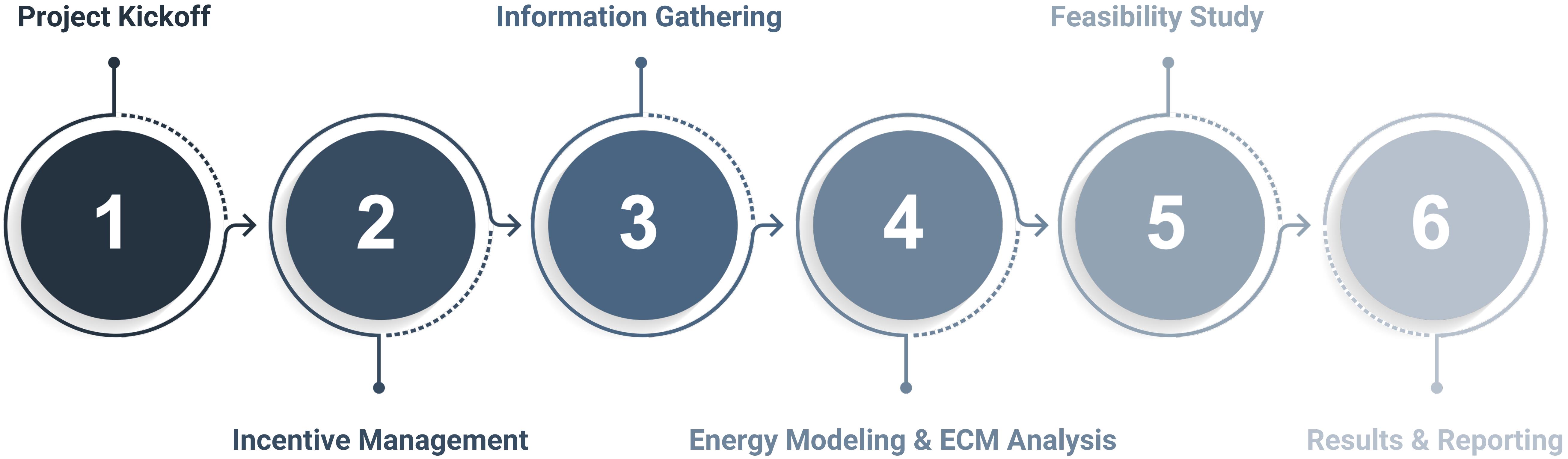
Cooling Plant
Steam Turbine Chillers + New Electric Centrifugal Chillers

Co-Generation Plant (Waste Heat)
6 MW Combustion Engines

Heating Plant + DHW
Steam-to-HW Heat Exchangers

Decarbonization Study Process

To achieve Vornado's carbon neutrality goals, this study explored several advanced technologies and various scenarios. These strategies, which include full building electrification, were evaluated from an energy, carbon, and utility cost perspective to inform the roadmap. This study was executed in six distinct phases:



Project Kickoff

Information Gathering

Feasibility Study

Incentive Management

Energy Modeling & ECM Analysis

Results & Reporting

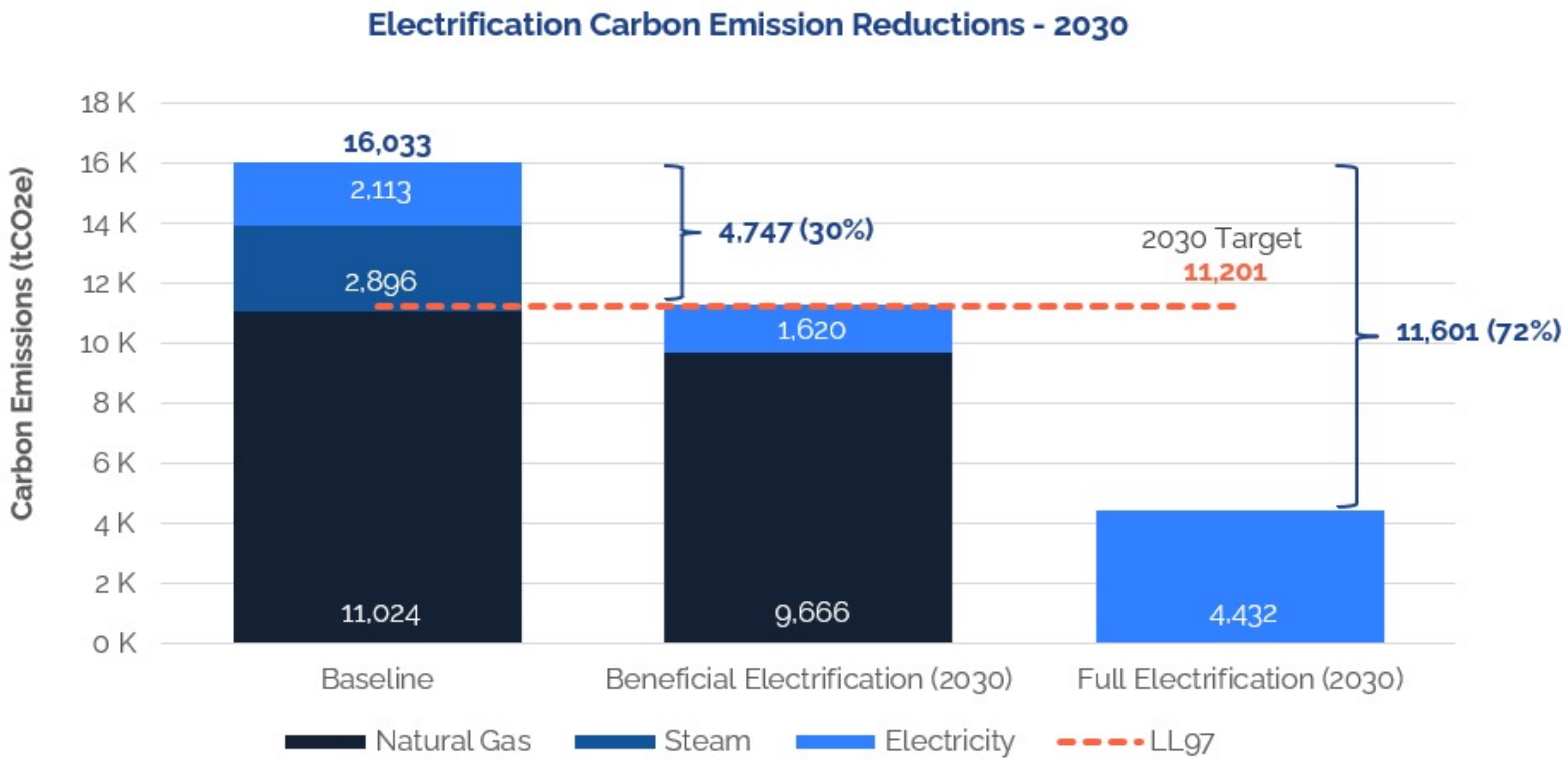
Project Approach

- What is the deepest level of decarbonization we can achieve?
- How feasible is electrification of heating systems?
- How can we completely remove dependence on district steam?
- How can we leverage the existing cogeneration plant?

Building Decarbonization Strategies

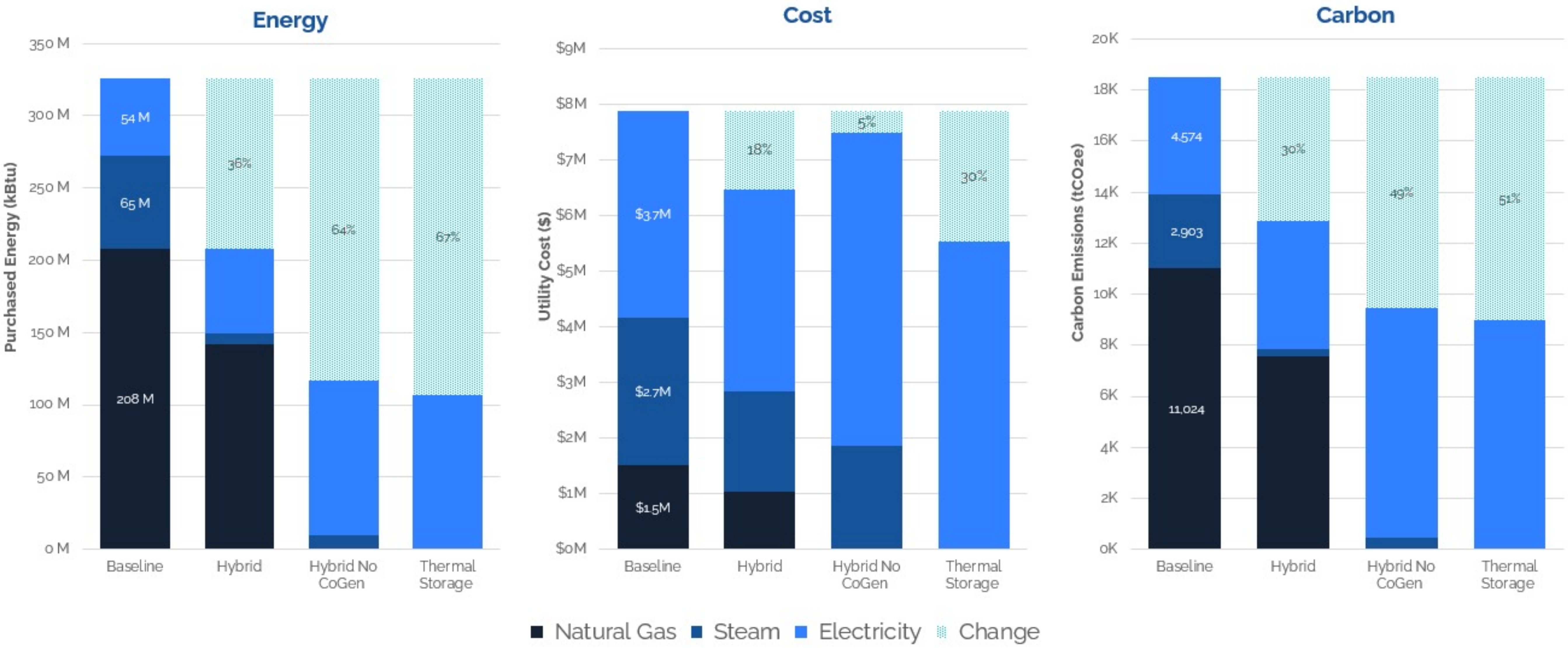
	Phase I (LCB)	Outcomes & Lessons Learned	Phase II (EBC)
Fenestration	- Triple Pane Glazing w/ Low-E Coating		- Same
Ventilation	- DOAS Air Handlers w/ DOAS Terminal Boxes (Forced overhead air)	- Determined to be **Impractical** - Disruption to tenants - Phasing challenges - Capital Cost	- CAV to VAV conversion - VAV Induction unit replacement
Cooling	- All-Electric Chillers		- Same
Heating	- Low Temperature Hot Water (95F) - Condenser Water Heat Recovery - Air Source Heat Pumps	- Determined to be **Impractical** - Can't use existing piping distribution - Space requirements for ASHP - Capital Cost	- High temp HW at perimeter w WSHP - Low temp HW interior zones & AHUs - Thermal dispatch model w/ CoGen, Steam + Heat Pumps + Thermal Storage
CoGeneration	- Keep Cogen	- Financially advantageous - Waste heat can be reused - Does not support decarbonization	- Keep until 2030
	- Remove CoGen	- Supports decarbonization	
Thermal Storage	- None		- Thermal ice storage to flatten demand peaks and downsize ASHP equipment

