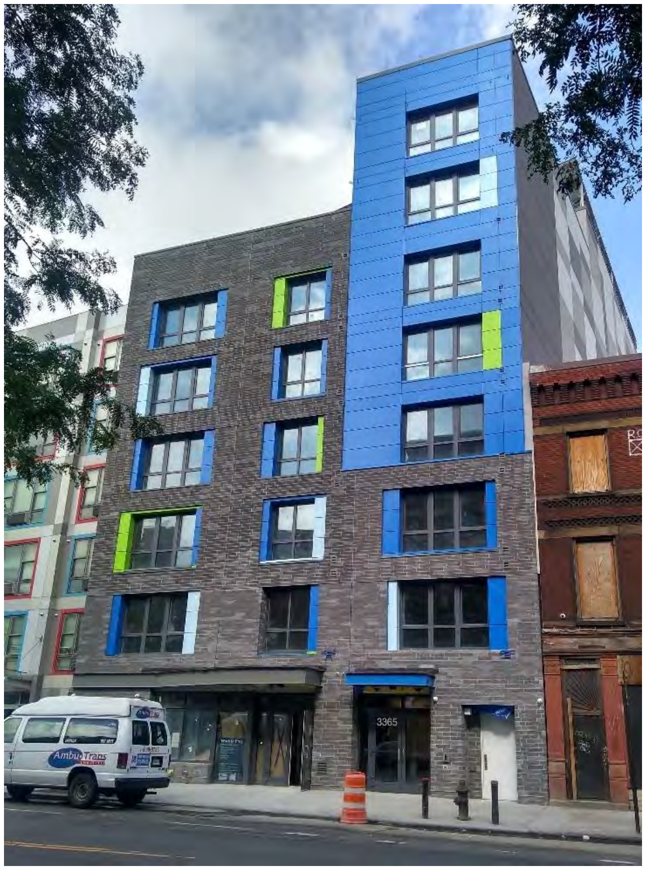
Electrification and Large Buildings



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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Learning Objectives

1. Explain what is meant by electrification and a clean grid.
2. Identify three unique areas that pose challenges when attempting to electrify large* buildings.
3. List three solutions for achieving electrification in large buildings.
4. Explain the types of hot water heat pump technologies currently available.

*Large buildings = multifamily properties over ~25k SF

Why Now?

- Climate Change – Get Rid of Carbon
  - Once you burn fossil fuels you have released carbon. Electricity can be carbon free.
- New York City's Emissions Law - Local Law 97
- New York State grid 100% renewable energy sourcing by 2040, Climate Leadership and Community Protection Act
- Gas Moratorium/ia

NYC Emissions Law Local Law 97

- Over 70% of NYC emissions come from buildings
- Carbon emissions caps for buildings beginning 2024, tightening in 2030, 2050
- Some affordable housing exemptions or required prescriptive measures
  - To meet carbon reduction goals exemption will not last.

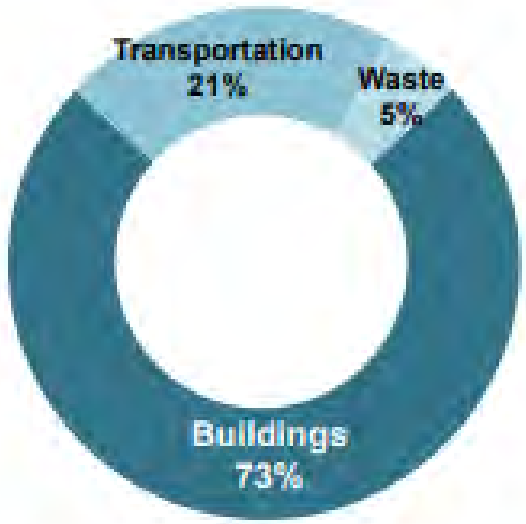


Fig. E1. **Share of New York City Greenhouse Gas Emissions by Sector**

Source: NYC Mayor's Office

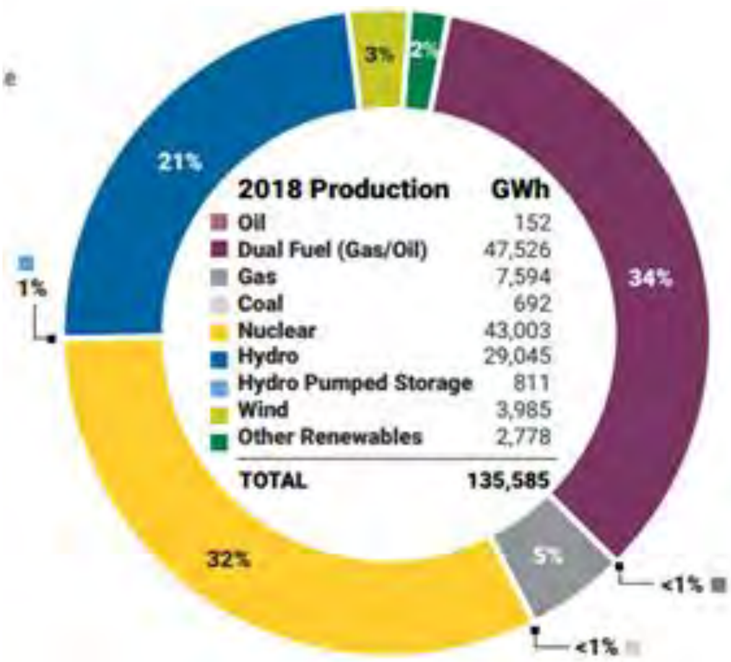
Carbon Neutral NYS Grid by 2040 (CCPA)

- Eliminate 85% NYS grid carbon emissions, offset the additional 15%
  - 6th state to adopt a 100-percent clean electricity target
  - Source 70+% renewable energy by 2030, 100% renewable energy sourcing by 2040

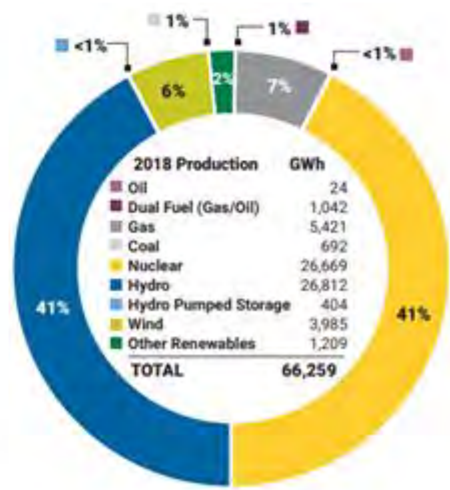
- Currently 60% energy from wind, solar, hydroelectric, and nuclear

Current Electricity Production

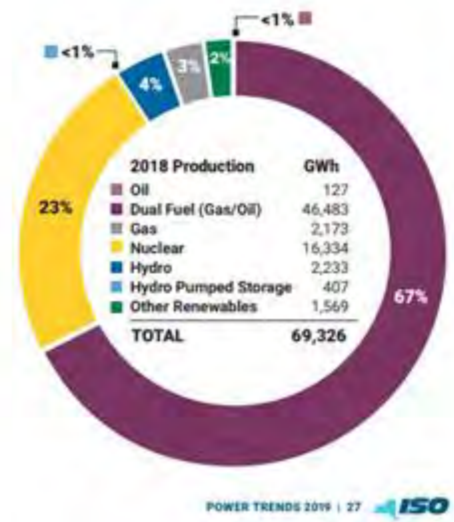
State



Up-State



Down-State



Gas Moratorium

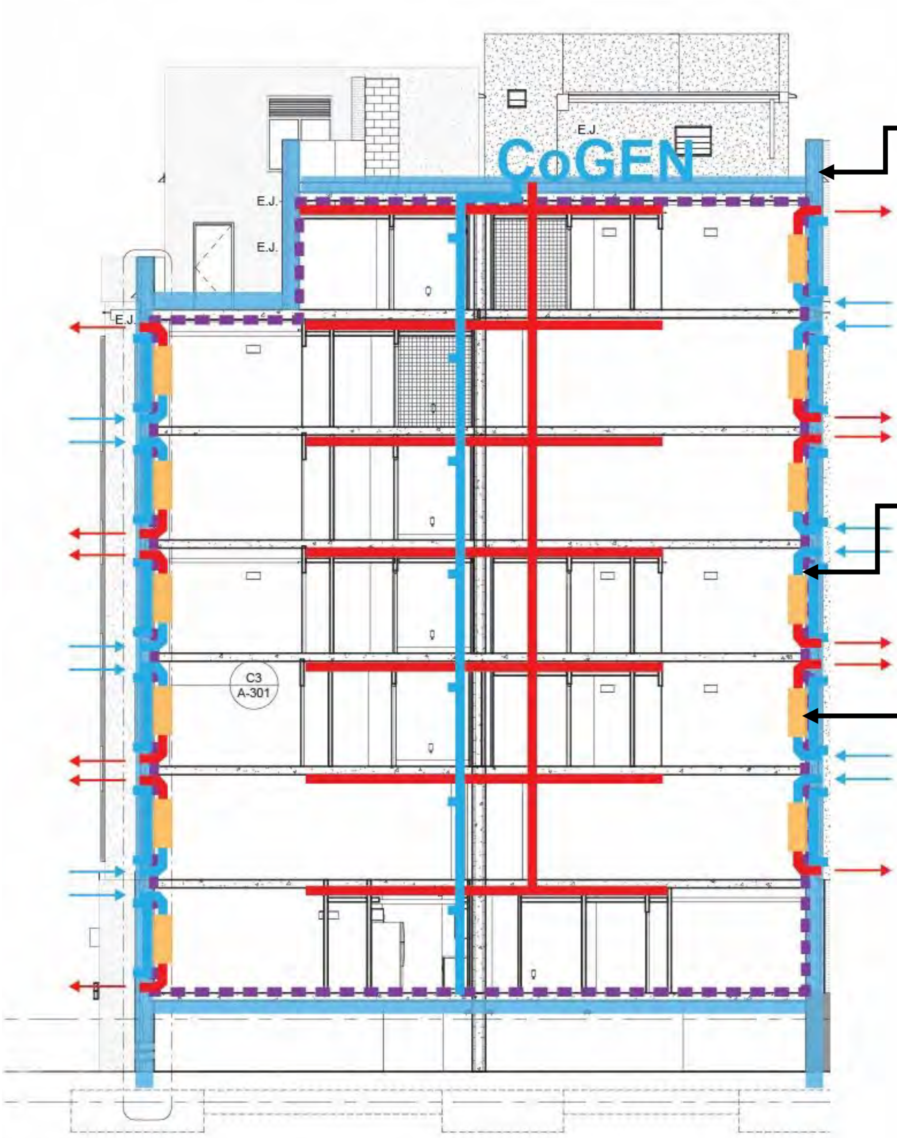
- ConEdison moratorium on firm gas in Westchester (15 March 2019)
- National Grid gas moratorium in parts of Brooklyn and Queens (15 May 2019)
- Talk of more moratoriums to come?

How can buildings respond?

