World as Laboratory: Updates on Partner Field Verifications of New Technologies

Thursday, August 23, 2018
4:00-5:30 pm
World as Laboratory: Updates on Partner Field Verifications of New Technologies

Moderator

- Jordan Hibbs, U.S. Department of Energy

Speakers

- Michael Deru, NREL
- Alicen Kandt, NREL
- Gina Schrader, NextEnergy
Michael Deru
National Renewable Energy Laboratory (NREL)
Field Testing Technologies

Michael Deru
Better Buildings Summit
August 23, 2018
High-Efficiency Smart Motor

- High Rotor Pole Switched Reluctance Motor (HRSRM)
- Simple, robust, low-cost construction
- No rotor windings
- No magnets or rare earth metals
- High efficiency and torque across a wide speed range
- Flexible data and control platform

Variable speed drive
Controller
SMC Motor Efficiency

Efficiency Curve Comparisons 1hp Motor

Motor Efficiency (%)

Motor Speed (rpm)
Refrigeration Condenser Motor Test

- Replaced half the motors in two refrigeration racks – 9 SMC motors
- Legacy system has one VFD for all motors in a rack
- SMC has a VFD for each motor and each motor

1 to 3 hp SMC motor
1.5 hp induction motor
Testing

1. Run all motors at full speed
2. Run all motors following the speed signal from the legacy VFD
   ➤ Failed because speed signal changed rapidly and difficult to verify all motors were running at the same speed
3. Run all motors at the same speed for 60 min from 5 Hz to 60 Hz

<table>
<thead>
<tr>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressor power</td>
</tr>
<tr>
<td>Condenser fan motor power</td>
</tr>
<tr>
<td>Suction and discharge pressures</td>
</tr>
<tr>
<td>Condenser outlet pressure</td>
</tr>
<tr>
<td>Condenser inlet temperature</td>
</tr>
<tr>
<td>Condenser outlet temperature</td>
</tr>
<tr>
<td>Outdoor air temperature</td>
</tr>
<tr>
<td>Fan speed</td>
</tr>
</tbody>
</table>
Qualitative Results

• Installation was straight forward
• No issues with SMC motors during testing
• Minor bugs in controller and communications
• One SMC motor was automatically shut down when a piece of foam jammed the fan and a fault signal was generated. The foam was removed and the motor ran with no problems.
Quantitative Results

- Power curves for the motors show greater than 30% reduction in power input
Annual Results

- Estimated annual energy savings:
  - 34% for Rack A
  - 31% for Rack B
# Energy Savings

<table>
<thead>
<tr>
<th>Rack</th>
<th>Control Type</th>
<th>Energy Savings</th>
<th>Annual Savings per Motor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(kWhr)</td>
<td>($)</td>
</tr>
<tr>
<td>Rack A</td>
<td>Variable speed</td>
<td>8,906 kWhr</td>
<td>$872.79</td>
</tr>
<tr>
<td>Rack A</td>
<td>Constant speed</td>
<td>19,459 kWhr</td>
<td>$1,906.98</td>
</tr>
<tr>
<td>Rack B</td>
<td>Variable speed</td>
<td>6,836 kWhr</td>
<td>$669.93</td>
</tr>
<tr>
<td>Rack B</td>
<td>Constant speed</td>
<td>13,046 kWhr</td>
<td>$1,278.51</td>
</tr>
</tbody>
</table>
HRSRM Applications

• Good for
  – Harsh environments
  – Long runtimes
  – Remote locations

• Retrofits
  – Best for 1-10 hp motors with a variable speed
  – Applications
    • Condenser fans
    • RTU supply fans
    • AHU fans

• New
  – 1-10 hp motors with high runtimes and variable speed
High-Performance Circulator Pump

• Applied to pumps 2.5 hp or smaller
  – DHW recirculation pumps, small hot water and chilled water pumps
• EC motor
• Local and remote monitoring and control
• Zero maintenance

