SCALING HEAT PUMP RETROFITS

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AGENDA

- Overview of Advancing Electrification research
- Technical challenges to electrification
- Heat pump business case and owner’s perspective
- Q&A

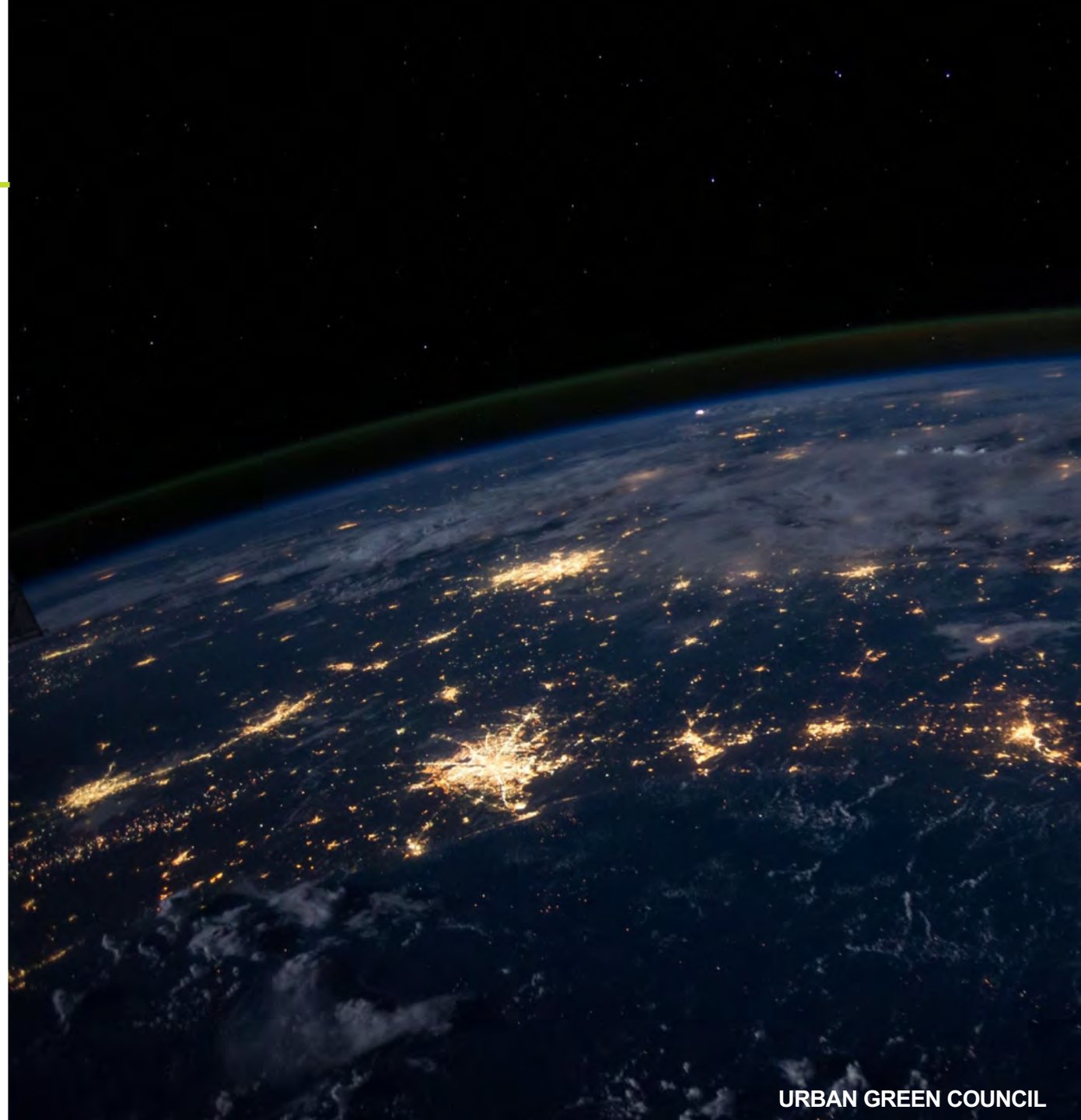
NYC'S ELECTRIC PAST

Electrification of light

- Turn of 20th century – Edison, Tesla and Westinghouse

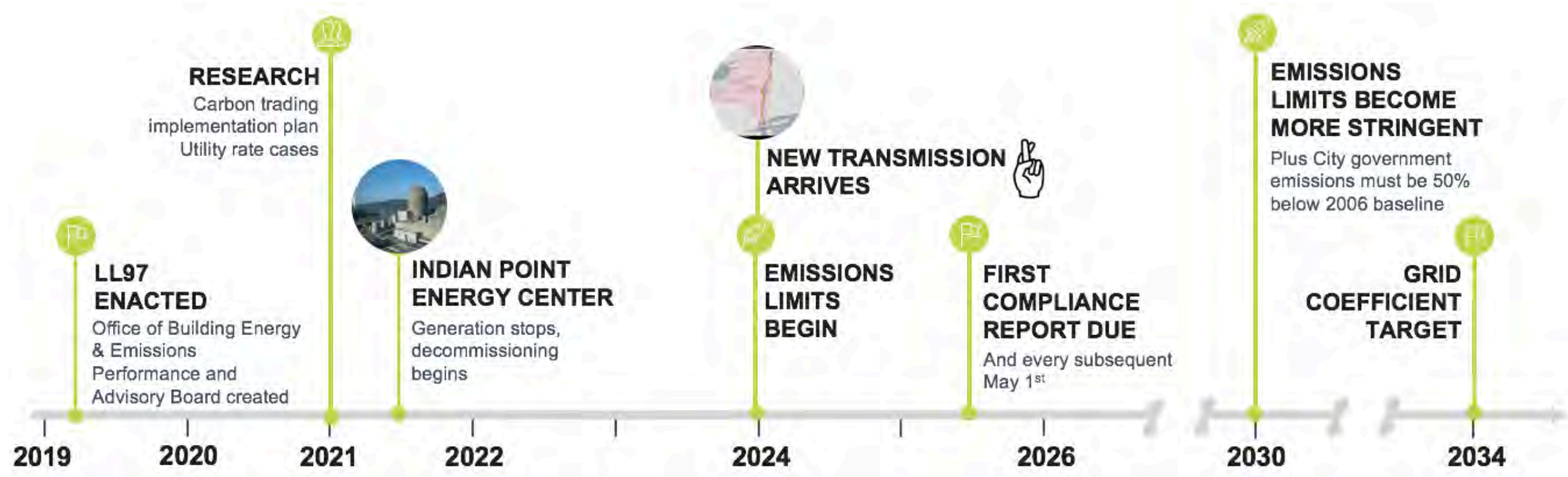
Science seldom proceeds in the straight-forward logical manner imagined by outsiders.

