Measured vs. Modeled Energy Performance in Passive House Multifamily Properties

Passive House Institute US
James Ortega, PHIUS Certification Staff
1. Background
   1. Motivation for monitoring
   2. Potential Factors

2. Four Multifamily Projects - Monitored Data Analysis:
   1. Building Rundown
   2. Data Rundown
   3. Monitored vs Modeled

3. Lessons Learned
IMPORTANCE OF MONITORING

• PHIUS+ Certification is based on design – need to verify actual performance
• Realize & quantify savings
• Troubleshoot issues
• Adjust modeling protocol to improve predicted values
• Shape incentives from local jurisdictions & rating systems
POTENTIAL FACTORS AFFECTING DIFFERENCES BETWEEN MODELED AND MONITORED

- Varying heating setpoint above/below 68F (winter)
- Varying cooling setpoint above/below 77F (summer)
- Climatic differences between measured year and ‘typical year’ used for modeling
- Varying number of occupants from modeled assumption (BR+1)
- Occupant behavior (work from home, kids vs adults, lifestyle, habits)
- Equipment tested efficiency varying from real performance
- System/Operator Error
<table>
<thead>
<tr>
<th><strong>Internal Heat Gains (Residential)</strong></th>
<th>Varies Calculated</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Square Footage</strong></td>
<td>Interior Conditioned Floor Area (iCFA)</td>
</tr>
<tr>
<td><strong>Occupancy</strong></td>
<td># Bedrooms + 1</td>
</tr>
<tr>
<td><strong>Residential Lighting</strong></td>
<td>80% RESNET Lighting Assumptions</td>
</tr>
<tr>
<td><strong>Residential Miscellaneous Electric Loads (MELS)</strong></td>
<td>80% RESNET MELS Assumptions</td>
</tr>
<tr>
<td><strong>Source Electric Energy Factor</strong></td>
<td>3.16 kWh/kWh (US Average)</td>
</tr>
</tbody>
</table>

*Assumes one light on per person at a time

**Reference: 25” color TV consumes 150W/hr
**TERMINOLOGY**

**Demands, Peaks, Site & Primary Energy**

**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)
Four Case Studies

<table>
<thead>
<tr>
<th>Location</th>
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<th>Village Center</th>
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<tr>
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<td><strong>PHIUS+ Project #</strong></td>
<td>1188</td>
<td>1343</td>
<td>1279</td>
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</tr>
</tbody>
</table>
## Four Case Studies

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</table>
Uptown Lofts
Pittsburgh, PA
24 units
25,000 ft²
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
Site Energy: Monitored vs Modeled

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

Monthly (kWh)

- Jan: Monitored (2016) 8,500kWh, Modeled - PHIUS+ 2015 7,000kWh
- Feb: Monitored (2016) 7,900kWh, Modeled - PHIUS+ 2015 7,000kWh
- Mar: Monitored (2016) 8,500kWh, Modeled - PHIUS+ 2015 7,000kWh
- Apr: Monitored (2016) 8,500kWh, Modeled - PHIUS+ 2015 7,000kWh
- May: Monitored (2016) 8,500kWh, Modeled - PHIUS+ 2015 7,000kWh
- Jun: Monitored (2016) 8,500kWh, Modeled - PHIUS+ 2015 7,000kWh
- Jul: Monitored (2016) 8,500kWh, Modeled - PHIUS+ 2015 7,000kWh
- Aug: Monitored (2016) 8,500kWh, Modeled - PHIUS+ 2015 7,000kWh
- Sep: Monitored (2016) 8,500kWh, Modeled - PHIUS+ 2015 7,000kWh
- Oct: Monitored (2016) 8,500kWh, Modeled - PHIUS+ 2015 7,000kWh
- Nov: Monitored (2016) 8,500kWh, Modeled - PHIUS+ 2015 7,000kWh
- Dec: Monitored (2016) 8,500kWh, Modeled - PHIUS+ 2015 7,000kWh
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

Monthly (kWh)
Site Energy: Monitored vs Modeled

Monthly (kWh)

- Tenant Meters - Monitored (2016)
- Tenant Meters - PHIUS+ 2015 Modeled
- Tenant Meters - Monitored (2017)
Site Energy: Monitored vs Modeled

Monthly (kWh)

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

Tenant Meters - Monitored (2016)
Tenant Meters - PHIUS+ 2015 Modeled
Tenant Meters - Monitored (2017)
Site Energy: Monitored vs Modeled

Monthly (kWh)

- Tenant Meters - PHIUS+ 2015 Adj. - 2017
- House Meter - Monitored (2017)
- House Meter - Monitored (2016)
Site Energy: Monitored vs Modeled

Monthly (kWh)

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

• Mean Temperatures Adjusted (2016 & 2017)
• 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

- Monitored (2016)
- Monitored (2017)
- Modeled - PHIUS+ 2015 Adj - 2016
- Modeled - PHIUS+ 2015
- Modeled - PHIUS+ 2015 Adj - 2017

