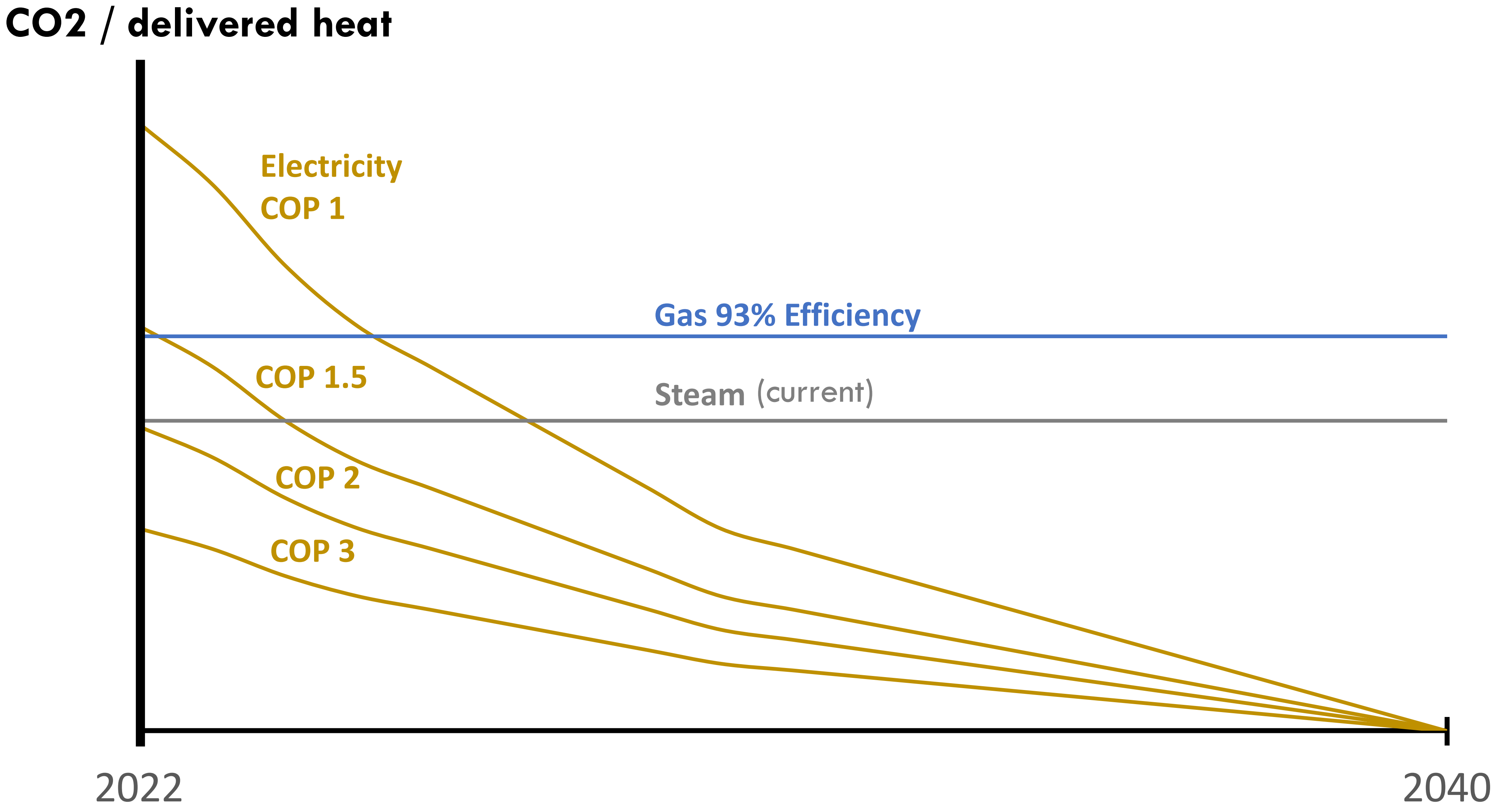
Cold Climate Tall Building Decarbonization

Technical Roadmap Framework

RMI
ENERGY. TRANSFORMED.

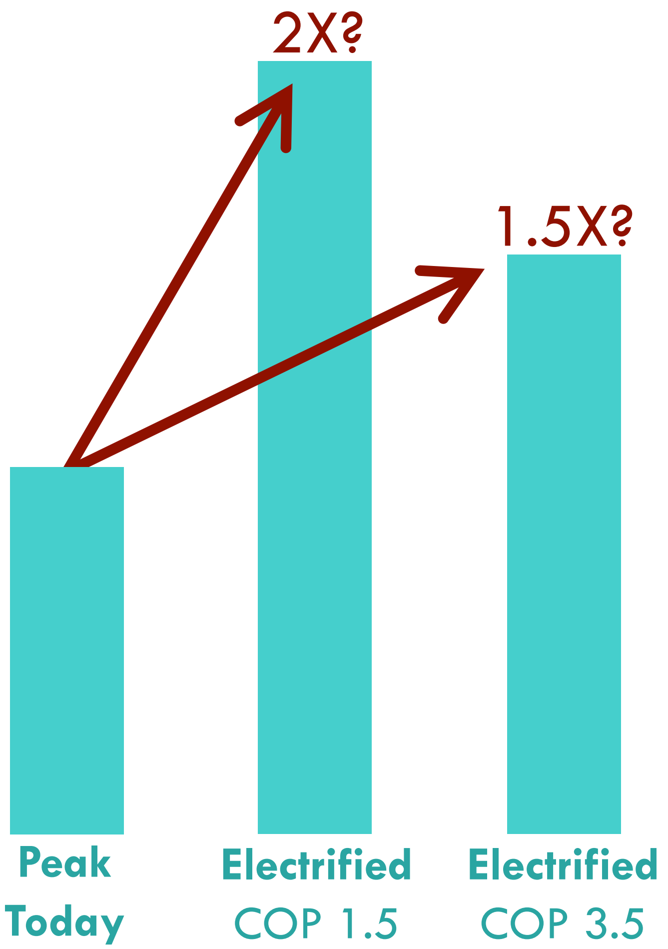
NEW YORK STATE OF OPPORTUNITY.™ | Empire Building Challenge

Heating electrification reduces CO_2.



We need a scalable framework to overcome constraints.

…on the grid



…in tall buildings

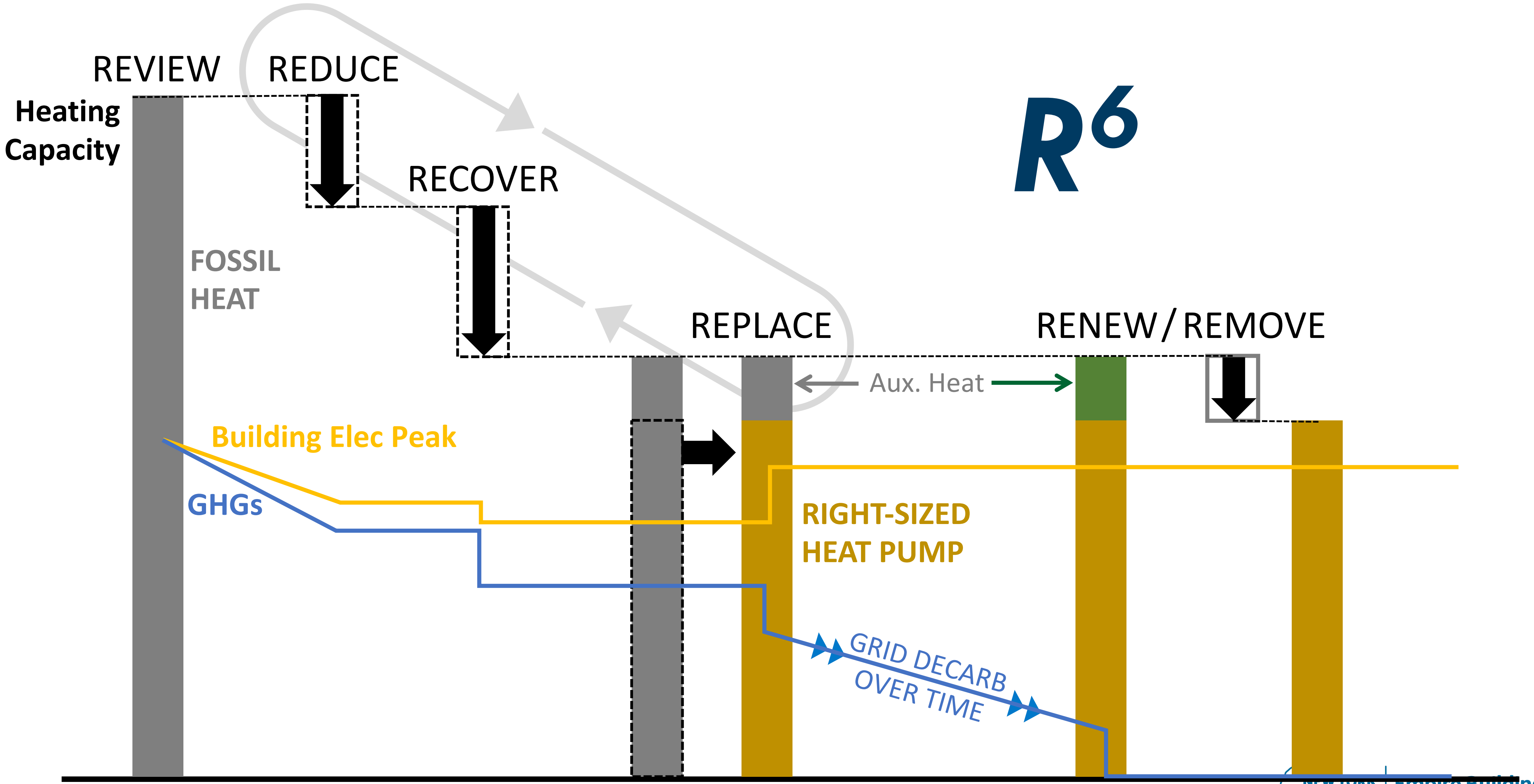
The EBC Approach

Fall 2021
NESEA
NORTHEAST SUSTAINABLE ENERGY ASSOCIATION

BLIND SPOT		SOLUTION
Really Simple Simple Paybacks	→	Strategic Decarb Assessment
1:1 equipment swap	→	Resource Efficient Electrification
Electrify everything…at once	→	Electrify everything… efficiently
Wait for better tech to come along	→	Enabling steps
Not a tenant priority	→	Non-energy benefits
Electricity Produces Emissions	→	NY CLCPA
Too disruptive	→	Decision tree

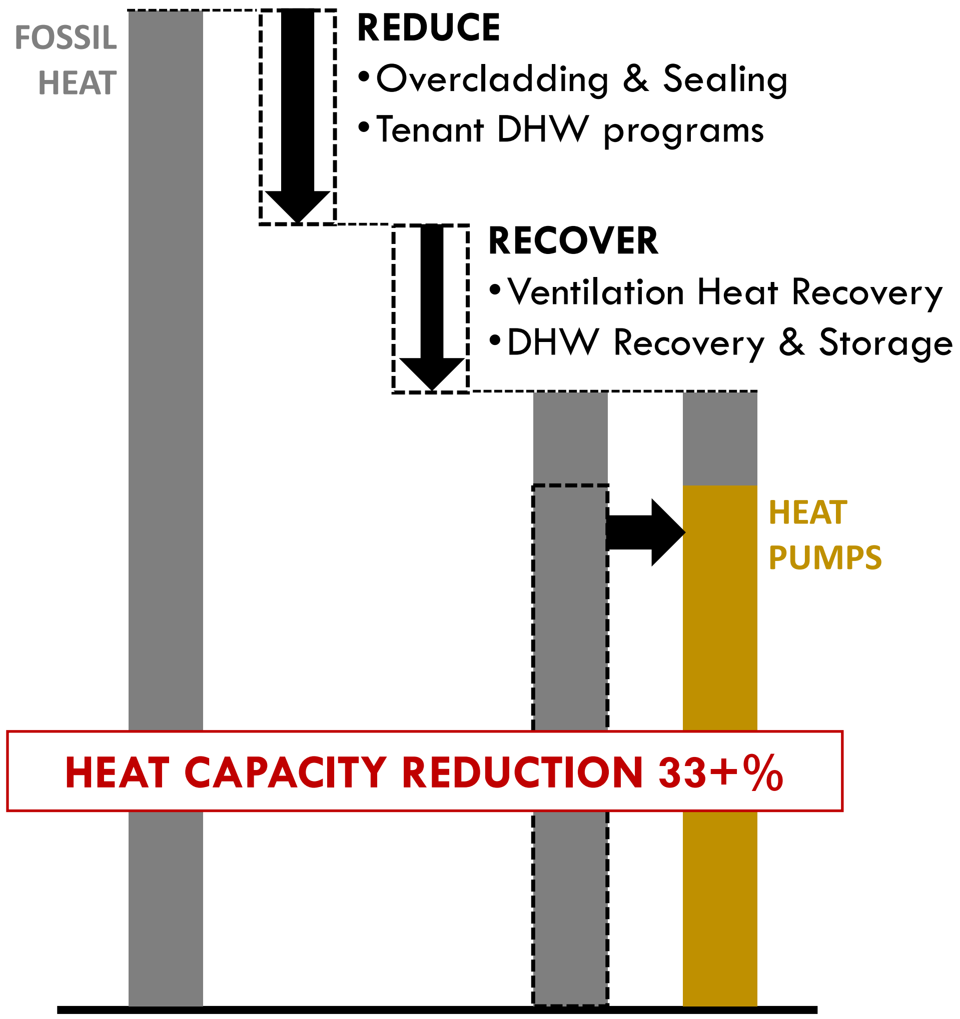
- https://pxhere.com/en/photo/1164805

Resource Efficient Electrification



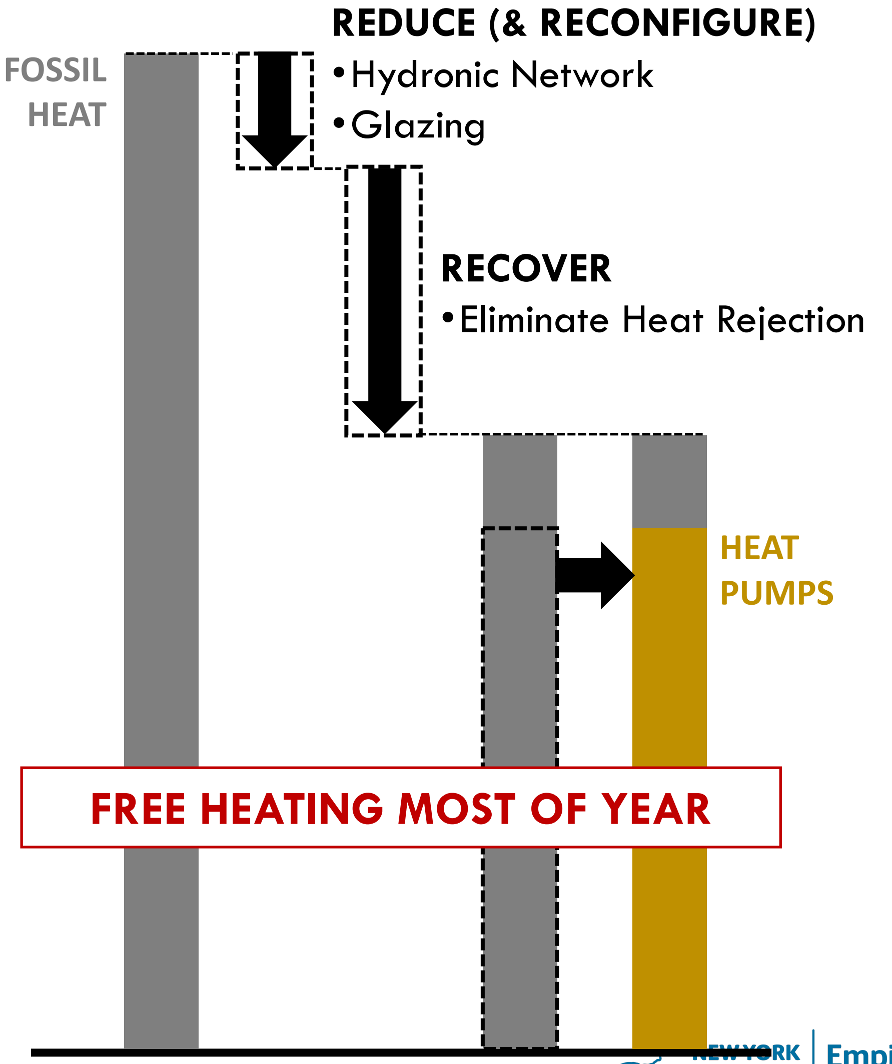
MULTI-FAMILY

example



OFFICE

example

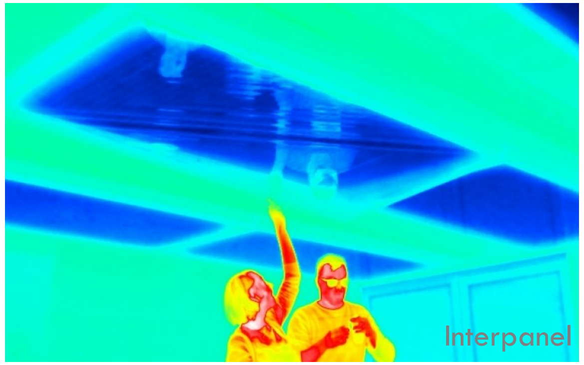


REDUCE loads

- **Over-cladding**
  - Justification: LL11, repositioning
  - Solutions:
    - EIFS
    - Energiesprong
- **Window inserts/replacements**
  - Justifications: comfort, equip downsizing
- **Internal Load Management**
  - Integrated controls (lighting + HVAC), computer equipment
- **BAS enablers**
  - Granular, demand-controlled, adaptive-comfort space management
  - Full visibility into distributed equipment and terminal unit operation
  - Part-load & temperature reset optimization

