Affordable Multifamily Housing: Net Zero and Passive House? Challenges, Opportunities, Mistakes, and Solutions

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Karen Bushey – VEIC, kbsbushey@veic.org
Learning Objectives

1. Participants will identify cost effective envelope enclosures and mechanical systems for multi-family net zero projects.

2. Participants will understand and use a proven, replicable energy modeling and financial analysis methodology for determining the most cost effective high-performance strategies and what level of energy performance is the most cost effective for building owners and managers.

3. Participants will understand the differences in NZE and Passive House Certification and the applicability, including benefits and liabilities, for multifamily housing projects.

4. This session will increase participants ability to select and successfully pursue and achieve NZE and Passive House
Project Team

- Twin Pines Housing - Owner
- Maclay Architects - Architect
- Engineering Services of Vermont - MEP
- Engineering Ventures – Civil, Structural
- GPI – Landscape Architects
- Estes & Gallup – Contractor
- Eco Houses of Vermont – PHIUS modeler
- Norwich Solar – Solar installer/consultant
- VEIC – Karen Bushy PHIUS rater
- VEIC
- Norwich Solar Technologies
- Eco Houses of Vermont, LLC
- Estes & Gallup Incorporated
Who is Twin Pines Housing?

- Upper Valley’s leading developer and provider of Affordable Housing.
  - **417** Rentals at 19 Properties
    - 161 in VT
    - 256 in NH
  - **48** Homeownership Properties
    - Twin Pines is permanent steward
  - **Over 1,000** people are housed
- 20-member staff with expertise in project development, property management, and resident support services.

Serving the Upper Valley since 1990
Tracy Community Housing
West Lebanon, NH
A new 3-story, net-zero, passive house, residential building to include:
• 29 one- and two-bedroom units for all ages and incomes.
• 18 units for households below 50% of AMI, 11 units for households below 60% of AMI.
• Building adjacent to Kilton Library, on Advance Transit bus line.
Site Plan

• Infill

ORTHO MAP

ZONING MAP
1st Floor Plan

- 1 and 2 bedroom units
- Community room
- Tenant Storage
- Shared Laundry
2nd/3rd Floor Plan

- 1 and 2 bedroom units
Why Net Zero and Passive House?

• As an organization, we are striving to develop a more energy efficient portfolio;
• Our housing typically includes heat and hot water in the rent. Controlling energy costs benefits our organization and our residents;
• Serves as model for future development
• Extra funding points for NZ or PH
Net Zero Building Metrics

PERFORMANCE METRICS
(without process loads)

- Typical Existing
- Code Compliant
- High Performance
- Net-Zero Ready
- Net-Zero/Positive

PRESCRIPTIVE METRICS

Air Infiltration - Maximum 0.05 cfm/sf @ 50 Pascals

kBTU/sf-yr

-120
-100
-80
-60
-40
-20
0

The New Net Zero
Key Elements

Conservation + High-Efficient Systems + Renewables

Energy Use Intensity (EUI)

Heat Pumps (COP 2.3-3.0)

Usually Photovoltaics (sized for annual load)
Passive House Metrics

**Energy Model Targets:**
- Annual Heating
- Peak Heating
- Annual Cooling
- Peak Cooling
- Source Energy / person for residential PHIUS review

**Construction:**
- 3rd party verified built as constructed
- 0.05 cfm50/sf gross envelope
- Interior containment between apartments
Why PHIUS?

Climate Specific Targets

Lebanon Municipal Airport, NH

Climate Zone 6

Annual Heating Demand 6.9 kBTU/sf-iCFA-yr

Annual Cooling Demand 1.8 kBTU/sf-iCFA-yr

Peak Heating Load 5.2 Btu/sf-iCFA-h

Peak Cooling Load 4 Btu/sf-iCFA-h

Manual J Peak Cooling Load 5.7 Btu/sf-iCFA-h
Key Decision Timeline

• Site Identification  
  Spring 2016
• 1st Funding application  
  Summer 2016- not funded
• Revised Site  
  Winter 2017
• 2nd Funding application  
  Summer 2017
  • NZE target for additional funds
  • Financing enabled extra $10,000/unit adjusted for NZ or PH
• Construction Manager hired  
  Winter 2017
• Solar Coordination/Consultation  
  Summer 2017
• Funding Secured  
  Winter 2018
• Construction begins  
  Summer 2018
• PHIUS exploratory model  
  Summer 2018
• PHIUS Certification pursued  
  Fall 2018
Why NZ first then PH?

