HARTLEY SOLAR PLUS STORAGE

BRET PENCE
ECOLIBRIUM 3

DR. ALISON HOXIE
MECHANICAL & INDUSTRIAL ENGINEERING

SWENSON COLLEGE OF SCIENCE & ENGINEERING
UNIVERSITY OF MINNESOTA DULUTH
DULUTH, MN – 86,000 (POP.)
**ECOLIBRIUM3**

**Non-Profit Mission:** Our mission is to inspire and lead change in our community toward an equitable and sustainable future.

**Solar Market Pathways:**

- Find out what is happening with solar in our community
- Define barriers to solar adaptation
- Develop pathways to reduce costs and increase adaptation of this technology in our community
- End goal of 1MW of solar on the ground in Duluth
• 11,000 students
• Over 500 full-time faculty
• Land-grant university

SWENSON COLLEGE
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PROJECT OVERVIEW

• Hartley Nature Center is a City-owned, nonprofit operated green building.

• The Center serves as a park, environmental center and outdoor-based preschool with annual visitors ~ 30,000
• HNC had one of the first PV systems in northern MN, installed in 2002–2003. There is 11 kW on the roof and 2 kW on a ground-mounted dual-axis tracker, with 6 inverters.

• By 2016, 4 out of 5 roof inverters were no longer operable, and replacing them all with 2 inverters and rewiring would cost ~$10,000.

• The installation is part of a larger energy retrofit of Hartley Nature center, which includes replacement of the HVAC controls and GSHP, separation of hot water from the GSHP, and lighting upgrades.
PROJECT TEAM

- Bret Pence, Ecolibrium3
- Alison Hoxie, UMD
- Alex Jackson, City of Duluth
- Tom O’Rourke, Director Hartley Nature Center
- Brett Amundson, Operations Hartley Nature Center
- Chris LaForge, Great Northern Solar
- Paul Helstrom, Minnesota Power
PROJECT GOALS

- Replace Inverters
- Create a public emergency shelter
- Move building to net-zero
- Explore added values with storage such as critical load backup and behind the meter savings, including peak demand shaving
- Create an education platform for energy storage
## Battery Selection

<table>
<thead>
<tr>
<th>Name</th>
<th>Cost ($)</th>
<th>kWh</th>
<th>Type</th>
<th>Cycles</th>
<th>Warranty (yr)</th>
<th>Depth of Discharge %</th>
<th>Inverter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Juicebox</td>
<td>13,500</td>
<td>8.6</td>
<td>Li (NMC)</td>
<td>4000</td>
<td>10</td>
<td>70-88</td>
<td>5</td>
</tr>
<tr>
<td>Tesla</td>
<td>3,000</td>
<td>6.4</td>
<td>Li?</td>
<td>10 yrs?</td>
<td>10</td>
<td>100</td>
<td>3.3</td>
</tr>
<tr>
<td>Sonnen</td>
<td>18,750</td>
<td>12</td>
<td>Li?</td>
<td>10000</td>
<td>10</td>
<td>100</td>
<td>8</td>
</tr>
<tr>
<td>Sunverge</td>
<td>17,600</td>
<td>14.2</td>
<td>Li (NMC)</td>
<td>7000</td>
<td>10</td>
<td>80</td>
<td>6</td>
</tr>
</tbody>
</table>

The Challenge – Commercial grade features for a load that may be considered large residential.
BUILDING ENERGY USE - TYPICAL WINTER DAY
<table>
<thead>
<tr>
<th>Critical Load Backup</th>
<th>Description</th>
<th>Surge Load</th>
<th>Operating Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Server, Wi-Fi, Phones</td>
<td>Plug load: mech. Room</td>
<td>135 W</td>
<td>15 W</td>
</tr>
<tr>
<td>Refrigerator</td>
<td>115 Volts, 7.7 Amps</td>
<td>250 W</td>
<td>250 W</td>
</tr>
<tr>
<td>Lighting</td>
<td>Bathroom</td>
<td>610 W</td>
<td>232 W</td>
</tr>
<tr>
<td></td>
<td>Mechanical Room</td>
<td>128 W</td>
<td>128 W</td>
</tr>
<tr>
<td></td>
<td>Classroom 1</td>
<td>46 W</td>
<td>46 W</td>
</tr>
<tr>
<td></td>
<td>Classroom 2</td>
<td>46 W</td>
<td>46 W</td>
</tr>
<tr>
<td>Plug Loads</td>
<td><strong>Exhibit Hall:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Hartley:</strong> (1: 4 plug outlet)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Civil:</strong> (3: 4 plug outlet)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Office:</strong> 2 desktops</td>
<td>1200 W</td>
<td>10 W standby</td>
</tr>
<tr>
<td></td>
<td><strong>Office Library:</strong> 2 Laptops &amp; 6 phones</td>
<td>248 W</td>
<td>248 W</td>
</tr>
<tr>
<td></td>
<td><strong>Classroom 2:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Hartley:</strong> (1: 2 plug outlet)- 100 W laptop</td>
<td>200 W</td>
<td>200 W</td>
</tr>
<tr>
<td></td>
<td><strong>Civil:</strong> (5: 2 plug outlet)-(2) 100 W laptops, (8) 8 W/ phones</td>
<td>248 W</td>
<td>248 W</td>
</tr>
<tr>
<td>Maximum Total Loads</td>
<td>H:2895 W / C:3007 W</td>
<td></td>
<td>H:1208 W / C:1319</td>
</tr>
</tbody>
</table>
BATTERY SELECTION