REDUCE heating supply temps

- **Benefits of reducing heating supply temps**
  - Efficiency in lower temperature lift
  - Matching to heat pump optimal lifts and output temps
- **Lower supply temps but still meet space loads**
  - Radiant solutions (e.g. Interpanel)
  - Hydronic additives
  - Thermally active buildings (enable by overcladding, topping slabs, PCM)
- **Optimize cooling supply temperatures**
  - Balance compressor power vs fan/pump power
  - Enable radiant cooling without condensation



REDUCE forced air

- **Reconfigure distribution to enable electrification**
- **Converting air-based**
  - → hydronic radiative cooling
  - → hydronic fancoils
  - → upgrading induction units
- **Ancillary benefits of decoupling ventilation from heating/cooling**
  - Hydronic systems use 5-10x less distribution energy than air-based
  - Remove ductwork and AHU closets
  - More targeted conditioning

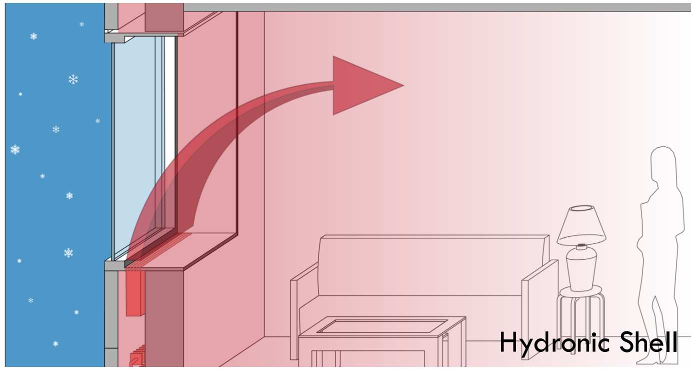
REDUCE steam

- **Reconfigure distribution to enable decarb**
- **Converting steam radiators**

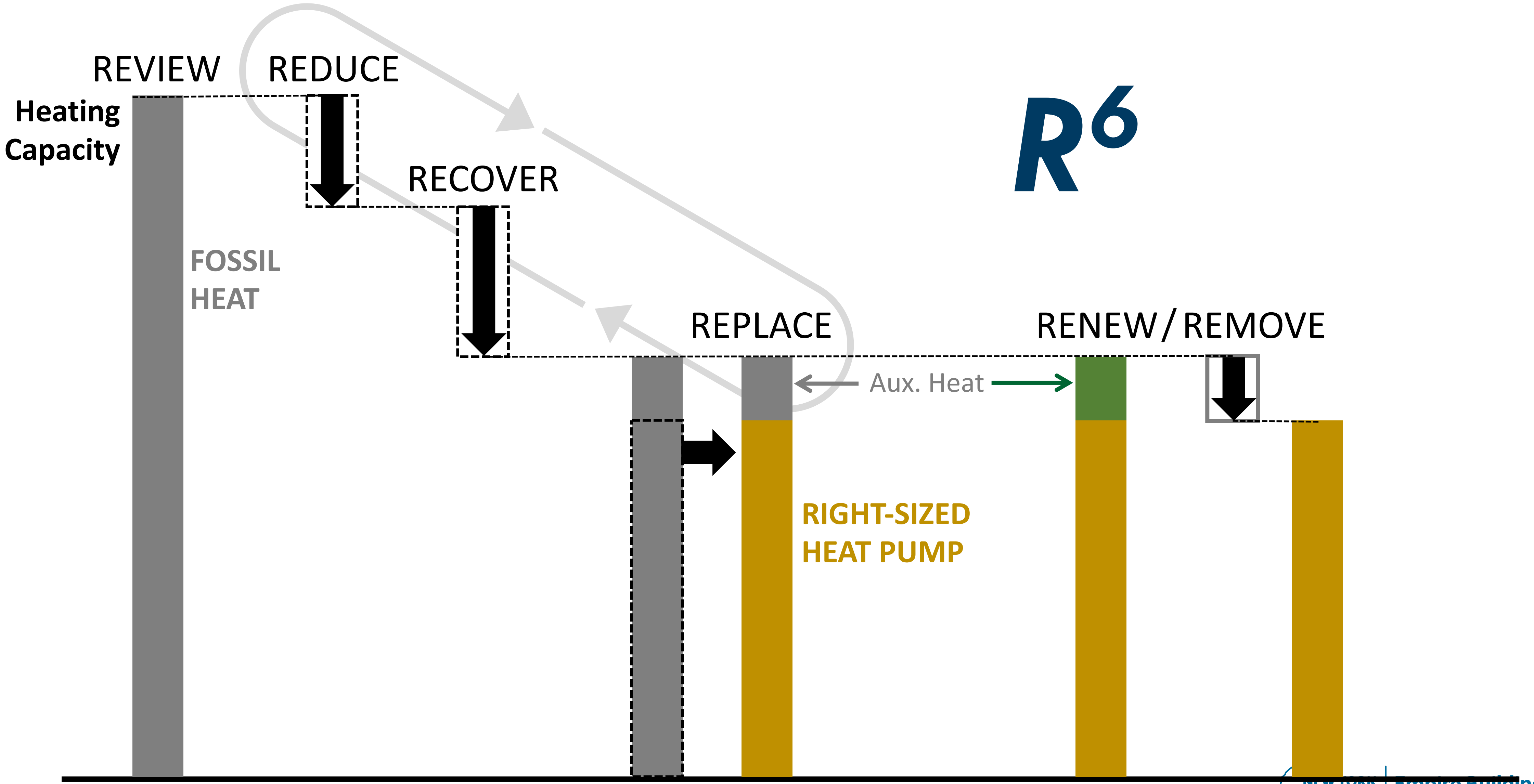
  →partial electrification with distributed HVAC
  (e.g. radiator controls communicate with ASHPs)

  → hydronic, for comfort reasons (internal risers)

  → hydronic, with capital overhaul (hydronic shell)
- **Ancillary benefit– more efficient way to move heat**
  - Inefficiency of high temp lift
  - Wasted steam condensate
  - Poor control (overheating & opening windows)



Resource Efficient Electrification

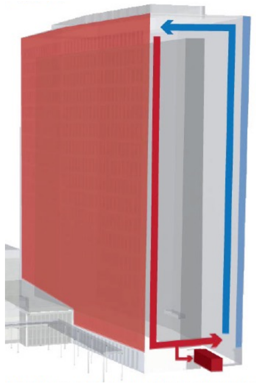


RECOVER from coincident cooling/exhaust

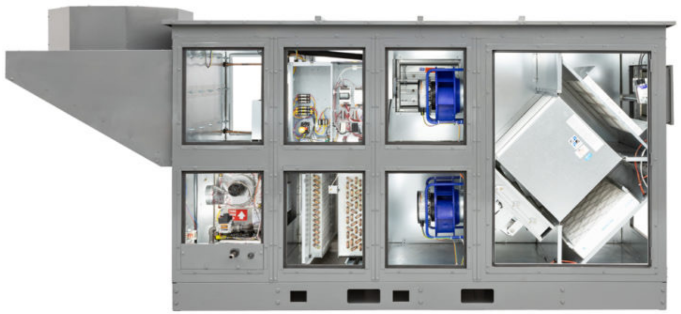
- **Exhaust heat recovery**
  - Air handlers – crossflow, wheels, heat pumps
  - Distributed ERVs/HRVs
- **Heat recovery chillers**
- **VRF and distributed WSHPs on ambient/CW loops**
- **Multi-family recovery from toilet/kitchen exhaust for makeup air preheat**

Bundle ventilation improvements with envelope tightness improvements

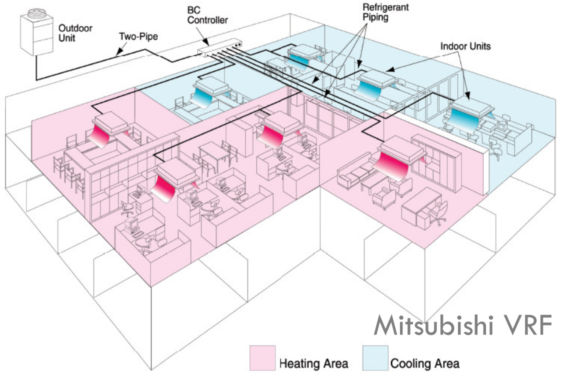
Consider IAQ implications of gas cooking



Byron Rogers (HRC



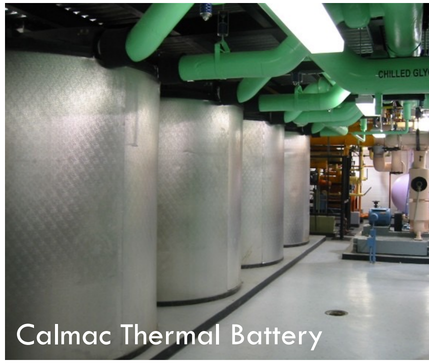
RenewAir DOAS w/ ERV & Refrigeration



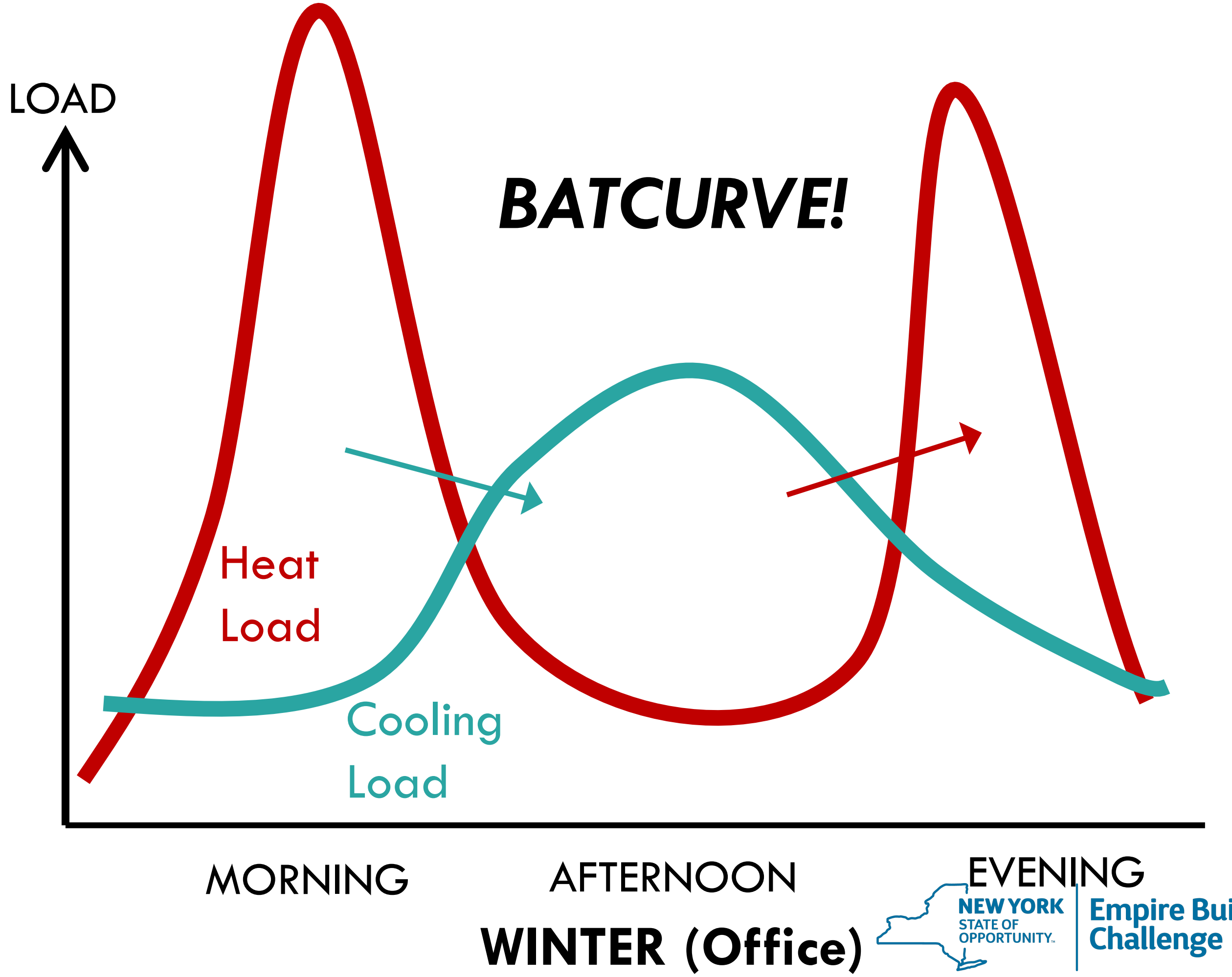
Mitsubishi VRF

RECOVER daily differentials

- **Commercial buildings that heat themselves!!**
- **Eliminate "economizer" waste. Rejecting heat is wasting energy.**
- **Storage source heat pumps on a thermal network**
- **Overlay disaggregated 8760 thermal loads to identify thermal coincidences:**
  - Core vs perimeter zones
  - East vs west zones
  - Include opportunistic heat sources!

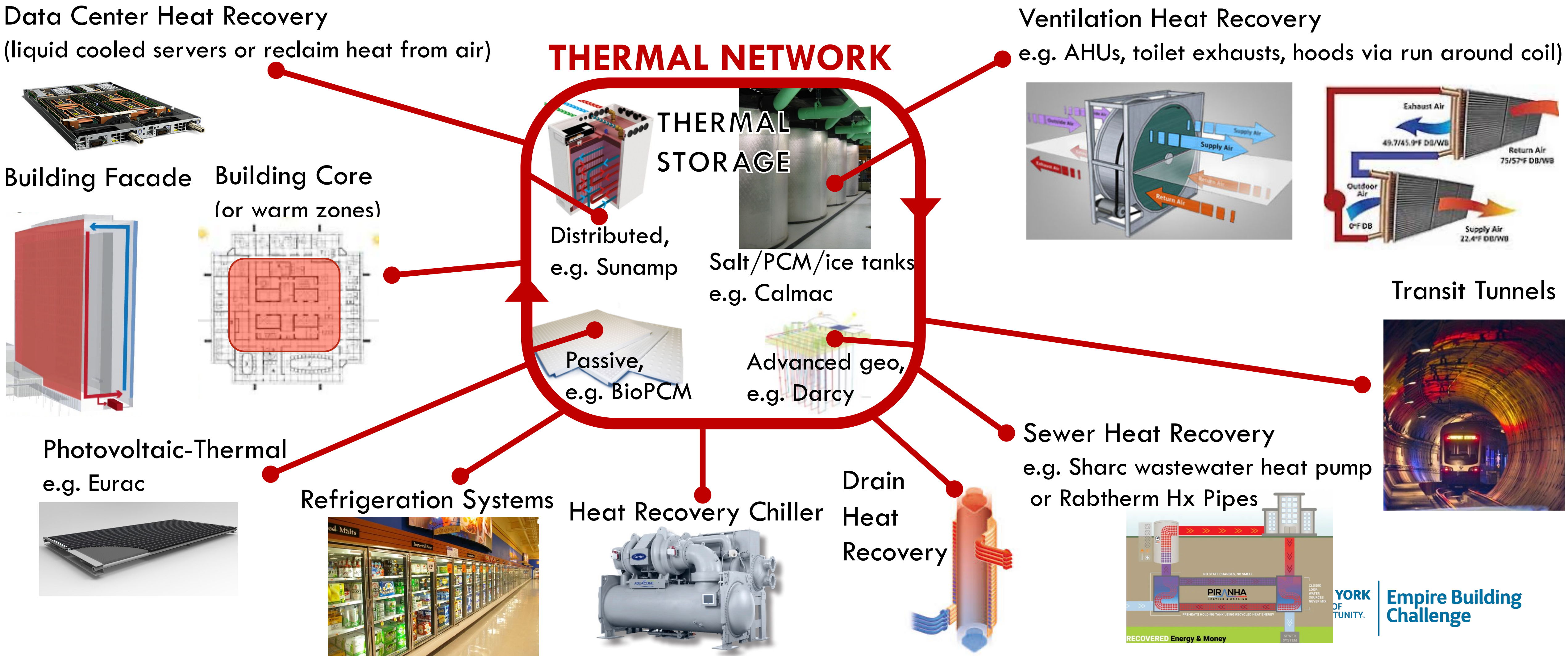


Calmac Thermal Battery



RECOVER from everywhere

Use directly at point of use (e.g. preheat), store for later use (directly or by boosting with heat pump)