Building Decarbonization Strategies

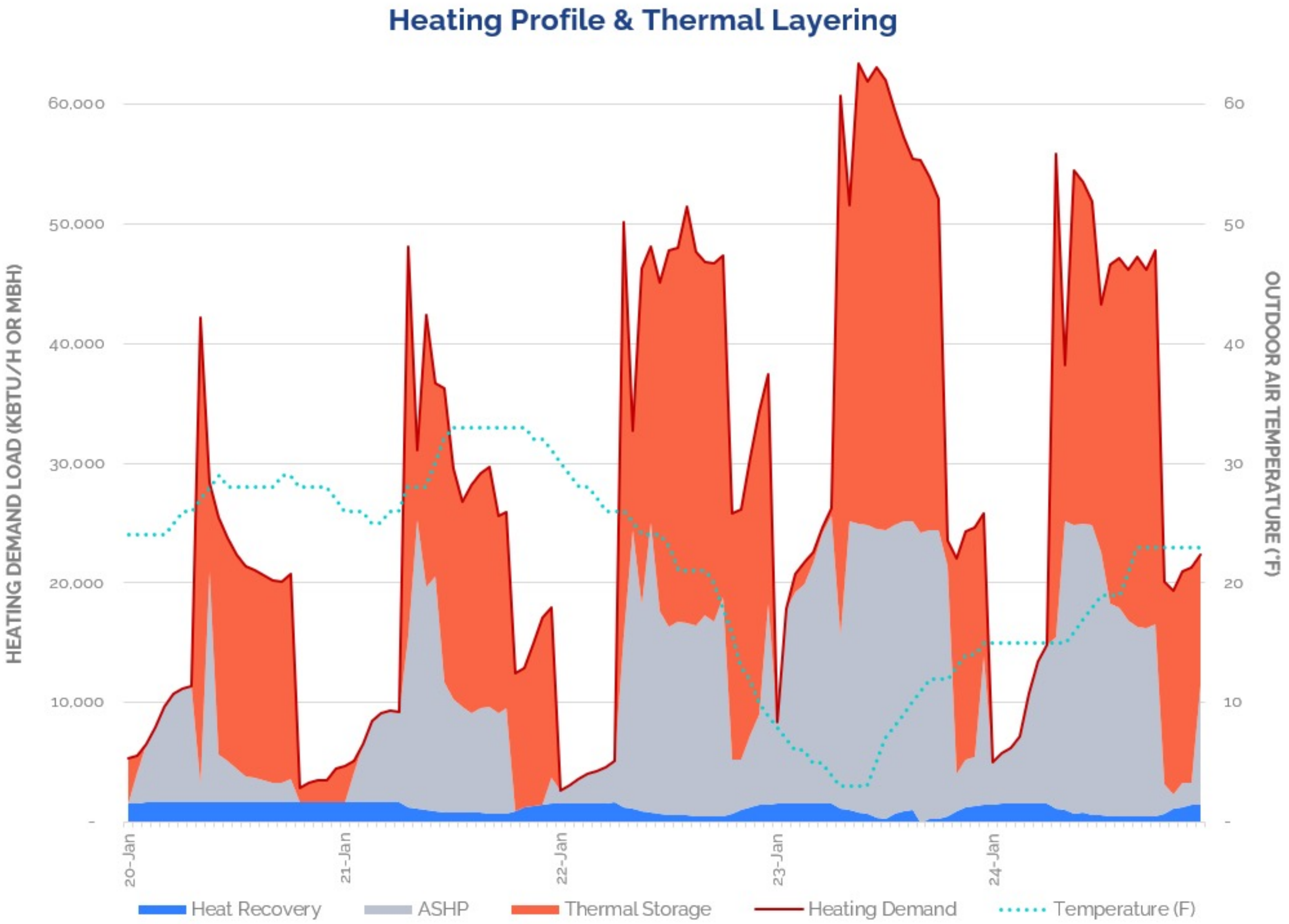


Takeaway: a critical piece to electrification feasibility is the implementation of all the ECMs discussed in the previous slide to reduce loads and minimize ASHP quantity. This is where we land using LL97 thresholds as the benchmark.