Monthly (kWh)
Site Energy: Monitored vs Modeled

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

- Tenant Meters - PHIUS+ 2015 Modeled
- Tenant Meters - Monitored (2017)
- Tenant Meters - PHIUS+ 2015 Adj. - 2017
Site Energy: Monitored vs Modeled

Monthly (kWh)

- House Meter - Monitored (2016)
- House Meter - PHIUS+ 2015 Modeled
- House Meter - PHIUS+ 2015 Adj. - 2016
Site Energy: Monitored vs Adjusted Models

61% Modeled vs Actual

Uptown Lofts
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BAYSIDE ANCHOR
Portland, ME

45 Units
iCFA: 36,161 ft²

Electric heating, no cooling
Gas Water Heating
Gas Exhaust Dryers
All other electric

© Passive House Institute US
1343 - Bayside Anchor | Portland, ME
Modeled = Dashed Lines, Measured = Full Lines

91% Modeled vs Actual

- Modeled Elec (kWh)
- Modeled Gas (kWh equiv)
- Measured Elec (kWh)
- Measured Gas (kWh equiv)

© Passive House Institute US
### Four Case Studies

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VILLAGE CENTER
Brewer, ME

48 Units
iCFA: 51,778 ft²

Central Heating
Individual Unit Cooling
Gas Water Heating
All other electric

© Passive House Institute US
TOTAL ENERGY USE
1279 - Village Center - Brewer, ME
Modeled = Dashed Lines, Measured = Full Lines

Modeled Energy Use vs Measured Energy Use for Village Center in Brewer, ME.
1279 - Village Center - Brewer, ME
Modeled = Dashed Lines, Measured = Full Lines

93% Modeled vs Actual
# Four Case Studies

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Beach Green Dunes
Far Rockaway, NY
101 units
107,800 ft$^2$

Central VRF
In-Unit ERVs
Gas Water Heating
Central Laundry
*Months Under Occupied

84% Average Occupancy

UNITS POPULATED

PERCENT

© Passive House Institute US
Beach Green
Dunes
Far Rockaway, NY
101 units
107,800 ft²

NATURAL GAS
COMBINED HEAT & POWER
DOMESTIC HOT WATER
DRYERS
BEACH GREEN DUNES

NATURAL GAS

COMBINED HEAT & POWER (CHP)

HEAT

DHW

ELECTRICITY

LIGHT PLUG LOADS METER RUN-BACK

© Passive House Institute US
CHP USAGE

*Months Under Occupied

kBtu/yr

- 10,000
- 20,000
- 30,000
- 40,000
- 50,000
- 60,000
- 70,000
- 80,000
- 90,000
- 100,000

2017 2018

Model Cogen
WegoWise Cogen

© Passive House Institute US
DHW USAGE

*Months Under Occupied

kBtu/yr

- Model DHW
- Occ. Adj.
- Occ. Adj.
- Aegis Cogen DHW
- WegoWise DHW

<table>
<thead>
<tr>
<th></th>
<th>2017</th>
<th>2018</th>
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<tbody>
<tr>
<td>S*</td>
<td>40,000</td>
<td>60,000</td>
</tr>
<tr>
<td>O*</td>
<td>50,000</td>
<td>70,000</td>
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<td>90,000</td>
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© Passive House Institute US
Beach Green Dunes
Far Rockaway, NY
101 units
107,800 ft²

COMMON
- VRF (HEAT/COOL)
- COMMON LIGHTS
- ELEVATORS
- PUMPS
- PV
- FIRE ALARMS, SECURITY, ETC..

ELECTRICITY

TENANT
- ERV
- UNIT LIGHTS
- UNIT PLUG LOADS / APPLIANCES
Beach Green Dunes
Far Rockaway, NY
101 units
107,800 ft²

**ELECTRICITY**

**COMMON**
VRF (HEAT/COOL)
COMMON LIGHTS
ELEVATORS
PUMPS
PV
FIRE ALARMS, SECURITY, ETC..

**TENANT**
ERV
UNIT LIGHTS
UNIT PLUG LOADS / APPLIANCES
Unit Average Electricity

37 units – 7 months
3 – Studio
17 – 1 Bedroom
10 – 2 Bedroom
7 – 3 Bedroom

© Passive House Institute US
UNIT ELECTRICITY

ENERGY USE PER UNIT

3.67 kWh/day \times 365 \text{ days/yr} = 1,340 \text{ kWh/yr}

TENANT ENERGY USE

1,340 \text{ kWh/yr} \times 101 \text{ Units} = 135,340 \text{ kWh/yr}

Average Unit Use

3.67 \text{ kWh/day}
Beach Green Dunes
Far Rockaway, NY
101 units
107,800 ft²

ELECTRICITY

COMMON
VRF (HEAT/COOL)
COMMON LIGHTS
ELEVATORS
PUMPS
PV
FIRE ALARMS, SECURITY, ETC..

TENANT
ERV
UNIT LIGHTS
UNIT PLUG LOADS / APPLIANCES
COMMON ELECTRICITY

kWh/yr

-  5,000  10,000  15,000  20,000  25,000  30,000  35,000  40,000  45,000

2017  2018

Model Common

Electric Bill

© Passive House Institute US
Temperature Comparison

Actual Temp. vs. Model Temp.