- James Watson



NYC'S ELECTRIC FUTURE

Roadmap to Zero Carbon NYC



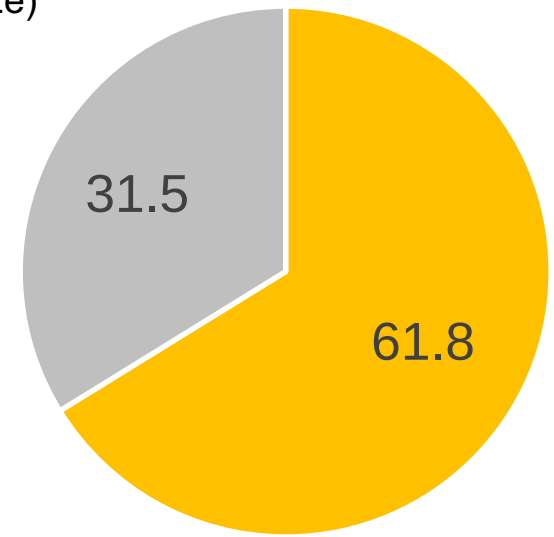
CURRENT MARKET

Heat pump potential

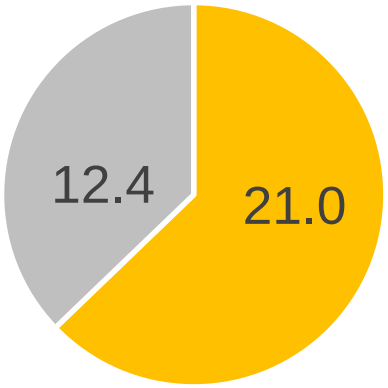
- Almost two-thirds of building emissions come from fossil fuel combustion
- Similar pattern between NYC and NYS
- Electrification can cut carbon emissions while improving air quality

Carbon emissions – 2017
(millions of tonnes CO2e)

NYS



NYC



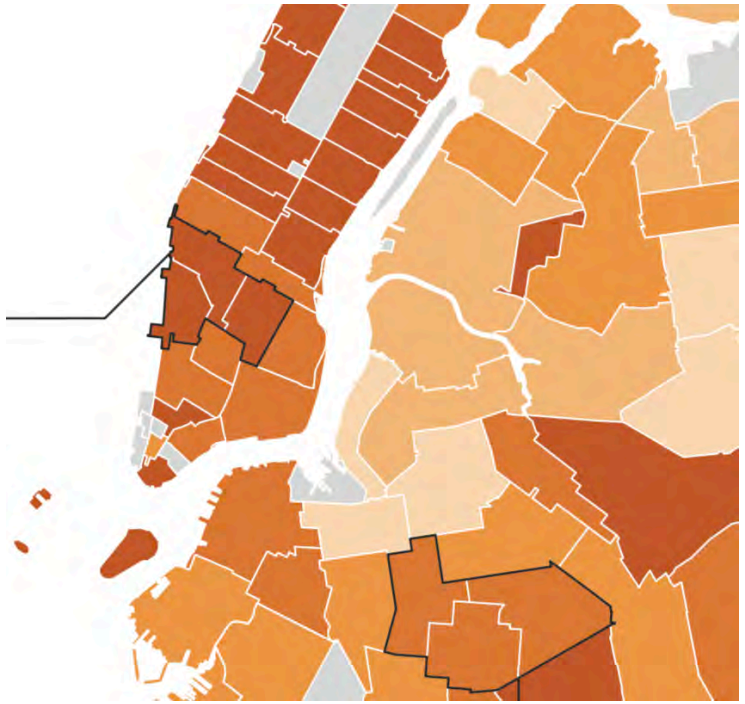
District steam and electric

Fossil fuel combustion

CURRENT MARKET

Multifamily potential

- Demystifying Steam update coming October 2019
- Over 46,000 steam heated small and medium buildings[1]
- Citywide, 1.8B SF of multifamily area uses steam heat



Predicted Small and Medium Multifamily[1] Steam Heated Properties by Borough

NOTE1: Buildings larger than 5,000 SF, smaller than 50,000 SF

CURRENT MARKET

Medium multifamily projects

- Harlem (The Levy Partnership, JOE NYC)
  - Construction to start in 2020
- Bronx (Bright Power, Vomar)
  - Design complete, construction start 2019 - DHW served by heat pumps
- Brooklyn (CB, RiseBoro)
  - Casa Pasiva converts 143 units in Bushwick from steam to ASHPs