Lower Loads and Smart Electrification

- Passive House
  - Reduce loads
  - Improve comfort
  - Dramatically lower energy usage
- Control over heating/cooling
- Long term planning for EUL upgrades in existing buildings

Passive House Principles



Optimizing Building Envelope

- Continuous Insulation
- Controlling Solar Gain
- Reducing Thermal Bridging

Creating Air/Wind Tightness

Provide Ventilation w/ Heat/Moisture Recovery

= Minimal Mechanical / Minimal Energy Consumption

Technical Challenges and Opportunities by System

First up, envelope

ICF

Thermal Performance

2 5/8” EPS each side + thermal mass of concrete for effective R-24.1
Additional insert at 2” increments up to R-48

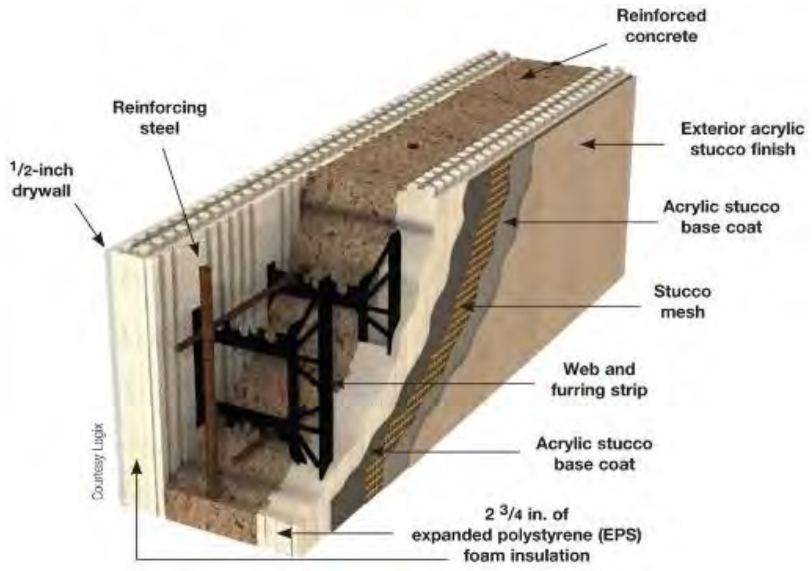
ICF

Air Barrier and Sealing

- Integral cast insulated jamb are cleanest tightest detail
- Avoid Panel Joint at Opening, which allow water/air infiltration
- Min. Thermal bridge of Brick Angle
- Coordination of Min. Penetration Sleeve
- Provide reinforcement at floor edge to prevent gaps

Interlocking EPS form is Class 1 vapor barrier

ICF Pros and Cons



Pros

- Reduces Trades/More done with one system
- Watertight Quickly
- Greater Design Flexibility
- Great Sound Isolation (OITC 41 to 65)
- Energy Efficiency System with high R-value and integrated air barrier

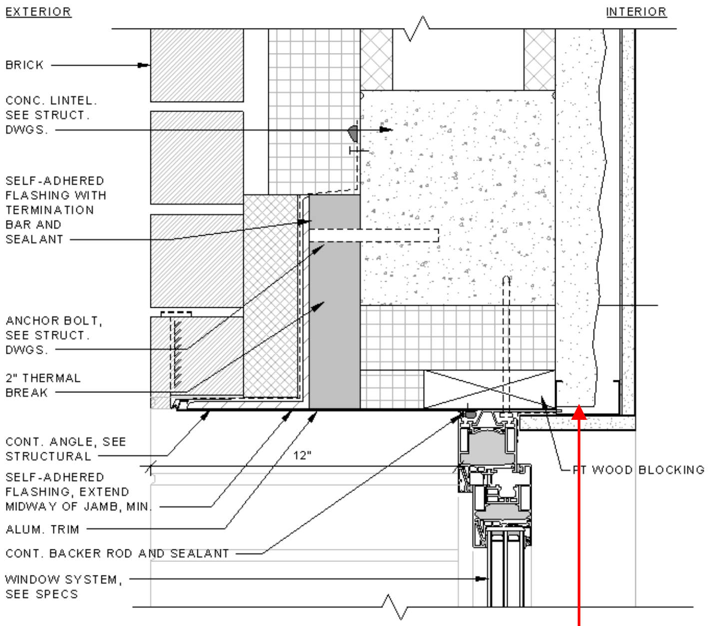
Cons

- Unfamiliar construction technology and limited sub contractor
- Implementation crucial to maintain vapor/air barrier continuity

CMU Backup

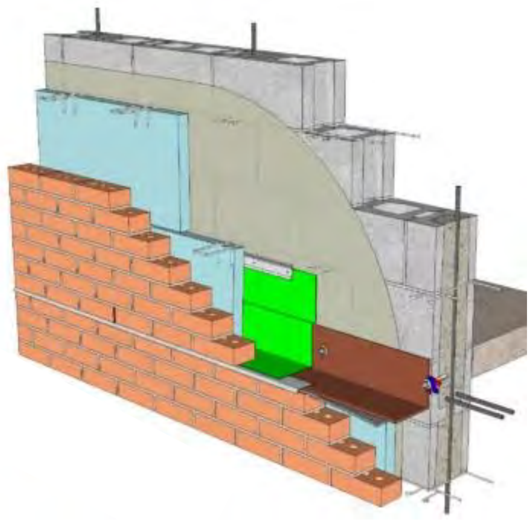
Air Barrier and Sealing

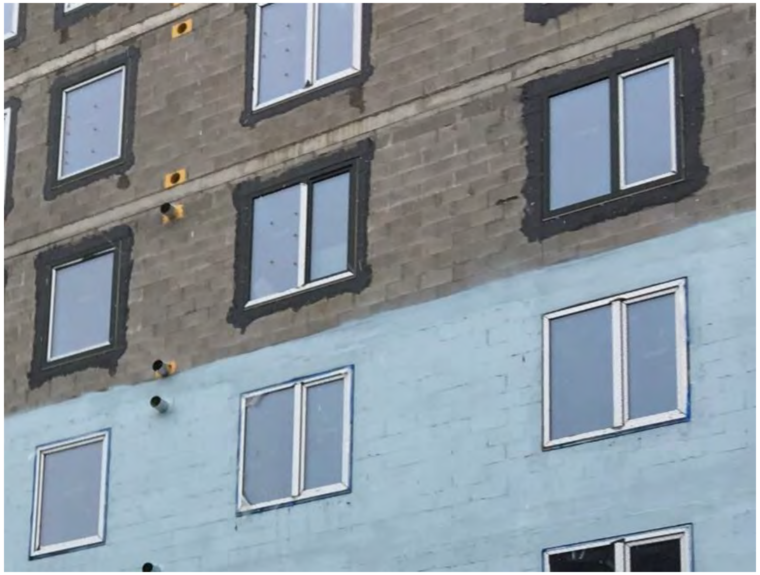
CMU wall not as tight as Concrete wall



Possible solution to have spray foam on the interior

CMU Pros and Cons





Pros

- Ease and knowledge of construction method

Cons

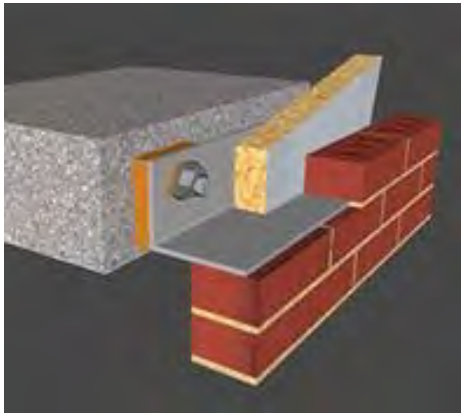
- Need more diligence on air tightness
- May require more structural thermal break for façade elements

Evaluating Different Envelopes

Thermal Bridging – Shelf Angle

Typical Shelf Angle
Thermal Efficiency
55% Steel Backup
67% CMU Backup

Stand-off Angle
Thermal Efficiency
72% Steel Backup
81% CMU Backup



Angle with 1" Thermal Break
Thermal Efficiency
80% Steel Backup
86% CMU Backup

Evaluating Different Envelopes

Thermal Bridging – Brick Ties

Galvanized Steel Brick Ties
Thermal Efficiency
75% Steel Backup
84% CMU Backup

Stainless Steel Brick Ties
Thermal Efficiency
87% Steel Backup
93% CMU Backup

Thermal Break Brick Ties
Thermal Efficiency
88% Steel Backup
94% CMU Backup

Evaluating Different Envelopes

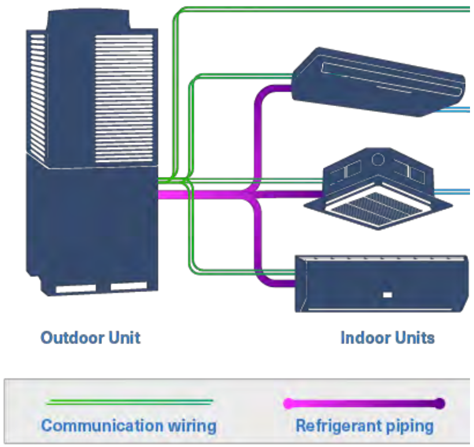
Windows

Thermally Broken Aluminum
U-value:~.1
U-Frame: ~.211
Greatest Structural Capacity
$$

Fiberglass
U-value: ~.17
U-Frame: ~.2
$$$

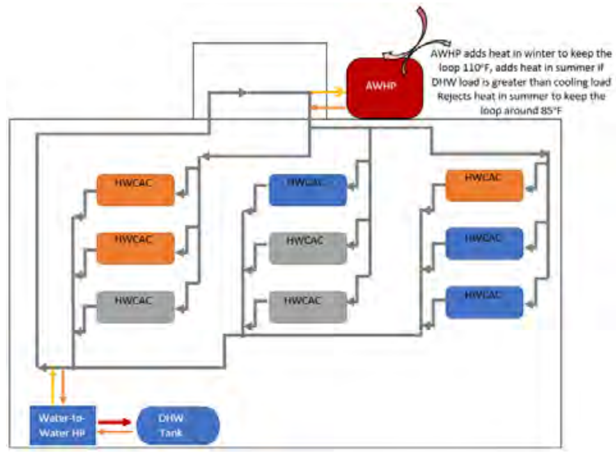
uPVC
U-value: ~.12
U-Frame:~.167
Reinforced with Steel
$

Heating and Cooling



Source: Cool Automation

Air source Heat Pump (VRF)