EBC Modeling Results

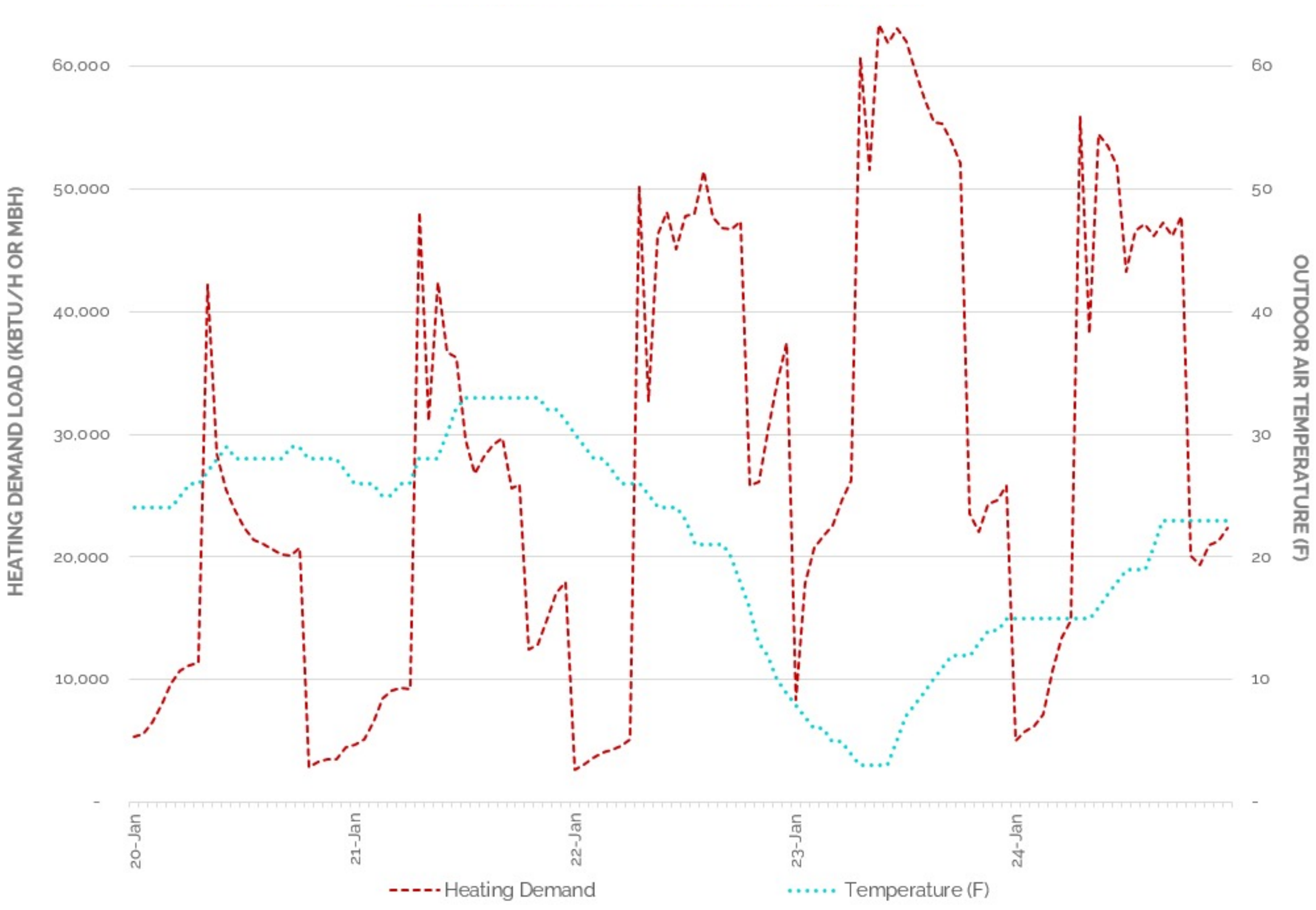


Thermal Dispatch of Heating Loads at PENN 1



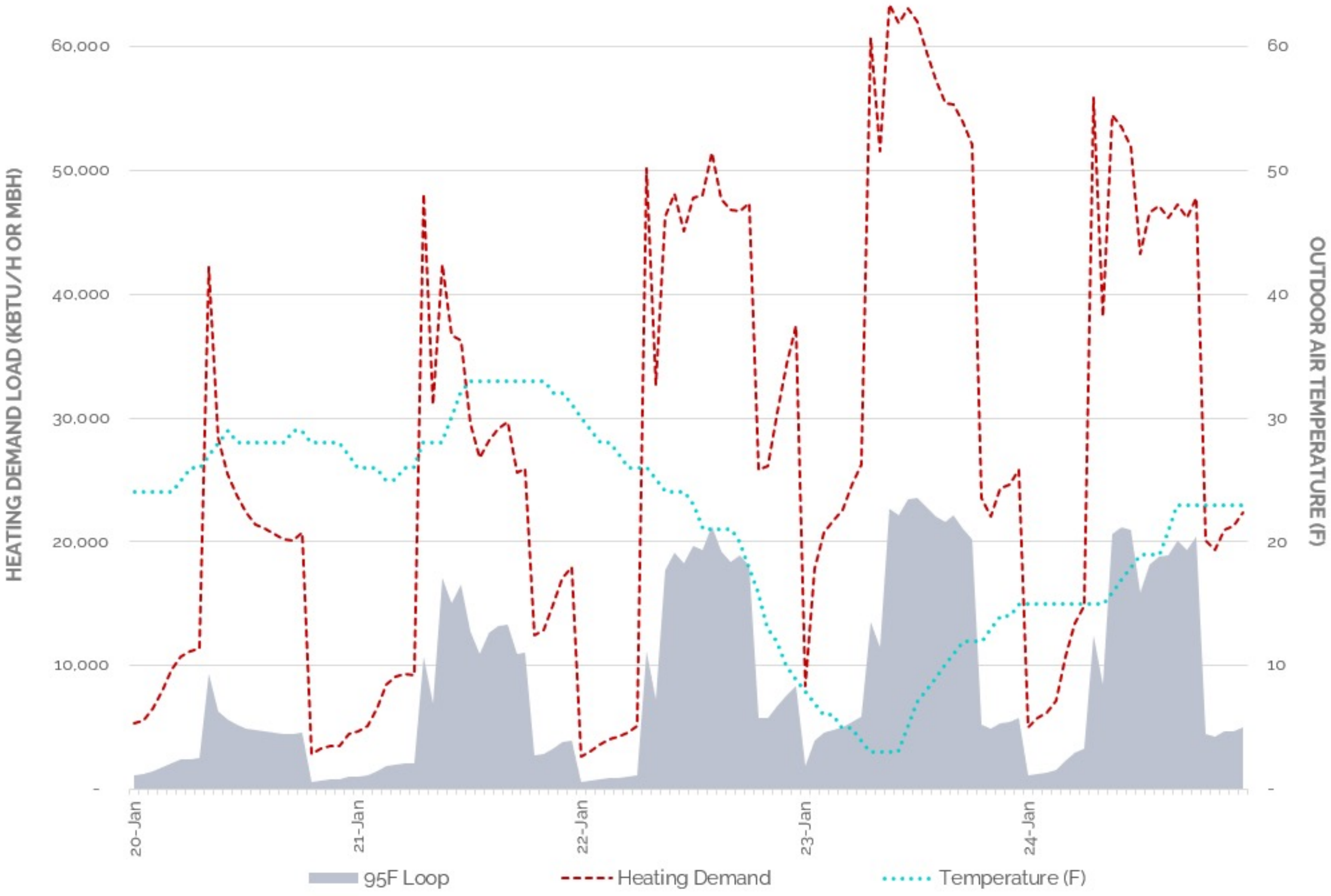
The Team designed a thermal dispatch strategy to meet a simulated daily heating demand. This strategy consists of layering the heating capacity from different heat sources in order of availability. As heating capacity from recovered and electrical sources reaches a limit, fossil fuel sources are engaged to meet the remaining demand.

Heating Profile and Thermal Layering



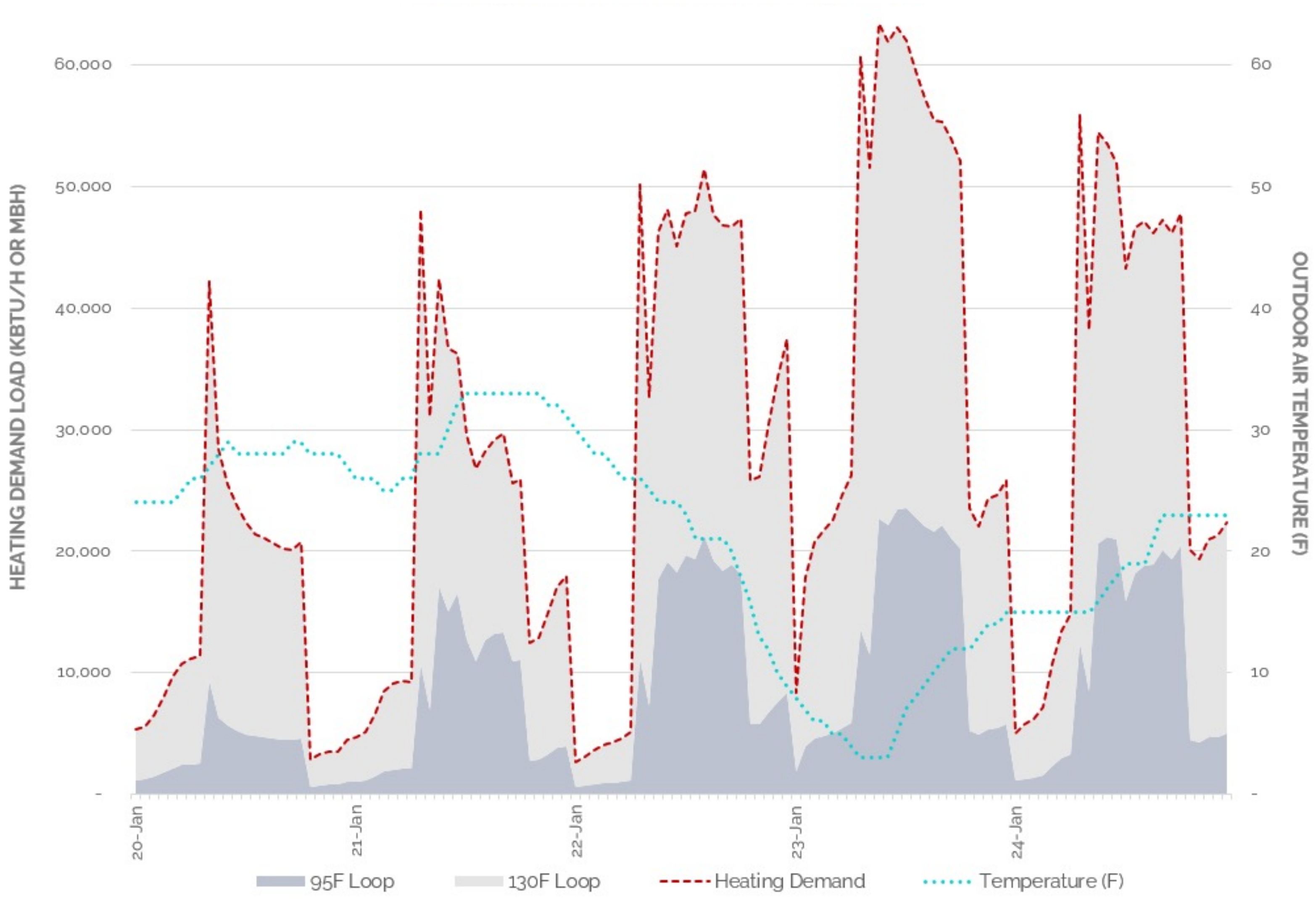
The building's heating needs for a typical winter week in January plotted with outdoor ambient temperature.

Heating Profile and Thermal Layering



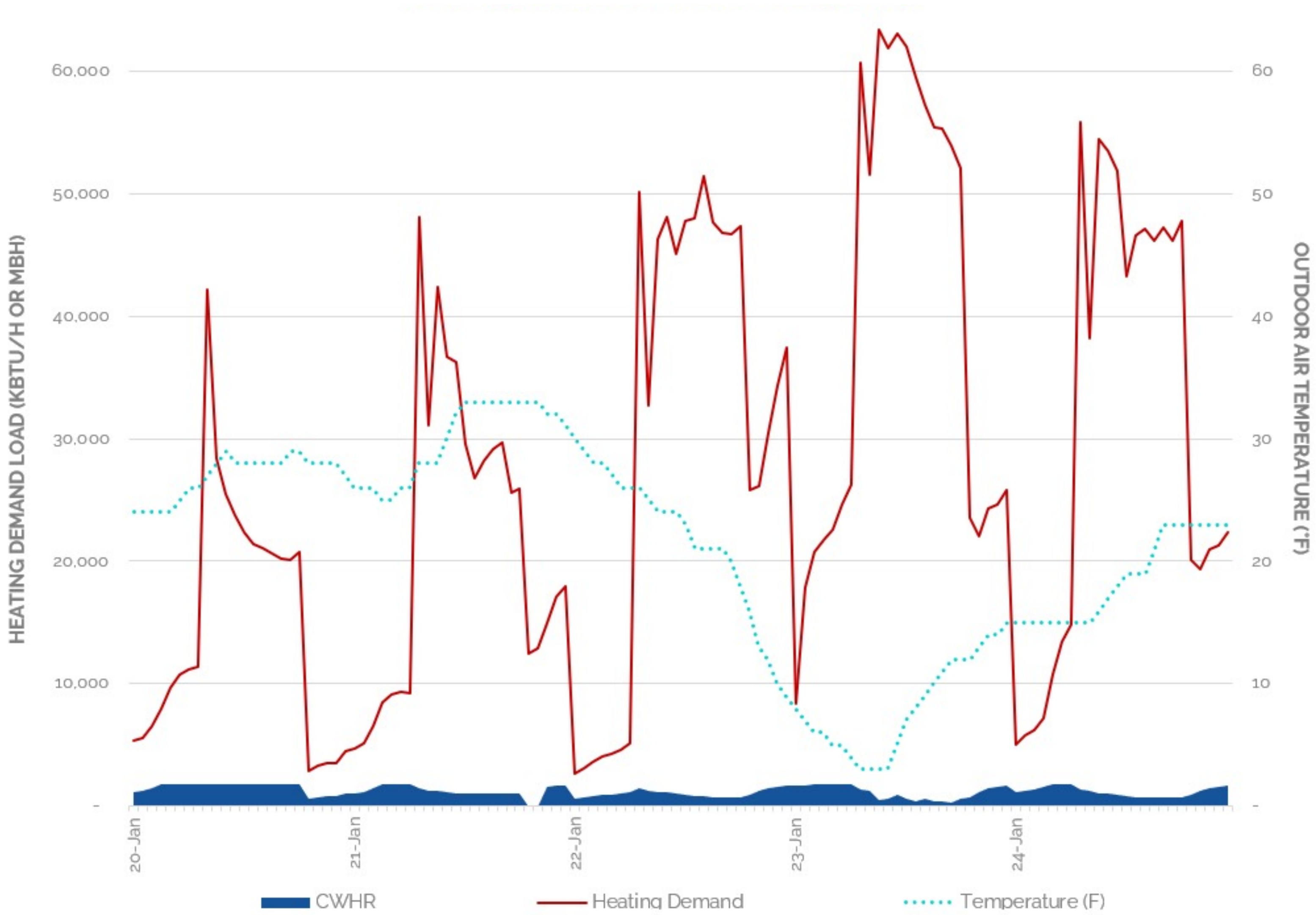
The building's heating need is split for two end uses, a low-temperature (95°F) loop that serves interior spaces.