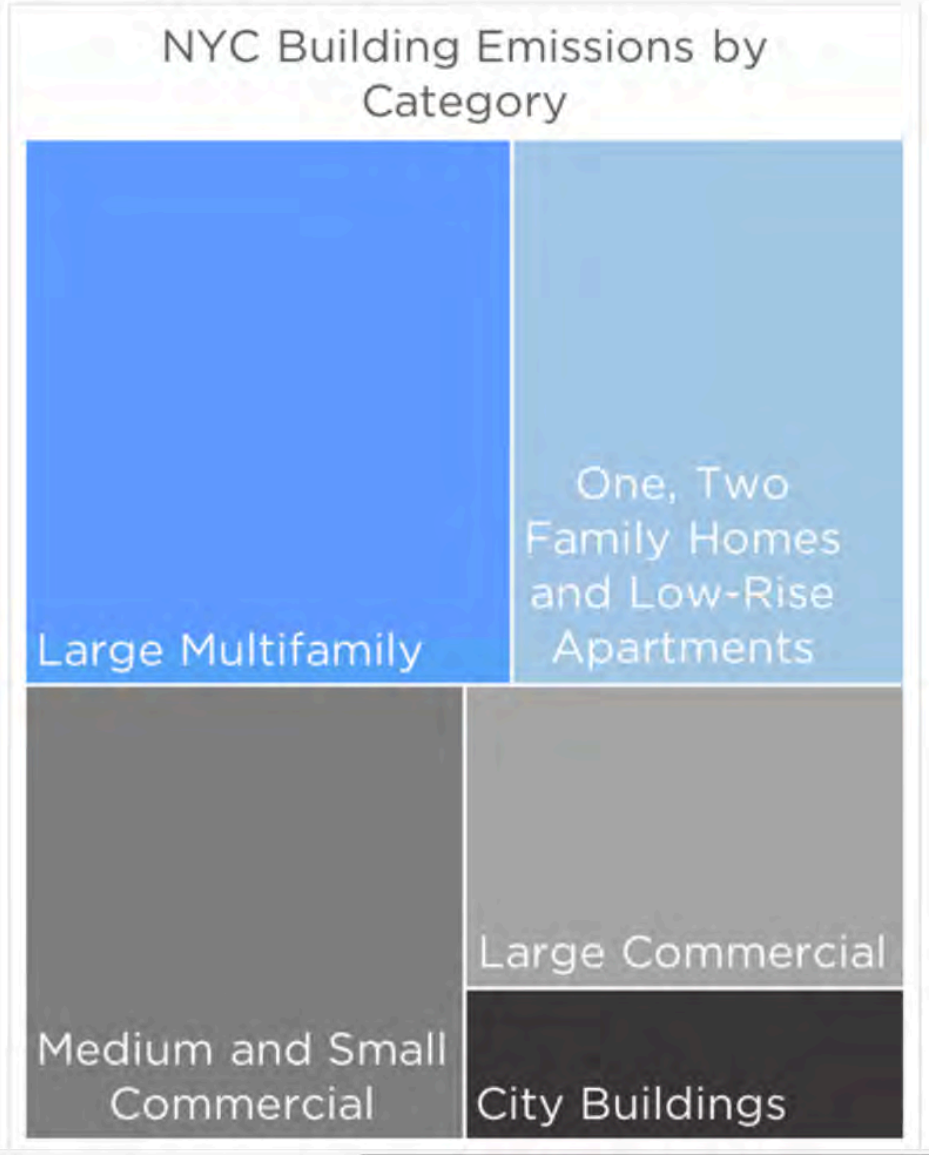
CURRENT MARKET

Large Multifamily projects

Residential larger than 25,000 SF:

40% of NYC building area

30% of NYC building emissions



NOTE1: Buildings larger than 25,000 SF

TECHNICAL CHALLENGES

Overview

- Technological uncertainty
- Existing electrical capacity
- Equipment placement
- Envelope improvements
- Refrigerant piping and selection

SYSTEM SELECTION

Central (VRF)

- Less roof space required
- Larger refrigerant runs and volumes
- Easier to connect additional electricity
- Difficult to meter

Unitary (mini-split)

- More space required, but smaller units
- Smaller, isolated refrigerant runs
- Some apartments will need electrical upgrade
- Tenant pays for heat through electricity
- Tendency to oversize based on product availability (2 tons is too big)

TECHNICAL CHALLENGES

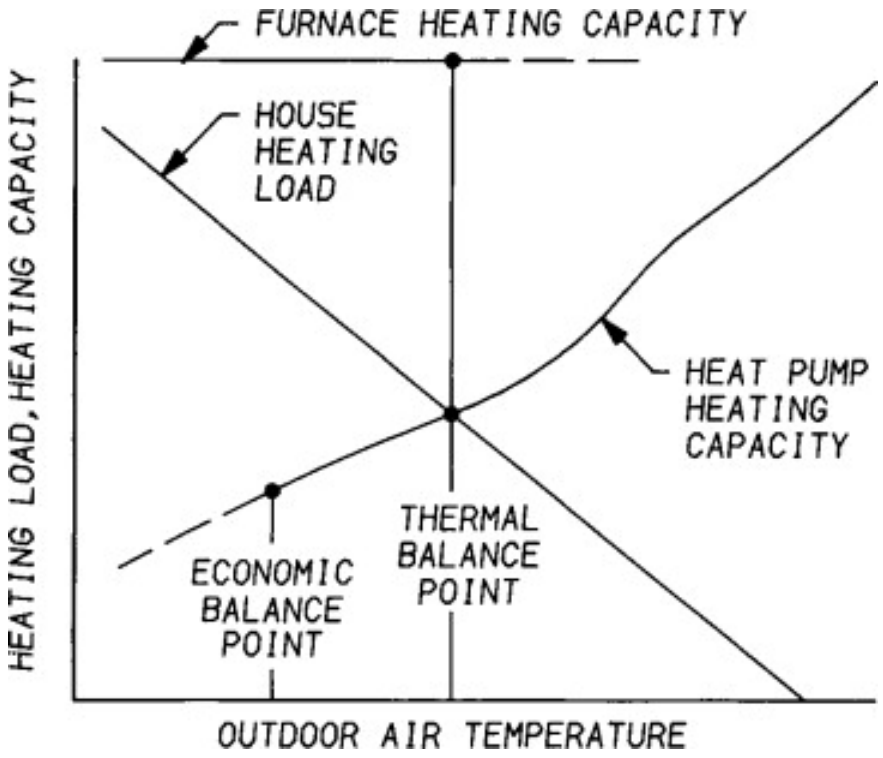
Electrical capacity

- Issues for buildings and the grid
- Gathering data from utility customers with smart meters to understand demand and headroom
- Electrical upgrades could double retrofit cost

TECHNICAL CHALLENGES

Envelope Improvements

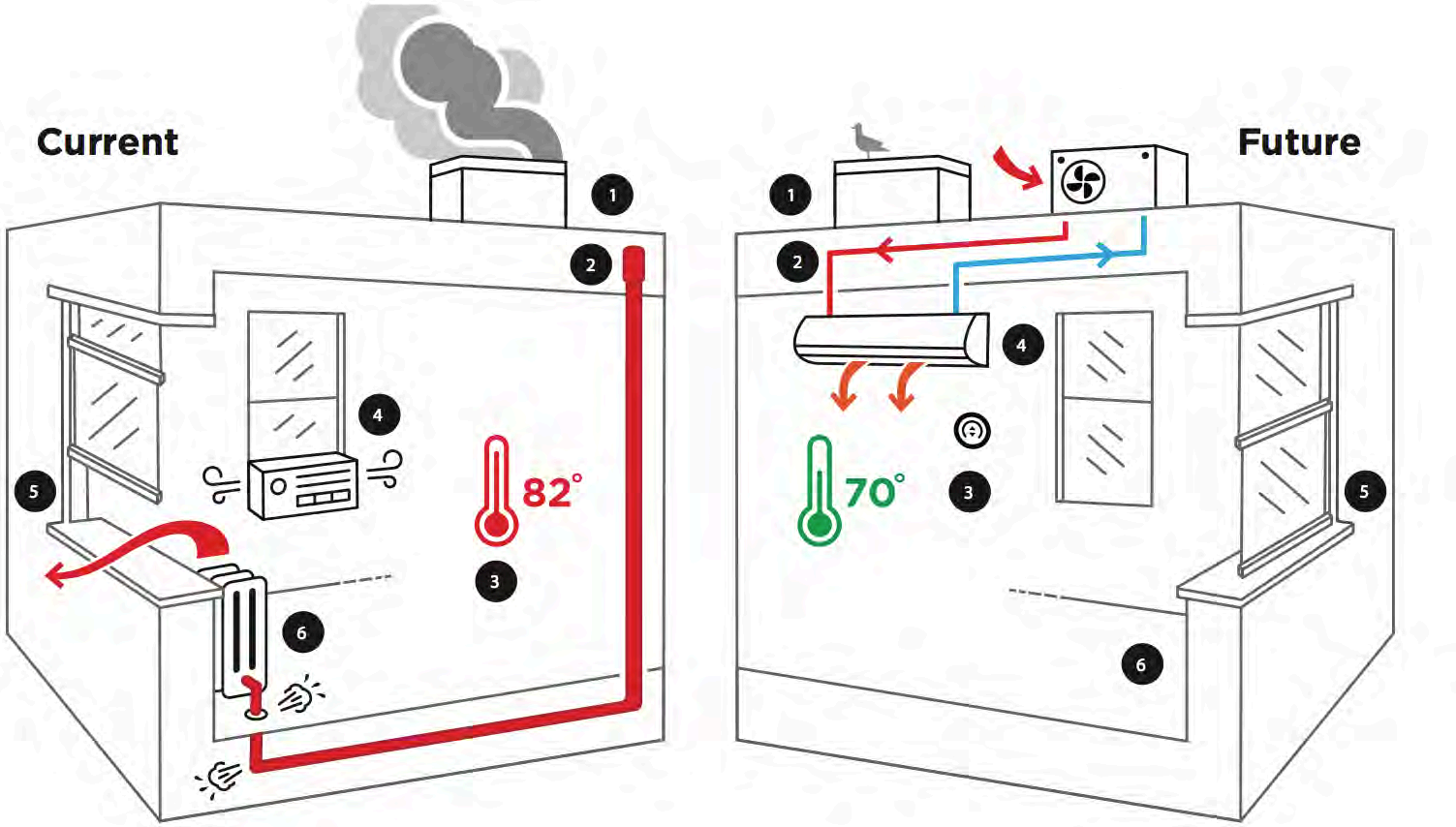
- Trade-off between investing in better envelope and HVAC equipment
- Heating load and heat pump capacity move in opposite directions
- Low-cost improvements like air-sealing should be planned and modeled



