Create a large scale, self-sustaining market for high performance retrofit solutions

Industry-designed, cost-effective, long-lasting retrofit solutions for tenanted buildings reaching or approaching net zero energy.

Implement solutions on a large scale to drive industrialization, reduce cost, and standardize and guarantee long-term performance.
Revolutionizing the way multifamily buildings are renovated in NYS

- Keeping residents in their homes
- Minimizing tenant disruption
Adapting the successful Energiesprong model for New York State

- 2,500 rehabs
- 2,500 new construction
- 20,000 in pipeline
Transfer of Knowledge from Energiesprong

- Workshops in NYC or webinars led by Energiesprong program officials and/or industry professionals.
- Case studies and reports
- Energiesprong team mock design on NYC building (Bronx)
- Netherlands field trip (week of August 27)
Field Trip to the Netherlands

Itinerary
1. Amsterdam
2. Soesterberg
3. Utrecht: BAM-Rennovates Conference
4. Groningen
5. Assen
6. Lemelerveld: RC Panels Factory
7. Utrecht: Mitros Housing Association
8. Tiel: Factory Zero
9. Amsterdam
10. Zoetermeer
11. Amsterdam
Field Trip to the Netherlands

- Garden style apartments - Soesterberg
Developing new business models in the multifamily sector to tackle climate challenges of today.
RetrofitNY’s Role
Market Transformation & Aligning the Market
Midway into the Pilot Phase

- **Preparation**

- **Pilot Projects**
  - First Projects

- **First Market**

- **Market Growth**

  **Design RFP:** First projects start June 2018
  First of a series

  **Unlocking Additional Markets**
  - NYC Housing Authority (178,000 apartments)
  - State University of New York (400 buildings, 70,000 beds)

  **Volume Market for “Net Zero” Retrofits**
Affordable Housing Buildings

- 1-2 story garden style
- 3-7 story building
- Simple architecture

Match

6 months design period

- Can design and install the solution
- $75,000 stipend for design
- Open source design

Qualified Industry Teams

- Designs that can be approved and executed
- Trust and understanding of the financial models
- Clarity on what regulations may need adjustment
- Solutions adaptable to other buildings
6 months design period

Supporting the Teams
- Transfer of knowledge from Energiesprong
- Coaches
- $75,000 stipend
- IPNA for Buildings

Making the Deal
- Regular touch base
- HPD, HCR and HUD
- Financing partners
- Permitting agencies

Encourage collaboration between teams and open communication with owners and agencies

Deal Closing + Construction
Gap Funding Available
Milestones Summary

1. Start Up
   - Conducting IPNAs in selected Buildings as required by HPD & HCR and to support Teams
   - Assigning each Team a coach

2. Conceptual Design – end of Month 3
   - Demonstrate the strategy for implementing the proposed retrofit
   - First estimate of the solutions costs and performance
   - Start identifying hurdles to building the retrofit

3. Schematic Design – end of Month 6
   - Set of documents needed to start closing the transaction and move to construction
Key Elements of a Net-Zero Building

- Air sealed & high performance building envelope
  - Panelized construction
  - Site applied façade
  - High performance windows & doors

- Efficient mechanical & ventilation systems
  - Electrified buildings
  - Heat pump technology
  - Energy recovery ventilation

- On-site energy generation
  - Solar PV
Costs Premium Today

100% Electrified solution

- Average incremental costs across pilot projects at conceptual design: $60K/DU

Understanding main cost drivers

- Domestic hot water delivery
- Panels

Getting projects to construction

- Design flexibility
- NYSERDA gap funding
- Underwriting performance
Opportunity In Scope Overlap + Our Commitment to Getting Projects Built

- Incremental cost of NZE retrofit vs. BAU
- Monetized operational savings + NYSERDA funding to bridge the gap
- NZE Retrofits will be more cost-effective in coming years via cost compression, innovation, standardization, and scale

Incremental cost

- Incremental cost of NZE retrofit vs. BAU
- Monetized operational savings + NYSERDA funding to bridge the gap
- NZE Retrofits will be more cost-effective in coming years via cost compression, innovation, standardization, and scale
RetrofitNY Financing Working Group

Launched September 13, 2018

1. Understand the business case for net-zero buildings
2. Identify challenges with financing a net-zero pipeline
3. Propose and develop innovative scalable financing solutions that:
   ▪ monetize the operational savings from net-zero/ deep energy retrofits
   ▪ help fund the incremental upfront cost
$26M in Gap Funding Over 5 Years