- NZ Energy conservation is almost passive house
- NZ further reduces operational costs compared to code
- Minimal certification fees for same funding incentives
Design for Net Zero

- Wall – 2x6 cellulose +4” polyiso (R38)
- Roof – 11” polyiso (R60)
- Sub-slab – 5” rigid insulation (R20)
- Windows – U-value 0.22, SHGC 0.41
- Air infiltration - 0.05 cfm50/sf gross envelope
- Air Source Heat Pumps
- Electric hot water
Design for Net Zero

- Solar system size – 110% predicted
- Solar location –
  - Roof
  - Cornice
  - Façade
  - Arbors
  - Carports
Design for Net Zero

- 180 kW DC solar
  - Roof - 85 kW, ballasted system
  - Cornice – 50 kW - structure
  - South Façade - 24 kW conduit, penetrations
  - Arbor – 20 kW

Estimated production
196,000 kWh/yr
Design for Net Zero

- Solar Inverter and electrical panel size needs
Design for Net Zero

- Heat Pump changes 12 to 38 rooftop units

12 unit layout – maximizes solar

38 unit layout visible from street and reduces solar area
# Design for Passive House

## ADDITIONAL COSTS ASSOCIATED WITH PASSIVE HOUSE CERTIFICATION

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>COST</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CONSTRUCTION COSTS:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extend Ventilation (includes CM Fee)</td>
<td></td>
<td>Improves Indoor Air Quality/Health</td>
</tr>
<tr>
<td></td>
<td>$6,240</td>
<td>actual was $60,000!</td>
</tr>
<tr>
<td>Window Upgrade (includes CM Fee)</td>
<td></td>
<td>$0-$7280 Very likely windows will not need to be upgraded</td>
</tr>
<tr>
<td><strong>PHIUS RELATED FEES:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHIUS modeling</td>
<td>$5,000-$9,000</td>
<td>Eco Houses of VT</td>
</tr>
<tr>
<td>PHIUS Certification Fee</td>
<td>$7,336</td>
<td></td>
</tr>
<tr>
<td>PHIUS Rater Fee</td>
<td>$12,000</td>
<td>VEIC; $11,000 in project for BE Commissioning</td>
</tr>
<tr>
<td><strong>TOTAL POTENTIAL COST</strong></td>
<td>$27,440-$38,720</td>
<td></td>
</tr>
</tbody>
</table>

## POTENTIAL REBATES:

<table>
<thead>
<tr>
<th>Rebate</th>
<th>Cost</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>LU Potential Custom Incentive Rebate</td>
<td>$33,000</td>
<td>Unknown amount until built</td>
</tr>
<tr>
<td>Solar Rebate</td>
<td>$52,000</td>
<td>Total solar cost $450,000</td>
</tr>
<tr>
<td><strong>TOTAL POTENTIAL REBATES</strong></td>
<td>$85,000</td>
<td></td>
</tr>
</tbody>
</table>
Design for Passive House

- Ventilation - same equipment, extension needed to bedrooms
- Window SHGC increase to 0.41 from 0.2 – No cost change
Financial Analysis Methodology

**INPUTS**
- Energy Consumption
- Increased Capital Costs for Efficiency
- Capital Cost for PV
- Financing Assumptions

**OUTCOMES**
- Capital and operating costs over time
## Energy Consumption

<table>
<thead>
<tr>
<th></th>
<th>Code</th>
<th>ESVI energy model (Carrier HP)</th>
<th>EHVT Wufi Passive</th>
<th>REGIONAL AVERAGE (CBECS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Electric</td>
<td>kBtu/yr</td>
<td>974,000</td>
<td>527,000</td>
<td>425,254</td>
</tr>
<tr>
<td>Total BuildingEUI</td>
<td>kBtu/sf-yr</td>
<td>35</td>
<td>19</td>
<td>16</td>
</tr>
</tbody>
</table>

**Code:** Really that low? No air barrier testing required  
**Actual:** ???
## Capital Costs for NZ Over Code under $8/sf