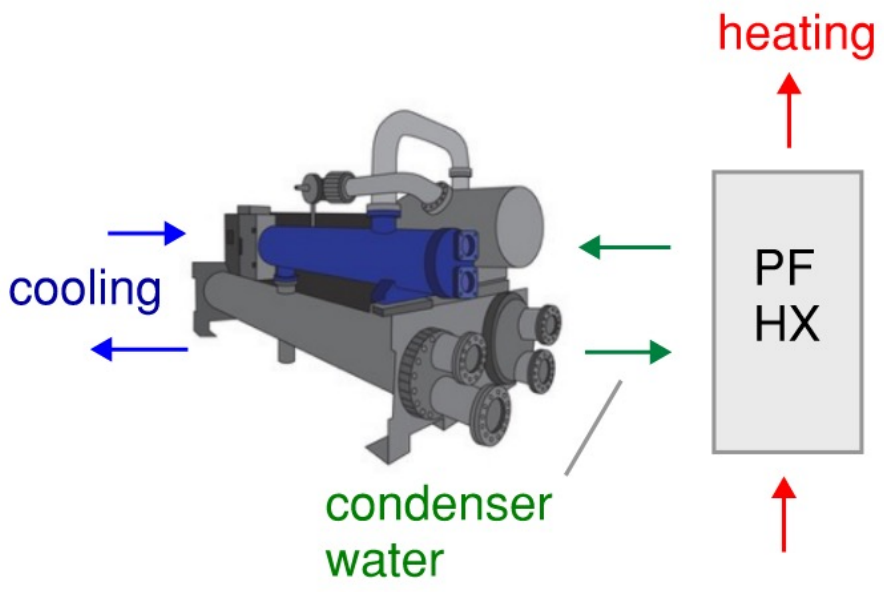
Heating Profile and Thermal Layering



A medium temperature loop (130°F) that serves perimeter spaces. Combined, these loops make up the total heating demand.

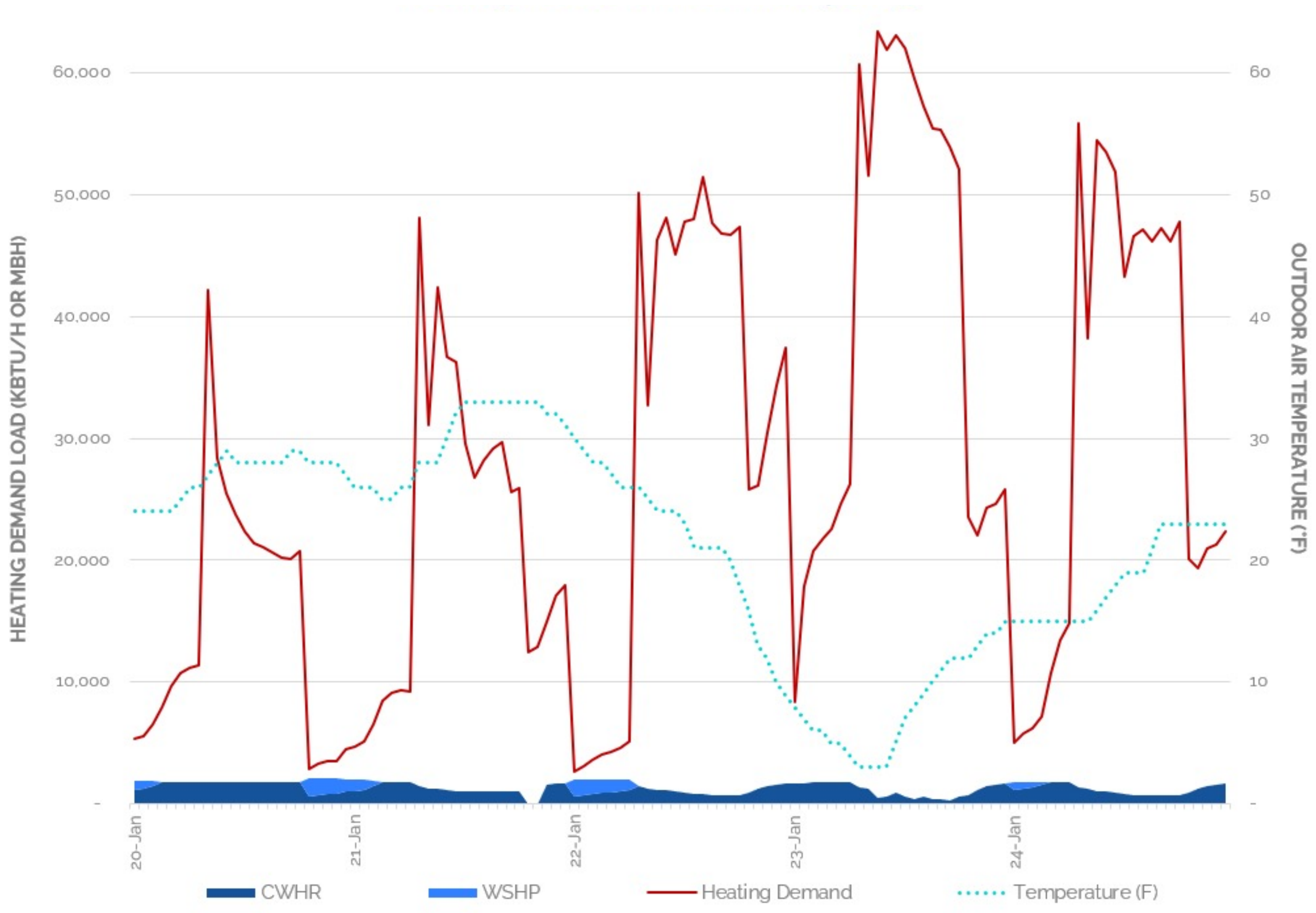
Heating Profile and Thermal Layering





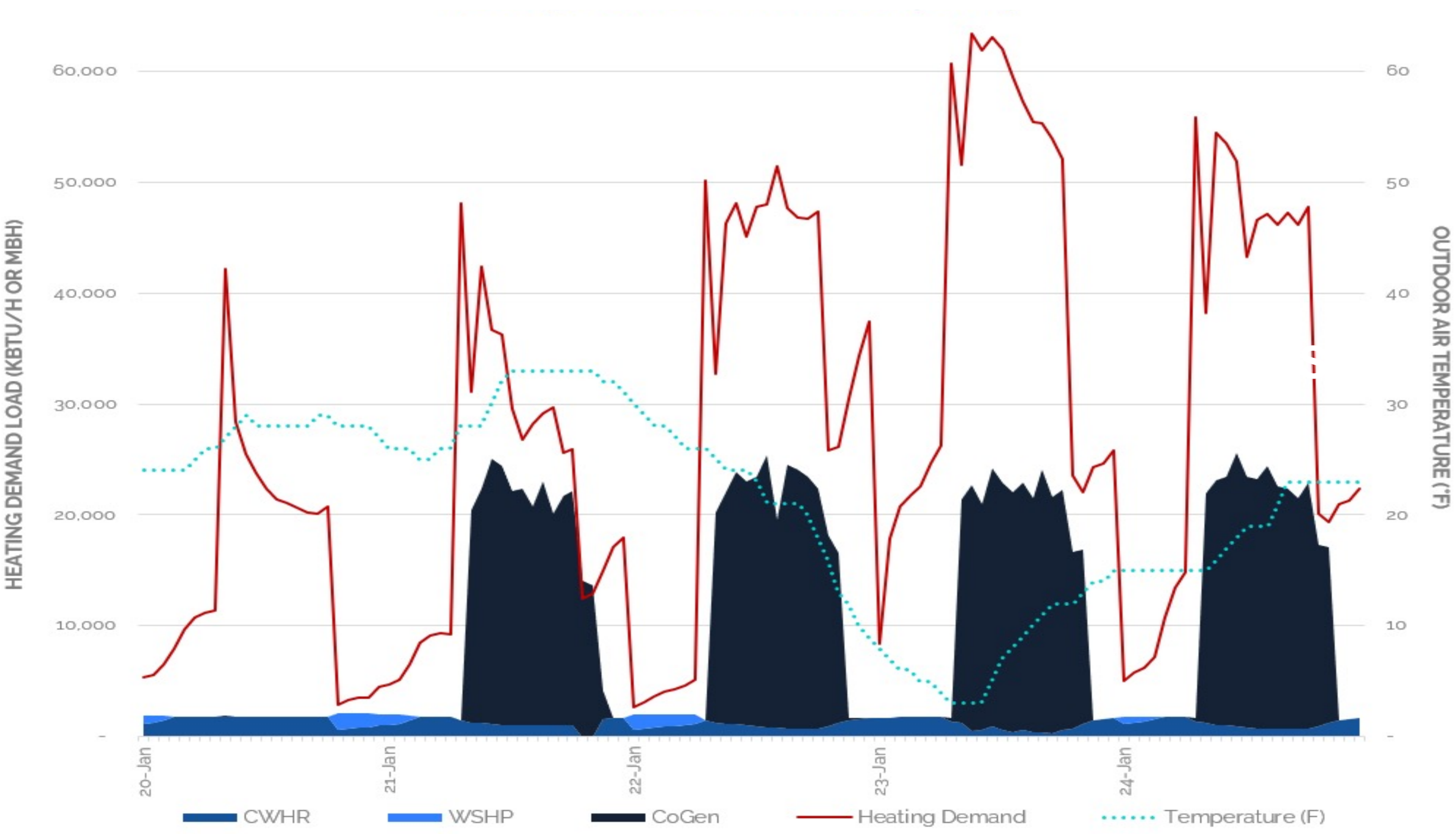
To meet this heating need, we fill the heating demand bucket with various heat resources, the first being Condenser Water Heat Recovery.