Control Modes
• Constant speed
• Constant pressure
• Proportional pressure
• Constant temperature
• AUTOADAPT
• FLOWADAPT

Onboard Metering
• Temperature
• Speed
• Flow
• Power
• Head
• Energy (kWh)
• BTU
• History

Grundfos Magna 3
High-performance circulator pump (HPCP)
Comparison to Standard Pumps

- **Optimized Impeller**: 10% to 15% improvement in hydraulic efficiency
- **ECM with variable speed operation vs induction motor**: 10% to 20% electric efficiency improvement
- **Self-optimizing control logic and built in night time setback**: Up to 65% savings
Domestic Hot Water Pump Tests

14 floor office building in Lakewood, CO

1. DHW loop #1: 8 hr/day, weekdays only

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>HPCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power (hp)</td>
<td>¼</td>
<td>¼</td>
</tr>
<tr>
<td>Wire-to-water eff.</td>
<td>8.2%</td>
<td>30.1%</td>
</tr>
<tr>
<td>Control</td>
<td>constant speed</td>
<td>constant temp</td>
</tr>
</tbody>
</table>

2. DHW loop #2: 11 hr/day, weekdays only

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>HPCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power (hp)</td>
<td>½</td>
<td>¼</td>
</tr>
<tr>
<td>Wire-to-water eff.</td>
<td>unknown</td>
<td>44.3%</td>
</tr>
<tr>
<td>Control</td>
<td>constant speed</td>
<td>constant temp</td>
</tr>
</tbody>
</table>
## DHW Results

<table>
<thead>
<tr>
<th></th>
<th>DHWP #1</th>
<th></th>
<th>DHWP #2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>HPCP</td>
<td>Baseline</td>
<td>HPCP</td>
</tr>
<tr>
<td><strong>Max Power (W)</strong></td>
<td>281</td>
<td>12</td>
<td>373</td>
<td>72</td>
</tr>
<tr>
<td><strong>Weekday Total Energy (kWh)</strong></td>
<td>2.36</td>
<td>0.10</td>
<td>4.18</td>
<td>0.18</td>
</tr>
<tr>
<td><strong>% savings</strong></td>
<td>96%</td>
<td></td>
<td>96%</td>
<td></td>
</tr>
</tbody>
</table>
DHW Economic Performance

Compared to a new constant speed standard efficiency pump

<table>
<thead>
<tr>
<th></th>
<th>DHWP #1</th>
<th>DHWP #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy and demand savings</td>
<td>$58</td>
<td>$79.5</td>
</tr>
<tr>
<td>Maintenance savings</td>
<td>$75</td>
<td>$75</td>
</tr>
<tr>
<td>Incremental cost of HPCP</td>
<td>$575</td>
<td>$575</td>
</tr>
<tr>
<td>Simple payback (y)</td>
<td>4.3</td>
<td>3.7</td>
</tr>
<tr>
<td>Savings-to-Investment Ratio</td>
<td>2.7</td>
<td>3.1</td>
</tr>
</tbody>
</table>
Heating Hot Water Circulator Pump Test

- Office building air handling unit, Lakewood, CO
- Tested over 2016-17 and 2017-18 winters

Baseline
New ½ hp constant speed pump
3-way valve controls flow through AHU

Grundfos Magna 3
Automated flow control

Bypass valve closed
AHU Heating Hot Water Results

• Operation problems invalidated data from 2016-17 season
• The AHUs serve different loads making a direct comparison difficult
• AHU19 had low heating runtimes and sometimes switched to cooling during the middle of the day
• Savings were estimated by applying the baseline pump power to the AHU 19 pump runtimes
## HHW Results

