**Sendero Verde:**
America's Largest Passive House Complex and a Model for Sustainable Affordable Housing

Getting to Zero Forum NYC

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**Why Are We Here?**
Greenhouse gas emissions

Since buildings make up a majority of the world’s carbon output, making them even just a little bit more efficient would have an out-sized result.

Large Scale Passive House: NYC & Beyond

THE HOUSE AT CORNELL TECH, NYC
- 270,000 SF
- 352 Units; 500 beds
- 26 Floors
- Graduate Student & Faculty Housing
- PH System: PHI
- LEED Project of the Year 2017

SENDERO VERDE, NYC
- 812,250 SF
- 700 Units
- 3 Buildings: 37 Floors, 16 Floors and 10 Floors
- 100% Affordable Housing & Community Facilities
- PH System: PHI

WINTHROP CENTER, BOSTON
- 1,882,150 SF Total
- 735,000 SF of Commercial Office Passive House
- 21 Floors
- Mixed-Use Office, Retail & Condo
- PH System: PHI

UNIVERSITY OF TORONTO (UTSC)
- 270,000 SF
- 369 Units; 752 Beds
- 9 Stories
- Undergraduate Dorm & Cafeteria
- PH System: PHI
**PROJECT SUMMARY**

Overall: 750,851 GSF  
Residential: 653,162 GSF  
Community Facilities: 78,829 GSF  
Commercial: 18,860 GSF  
709 Units - 100% Affordable

**USERS**

- Students  
- Residents  
- Seniors  
- Neighbors

**Sendero Verde: Project Summary**

- **COMMON AREAS**
- **APARTMENTS**
- **GREEN / OPEN AREAS**
- **OFFICE**
- **COMMUNITY FACILITY**

**Publicly Accessible Courtyard**

- Madison Ave. entrance accessible by ramp  
- Community Garden  
- Park Ave. entrance accessible by elevator/stair
Passive House as a pathway towards NetZero

**PUBLIC**
More Efficient Source

Transition to more renewable, low-carbon energy sources

**PRIVATE**
More Efficient Use

Design more energy-efficient buildings

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Tackle the Issue
Residential Decarbonization Framework

**Assessment & Planning**
- Residential Vision
- Existing Conditions Investigation
- Data Collection & Analysis
- Central Plant Assessment
- Decarbonization Planning

**Load Reduction**
- HVAC Scheduling
- Building Control Optimization
- Water-side Plant Temperature Reset

**Near-term Electrification**
- Heat Recovery & Heat Pumps
- Gas/Steam Equipment Replacement

**Optimization**
- Thermal Energy Storage
- Economizer Controls
- Central Plant Optimization

**Continuous Improvement**
- Building Retrofits
- Control Upgrades
- Gas/Steam Plant Replacement
- Gas Equipment Phase Out
- Measurement & Verification

**Long-term Electrification**
- Additional Heat Sources
- Full Electrification

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Challenges for Residential

- **Dependence on gas**
  Gas is used to generate hot water for fan coils, condenser water, and domestic hot water due to the high demand for immediate heating
- **Glazing Percentage**
  For many reasons, including views and constructability, curtain walls have been very prevalent in design. The recent addition of the city energy code ‘envelope backstop’ aims to curb exceedingly high glazing percentages
- **Tenant Behavior**
  What tenants do in their apartments is up to them – e.g. what is the thermostat setpoint?
- **24/7 Operations**
  Residential HVAC is available all day
- **Potential Energy Penalty**
  Cities to penalize high energy usage buildings

Boundary Assessment

In order to better visualize potential improvement strategies, a boundary assessment is performed. A boundary assessment is a process to identify all energy in and energy out of the building and identify a strategy to tackle each.

**Examples of energy we use:**
- Thermal Envelope – Solar
- Thermal Envelope – Conduction
- Cooking Utilities – Gas or Electric
- Ventilation
- Makeup air for balancing
- Space Conditioning
- Domestic Hot Water

**Energy Out**

**Examples we can recover:**
- Wastewater
- Exhaust
- Heat Recovery
- Condenser water evaporation
- Heat of Rejection
- Solar Photovoltaics
- Geothermal
Zero Net Energy Buildings

**DECARBONIZATION** requires a systems-engineering approach to analyze each step of a potential design solution

**PASSIVE MEASURES**
- Passive House compliant envelope
- Infiltration tightness (ACH50 < 0.06 CFM)
- Triple Glazing – u-value and solar heat gain coefficient
- Minimize window-to-wall ratio
- Curtain wall thermal performance
- Thermal massing - use of phase change materials
- Building orientation, shading, and site selection

