36.8 kW of solar electric photovoltaics

SUMMER

WINTER

indoor coil

inverter DC to AC

composting toilets

compost used as fertilizer

latent heat (heating mode)

heat dump (cooling mode)

supply-air intake

exhaust air

air-to-air heat pumps (outdoor coil)
Putney Field House - Enclosure

- High efficiency R-5 windows, SHGC-0.26 and R-2.5 skylights
- Super-insulated structure, walls, roof, R/20/45/60
- Very tight construction --- 0.065 cfm50/sq.ft
  0.37 ACH-50
  0.024 ACH natural estimated
INSTALL SHEET OF SARNAVAP-10 VAPOR RETARDER OVER SLOPED AND VERTICAL BLOCKING. STAPLE TO VERT. BLOCKING AND SPRAY FOAM OVER SARNAVAP AND ONTO SIP PANEL

DASHED LINE INDICATES VAPOR RETARDER LOCATION - SEAL VAPOR RETARDER ON WALL TO VAPOR RETARDER ON ROOF, ALLOW ENOUGH SLACK FOR ROOF TO MOVE UP AND DOWN AT LEAST 1 IN.

DASHED LINE INDICATES LOCATION OF MOISTURE/AIR BARRIER - SEAL TO UNDERSIDE OF SIP

AIR & MOISTURE BARRIER

VAPOR BARRIER

EXTERIOR FINISH

INSULATION

STRUCTURE

INTERIOR FINISH

EAVE WINDOW HEAD DETAIL

1 1/2" MATTRESS FOAM FILLER

2" SPRAY FOAM INSULATION AT COLUMNS AND BEAMS

DENSE PACK CELLULOS

INSULATE AREA WITH DENSE PACK AFTER INSTALLING COMPRESSIBLE FILLER AT BOTTOM FLANGE OF I-BeAM
COAT COLUMN BELOW TOP OF SLAB WITH BITUMINOUS COATING

INFILL WITH GROUT OR CONCRETE AFTER SLAB PLACEMENT. SEE TYPICAL DETAIL FOR ISOLATION JOINT AT SLAB-ON-GRADE.

SLAB-ON-GRADE

STEEL COLUMN

URETHANE THERMAL BREAK LOCK

BASE PLATE ON 1/4" LEVELING PLATE AND 1/2" NON-SHRINK GROUT, SEE COLUMN SCHEDULE

PROVIDE (3)-TIES AT TOP OF PIER

TOP OF PIER

ELEV. SEE PLAN

PIER REINFORCING, SEE PIER DETAILS

TOP BARS, WHERE SPECIFIED

TOP OF FOOTING

ELEV. SEE PLAN

SEE FOOTING SCHEDULE

FOOTING REINFORCING, SEE FOOTING SCHEDULE

AIR & MOISTURE BARRIER

VAPOR BARRIER

EXTERIOR FINISH

INSULATION

STRUCTURE

INTERIOR FINISH

PIER DETAIL
1. Install Sill Blocking, Fiberglass Angles, Brick Ties, & Other Sheathing Penetrations
2. Install Flex Wrap @ Sill
3. Install Membrane Flashing @ Sill
4. Install Window
5. Install Membrane Flashing @ Jams
6. Install Flex Wrap @ Headers
7. Install Metal Flashing @ Head
8. Install Membrane Flashing @ Head
9. Install Monolithic Liquid- Applied Air/Moisture Barrier
10. Install Insulation, Insulation Retainer Clips, & Metal Panel Furring
11. Install Veneer Masonry & Metal Panels
• “Light Louvers”
• Sun-Optics clear prismatic skylight
Putney Field House - Lighting

- High efficiency lighting
- Automatic daylight harvesting controls
- Three step auto dimming in gym
- Occupancy sensors everywhere
Natural cooling
Putney School - Total Cost for heat Pump and PV Systems

<table>
<thead>
<tr>
<th>PV Cost to Achieve Net Zero</th>
<th>HP System Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground source heat pump system</td>
<td>$400,000 - $600,000</td>
</tr>
<tr>
<td>Air source heat pump system</td>
<td>$200,000 - $400,000</td>
</tr>
</tbody>
</table>
Energy sources

- PV electricity production!
- 16 Zomeworks 2.3 kW tracking arrays
- 36.8 kW / Expect ~avg of 45,000 kWh/yr
OUTCOME