RECOVER heat flows in multi-family

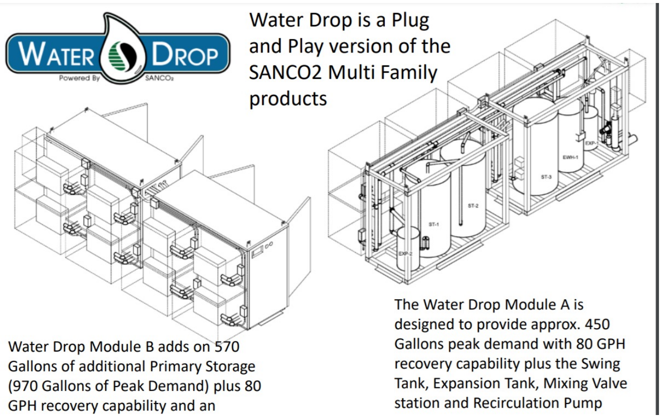
DHW

- Wastewater heat recovery
- Additional storage – optimize storage size for equipment efficiency (e.g. larger storage beneficial for heat pump water heaters)
- Reduce recirculation energy: e.g. thermostatic balancing valves, variable speed recirculation

Space heat

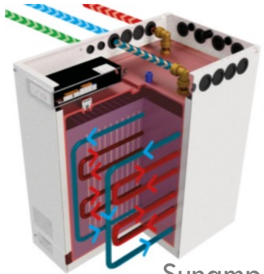
- Heat recovery from exhaust air to supply air (including toilet and kitchen exhaust)
- Other heat sources – adjacent buildings, ground-source, waste water

Colmac HPWH w/ storage

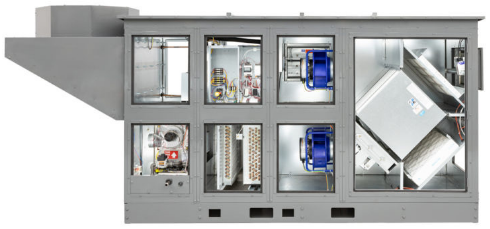


SanCO2


Circuit Solver

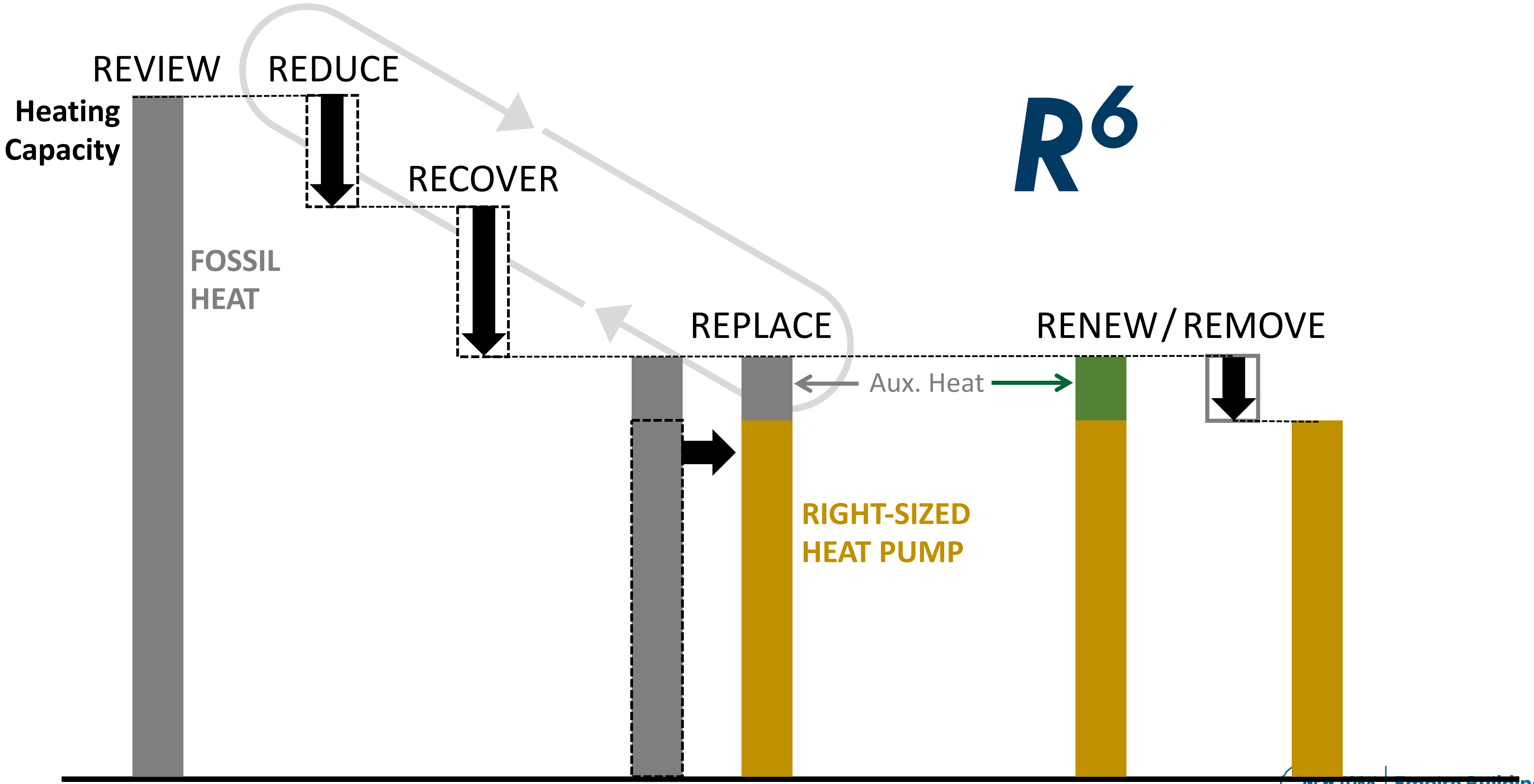

Sunamp

Sharc Piranha


RenewAir DOAS w/ ERV & Refrigeration

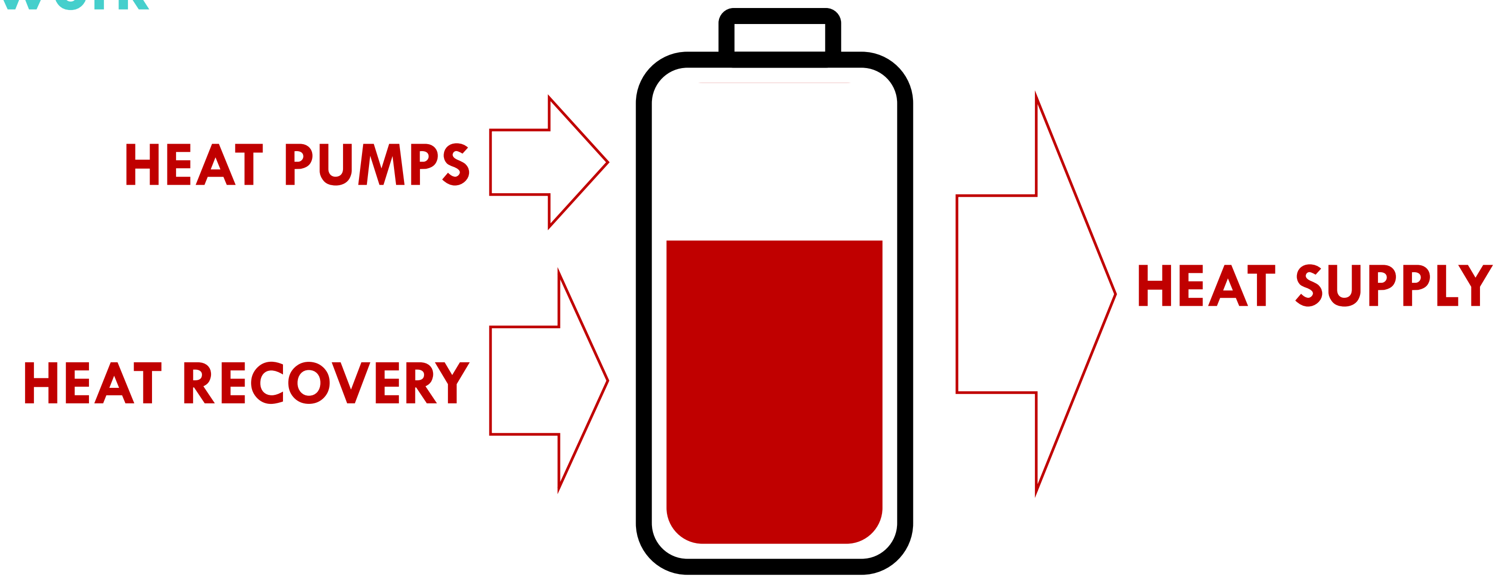
RMI – Energy. Transformed.

Resource Efficient Electrification



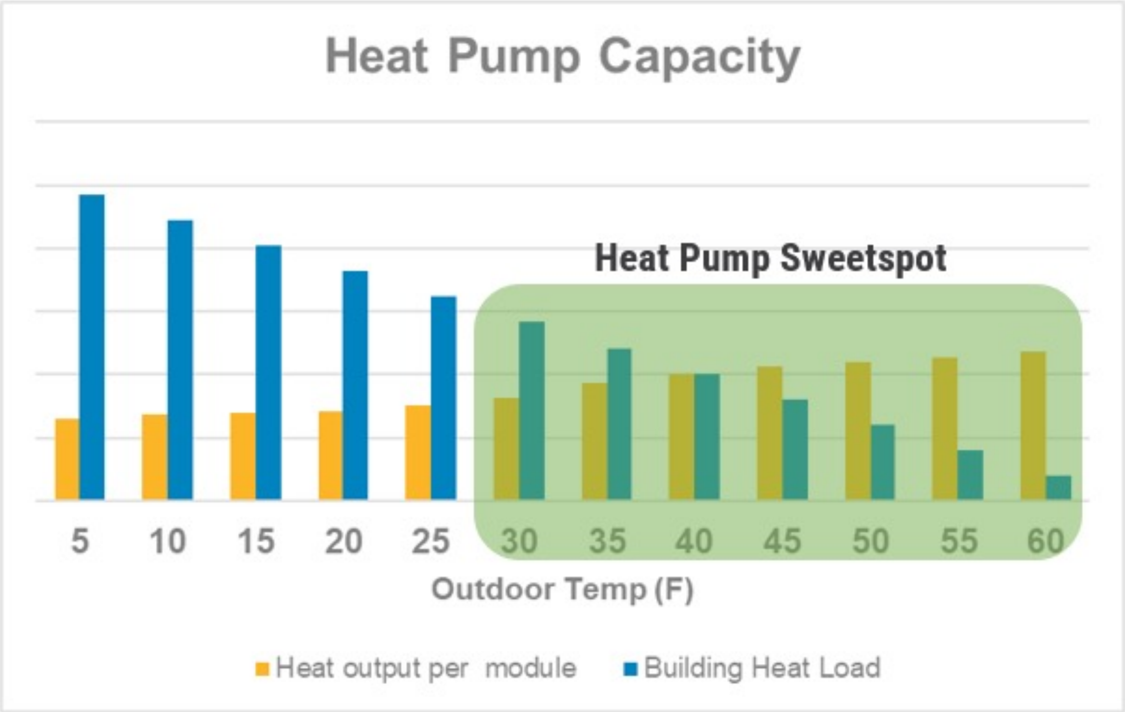
REPLACE fossil heat inputs

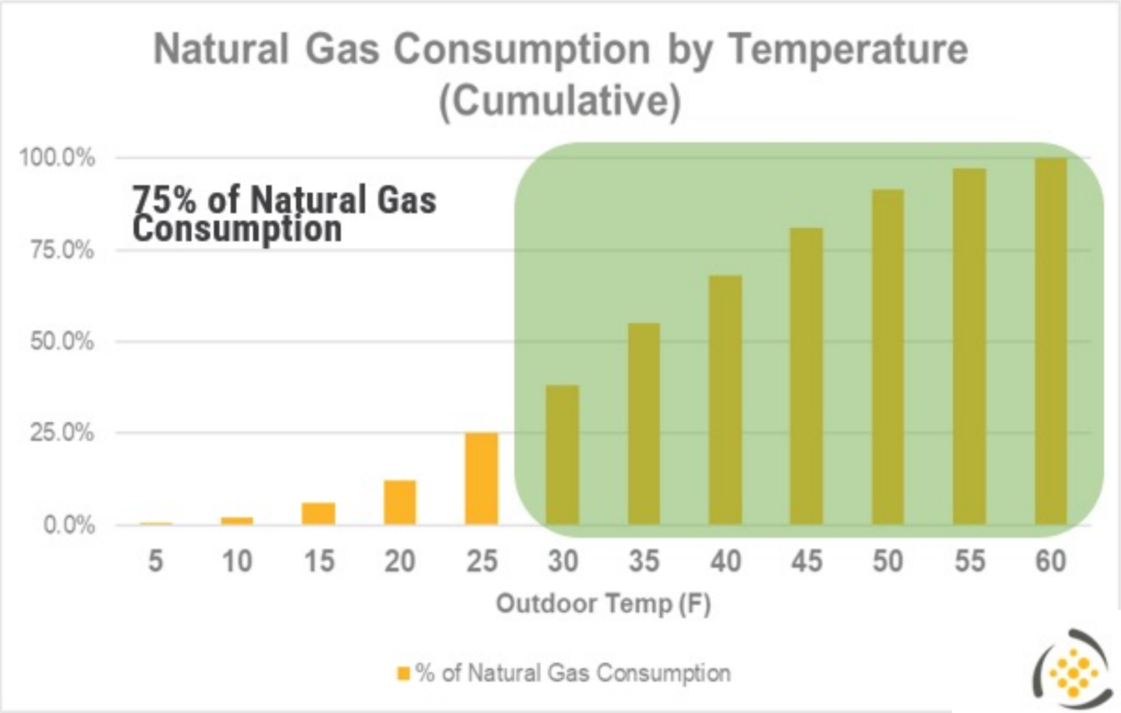
- **Not just 1:1 swap! REDUCE & RECOVER first**
  - Probably not enough roof space for 1:1 ASHP swap
  - 1:1 replacement would spike NY electric grid demand up to 1/3RD
- **Size heat pumps to top-off the remaining heat/cool imbalance on a thermal network**



REPLACE fossil heat inputs

- **Prioritize the techno-economic portion of load**
- **Right-size based on integrated annual load**
- **The techno-economic solution is rapidly changing**





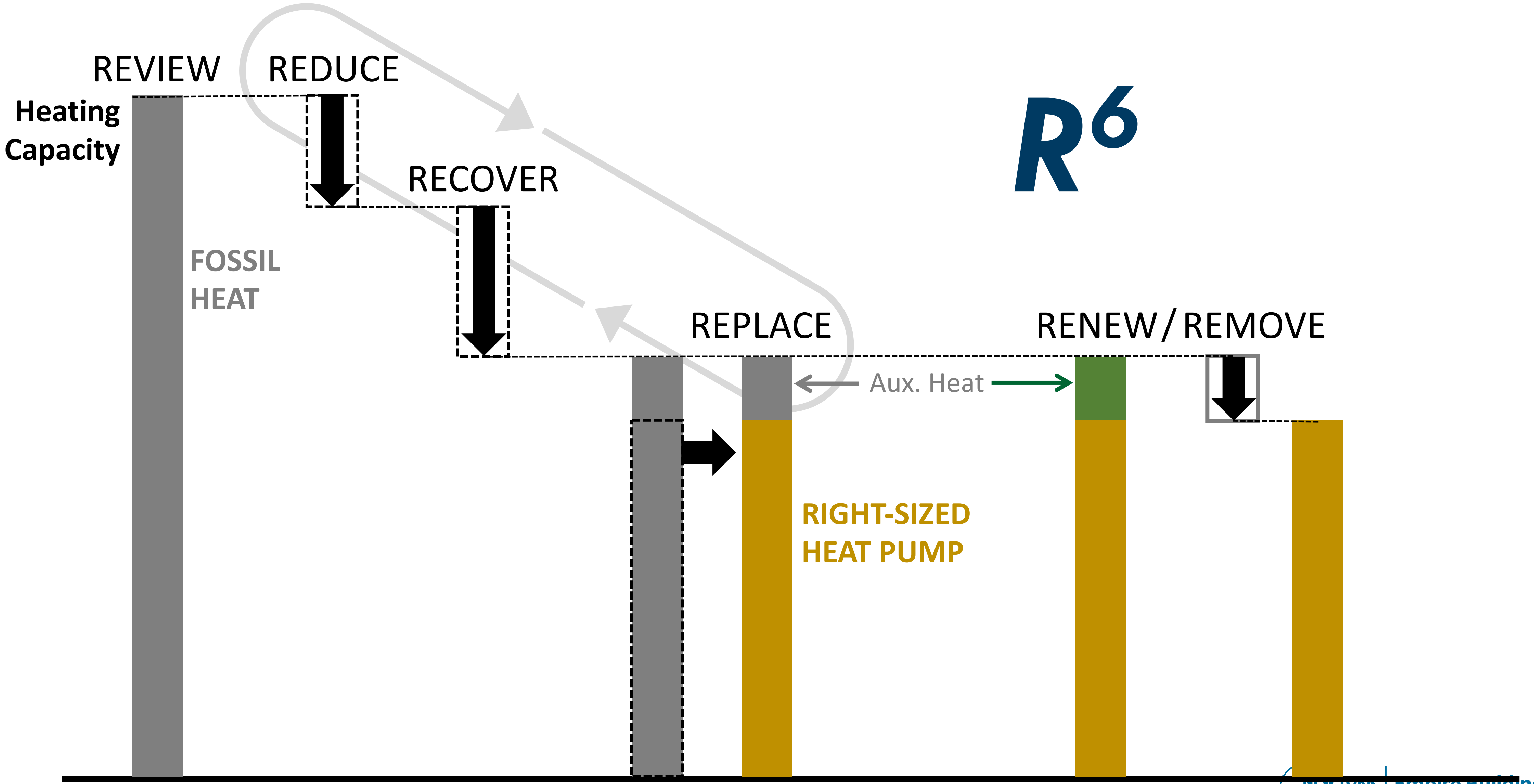
REPLACE fossil heat inputs

- **Peak condition challenges don't have to prevent partial electrification and electrification enabling decisions today**
- **Give separate consideration to challenging loads, extreme conditions**
- **Retaining resilience & optionality in the transition**
  - Central systems: Thermal network allows optionality
  - Distributed systems:
    - Retain backup
    - Hybrid VRF allows heat source optionality and refrigerant GWP/toxicity risk mitigation