FINANCIAL CHALLENGES

Overview

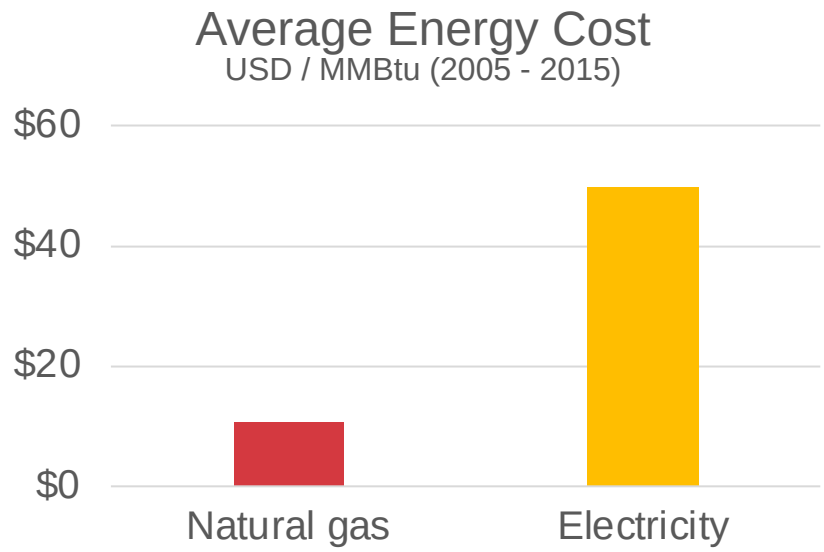
- Capital costs
- Operating costs and gas cost
- Co-benefits
- Tenant relationship and rents

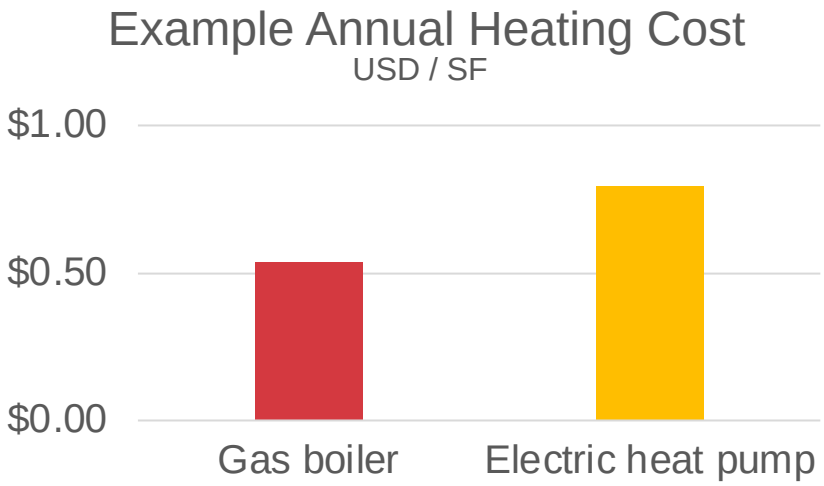


FINANCIAL CHALLENGES

Overview

- Heating – using gas will still be cheaper even with huge increases in efficiency
- Hot water – better business case given summer load
- Natural gas prices continue to fall, but ConEd has introduced ‘Rider Z’