- $30.5 Million allocated to program through 2025
- $26M to ensure solutions designed are built
- $4.5M designated for program implementation
- Gap funding solicitation in Q4 2018
Cost Compression is Key

Achievements of the Energiesprong program

- Cost reduction: Net Zero buildings at 40% of the cost of initial pilots
- The market is scaling up
  - 2,500 retrofits completed
  - 2,500 n/c projects completed
  - 20,000 projects in the pipeline
Where we want to go

- scale essential to transforming industry
- Achieving manufacturing efficiencies
Program Focus on Pipeline Building and Manufactures Needs

1. Understanding manufactures needs
2. Aggregation of guaranteed pipeline
   - HCR
   - HPD
   - SUNY
   - NYCHA
   - Military Housing
   - Other States
Near-Term Program Objectives

- Demand pipeline aggregation
- Scalable financing models
- Technical solution providers & Manufacturers
Thank you
RetrofitNY@nyserda.ny.gov
RetrofitNY
PRE-WAR MASONRY (BROX NY)

PROJECT TEAM: BRIGHT POWER / VOLMAR / MAGNUSSON ARCHITECTURE & PLANNING / DAGHER ENGINEERING / OLIVE BRANCH CONSULTING
EXISTING CONDITIONS

- DUE FOR DEEP RETROFIT
- MASONRY LOAD BEARING EXTERIOR WALLS
- WOOD JOISTS FLOORS + ROOF
- PRE-WAR BUILT 1913
- 5 STORY + BASEMENT

- 8”+ BETWEEN PROP LINE AND FAÇADE
- NEW KITCHENS AND BATHS NEEDED
- GAS FIRED BOILER NEEDS REPLACING
- NEW WINDOWS + ROOF NEEDED

- WASTE MANAGEMENT NEEDED
- PEST ISSUES
- ILLEGAL WASHERS IN MANY APARTMENTS
- LARGE UNUSED AREAS IN BASEMENT
INTEGRATIVE PROCESS

Law of Three:
This framework imagines the necessity of restraints to engage and develop creative outcomes through a process of reconciling (or harmonizing) processes by focusing on Potential:

- Reconciling/Harmonizing Force (aimed at Potential)
- Activating Force
- Restraining Force
- Compromise (everyone loses something)

(framework from Carol Sanford, The Responsible Business)

- The Users (building occupants)
- The Co-creators (design, construction, operations team)
- The Community (community members within which the building is nested)
- The Earth’s value-adding processes (soil health, clean water, clean air, healthy habitat, etc.)
- The Investors (Owner, NYSERDA – and others, including taxpayers)

Coach: 7Group (John Boecker)
PROJECT GOALS

- TO: develop a replicable approach for designing, constructing, and operating an earth-centric tenant-in-place, affordable multi-family housing retrofit.

- IN A WAY THAT: invites meaningful discovery through a co-creative process that benefits all stakeholders and values the roles of all participants

- SO THAT: the project serves as an instrument for cost-neutral, net zero energy, regenerative retrofits becoming the standard in NY and beyond.
DESIGN – PATH TO NET ZERO

A BALANCE OF KEY INTERVENTIONS:
- ENVELOPE
- VENTILATION + IAQ
- SPACE HEATING + COOLING
- DOMESTIC HOT WATER
- MISC ELECTRIC LOADS
- DISTRIBUTED ENERGY RESOURCES