REPLACE fossil heat inputs: Heat Pumps

	TYPE	DESCRIPTION / BENEFITS	EXAMPLES	TEMP IN/OUT (MIN / MAX)
Central	• Heat Recovery Chiller (water-water) • Ground Source • Air Source • Air Source DHWHP	• Modular chiller designed to meet simultaneous heating and cooling loads – heat rejected from cooling cycle can be used directly for heating • Central heat pumps can also create hot water for heating distribution (or DHW) using outdoor air, or ground (via a ground heat exchanger / borefields) • Dedicated DHWHPs can be most efficient option for some building types	• York CYK, available from other large manufactures such as Trane and Carrier • SanCO2, Lync, Mitsubishi Heat2No +Sunamp storage	• 44 F / 140 F • 14 F/ 122 F • 0 F/ 86 F (at min temp) 43 F / 131 F • - 20F / 175 F
Distributed - Connected	• Water-Air Unitary • Water-Water Unitary • VRF	Distributed unitary equipment can be more economical and efficient (lower distribution energy) while also enabling load sharing VRF can further reduce distribution energy due to energy density of refrigerant but faces challenges around refrigerant GWP	• Carrier Aquasnap, Trane Axiom (and many others) •Mitsubishi City-Multi (and many others)	• 23 / 150 F **
Distributed - Stand Alone	• Packaged Terminal Units (PTAC/PTHPs) and Minisplits DHWHPs (see above)	Avoids need for thermal distribution system, maybe a cost effective option for some building types (e.g. residential). Misses opportunity to share thermal loads / recover.	•Mitsubishi HyperHeat, Fujitsu, Innova, IceAir, Gradient (and many others)	• 13 F (80%) / 95 F • 5 F (100%)

Resource Efficient Electrification



RENEW auxiliary heat

- **Solve the most challenging load conditions as the need is fully understood and technically, economically and environmentally resilient.**
- **Engage on a clean future for district systems**
  - Clean steam?
  - District wastewater heat recovery (Seattle, Denver, DC)
  - District ambient loops
- **Engage on forthcoming grid challenges/opportunities**
  - Winter peaks
  - Demand flexibility & grid-interactivity on decarbonizing NY grid
  - Solutions: central storage, distributed storage, tenant engagement

STEAM
EBC AFFINITY GROUP

GEB
EBC AFFINITY GROUP

or **REMOVE** redundant capacity

R6 framework for cooling

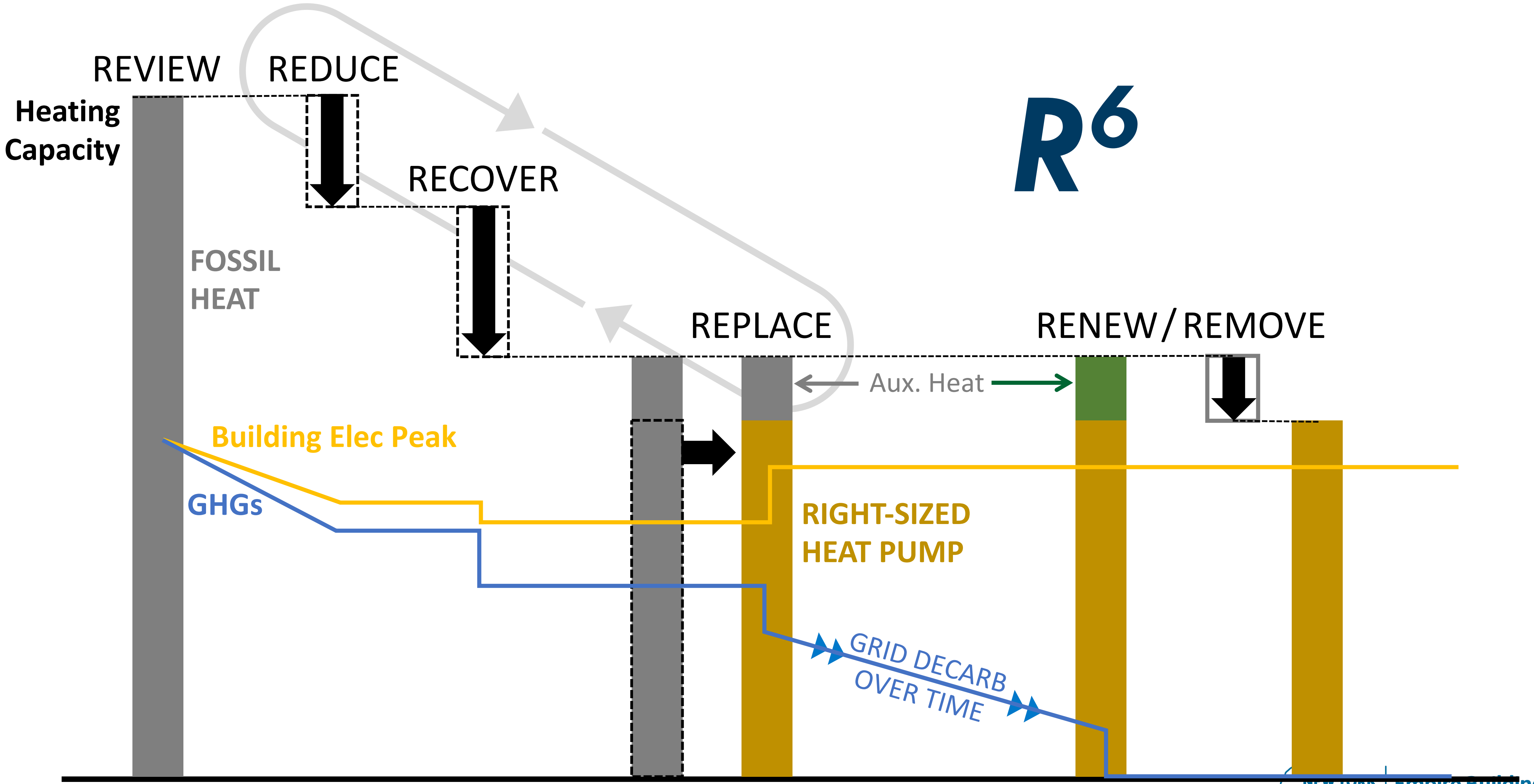
Why focus on cooling?

- Short term – significant carbon reduction opportunity
- Long term – peak load reduction and flexibility is a key enabler for renewable sources
- Transition to low GWP refrigerants is an opportunity to reduce emissions directly but also a trigger point for re-thinking cooling system

Additional areas to consider for cooling:

- Reduce internal gains
  - E.g. tenant engagement to reduce plug loads, lighting, controls, other equipment.
- Hydronic distribution, pre-cooling / leveraging mass or storage to reduce peaks
- Explore opportunities for more efficient heat rejection (e.g. consolidating smaller systems onto efficiency cooling tower, ground borefields)
- Phase out absorption chillers

Resource Efficient Electrification



Ecosystem

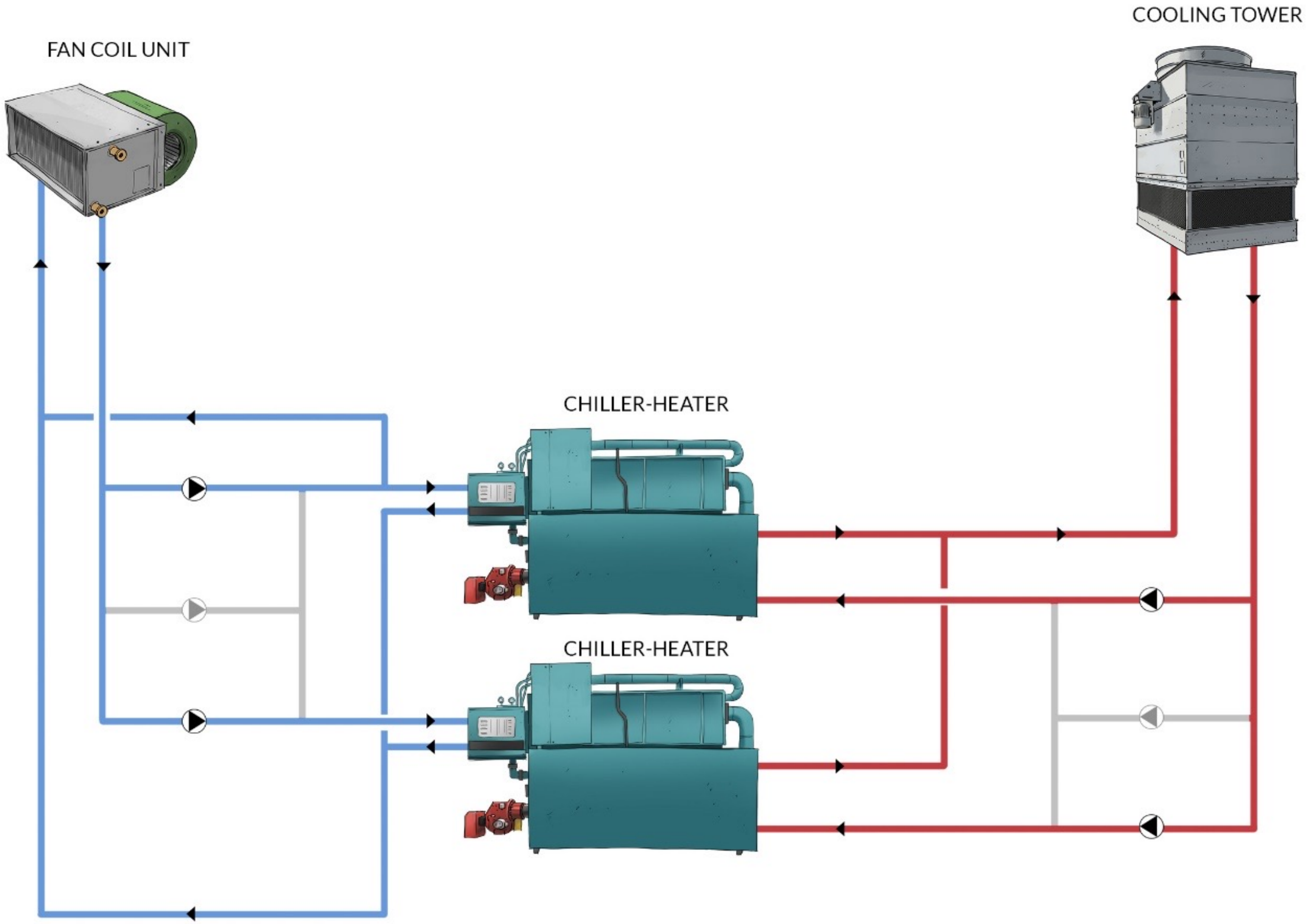
Case Studies

156,000 sqft, 180-unit residential building in Union Square, Manhattan

Project Drivers

- Mechanical equipment close to end of life
- Operationally complex system
- Comfort complaints due to switchover system
- Eliminate exposure to LL97 fines

Existing System



- Individual apartment-based fan coils units – 150F Winter, 45F Summer
- Two-pipe hydronic system
- Gas-fired absorption chiller/boiler combo units

Project Design & Evolution

We initially evaluated two electrification scenarios.

- Partial/Enabling Electrification
- Full Electrification

Partial/Enabling Electrification

Terminal WSHPs with condensing boiler and cooling tower

Pros

- Enabling step towards electrification with a low temperature heating network
- Internal heat recovery gains
- Existing electrical infrastructure could support system

Challenges

- Increased day one greenhouse gas emissions compared to existing system, requires grid to almost half in GHG intensity to match current emissions
- LL97 fines not addressed

Full Electrification

Low temperature fan coil terminal units with ASHPs providing heating and cooling

Pros

- Significant day one GHG reduction that continues as grid decarbonizes – fully compliant with LL97

Challenges

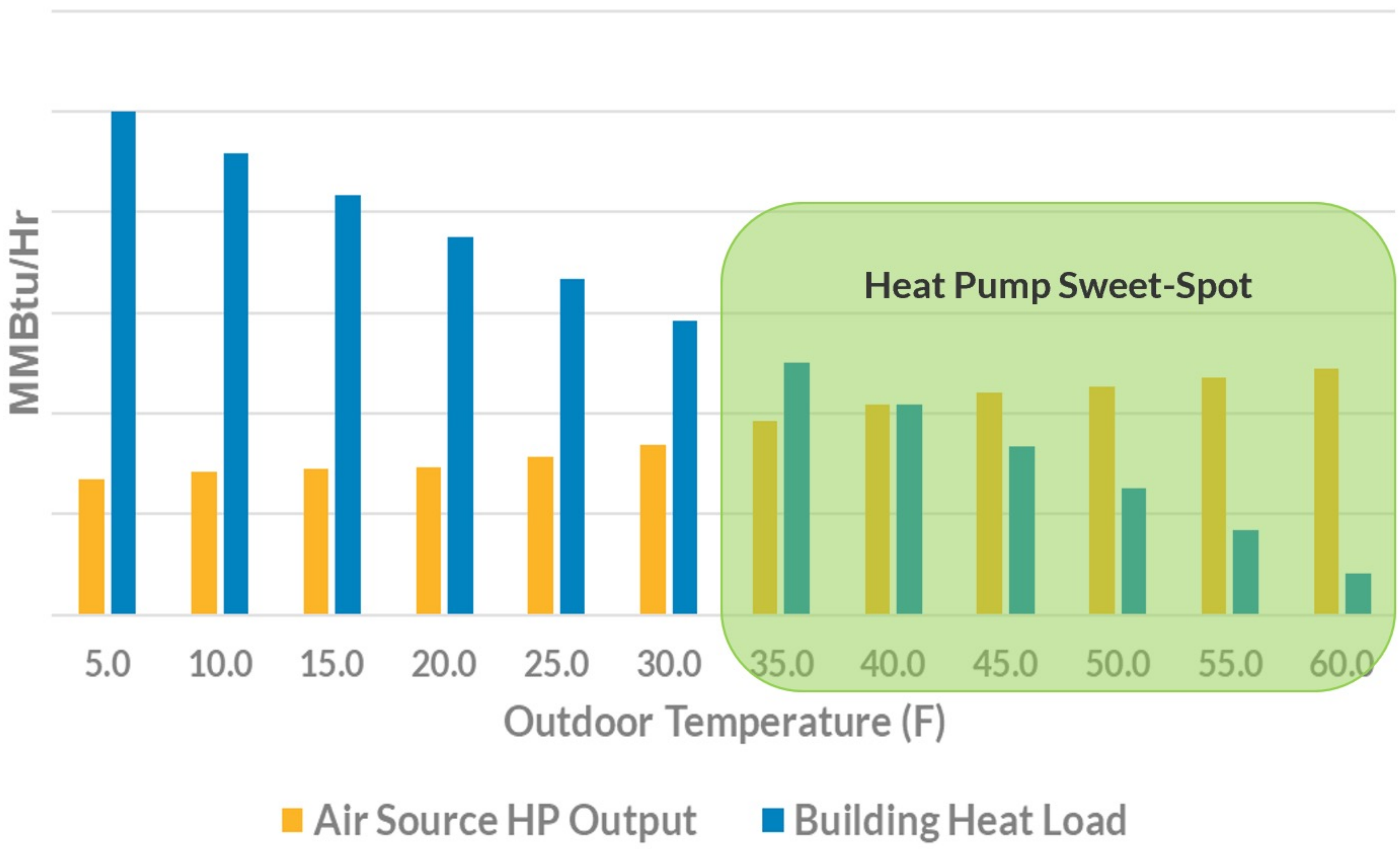
- Electrical infrastructure of the building needs to support large increase
- Physical space constraints of locating ASHPs, especially in existing buildings
- High capital and operating costs
- Resiliency