Heating Profile and Thermal Layering



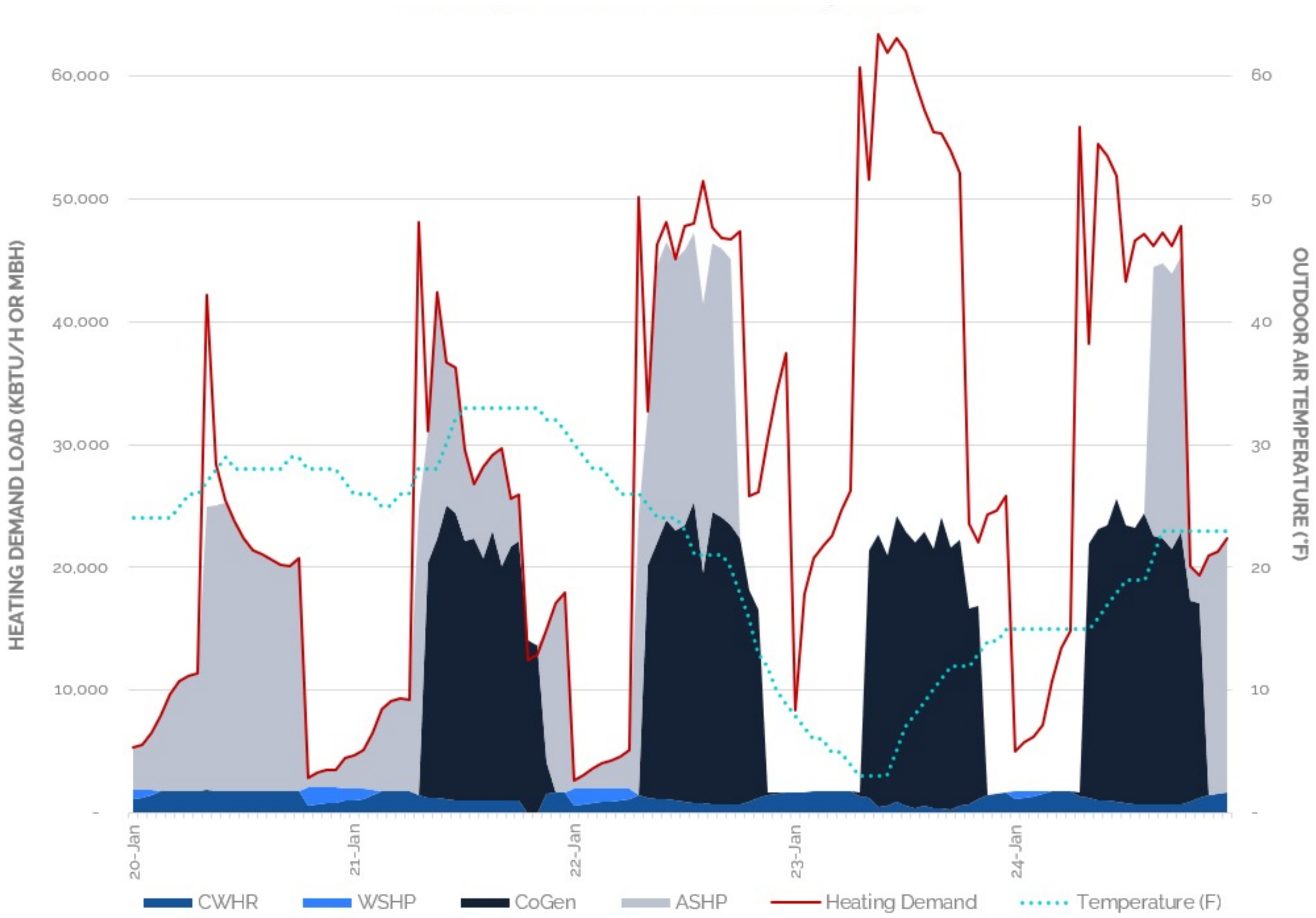
The next item that fills the heating bucket is Water Source Heat Pumps, another heat recovery strategy like CWHR.

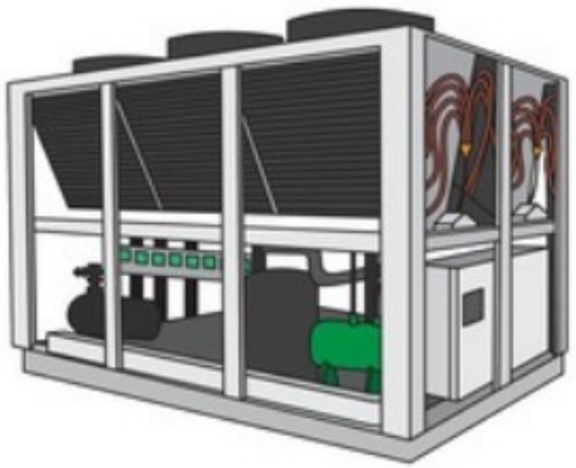
Heating Profile and Thermal Layering



Next available resource is waste steam produced by the operation of the Co-Generation plant.