RESULTANT METRICS:
- BUILDING PERFORMANCE
- LIFE CYCLE COST ANALYSIS
- CONSTRUCTION BUDGET
- CONSTRUCTION SCHEDULE

Current EUI 26.2 (w/o solar)
Current ROI over 30 yrs
### Parametric Analysis

<table>
<thead>
<tr>
<th>Component</th>
<th>Baseline</th>
<th>Option B Without Renewables</th>
<th>Option C Without Renewables</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bundle 1</td>
<td>Option A</td>
<td>Bundle 1</td>
<td>Option B</td>
</tr>
<tr>
<td>Exterior insulation of 1st floor street facade</td>
<td>6&quot;</td>
<td>6&quot; + interior insulation</td>
<td>0.03%</td>
<td>0.03%</td>
</tr>
<tr>
<td></td>
<td>all the way down past grade (sidewalk and courtyard) on all facades 3'</td>
<td>down to grade</td>
<td>-3.6%</td>
<td>-3.6%</td>
</tr>
<tr>
<td>Roof insulation</td>
<td>R-50+ Stone Wool 4&quot;</td>
<td>R-50+ nothing</td>
<td>-0.11%</td>
<td>-0.11%</td>
</tr>
<tr>
<td>Windows</td>
<td>Tilt &amp; Turn / Casement (tripple glazed) U-0.203 SHGC 0.206</td>
<td>Tilt &amp; Turn / Casement (double glazed) U-0.277 SHGC 0.258</td>
<td>-0.9%</td>
<td>-0.9%</td>
</tr>
<tr>
<td>Slab Insulation</td>
<td>rigid stone wool: R16 (4&quot;) over existing slab + floated floor</td>
<td>No slab insulation</td>
<td>-2.2%</td>
<td>-2.2%</td>
</tr>
<tr>
<td>Heating &amp; Cooling</td>
<td>VRF</td>
<td>Mini Splits</td>
<td>-3.1%</td>
<td>-3.1%</td>
</tr>
<tr>
<td>DHW Heating</td>
<td>HP Water Heater</td>
<td>Electric Resistance</td>
<td>-37.9%</td>
<td>-37.9%</td>
</tr>
<tr>
<td>Washers and Dryers</td>
<td>1 laundry room for 2 buildings</td>
<td>in unit</td>
<td>$</td>
<td>-</td>
</tr>
<tr>
<td>Grey water heat recovery</td>
<td>Grey water heat recovery</td>
<td>No recovery</td>
<td>-7.0%</td>
<td>-7.0%</td>
</tr>
<tr>
<td>Shades</td>
<td>No shades</td>
<td>Horizon and Vertical Shades</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Metal Girts</td>
<td>Thermally broken Girts</td>
<td>Metal Girts</td>
<td>-0.14%</td>
<td>-0.14%</td>
</tr>
</tbody>
</table>

Interior insulation not required in addition to ext insulation:
Interior insulation instead of ext may be okay.

3' past grade should be selected

Adding insulation on deck has no impact => remove deck insulation

Triple pane adds significant energy savings => keep

Slab Insulation adds significant energy savings => keep if possible.

VRF is significantly more efficient than mini-splits and heat pump to water => choose VRF

Heat pump water heater has a VERY significant impact on energy savings => use heat pumps.

Option already selected (central laundry)

Grey water adds significant energy savings.

b. Heating penalty outweighing cooling savings => include?
DESIGN – PATH TO NET ZERO

![Energy Use Chart](chart.png)

- **Energy Use**
  - **End Uses**
    - Heating
    - Cooling
    - Lighting
    - Hot Water
    - Appliance
    - Fans
    - Pumps
    - Solar

![EUI (kBTU/sq ft) Chart](chart_2.png)

- **EUI (kBTU/sq ft)**
  - **PV Not Included**
    - Existing Condition Baseline: 133
    - Baseline Renovation Scope: 85
    - Deep Retrofit: 26
DESIGN – PATH TO NET ZERO

ENVELOPE (AIRTIGHT & INSULATED)
• ROOF + PARAPET
• FIRE ESCAPE
• MEETING GRADE
• PROPERTY LINE
• NEIGHBORING BUILDING
• WINDOWS + STOREFRONTS

PROGRAM
• TRASH CHUTE
• LAUNDRY ROOM

MOST COST EFFECTIVE SOLUTION FOR LOWEST EUI + PROGRAM
NEIGHBORING LOT LINE - ADIABATIC

ROOF – PREVENT CONDENSATION AT SHEATHING
Emitted Energy/GWP

Emissions we produce between now and 2050 will determine if we meet the Paris Climate Accord

(....and prevent the worst effects of climate change.)

Path to Carbon Neutral
How long is Carbon Payback of our Intervention?

Business as Usual Emissions
Source: AIA Architecture 2030

Yearly Emissions
## ENVELOPE – PATH TO NET ZERO

<table>
<thead>
<tr>
<th>Material</th>
<th>Full Name</th>
<th>As Built/As Proven</th>
<th>R&amp;D/Commercialization</th>
<th>Life-Cycle Benefits</th>
<th>Net Zero Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprayfoam</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Celulose</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EPS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stone Wool</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### R&D/Commercialization
- Sprayfoam: High innovation in insulation technology, research on improved thermal performance, and development of more sustainable production methods.
- Celulose: Active R&D on energy-efficient production processes and innovation in insulation systems.
- EPS: Commercialization of advanced materials and technologies, ongoing developments in lightweight insulations.
- Stone Wool: High innovation in insulation technology, research on improved thermal performance, and development of more sustainable production methods.

