Innovative Plug Load Equipment Monitoring for Energy Savings and Asset Tracking at a National Laboratory

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Learning Objectives

• Identify energy monitoring and asset tracking benefits for your facilities

• Review strategies for reducing equipment energy use through commercially available monitoring technology

• Recognize and implement best practices for equipment purchase, setup, and operation

• Identify best options in plug load energy monitoring and asset tracking
PNNL is addressing complex challenges and providing solutions to critical national needs

- Scientific Discovery
- Energy Resiliency
- National Security
Sustainability Program has commitment to reduce energy use.

Plug Loads consume 20-30% of laboratory energy use.

PNNL HAS OVER 40,000 assets that require annual or biennial inventory – at significant time and cost.

WHAT OPTIONS ALLOW US TO REDUCE ENERGY WHILE IMPROVING EFFICIENCY IN ASSET TRACKING?

Property Management wants to improve inventory process.
Project Objective and Approach

• Objective
  ▪ Identify and evaluate a technology to support energy monitoring and asset tracking of plug load devices

• Desired Benefits
  ▪ Better understand and reduce energy use
  ▪ Facilitate equipment inventories
  ▪ Track asset utilization to foster equipment sharing

• Approach
  ▪ Evaluate chosen technology within multiple laboratory spaces on PNNL campus
2018 Experiment Led to Selection

- Plug load monitoring technology helped identify energy waste at PNNL
  - Highlighted the importance of best practices for equipment purchase, setup, and operation
  - 80% energy savings achieved for informational flat panel monitors

Before:
- 7am – 8pm: 25W
- 8pm – 7am: 65W

After:
- M-F 6am – 6pm: 25W
- All other: 0.4W
- 300 kWh/yr savings
## Technology Solutions Considered

<table>
<thead>
<tr>
<th>Technology</th>
<th>Energy Monitoring?</th>
<th>Location Tracking?</th>
<th>Compatibility Summary</th>
<th>Example</th>
</tr>
</thead>
</table>
| Commercial Plug Load Monitors           | ✓                  | ?                 | • Robust energy monitoring  
• Secure wireless communication  
• Real-time monitoring and control of connected equipment | ![Commercial Plug Load Monitors](image) |
| Wifi Smart Plugs                        | ✓                  | ?                 | • Limited energy monitoring  
• Potential burden on wifi network | ![Wifi Smart Plugs](image) |
| Passive Radio-Frequency Identification (RFID) | ✗                  | ✓                 | • No energy monitoring  
• Very limited tracking range | ![RFID](image) |
| Bluetooth Low Energy (BLE)              | ✗                  | ✓                 | • No energy monitoring  
• Good range, flexibility and locational resolution | ![Bluetooth Low Energy (BLE)](image) |
Laboratory Equipment Monitored

- Lab refrigerators, freezers, ULTs
- Computers/monitors
- Centrifuges
- Spectrometer
- Auto-samplers
- Vacuum ovens
- Specialty vent hoods
- Balances
- Furnace
- Biodiesel Rancimat
- Incubators
- Titrators
- Vortexers
- Sonicators
## Core Monitoring Capabilities

### Power, Energy Use, Utilization

<table>
<thead>
<tr>
<th>Device</th>
<th>Power (W)</th>
<th>Energy (kWh)</th>
<th>Days w/ Usage</th>
<th>Avg. Daily Use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Peak</td>
<td>Standby</td>
<td>Study</td>
<td>Annual</td>
</tr>
<tr>
<td>Vacuum Oven</td>
<td>1500</td>
<td>1.4</td>
<td>148.2</td>
<td>1094</td>
</tr>
<tr>
<td>FTIR Spectrometer</td>
<td>42</td>
<td>42</td>
<td>47.5</td>
<td>366</td>
</tr>
<tr>
<td>Lab Freezer</td>
<td>130</td>
<td>0</td>
<td>41.3</td>
<td>317</td>
</tr>
<tr>
<td>Lab Refrigerator</td>
<td>155</td>
<td>0</td>
<td>13.0</td>
<td>100</td>
</tr>
<tr>
<td>Centrifuge</td>
<td>725</td>
<td>3</td>
<td>11.3</td>
<td>81</td>
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<tr>
<td>Refrigerated Circulating Bath</td>
<td>370</td>
<td>1</td>
<td>8.1</td>
<td>61</td>
</tr>
<tr>
<td>Powder Safe Hood</td>
<td>166</td>
<td>1.6</td>
<td>2.2</td>
<td>17</td>
</tr>
<tr>
<td>Vacuum Pump</td>
<td>157</td>
<td>1</td>
<td>1.3</td>
<td>10</td>
</tr>
<tr>
<td>Particle Size Analyzer</td>
<td>41</td>
<td>0</td>
<td>0.4</td>
<td>3</td>
</tr>
</tbody>
</table>


Lab Equipment Daily Energy Usage

- Lab Refrigerator (100 kWh/y)
- Refriger. Circulating Bath (61 kWh/y)
- Spectrometer (366 kWh/y)
- Vacuum Oven (1094 kWh/y)
- Particle Size Analyzer (3 kWh/y)
- Vacuum Pump (10 kWh/y)
- Lab Freezer (61 kWh/y)
- Powder Safe Hood (17 kWh/y)
- Centrifuge (81 kWh/y)
Load Signatures Help Differentiate Equipment
Minute-Interval Load Profiles (Watts Over a 24 Hour Period)

- ULT Freezer, 2500 kWh/y
- Lab Freezer, 317 kWh/y
- Lab Refrigerator, 100 kWh/y
- Vacuum Oven, 1094 kWh/y
- FTIR Spectrometer, 366 kWh/y
- Centrifuge, 81 kWh/y
Energy Saving Opportunity: Vacuum Ovens

- Vacuum ovens used the most energy during the study period
- ~4.5 kWh/day (including weekends), before dropping to 1 kWh/day
- Opportunity for scheduling run times or working with researchers to turn down (or off) between uses
Average Use: Vacuum Oven

Graphs showing the baseline power usage for different days and scenarios:
- Generic Weekday
- Generic Weekend Day
- Low Consumption
- Full Week
Average Use: FTIR Spectrometer
Average Use: Centrifuge

Generic Weekday

Generic Weekend Day

Low Consumption

Full Week
Equipment Utilization

- Heat map shows average utilization for devices
- Identifies most and least used equipment
- Helpful to understand equipment utilization pattern and potential availability for other research staff
Conclusions

• Commercial plug load monitoring equipment can be used to:
  ▪ Monitor equipment energy use
  ▪ Identify energy savings opportunities
  ▪ Alert staff of off-normal events or indicators of potential issues
  ▪ Track equipment utilization
  ▪ Assist with asset inventories

• Some questions and gaps remain:
  ▪ Improved location tracking potential
  ▪ Options to secure the monitoring socket to the device power cord
  ▪ Enhanced alert capabilities

• Monitoring supports plug load equipment best practices
Sustainable Laboratory Equipment Best Practices

- Purchase
- Setup
- Monitor
- Operate
- Review

Circular diagram showing the cycle of Sustainable Laboratory Equipment Best Practices.
For both Energy and Cost Efficiency
Questions?

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Thank you