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>HPCP</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Max Power (W)</strong></td>
<td>222</td>
<td>204</td>
<td></td>
</tr>
<tr>
<td><strong>On Peak Avg (kWh/day)</strong></td>
<td>0.144</td>
<td>0.093</td>
<td>35%</td>
</tr>
<tr>
<td><strong>Off Peak Avg (kWh/day)</strong></td>
<td>0.728</td>
<td>0.550</td>
<td>24%</td>
</tr>
</tbody>
</table>
Compared to a new constant speed standard efficiency pump

<table>
<thead>
<tr>
<th></th>
<th>High Efficiency Baseline</th>
<th>Typical Efficiency Baseline</th>
<th>Typical Efficiency Baseline &amp; $0.11/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy and demand savings</td>
<td>$3</td>
<td>$41</td>
<td>$76</td>
</tr>
<tr>
<td>Maintenance savings</td>
<td>$75</td>
<td>$75</td>
<td>$75</td>
</tr>
<tr>
<td>Incremental cost of HPCP</td>
<td>$500</td>
<td>$500</td>
<td>$500</td>
</tr>
<tr>
<td>Simple payback (y)</td>
<td>6.4</td>
<td>4.3</td>
<td>3.3</td>
</tr>
<tr>
<td>Savings-to-Investment Ratio</td>
<td>1.8</td>
<td>2.7</td>
<td>3.5</td>
</tr>
</tbody>
</table>
Recommendations

• **DHW Recirculation Pumps** – Deploy as end-of-life replacement with as little as 40 hours/week with low electric rates.

• **Heating Hot Water and Chilled Water Pumps** – Target constant volume pumps that operate for more than 10-12 hours per day, 8 months per year, with electric rates of 11 cents/kWh or higher.
  – Pumps serving multiple heating coils are anticipated to have greater energy savings due to more intermittent operation, and longer run times.
  – Three way valve bypass must be closed or converted to two way valves.

• **GSHP Circulator Pumps** – Deploy as end-of-life replacement with greater than 40-60 hours/week with low electric rates.
Thank you

michael.deru@nrel.gov
Alicen Kandt
National Renewable Energy Laboratory (NREL)
Plug Load Management System Field Study

Wireless Meter & Controls
Alicen Kandt
Senior Mechanical Engineer
National Renewable Energy Laboratory (NREL)
Presentation Overview

- Why we tested this technology (Plug Load Management (PLM))
- Introduction to PLM
- Field Study
- Results
- Lessons learned
Why We Tested This Technology

- Plug and process loads (PPLs)—loads plugged into electrical outlets in a building such as computers, coffee makers, etc.—and hard-wired loads, such as fire detectors, escalators, etc.
- PPLs consume about one third of primary energy in U.S. commercial buildings.
- As buildings become more efficient, PPL efficiency becomes more relevant to achieving aggressive energy targets.

<table>
<thead>
<tr>
<th>SAVINGS POTENTIAL*</th>
<th>Individual Equipment</th>
<th>Whole Building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>17-33%</td>
<td>5-10%</td>
</tr>
<tr>
<td>Commercial</td>
<td>10-48%</td>
<td>6-10%</td>
</tr>
</tbody>
</table>

*Based on numerous studies
Introduction to Plug Load Management (PLM)

- **Ibis InteliNetwork™ PLM system:**
  - Intelligent socket devices, which plug into existing electrical outlets and collect energy usage information
  - A gateway, which manages communication between the intelligent sockets and the PLM cloud service
  - A PLM network, which is a cloud-based measurement and control network for the entire system.
- Estimated potential plug load savings of 20%-50%

Figure 1: Intelligent Sockets
Image: Ibis Networks
Field Study Sites

- Two test sites

<table>
<thead>
<tr>
<th>Test Location A</th>
<th>Test Location B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Chandler, AZ</td>
</tr>
<tr>
<td>Type of Facility</td>
<td>Pet-oriented retail store</td>
</tr>
<tr>
<td>Devices Identified for Pilot Inclusion (monitoring, control, or other efficiency strategies)</td>
<td>46</td>
</tr>
<tr>
<td>Average Electric Rate</td>
<td>$0.12/kWh</td>
</tr>
<tr>
<td></td>
<td>Honolulu, HI</td>
</tr>
<tr>
<td></td>
<td>Eyewear manufacturer and retail store</td>
</tr>
<tr>
<td></td>
<td>130</td>
</tr>
<tr>
<td></td>
<td>$0.30/kWh</td>
</tr>
</tbody>
</table>