### Life-Cycle Benefits
- Sprayfoam: Reduction in energy consumption, improved thermal insulation, and contribution to net zero goals.
- Celulose: Increased energy efficiency, reduced embodied energy, and improved thermal comfort.
- EPS: High innovation in insulation technology, research on improved thermal performance, and development of more sustainable production methods.
- Stone Wool: Reduction in energy consumption, improved thermal insulation, and contribution to net zero goals.

### Net Zero Potential
- Sprayfoam: Potential for significant contribution to net zero targets, with ongoing developments in production processes and materials.
- Celulose: Significant potential for net zero initiatives, with focus on sustainable production and energy efficiency.
- EPS: High potential for net zero, with ongoing developments in production processes and materials.
- Stone Wool: Significant potential for net zero, with ongoing developments in production processes and materials.

### Notes
- Sprayfoam: Ongoing research on improved thermal performance and sustainable production methods.
- Celulose: Increased focus on sustainable production processes and energy efficiency.
- EPS: High innovation in insulation technology, with ongoing developments in lightweight insulations.
- Stone Wool: Ongoing research on improved thermal performance and sustainability.

---

**SPRAYFOAM**

**CELULOSE**

**EPS**

**STONE WOOL**
Petroleum products

(Review XPS in this chart, are they indicating new blowing agent HFO? Current HCF 134a is over 1,450k GWP)

Also of concern are toxic and bio-cumulative flame retardants in XPS + EPS.

Source: Materialspallette.org/insulation
INDUSTRIALIZE + SCALE

Exhibit 9

In the United States, labor productivity in construction has declined since 1968, in contrast to rising productivity in other sectors.

Gross value added per hour worked, constant prices
Index: 100 = 1947

<table>
<thead>
<tr>
<th></th>
<th>Compound annual growth rate, 1947–2010</th>
<th>Total change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>4.5</td>
<td>16.1x</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>3.5</td>
<td>8.6x</td>
</tr>
<tr>
<td>Wholesale and retail</td>
<td>3.4</td>
<td>8.0x</td>
</tr>
<tr>
<td>Overall economy</td>
<td>1.9</td>
<td>3.3x</td>
</tr>
<tr>
<td>Mining</td>
<td>0.5</td>
<td>1.4x</td>
</tr>
<tr>
<td>Construction</td>
<td>0.1</td>
<td>1.1x</td>
</tr>
</tbody>
</table>

Many sectors have transformed and achieved quantum leaps in productivity; construction has changed little, limiting productivity gains.

Key advances, 1947–2010

<table>
<thead>
<tr>
<th>Agriculture</th>
<th>Manufacturing</th>
<th>Retail</th>
<th>Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leveraged scale through land assembly and automation, deployed advanced bioengineering to increase yields</td>
<td>Implemented entirely new concepts of flow, modularized and standardized designs, and aggressively automated to increase production</td>
<td>Utilized scale advantages and cutting-edge logistics to provide affordable goods to the masses</td>
<td>Limited improvements in technological capabilities, production methods, and scale</td>
</tr>
</tbody>
</table>

SOURCE: World KLEMS; BLS; BEA; McKinsey Global Institute analysis

MCKINSEY GLOBAL INSTITUTE - REPORT 2017
“REINVENTING CONSTRUCTION: A ROUTE TO HIGHER PRODUCTIVITY”
INDUSTRIALIZATION
INDUSTRIALIZATION
RetrofitNY
300 & 304 East 162nd St

Project Team:
Volmar, Bright Power, MAP Architects, Dagher Engineering, Olive Branch Consulting

October 15, 2018
Considerations for Design Decisions

- 100% electrification
- EUI of 20
- Budget of $30,000/unit
- Replicability
- Lifecycle analysis
- Embodied energy/global warming potential
- Indoor air quality
- Residents in place
- Durability/sustainability
- Resident engagement
- Aesthetics
- Utility bills (who pays for what?)
- Realistic O&M of new systems
Design Concepts – Heating/Cooling

Variable Refrigerant Flow (VRF)

- Heat pump (no heat recovery)
- Ducted evaporators (indoor units)

Meeting considerations

- Readily available technology
- Reduced loads
- Reduced refrigerant piping
- Increased comfort
- Decent maintenance
- Runs on electricity
Design Concepts - Ventilation

Energy Recovery Ventilation (ERV)