Hybrid Electrification

Maximize GHG reduction while engineering around existing building constraints

ASHP vs. Building Heat Load

IN A 40F HYBRID SYSTEM



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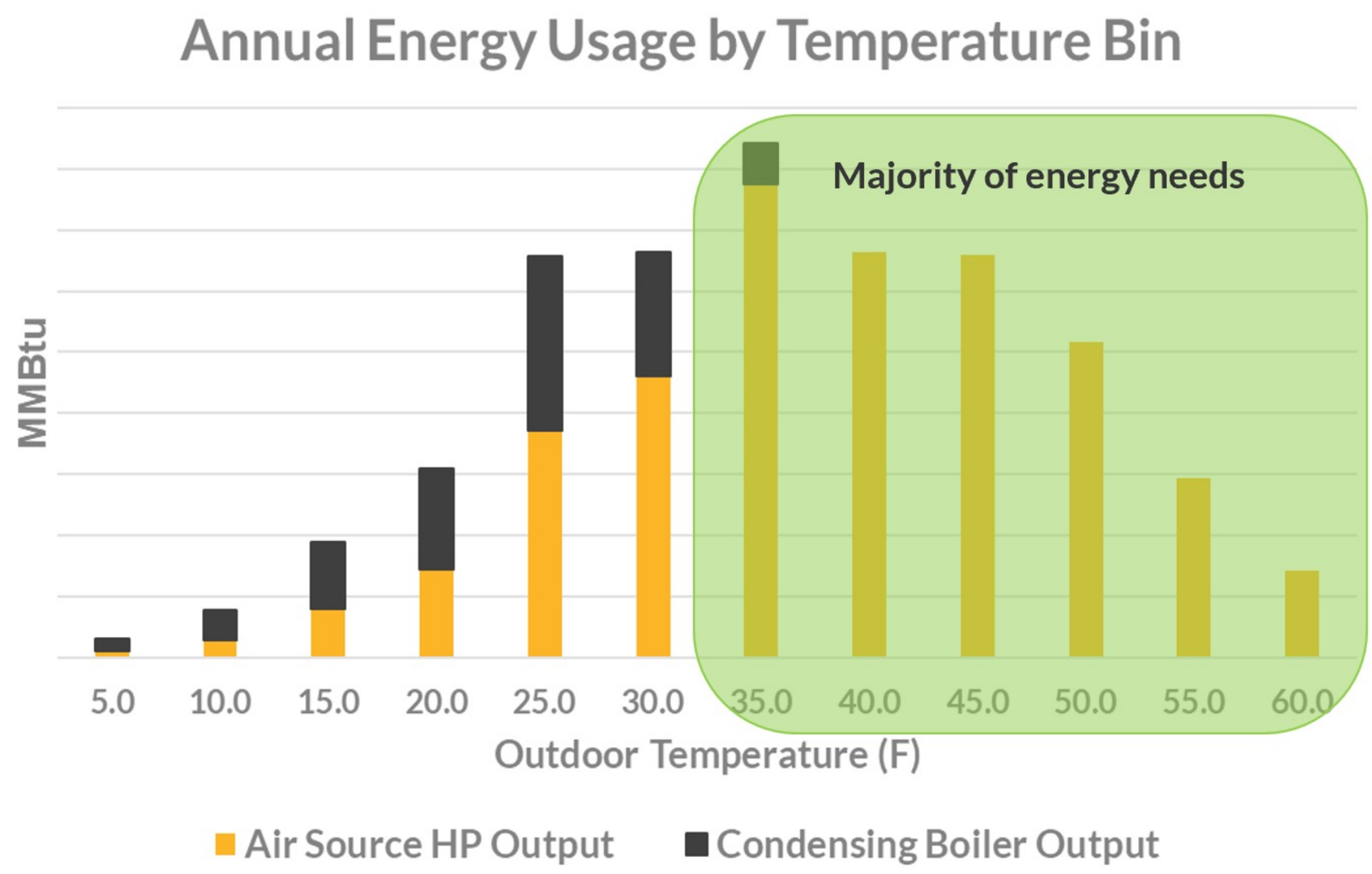
Annual Energy by OA Temp Bin

IN A 40F HYBRID SYSTEM



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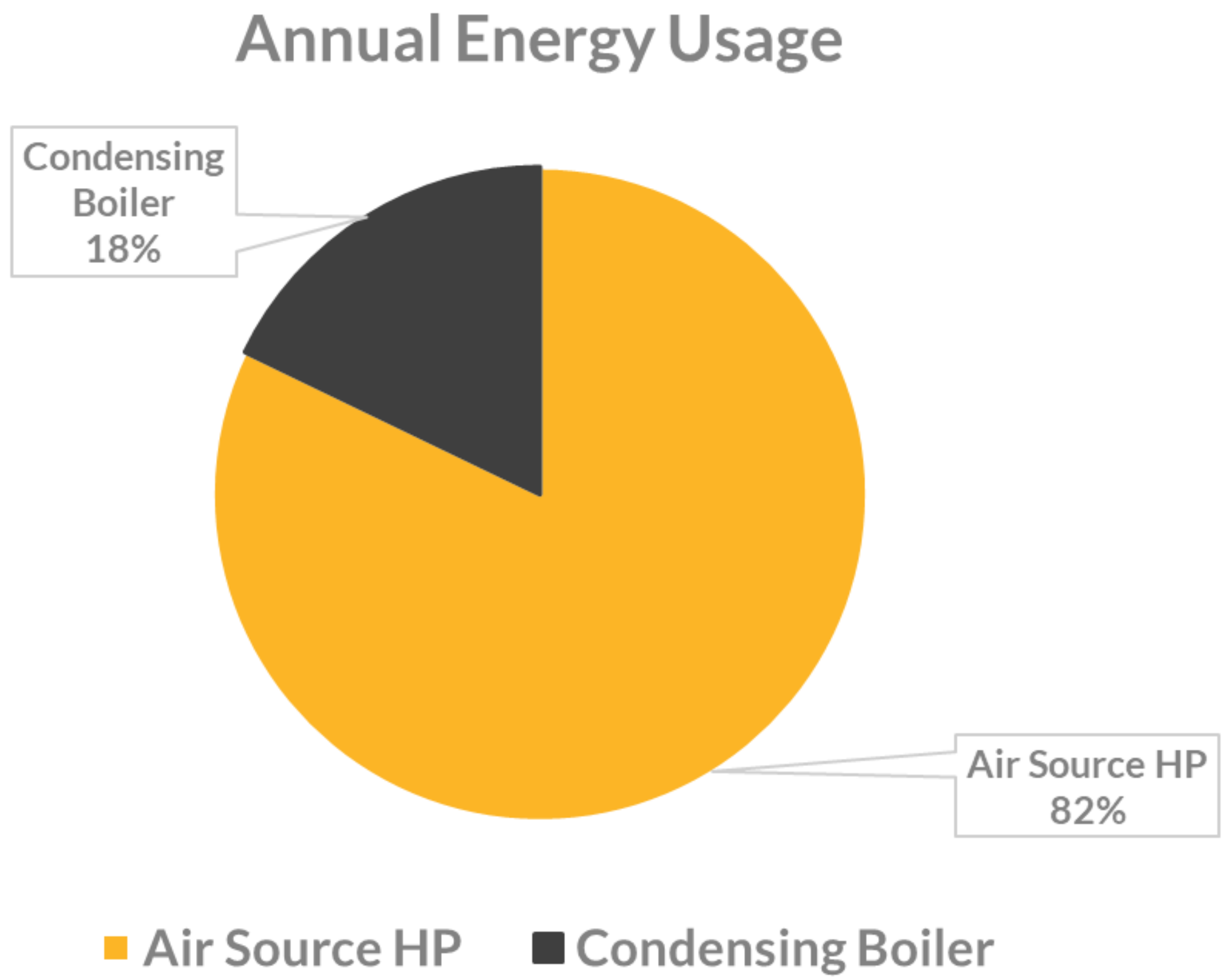
Annual Energy Breakdown

IN A 40F HYBRID SYSTEM



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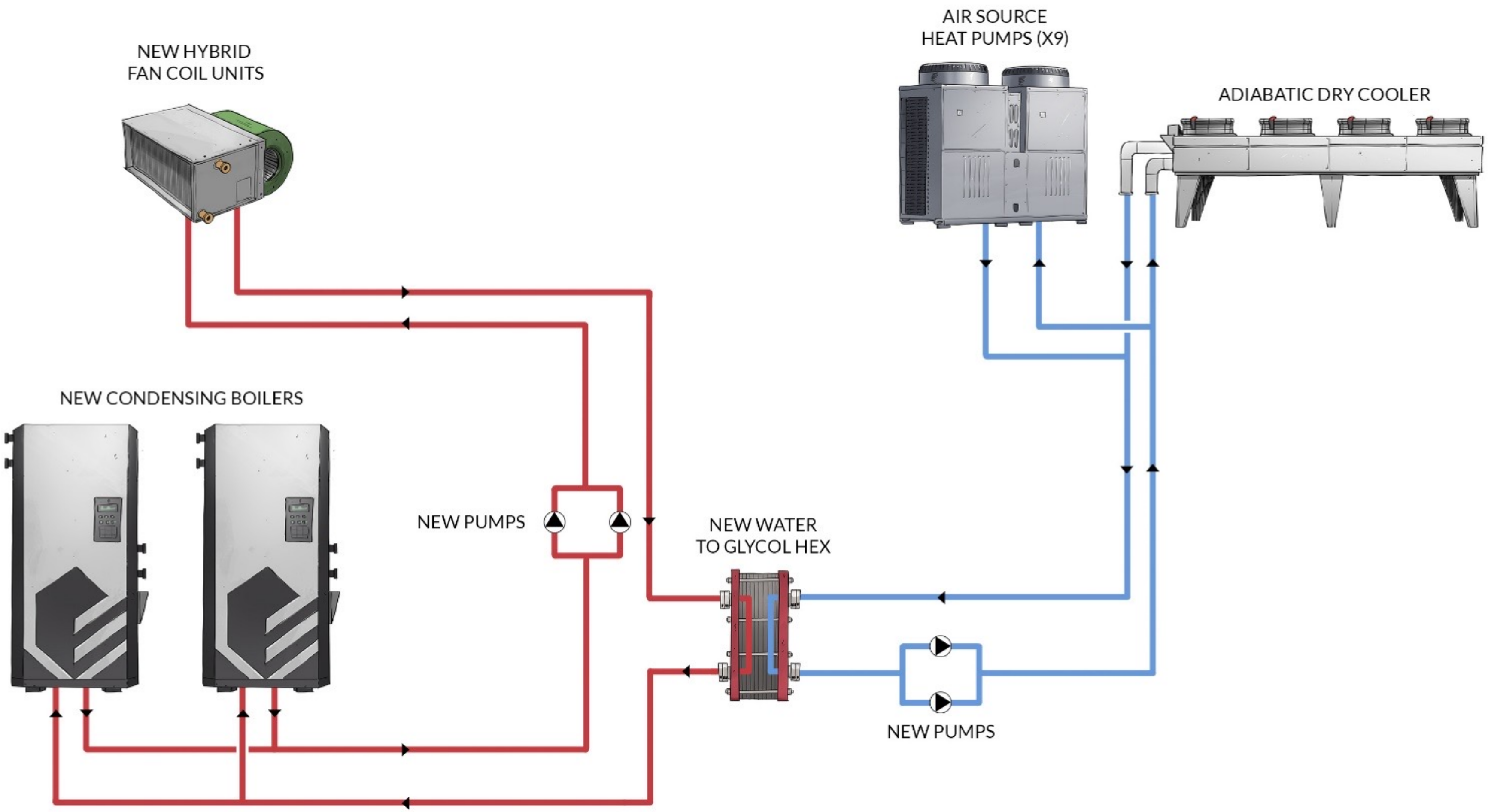
Hybrid Electrification Strategy

1. Enable low temperature hydronic heating
2. Prioritize internal heat recovery
3. **Low-carbon heating system sized for GHG reduction, not peak energy needs**
4. Resiliency + Supplemental System

Hybrid System



- Low temperature HW heated, Water cooled DX based fan coil system – ~90-105F year round
- Two pipe hydronic system
- ASHPs sized for 40F
- 2050 LL97 Compliant

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Hybrid Electrification Summary

There are significant constraints to retrofitting existing NYC buildings to be fully electrified.

Hybrid Electrification can be designed with those constraints to enable buildings to significantly reduce GHG emissions

- Technically feasible today
- Sizing for 40°F reduced number of ASHP to 1/3 of peak capacity
- Improved economics with reduced capital costs
- Potential for future winter grid response by switching to low electric heating mode

Montreal’s Olympic Park

GHG Reduction – 57%

Energy Costs Reduction – 26%

Project Description

- Steam to hot water conversion
- Heat Recovery Chillers
- Chiller plant replacement
- Control of peak electric demand
- Ventilation system optimization for heat recovery

Steam to Hot Water Conversion

BEFORE

AFTER

ecosystem

Steam to Hot Water Conversion

BEFORE

AFTER

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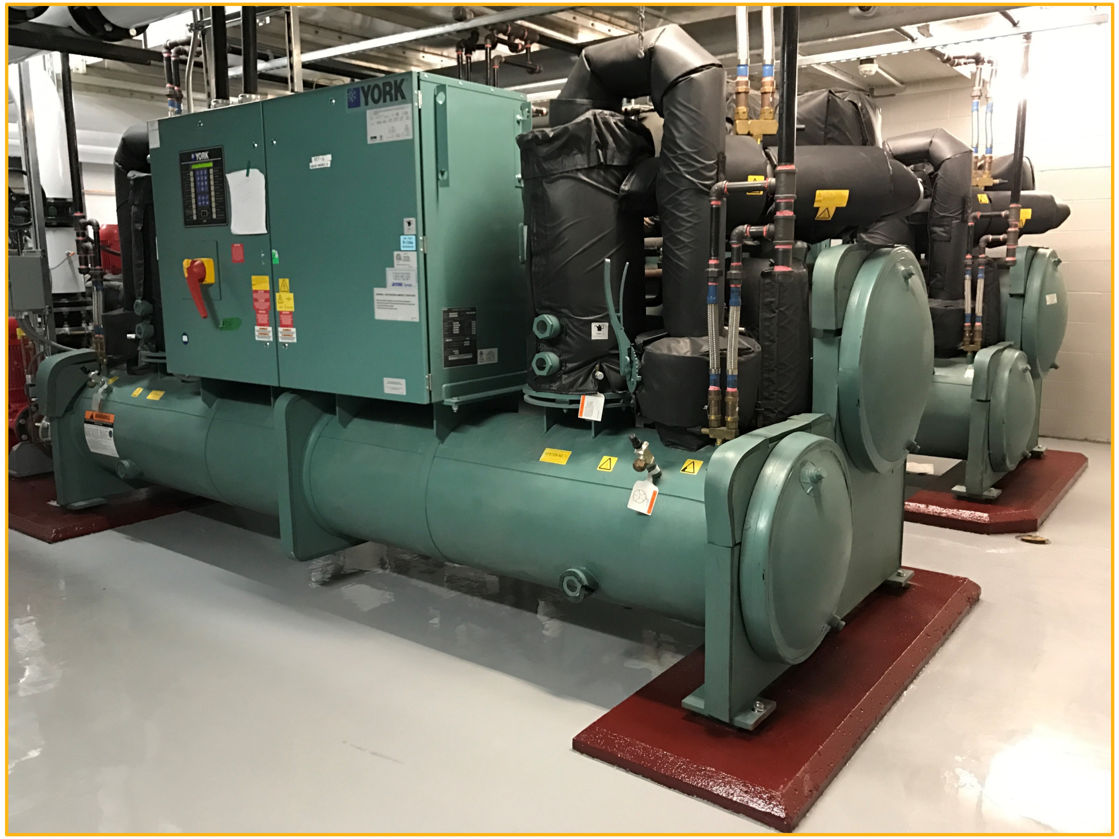
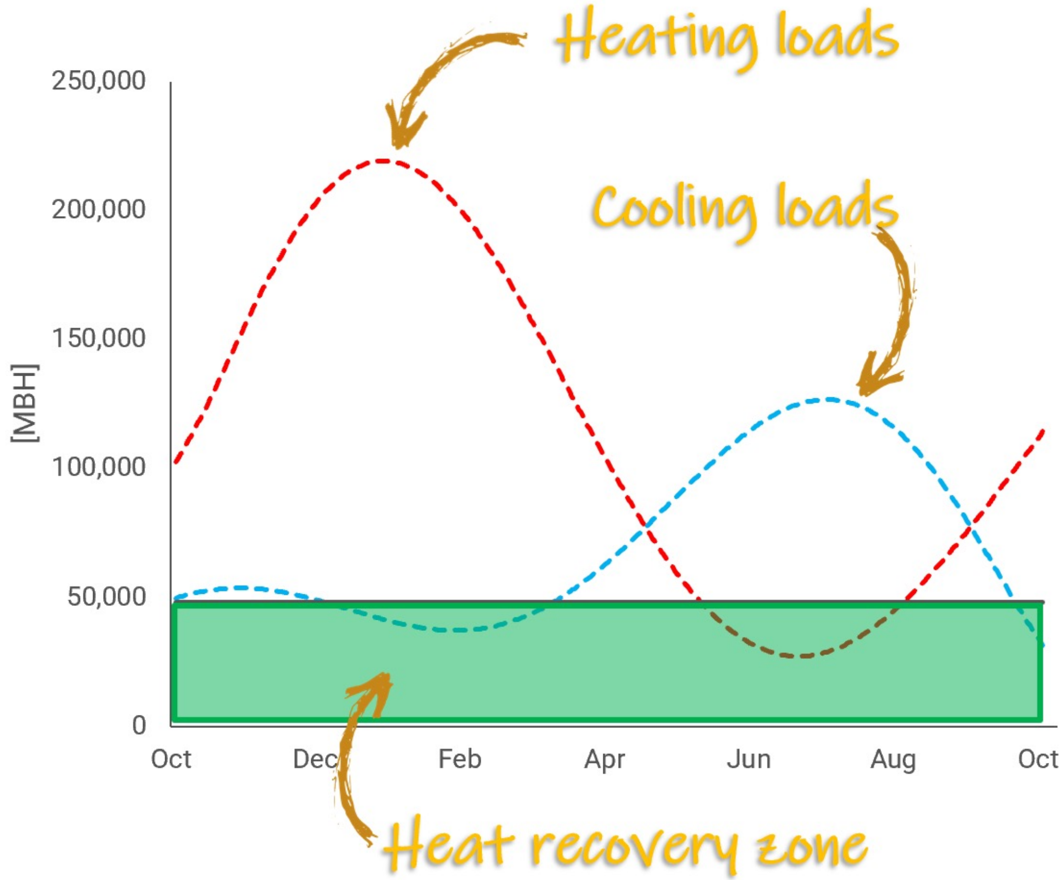
Heat Recovery Chillers





