Where We Went Right & Where We Went Left:
Measured vs. Modeled Performance Data Analysis for Affordable Occupied Passive Multifamily Projects

Village Centre Apartments - Brewer, ME
DESIGN & VERIFICATION TOOLS, MODELING PROTOCOLS
**Annual Demand [kBtu/yr-ft²]:** Space conditioning energy consumed over the course of the year, delivered by the equipment to the space.

**Peak Load [BTU/hr-ft²]:** Space conditioning requirement during the peak climate conditions (average over the worst 24 hours). Determines the size of the mechanical system.

**Site Energy [kWh/person.yr] OR [kBtu/yr-ft²]:** Total energy consumed over the course of the year, including space conditioning, hot water, plug loads, lighting, appliances, systems, etc. (Excludes electrical vehicle charging energy, and lighting energy specific to vehicle parking areas)

*No requirement for PHIUS+ Certification*

**Source (Primary) Energy [kWh/person.yr] OR [kBtu/yr-ft²]:** Site energy as described above, multiplied by the source/primary energy factor for the specific fuel type used.  
Ex: Electricity has a PE factor of 3.16 kWh/kWh (generation at the source vs use on site)
## Certification Target Differences

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<tr>
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<th>PHIUS+ 2015</th>
<th>PHI</th>
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<tr>
<td><strong>Annual Heat Demand</strong></td>
<td>Varies by Climate</td>
<td>4.75</td>
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<td><em>(kBTU/ft².yr)</em></td>
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<td><strong>Annual Heating Load</strong></td>
<td>Varies by Climate</td>
<td>3.14</td>
</tr>
<tr>
<td><em>(BTU/ft².hr)</em></td>
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<tr>
<td><strong>Annual Cooling Demand</strong></td>
<td>Varies by Climate (+ allowance for latent)</td>
<td>4.75</td>
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<tr>
<td><em>(kBTU/ft².yr)</em></td>
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<td></td>
</tr>
<tr>
<td><strong>Annual Cooling Load</strong></td>
<td>Varies by Climate</td>
<td>2.54</td>
</tr>
<tr>
<td><em>(BTU/ft².hr)</em></td>
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<tr>
<td><strong>Airtightness</strong></td>
<td>*0.05 cfm/ft² (Based on Envelope Area)</td>
<td>0.6 ACH50 (Based on Net Volume)</td>
</tr>
<tr>
<td><strong>Source Energy Factor</strong></td>
<td>6,200 kWh/person.yr</td>
<td>38 kBTU/ft².yr</td>
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<tr>
<td><em>(Residential)</em></td>
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*0.08 cfm/ft² for non-combustible construction >5 stories*
CLIMATE SPECIFIC METRICS

PASSIVE STANDARDS IN VARYING CLIMATES

Olympia

City: Olympia
State: WA

ASHRAE 2013 & Global Solar Radiation Location: Olympia Regional Airport

Zone: 4C

Annual heating demand kBTU/sf-ICFA yr: 6
Annual cooling demand kBTU/sf-ICFA yr: 1
Peak heating load Btu/sf-ICFA.h: 3.9
Peak cooling load Btu/sf-ICFA.h: 3.5

Chicago

City: Chicago
State: IL

ASHRAE 2013 & Global Solar Radiation Location: O'Hare International Airport

Zone: 5

Annual heating demand kBTU/sf-ICFA yr: 6
Annual cooling demand kBTU/sf-ICFA yr: 3.6
Peak heating load Btu/sf-ICFA.h: 5.1
Peak cooling load Btu/sf-ICFA.h: 4.4
## CERTIFICATION PROTOCOL DIFFERENCES

<table>
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<tr>
<th>Internal Heat Gains (Residential)</th>
<th>PHIUS+ 2015</th>
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<tbody>
<tr>
<td>Varies Calculated</td>
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<td>0.67 BTU/hr.ft² (2.1 W/m²) Default</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Square Footage</th>
<th>Interior Conditioned Floor Area (iCFA)</th>
<th>Treated Floor Area (TFA)</th>
</tr>
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<tbody>
<tr>
<td></td>
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<td>TFA ÷ 376.7ft² (TFA ÷ 30m²)</td>
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<tr>
<th>Occupancy</th>
<th># Bedrooms + 1</th>
<th>TFA ÷ 376.7ft² (TFA ÷ 30m²)</th>
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<tr>
<th>Residential Lighting</th>
<th>80% RESNET Lighting Assumptions</th>
<th>*11W light x 8 hrs/day x Occupancy</th>
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<tr>
<th>Residential Miscellaneous Electric Loads (MELS)</th>
<th>80% RESNET MELS Assumptions</th>
<th>**80W x 1.5 hrs/day x Occupancy + 50 kWh x Occupancy</th>
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<tr>
<th>Source Electric Energy Factor</th>
<th>3.16 kWh/kWh (US Average)</th>
<th>2.6 kWh/kWh (German Average)</th>
</tr>
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</table>