- Centralized (2 units on roof)
- Supply to each living space
- Exhaust in kitchens and bathrooms
- Supply air ducted to evaporator unit

Meeting considerations

- Optimized ductwork
- Efficient system
- Increased indoor air quality
- Accessibility for maintenance
- Readily available technology
- Runs on electricity
Design Concepts - DHW

Heat Pump Water Heater
(air source)

- Units mounted on roof
- Combined with low flow plumbing fixtures

Meeting considerations

- Expensive
- Few multifamily options available
- Winter COP not great
- Runs on electricity
- Extreme affect on building performance
- Plumbing fixture flow rates selected with residents in mind
# Parametric Analysis

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<tbody>
<tr>
<td></td>
<td>Bundle 1</td>
<td>Bundle 1</td>
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<tr>
<td></td>
<td>Option A</td>
<td>Option B</td>
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<tr>
<td>Exterior insulation of 1st floor street facade</td>
<td>6”</td>
<td>6” + interior insulation</td>
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<td>Exterior insulation of the exterior walls - other walls</td>
<td>all the way down past grade (sidewalk and courtyard) on all facades</td>
<td>down to grade</td>
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<tr>
<td>Roof Insulation</td>
<td>R-50+ Stone Wool 4”</td>
<td>R-50 + nothing</td>
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</tr>
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</table>
Results

Energy Savings (%)

- Baseline Renovation Scope: 36%
- Deep Retrofit: 80%
- Deep Retrofit + Solar: 87%

Utility Cost Savings (%)

- Baseline Renovation Scope: 29%
- Deep Retrofit: 30%
- Deep Retrofit + Solar: 53%

Due to electrification!
Results - continued

EUI (kBTU/sq ft)
PV Not Included

Existing Condition Baseline  Baseline Renovation Scope  Deep Retrofit

133  85  26
Thank you!

Andrea Mancino, Director of New Construction

amancino@brightpower.com

646-780-5512

October 15, 2018
The Team
The Building

439 West 125th Street, Manhattan

- Multifamily affordable housing
- 1997 construction
- 23,004 SF, counting basement
- Built to lot line on 3 of 4 sides
The Building

- 6 story elevator building
- 21 residential units
- 2 commercial units
- Community room
Systems

- Natural gas fired boiler
- Baseboard forced hot water distribution
- Natural gas fired DHW storage tanks
- Window and through-wall AC units
- Exhaust fan ventilation
- Hallway ventilation air handler/heater
Access

- Located on busy 125th street
- Construction in rear - no access
- 8’ ceilings
- “Efficient” floor plans
Street Facade

- Built to lot line at street
- Code prohibits post-1968 buildings from overcladding over street line
- Options:
  - Strip brick & EIFS
  - Pursue variance
  - No overclad

3202.2 Encroachments above grade. Encroachments into the public right-of-way above grade shall be prohibited except as provided for in Sections 3202.2.1 through 3202.2.3.

3202.2.1 Encroachments subject to the area limitations. Encroachments that are subject to area limitations are those elements listed in Sections 3202.2.1.1 through 3202.2.1.9, generally of an architectural character, that form an integral part of the building facade. The aggregate area of all such elements constructed to extend beyond the street line shall not exceed 10 square feet (0.93 m²) within any 10 feet (3048 mm) by 10 feet (3048 mm) square area of wall, except that a veneer may be applied to the entire facade of a building erected before December 6, 1968, if such veneer does not project more than 4 inches (102 mm) beyond the street line. The area of any such projection shall be measured at that vertical plane, parallel to the wall, in which the area of the projection is greatest. This plane of measurement may be at the street line, the line of maximum projection or any point in between. For the purpose of measuring the projected area of a balcony, air spaces of less than 6 inches (152 mm) between closely spaced railing or guards elements shall contribute to the area of the projection.
### Street Facade: Energy & Budget Impacts

- 30 year NPV of EIFS energy savings = ~$20,000
- System sizing savings = ~$5,000
- Gap financing required for all scenarios

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Cost</th>
<th>Energy</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strip Brick, add 4” EIFS</td>
<td>~$126,700</td>
<td>-4160 kWh / year</td>
<td>Requires scaffolding</td>
</tr>
<tr>
<td>4” EIFS</td>
<td>~$66,700</td>
<td>-4160 kWh / year</td>
<td>Requires variance, requires scaffolding</td>
</tr>
<tr>
<td>No Overclad</td>
<td>Energy penalty</td>
<td>Energy penalty</td>
<td>Increases HVAC size for front units</td>
</tr>
</tbody>
</table>
Space Conditioning Options