Source: SWA

Low Temp Hydronic

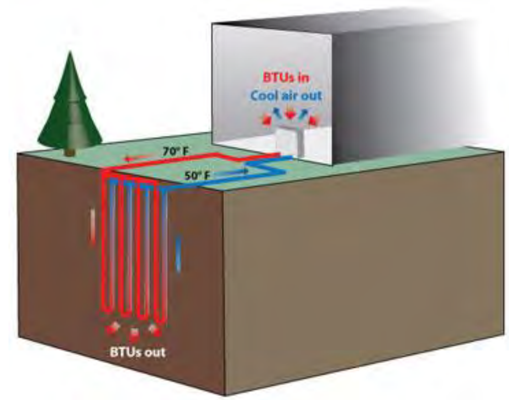
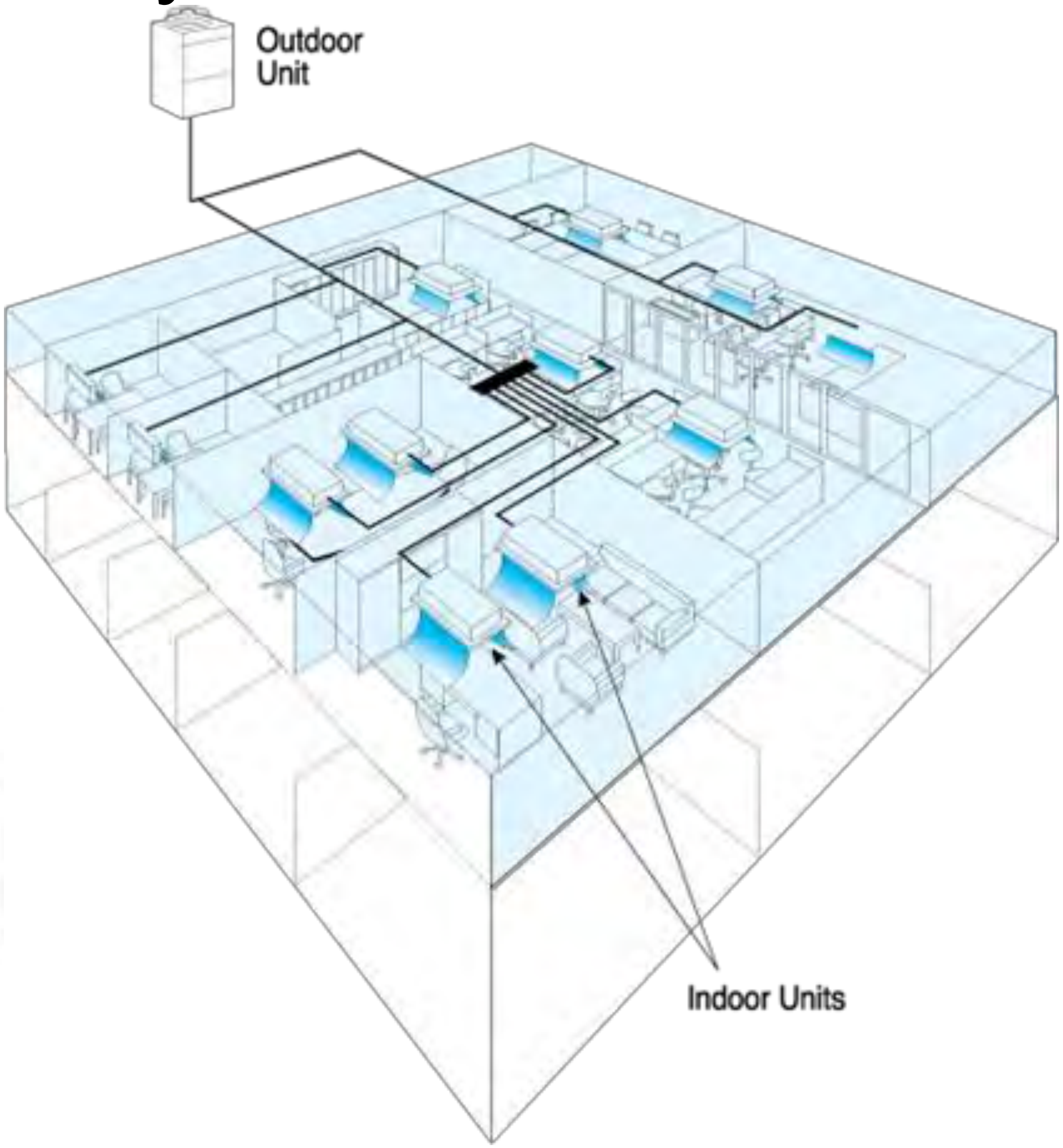


Image: NYSERDA

Water/Geothermal Heat Pump

Cooling is becoming a safety and equity concern. Future-proof systems must be efficient, low/no-carbon, and provide heating + cooling.

Heat Pump / VRF System



Heat Pump / VRF

Wall unit

Ducted Ceiling Units

Performance

+ High rated efficiency
+ Heat recovery option can allow for simultaneous heating and cooling

Design

- Refrigerant piping required
- Proprietary design, not open source

Wall Units

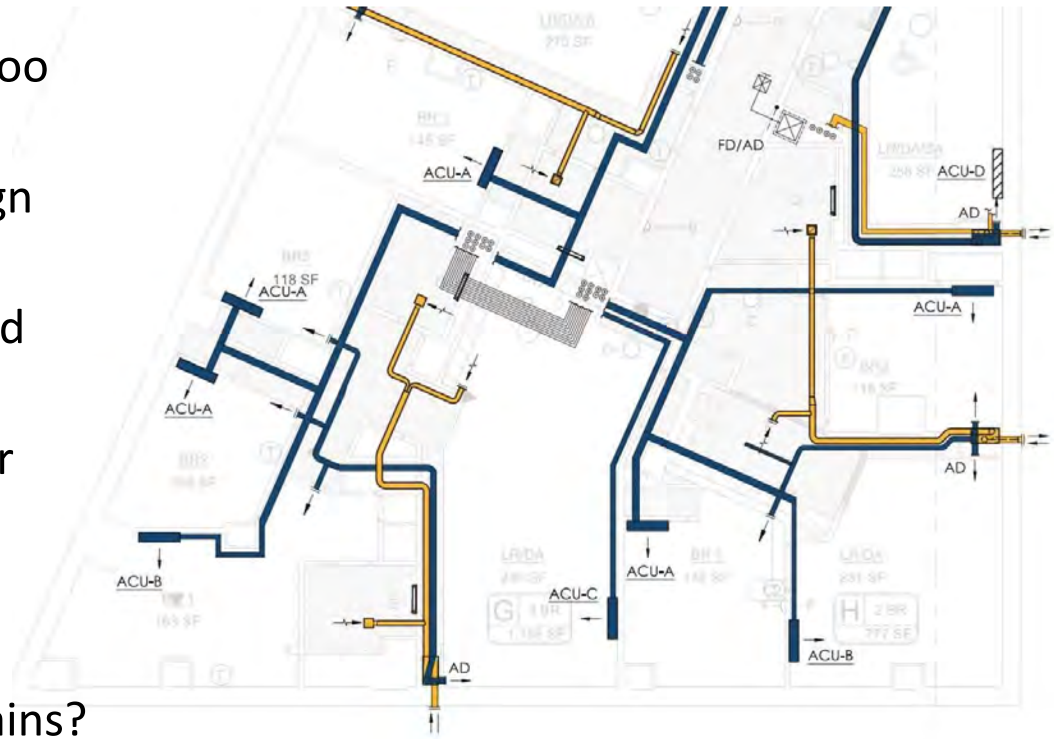
+ No additional ceiling space required
- No current units on market for tiny loads

Ducted Units

- Requires additional ceiling space
- Required sealing of ducts

Issues

- Refrigerant leaks
- High cost as soon as bldg. is too big for residential models
- Larger buildings require design compliant with ASHRAE 15
- Smallest unit 4,500 BTU, could really use a 2,000 BTU unit
- How you have tenants pay for cooling and owner pay for heating?
- Changing filters
- Where to run condensate drains?

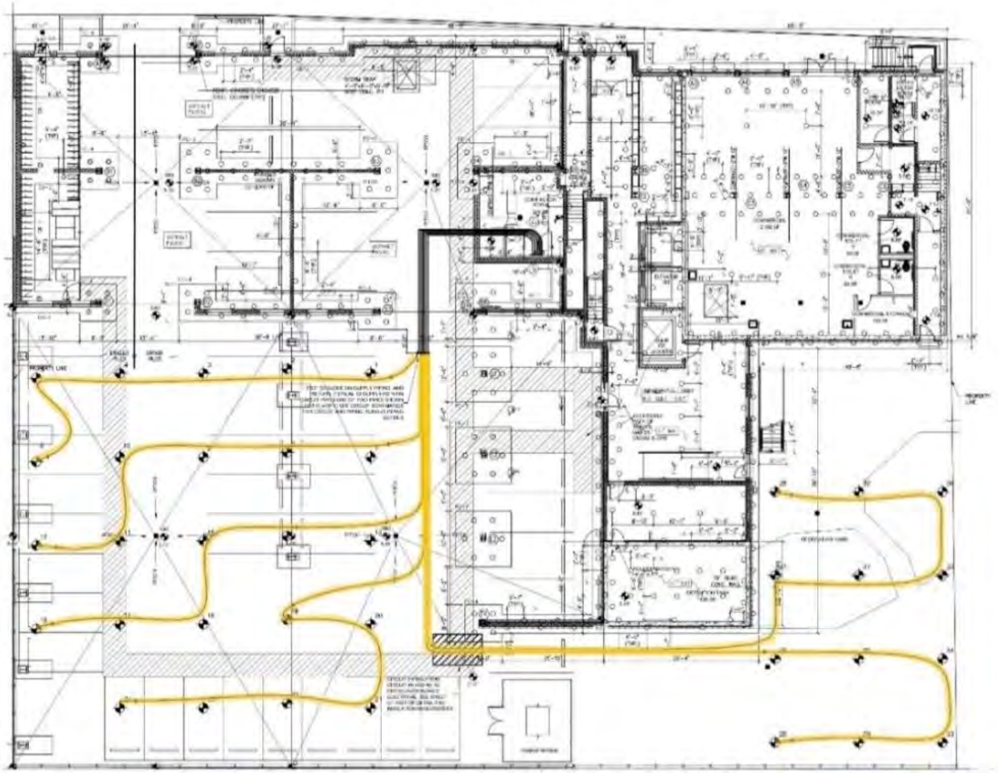


Hydronic Options

- Baseboard
- Watersource heat pumps
- Hybrid water-cooled ACs
- Fan coils
- Radiant
- And more

There are numerous solutions for mixing and matching hydronics with traditional and electrified systems but a holistic design approach is required.

Low Temp Hydronic



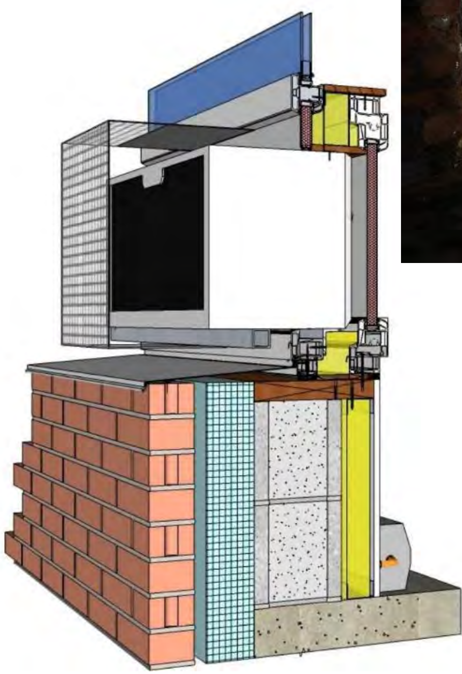
Performance

- \+ High COP options IF designed well
- \- Pumping energy for water loops

Design

- \+ Can be designed for gas today and electric tomorrow, or for hybrid operations
- \+ Flexibility in terminal units (floor units, ceiling mounted, vertical units in cabinets)
- \+ Heat recovery for DHW possible
- \- Simultaneous heating-cooling options are more limited

Hydronic Heating and Window AC



Performance

- \+ Boiler/radiator sizing matched to heat load
- \+ Heat recovery option allows for simultaneous heating and cooling
- \- Pumping power for hydronic can be high
- \- Least efficient cooling option

Design

- \- Less riser and ceiling space
- \- Need rigorous system to prevent air leakage through window A/C during winter months

Maintenance Operation

- \+ Cooling on tenant meter
- \- Price of Gas
- \+ Occupants can turn on cooling whenever they want

Ground Source Heat Pump

System pushes/pulls heat between water loop and ground. Heat pump can be gas or electric-fired. Could be coupled with many hydronic systems.