- Paradigm Shift in Net-Zero Financial Analysis
- Strengthen Fundraising Support
- Environmental leadership
Step 10 - Detail & Build
Commissioning & Monitoring

Commission everything
Step 10 - Detail & Build
Commissioning & Monitoring

Commission everything

Building Enclosure
Building Envelope Schedule - MASTER 3-21-2011.pdf
Step 10 - Detail & Build
Commissioning & Monitoring

Commission everything
Step 10 - Detail & Build
Commissioning & Monitoring

Commission everything
Step 10 - Detail & Build
Commissioning & Monitoring

Commission everything

Building Enclosure -- Why bother?

• Critical to meeting energy goals
• Critical to meet peak load, equipment sizing and comfort requirements
• Risk reduction!
Step 10 - Detail & Build
Commissioning & Monitoring

Commission everything

Show up
- Who: Architect, Engineers, Energy Champion, Owners’ Rep, Clerk
- When: Construction
Step 10 - Detail & Build
Commissioning & Monitoring

Commission everything

Show up
Step 10 - Detail & Build
Commissioning & Monitoring

Commission everything

- Who: Commissioning Authority, Architect, Engineers, Energy Champion, Owners’ Rep, Clerk
- When: Construction
Step 10 - Detail & Build
Commissioning & Monitoring

Commission everything

- Enclosure
- Mechanicals
- HVAC controls
- Lighting controls
- Electrical systems
- Other (e.g., rainwater)
Step 10 - Detail & Build

Commissioning & Monitoring

Commission everything
Step 10 - Detail & Build
Commission & Monitoring

Commission everything

Lighting controls
• Critical for commissioning
• Highly visible and constant interaction with occupants
• Not always straightforward
Step 10 - Detail & Build
Commissioning & Monitoring

Commission everything

Building Enclosure

• Systematic review of CD’s
  – Clear drawings and details
  – Clear, complete specifications

• Meeting with contractor and subs about building enclosure
  – Specs
  – Drawings
  – Testing schedule and requirements

• Submittal review
  – Compatibility matrix

• On site observation and testing
• Step 11-Learn & Operate

1. Operation
2. Post Occupancy Monitoring
3. Tabulate Actual Energy Performance
Step 11-Learn & Operate
Operation & Post Occupancy Monitoring

Track the first year of occupancy

– When: First Year
Track the first year of occupancy

Putney Field House, Energy Use + Solar Production
Dec 09 - Nov 10
### EUI Tabulation

**Energy Balance, Inc.**

#### Step 11-Learn & Operate

**Operation & Post Occupancy Monitoring**

<table>
<thead>
<tr>
<th>Building number</th>
<th>Building Name</th>
<th>Building Use</th>
<th>Conditioned sq.ft</th>
<th>Fuel Use Start date</th>
<th>Fuel Use End Date</th>
<th>EUI actual kBtu/sq.ft.-yr</th>
<th>Energy Use kBtu/year</th>
<th>EUI predicted kBtu/sq.ft.-yr</th>
<th>Notes effecting energy performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NRG Systems- I</td>
<td>66% office, 34% manufacturing/warehouse</td>
<td>45,000</td>
<td>1/1/2006</td>
<td>12/31/2006</td>
<td>22</td>
<td>998,225</td>
<td>20</td>
<td>Manufacturing not air conditioned</td>
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<tr>
<td>2</td>
<td>Putney Field House</td>
<td>Gym, workout, yoga, social space</td>
<td>17,500</td>
<td>12/1/2009</td>
<td>11/30/2010</td>
<td>10</td>
<td>11</td>
<td>Gym kept at ~60F</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Aiken Renovation</td>
<td>classrooms, faculty and open offices,</td>
<td>39,544</td>
<td>9/1/2010</td>
<td></td>
<td></td>
<td>998,225</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Waterfront Housing</td>
<td>Affordable Housing, 40 units</td>
<td>40,000</td>
<td>11/1/2004</td>
<td>10/31/2005</td>
<td>26</td>
<td>1,685,000</td>
<td>42</td>
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<tr>
<td>5</td>
<td>Pill House</td>
<td>SF home, net zero</td>
<td>2,800</td>
<td>1/10/2008</td>
<td>1/9/2009</td>
<td>7.6</td>
<td>26,545</td>
<td>9.5</td>
<td></td>
</tr>
</tbody>
</table>
Step 11-Learn & Operate
Tabulate Actual Energy Performance