- Unitary heat pumps (i.e. mini-splits)
- Central VRF
- Hydronic with valance
- Hydronic with radiant panels
# Unitary Heat Pumps

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual control</td>
<td>Need to locate ~24 condensers</td>
</tr>
<tr>
<td>Easily available labor for installation and maintenance</td>
<td>Many units to maintain</td>
</tr>
<tr>
<td>Each system simpler</td>
<td>More refrigerant line runs</td>
</tr>
<tr>
<td></td>
<td>Less replicable</td>
</tr>
</tbody>
</table>
Radiant Panels

- Heated/Chilled Water System
- Ceiling mounted radiant panels

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential reuse of pipe distribution system</td>
<td>High up-front cost</td>
</tr>
<tr>
<td>No refrigerant distributed to apartments</td>
<td>Issues with UL and other necessary certifications for use in NYC</td>
</tr>
<tr>
<td>Comfort</td>
<td>Dehumidification critical</td>
</tr>
</tbody>
</table>
## Valance

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual controls</td>
<td>Unfamiliar technology for users</td>
</tr>
<tr>
<td>Use of water instead of refrigerant distribution</td>
<td>Unfamiliar technology for design - some unknowns</td>
</tr>
<tr>
<td></td>
<td>Can’t reuse existing hydronic piping</td>
</tr>
<tr>
<td></td>
<td>Installation labor may be more expensive</td>
</tr>
<tr>
<td></td>
<td>Water leaks a potential problem</td>
</tr>
</tbody>
</table>
Central VRF

- Central VRF was established as primary strategy
- Least occupant disturbance
- Easier for maintenance
- Most replicable

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar technology</td>
<td>Limited to 2 zones (no space for branch controllers)</td>
</tr>
<tr>
<td>Thermostatic controls in each room</td>
<td>No simultaneous heating/cooling within each zone</td>
</tr>
<tr>
<td>Central system for maintenance</td>
<td>Use of refrigerants - large volume, requires through-wall vents</td>
</tr>
<tr>
<td>Consolidated refrigerant lines</td>
<td></td>
</tr>
</tbody>
</table>
Central VRF

- Wall or floor mounted air handlers possible
- Through wall vents
- Exterior refrigerant lines
Ventilation System Options

- HRV vs ERV
- Unitary ventilators
- Central ventilators
## Ventilation - Unitary systems

<table>
<thead>
<tr>
<th><strong>Pros</strong></th>
<th><strong>Cons</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher efficiency</td>
<td>Need to locate unit in apartments - no space</td>
</tr>
<tr>
<td>Reliable commissioning</td>
<td>Ductwork takes up interior space</td>
</tr>
<tr>
<td></td>
<td>Disruptive to tenants - work in apartments</td>
</tr>
<tr>
<td></td>
<td>Maintenance in apartments</td>
</tr>
<tr>
<td></td>
<td>More expensive</td>
</tr>
<tr>
<td></td>
<td>More difficult to add dehumidification capability</td>
</tr>
</tbody>
</table>
Ventilation Central system

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central system for maintenance - not in apartments</td>
<td>Challenging to design supply ducts</td>
</tr>
<tr>
<td>Reuse existing exhaust ducts</td>
<td>Less efficient</td>
</tr>
<tr>
<td></td>
<td>Harder to commission flows</td>
</tr>
</tbody>
</table>
Ventilation

- Collect exhaust ducts at two locations
- Plan shows four VRFs - may reduce to two
- Two ventilation/dehumidification units
- FDNY access paths
Domestic Hot Water

- Solar hot water not chosen due to need to maximize space for PV
- Ground source heat pump no replicable
- Heat pump water heater selected

<table>
<thead>
<tr>
<th></th>
<th>Energy (kBTU)</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing</td>
<td>667,471</td>
<td>$8,476</td>
</tr>
<tr>
<td>Proposed (Modeled)</td>
<td>94,216</td>
<td>$6,428</td>
</tr>
</tbody>
</table>
Energy Modeling

- Existing energy performance taken from historic utility bills
- WUFI used to model post-retrofit performance
Finance Targeting

- $40,000 /DU business as usual budget
- ~$29,000 /DU net present value energy savings
- ~$46,000 /DU gap financing
Finance Targeting

- Adjusted budget, assuming no monetized energy savings
- ~$93,000 / DU
- ~$53,000 / DU incremental gap