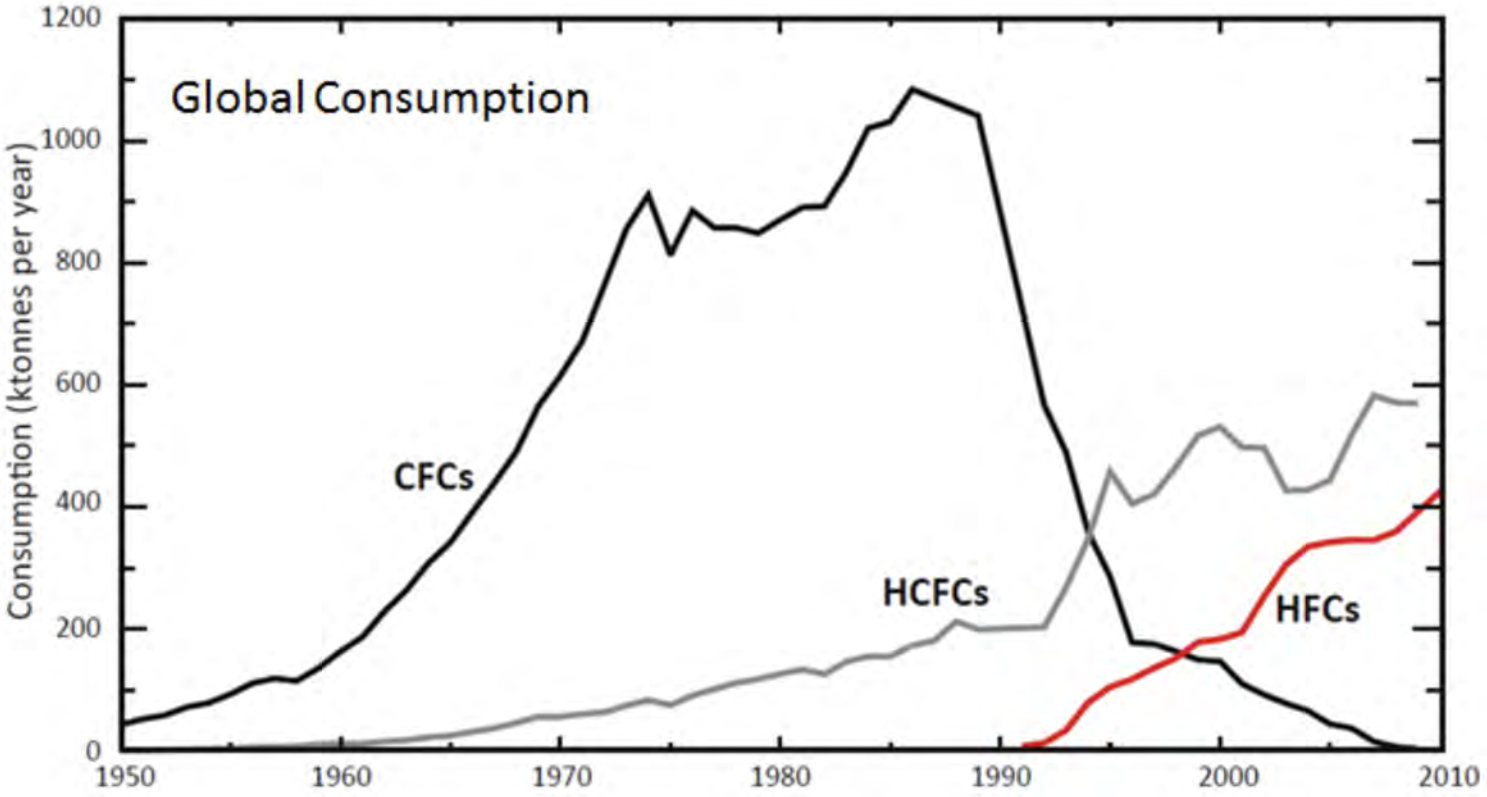




CARBON SAVINGS

Refrigerants

- Fourth Generation refrigerants
- Common assumption is 10% leakage annually and 170% over lifetime of unit.[1]
- Low GWP refrigerants in more efficient equipment



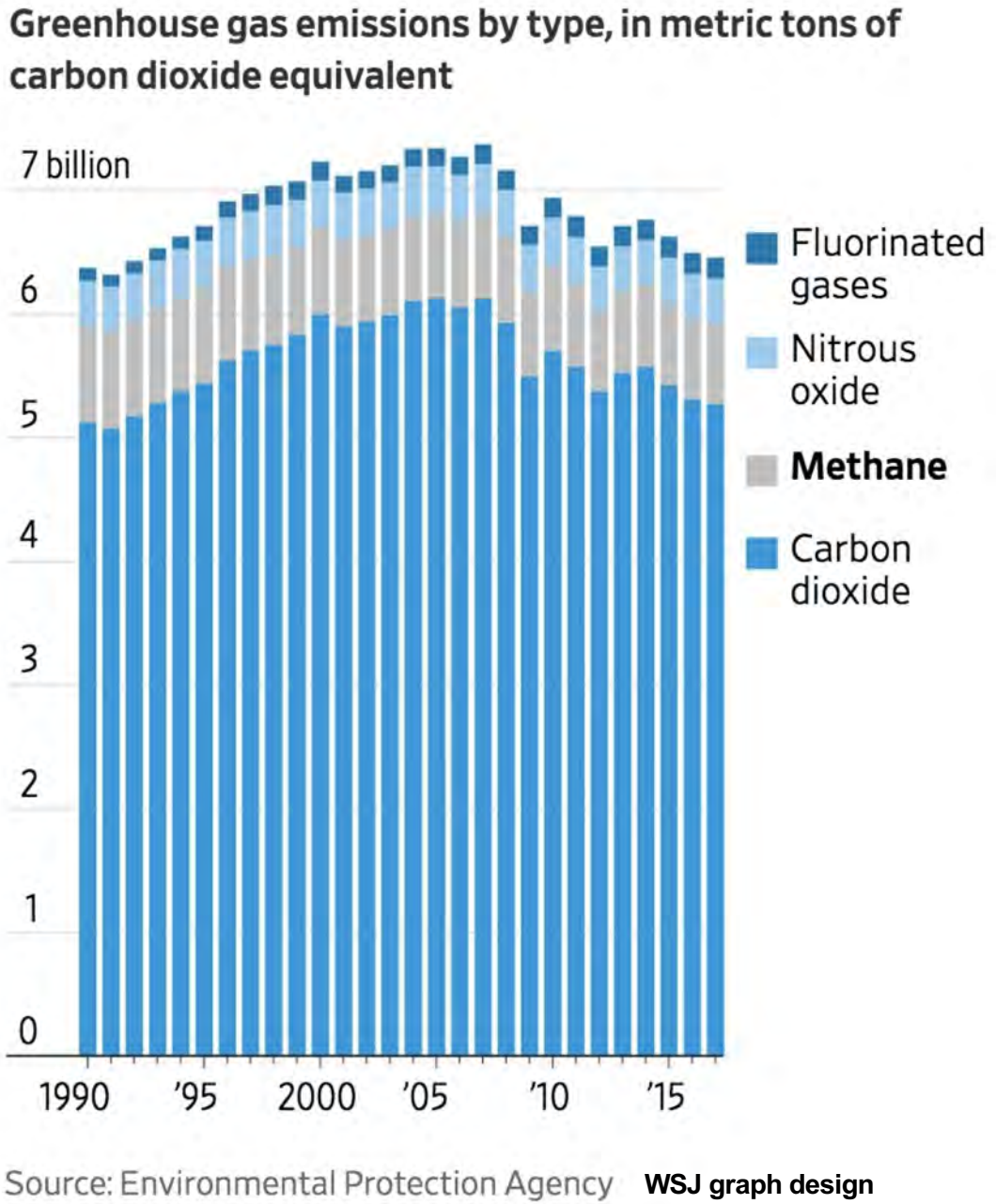
NOTE1: Gallagher et al. (2014), and Intergovernmental Panel on Climate Change - IPCC (2006)

CARBON SAVINGS

Natural gas

- US EPA estimates fugitive gas emissions at 1.4%, but 2018 study found **2.3% - 60% higher**![1]
- EPA considering rolling back methane monitoring rules and exempting old well-sites
- Coal to gas carbon savings wiped out over 20 year period

NOTE1: Assessment of methane emissions from the U.S. oil and gas supply chain - Alvarez et al July 2018.