Considerations

- GSHP unit (and drilling) can be noisy
- Difficult to permit in NYC
- Type of system is dependent on application and location
- Need space to drill (under basement, sidewalk, etc.)

Domestic Hot Water

- 80x50 – efficient electrification of 95% of DHW is needed
- It gets very cold outside, central plants need high temperature water
- CO2 is a good fit
- Very few big building options on the market in US (many elsewhere)
- R-410a and R-134a options (slightly) more common

Domestic Hot Water – Individual

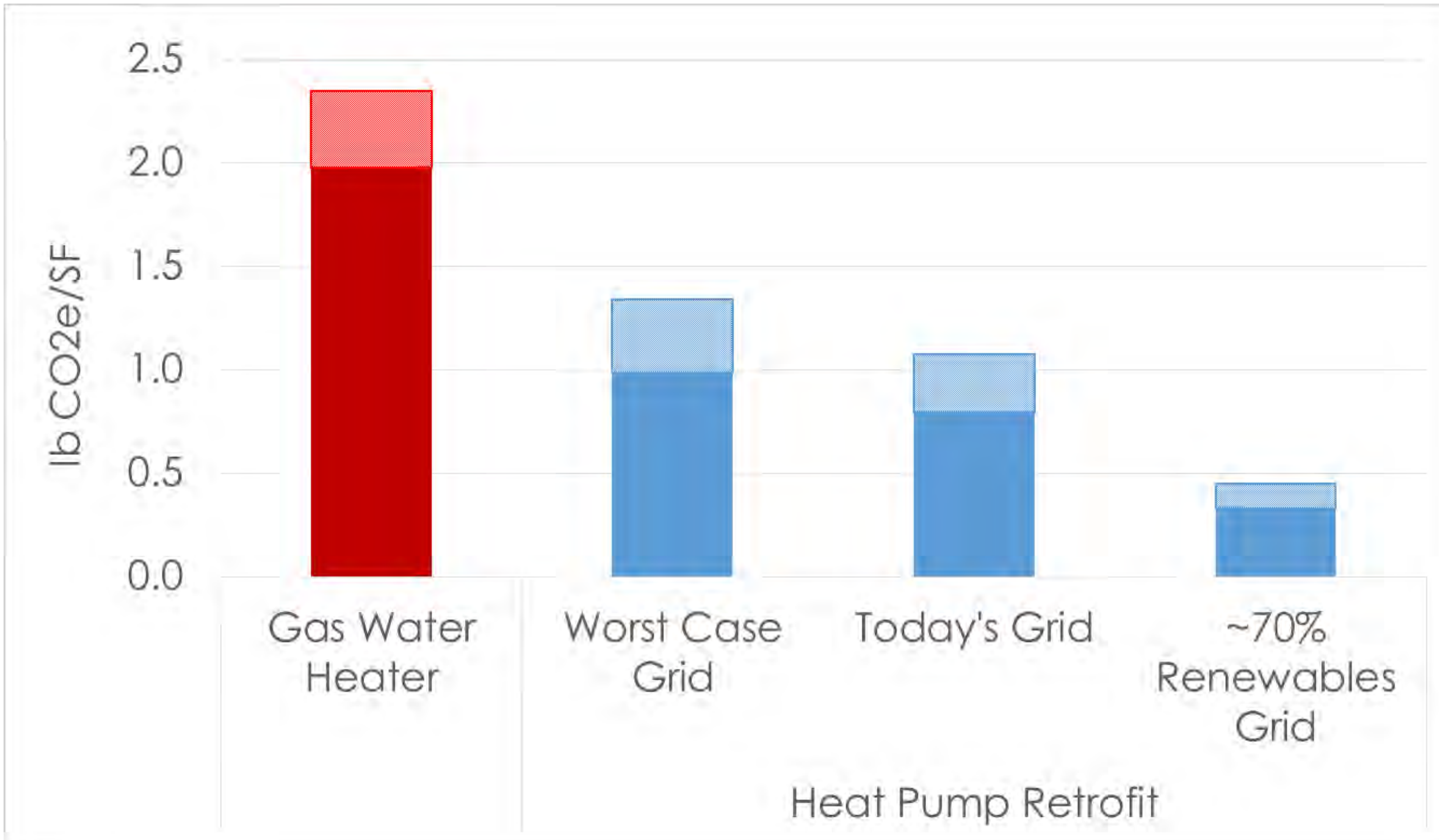
Benefits

- On tenant meter
- If unit is down, only one apartment is affected
- Minimized piping losses

Challenges

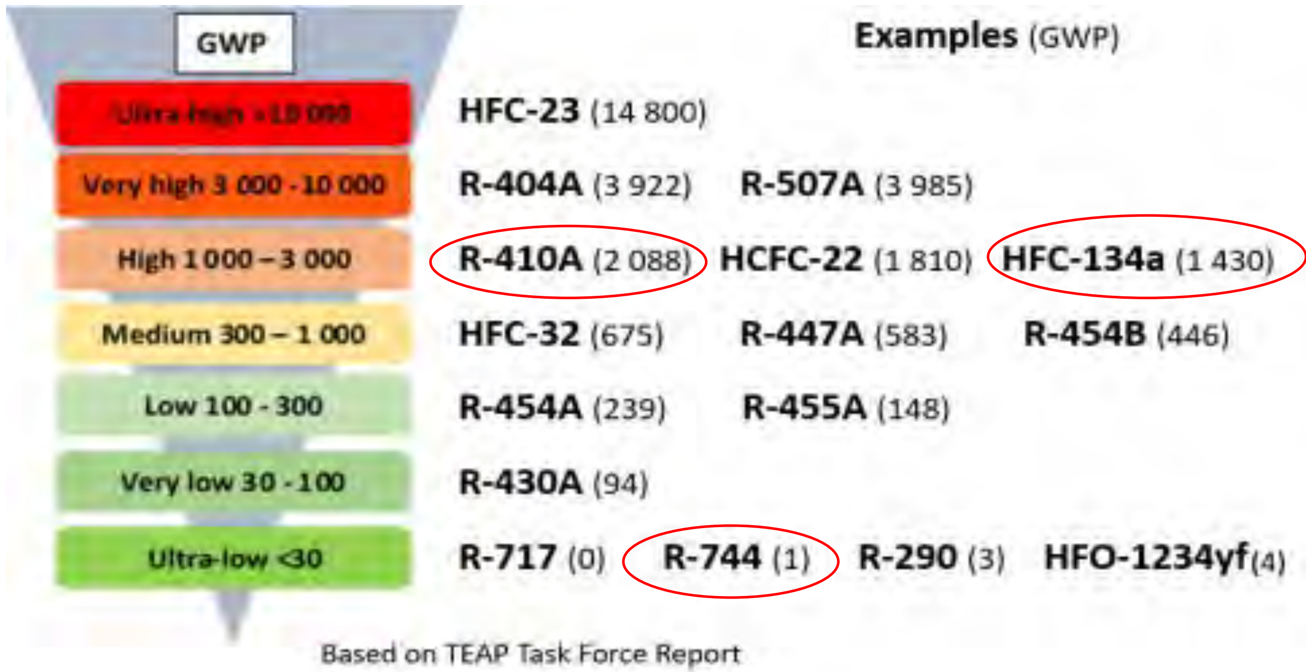
- loss of floor space
- Maintenance goes up with quantity – unmanageable in big buildings
- Heat pump water heaters require large volume of airflow for proper operation
- Heat is pulled from surroundings and can make them very cold
- Noisy

Emissions from Traditional DHW vs Heat Pumps in NYC



Not All Refrigerants are Created Equal

- Leaks happen--refrigerants have different greenhouse gas equivalences
- NYC's other interest in CO_2



Dryers

<u>Commercial Grade - Common Laundry</u>

- No coin operated, non-vented commercial grade electric dryers available in the US.
- **Gas, vented** is most powerful and works fastest
- **Electric, vented** available but can be slower and more costly to tenants

<u>Residential Grade - In-suite Laundry</u>

- Non-vented dryers for in suite laundry work well but can be slow.
- Non-vented dryers cost more than conventional vented units, but no ducting to exterior or make up venting needed so could be much cheaper installed.

Renewables and “Renewables”

Combined Heat and Power

- NOT renewable – gas-fired
- Provides convenience power
- Reduces demand of domestic hot water heater and grid electricity
- Saves money, eventually not carbon

Solar

- Reduces electricity consumed from grid
- Requires battery for emergency power
- Saves operating cost, saves carbon
- House meter vs unit meter connections change economic impact

Renewables and “Renewables”

Ground-source
- Heat source is renewable, but heat pump is needed to extract it. Renewable-non renewable hybrid.
- Saves operating cost, saves carbon

Batteries
- Result in a net increase in electricity usage (not 100% efficient).
- Can store electricity during times of cleaner grid fraction (more renewables online) and use when peaker plants on
- Can lower cost and carbon, but controls and accounting are more complex

Who Benefits?

- Connecting to resident meters vs central meters
  - We pay for our energy even if its on the house meter
  - People save when they pay directly & have a feedback loop
- Some systems are easier to direct meter vs master meter.
- Direct metering yields energy savings.

  - Affordability status impacts legality of passing costs onto residents

This assumes basic needs and safety are met.

Who Benefits?

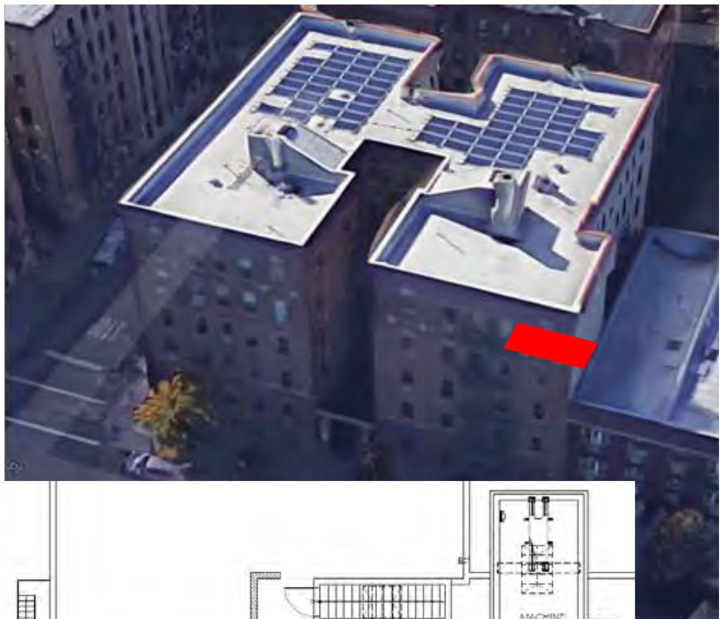
- Electricity is more expensive than gas (per Btu)
- Electrification drives up operating cost unless it's done REALLY well
- Who can/should pay for the first cost and operating costs of these systems?