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Chiller Replacement

BEFORE

AFTER

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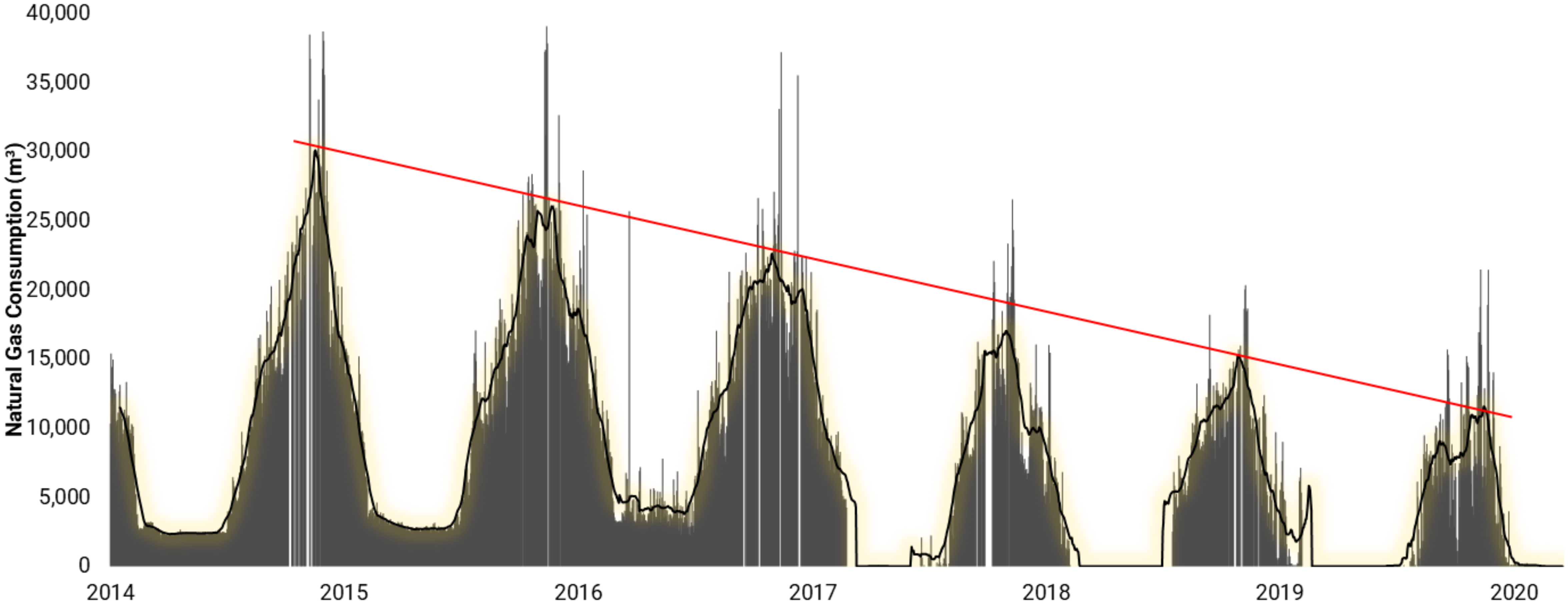
Gas Consumption – 6 years



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BEFORE

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Société en commandite Gaz Métro

Service à la clientèle

info@gazmetro.com

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En cas d'ODEUR DE GAZ

911 ou **1 800 361-8003** 711

Historique de consommation

Période du	au	Nombre de jours	Volume (m³)	Montant ($)
01 DE 2015	31 DE 2015	31	526 323 R	167 392,74
01 JA 2016	31 JA 2016	31	705 704 R	234 771,94
01 FE 2016	29 FE 2016	29	751 314 R	275 944,97
01 MR 2016	31 MR 2016	31	568 738 R	188 179,79
01 AL 2016	30 AL 2016	30	486 620 R	153 327,37
01 MA 2016	31 MA 2016	31	245 171 R	77 658,79
01 JN 2016	30 JN 2016	30	141 835 R	45 665,47
01 JL 2016	31 JL 2016	31	128 095 R	42 624,65
01 AU 2016	31 AU 2016	31	132 477 R	45 473,44
01 OC 2016	31 OC 2016	31	287 352 R	92 869,93
01 NO 2016	30 NO 2016	30	381 573 R	127 057,01
01 DE 2016	31 DE 2016	31	601 093 R	217 559,70

AFTER

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Historique de consommation

Période du	au	Nombre de jours	Volume (m³)	Montant ($)
01 DE 2018	31 DE 2018	31	347 633 R	168 185,29
01 JA 2019	31 JA 2019	31	428 713 R	218 386,02
01 FE 2019	28 FE 2019	28	351 262 R	153 323,86
01 MR 2019	31 MR 2019	31	175 205 R	66 160,27
01 AL 2019	30 AL 2019	30	56 740 R	22 004,07
01 MA 2019	31 MA 2019	31	29 138 R	11 018,38
01 JN 2019	30 JN 2019	30	0 R	0,00
01 JL 2019	31 JL 2019	31	0 R	0,00
01 AU 2019	31 AU 2019	31	0 R	0,00
01 OC 2019	31 OC 2019	31	6 158 R	2 229,97
01 NO 2019	30 NO 2019	30	183 160 R	62 426,30
01 DE 2019	31 DE 2019	31	265 250 R	87 538,59

ecosystem

Urbs

Case Studies


decarbonization lessons
UMEÅ TO NY

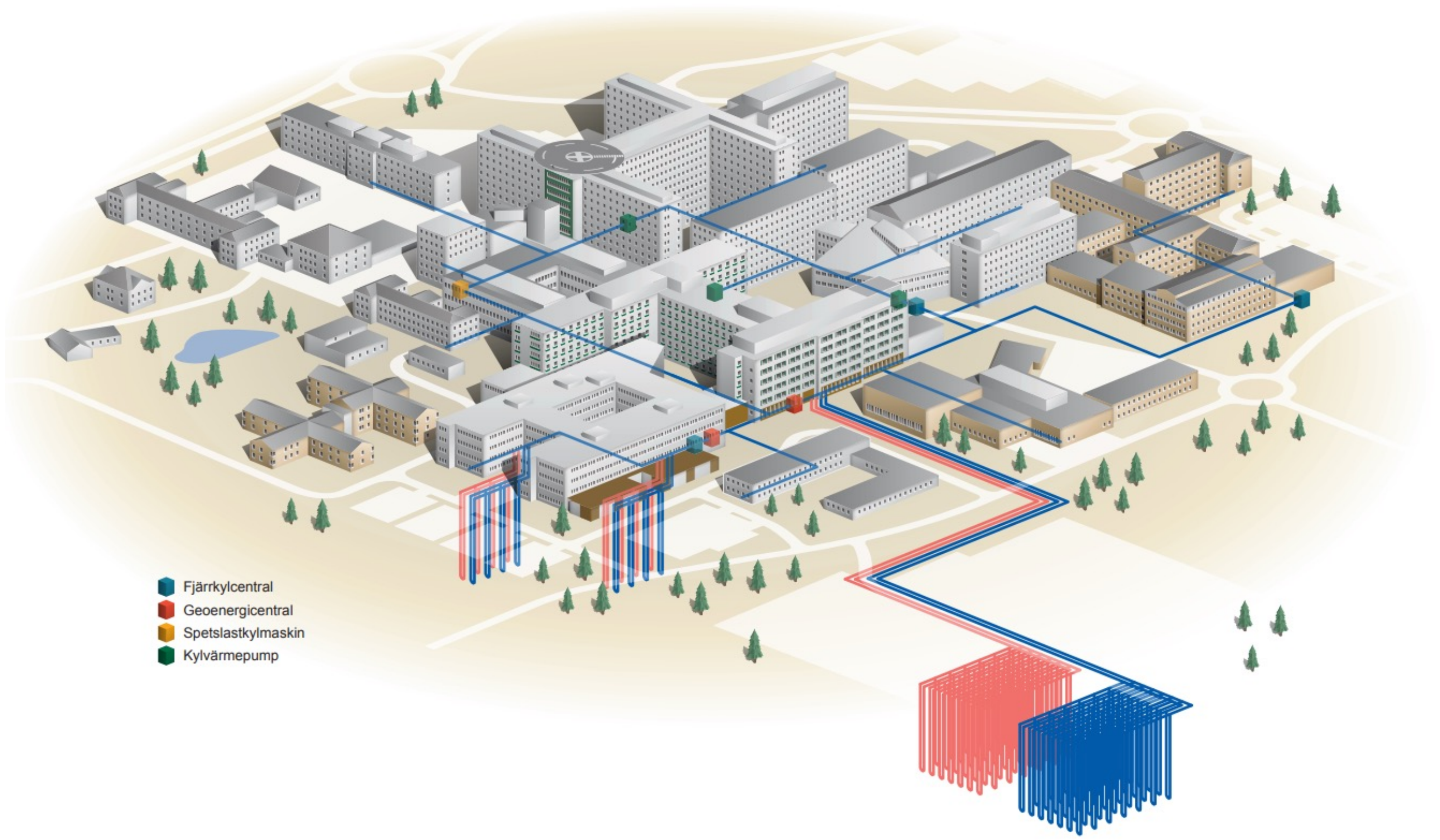
02 project

urbs.
URBAN SYSTEMS

- Super Specialty Hospital
- Serves Half of Sweden’s Area
- Over 3.5 Mn Sq ft.
- 5600 full time employees
- 600 doctors
- 2000 nurses

03 thermal network

urbs.
URBAN SYSTEMS



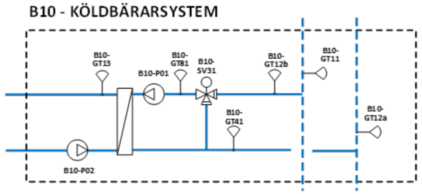
- 125 Boreholes
- 700 ft deep
- 7000 MWh of heating
- 5000 MWh of cooling

04 modular

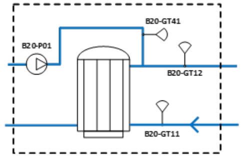
urbs.
URBAN SYSTEMS

MODULBIBLIOTEK

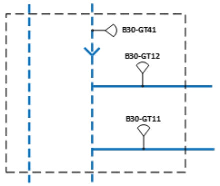
B10 - KÖLDBÄRARSYSTEM



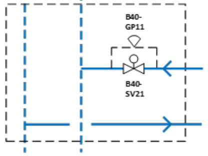
B20 - KÖLDBÄRARSYSTEM



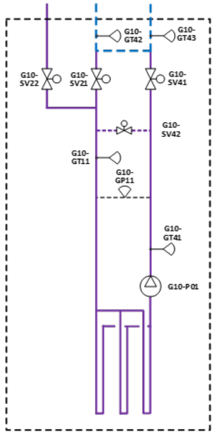
B30 – ANSLUTNING KÖLDBÄRARSYSTEM



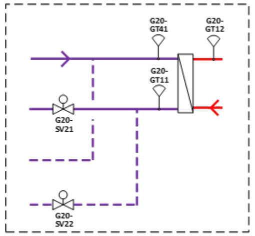
B40 – ANSLUTNING TERMISKT NÄT



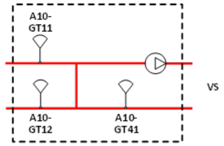
G10 - BORRHÅLSLAGER



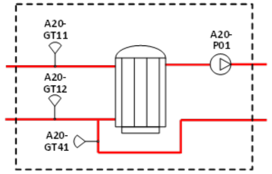
G20 - ÅTERLADDNING BORRHÅLSLAGER



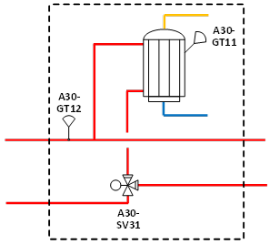
A10 - VÄRMESYSTEM



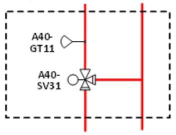
A20-VÄRMESYSTEM

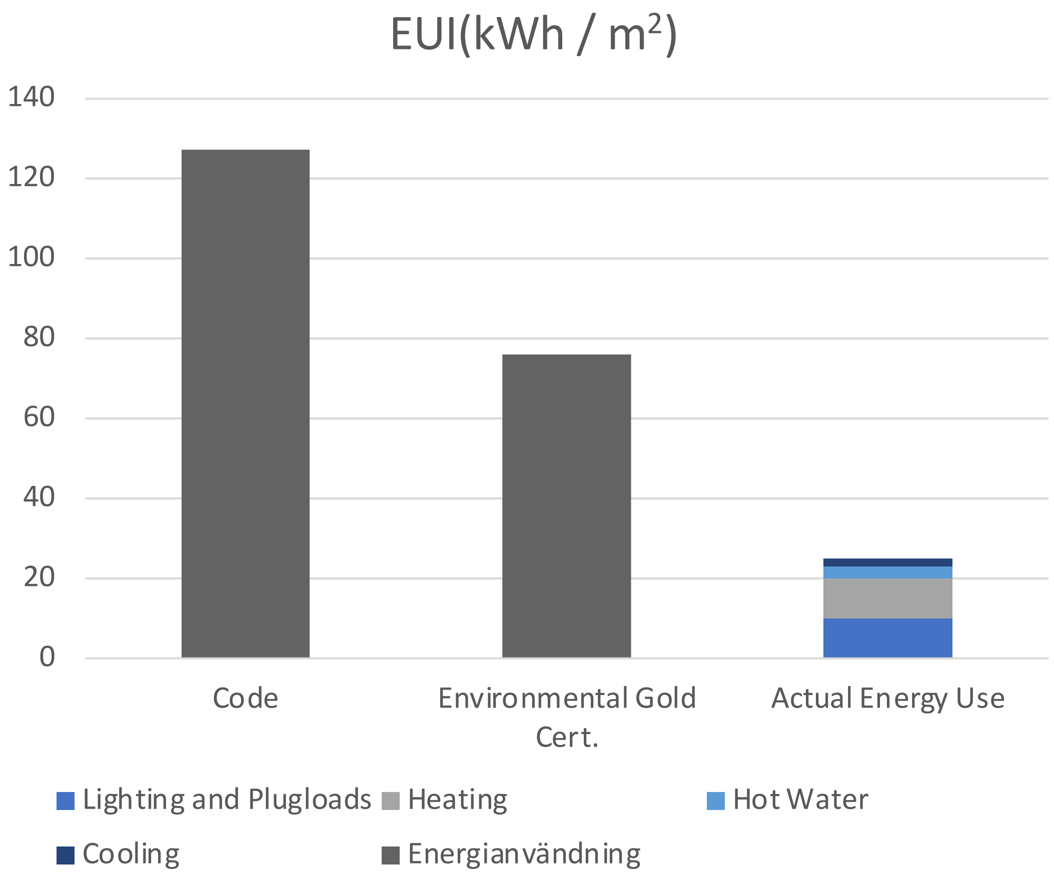


A30 - TAPPVARMVATTEN



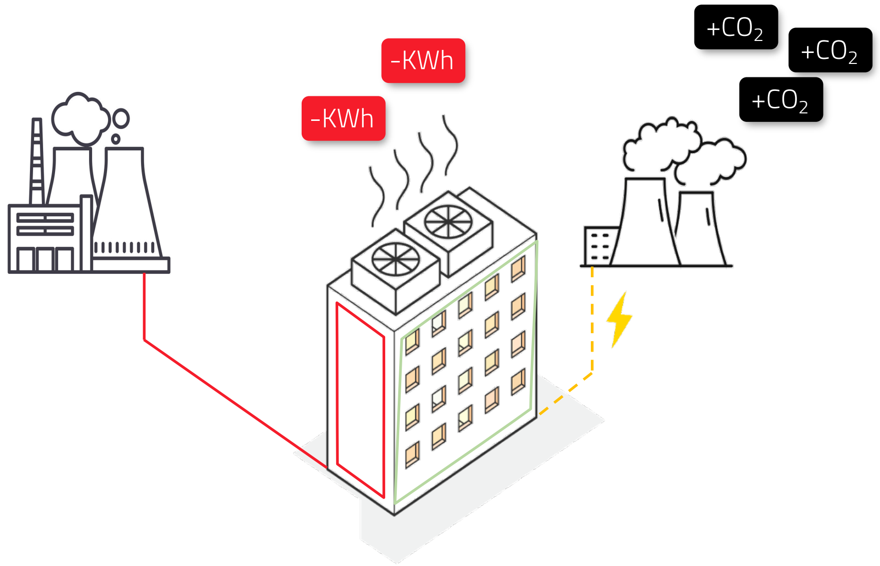
A40 – AVKYLNING KONDENSORVÄRME





05 the principle

urbs.
URBAN SYSTEMS



Generate

Power the system entirely using sustainable, locally-generated electricity. Excess power can be stored in batteries or sold back in to the grid.