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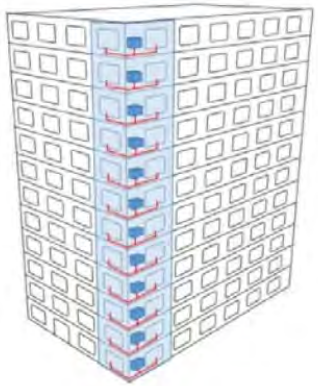
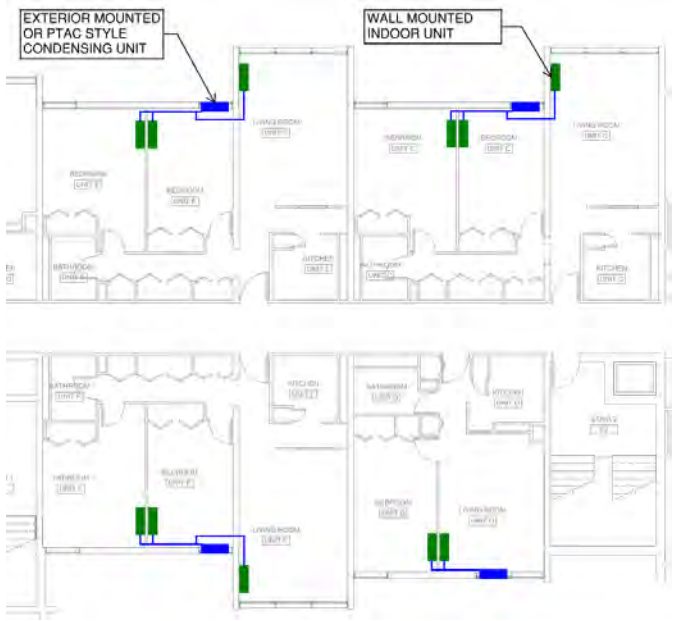
Designing VRF Retrofits for Multifamily Buildings

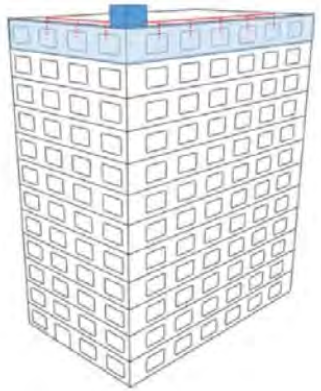
David Goldstein, PE
September 26, 2019

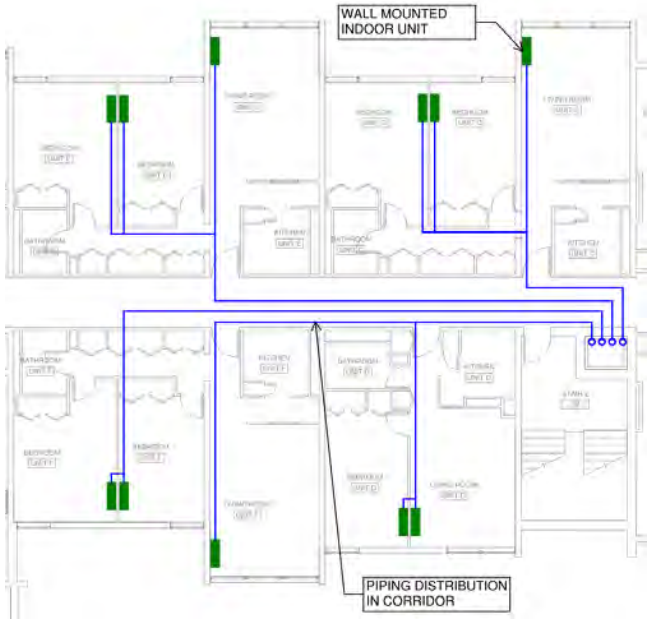
ARUP

Distributed vs Central Condensing Units

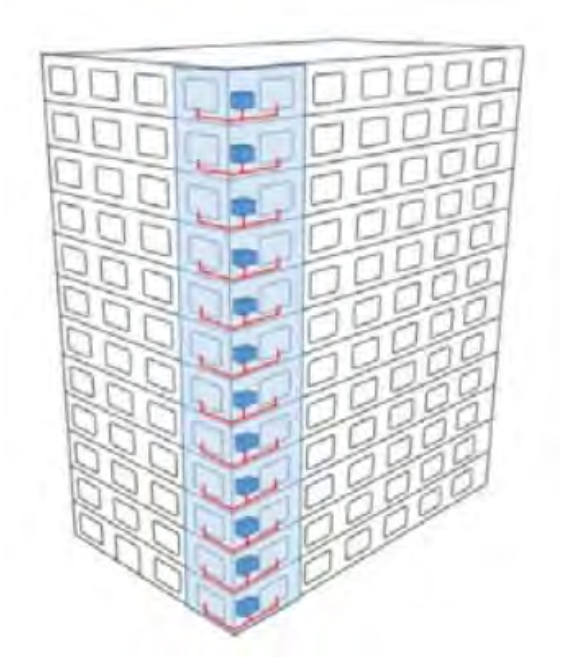








Distributed Condensing Units



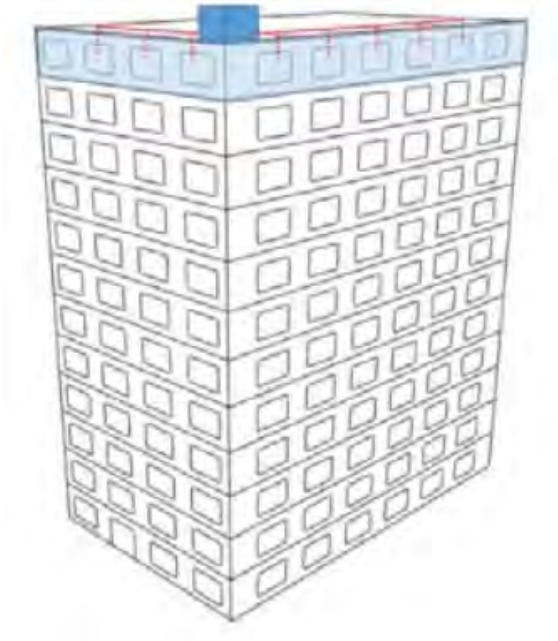
Mounting Options:

- Exterior wall mounting
- Installation on balconies
- Wall opening similar to PTAC

Advantages:

- Less disruptive piping distribution
  - No routing through corridors or risers
- Less overall piping means less refrigerant
  - Simple ASHRAE Standard 15 compliance
- Not restrained by pipe length limitations
  - Max vertical pipe run is typically 150-200 ft
- Does not occupy roof space
- Simpler power distribution
  - Existing capacity may be adequate
- No additional submetering required
- More flexibility with tenants
  - Apartment can be retrofit as they become available

Central Condensing Units



Advantages:

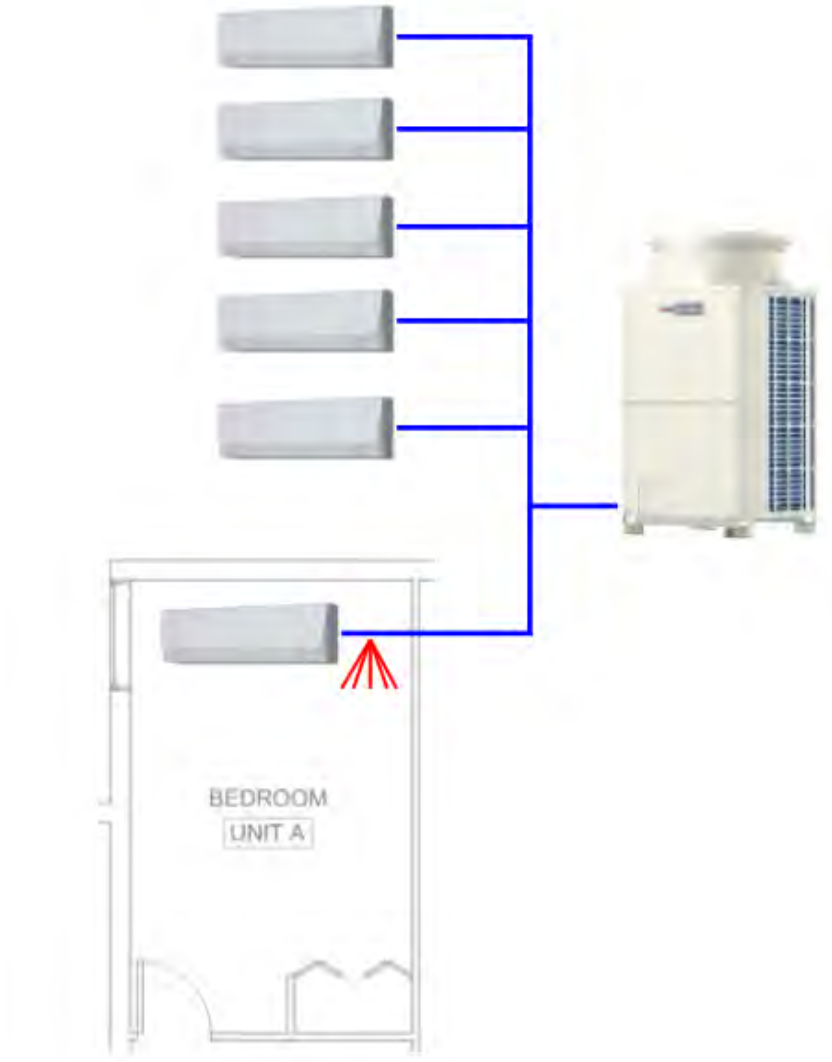
- Little or no façade impact
- Less installation work required within each apartment
  - Only refrigerant lines and wall-mounted unit
- Eliminates regular maintenance within each apartment
  - Regular filter cleaning can be done by tenant
- Easier to access the condensing units
- Easier condensate drainage from defrost

Pipe Routing Options:

- Distributed risers within the apartments
- Central riser with corridor distribution

Refrigerant Safety
ASHRAE Standard 15 & 34

- Current VRF systems use R-410A which is a safety group A1 refrigerant:
  - low toxicity and low flammability
  - Hazard is caused by displacement of oxygen
- ASHRAE Standard 34 defines refrigerant concentration limits (RCL) to ensure occupant safety
  - Also refer to local codes



Refrigerant Safety
ASHRAE Standard 15 & 34

- Example
  - 150 sq ft bedroom with 8 ft ceiling height = 1200 cubic ft
  - Refrigerant concentration limit (RCL) = 26 lbs / 1000 cubic feet
  - Maximum system refrigerant charge for this apartment is 31.2 lbs
  - Preliminary estimate of 5 lbs of refrigerant per ton
    - Verify actual charge after system design is complete
  - Maximum system capacity of **6 tons**
- Strategies to comply with refrigeration volume limits:
  - Split condensing units into smaller capacities
  - Reduce piping lengths
  - Reduce the system capacity by improving envelope
  - Connect smaller rooms with door undercuts or transfer grilles

Thank you!

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Heat Pump Retrofits: the owner's perspective

Kelly Dougherty

What Does a Co-op/ Condo Board Consider?

Approve

- Clarity
  - What is VRF
  - Installation Cost
  - Utility Cost/Savings
  - Operational Costs/Savings
  - Tenant Disruption
  - Process Changes: Billing etc.
  - Timeline: When to Act
  - Benefits of Electrification
  - Success Stories
- Incentives
- Connection to Local Laws

Disfavor

- Conflicting Information
  - Engineering Study vs. Contractor
  - Complicated Information
- Disruption to Tenants
- Increased Cost to Operate
- Complicated Billing Systems/added expense
- Refrigerant Health Risks
- More Expensive Option Than “for-like” replacement

Board members have an important responsibility to their fellow building owners. Board members must understand and agree with the benefits of converting.

Queens Co-Op I – Feasibility Report Costs

Option 1 – Replace Boiler	
Boiler Demo	$50,000
New Boiler	$165,000
Chimney Liner	$65,000
Boiler Room Code Upgrade	$35,0000
Distribution	$95,000
Design/Soft Cost	$30,000
Contingency	$55,000
Total	**$495,000**

Option 2 – New VRF System	
Boiler Demo	$50,000
VRF	$1,540,000
New DHW	$80,000
Design/Soft Cost	$80,000
Contingency	$250,000
Total	**$2,000,000**

Queens Co-Op I – Operating Cost

VRF System Heating Energy Summary				
	Weather-Normalized Annual Heating Energy Consumption		Annual Heating Energy Cost	Energy Cost Rate ($/MMBTU)
Existing Steam Boiler	69,600 therms	7,000 MMBTU	$68,900	$9.90 (nat. gas)
VRF System	514,000 kWh	1,800 MMBTU	$97,700	$55.69 (elec)
VRF Savings		5,200 MMBTU	-$28,800	

Queens Co-Op I: DECISION

Option 1 – Replace Boiler	
Boiler Demo	$50,000
New Boiler	$165,000
Chimney Liner	$65,000
Boiler Room Code Upgrade	$35,0000
Distribution	$95,000
Design/Soft Cost	$30,000
Contingency	$55,000
Total	**$495,000**

1. VRF was too expensive for shareholders
2. Board couldn't visit a retrofitted multifamily building in NY
3. The added cost to operate the units was difficult to explain to shareholders
4. Sponsor did not agree with VRF
5. Disruption to shareholders was too great
6. Providing/managing AC in the units is not in the buildings bylaws and was not an added responsibility the board wanted to take on.
7. Façade repairs for PTAC sleeves was not included in the budget.

Queens Co-op II – Feasibility Report Estimates

For like replacement (w/o chiller):
$2,621,440

Vs.