Temp. F°

Month

2017
S
O
N
D
J
F
M
A
2018
M
J
J
A

© Passive House Institute US
ELECTRIC RENEWABLE OFFSET

- kWh/yr

- Model Cogen
- Model PV
- Cogen
- PV

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LESSONS LEARNED

• Assigning roles/responsibilities upfront is critical. 
  Need a contact for design, installation, monitoring, debugging, resident.

• Monitoring never seems to be a priority, just “nice to have”.
  Hard to place priority on that over other budgetary/time constraints.

• Systems work incorrectly (or not at all) quite often. Meters also break.
  Whose responsibility is it to check up on that, and then fix it?

• Monitoring should be part of the design process at the start, not finish.
  And maintained throughout all phases of design.

• Critical to follow through with plan during construction.
  And inspect/track after final installation.
PASSIVE BUILDING
PART OF THE SOLUTION

James Ortega - james@passivehouse.us
www.PHIUS.org
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ENERGY STAR Benchmarking Passive House Multifamily Properties

October 4, 2018

NESEA Building Energy 2018, New York

Stuart Brodsky, Clinical Assistant Professor, Director

New York University School of Professional Studies Schack Institute of Real Estate

Center for the Sustainable Built Environment
Contents

- Why Benchmark to Energy Star
- Performance of Three Properties
- Next Steps
Why Benchmark to ENERGY STAR
Why Benchmark to ENERGY STAR

- National point of reference
- Required in some jurisdictions
  - NYC
- FANNIE MAE funding
Performance of Three Properties
### Benchmarked Performance

<table>
<thead>
<tr>
<th>Property</th>
<th>ENERGY STAR Rating</th>
<th>Total GHG (Metric tons)</th>
<th>CO2e lbs / SF</th>
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</thead>
<tbody>
<tr>
<td>188 Uptown Lofts, Pittsburgh, PA</td>
<td>72*</td>
<td>126</td>
<td>11.4</td>
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<tr>
<td>1279 Apartments, Brewer, ME</td>
<td>100</td>
<td>50.8</td>
<td>2.04</td>
</tr>
<tr>
<td>1343 Apartments, Portland, ME</td>
<td>100</td>
<td>63.1</td>
<td>3.59</td>
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</table>
## Property & Contact Information

<table>
<thead>
<tr>
<th>Property Address</th>
<th>Property Owner</th>
<th>Primary Contact</th>
</tr>
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<tbody>
<tr>
<td>1279 Apartments</td>
<td>New York University, Schack Institute of Real Estate</td>
<td>Stuart brodsky</td>
</tr>
<tr>
<td>266 Center Street</td>
<td>11 West 42nd St, New York, NY 10036</td>
<td>11 West 42nd St, New York, NY 10036</td>
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<tr>
<td>Brewer, Maine 04412</td>
<td>New York, NY 10036</td>
<td>202 531 0036</td>
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<td></td>
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<td><a href="mailto:sb4311@nyu.edu">sb4311@nyu.edu</a></td>
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<td>Property ID: 6458182</td>
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## Energy Consumption and Energy Use Intensity (EUI)

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<tr>
<th>Site EUI</th>
<th>Annual Energy by Fuel</th>
<th>National Median Comparison</th>
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<tr>
<td>15.1 kBtu/ft²</td>
<td>Electric - Grid (kBtu) 363,940 (44%)</td>
<td>National Median Site EUI (kBtu/ft²) 60.2</td>
</tr>
<tr>
<td></td>
<td>Electric - Solar (kBtu) 90,162 (11%)</td>
<td>National Median Source EUI (kBtu/ft²) 115.3</td>
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<td></td>
<td>Natural Gas (kBtu) 375,824 (45%)</td>
<td>% Diff from National Median Source EUI -75%</td>
</tr>
<tr>
<td>Source EUI</td>
<td></td>
<td>Annual Emissions</td>
</tr>
<tr>
<td>29 kBtu/ft²</td>
<td></td>
<td>Greenhouse Gas Emissions (Metric Tons CO2e/year) 51</td>
</tr>
</tbody>
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1343 Apartments / Oxford Street

Property & Contact Information

Property Address
1343 Apartments / Oxford Street
81 East Oxford Street
Portland, Maine 04412

Property Owner
New York University, Schack Institute of Real Estate
11 West 42nd St,
New York, NY 10036
(____)____ - ______

Primary Contact
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Property ID: 6454351

Energy Consumption and Energy Use Intensity (EUI)

Site EUI
23.9 kBtu/ft²

Annual Energy by Fuel
Electric - Grid (kBtu) 635,841 (69%)
Natural Gas (kBtu) 290,162 (31%)

Source EUI
53.8 kBtu/ft²

National Median Comparison
National Median Site EUI (kBtu/ft²) 49.8
National Median Source EUI (kBtu/ft²) 112.1
% Diff from National Median Source EUI -52%

Annual Emissions
Greenhouse Gas Emissions (Metric Tons CO2e/year) 63
Next Steps
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- Energy operating cost data
- Impact on rental rates
- Impact on net operating income
- Impact on asset value