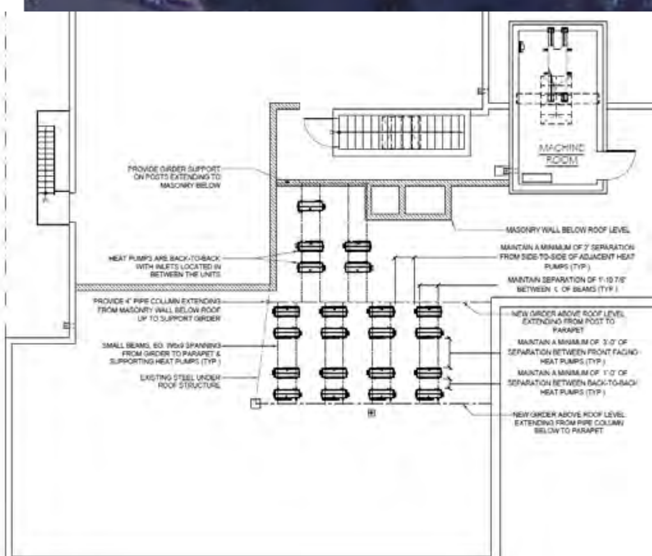
This assumes basic needs and safety are met.

Case Studies

DHW Electrification

Case 1: Mid-sized aggregation





- 14 Sanden units to go on the roof, feeding central plant in the basement
- Control system to make DHW with gas or electric cost-effectively
- ~50 apartment units

AIR TO WATER HEAT PUMP

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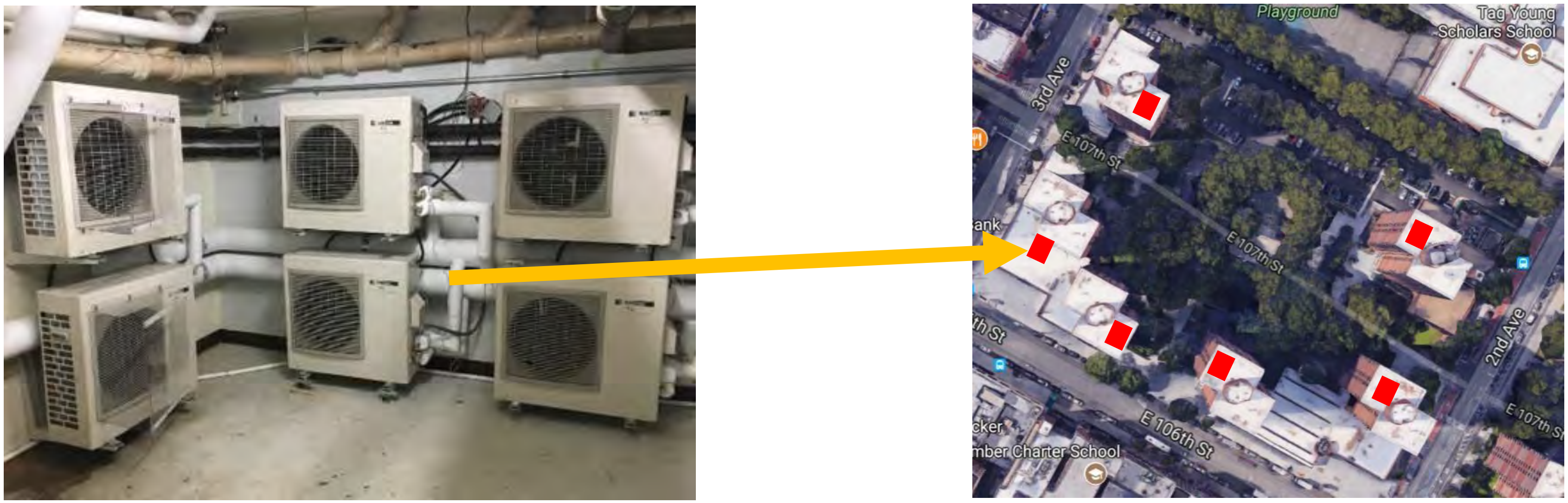
Case 2: Summer AC concept



- Decentralized DHW and energy storage for campuses – allows for central steam plant to be taken off-line during the summer months.
- HPWHs in basements with ducting to lobbies
- Water heaters provide useful air conditioning in summer

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Pursuing Passive

Subject Building

- 15 floors + cellar
- 163 units
- Gross:123,000 sq.ft.
- Built 1950

Costs

- rentals: $50/sf avg
- sales: $850/sf avg

ACTUAL BUILDING

FULLY OCCUPIED

TYPICAL CHALLENGES

TALL “LOOKS LIKE NYC”

POST WAR

MARKET RATE

FOCUS: PHASING/BENEFITS

FOCUS: BREAK INERTIA DOMINATED DECISION MAKING

Systems

Envelope
- No insulation
- 21% window to wall ratio

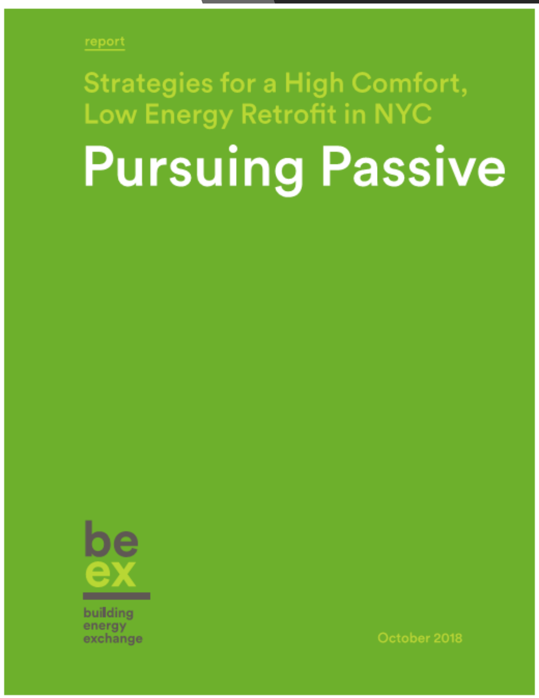
Heating
- 2-pipe steam

Ventilation
- Exhaust only

Cooling
- window units only

DHW
- Steam heat exchanger

Retrofit Strategies



ENVELOPE
- Windows - replace
- Insulation - add
- Airtightness - add

VENTILATION
- Refurbish/add balanced system, with recovery

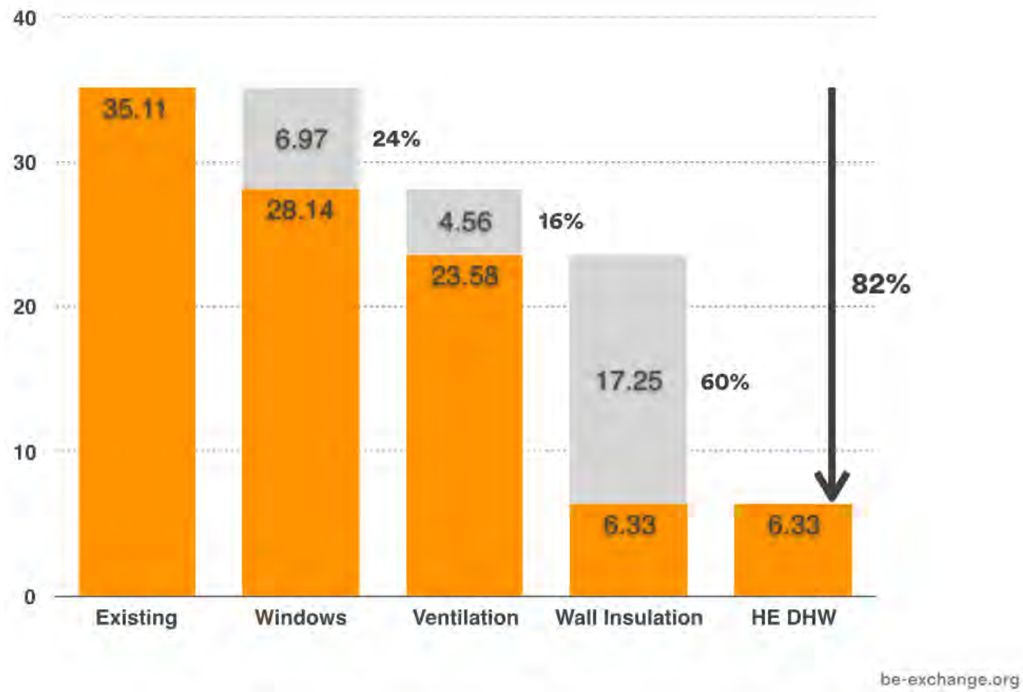
HEATING/COOLING
- Replace steam/window units with VRF

DHW

- Upgrade heat exchanger to high efficiency boiler

Lighting/Equipment
- LEDs
- EnergyStar

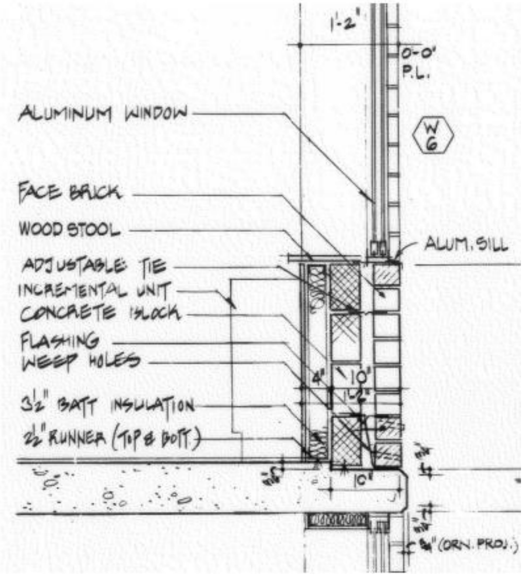
Demand Reduction - heating



Phasing

PHASE	YR		
1	0	ENVELOPE 1	Windows + Roof insulation+ Airtightness (shafts, etc)
2	4	VENTILATION	Balanced ERV system + Exhaust upgrades
3	8	ENVELOPE 2	Wall insulation + Airtightness (walls)
4	12	HEATING/COOLING	VRF system
5	16	HOT WATER	High efficiency boiler
6	-	PLUGS/LTG/APPS	Energy star appliances, Elevator upgrades

NYU Energy Master Plan – Student Housing

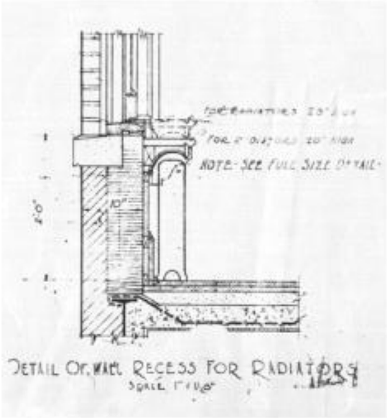


EnerPHit Study: Carlyle III - Exterior Insulation Proposed

- Carlyle III – 1986
- Insulated Walls – 4” face brick + 2” cavity + 4” CMU + 4” cavity w/ foil faced fiberglass batts
- Metal pane, double glazed windows