Sources include:

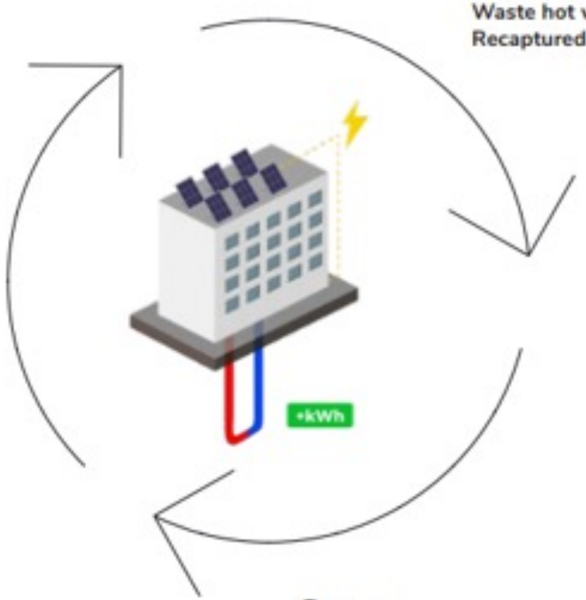
Rooftop solar
Wind turbines
Geothermal energy

Reuse

Re-capture and circulate waste energy back in to the system, or store for later use.

Sources include:

Ventilation exhaust
Waste hot water
Recaptured heat



Store

Store and access excess energy throughout the year, day and night.

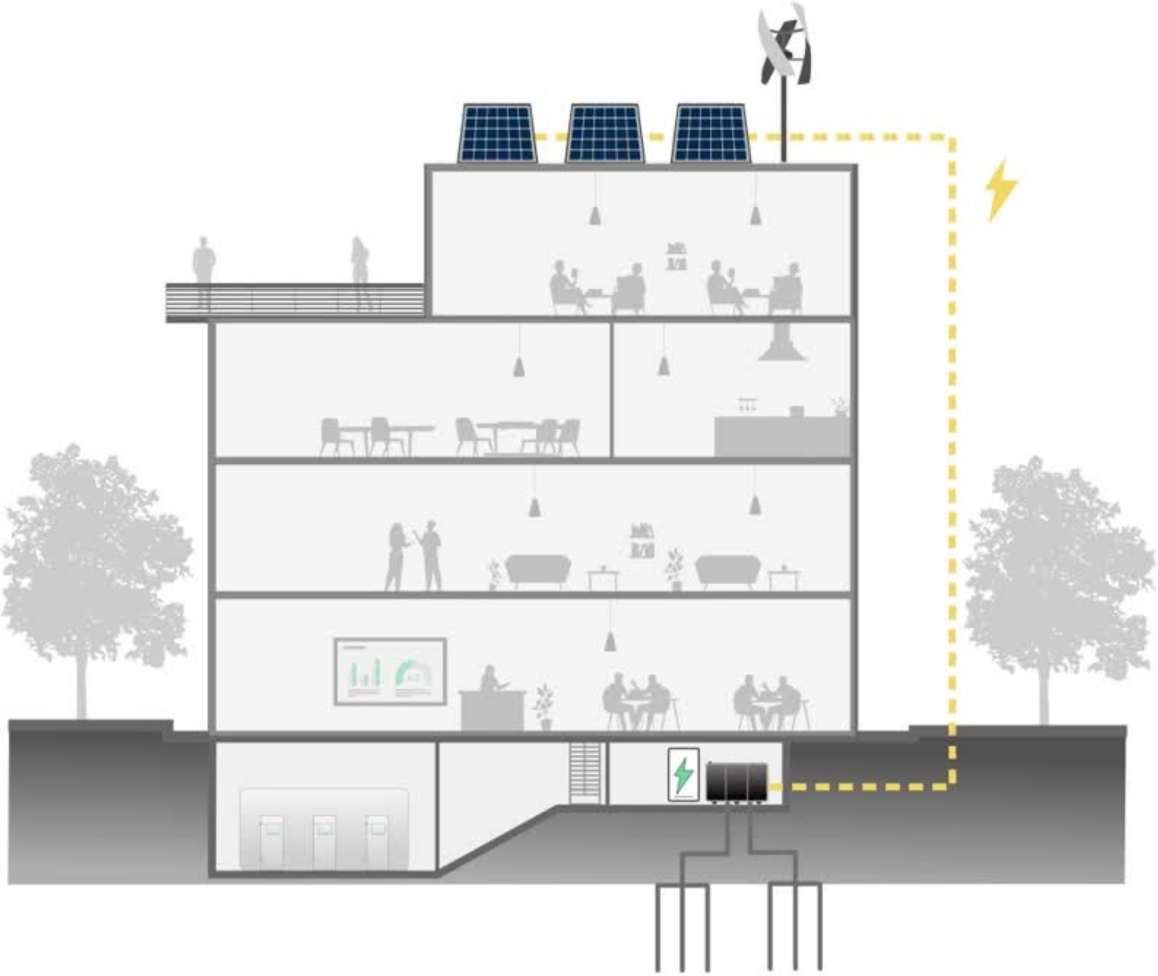
Sources include:

Borehole thermal storage
Aquifer thermal storage
Geothermal piles
Battery power storage

06 consumer to prosumer

urbs.
URBAN SYSTEMS

- Flexible
- Scalable
- Adaptable
- Circular
- Cost Efficient
- Future Proof



18 GWh Energy Annually

600 TCO2 Saved Annually

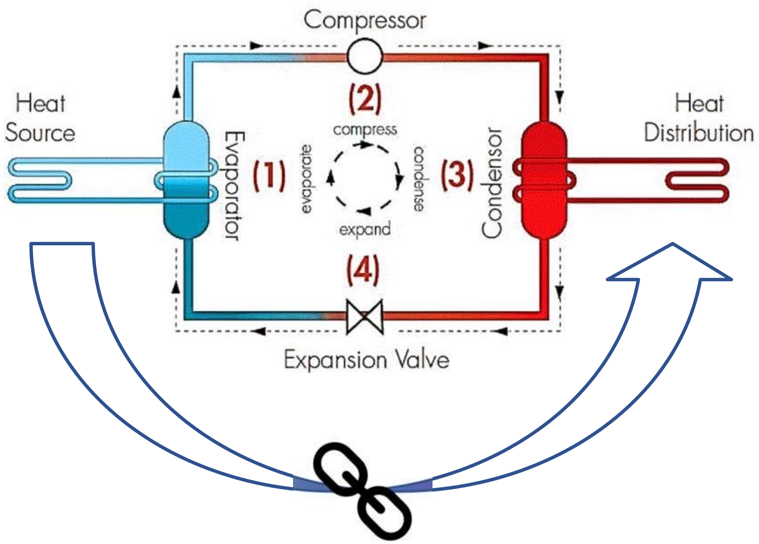
A building that generates, stores and reuses its own energy in one integrated system

