Welcome

Conservation Applied Research & Development (CARD) Webinar
Webinar Basics

- Attendees in listen-only mode
- Type your questions into Question Box
- Questions addressed at end
- Webinar recorded
- Handout: webinar slide deck
• Purpose to help Minnesota utilities achieve 1.5% energy savings goal by:
  • Identifying new technologies or strategies to maximize energy savings;
  • Improving effectiveness of energy conservation programs;
  • Documenting CO₂ reductions from energy conservation programs.

Minnesota Statutes §216B.241, Subd. 1e

• Utility may reach its energy savings goal
  • Directly through its Conservation Improvement Program (CIP)
  • Indirectly through energy codes, appliance standards, behavior, and other market transformation programs
CARD RFP Spending by Sector thru mid-FY2017

- 8 Funding Cycles
- Nearly 380 proposals
- 92 projects funded
Industrial Battery Charger Field Study

Minnesota Conservation Applied Research and Development (CARD) Program
TOPICS

- Background
- Past Research
- Methodology
- Findings
- Conclusions and Recommendations
BACKGROUND
Background

- Battery-powered lift-trucks are very common in industry
  - A manufacturing facility typically has at least one
  - > 7,300 manufacturing facilities in MN
- A battery charger with regular usage may consume about 15,000 kWh per year
Background

- A battery charger’s basic function is to convert AC to DC
- Control circuitry is needed to prevent damage to battery
- Most existing chargers are ferroresonant (FR) or silicon-controlled rectifier (SCR)
- High frequency (HF) chargers are gaining market share
  - Promoted as more energy efficient, offering faster charging capability
Background

• Facilities that regularly use lift-trucks commonly use a conventional charging approach
  – Lift-truck batteries are run down to low charge levels (ideally > 20%), then slowly recharged during off-peak hours
  – Facilities with heavy lift-truck usage and multiple shifts may need to change batteries daily
  – Changing batteries increases costs, hurts productivity, and presents health and safety risks
Background

• Some chargers offer “fast charging” or “opportunity charging” capability
  • Opportunity charging means plugging in during breaks in the workday, and rapidly charging the battery banks to a sufficient level
  • Avoids the need for battery change-outs, purchasing additional batteries
• EPRI studies demonstrated productivity and safety benefits of fast charging
• However, higher charging rates and shift to peak periods may drive up demand charges
There are four types of industrial battery chargers:

<table>
<thead>
<tr>
<th>Technology</th>
<th>Approx. Percent of Existing Stock</th>
<th>Average Power Conversion Efficiency</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferroresonant (FR)</td>
<td>50%</td>
<td>85%</td>
<td>$1,500-$2,300</td>
</tr>
<tr>
<td>Silicon-Controlled Rectifier (SCR)</td>
<td>30%</td>
<td>85%</td>
<td>$1,300-$2,700</td>
</tr>
<tr>
<td>Hybrid</td>
<td>5%</td>
<td>86%</td>
<td>$2,000-$3,500</td>
</tr>
<tr>
<td>High Frequency (HF)</td>
<td>10%</td>
<td>92%</td>
<td>$2,000-$3,500</td>
</tr>
</tbody>
</table>

Source: Ecos Consulting, 2009
Background

• Battery charger energy efficiency metrics:
  • *Charge Return Factor* (ideal range is 1.05 to 1.15)
  • *Power Conversion Efficiency*
  • *Maintenance Power*
  • *No Battery Power*
  • *Power Factor* (ideal power factor is 1)

• *Charge Return Factor* and *Power Conversion Efficiency* are most important predictors of energy use for most facilities

• HF chargers thought to have technological advantage in Power Conversion Efficiency and Power Factor
Background

• PG&E completed formalized testing of industrial battery chargers in 2009 that demonstrated higher energy efficiency of HF chargers

• Our goal was to test HF chargers in actual facilities
  • Compare energy use of HF chargers to existing chargers
  • See if operators switch from conventional charging to opportunity charging, and measure impact on peak demand
  • Assess any non-energy benefits from opportunity charging
PAST RESEARCH
Past Research

- PG&E studies demonstrated energy efficiency benefits of HF chargers
  - Began with development of a consumer battery charger test procedure by the California Energy Commission (CEC)
  - PG&E and SCE adapted the procedure for industrial battery chargers; formerly adopted by the CEC in December 2008
  - PG&E Emerging Technologies Program sponsored formalized testing of industrial battery chargers, results published in 2009
### Past Research

