Importance of Monitoring Energy Use

1. Verify Energy Model Predictions
3. More Accurate Modeling & Building Performance Certification
4. Provide Feedback to Occupants
5. HVAC Performance Verification
Methods - Modeling

3 Comparative Data Sets per Project

1. **Monitored**: Actual Measured Energy Use
2. **PHIUS+**: Modeled Energy Use under PHIUS+ Passive Building Standard
   a. ‘Passive House Planning Package’ (PHPP)
3. **PHIUS+ 2015**: Modeled Energy Use under PHIUS+ 2015 Passive Building Standard
   a. WUFI-Passive
# Methods - Variances in Modeling Protocol

<table>
<thead>
<tr>
<th></th>
<th>WUFI-Passive (PHIUS+ 2015)</th>
<th>PHPP (PHIUS+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupancy</td>
<td># bedrooms + 1, per unit</td>
<td>1 person per 377 sf</td>
</tr>
<tr>
<td>Internal Heat Gains</td>
<td>Calculated Value</td>
<td>Default Value</td>
</tr>
<tr>
<td>Misc Loads &amp; Lighting</td>
<td>80% RESNET Assumptions</td>
<td>PHPP Default</td>
</tr>
<tr>
<td>Space Conditioning Criteria</td>
<td>Climate Specific</td>
<td>Passivhaus Targets</td>
</tr>
</tbody>
</table>
Methods - Derivation of Estimated Monthly Data

● Monthly Estimates from Static Model
  ○ Limitation: PHPP & WUFI Passive - Output Annual Energy Use

● Systems:
  ○ Heating Energy - Monthly Demand + Seasonal Performance of System
  ○ Cooling Energy - Monthly Demand
  ○ Hot Water (Heat Pump Water Heaters only) - Seasonal Performance of System

● Appliances:
  ○ Major Appliances (Refrigerators, Freezers, Clothes Washers, Clothes Dryers, Dishwashers, Cooktops, Lighting, etc…) - Divided Evenly
  ○ Hot Water (Electric Resistance or Natural Gas)
  ○ Heat Recovery Ventilation (HRV & ERV)
# Three Case Studies

<table>
<thead>
<tr>
<th></th>
<th>Stellar Apartments</th>
<th>Orchards at Orenco Phase 1</th>
<th>Knickerbocker Commons</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location</strong></td>
<td>Eugene, OR</td>
<td>Hillsboro, OR</td>
<td>Brooklyn, NY</td>
</tr>
<tr>
<td><strong>Square Footage (iCFA)</strong></td>
<td>5,848 ft²</td>
<td>48,035 ft²</td>
<td>31,903 ft²</td>
</tr>
<tr>
<td><strong>Number of Units</strong></td>
<td>6</td>
<td>57</td>
<td>24</td>
</tr>
<tr>
<td><strong>Modeled Occupancy</strong></td>
<td>13 (PHIUS+)</td>
<td>113 (PHIUS+)</td>
<td>72 (PHIUS+)</td>
</tr>
<tr>
<td></td>
<td>18 (PHIUS+ 2015)</td>
<td>131 (PHIUS+ 2015)</td>
<td>72 (PHIUS+ 2015)</td>
</tr>
<tr>
<td><strong>PHIUS+ Project #</strong></td>
<td>1174</td>
<td>1203</td>
<td>1274</td>
</tr>
</tbody>
</table>
Stellar Apartments
Stellar Apartments

Monitored Data
- 54 - Unit Multifamily Affordable Housing Development
- One - 3-Story (6 units) built to PHIUS+ Standard
- Monitoring Systems
  - 8 Electricity Monitors per Unit
    - Heating
    - ERV
    - Water Heater
    - Kitchen Range
    - Kitchen Outlets
    - Kitchen Fridge
    - Clothes Washer
    - Other

Limitations
- Energy Model Limitations
  - ‘Other’ + ‘Kitchen Outlets’ = ‘Lighting/Plug Loads’
  - 7 total categories for comparison
- Shared Space
  - Small Central Stairwell - Not included
- Actual Occupancy Recorded (9)
  - 7 - Adults
  - 1 - Teenager
  - 1 - Toddler
- PHIUS+ Occupancy (13)
- PHIUS+ 2015 Occupancy (18)
Stellar Apartment - Monthly Energy Use