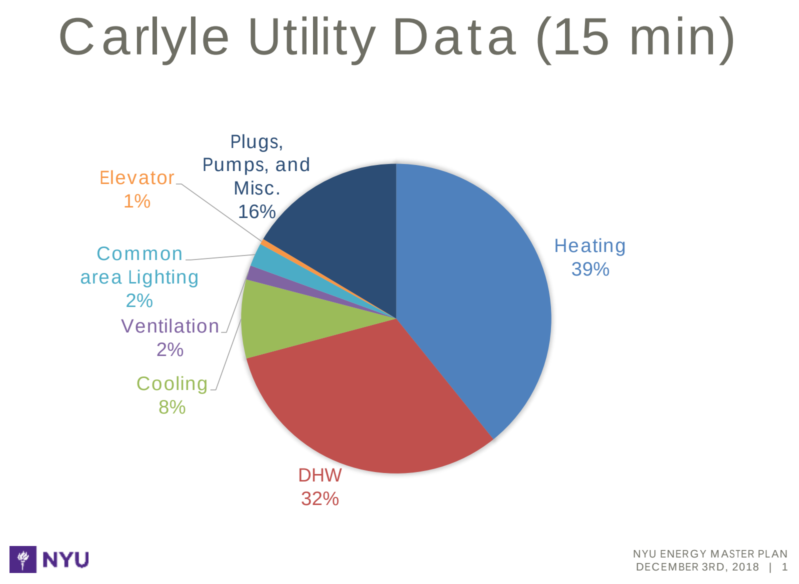
EnerPHit Study: Rubin Hall - Interior Insulation Proposed

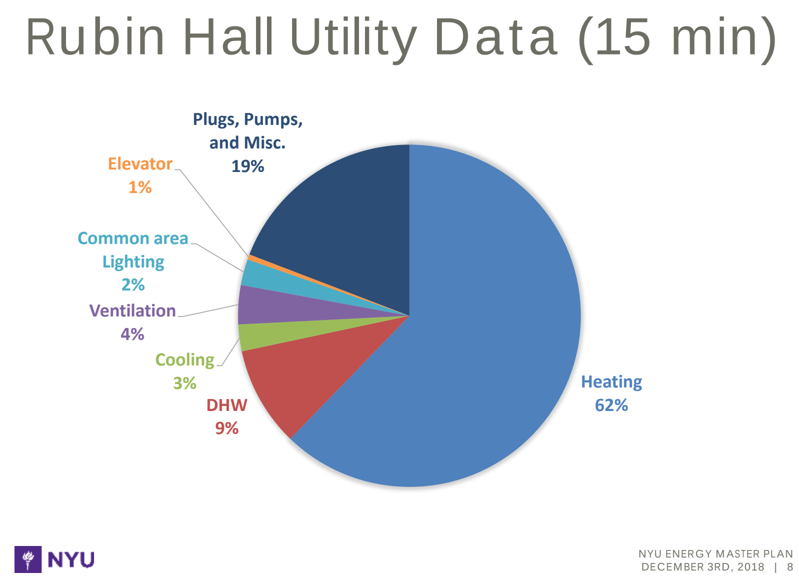
- Rubin Hall – 1925 Historic Bldg
- Uninsulated Walls: 4” face brick + 8” Terracotta
- Metal, Single Pane Windows



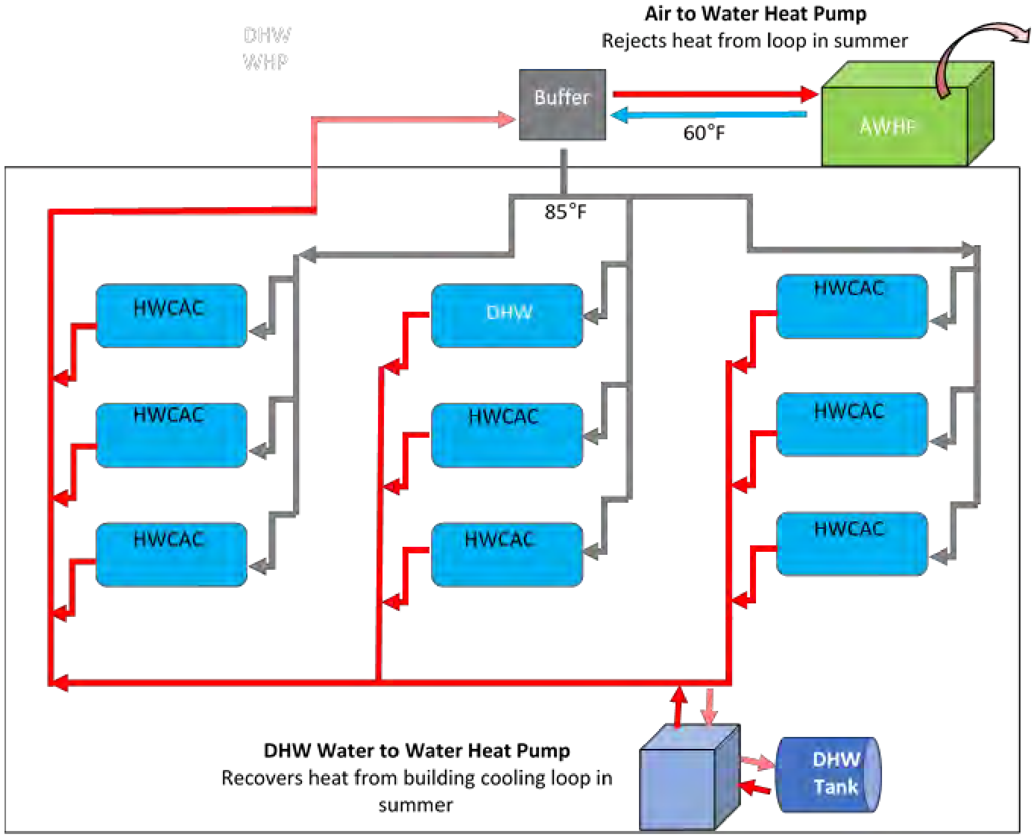
WALL SECTION DETAIL DATED 1948

As Built Utility Analysis





Hydronic Loop with HWCACs : Cooling-Mode



Heating and Cooling System Comparison

	Hydronic Loop with HWCACs	VRF System
Pros	• Minimal distribution losses • Simultaneous heating and cooling • Waste heat recovery during cooling season for DHW • Compatible w future AWHPs	• Simultaneous heating and cooling • Flexibility in terminal unit selections
Cons	• Larger rooftop footprint than VRF units • Rooftop structural considerations • Pumping energy	• Potential for refrigerant leakage • Refrigerant phase out and piping lifetime (~20 years) • Rooftop structural considerations

Sheffield Sterling Strathcona Hall "SSS" at Yale

- Yale - New Haven, CT
- Built in 1931
- Two 4 story wings + a central 11 story tower
- Primarily student and faculty offices
- Has one lecture hall

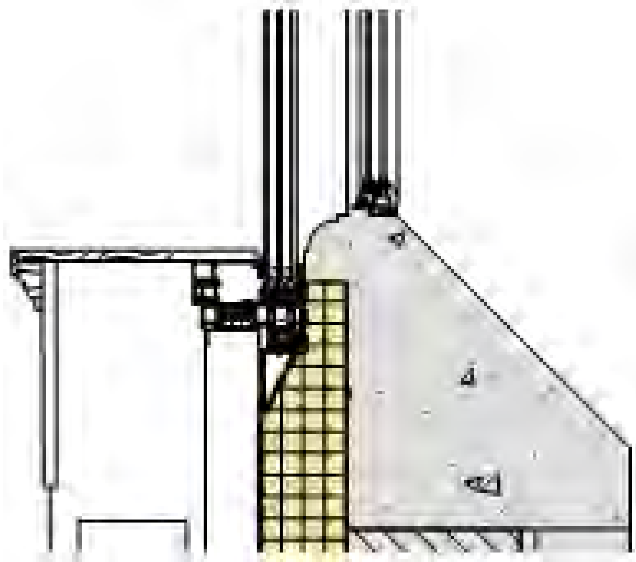
ICTION PHOTO, 1931

SSS – Existing Conditions
Windows

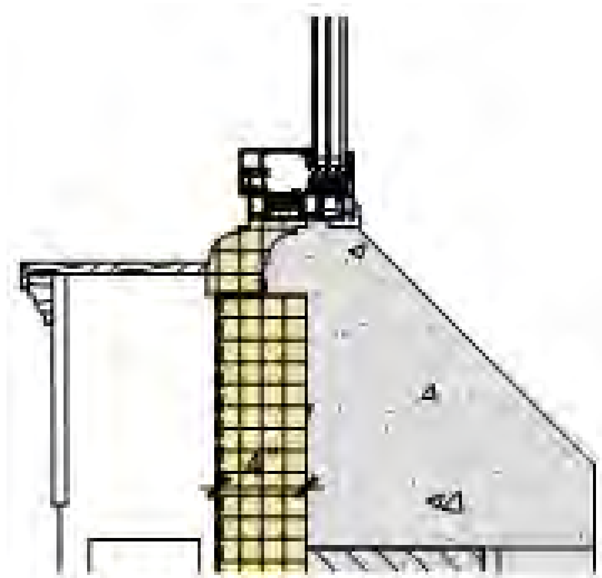
IMAGE 11: TYPICAL RESTORED PODIUM WINDOWS (EXTERIOR VIEW)

IMAGE 12: TYPICAL RESTORED PODIUM WINDOWS (INTERIOR VIEW)

SSS – EnerPHit Design Recommendations
Windows



ECM-WIN-01
EXISTING CRITTAL + INTERNAL WINDOW BY SCHUCO
WINDOW NOT VISIBLE FROM EXTERIOR
U-VALUE 0.14 / R-VALUE 7
(CALCULATED PER EN STANDARDS)



ECM-WIN-02
REPLACEMENT PH WINDOW BY SCHUCO
-
U-VALUE .14 / R-VALUE 7
(CALCULATED PER EN STANDARDS)

SSS – Existing Conditions
Heating and Cooling

EXAMPLE OF LOCALIZED A/C UNIT LOCATED IN ROOM 403

SSS – EnerPHit Design Recommendations HVAC

Heating & Cooling

or • **HC-01 – VRF heat pumps**

or • **HC-04 – Ground-source water loop with WSHP terminal units**

• **HC-06 – Air to water heat pump(s) with WSHP terminal units**

DHW

• **DWH-01 – Convert existing water heaters to heat pump water heaters**

or • **DWH-02 – Convert central water heaters to point of use instant ER heaters**