Device Category
- Office Equipment
- Additional Store Equipment
- Kitchen Equipment
- Pet Care Equipment

Device Category
- Kitchen Equipment
- Office/Retail Equipment
Testing Protocol

- Equipment inventory and PLM installation period
- Baseline period
- Controls period

<table>
<thead>
<tr>
<th>Test Site</th>
<th>Baseline Period</th>
<th>Controls Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Location A</td>
<td>4 weeks 1 day</td>
<td>4 weeks 1 day</td>
</tr>
<tr>
<td>Test Location B</td>
<td>3 weeks 6 days</td>
<td>3 weeks 6 days</td>
</tr>
</tbody>
</table>
## Quantitative Objectives

<table>
<thead>
<tr>
<th>Objective</th>
<th>Metrics &amp; Data</th>
<th>Success Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity Savings</td>
<td>Electricity savings</td>
<td>Electricity savings compared to a baseline period:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• At least 10% electricity reduction in measured plug loads</td>
</tr>
<tr>
<td>Cost-Effectiveness</td>
<td>Simple payback and SIR</td>
<td>• Simple payback &lt; 10 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• SIR &gt; 1</td>
</tr>
<tr>
<td>Deployability</td>
<td>PLM solution has broad applications across the retailer’s portfolio of buildings (for a large quantity of devices within each store)</td>
<td>Favorable payback and SIR are achieved in most building and equipment types</td>
</tr>
</tbody>
</table>
Quantitative Findings

<table>
<thead>
<tr>
<th>Metrics &amp; Data</th>
<th>Test Location A</th>
<th>Test Location B</th>
<th>Success Criterion Met</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity Savings</td>
<td>Metered electric consumption</td>
<td>1,040 kWh/year</td>
<td>2,730 kWh/year</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$124.80/year&lt;sup&gt;1&lt;/sup&gt;</td>
<td>$819/year&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11% savings&lt;sup&gt;2&lt;/sup&gt;</td>
<td>18% savings&lt;sup&gt;4&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cost-Effectiveness</td>
<td>Simple payback</td>
<td>59 years</td>
<td>24 years</td>
</tr>
<tr>
<td>Savings to investment ratio (SIR)</td>
<td></td>
<td>0.17</td>
<td>0.41</td>
</tr>
<tr>
<td>Deployability</td>
<td>PLM solution has broad applications across the retailer’s portfolio of buildings (for a large quantity of devices within each store)</td>
<td>Unfavorable payback and SIR; however, complications during pilot negatively affected outcomes and savings potential</td>
<td>Unfavorable payback and SIR; however, complications during pilot negatively affected outcomes and savings potential</td>
</tr>
</tbody>
</table>

<sup>1</sup> Assuming an electric rate of $0.12/kWh
<sup>2</sup> Percent savings in measured plug loads
<sup>3</sup> Assuming an electric rate of $0.30/kWh
<sup>4</sup> Percent savings in measured plug loads
<table>
<thead>
<tr>
<th>Objective</th>
<th>Metrics &amp; Data</th>
<th>Success Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of Installation</td>
<td>Interview with vendor and retailer representative(s):</td>
<td>• &lt; 1 day to install</td>
</tr>
<tr>
<td></td>
<td>• Time required to install and configure</td>
<td>• &lt; 1 week to provide online data access</td>
</tr>
<tr>
<td></td>
<td>• Labor associated with install</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Impact of install on operations</td>
<td></td>
</tr>
<tr>
<td>Operability</td>
<td>Interview with retailer representative(s):</td>
<td>• No impact to operation and maintenance effort</td>
</tr>
<tr>
<td></td>
<td>• Usability of intelligent sockets</td>
<td>• &lt; 4 hours to understand online data interface</td>
</tr>
<tr>
<td></td>
<td>• Usability of PLM network</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Time commitment required for continual management of plug loads</td>
<td></td>
</tr>
<tr>
<td>Nonenergy Benefits</td>
<td></td>
<td>At least one non-energy benefit is realized</td>
</tr>
</tbody>
</table>
## Qualitative Findings