**ACTIVE STRATEGIES**
- Maximizing equipment efficiencies
- Active overall and ventilation airflow reduction
- Upgraded and enhanced energy recovery
- Integrated lighting control and minimization of lighting power density (+/- 0.15 W/ft²)
- Heat Recovery Chiller Systems
- Optimization of controls across systems for smart energy management
- Thermal and Battery Storage

**ELECTRIFICATION**
- Designing buildings for all-electric systems in the present, or future-proofing buildings for future transition
- Heat pumps for HVAC and DHW generation
  - Air-to-air
  - Air-to-water (chilled water / hot water)
  - Air-to-water (non-potable/potable hot water)
  - Geothermal (chilled water / hot water)
  - Geothermal (non-potable/potable hot water)
  - Wastewater

**GENERATION**
- On-site power generation, energy storage, and demand management
- Lease areas for PV generation
- Reduce, reuse, recycle resources
- Purchase green power
- Invest in renewable energy credits
- Owned offsite generation

**Path to Net Zero**

1. **Passive Strategies**
   - Building Massing, Shading Envelope, Thermal Mass, Glazing
   - District CHW / HHW, Geothermal, DHW Heat Pumps, LED Lighting
   - Heat Recovery Chiller Systems, DOAS w/ Energy Recovery
   - Smart Controls, User Education, Battery Storage, Thermal Energy Storage

2. **Efficient Systems**
   - Solar PV, Biomass

3. **Energy Recovery**
   - Virtual Power Purchase Agreement (VPPA)

4. **Awareness + Controls**
   - Renewable Energy Credits (RECs), Carbon Offsets

5. **On-Site Renewables**

6. **Off-Site Renewables**

7. **Offsets**

NET ZERO CARBON
Making the Case for PH
The Passive House Impact: Source Energy Use Intensity (pEUI) Distribution Comparison

Typical NYC Multifamily Residential Building

- 14% PUMP & AUX ELEC
- 10% LIGHTING
- 15% PLUG LOADS
- 15% DHW DEMAND
- 8% COOLING
- 38% HEATING

Multifamily Passive House Building

- 13% LIGHTING
- 13% PUMP & AUX ELEC
- 5% HEATING
- 34% PLUG LOADS
- 29% DHW DEMAND
- 6% COOLING

118 kBtu/ft²/yr → 58% REDUCTION → 50 kBtu/ft²/yr


Energy Star Portfolio Manager, "U.S. Energy Use Intensity by Property Type", April 2021

Passive House Envelope & Certified Area: Economies of Scale!
### Exterior Wall Assemblies

<table>
<thead>
<tr>
<th>Component</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof</td>
<td>R-40</td>
</tr>
<tr>
<td>Walls</td>
<td>R-23 Effective</td>
</tr>
<tr>
<td>Windows - Operable</td>
<td>U: 0.16</td>
</tr>
<tr>
<td>Windows - Fixed</td>
<td>U: 0.14</td>
</tr>
<tr>
<td>Cantilevered Floors</td>
<td>R-11</td>
</tr>
<tr>
<td>Glazing</td>
<td>21%</td>
</tr>
</tbody>
</table>

**SENDERO VERDE A**

- Masonry Cavity Wall
- 9" Mineral Wool Insulation (6" Cavity, 3" Cont.)
- Continuous Air/ Water Barrier/ Permeable Vapor Barrier
- Liquid Applied Impermeable Vapor Barrier
- Service Cavity

**SENDERO VERDE B**

- EIFS
- 4-6' EPS Insulation
- Liquid applied vapor permeable air barrier and waterproofing
- Service Cavity

### Thermal Breaks: AAC Block

**AAC-1**

- Autoclaved Aerated Concrete Masonry Units

**AAC BLOCK @ PARAPETS**

**THERM MODEL @ AAC PARAPET**
Heating & Cooling

1 Floor Mounted Air Handling Unit in Each 1-2- & 3-bedroom Apartment.

Condenser

1 Wall Mounted Air Handling Unit. Unit Serves Each Studio.

VRF Diagram
Rooftop Design

CONDENSER PARK AT BULKHEAD ROOF LEVEL
BULKHEAD ROOF
ROOFTOP AMENITY/MECH LEVEL
CONDENSER LOCATED AT SETBACK ABOVE RISER
SINGLE HORIZONTAL TRANSFER BELOW ROOFTOP AMENITY SLAB
TWO RISERS SHARE A PLUMBING CHASE WHEN POSSIBLE
BULKHEAD ROOF
REFRIGERANT LINES COLLECTED BELOW ROOFTOP AMENITY SLAB
REFRIGERANT RISERS SERVING EACH LINE OF UNITS
TWO RISERS SHARE A PLUMBING CHASE WHEN POSSIBLE
SOUTH SIDE DISTRIBUTION STRATEGY
NORTH SIDE DISTRIBUTION STRATEGY

