
Craig Simmons, Energy Consultant, VEIC
Karen S. Bushey, Energy Consultant, VEIC
Who Are You?

Why Are You Here?

Experiences in Energy Modeling?
Modeling Tools
Modeling Tools - Types

• Static
  – Instantaneous Loads
  – Utilizes Annual Average Loads (Degree-Days)
  – REM/Rate, PHPP, WUFI-Passive

• Dynamic
  – Accounts for Dynamic Responses (Brick Wall)
  – Hourly/Sub-Hourly Simulation
  – eQuest, EnergyPlus, OpenStudio, WUFI Passive
Modeling Tools - Goals

• Rating – “Asset Score”
  – Focused on the building characteristics (Asset)
  – Normalizes user behavior
  – MPG
  – REM/Rate, PHPP

• Prediction
  – Must consider the user
  – Include some form of calibration
  – Account for inefficiencies of operation
Modeling Tools

1. REM/Rate
2. Passive House Planning Package (PHPP)
3. Open Studio (Energy Plus platform)
4. eQuest
REM/Rate

- Developed for HERS providers = simple to use
- New and used homes, up to 3 stories
- Demonstrate code compliance
- Result is HERS Index score
- Not open source
Passive House Planning Package (PHPP)

• Developed for PH certification = complex
• Works with residential and commercial, new and retrofit
• Design, Verification and Certification tool
• Result is PH Compliance: meets targets?
  – Heating/cooling demand (kBTU/sf yr) and heating/cooling load (BTU/(hr sf))
  – Primary Energy (source)
• Open source (excel file)
OpenStudio

• Developed and supported by DOE/NREL
• Interface to EnergyPlus
  – Sub-Hourly Simulation
  – Iterative Solutions
• Software Development Kit (SDK)
  – 90% is “below the surface”
  – Designed for Software
• Open Source
eQUEST

- Developed by DOE (no longer supported)
- Interface to DOE2
- Hourly Simulation
- “Relatively” Simple and Fast
  - Wizard feature is very useful (Asset)
- Outdated
  - No direct modeling of modern systems
  - Limitations around small and low-load
Selected Residential Projects

- Single Family #1: Vermod
- Single Family #2: Middlebury PH
- Multifamily: Elm Place
Single Family #1: Vermod

- High Performance Modular Home, 1 story, 980 SF
Single Family #1: Vermod

- **FLOOR** R-40
- **WALLS** R-43
- **ROOF** R-60

- 14" roof truss (fiberglass, R-60)
- Airtight ducts inside house
- 1 foot overhang
- 5/8" sheetrock & low emitting paints
- Double stud walls, 10" cavity (fiberglass, R-43)
- Plywood decking and sheathing without added formaldehyde
- 2.5" floor system (fiberglass, R-40)
- Frost protected foundation/peri

Triple pane windows
Single Family #1: Vermod

- Envelope: R-43 wall, R-60 roof, R-40 floor, U-0.19 windows, 0.77 ACH 50

- Systems:
  - Cold climate air source heat pump (mini-split), single zone
  - CERV (conditioning energy recovery ventilator), with integral heat pump
  - Heat pump hot water heater
Single Family #2: Middlebury PH

- Custom, Single Family Passive House, 2 story, 2100 SF
Single Family #2: Middlebury PH
Single Family #2: Middlebury PH

• Envelope: R-57 wall, R-111 roof, R-88 floor, U-0.14 windows, 0.2 ACH 50

• Systems:
  – Cold climate air source heat pump (mini-split), 2 zones
  – Zehnder Comfoair 350 ERV
  – On-demand/tankless propane hot water heater
Multifamily: Elm Place

- 30 unit Multifamily Passive House, 3 story – 2 stories of residential, 28,600 SF
Multifamily: Elm Place
Multifamily: Elm Place
Multifamily: Elm Place

- Envelope: R-41 wall, R-80 roof, R-76 floor, U-0.13 windows, 0.7 ACH 50

- Systems
  - Cold climate air source heat pumps in each apartment
  - Centralized ERVs, (2) – apartments and common space
  - Centralized gas water heaters
## Project vs. Modeling Tool