VRF Replacement:
$2,565,400

Project Cost Estimate				
Item	Quantity	Unit	Unit Cost	Totals
Replace Steam Boiler	1	ea	$ 300,000	$ 300,000
Line Chimney	130	ft	$ 1,000	$ 130,000
Replace Pumps	3	ea	$ 50,000	$ 150,000
Replace Cooling Tower	1	ea	$ 150,000	$ 150,000
Replace C/HW and Condensate Main Piping	1200	ft	$ 100	$ 120,000
Replace C/HW and Condensate Risers	11	ea	$ 50,000	$ 550,000
Replace Fan Coil Units	216	ea	$ 3,000	$ 648,000
Subtotal				$ 2,048,000
Contingency Fee	20%			$ 409,600
Design Fee	8%			$ 163,840
Total:				$ 2,621,440

Project Cost Estimate				
Item	Quantity	Unit	Unit Cost	Totals
Demolish Steam Boiler & Piping	1	ea	$ 50,000	$ 50,000
Demolish Chiller & Pumps	1	ea	$ 50,000	$ 50,000
Demolish Cooling Tower	1	ea	$ 50,000	$ 50,000
VRF Condenser Units	22	ea	$ 25,000	$ 550,000
VRF Indoor Units	166	ea	$ 7,500	$ 1,245,000
DHW Water Heater	1	ea	$ 75,000	$ 75,000
Line Chimney	130	ft	$ 750	$ 97,500
Subtotal				$ 2,020,000
Contingency Fee	20%			$ 404,000
Design Fee	7%			$ 141,400
Total:				$ 2,565,400

Queens Co-Op II: **DECISION**

- ASHP system throughout the building
- Decentralize cooling system w/ window PTAC

How? requiring shareholders to purchase and install window units.

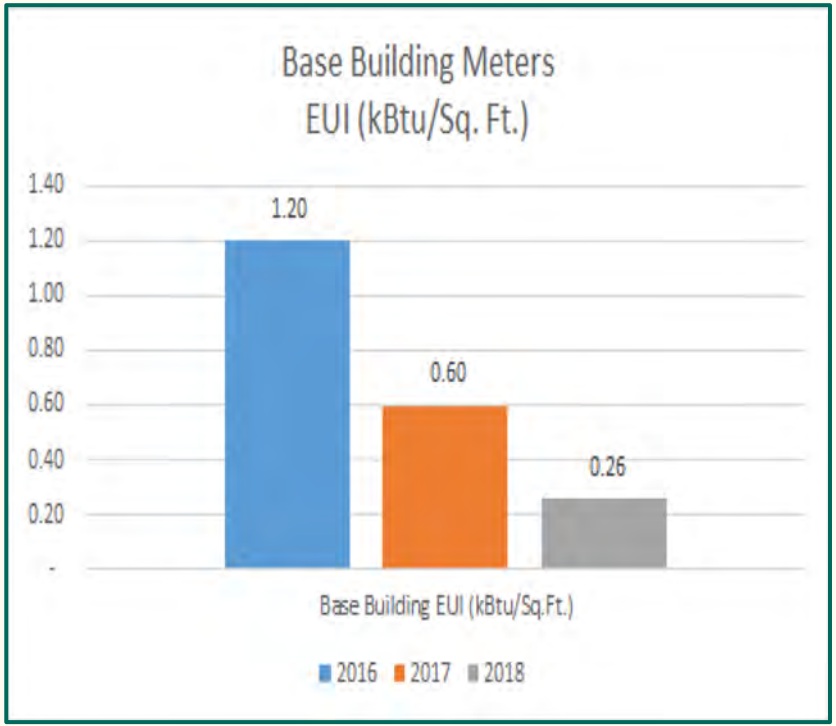
Unexpected Benefit: behavioral impact, shareholders now have complete cooling control and are paying for their individual use.

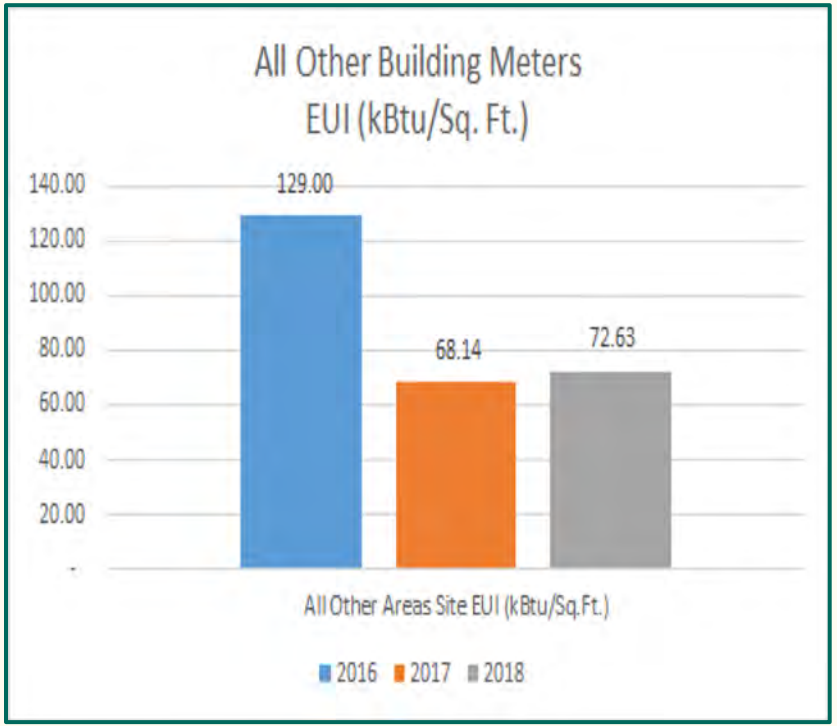
A couple of things to note:

1. Will apartment values drop without central air?
2. Not every room/window can accommodate a window A/C
3. Without running the cooling plant the building is saving $119,200 annually*

**Unit owner additional spend (electric) for window A/C has not been included in this figure.*

Queens Co-Op II – EUI Reduction





Considerations to Include in Full Analysis

On-Going Operational Cost Items

- **Steam Systems:** Boiler Cleaning, Tuning, Chemical Treatment, Tube Replacements, Steam Trap Replacements, etc.
- **Hydronic Systems:** Water Treatments, LL77 Compliance, Bi-Annual Unit Maintenance, Cooling Tower Maintenance/Repairs, Chiller Maintenance/Repairs, etc.
- **ASHP:** Annual Maintenance/Repairs

Other Useful Information

- Useful life comparison between systems
- Provide a reasonable increased value analysis from a realtor for decentralized heating and cooling apartments
- Include the possible LL97 GHG fines that may be avoided by converting to electric heating and cooling

Combining Measures in Feasibility Study

- Potential increase of efficacy of projects due to combining measures
  - Whole building weatherization
  - Windows
  - Facade Repairs/ Insulation
  - Low hanging fruit
    - Lighting
    - Controls
    - Pipe Insulation
    - Retro-commissioning

Non-energy related benefits

- Tenant Comfort & Control
- Behavioral Energy Reduction Leading to Higher LL133 Scores/Grades
- GHG emissions + Potential Fines
- Apartment value
- Operational costs

Conclusions

1. Consistency needed between Engineers & Contractors
2. ASHP may not be a financial fit for every type of building or system
3. Inclusion of non-energy related benefits is very important
4. Inclusion of all cost expenditures including PTAC, Fan Coil, WSHP, etc.

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