GETTING TO ZERO  | © Handel Architects 2021
Ventilation

Balanced Ventilation with Heat Recovery Central Systems

**SENDERO VERDE: CENTRAL RISER**

**ERVs INSTALLED ON ROOF**
ERV Performance

<table>
<thead>
<tr>
<th>SIZE</th>
<th>EFFICIENCY</th>
<th>MANUFACTURER</th>
</tr>
</thead>
<tbody>
<tr>
<td>THE HOUSE</td>
<td>12,000 CFM</td>
<td>73%</td>
</tr>
<tr>
<td>SENDERO VERDE: A &amp; B-NORTH</td>
<td>14,500 CFM</td>
<td>81%</td>
</tr>
<tr>
<td>SENDERO VERDE: B-SOUTH</td>
<td>7,000 CFM</td>
<td>86%</td>
</tr>
<tr>
<td>UTSC</td>
<td>7,000 CFM</td>
<td>86%</td>
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ERV Performance

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Passive House Variables

<table>
<thead>
<tr>
<th>Density (occupants/sf)</th>
<th>Surface to Volume Ratio (ft² : ft³)</th>
<th>Window Wall Ratio (Glazing %)</th>
<th>Roof R-value</th>
<th>Opaque Wall R-value</th>
<th>Installed glazing U-value</th>
<th>ERV Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/500</td>
<td>0.03 : 1</td>
<td>70%</td>
<td>R-60</td>
<td>R-50</td>
<td>.45</td>
<td>90%</td>
</tr>
<tr>
<td>1/50</td>
<td>2.5 : 1</td>
<td>10%</td>
<td>R-10</td>
<td>R-7</td>
<td>.12</td>
<td>50%</td>
</tr>
</tbody>
</table>

Passive House Criteria

<table>
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<tr>
<th>SVA: 38.1</th>
<th>Overall Source Energy (kBtu/ft²/yr)</th>
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<tr>
<td>4.75</td>
<td>Heating Energy Demand (kBtu/ft²/yr)</td>
</tr>
<tr>
<td>5.39</td>
<td>Cooling Energy Demand (kBtu/ft²/yr)</td>
</tr>
</tbody>
</table>
It’s About the People!

- Enhance the living experience!
- Great acoustical separation from neighboring units and exterior.
- Low cost for heating and cooling (equitability)
- Comfortable temperatures, with option for control
- Healthy filtered fresh air 24/7

Thank You!
Passive House & Local Law 97: A Case Study

350,000 SF R-2 Energy Star Benchmark Building ¹

<table>
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<tr>
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<th>2021 NYS Energy Sources</th>
<th>2030 NYS Target: 70% Renewables ³</th>
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<tbody>
<tr>
<td>Emission (kbtu/ft²)</td>
<td>8.60</td>
<td>3.90</td>
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350,000 SF R-2 Passive House

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<td>1.65</td>
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¹EnergyStar Portfolio Manager, “U.S. Energy Use Intensity by Property Type”, April 2021
²New York Local Law 97 of 2019
³New York Climate Leadership and Community Protection Act

*Assumed operational Energy Use Intensity, may be adjusted for density.
WHAT IS PASSIVE HOUSE?

- A rigorous certification program whose primary focus is to curtail energy usage and increase user comfort.
- Unlike pass/fail checklists of Prescriptive standards, Passive House is an overall holistic approach based on ultimate full building performance.
- Focus is on Building Enclosure and MEP systems.
- Requires careful detailing during design and a strict quality control program during construction to yield an extremely well built building.

WHY PASSIVE HOUSE TO COMBAT CLIMATE CHANGE

- Reduce energy needed to operate buildings by 60-80%.
- Eliminate dependence on fossil fuels.
- Reduce carbon emissions.
- Lower greenhouse gas impact.
- Bridge the gap to NZR and/or NZC buildings.
- Ease compliance with government mandates (new laws, codes, standards).
WHY PASSIVE HOUSE

HEALTH AND WELLNESS

- Offer a healthier interior environment
- Provide superior indoor air quality via fresh filtered ventilation to every habitable rooms 24/7
- Offer a quieter interior environment
- Increase durability of building materials
- Eliminate drafts/temperature differentials and provide superb thermal comfort

HOW TO ACHIEVE PASSIVE HOUSE?

