COMMERCE DEPARTMENT
ENERGY RESOURCES

Welcome

Conservation Applied Research & Development (CARD) Webinar

Industrial Battery Charger Field Study

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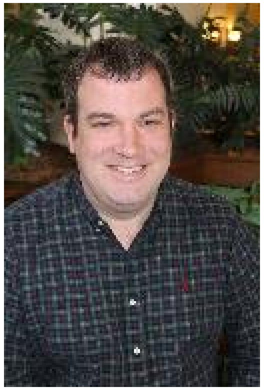

Franklin Energy
WHEN Experience MATTERS

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Webinar Basics

Image: Nick Youngson http://www.picserver.org/w/webinar.html

- Attendees in listen-only mode
- Type your questions into Question Box
- Questions addressed at end
- Webinar recorded
- Handout: webinar slide deck

Minnesota Applied Research & Development Fund

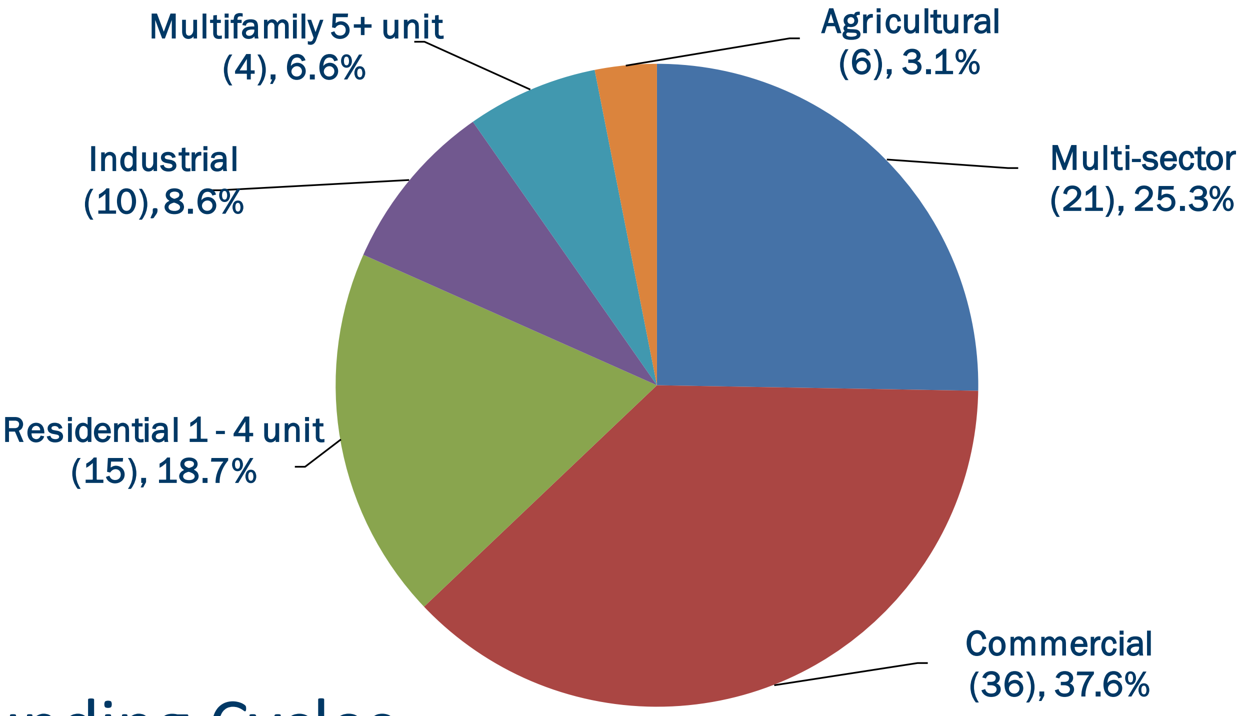
- **Purpose to help Minnesota utilities achieve 1.5% energy savings goal by:**
  - ***Identifying new technologies or strategies to maximize energy savings;***
  - ***Improving effectiveness of energy conservation programs;***
  - ***Documenting CO_2 reductions from energy conservation programs.***

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**

State Capitol Image: Courtesy Minnesota Department of Administration

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

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WHEN Experience MATTERS

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

Background

- There are four types of industrial battery chargers

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

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

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

Orange fill indicates within ideal range

Yellow fill indicates best (highest or lowest)