Ventilation

• **Central**

or • **By floor**

or • **By suite**

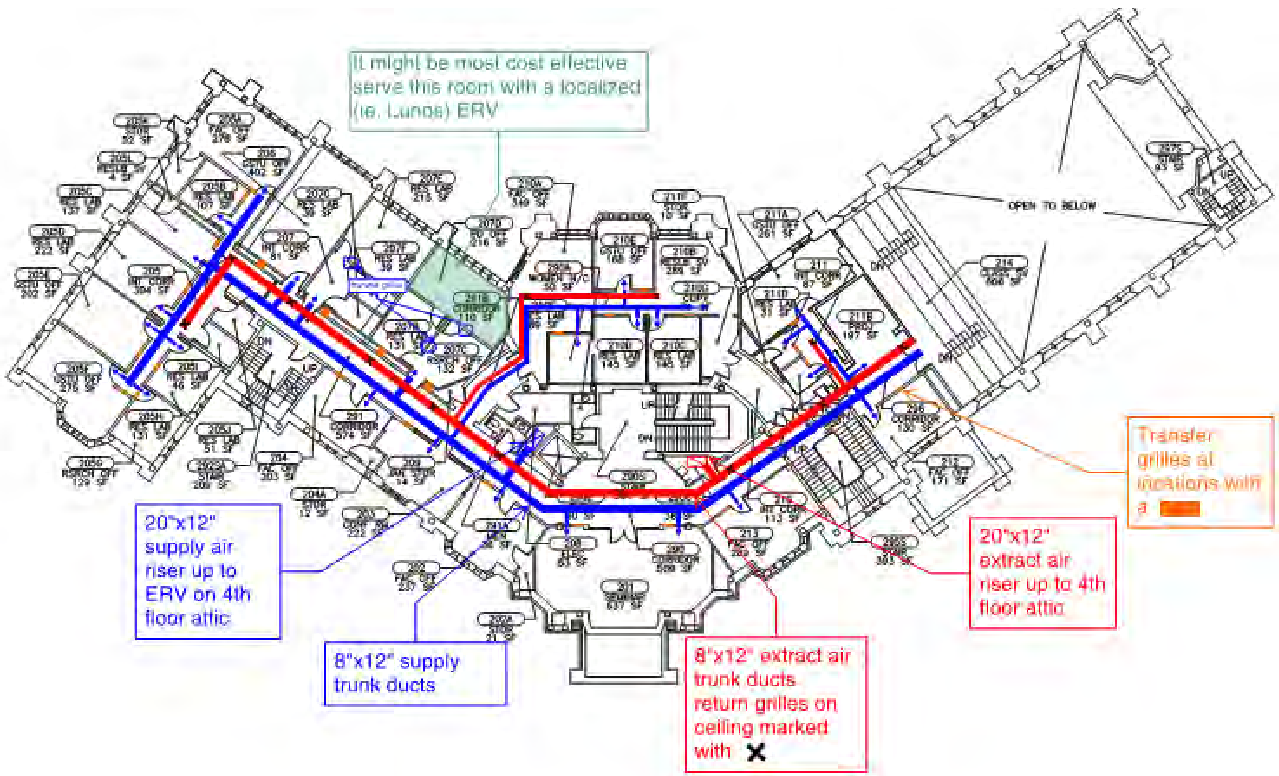
SSS – EnerPHit Design Recommendations
Phasing Considerations

1. SUITE

2. FLOOR

3. WING

SSS – EnerPHit Design Recommendations
Ventilation



TYPICAL CENTRAL DUCTWORK STRATEGY

Heating, Cooling & DHW Packages

Package	Predicted Savings	Pros	Cons
1. VRF and Local ER Water Heater Package	70%	• Minimal ductwork • Ideal sizing options • Heat recovery for better zone-level control	• Refrigerant leaks and potential future bans • Extra piping for heat recovery
2. Decentral GSHPs and Local ER Water Heater Package	63%	• Flexibility in terminal units • Can have simultaneous heating cooling with just 2-pipe hydronic • Improved cold weather performance b/c heat pump is inside	• Potential space availability limitations • Pumping energy water loops • Noisy compressors • Phasing more challenging • 220V electrical needed at all terminal units
3. Central Air to Water Heat Pumps and terminal WSHPs, Heat Pump Water Heater, & PV Package	65%	• Flexibility in terminal units • Only one central piece of equipment needed (the HP) • Can have simultaneous heating cooling with just 2-pipe hydronic • Small exterior impact	• Pumping energy for water loops • Noisy compressors • Phasing more challenging • 220V electrical needed at all terminal units

200 Tyler Street – Historic Retrofit

PROJECT SCOPE & SPECS

Developer / Owner:	WinnCompanies
Architect:	The Architectural Team, Inc.
Project Services:	Passive Certification Services; Energy & Thermal Bridge Modeling; Testing & Verification
Building Size:	65,000 sf, 4 stories
Certification:	Passive House Institute - EnerPHit
Incentive Programs:	
Funding:	2017 CHFA 9% LIHTC Program
Primary Energy Conservation Measures:	Projected savings of 60-70% whole building energy demand
SWA Contact:	Lois Arena (larena@swinter.com)

Exemptions for EnerPHit

The limit values in Table 2 for the heat transfer coefficients of the exterior envelope building components may be exceeded if absolutely necessary based on one or more of the following compelling reasons:

- *If required by the historical building preservation authorities*
- *If the cost-effectiveness of a required measure is no longer assured due to exceptional circumstances or additional requirements*
- *Due to legal requirements*
- *If implementation of the required standard of thermal insulation would result in unacceptable restriction of the use of the building or adjacent outer areas*
- *If special, additional requirements (e.g. fire safety) exist and there are no components available on the market that also comply with the EnerPHit criteria*
- *If the heat transfer coefficient (U-value) of windows is increased due to a high thermal transmittance (psi value) of the window installation offset to the insulation layer in a wall that has interior insulation*
- *If reliably damage-free construction is only possible with a smaller insulation thickness in the case of interior insulation*
- *If other compelling reasons relating to construction are present*

Comfort Analysis

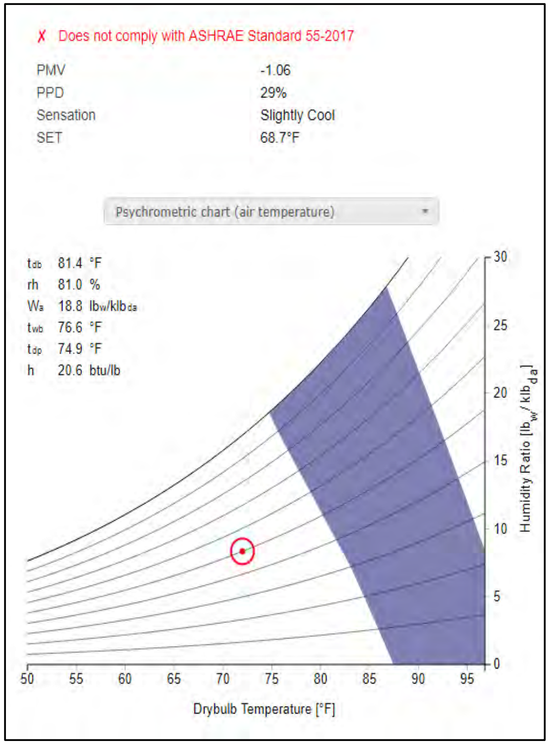


Figure 1. Current conditions result in situation outside of the ASHRAE 55 comfort zone.

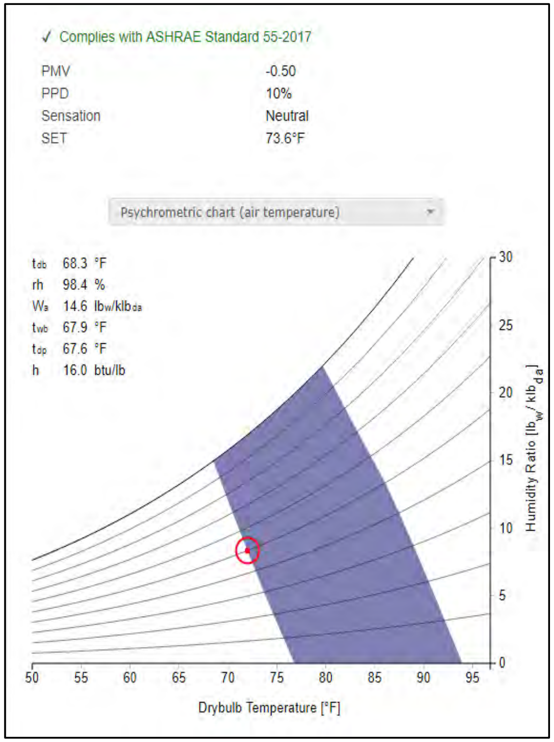
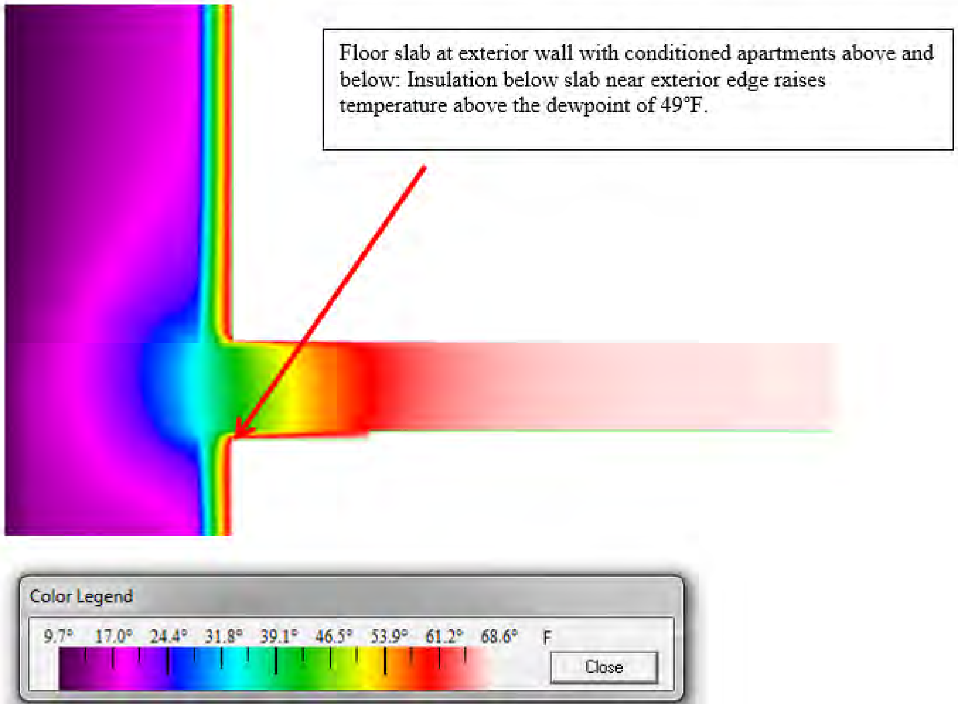