*Assumes one light on per person at a time

**Reference: 25” color TV consumes 150W/hr
# 3 Protocols Tested + 1 Hypothetical Adjusted Model

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<tr>
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<th>ASHARE 90.1 -2010 Appendix G Baseline</th>
<th>PHI</th>
<th>PHIUS+ 2015</th>
<th>PHIUS+ 2015 Adjusted</th>
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<tr>
<td><strong>Roof</strong></td>
<td>R-value by Climate Zone from Table 5.5</td>
<td>Same as Designed</td>
<td>Same as Designed</td>
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<tr>
<td><strong>Walls</strong></td>
<td>R-value by Climate Zone from Table 5.5</td>
<td>Same as Designed</td>
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<td><strong>Windows</strong></td>
<td>U-Value/SHGC by Climate Zone from Table 5.5</td>
<td>Same as Designed</td>
<td>Same as Designed</td>
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<tr>
<td><strong>Area</strong></td>
<td>Same as PHIUS+ 2015</td>
<td>TFA</td>
<td>iCFA</td>
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<td><strong>Lighting</strong></td>
<td>RESNET Values</td>
<td>PHI Defaults</td>
<td>80% RESNET Values</td>
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<td><strong>MELS</strong></td>
<td>RESNET Values</td>
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<tr>
<td><strong>HVAC</strong></td>
<td>50% Efficient ERV H/AC – Same as Designed</td>
<td>Same as Designed</td>
<td>Same as Designed</td>
<td>System Efficiencies adjusted</td>
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<tr>
<td><strong>DHW</strong></td>
<td>140F Supply Temp Same gal/person/day as PHI/PHIUS</td>
<td>120F Supply Temp 6.6 gal/person/day</td>
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<td>Varies by project</td>
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<td><strong>Occupancy</strong></td>
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CERTIFICATION PROTOCOL DIFFERENCES

Figure 1: Annual Source Energy by end use and Protocol (Using EPA Portfolio Manager Site-to-Source Conversions)

Comparison Evaluation of ASHRAE 90.1 Appendix G vs. Passive House
https://www.nyserda.ny.gov/About/Publications/EA-Reports-and-Studies/Energy-Efficiency-Services-Reports
Figure 1: Annual Source Energy by end use and Protocol (Using EPA Portfolio Manager Site-to-Source Conversions)
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Most Improved Building
# Three Case Studies

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Uptown Lofts
Things to keep in mind

• Site Energy analyzed
• All electricity monitored together (includes all HVAC, hot water usage, lighting and MELs)
• Heat pumps (heating/cooling) in apartments
• Direct Electric baseboards in common stairs
• HRV
• Direct Electric WH
Site Energy: Monitored vs Modeled

Monthly (kWh)

- Monitored (2016)
- Modeled - PHIUS+ 2015
- Modeled - PHI Standard
Site Energy: Monitored vs Modeled

- Monitored (2016)
- Monitored (2017)
- Modeled - PHIUS+ 2015
- Modeled - PHI Standard

Monthly (kWh)

- 7,000kWh
- 8,500kWh
- 7,900kWh
Two Meters

- Tenant Meter: Unit Plug loads/electricity, Unit Lighting & Fans for Heating/Cooling
- House Meter: Hallway/Stairwell/Exterior Lighting, 1st Floor Office Plug Loads, Laundry, Heat Pumps, Hot water tanks, all Ventilation
Site Energy: Monitored vs Modeled

- Tenant Meters - Monitored (2016)
- Tenant Meters - PHIUS+ 2015 Modeled
- Tenant Meters - Monitored (2017)
PHIUS+ 2015 – Adjusted Model