urbs.
URBAN SYSTEMS

~ 90% efficiency

Traditional Heating System

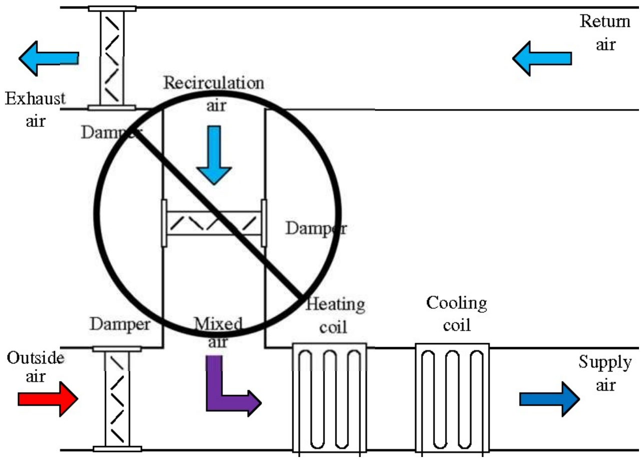
5x+ greater efficiency

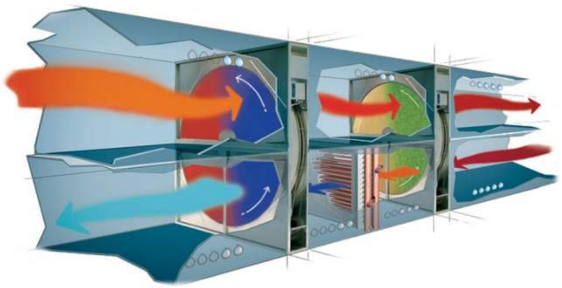


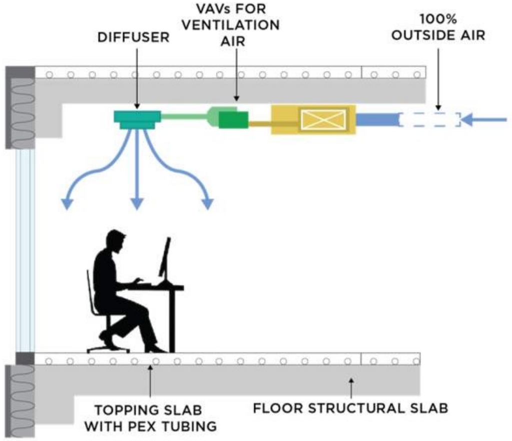
Heat Pump

08 adapting to ny

urbs.
URBAN SYSTEMS



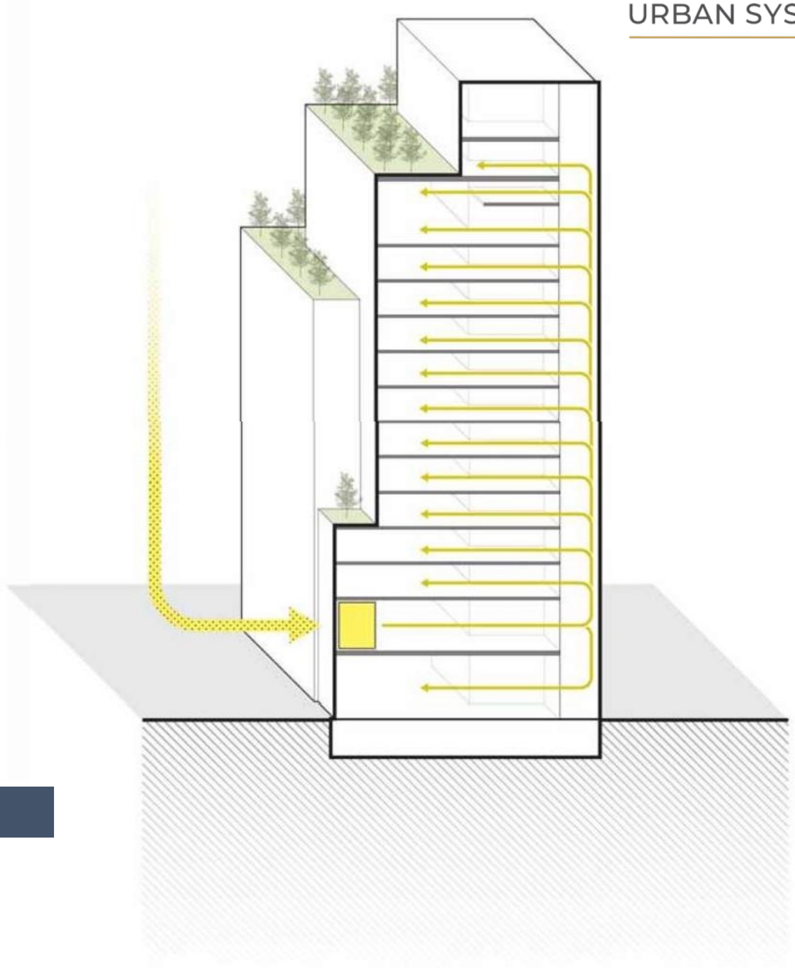




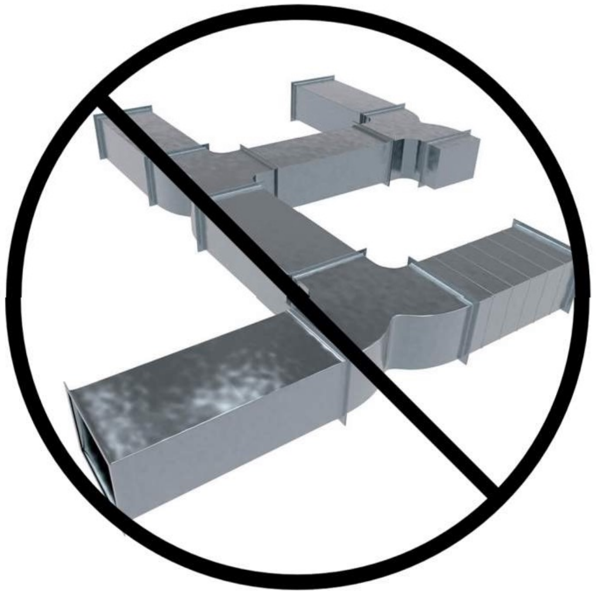
Dedicated Outside Air System

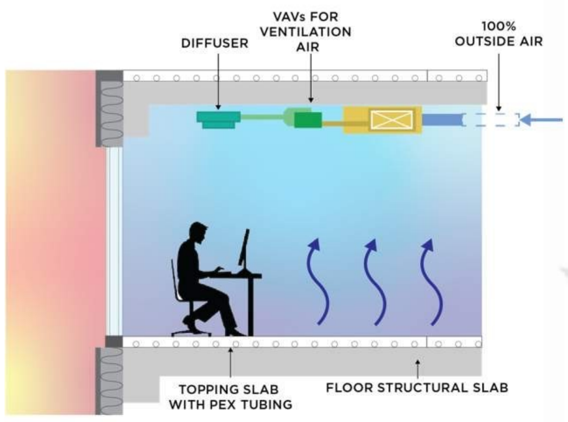
80% energy recovery

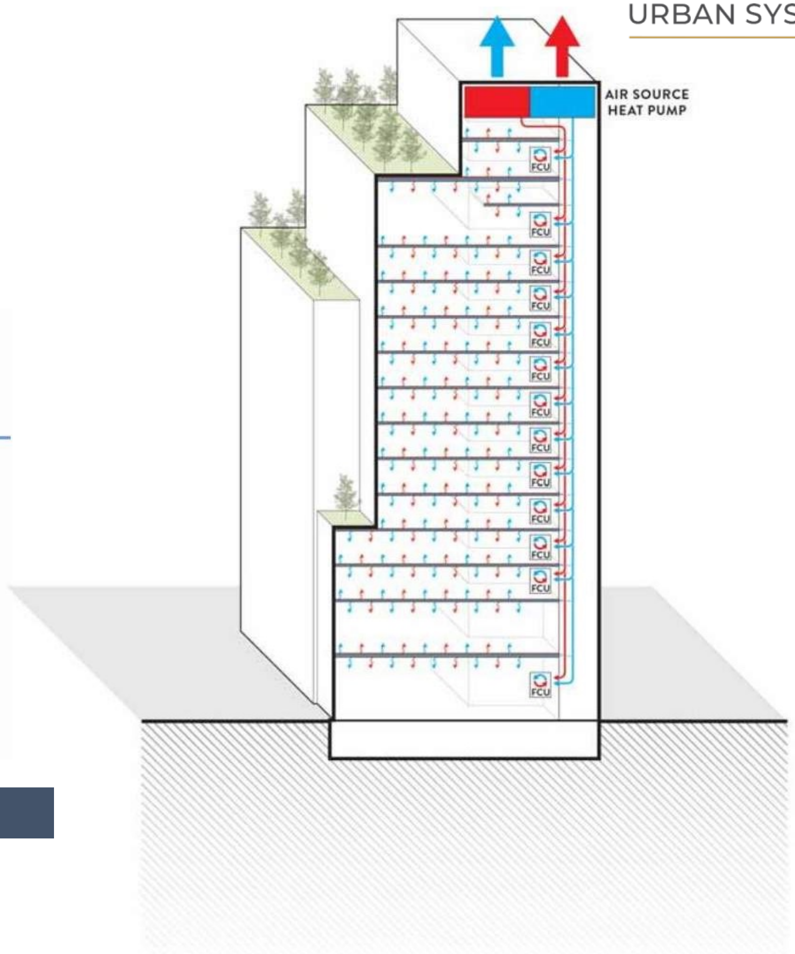
Better air quality



09 adapting to ny







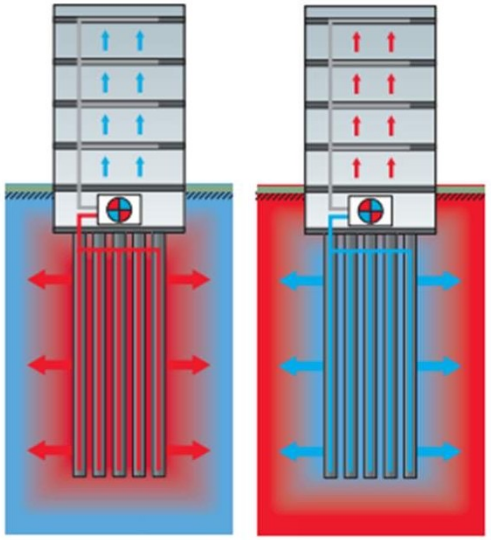
Thermally Active Building

16% greater thermal comfort

60 |80 water

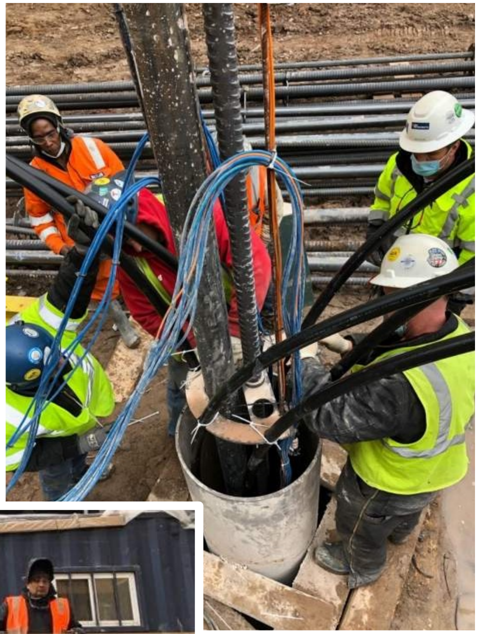
10 adapting to ny

urbs.
URBAN SYSTEMS



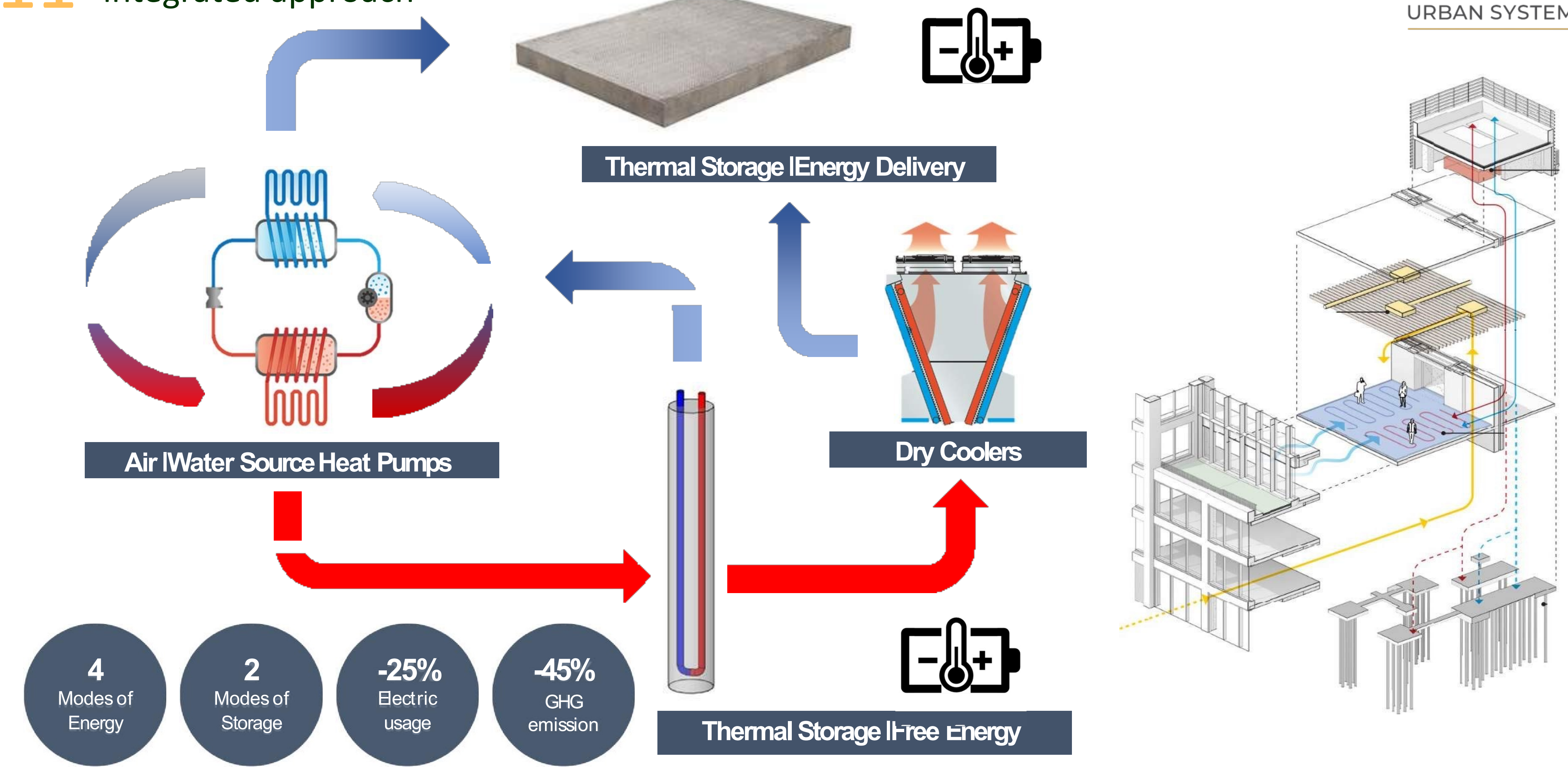
25% Cooling

40% Heating



Geothermal Piles

11 integrated approach

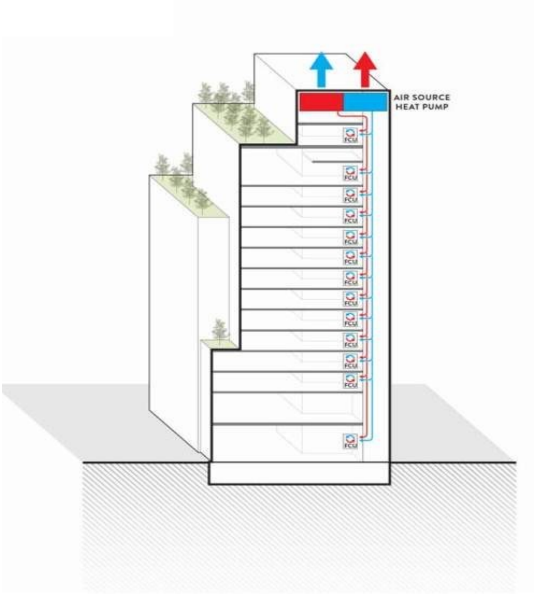


12 circular infrastructure

urbs.
URBAN SYSTEMS

Energy Production

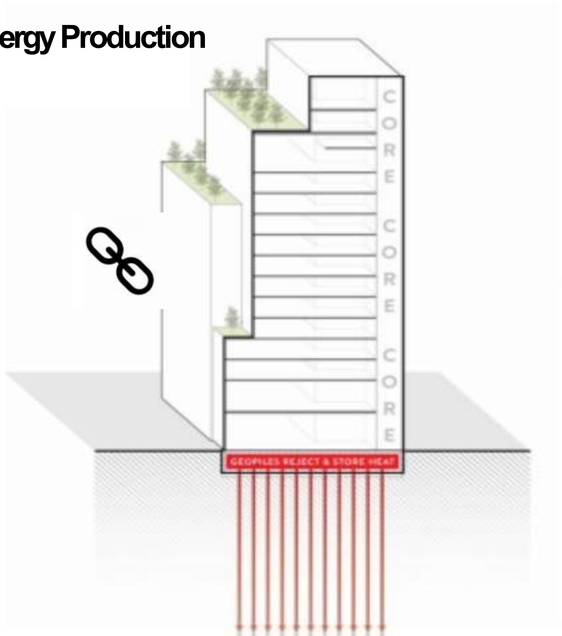
Energy Distribution



Electrification

- Air Source Heat Pump
- Simultaneous production of hot and chilled water

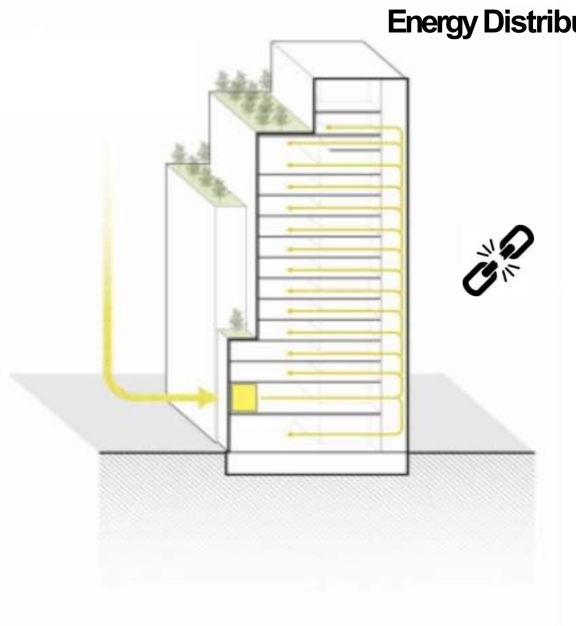
Most efficient during simultaneous heating + cooling utilizing waste energy. Movement of thermal energy.



Geothermal Piles

- Exchange energy within the deep foundations to minimize external energy needed
- Compliments more ambient temperature radiant slab system

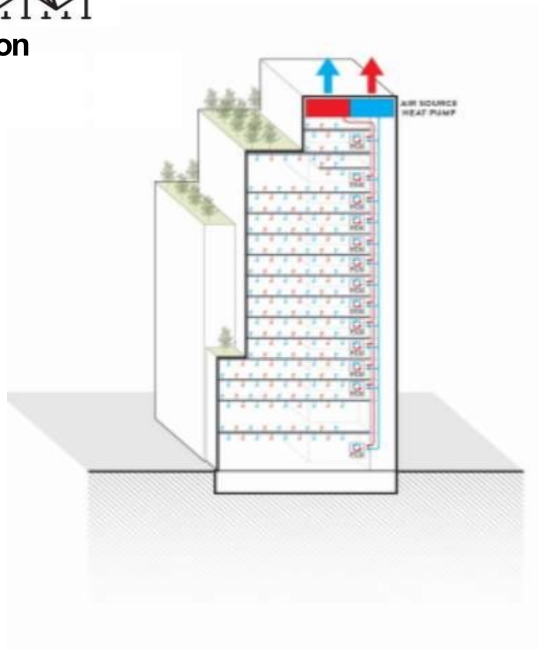
Most efficient production during peak cooling demand



DOAS Ventilation System

- Decoupling air systems to more efficient hydronic systems
- 70%+ more OA delivery to the space than current code
- 75% energy recovery

Delivers outside air directly where it is needed to the occupant and not in a Mechanical Equipment Room



Thermally Active Building

- Thermal storage
- Reduces airflow required and associated hot/cold drafts
- Low temperature hot water, high temperature chilled water

Reduces peak loads and increases thermal storage

bottom line

25%

Reduction in electrical consumption

800,000

Gallons of water saved per year

No fossil fuels

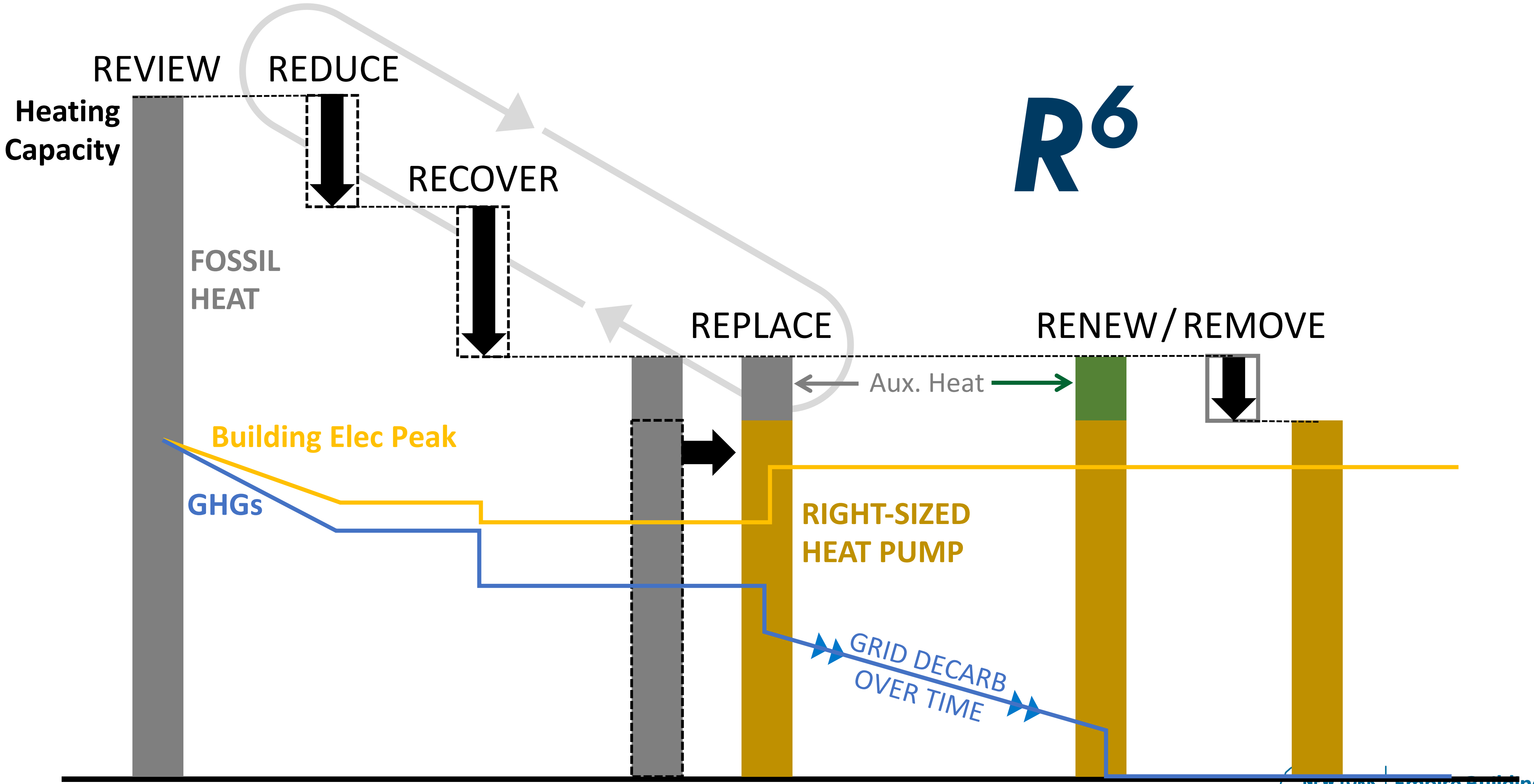
Burning or air pollution at site

50%

Carbon reduction from NYC 2030 targets

U.S. GREEN BUILDING COUNCIL
LEED PLATINUM
USGBC™

Resource Efficient Electrification



DISCUSSION

1. How might this framework (or a version of it) help you achieve decarbonization goals on your project?
2. Does this framework resonate with you?
3. Are there parts of the framework that confuse?
4. What components/topics need further technology research or development?