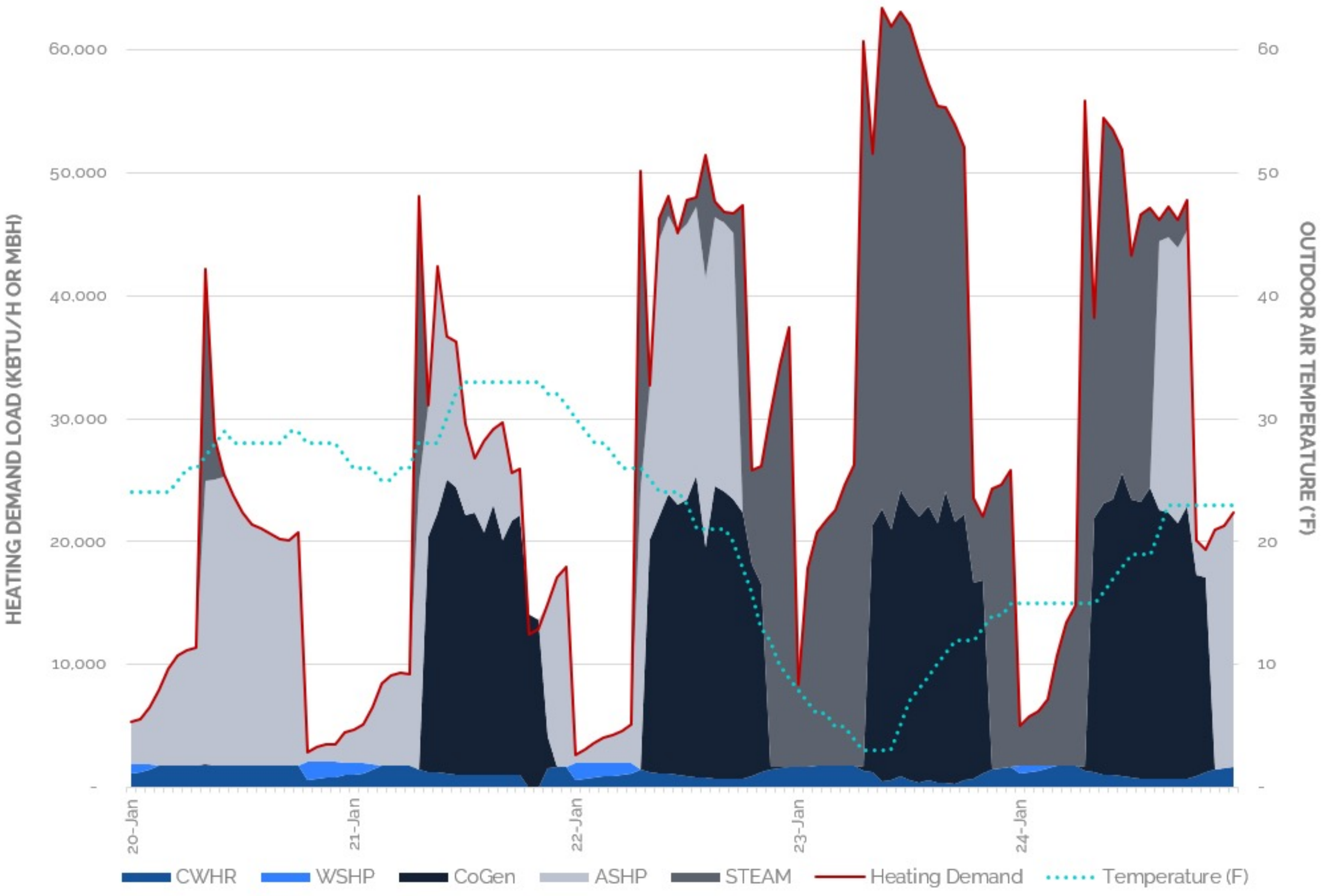
Heating Profile and Thermal Layering





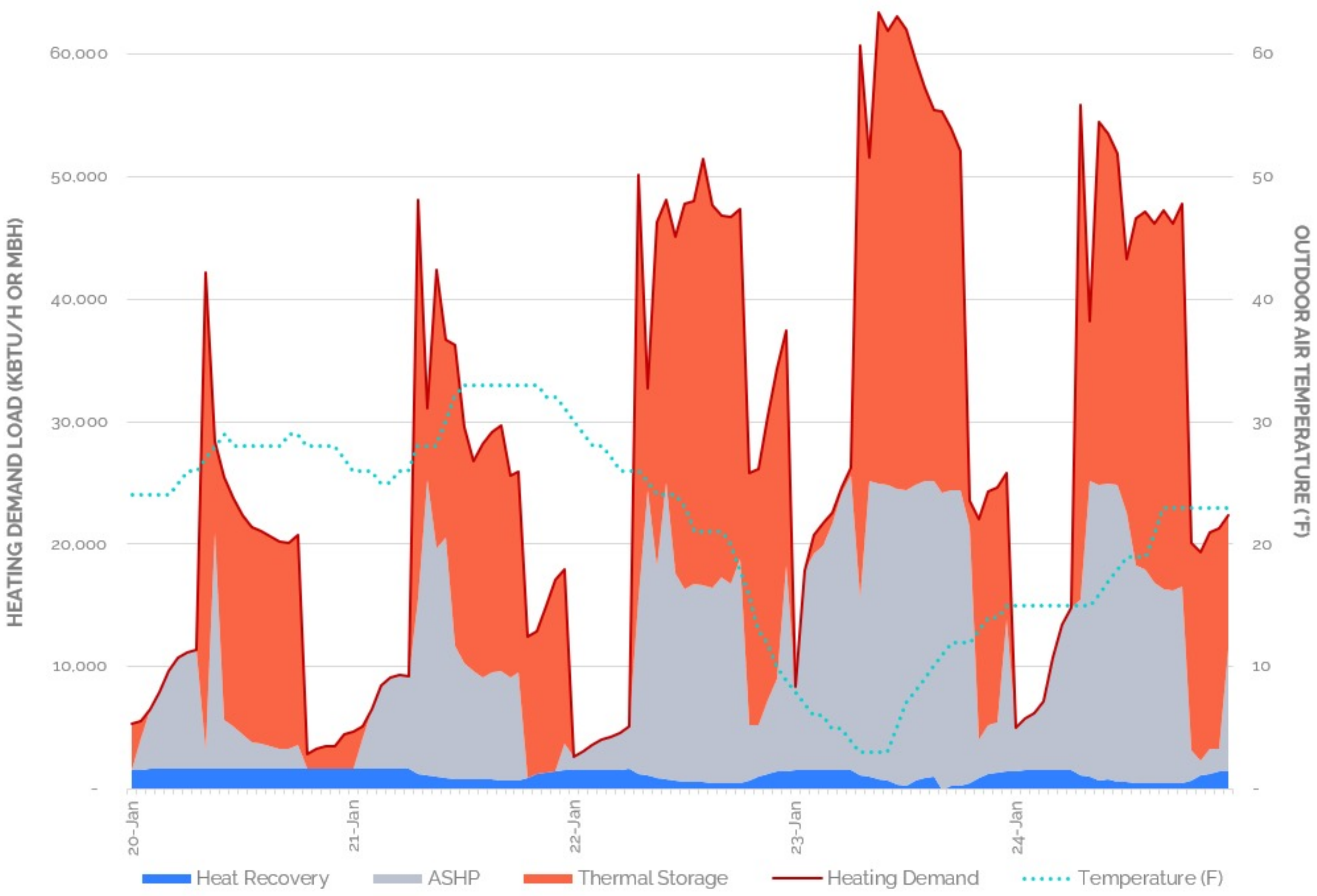
Finally, maximize the available capacity of Air Source Heat Pumps to make hot water directly.

Heating Profile and Thermal Layering



The remainder of the heating demand, including the morning peaks and when outdoor ambient is below 20°F, is met with backup District Steam.

Heating Profile and Thermal Layering



In the future, when the building is 100% electric, no more CoGen waste steam nor district steam are available resources. This gap can be met with thermal storage.

Developing the Decarbonization Strategy for PENN 1 - An Iterative Process

In the first iteration of the decarbonization strategy, the team approached the project with an all-or-nothing electrification mindset. We found that the strategies that achieve the deepest levels of decarbonization and fully eliminate district steam and cogen waste heat as heating sources may not be practical or cost efficient enough to be implemented in such a complex existing building. So we went back to the drawing board.

In the second iteration of the project, we developed a more wholistic strategy emphasizing the following core principles:

- Re-Use Existing Infrastructure (i.e., piping and ductwork) where possible
- Electrify Heating Loads Affordably
- Reduce Space Requirements for Electrification Equipment/Systems
- Use Thermal Storage to Shift & Smooth Loads to Promote Grid Flexibility

With these guiding principles, the Vornado team developed a new strategy that follows the **Resource Efficient Electrification framework**. JB&B has its own version of this framework called "Reduce, Recycle, Electrify".

Phasing, cost compression, and space compression were prioritized so that measures are more likely to be installed and scaled to other Vornado properties. ***The strategy allows for some district steam and cogen heat in the short term, while providing a phase out plan and path to full electrification in the long term.***

Lessons and Recommendations

- **Invest in a Calibrated Energy Model** – In large and complex buildings, building owners should invest in a decarbonization study with a highly accurate calibrated energy model. Accuracy in the energy analysis really matters and not all energy models are created equal. A decarbonization model should represent the building very closely so that studied strategies and measures have realistic energy and carbon reduction projections.

- **Heating System Electrification Isn’t an All-or-Nothing Endeavor** – Some heating end uses will be easier to electrify than others. A useful exercise is to look at each heating end use separately and prioritize easy-to-electrify systems first. For example, domestic hot water end uses are a great place to start. Additionally, some heating systems can be partially electrified and still achieve deep levels of carbon reduction. For example, Penn One evaluated a pathway where 80% of comfort heating loads were electrified with heat pumps and the remaining 20% of the loads were satisfied by district steam. That 20% of the load occurs very infrequently roughly 1% of the hours in a year, and as a result, using district steam to satisfy them had a very small carbon impact.

- **Reduce, Recycle, Electrify!** – Electrifying heating loads as they exist today is cost prohibitive and will negatively impact grid resiliency. A better strategy is to drive heating loads down through energy efficiency and advanced heat recovery techniques first, and then electrify heating loads once they are a fraction of what they are today. Some refer to this framework as "Resource Efficient Electrification".

Lessons and Recommendations

- **Just Because It's Feasible Doesn't Mean It's Practical** - Anything is possible in an energy model. Technical teams must be aware that building ownership teams care about more than just the energy and carbon results from the model. Strategies must be practical in a real-world sense and should aim to re-use existing infrastructure where possible, minimize disruption, use space efficiently, and compress costs as much as possible. Technical teams must be prepared to show building owners how a particular measure will be installed in a way that makes sense.

- **Don't Expect 5–7 Year Paybacks on Decarbonization Measures** - Deep decarbonization measures will likely have long paybacks. This is due to a combination of high upfront costs of electrification technology, electricity prices that are 5 to 6 times more expensive than natural gas, and an inability to capture the true value of decarbonization investments. Ownership teams will have to adjust their payback expectations when considering deep decarbonization measures.

- **Technological Innovation Isn't the Only Innovation** - There is a lot of new and exciting technology out there that could someday revolutionize the way we electrify buildings, but in the meantime, there are innovative approaches to electrifying buildings today with technology that is currently available. Purposeful dispatch of thermal energy sources and optimization for scalability, practicality and affordability are innovative strategies in their own right.

New Solutions Have Emerged

- **Low Temperature Hot Water in Existing Chilled Water Coils** - Low temperature hot water enables heat recovery and air source heat pumps to have a big impact but reconfiguring all comfort heating systems in existing buildings to be low temp is difficult and costly. A more practical approach is to do the following:
    - Electrify high temp hot water systems (i.e., perimeter systems) with water-source heat pumps and condenser heat recovery. Existing distribution infrastructure can stay in place.
    - Transition AHU steam or hot water coils to low temperature, which can be served by air-souce heat pumps. The cost and scope of coil replacements is much more manageable than replacing all heating systems with low temp hot water infrastructure. In some cases, existing chilled water coils can be used with the low temp hot water and becoming a modified change-over coil where coil replacement is no longer necessary.

- **Condition Leaving Exhaust Air** - Recycling waste heat from exhaust air streams isn't a new idea...but using the refrigeration cycle to extract and lift heat from exhaust air streams to serve heating loads is a new and innovative concept. Essentially by air conditioning the exhaust air, heat can be recovered and lifted to higher temperatures by a heat pump to offset heating loads. The reverse is also true in the summertime, where exhaust air can serve as a heat rejection medium for the chilled water production of cooling loads.

New Solutions Have Emerged

- **Thermal Source Heat Pumps (Aka “Ice Heating”)** - Coupling air source heat pumps (ASHPs) directly to heating loads is prohibitively cost and space intensive. In this direct-coupling method, ASHPs must be sized to meet the peak heating condition, which only occurs for a handful of hours during the year. This approach takes up a lot of roof space and system utilization is low. A better and more innovative solution is to couple the air-source heat pumps to thermal storage in the form of ice tanks. These tanks serve as a thermal buffer tank of sorts, where heat can be extracted from the ice (thereby freezing it) and lifted to higher temperatures with traditional water-source heat pump equipment to meet instantaneous heating loads. ASHPs can then be used to melt ice to free up additional heating capacity or to support heating demand as an additional thermal source instead of the only heating source. With this approach, ASHP equipment can be downsized, thereby compressing capital costs and space requirements. The thermal storage plant associated with this strategy is very space efficient and operations teams are more familiar with that system.