- **PHIUS+**
- **PHIUS+ 2015**
- **Monitored**

<table>
<thead>
<tr>
<th>Month</th>
<th>PHIUS+</th>
<th>PHIUS+ 2015</th>
<th>Monitored</th>
</tr>
</thead>
<tbody>
<tr>
<td>JAN</td>
<td>3,000</td>
<td>2,500</td>
<td>3,500</td>
</tr>
<tr>
<td>FEB</td>
<td>2,500</td>
<td>2,000</td>
<td>2,500</td>
</tr>
<tr>
<td>MAR</td>
<td>2,000</td>
<td>1,500</td>
<td>2,000</td>
</tr>
<tr>
<td>APR</td>
<td>1,500</td>
<td>1,000</td>
<td>1,500</td>
</tr>
<tr>
<td>MAY</td>
<td>1,000</td>
<td>500</td>
<td>1,000</td>
</tr>
<tr>
<td>JUN</td>
<td>500</td>
<td>0</td>
<td>500</td>
</tr>
<tr>
<td>JUL</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>AUG</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>SEP</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>OCT</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>NOV</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>DEC</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Stellar Apartments - Monthly Energy Use by Type

- **ERV**
- **Washer**
- **Total Plugs**
- **Dryer**
- **Range**
- **Water Heater**
- **Heat**

* Denotes data adjusted for broken thermostat.
Stellar Apartments - Test Case

- Modeled PHIUS+ 2015 Hypothesis Test
- Occupancy
  - Changed from 18 to 9 (to match recorded occupancy)
- Heating Set-Point
  - Changed from 68F to 70F
- Hot Water Usage
  - Changed from 6.6 Gallons/Person/Day to 13.2 Gallons/Person/Day (Doubled)
Annual Energy Use by Apartment

Worst Unit (7B)

Average Unit (7C)

kWh

7A 7B 7C 7D 7E 7F PHIUS+ 2015 Average Monitored Average
Stellar Apartments - Best & Average Units

- Unit 7B - Worst Case Apartment
  - 3 Occupants Assumed
- Unit 7C - Average Apartment
  - 3 Occupants Assumed
Stellar Apartments Unit 7B - Monthly Energy Use by Type

*Worst Case

- **ERV**
- **Washer**
- **Fridge**
- **Total Plugs**
- **Dryer**
- **Range**
- **Water Heater**
- **Heat**

* Denotes data adjusted for broken thermostat.
Stellar Apartments Unit 7C - Monthly Energy Use

*Average Case

- **PHIUS+ 2015**
- **Monitored**

<table>
<thead>
<tr>
<th>Month</th>
<th>kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>JAN</td>
<td>400</td>
</tr>
<tr>
<td>FEB</td>
<td>500</td>
</tr>
<tr>
<td>MAR</td>
<td>600</td>
</tr>
<tr>
<td>APR</td>
<td>700</td>
</tr>
<tr>
<td>MAY</td>
<td>800</td>
</tr>
<tr>
<td>JUN</td>
<td>900</td>
</tr>
<tr>
<td>JUL</td>
<td>1000</td>
</tr>
<tr>
<td>AUG</td>
<td>1100</td>
</tr>
<tr>
<td>SEP</td>
<td>1200</td>
</tr>
<tr>
<td>OCT</td>
<td>1300</td>
</tr>
<tr>
<td>NOV</td>
<td>1400</td>
</tr>
<tr>
<td>DEC</td>
<td>1500</td>
</tr>
</tbody>
</table>
Stellar Apartments Unit 7C - Monthly Energy Use by Type

*Average Case

* Denotes data adjusted for broken thermostat.
Stellar Apartments - Results Analysis

- Annual Energy Use by Type
- Discrepancies
  - Domestic Hot Water Use - Heat Pump Water Heaters
  - Lighting/Plug Loads
  - Space Heating
    - Broken Thermostat
    - July Heating
    - Actual Weather vs TMY3 Climate data
Stellar Apartments - Results Analysis

- Annual Energy Use
- **Discrepancies**
  - **Domestic Hot Water Use - Heat Pump Water Heaters**
  - Lighting/Plug Loads
  - Space Heating
    - Broken Thermostat
    - July Heating
    - Actual Weather vs TMY3 Climate data
Stellar Apartments - Results Analysis

- Annual Energy Use
- **Discrepancies**
  - Domestic Hot Water Use - Heat Pump Water Heaters
  - **Lighting/Plug Loads**
    - Space Heating
      - Broken Thermostat
      - July Heating
      - Actual Weather vs TMY3 Climate data
Stellar Apartments - Results Analysis