Energy Performance of Maclay Architect's Commercial Projects

- Coastal Maine Botanical Gardens
- The Willow School -
- Mass Audubon - Environmental Learning Center (modeled)
- North Country School Performing Arts Center (modeled)
- Proctor Academy Dining Hall (modeled excluding process loads)
- Waitsfield Town Offices (modeled)
- George D. Aiken Center - UVM (modeled)
- SunCommon Headquarters (modeled)
- Bennington Superior Courthouse SOB
- Bennington Downtown SOB
- Renewable NRG Systems 2
- Renewable NRG Systems 1
- Middlebury South Village
- Putney School Field House
- Maclay Offices

EUI - kBtu/sf-yr

- Building energy from renewable sources
- Building energy from non-renewable sources
- Before Renovation added energy intensity - kBtu/SF-yr
Step 11-Learn & Operate
Tabulate Actual Energy Performance

Energy Performance of Maclay Architect’s Residencial & Multi-Family Projects

- Mountainside Residence
- Mountainview Residence
- Lake Sunapee Residence
- Putney Residence
- Newton Residence
- Historic Deep Energy Renovation, Burlington
- Warren Residence
- Mankton Residence
- VT Healthy Home (Maclay Residence)
- Darit House (2 apartments)
- Evergreen Place
- Burlington Cohousing
- Phoenix House
- Wheeler Brook Affordable Housing

Legend:
- Building energy from renewable sources
- Building energy from non-renewable sources
- Before Renovation added energy intensity
Step 11-Learn & Operate
Tabulate Actual Energy Performance

Exercise:
Summary Project EUI Data Sheet.xlsx
Step 11-Learn & Operate
Operation & Post Occupancy Monitoring

Tracking your projects EUI’s is a powerful learning tool and powerful marketing tool.

Not knowing your EUI is like…
• Step 12 - Celebrate
Join the Energy Challenge to Net-Zero Performance

<table>
<thead>
<tr>
<th>Project</th>
<th>SF</th>
<th>Completed</th>
<th>Existing</th>
<th>Modeled</th>
<th>Energy Use Intensity [EUI]</th>
<th>Project renewable energy production</th>
<th>Net EUI</th>
<th>Actual Air cooling Cost</th>
<th>Actual Cooling Cost</th>
<th>Additional Cooling Cost</th>
<th>Additional Cooling Cost</th>
<th>Total Additional Cooling Cost</th>
<th>Air infiltration [air/min/ft²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bennington Downtown SOB</td>
<td>22,772</td>
<td>100%</td>
<td>55</td>
<td>N/A</td>
<td>40</td>
<td>N/A</td>
<td>N/A</td>
<td>15,000</td>
<td>2,700</td>
<td>32,000</td>
<td>N/A</td>
<td>55,700</td>
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<td>Bennington Superior Courthouse and SOB</td>
<td>65,000</td>
<td>100%</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>23.5</td>
<td>10</td>
<td>10</td>
<td>23.5</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
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<tr>
<td>Coastal Maine Botanical Gardens – Bostage Education Center</td>
<td>8,200</td>
<td>100%</td>
<td>N/A</td>
<td>10</td>
<td>10</td>
<td>23.5</td>
<td>10</td>
<td>TBD</td>
<td>TBD</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>0.25</td>
</tr>
<tr>
<td>DVTA, Transit Facility</td>
<td>15,000</td>
<td>100%</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<td>N/A</td>
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<td>Environmental Learning Center – Mass Audubon</td>
<td>9,790</td>
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<td>N/A</td>
<td>15</td>
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<td>23.5</td>
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<td>TBD</td>
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<td>George D. Aiken Center</td>
<td>40,000</td>
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<td>20</td>
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<td>TBD</td>
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<td>0.35</td>
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<tr>
<td>Maday Offices</td>
<td>10,000</td>
<td>100%</td>
<td>10</td>
<td>20</td>
<td>20</td>
<td>24</td>
<td>10</td>
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<td>TBD</td>
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<td>0.35</td>
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<tr>
<td>Middlebury South Village</td>
<td>17,005</td>
<td>100%</td>
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<td>TBD</td>
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<tr>
<td>Morehouse Student Lodge</td>
<td>12,000</td>
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<td>10</td>
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<tr>
<td>Moretown Town Offices</td>
<td>1,930</td>
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<td>10</td>
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<td>10</td>
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<td>TBD</td>
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</tr>
<tr>
<td>North Country School Performing Arts Cty</td>
<td>30,000</td>
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<td>24</td>
<td>10</td>
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<td>TBD</td>
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<tr>
<td>Renewable RNG 1</td>
<td>40,000</td>
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<td>10</td>
<td>20</td>
<td>20</td>
<td>24</td>
<td>10</td>
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<td>TBD</td>
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<tr>
<td>Renewable RNG 2</td>
<td>25,000</td>
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<td>10</td>
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<td>24</td>
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<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>0.35</td>
</tr>
<tr>
<td>Proctor Academy Dining Hall</td>
<td>15,000</td>
<td>100%</td>
<td>10</td>
<td>20</td>
<td>20</td>
<td>24</td>
<td>10</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>0.35</td>
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<tr>
<td>Putney School Field House</td>
<td>10,000</td>
<td>100%</td>
<td>10</td>
<td>20</td>
<td>20</td>
<td>24</td>
<td>10</td>
<td>TBD</td>
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<td>TBD</td>
<td>TBD</td>
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<tr>
<td>SunCommon Headquarters - Warehouse</td>
<td>7,000</td>
<td>100%</td>
<td>10</td>
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<tr>
<td>SunCommon Headquarters - office</td>
<td>5,000</td>
<td>100%</td>
<td>10</td>
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<td>The Willow School</td>
<td>20,000</td>
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<tr>
<td>Vermont Creamery Offices</td>
<td>5,000</td>
<td>100%</td>
<td>10</td>
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<td>20</td>
<td>24</td>
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<td>0.35</td>
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<tr>
<td>Vermont Land Trust</td>
<td>4,000</td>
<td>100%</td>
<td>10</td>
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<td>24</td>
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<td>TBD</td>
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<tr>
<td>Waterfield Town Office</td>
<td>4,700</td>
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<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>0.35</td>
</tr>
</tbody>
</table>