Enclosure: Roofs, Walls, and Foundation

- Strive for a compact shape
- Take building orientation into account
- Carefully detail to achieve air tightness
- Select Windows with exceptionally low U-Values.
- Provide Continuous insulation and thermal bridge free detailing leading to high R-Values

MEP Systems

- Provide a high performance, low energy heating and cooling system that is powered primarily by electricity
- Ventilate all habitable spaces with constant fresh air with heat recovery
- Balance exhaust and supply ventilation within 10% of one another
- Specify energy efficient equipment, lighting and appliances
Passive House Institute (PHI) Performance Criteria for Certification

Overall Source Energy Allowed (pEUI) 38.1 kBtu/ft²/yr*
Heating Energy Allowed Max 4.75 kBtu/ft²/yr
Cooling Energy Allowed (NY) Max 5.39 kBtu/ft²/yr (region specific)
Minimize Air Infiltration (5-10 times tighter than typical) 0.6 ACH (Air Changes per Hour) through the facade at 50 pascals of pressure
Exhaust and Supply Ventilation Balanced, with energy recovery

*Can be adjusted for density and use.

Electrification of Buildings

ELIMINATING FOSSIL FUELS
Designing for now or “future-proofing” buildings for eventual transitions. Considerations include:
- Space for central plants and decentralized equipment
- Vertical distribution pathways
- Horizontal air and water distribution
- Floor-to-floor heights
- Base building electrical infrastructural capacity and distribution

EV CHARGING
- Future infrastructure to support 100% of parking spaces
- Level 2 “Smart Chargers” can share a single circuit between two EVs
- Managed system may be used to throttle back charging to limit overall demand. Typically set to 50% of full EV charger capacity to allow vehicles to charge during a normal workday.

AIR-SOURCE HEAT PUMPS
- Heating load is offset by cooling load. DHW load is purely additive.
- Deployment in HVAC and DHW generation applications limited by derated performance in low-ambient temperatures.
- Newer technologies are emerging but lack published data and project precedent.
- Custom heat pump technologies that use alternate refrigerants (CO2, ammonia, etc.) are used in other geographies, and are in the process of seeking UL-listing in the United States.

GEOTHERMAL HEAT PUMPS
- Site and regulatory limitations.
- High first cost.
- Mechanical space required for heat pumps – central or decentralized
- District scale installations are the future
Next Generation Energy Conservation Technologies

OUTSIDE AIR OPTIMIZATION
- HVAC design typically prescribes to ASHRAE 62.1 Ventilation Rate Procedure (VRP). Conditioning outside air is energy-intensive.
- Recovering as much energy as possible for exhaust airstreams is imperative – high efficiency energy recovery wheels can accomplish this. In addition, exhaust can be located near domestic hot water air source heat pumps to scavenge remaining heat.

ENERGY USE OPTIMIZATION
- Photovoltaics coupled with energy storage and demand response management.
- Integration of building systems controls (HVAC, lighting, occupancy, security, etc.) to aggregate/analyze data, generate recommendations, and allow for intelligent monitoring.

WASTEWATER ENERGY RECOVERY
- Microscale - shower coil heat exchangers.
- Industrial scale – building or district level wastewater filtration and heat recovery for heating, cooling, domestic hot water production, and process loads. Example: Sharc Energy.
- First cost may be limiting.
- Space considerations for equipment and piping are important maybe be restrictive.

THERMAL ENVELOPE
- Use of low-cost phase-change materials for thermal massing in new projects, existing buildings, and repositioning applications.
- Window films may be a cost-effective alternative or supplement to triple-glazing.
- Passive House construction will continue to envelope design to manage envelope infiltration and massing.

Technology Challenges

METERING
- Direct metered tenants can pose challenges for on-site renewable power sharing.
- Leasing area to a PV developer may make more sense as the LL does not need to deal with utility compliance issues.

REGIONAL MARKETS
- Markets in the south and west, although a more advantageous climate from a heat pump perspective, may not be looking down as far down the road.
- Local air source heat pumps may be a good compromise here over central systems.

PHASING AND STAKEHOLDERS
- Initial investment of central geothermal or sewer heat recovery is costly without incentives or tax credits.
- Projects with phasing or multiple owners may pose challenges for billing, ownership, and first cost.

TECHNOLOGY DEVELOPMENT
- Still in infancy.
- Cold climate reliability is a concern, as well as storage and supplemental/backup heating.