- Annual Energy Use
- **Discrepancies**
  - Domestic Hot Water Use - Heat Pump Water Heaters
  - Lighting/Plug Loads
  - **Space Heating**
    - Broken Thermostat
    - July Heating
      - Actual Weather vs TMY3 Climate data
Heating Energy Consumption by Apartment per Month

- 7A
- 7B
- 7C
- 7D
- 7E
- 7F
- PHIUS+ 2015 (68F)
- PHIUS+ 2015 (70F)
Stellar Apartments - Results Analysis

- Annual Energy Use
- **Discrepancies**
  - Domestic Hot Water Use - Heat Pump Water Heaters
  - Lighting/Plug Loads
  - **Space Heating**
    - Broken Thermostat
    - July Heating
    - **Actual Weather vs TMY3 Climate data**
Stellar Apartments - Test Case - Monthly Heating Energy
Orchards at Orenco Phase 1
Orchards at Orenco Phase 1

**Monitored Data**
- 150 - Unit Multifamily Affordable Housing Development
- One - 3-Story (57 units) built to PHIUS+ Standard
- Monitoring Systems Installed
  - Track & Improve Tenant Energy Use Habits
- Data for November 2015 - March 2016

**Limitations**
- Electricity Monitored (5 categories)
  - Per Unit
  - Strip Heating (8 of 57 units)
  - Common Space - Total per Month
  - Air Handlers + HRVs
  - Central Heat Pump
- Natural Gas
  - Gas Bill - Whole Building
  - Individual Hot Water Meter - Problem Prevented Separate Metering
  - 15% Natural Gas - Dryers (estimate)
  - 85% Natural Gas - Hot Water (estimate)
Orchards at Orenco Phase 1 - Results Analysis

- Whole Building Energy Use
  - Discrepancies
    - Lighting/Plug Loads
    - Common Space Energy Use
      - Exterior Stairwells
      - Distributed Antenna System (DAS)
      - Heating Energy
      - Unoccupied Units
  - Hot Water Usage
Orchards at Orenco Phase 1 - Results Analysis

- Annual Energy Use
- **Discrepancies**
  - Lighting/Plug Loads
  - Common Space Energy Use
    - Exterior Stairwells
    - **Distributed Antenna System (DAS)**
    - Heating Energy
    - Unoccupied Units
- Hot Water Usage
Overall electricity lines up better than broken down between common/residential
Orchards at Orenco Phase 1 - Results Analysis

- Annual Energy Use
- **Discrepancies**
  - Lighting/Plug Loads
  - **Common Space Energy Use**
    - Exterior Stairwells (40F to 68F)
    - Distributed Antenna System (DAS)
  - **Heating Energy**
    - Unoccupied Units
- Hot Water Usage
Orchards at Orenco Phase 1 - Results Analysis

- **Annual Energy Use**
- **Discrepancies**
  - Lighting/Plug Loads
  - **Common Space Energy Use**
    - Exterior Stairwells
    - Distributed Antenna System (DAS)
    - Heating Energy
    - **Unoccupied Units**
- **Hot Water Usage**
Orchards at Orenco Phase 1 - Results Analysis

- Annual Energy Use
- Discrepancies
  - Lighting/Plug Loads
  - Common Space Energy Use
    - Exterior Stairwells
    - Distributed Antenna System (DAS)
    - Heating Energy
    - Unoccupied Units
- Hot Water Usage
Knickerbocker Commons
Knickerbocker Commons

Monitored Data

- One - 6-Story (24 units) built to PHIUS+ Standard
- Common Electricity (single value)
  Includes:
  - Common Space Lighting
  - Common Space Miscellaneous Plug Loads
  - Elevator
  - Common Auxiliary Energy
  - Common Space ERVs
  - Clothes Washers

Limitations

- PHIUS+ 2015 Electricity
  - Default Lighting Power Density (LPD)
- Unit Electricity not Provided
  - No Data Provided, Yet
  - Separately Metered - Future Analysis Possible
- Natural Gas
  - Dead Meter Battery - Incomplete Data
  - Not Included in Study
Knickerbocker - Results Analysis

- Discrepancies
  - Common Space Electricity
    - Seasonal Lighting Increase
    - Spike in Winter Electricity usage
Conclusions

Major Differences:

- Stellar Apartments
  - Hot Water Heating Energy
  - Heating Energy
- Orchards at Orenco Phase 1
  - Common Space Electricity
- Knickerbocker Commons
  - Lighting
  - MELS
- Monitored Energy Use by Type

Note: PHIUS Technical Committee - Draft Monitoring Data Protocol
Contact certification@passivehouse.us if interested.
Thanks!

Questions?

References