<table>
<thead>
<tr>
<th>Metrics &amp; Data</th>
<th>Test Location A</th>
<th>Test Location B</th>
<th>Success Criterion Met</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of Installation</td>
<td>Time required to install system at test site</td>
<td>Less than a day to install</td>
<td>More than a day to install</td>
</tr>
<tr>
<td></td>
<td>Time required by vendor to configure and provide online data interface access</td>
<td>2–3 days</td>
<td>2–3 days</td>
</tr>
<tr>
<td>Impact of install on operations</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Metrics &amp; Data</td>
<td>Test Location A</td>
<td>Test Location B</td>
<td>Success Criterion Met</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>Operability</td>
<td>Usability of intelligent sockets: Easy and intuitive</td>
<td>Easy and intuitive, but problems encountered with devices not functioning as intended after controls deployed and with staff unplugging sockets</td>
<td>✓ (Location A)</td>
</tr>
<tr>
<td></td>
<td>Usability of online data interface: Did not use enough to provide feedback</td>
<td>Did not utilize online data interface</td>
<td>x (Location B)</td>
</tr>
<tr>
<td></td>
<td>Time commitment required for monitoring and management of plug loads: Staff did not have the 1–2 hours needed per week</td>
<td>Staff did not have the 1–2 hours needed per week</td>
<td>x</td>
</tr>
<tr>
<td>Nonenergy Benefits</td>
<td>PLM solution results in increased equipment life, early detection of device failure, awareness of energy use trends resulting in savings not attributed to controls, staff become educated about and</td>
<td>None</td>
<td>x (Location A)</td>
</tr>
</tbody>
</table>
Key Takeaways

- Real world testing = real world complications
  - Mother nature
  - Sockets gone missing
  - Staff engagement

- Successful deployment conditions:
  - High electricity rates
  - Many ‘controllable’ devices
  - A staff member who can spend 1-2 hours per week monitoring the PLM
Report Forthcoming

- Plug Load Management System Field Study:
  - https://www.nrel.gov/research/publications.html
Thank You!

Alicen Kandt
National Renewable Energy Laboratory
303.384.7518
alicen.kandt@nrel.gov
Disclaimer

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Gina Schrader
NextEnergy
2018 Better Buildings Summit
August 23, 2018

Gina Schrader
Director, Building Model Innovation
NextEnergy
The problem
why do we care?

- Lighting accounts for more than 16% of electricity usage in small to medium sized commercial buildings
- Coupling lighting with controls can generate as much as 38% energy cost saving
- Low adoption rate of advanced lighting controls
The problem
Addressing market barriers

Market Barriers

- Past experience with tech
- Rapid Evolution
- Awareness & Education
- Resources to manage
- Cost
- Time
The solution
Lighting Energy Technology Solutions (LiTES)

goal
Reduce the energy footprint in small & medium commercial buildings by accelerating the adoption of advanced lighting controls solutions through training and technology deployment

audience
Building owners | Building managers | Contractors | Installers | Manufacturers of advanced lighting controls | Designers | Architects | Finance professionals
**MICHIGAN’S ENERGY EFFICIENCY VALUE CHAIN**

<table>
<thead>
<tr>
<th>RESIDENTIAL</th>
<th>COMMERCIAL</th>
<th>INDUSTRIAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>STAKEHOLDERS</td>
<td>AUDIT</td>
<td>ENGINEERING</td>
</tr>
<tr>
<td>107</td>
<td>120</td>
<td>240</td>
</tr>
</tbody>
</table>