#### PG&E 2009 Test Results

<table>
<thead>
<tr>
<th>Technology</th>
<th>Charge Return Factor</th>
<th>Power Conversion Efficiency</th>
<th>Maintenance Power (W)</th>
<th>No Battery Power (W)</th>
<th>Average Power Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FR</strong></td>
<td>Range 1.12 - 1.21</td>
<td>84% - 87%</td>
<td>7.0 - 293.5</td>
<td>7.0 - 39.5</td>
<td>0.91 - 0.97</td>
</tr>
<tr>
<td></td>
<td>Average 1.15</td>
<td>85%</td>
<td>81.7</td>
<td>18.2</td>
<td>0.92</td>
</tr>
<tr>
<td><strong>SCR</strong></td>
<td>Range 1.09 - 1.35</td>
<td>81% - 88%</td>
<td>10.0 - 262.8</td>
<td>10.0 - 285.0</td>
<td>0.60 - 0.85</td>
</tr>
<tr>
<td></td>
<td>Average 1.18</td>
<td>85%</td>
<td>137.1</td>
<td>125.3</td>
<td>0.76</td>
</tr>
<tr>
<td><strong>Hybrid</strong></td>
<td>Range 1.10 - 1.14</td>
<td>80% - 89%</td>
<td>53.0 - 73.9</td>
<td>6.0 - 19.0</td>
<td>0.87 - 0.97</td>
</tr>
<tr>
<td></td>
<td>Average 1.12</td>
<td>86%</td>
<td>62.3</td>
<td>14.1</td>
<td>0.91</td>
</tr>
<tr>
<td><strong>HF</strong></td>
<td>Range 1.06 - 1.29</td>
<td>91% - 92%</td>
<td>23.8 - 108.0</td>
<td>23.8 - 108.0</td>
<td>0.93 - 0.99</td>
</tr>
<tr>
<td></td>
<td>Average 1.15</td>
<td>92%</td>
<td>48.4</td>
<td>48.4</td>
<td>0.96</td>
</tr>
</tbody>
</table>

Orange fill indicates within ideal range
Yellow fill indicates best (highest or lowest)

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**Technology**
- FR
- SCR
- Hybrid
- HF
Past Research

• EPRI completed three large demonstration projects of fast charging in automobile assembly plants in 2002-2004. Results:
  • Increased productivity and reduced labor costs
  • Improved safety through fewer battery change-outs and reduced risk of vehicle collisions
  • Parts and maintenance savings
  • Battery and part protection, as batteries were less likely to go below 20% of charge capacity
METHODOLOGY
Methodology

• 9 sites/13 charging stations across MN, SD

• Field testing
  • Pre-monitoring
    • Install energy loggers
    • Monitor existing FR or SCR charger(s) for 2 weeks
  • Post-monitoring
    • Install HF charger(s)
    • Install energy loggers
    • Monitor existing FR or SCR charger(s) for 2 weeks

• Measurement equipment
  • Fluke 1730 energy logger or equivalent, 1/5 min intervals
  • Douglas DataTrac battery monitoring device (1 site)

• Customer Interviews (Sites 8 and 9)
FINDINGS
Findings

• Overview
  • Finding good test sites was a challenge throughout
    • Little traction from distributors
    • Many potential sites did not meet screening criteria
    • Most sites had no need for opportunity charging
    • Two sites did not have complete pre- and post-data

• Testing limitations
  • Could not replace all existing chargers with HF chargers
  • Could not find solution for measuring charger output power w/o voiding warranty
  • Could not control for differences in lift-truck usage between pre- and post-periods
  • Opportunity charging may not have been enabled on all HF chargers