Business and/or Technical Constraints

- **Resolved:** Cost and space compression techniques for heating system electrification.
  - Reduce, Recycle, Electrify
  - Thermal source heat pumps (aka "Ice heating")
  - Separating thermal loops (high temp perimeter vs. low temp interior at AHUs)

- **Unresolved Items:**
  - Understanding capital costs: Low confidence on cost estimates that are generated based upon concept-level design.
  - Properly valuing electrification projects: Energy savings and LL97 penalty avoidance in dollars and cents doesn't capture the real value of decarbonization and as a result, payback and ROI estimates are not enticing to building owners.
  - Disruption and phasing: Some of the best decarbonization strategies are also some of the most disruptive. Additionally, phasing must be based upon a number of factors including the rate of grid decarbonization, leasing turnover cycles and capital planning cycles.
  - Uncertainty around grid decarb (both electric and steam): Being early adopters of heat pump and other electrification technologies is a tricky proposition when there is so much uncertainty around the rate of grid decarbonization and the associated cost implications. If buildings want to stay on steam for standby or for peak shaving, what will happen with tariffs and the standby charge?

Business and/or Technical Constraints

- **Unresolved Items:**
    - Controls complexity: Using thermal ice storage as a heating source alongside water-source heat pumps, air-source heat pumps and heat recovered from other systems is very complex. Sequences of operation and design specifications for this type of system do not yet exist at scale.
    - Operations team adoption: These ideas are new and complex. Existing operations team must be part of the design and implementation of these systems and training is of critical importance. A system that is designed to be low-carbon will not be successful if it is not operated per the design intent.

External Dependencies

- Greening Con Ed Steam would significantly accelerate Vornado’s ability to achieve carbon neutrality while also maintaining building resilience in the face of power system disruption.

- Thermal DERs and thermal networks are non-wires, potentially renewable grid resources that could balance capacity constraints.

District Steam in a Carbon Neutral Building

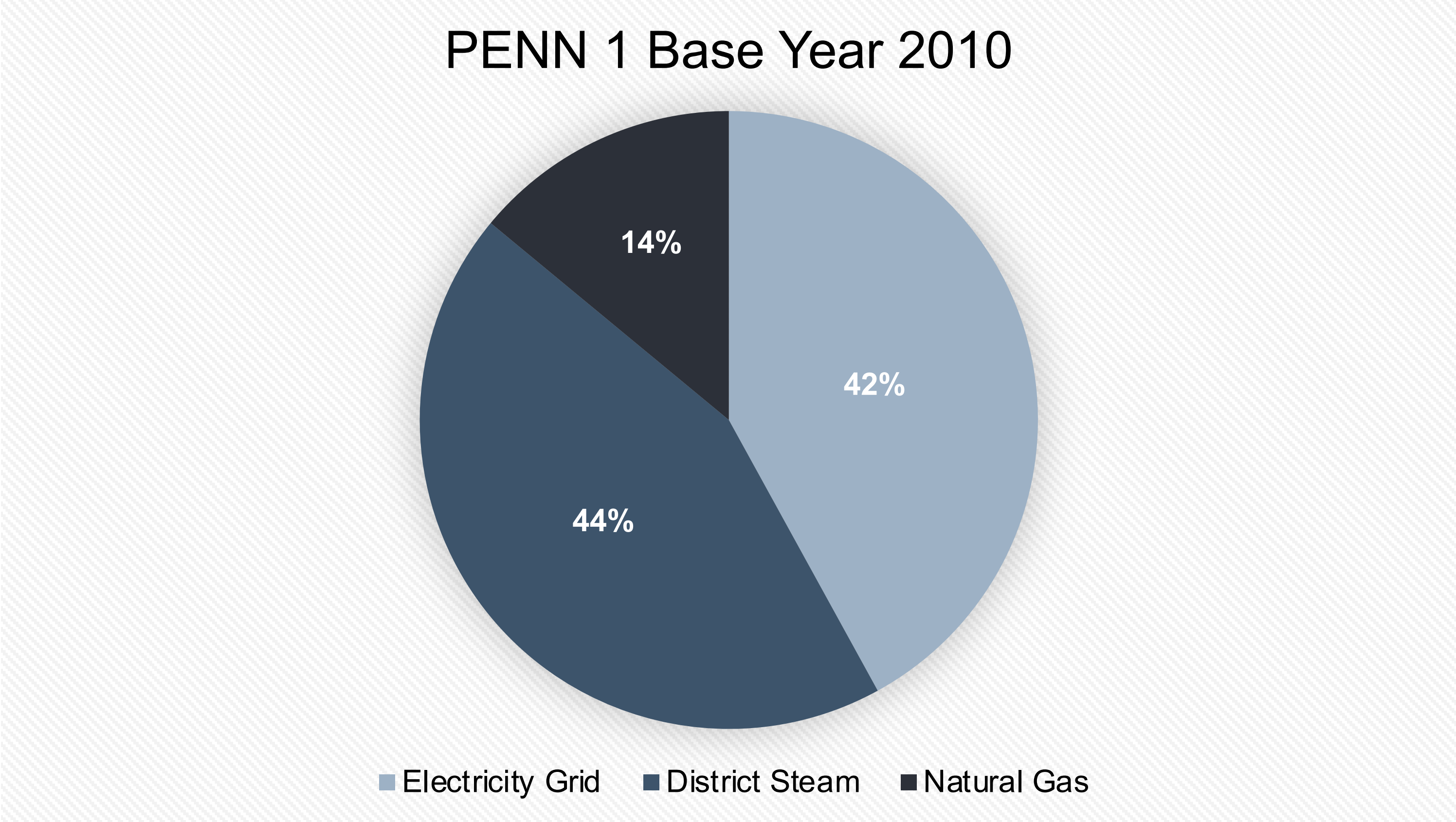
- District steam provides resilience benefits and should be a reliable supplemental source of power during the electricity grid's transition to zero carbon.
- Carbon intensity of district steam relies not on onsite fossil fuel combustion, but instead on the intensity of the resources used to produce it, as well as the efficiency with which it is cogenerated at the source.
- Solutions to de-carbonize district steam can be emboldened via CLCPA mandate and contribute to NYS climate goals.
- Con Edison is able to transition to low carbon thermal energy network. A regulatory framework for this pathway is needed.

Resource Efficient Electrification and PENN 1

ECM Category	ECM	Reduce	Reconfigure	Recover	Store
Heating and/or Cooling Electrification	Electric chillers	x	x		
	Centralized ASHP for core heating (low temp HW)		x		
	Centralized WSHP for perimeter heating (high temp HW)		x		
	Condenser water heat recovery			x	
	Ice storage				x
DHW Electrification	Centralized heat pump water heaters		x		
Envelopment Improvements	Window Replacement (Triple Pane Glazing w/ low E Coating)	x			
Ventilation Improvements	Adding VAV to AHUs and replacing induction units	x			

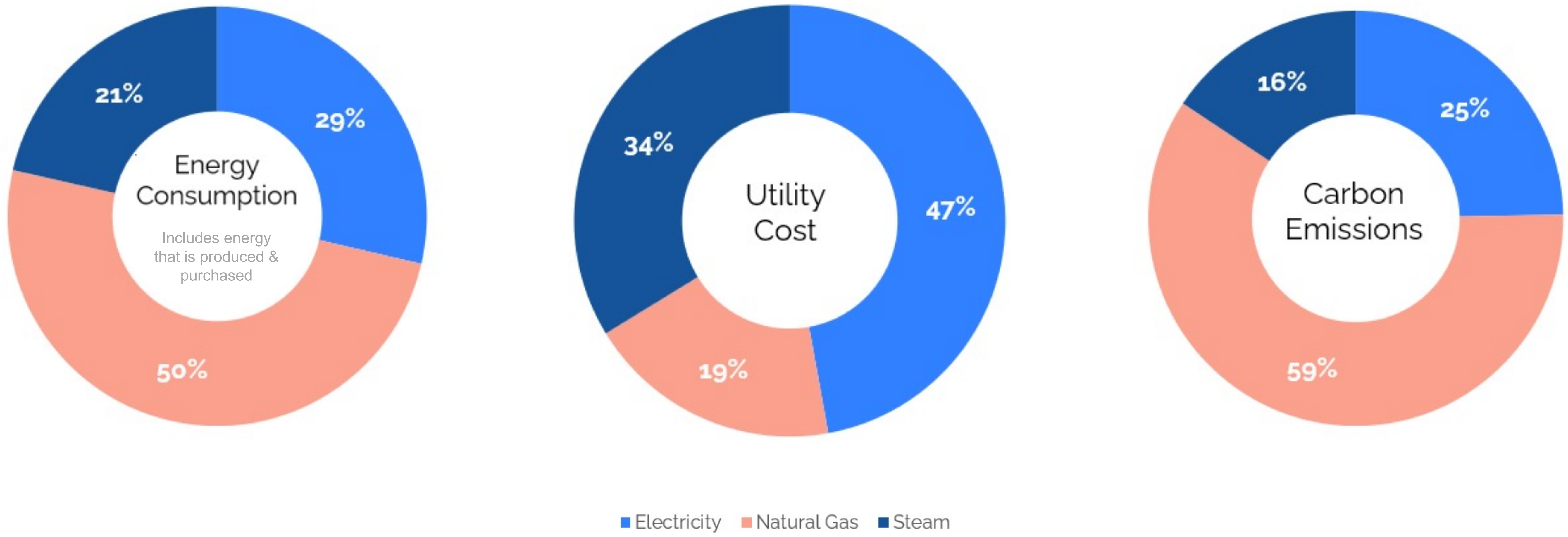
Baseline Year – Energy and Carbon Profile

Building	Base Year	Energy Star Score	EUI (kBtu/sqft)	CO2 Emissions (MtCO2e)	Total Energy Used (kBtu)	Target Year	Target EUI
PENN 1	2010	80	147	27,207	334,065,543	2030	74



Vornado’s Energy Efficiency Commitment at PENN 1: 50% reduction in energy consumption by 2030, below a 2009/2010 baseline year. As of 2021, PENN 1 has achieved a 31% reduction.