<table>
<thead>
<tr>
<th></th>
<th>SINGLE FAMILY #1</th>
<th>SINGLE FAMILY #2</th>
<th>MULTIFAMILY</th>
</tr>
</thead>
<tbody>
<tr>
<td>REM/Rate</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>PHPP</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Open Studio</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Process

• Align Inputs / Assumptions
  – To the extent possible (REM/Rate)
  – Aligned OpenStudio with PHPP
  – Lighting, MEL, Hot Water, Ventilation
  – Infiltration*
  – Equipment Type / Efficiency

• Compare Outputs
  – PHPP Metrics
  – Load Components
  – Data
Metrics
Metrics

• Demand/ Annual Demand
  – QUANTITY (KWh, BTUs)
  – Not Consumption
  – Load that the systems serve

• Load/ Peak Load
  – RATE (KW, BTU/Hr)
  – Equipment Sizing
Metrics

- **Site Energy**
  - At the meter
  - EUI = Energy Use Intensity (kBTU/ft²)

- **Source Energy**
  - At the “plant”
  - Primary Energy
  - Site/Source Conversion Factors
    - Grid Inefficiency
Inputs
Inputs / Assumptions

• REM/Rate and PHPP inputs left as-is (per certifications)
• Aligned OpenStudio with PHPP where possible
• Let OpenStudio generally autosize equipment and fans (W/cfm)
• Set Ventilation levels per PHPP inputs
## Inputs / Assumptions

<table>
<thead>
<tr>
<th></th>
<th>Internal (KWh/yr)</th>
<th>DHW gal/per-day</th>
<th>Htg Setpoint</th>
<th>Clg Setpoint</th>
<th>Ventilation CFM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vermod</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OS</td>
<td>1,435</td>
<td>6.6</td>
<td>68</td>
<td>77</td>
<td>34</td>
</tr>
<tr>
<td>PHPP</td>
<td>1,439</td>
<td>6.6</td>
<td>68</td>
<td>77</td>
<td>34</td>
</tr>
<tr>
<td>REMRate</td>
<td>3,631</td>
<td>?</td>
<td>68</td>
<td>78</td>
<td>65</td>
</tr>
<tr>
<td><strong>Middlebury</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OS</td>
<td>-</td>
<td>6.6</td>
<td>68</td>
<td>77</td>
<td>74</td>
</tr>
<tr>
<td>PHPP</td>
<td>4,436</td>
<td>6.6</td>
<td>68</td>
<td>77</td>
<td>73</td>
</tr>
<tr>
<td>REMRate</td>
<td>5,557</td>
<td>?</td>
<td>68</td>
<td>78</td>
<td>95</td>
</tr>
<tr>
<td><strong>Elm Place</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OS</td>
<td>73,066</td>
<td>6.6</td>
<td>68</td>
<td>77</td>
<td>1,567</td>
</tr>
<tr>
<td>PHPP</td>
<td>82,221</td>
<td>6.6</td>
<td>68</td>
<td>77</td>
<td>1,567</td>
</tr>
<tr>
<td>REMRate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Inputs / Assumptions - Infiltration

- REM/Rate PHPP Input test results directly
- OpenStudio utilizes “peak” values
- Vermod & Middlebury
  - Effective Leakage Area
  - Sherman and Grimsrud (1980) - Coefficients
- Elm Place
  - Translate to cfm/sf @ “Design”
  - DOE2 @ peak windspeed of 10mph
## Inputs / Assumptions - Infiltration

<table>
<thead>
<tr>
<th>Project</th>
<th>ACH50</th>
<th>ELA (in^2)</th>
<th>I agw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vermod</td>
<td>0.8</td>
<td>6.2</td>
<td>0.0042</td>
</tr>
<tr>
<td>Middlebury</td>
<td>0.2</td>
<td>3.8</td>
<td>0.0018</td>
</tr>
<tr>
<td>Elm Place</td>
<td>0.7</td>
<td></td>
<td>0.0147</td>
</tr>
</tbody>
</table>
Outputs
## Demand Components