- Actual Occupancy
- Unit MELS/Lighting Reduced
- Thermostats set to 80F (Winter) 72F (Summer)
- Doubled Hot Water Usage
- Eliminated Summer Natural Ventilation
- Heat Pumps Malfunction? (2.7 COP to 1.5 COP)
Site Energy: Monitored vs Modeled

- Tenant Meters - Monitored (2016)
- Tenant Meters - PHIUS+ 2015 Modeled
- Tenant Meters - PHIUS+ 2015 Adj. - 2016

Monthly (kWh)
Site Energy: Monitored vs Modeled

Monthly (kWh)

- Tenant Meters - PHIUS+ 2015 Modeled
- Tenant Meters - Monitored (2017)
- Tenant Meters - PHIUS+ 2015 Adj. - 2017

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Three Case Studies

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Knickerbocker Commons
Things to keep in mind

• Project did not go through on-site Verification to become a Certified Passive House Project
• Site Energy analyzed (converted to kWh)
• Electricity and gas monitored separately
  – Electric: cooling, lighting, MELs
  – Gas: heating, water heating, dryers
• Hydronic Heating/water heater system
• ERV
• Individual AC units for cooling
Site Energy: Monitored vs Modeled

Monthly (kWh)

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Monitored - 2015
Monitored - 2016
Monitored - 2017
Modeled - PHIUS+ 2015
Modeled - PHI Standard
Things to keep in mind

• Electric Meter
  – AC Units
  – Lighting
  – MELS

• Natural Gas Meter
  – Hydronic Heating
  – Water Heaters
  – Exhaust Clothes Dryers
Site Electricity: Monitored vs Modeled

- Monitored Electricity - 2015
- Monitored Electricity - 2016
- Monitored Electricity - 2017
- Modeled Electricity - PHIUS+ 2015
- Modeled - PHI Standard
Site Natural Gas: Monitored vs Modeled

- Monitored Nat. Gas - 2015
- Monitored Nat. Gas - 2016
- Monitored Nat. Gas - 2017
- Modeled Nat. Gas - PHIUS+ 2015
- Modeled Nat. Gas - PHI Standard

Monthly (kBTU)
PHIUS+ 2015 – Adjusted Model

• Mean Temperatures Adjusted (2016 & 2017)
• Thermostats set to 77F (Winter)
• Actual Occupancy
• Doubled Hot Water Usage
• 0.5 ACH50 -> 3 ACH50
  – (Leaky AC Units/Open Windows?)
• Lower Efficiency Boilers
Site Energy: Monitored vs Adjusted Models

Site Energy Comparison (kBtu/sf)

- Monitored - 2015: 39.2 kBtu/sf.yr
- Monitored - 2016: 51.7 kBtu/sf.yr
- Monitored - 2017: 33.3 kBtu/sf.yr
- Modeled - PHIUS+ 2015 Adjusted: 29.0 kBtu/sf.yr
- Modeled - PHIUS+ 2015: 20.7 kBtu/sf.yr
- Modeled - PHI Standard: 13.0 kBtu/sf.yr
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Orchards at Orenco I
Things to keep in mind

• Site Energy analyzed (converted to kWh)
• Electricity monitored separately
• Heat pumps (heating/cooling) in apartments w/ direct electric backup
• HRV
• Natural Gas WH
• Natural Gas Clothes Dryers
Site Energy: Monitored vs Modeled

- Monitored (Electricity + Gas) kWh
- Modeled - PHIUS+ 2015
- Modeled - PHI Standard

Orchards at Orenco I
Site Energy: Monitored vs PHIUS+ 2015 Predicted

Monitored - Unit Electric Heating
Predicted - Unit Electric Heating
Monitored - Heating/Cooling Heat Pumps + ERV
Predicted - Heating/Cooling Heat Pumps + ERV
Monitored - Hot Water - Gas
Predicted - Hot Water - Gas
Monitored - Clothes Dryers - Gas
Predicted - Clothes Dryers - Gas
Monitored - Electricity - Apts
Predicted - Electricity - Apts
Monitored - Electricity - Commons
Predicted - Electricity - Commons

Orchards at Orenco I
Site Energy Comparison

Orchards at Orenco I

Monitored (Electricity + Gas) kWh
Modeled - PHIUS+ 2015
Modeled - PHI Standard
PASSIVE BUILDING
PART OF THE SOLUTION

James Ortega, Certification Staff

www.PHIUS.org/www.PHAUS.org

Elm Place - Milton, VT