- **NGOs**: 54
- **ACADEMIC**: 32
- **INCUBATORS**: 21
- **LIGHTING**: 60
- **HVAC**: 49
- **SOFTWARE SENSORS & CONTROLS**: 82
- **OTHER**: 325
- **HVAC**: 1488
- **ELECTRICAL**: 102
- **INSULATION/WEATHERIZATION**: 160
- **WINDOW/DOOR/AIR SEALING**: 96
- **OTHER INSTALLER/CONTRACTOR**: 240

**UTILITY PROVIDERS - 46**

Clean Energy Roadmap, NextEnergy 2016
works with innovators
to accelerate solutions that create
smarter, cleaner, more accessible
communities and cities.
Our team
program partners
LiTES
program objectives

- Training & Education
- Technology Deployment
- Outreach & Marketing
Training
increasing education & awareness

Train 100 contractors via 19 trainings
Technology deployment
real-world examples

- Install tech in ~100 sites
- Collect M&V metrics @ 10 sites
- Report energy savings
Technology Deployment

develop incentives

Electric Utility Service Areas

Utilities Distributing Electricity
(select for information)

Inverter Owned shown in circles and letters
Cooperatives shown in letters only
## Technology deployment incentive structure

<table>
<thead>
<tr>
<th>Incentives offered</th>
<th>Overall Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ DTE Energy Electric Customers</td>
<td>▪ Must take place in a commercial building</td>
</tr>
<tr>
<td>▪ $0.12/kWh saved</td>
<td>▪ Space less than 100,000 sq. ft.</td>
</tr>
<tr>
<td>▪ Consumers Energy Electric Customers</td>
<td>▪ Tech should follow DLC networked lighting controls requirements</td>
</tr>
<tr>
<td>▪ $0.25/kWh saved</td>
<td>▪ Existing controls, LEDs, and/or circuit level controls are not necessary</td>
</tr>
<tr>
<td>▪ To qualify, contractor or electrician must attend training</td>
<td>▪ Simple payback must be between 1 and 8 years</td>
</tr>
<tr>
<td>▪ Energy savings must be reported</td>
<td>▪</td>
</tr>
</tbody>
</table>

### Installer requirement
- To qualify, contractor or electrician must attend training
Sharing the story

case studies
Sharing the story
engagement tools

About LiTES
The Lighting Technology Energy Solutions (LiTES) program is a three-year initiative supported by the Department of Energy (DOE) that will reduce the energy footprint in small and medium commercial buildings by accelerating the adoption of advanced lighting control solutions through training and technology deployment.

3 ways to get involved

Training & Education
- California incentive programs
- Federal government
- DOE projects
- Other federal
- Aircraft
- Commercial buildings
- Training programs
- Snaps
- Online
- Seminars
- Workshops
- Webinars
- Training
- LiTES

Technology Deployment
- Training
- LiTES programs
- DOE Energy Conservation
- Commercial buildings
- Training programs
- Snaps
- Online
- Seminars
- Workshops
- Webinars
- Training
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Events & Resources
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- LiTES programs
- DOE Energy Conservation
- Commercial buildings
- Training programs
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- Workshops
- Webinars
- Training
- LiTES

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Status
Success to date

8
Trainings hosted

100
Trained professionals

7
M&V Sites Secured

1
LiTES Summit
LiTES
learn more

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Gina Schrader
NextEnergy
ginas@nextenergy.org
Thank you!

Moderator
- Jordan Hibbs, U.S. DOE, Jordan.Hibbs@ee.doe.gov

Speakers
- Michael Deru, NREL, Michael.Deru@nrel.gov
- Alicen Kandt, NREL, Alicen.Kandt@nrel.gov
- Gina Schrader, NextEnergy, ginas@nextenergy.org