<table>
<thead>
<tr>
<th></th>
<th>SF #1: Vermod</th>
<th>SF #2: Middlebury</th>
<th>MF: Elm Place</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Heat Demand</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(kBTU/sf yr)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHPP</td>
<td>22.8</td>
<td>3.66</td>
<td>4.48</td>
</tr>
<tr>
<td>REM/Rate</td>
<td>13.5</td>
<td>4.6</td>
<td></td>
</tr>
<tr>
<td>Open Studio</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cooling Demand</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(kBTU/sf yr)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHPP</td>
<td>5.5</td>
<td>1.4</td>
<td>1.04</td>
</tr>
<tr>
<td>REM/Rate</td>
<td>2.4</td>
<td>6.7</td>
<td></td>
</tr>
<tr>
<td>Open Studio</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Load Metrics

<table>
<thead>
<tr>
<th></th>
<th>SF #1: Vermod</th>
<th>SF #2: Middlebury</th>
<th>MF: Elm Place</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Heating Load</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(BTU/hr sf)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHPP</td>
<td>10.2</td>
<td>3.5</td>
<td>4.6</td>
</tr>
<tr>
<td>REM/Rate</td>
<td>8.5</td>
<td>5.08</td>
<td>(20 F range)</td>
</tr>
<tr>
<td>Open Studio</td>
<td>7.8</td>
<td>4.77</td>
<td>9.7</td>
</tr>
<tr>
<td><strong>Cooling Load</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(BTU/hr sf)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHPP</td>
<td>5.6</td>
<td>3.2</td>
<td>2.3</td>
</tr>
<tr>
<td>REM/Rate</td>
<td>4.8</td>
<td>5.8</td>
<td></td>
</tr>
<tr>
<td>Open Studio</td>
<td>4.1</td>
<td>7.4</td>
<td>4.8</td>
</tr>
</tbody>
</table>
Load Metrics

Heating Load (BTU/hr sf)

- SF #1: Vermod
- SF #2: Middlebury
- MF: Elm Place

Cooling Load (BTU/hr sf)

- SF #1: Vermod
- SF #2: Middlebury
- MF: Elm Place

Graphs showing the heating and cooling loads for different locations, with data from PHPP, REM/Rate, and Open Studio.
## Energy Use

<table>
<thead>
<tr>
<th></th>
<th>SF #1: Vermod</th>
<th>SF #2: Middlebury</th>
<th>MF: Elm Place</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary Energy</strong></td>
<td>PHPP</td>
<td>75.6</td>
<td>40.8</td>
</tr>
<tr>
<td></td>
<td>REM/Rate</td>
<td>74.7</td>
<td>45.4</td>
</tr>
<tr>
<td></td>
<td>Open Studio</td>
<td>74.8</td>
<td>43.0</td>
</tr>
<tr>
<td><strong>EUI</strong></td>
<td>PHPP</td>
<td>23.9</td>
<td>12.9</td>
</tr>
<tr>
<td></td>
<td>REM/Rate</td>
<td>23.6</td>
<td>17.8</td>
</tr>
<tr>
<td></td>
<td>Open Studio</td>
<td>23.6</td>
<td>18.2</td>
</tr>
<tr>
<td><strong>Actual Use (10 Sites)</strong></td>
<td></td>
<td>26.1</td>
<td></td>
</tr>
</tbody>
</table>
Energy Use

Primary Energy (kBtu/sf yr)

- SF #1: Vermod
- SF #2: Middlebury
- MF: Elm Place

EUI (kBtu/sf)

- SF #1: Vermod
- SF #2: Middlebury
- MF: Elm Place

For detailed analysis, please refer to PHPP, REM/Rate, and Open Studio.
Energy Use - Actual

Data (2015/2016) vs OpenStudio

- kWh

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

Data

OpenStudio
Energy Use – Elm Place (large)
Energy Use – Elm Place (large)
Conclusions? (It’s Early)
Lessons Learned - Process

• Difficult to get Apples to Apples
• OpenStudio
  – Complicated
  – Flexible
  – Calibratable
• PHPP & REM/Rate
  – Straightforward for Single Family
  – Increasingly Complicated with Larger Buildings
Next Steps

- Monitoring / Calibration
  - Infiltration
  - VRF Performance
- Refine OpenStudio Techniques
  - Simplify
  - Focus on Strengths (Complexity, Predictive)
- Inform (Based on Above)
  - Elements of design that require more or less focus?
  - Topics of deeper study?
Discussion / Questions
Thank you!

Craig Simmons
802-540-7952
csimmons@efficiencyvermont.com

Karen S. Bushey
802-540-7818
ksbushey@efficiencyvermont.com