• Puzzling, inconsistent results
### Findings

<table>
<thead>
<tr>
<th>Site</th>
<th>Charging Station</th>
<th>1</th>
<th>2</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old Charger Type</td>
<td>FR</td>
<td>FR</td>
<td>FR</td>
<td>FR</td>
<td>FR</td>
<td>FR</td>
</tr>
<tr>
<td>New Charger Type</td>
<td>HF</td>
<td>HF</td>
<td>HF</td>
<td>HF</td>
<td>HF</td>
<td>HF</td>
</tr>
<tr>
<td>3-Phase AC Voltage</td>
<td>240V</td>
<td>240V</td>
<td>277/480V</td>
<td>277/480V</td>
<td>277/480V</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Changes Pre-Post</th>
<th>Site 1</th>
<th>Site 2</th>
<th>Site 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. Length of Charge (hrs)</td>
<td>-1.00</td>
<td>+0.06</td>
<td>+3.29</td>
</tr>
<tr>
<td>Peak Demand, kW</td>
<td>+1.85</td>
<td>+0.65</td>
<td>+3.26</td>
</tr>
<tr>
<td>Average Power Factor</td>
<td>-0.03</td>
<td>-0.02</td>
<td>+0.06</td>
</tr>
<tr>
<td>Average # Charges/Day</td>
<td>-2.17</td>
<td>-0.30</td>
<td>+0.47</td>
</tr>
<tr>
<td>Average kWh/Charge</td>
<td>-4.74</td>
<td>+1.13</td>
<td>+20.61</td>
</tr>
<tr>
<td>Average kWh/Day</td>
<td>-35.12</td>
<td>+0.80</td>
<td>+27.19</td>
</tr>
</tbody>
</table>
## Findings

<table>
<thead>
<tr>
<th>Site</th>
<th>3</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charging Station</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Old Charger Type</td>
<td>FR</td>
<td>FR</td>
<td>FR</td>
<td>SCR</td>
<td>FR</td>
</tr>
<tr>
<td>New Charger Type</td>
<td>HF</td>
<td>HF</td>
<td>HF</td>
<td>HF</td>
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<tr>
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<td>277/480V</td>
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<td>277/480V</td>
</tr>
<tr>
<td><strong>Changes Pre-Post</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avg. Length of Charge(hrs)</td>
<td>+2.49</td>
<td>-0.23</td>
<td>-1.90</td>
<td>+2.09</td>
<td>-1.01</td>
</tr>
<tr>
<td>Peak Demand, kW</td>
<td>-2.20</td>
<td>+4.73</td>
<td>-5.21</td>
<td>-8.30</td>
<td>+0.07</td>
</tr>
<tr>
<td>Average Power Factor</td>
<td>-0.00</td>
<td>-0.24</td>
<td>n/a</td>
<td>-0.23</td>
<td>+0.24</td>
</tr>
<tr>
<td>Average # Charges/Day</td>
<td>-1.39</td>
<td>+2.89</td>
<td>-1.39</td>
<td>-0.29</td>
<td>-0.11</td>
</tr>
<tr>
<td>Average kWh/Charge</td>
<td>+6.05</td>
<td>-3.01</td>
<td>-15.52</td>
<td>-27.10</td>
<td>-16.01</td>
</tr>
<tr>
<td>Average kWh/Day</td>
<td>-19.08</td>
<td>+30.41</td>
<td>-44.89</td>
<td>-11.90</td>
<td>-10.14</td>
</tr>
</tbody>
</table>
Findings

- Monitoring results:
  - kWh per charge did not consistently decrease with HF charger as expected
  - kWh per day did not consistently decrease with HF charger as expected
  - HF chargers did not consistently have a higher power factor
    - Some Ferro chargers (Sites 1, 3, 4, 6) had very high (>0.90) power factors
    - Very low power factors seen with HF chargers at Sites 4 and 8 (0.75, 0.62)
  - HF chargers did not consistently produce higher peak demand
Findings

• Power Conversion Efficiency
  • Measured at Site 8 only by comparing battery monitoring data with AC input data
  • Battery monitoring data is a time-stamped event summary; difficult to get a precise comparison with AC logger data; battery monitoring device calibration unknown
  • Results show higher conversion efficiency for HF charger compared to SCR charger

<table>
<thead>
<tr>
<th>Date</th>
<th>Charger</th>
<th>Time On Charge</th>
<th>Net AHRs Delivered</th>
<th>Battery Voltage</th>
<th>DC kWh Out</th>
<th>AC kWh In</th>
<th>Conversion Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fri May-13-2016</td>
<td>SCR</td>
<td>06H 16M</td>
<td>733</td>
<td>36.0</td>
<td>26.4</td>
<td>51.4</td>
<td>51.3%</td>
</tr>
<tr>
<td>Wed Jun-08-2016</td>
<td>HF</td>
<td>07H 59M</td>
<td>660</td>
<td>35.3</td>
<td>23.3</td>
<td>21.8</td>
<td>106.8%</td>
</tr>
<tr>
<td>Fri Jun-17-2016</td>
<td>HF</td>
<td>07H 59M</td>
<td>678</td>
<td>34.2</td>
<td>23.2</td>
<td>23.3</td>
<td>99.4%</td>
</tr>
</tbody>
</table>
Findings