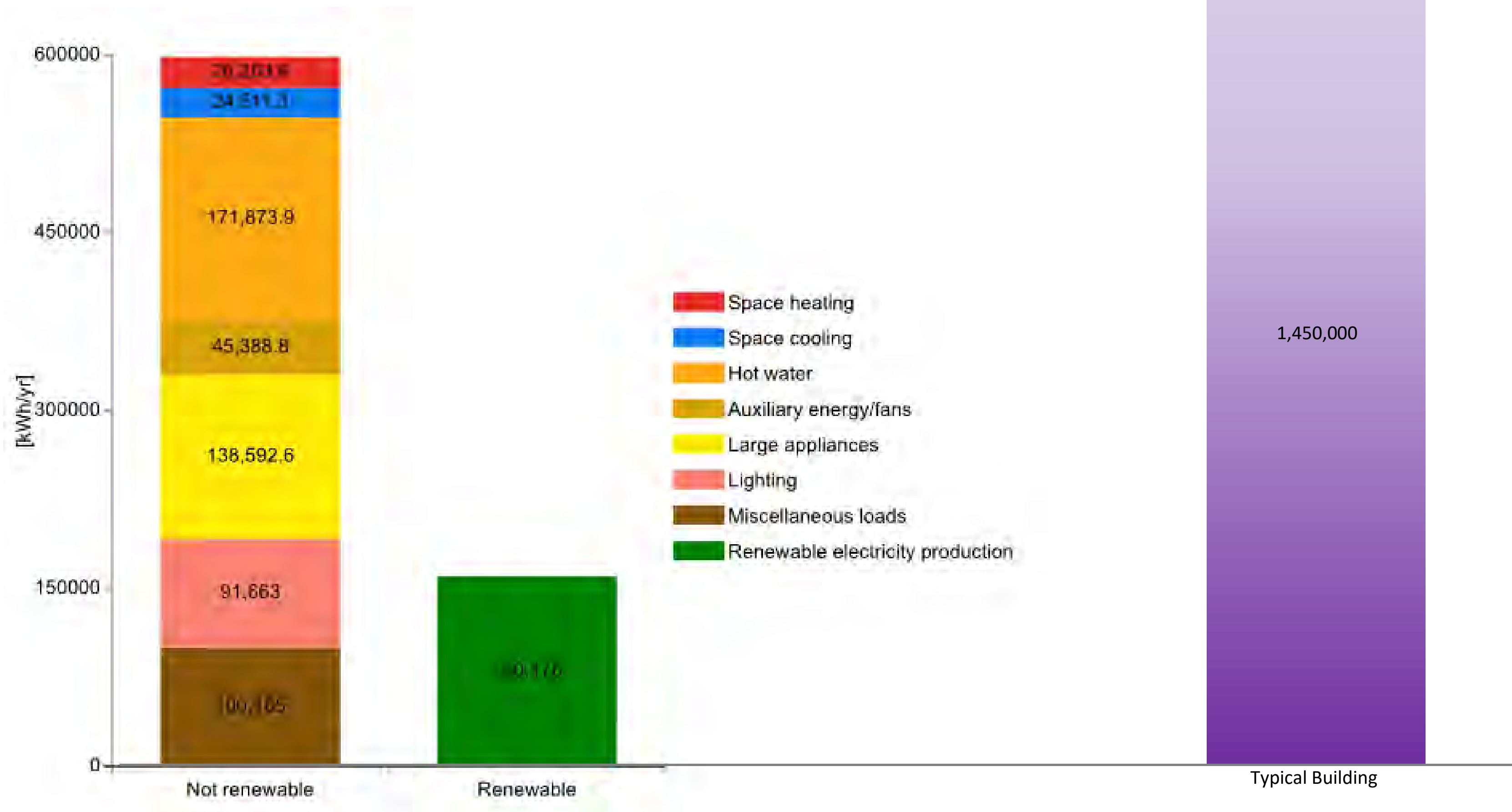
Figure 2. With the exterior walls insulated, the space falls within the ASHRAE 55 comfort zone.

Condensation Analysis

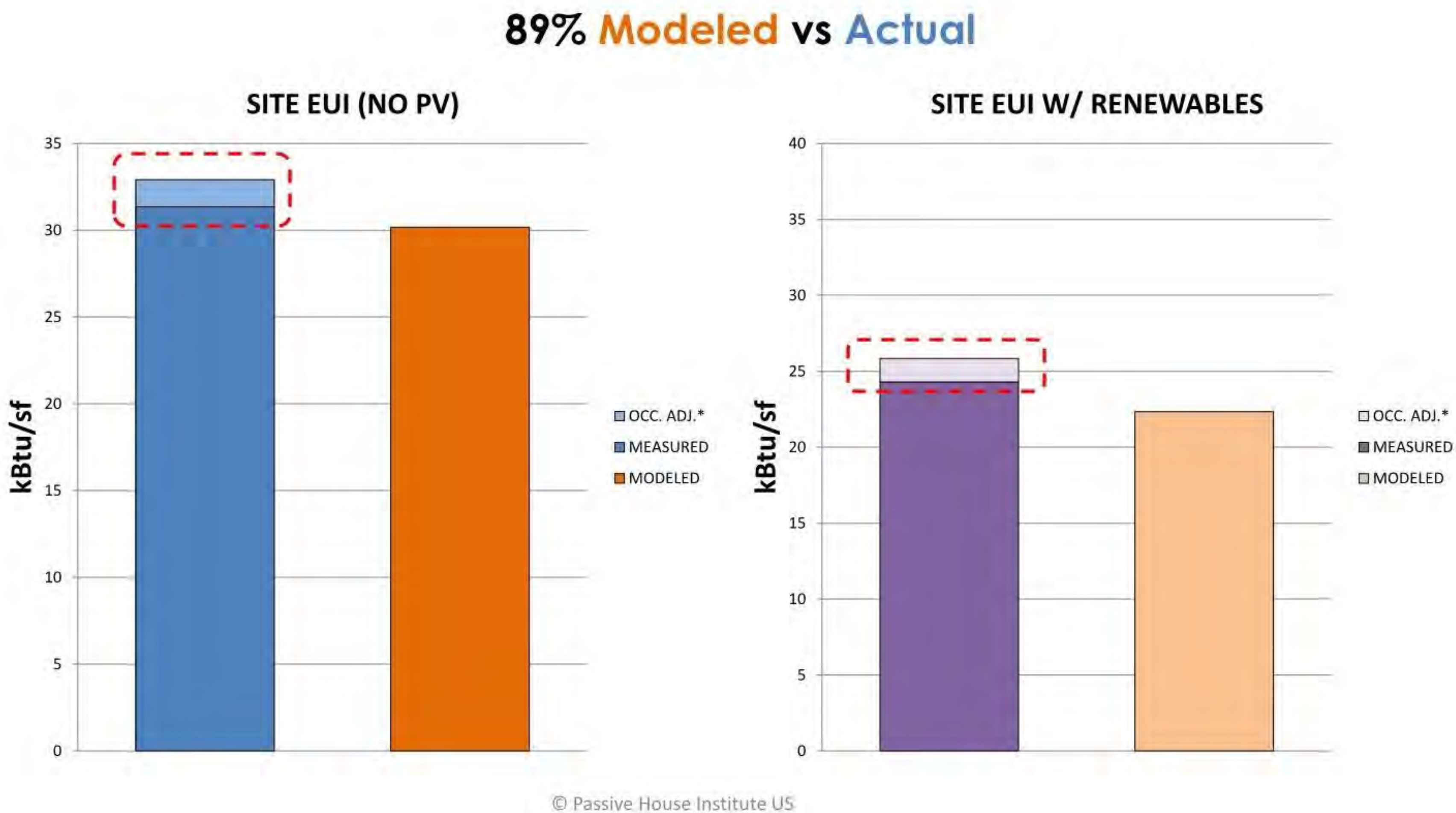


Beach Green Dunes I & 2

Results – Beach Green Dunes I

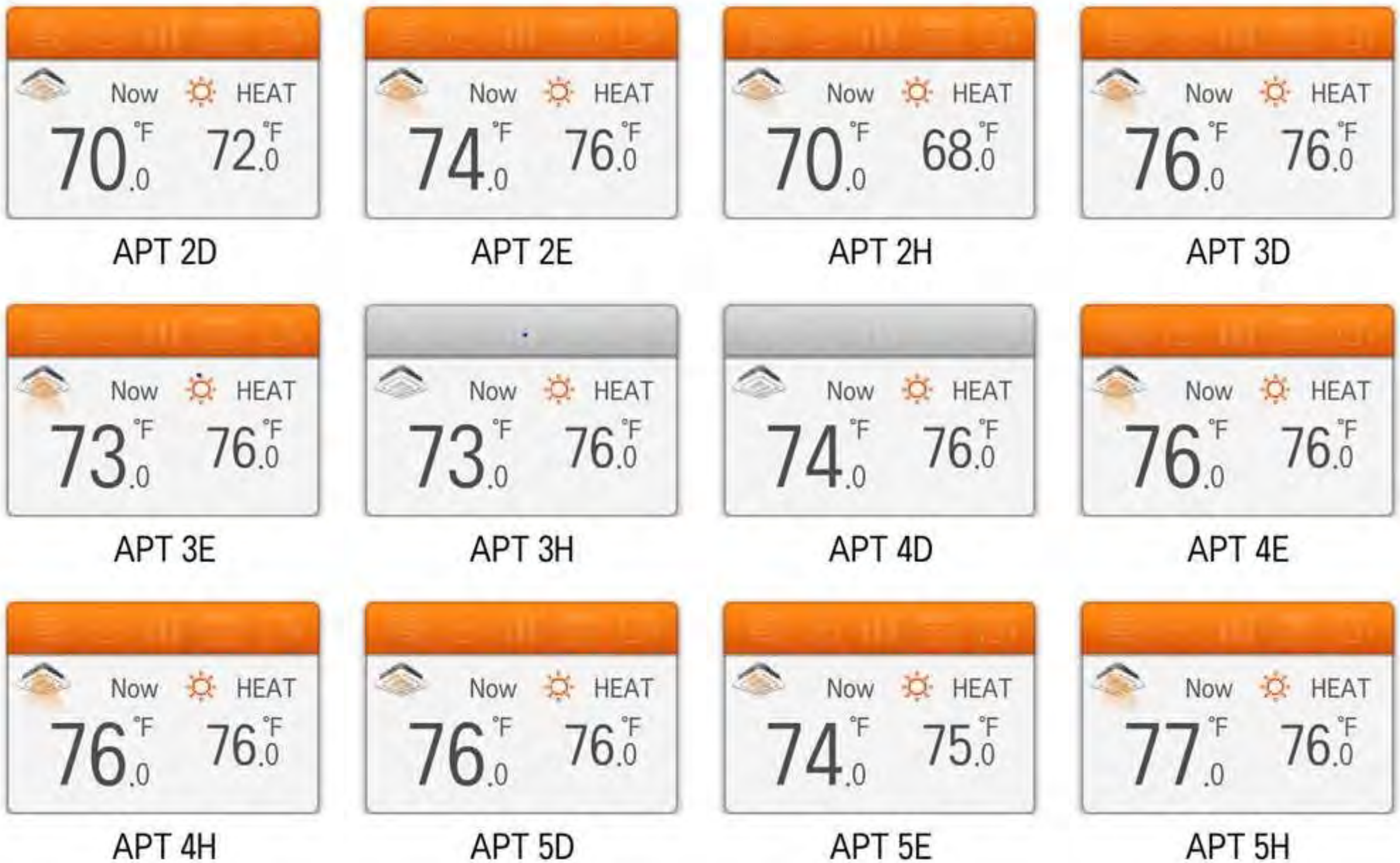


Results – Beach Green Dunes I



Results – Beach Green Dunes I

Thermostat Settings / Tenant Habitats



Results – Beach Green Dunes I

Co-Gen Valve

In Summary

- We covered five tough areas for electrification in larger buildings
  - Envelope (reducing loads via wall construction, thermal bridging, windows)
  - Heating and Cooling
  - DHW (central and unitary systems)
  - Dryers
  - Renewables

and presented case studies meeting these challenges

- Legislation and climate realities drive low/no-carbon solutions, tailored to an improving grid

Thank You!