- Sunverge, only company to meet project needs
- Small Commercial Unit (<15 kWh) & DC coupled (high voltage)
- Software ~ Energy Arbitrage, coming soon more sophisticated Peak Demand Shaving
- Other resiliency option – SPS outlet SunnyBoy grid-tied inverter connected to 5 kW of roof array
OPEN INSTALLATION PROCESS

- Continuing Ed Class
- City of Duluth
- Lake Superior College
- Chris LaForge, Great Northern Solar
- Community Celebration
- Solar Storage Awareness Day
CHALLENGES

- Replace 200 amp CT to 600 amp CT on main panel for monitoring building usage and minimizing peak demand charges and Rapid shutdown
- Install a combined RSD/Arc Fault protection device
- Peak Demand Shaving software installation
- Optimize battery deployment, continue to minimize building energy usage through equipment scheduling and energy efficiency improvements
- Monitoring and educational outreach
DATA COLLECTION AND ANALYSIS – SPRING 2016

HNC Data for 5/4, (Usage, PV Generation, State of Charge, and Active Rate)
DATA COLLECTION AND ANALYSIS – SPRING 2016
DATA COLLECTION AND ANALYSIS – SPRING 2016

![Operational View](image)

### System Diagram
- **PV DC**: 2569.80 W, 346.75 V, 7.54 A, 59.68 Hz, 253.06 VA
- **Grid 1 In**: 33.00 W, 124.08 V, 1.98 A, 59.68 Hz, 200.62 VA
- **Grid 2 In**: 0.00 W, 123.39 V, 0.00 A, 59.68 Hz, 0.00 VA
- **Load 1 Out**: 1846.90 W, 123.68 V, 12.62 A, 0.00 Hz, 1678.16 VA
- **Load 2 Out**: 190.80 W, 123.96 V, 1.84 A, 0.00 Hz, 200.62 VA
- **Grid 1 Out**: 0.00 W, 124.08 V, 0.00 A, 59.68 Hz, 0.00 VA
- **Grid 2 Out**: 1331.90 W, 123.39 V, 16.48 A, 59.56 Hz, 1269.00 VA
- **Site Line 1**: -1255.00 W, 123.88 V, 11.00 A, 0.00 Hz, 1300.04 VA
- **Site Line 2**: -2212.00 W, 124.00 V, 18.20 A, 59.68 Hz, 2251.76 VA
- **Battery**: -975.00 W, 56.70 V, -17.20 A, 0.00 Hz, 0.00 VA

**Operational View**
LESSONS – RETROFITS ARE HARD

- Code updates can upset the apple cart (increase cost)
  - Rapid shutdown and arc-fault protection
- Flex plans to accommodate the reality of the built environment – wiring, loads, etc.
- Initial project estimated cost ~20,000, actual ~45,000
• Project Costs – $45,000, cost to Hartley?
  • $5000

• Financial benefit- $1500/year, 30 year payback

• Value of backup – Wind storm and the value of storage

• Change to a non-demand tariff – $5000/year
  • Below 10kW peak demand, not over 2500kWh/month energy limit for 3 months in a row
  • Believe this is possible with energy efficiency upgrades, increased solar production, and strategic use of energy storage – Ask us in 3 months!
TIPS FOR SOLAR WITH STORAGE RETROFIT SUCCESS

• Determine values of your client(s) prior to examining economic project value

• An advocate at the local utility helps - external disconnect switch

• Great technical advisor is a must

• Flexibility is key! Design, backup loads, battery sizing, etc.

• Holistic approach to building systems helps – energy efficiency, systems operation
THANK YOU.

- Alison Hoxie, University of Minnesota Duluth
  - ahoxie@d.umn.edu
  - 218-726-8957
- Bret Pence, Ecolibrium3
  - bret@ecolibrium3.org
  - 218-336-1038