- Customer Interviews
  - Site Overview:

<table>
<thead>
<tr>
<th></th>
<th>Site 8</th>
<th>Site 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business Type</td>
<td>Commercial printing</td>
<td>Medical device manufacturer</td>
</tr>
<tr>
<td>Lift-Truck Functions</td>
<td>Stacking, moving, loading/unloading</td>
<td>Material handling and warehousing</td>
</tr>
<tr>
<td>No./Type of Chargers</td>
<td>2 SCR</td>
<td>35 FR</td>
</tr>
<tr>
<td>No. of Battery-Powered Lift-trucks</td>
<td>2</td>
<td>30</td>
</tr>
</tbody>
</table>

- Interview Results
  - Operators did not switch to opportunity charging with the HF chargers: no productivity gains, operators indifferent to HF chargers
  - Most important factors when considering new charger purchase:
    - Reliability #1 for both facilities
    - Charging speed important for #2, for productivity as well as battery health
    - Both interested in energy savings
CONCLUSIONS AND RECOMMENDATIONS
Conclusions

- Difficult to assess energy and peak demand impacts due to site, testing limitations
  - Power factor is one parameter where results are reliable: no clear advantage for HF chargers
- The value proposition for HF chargers is different for each facility
  - Many facilities have relatively light lift-truck usage: long paybacks from upgrading chargers and no need for opportunity charging
- Premise that HF chargers enable opportunity charging may be flawed
  - We found several examples of Ferro and SCR chargers on-line that are advertised as having fast charging or opportunity charging capability
Recommendations

• Insufficient evidence to recommend utilities discontinue custom incentives for HF chargers
  • Requires careful analysis of existing and proposed charger performance, as well as operational patterns

• If prescriptive incentives are desired, set qualification standards for proposed equipment based on energy efficiency metrics, rather than technology
  • Energy efficiency parameters should be rated according to California test procedures
Questions?

Send us your questions using GoToWebinar question box
## Conservation Applied Research and Development

Funds projects to identify new technologies or strategies to maximize energy savings, improve the effectiveness of energy conservation programs, or document the carbon dioxide reductions from energy conservation projects.

### Background

The [Next Generation Energy Act of 2007](https://mn.gov/commerce/industries/energy/utilities/cip/applied-research-development/) (the Act) established energy conservation as a primary resource for meeting Minnesota’s energy needs while reducing greenhouse gases and other harmful emissions. The Act also established a savings goal of 1.5 percent of annual retail electricity and natural gas sales for all utilities in the state. The utilities may reach this annual goal directly through its utility Conservation Improvement Program (CIP) and, indirectly, through energy codes, appliance standards, behavioral and other market transformation programs.

To help utilities reach their energy savings goal, the Act authorizes the commissioner to assess utilities $3,600,000 annually for grants for applied research and development projects:

- $2,600,000 for the Conservation Applied Research and Development (CARD) program through which Commerce awards grants in a competitive Request for Proposal (RFP) process.
- $500,000 for the Center for Sustainable Building Research to coordinate activities related to [Sustainable Building 2030](https://mn.gov/commerce/industries/energy/utilities/cip/applied-research-development/)
- $500,000 for the [Clean Energy Resource Teams](https://mn.gov/commerce/industries/energy/utilities/cip/applied-research-development/) (CERTs) for community energy technical assistance and outreach.

### CARD Program Updates

**FY 2017 CARD RFP**

Two CARD Request for Proposals (RFPs) have been posted for fiscal year 2017:

<table>
<thead>
<tr>
<th>Program Updates</th>
<th>Project Info</th>
<th>Stakeholder Info</th>
<th>Grantee Info</th>
</tr>
</thead>
</table>

For Reports use CARD Search Quick Link

For Webinars use CARD Webinars & Videos Quick Link

Webinar Recording & Final Report available in few weeks

CARD Web Page [https://mn.gov/commerce/industries/energy/utilities/cip/applied-research-development/]
Thanks for Participating!

Upcoming CARD Webinars:

• Oct 5:  Assessment of cold climate air source heat pumps
• Dec 7:  Ongoing commissioning in out-patient medical clinics
• Dec 14: Evaluation of moisture & heat transfer furnace retrofit

Commerce Division of Energy Resources e-mail list sign-up

If you have questions or feedback on the CARD program contact:

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651-539-1872