2019 Energy and Carbon Profile



EUI: 135 kBtu/sqft CO2 Emissions: 21,584 MtCO2e Total Energy Used: 333,192,863 kBtu

How Did the Team Conduct This Analysis?

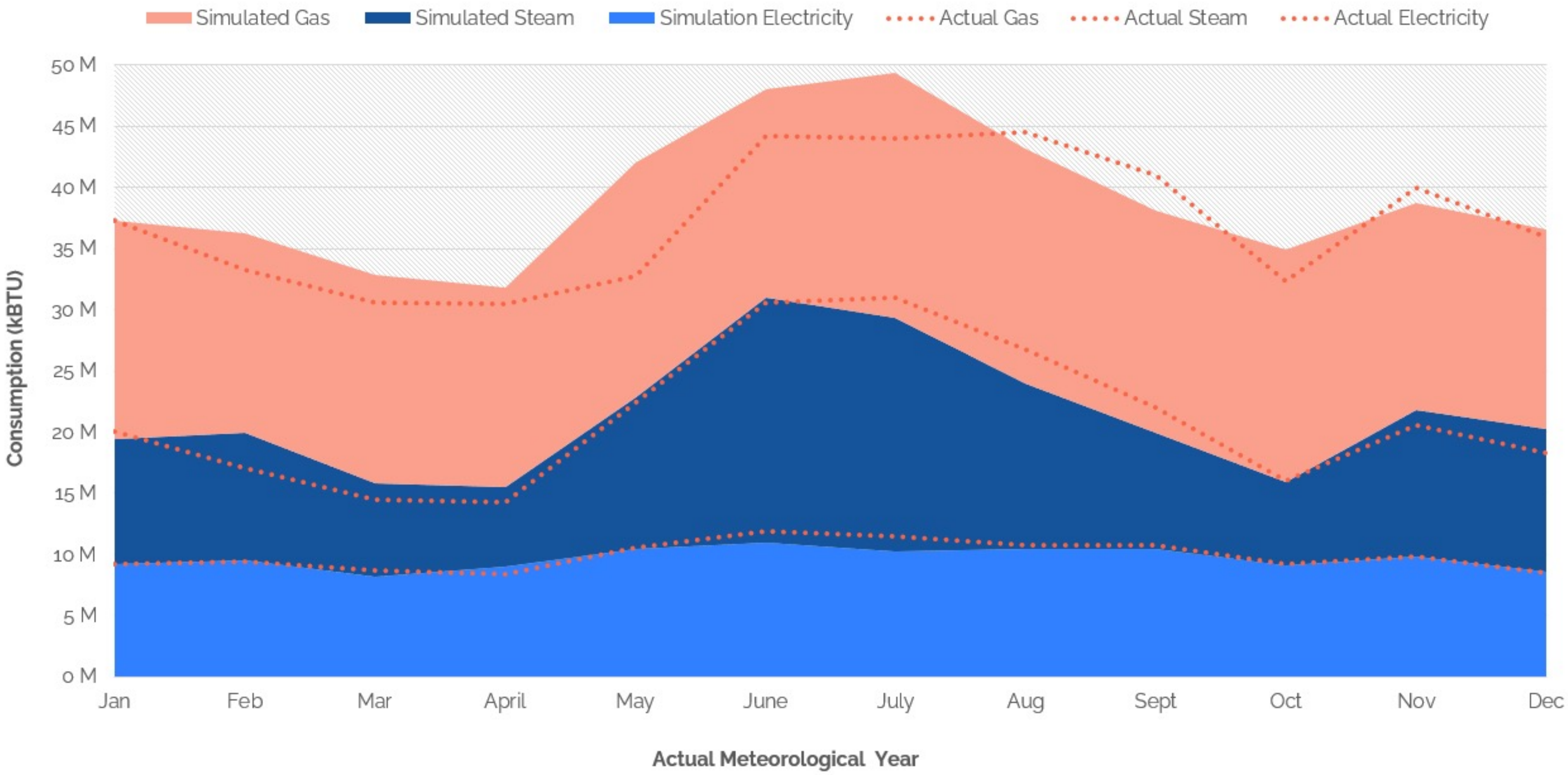
JB&B completed a **calibrated energy model** for the building. This is a key tool that allowed for an in-depth and successful analysis, enabled the electrification feasibility study, and identification of low carbon tenant space ECMs. The energy model provided two-fold benefits:

1) Show how the existing redevelopment plan makes contribution to reducing the building's carbon footprint, and related exposure to climate regulations such as NYC Local Law 97 ("LL97")

2) Test various retrofit pathways to achieve beneficial electrification, which includes the following elements:

- Tenant fit-out strategies including high efficiency lighting, plug load management and daylight harvesting
- Retrofit of existing HVAC to include either a variable air volume or DOAS conversion
- Transition to low temperature hot water system (95-105 deg)
- Advanced heat recovery including condenser water heat recovery and airside energy recovery to reduce building heating and cooling demand.
- Existing cogeneration plant optimization in collaboration with Blueprint Power to leverage the existing Cogen operating schedule, use waste heat efficiently to offset building heating loads and improve the building's grid-responsiveness
- Electrification of building heating and cooling end uses through air-source and water-source heat pumps in combination with the waste heat provided by the Cogen plant (beneficial electrification).

Calibration Process

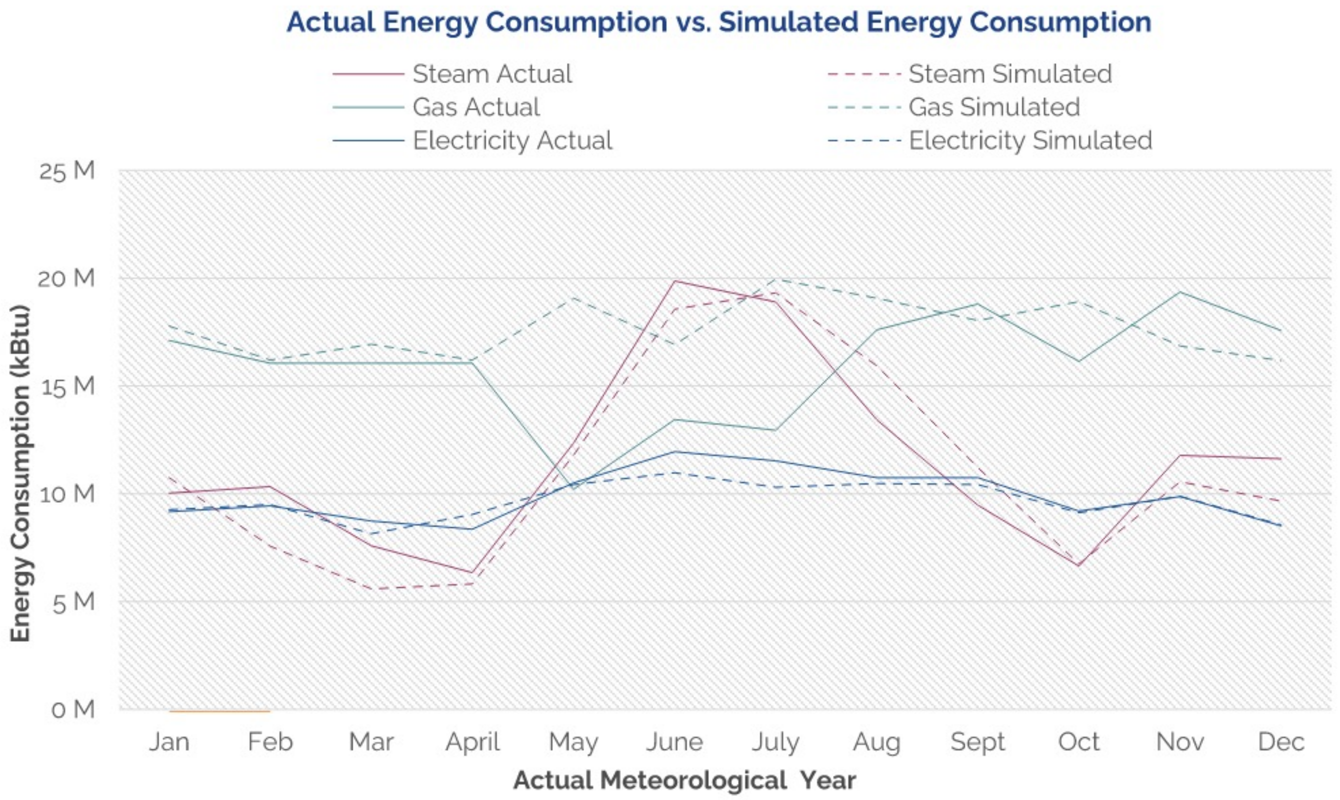


Insights From Calibrated Energy Model

Insights From The Energy Model:

- The calibrated energy model revealed that while the renovations to the building will yield significant energy and carbon reductions, the energy consumption from tenant spaces must also be significantly reduced to further drive down the carbon intensity of the building (and reduce/eliminate exposure to LL97 through the 2030 compliance period).

- The study provides insights into both beneficial and full electrification scenarios,
with ECMs grouped into low, medium, and high-impact energy and carbon reduction measures,
and phased in over time;
each scenario represents solutions and opportunities to reposition the building for a carbon-free future.



- These types of technical analyses are essential components for Vornado to further progress towards carbon neutrality as defined in its Vision 2030.

Limitations of Calibrated Energy Model

- While every effort has been made to ensure that the model reflects the design team's best understanding of the building design and future usage, the modeled energy consumption, energy cost and carbon emission estimates will likely vary from the actual energy, cost, and carbon of the building after construction due to variables such as weather, occupancy, building operation and maintenance, changes in energy rates, changes in carbon emission coefficients, and energy uses not covered by the current modeling scope.

- The analysis does not consider utility price escalations and it assumes the tariff structures of the fuels remain fixed over time:
    - Since today's electricity is approximately 6 times the cost of natural gas ($ per unit of energy), this analysis demonstrates that fuel switching from natural gas to 100% electricity may result in an energy cost increase.
    - A more detailed analysis is required to understand varying tariff structures and escalations of fuel costs projected into the future.