### Building Component

<table>
<thead>
<tr>
<th>Component</th>
<th>Code</th>
<th>Net Zero Ready</th>
<th>Added Cost</th>
<th>Category Added Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Windows</strong></td>
<td>U 0.35 min., SHGC max. 0.40</td>
<td>U 0.21 awning, U0.22 casement</td>
<td>$15,447</td>
<td></td>
</tr>
<tr>
<td><strong>Doors</strong></td>
<td>U 0.50, R2</td>
<td>U 0.31 (glazed doors)</td>
<td>Above</td>
<td></td>
</tr>
<tr>
<td><strong>Air/Vapor Barrier</strong></td>
<td>Continuous air barrier required, but not tested - Infiltration ~0.40 CFM75/sf gross envelope</td>
<td>Infiltration 0.065 CFM75/sf gross envelope (~0.05 cfm50/sf)</td>
<td>$27,000</td>
<td></td>
</tr>
<tr>
<td><strong>Insulation</strong></td>
<td>Roof R-20 cl entirely above deck</td>
<td>Roof R-61 cl entirely above deck</td>
<td>$38,380</td>
<td>$120,000</td>
</tr>
<tr>
<td></td>
<td>Floor R-30</td>
<td>Floors - R-60 + R-33 cl</td>
<td>$200</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Walls above grade, wood framed R 20 or R13 +R5 cl</td>
<td>Walls above grade, wood framed - R 20 +R22 cl</td>
<td>$12,168</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Walls below grade - R 19 or R15 cl</td>
<td>Walls below grade - R 20</td>
<td>$1,053</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Slab R-15 for 24” bel.</td>
<td>Slab - R-20 contin.</td>
<td>$4,570</td>
<td></td>
</tr>
<tr>
<td><strong>Envelope Cx</strong></td>
<td>none</td>
<td>Full envelope commissioning</td>
<td>$23,000</td>
<td></td>
</tr>
<tr>
<td><strong>Heating</strong></td>
<td>direct resistant electric baseboard</td>
<td>ASHPs</td>
<td>$37,300</td>
<td>$88,000</td>
</tr>
<tr>
<td><strong>Cooling</strong></td>
<td>Wall mounted units for each apartment</td>
<td>ASHPs provide included above</td>
<td>$-9,425</td>
<td></td>
</tr>
<tr>
<td><strong>Ventilation</strong></td>
<td>Direct exhaust ventilation with passive intake</td>
<td>Rooftop heat recovery unit, Daikin DPS 007A</td>
<td>$60,500</td>
<td></td>
</tr>
</tbody>
</table>

**Total Added Cost without PV** $210,000

- **Added Envelope Cost Per Square Foot**: $4.60
- **Added Mechanical Cost Per Square Foot**: $3.40
- **Total Added Cost Per Square Foot**: $7.90
## Increased Net Zero Cost

### Total Added Cost with PV

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost Per Square Foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Added Envelope Cost</td>
<td>$4.60</td>
</tr>
<tr>
<td>Added Mechanical Cost</td>
<td>$3.40</td>
</tr>
<tr>
<td>Added PV Cost</td>
<td>$12.00</td>
</tr>
<tr>
<td><strong>Total Added Cost Per Square Foot</strong></td>
<td><strong>$20.00</strong></td>
</tr>
</tbody>
</table>

- **PV**
  - Solar PV
  - 180 kW roof, façade and arbor, includes brackets ($52K and rebate $52K) $450k - $135
  - $315,000
Financial Analysis – Financial Assumptions

INPUTS

• Interest Rate - varies
• Loan Duration – 20 years
• Fuel Escalation Rate – 5%
  • “solar plateau” at year 13
  • (0% escalation from yr 13-20)
• Nominal Inflation rate equals the nominal discount rate therefore 0% used

1. TPH Scenario (financed)

2.375% interest rate

- 20-year loan
- Weighted average of TPH loans for $1M of project cost
- Assume all additional capital is loaned
- Solar same loan

![Graph showing cumulative capital, energy, and finance costs with solar.](image)
Cumulative Energy and Financing Costs *in 2019 dollars

- $610,000 Saving over 20 years

*Assumes financing of additional capital costs

Source: Mackay Architects
2. Typical Construction (financed)

4.625% interest rate

- 20-year loan
- Assume all additional capital is loaned
- Solar same loan

$380,000 Saving over 20 years

$460,000 Saving over 20 years
$460,000
Saving over 20 years

Cumulative Energy and Financing Costs *in 2019 dollars

*Assumes financing of additional capital costs

Source: Mackey Architects
3. No Financing

0% interest rate
$730,000 Saving over 20 years
PHIUS Certification Status

- Model completed – Eco Houses of Vermont January 2019
- Round 1 PHIUS - 2 months
- Revisions to model based on feedback
- Round 2 PHIUS - 6 weeks
- Revisions to model based on feedback
- Round 3 PHIUS
  - 4 weeks

### Energy Consumption

- **Heating demand:** 3.86 kBtu/ft²yr
- **Cooling demand:** 0.43 kBtu/ft²yr
- **Heating load:** 3.93 Btu/hr ft²
- **Cooling load:** 1.62 Btu/hr ft²
- **Source energy:** 5,305 kWh/Person yr
- **Site energy:** 16.14 kBtu/ft²yr
Passive House Rater/Verifier

• Goal is to start early – not always possible
• Certification often does NOT work out* if CPHC and/or Rater are not involved early (before DD)
  • Exceptional case with exceptional team
  • Net Zero design made it possible
• NH vs. VT - able to provide Rater services through VEIC outside of VT

* or results in higher cost