US Energy Information Administration Median Site EUI: Comparative

- Education/Education: 45/kBtu/ft²
- Education: 50/kBtu/ft²
- Food Service - Restaurant Cafeteria: 85/kBtu/ft²
- Lodging: 60/kBtu/ft²
- Public Assembly: 50/kBtu/ft²
- Office: 100/kBtu/ft²
- Warehouse/Storage: 95/kBtu/ft²

Source: EBCI 2005 and US EPA Climate 2050 Inc. EBCI 2013
Join the Energy Challenge to Net-Zero Performance

### Project Performance Metrics Comparison

<table>
<thead>
<tr>
<th>Project</th>
<th>SF</th>
<th>Year Completed</th>
<th>Energy Use Intensity (EUI)</th>
<th>Cost</th>
<th>Air Infiltration cm³/sf/ft²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education College/University</td>
<td>kBtu/sf-yr</td>
<td>104</td>
<td>104</td>
<td>104</td>
<td>104</td>
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<tr>
<td>Education</td>
<td>kBtu/sf-yr</td>
<td>88</td>
<td>68.8</td>
<td>68.8</td>
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<tr>
<td>Food Service - Restaurant</td>
<td>kBtu/sf-yr</td>
<td>207</td>
<td>282.7</td>
<td>282.7</td>
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<tr>
<td>Lodging</td>
<td>kBtu/sf-yr</td>
<td>88</td>
<td>96.9</td>
<td>96.9</td>
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<tr>
<td>Public Assembly</td>
<td>kBtu/sf-yr</td>
<td>119</td>
<td>86.5</td>
<td>86.5</td>
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<tr>
<td>Office</td>
<td>kBtu/sf-yr</td>
<td>93</td>
<td>77.8</td>
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<tr>
<td>Warehouse/Storage</td>
<td>kBtu/sf-yr</td>
<td>55</td>
<td>52.8</td>
<td>52.8</td>
<td>52.8</td>
</tr>
</tbody>
</table>

Source: US Energy Information Administration Median Site EUI Comparative

Source: EIA CBECS 2003 and Architecture 2030 Inc. EIA CBECS 2012