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

Site	1		2		
Charging Station	1	2	1	2	3
Old Charger Type	FR	FR	FR	FR	FR
New Charger Type	HF	HF	HF	HF	HF
3-Phase AC Voltage	240V	240V	277/480V	277/480V	277/480V
Changes Pre-Post					
Avg. Length of Charge(hrs)	-1.00	+0.06	+3.29	-2.63	-1.90
Peak Demand, kW	+1.85	+0.65	+3.26	+3.14	+3.15
Average Power Factor	-0.03	-0.02	+0.06	-0.00	+0.01
Average # Charges/Day	-2.17	-0.30	+0.47	+0.14	+0.13
Average kWh/Charge	-4.74	+1.13	+20.61	+3.31	+3.52
Average kWh/Day	-35.12	+0.80	+27.19	+7.15	+6.89

Findings

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

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

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

Findings

- Customer Interviews
  - Site Overview:

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

- 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

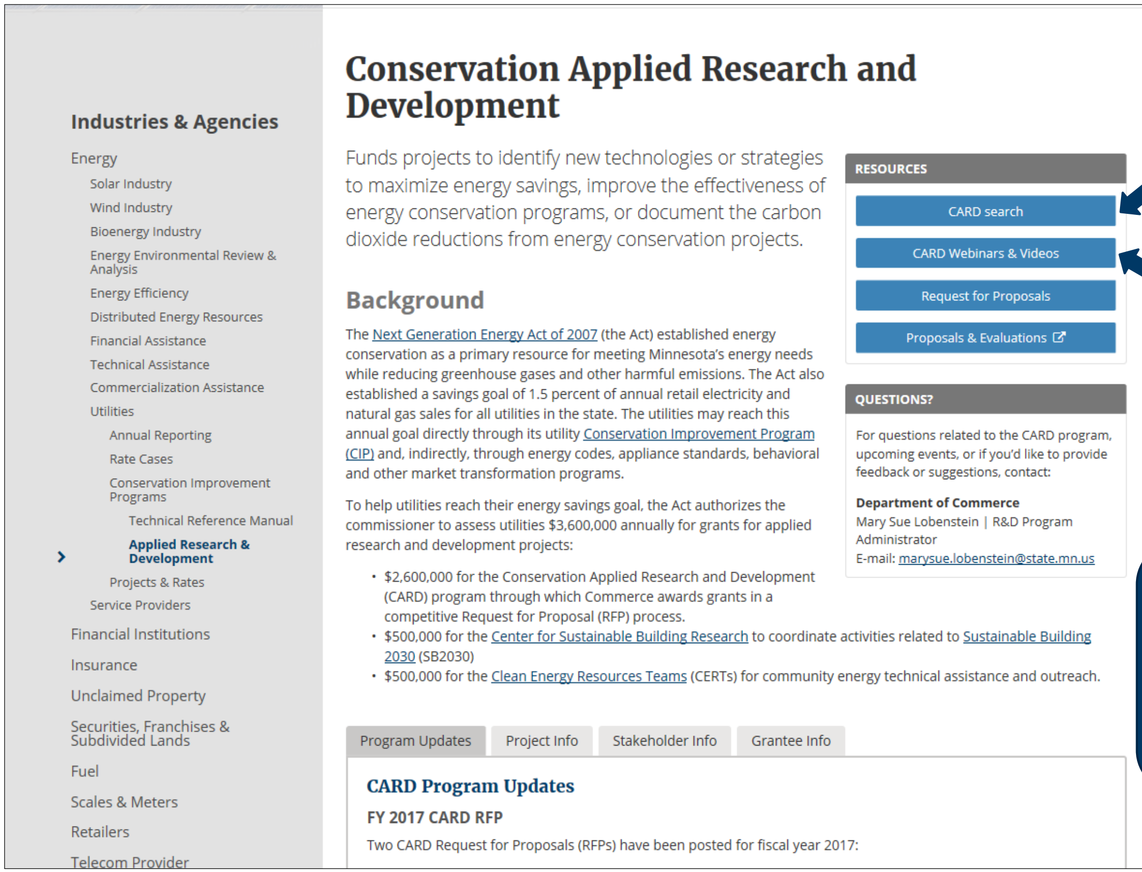
Recommendations

- 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

CARD Project Resources



Industries & Agencies

Energy
- Solar Industry
- Wind Industry
- Bioenergy Industry
- Energy Environmental Review & Analysis
- Energy Efficiency
- Distributed Energy Resources
- Financial Assistance
- Technical Assistance
- Commercialization Assistance
- Utilities
  - Annual Reporting
  - Rate Cases
  - Conservation Improvement Programs
    - Technical Reference Manual
    - **Applied Research & Development**
  - Projects & Rates
- Service Providers

Financial Institutions

Insurance

Unclaimed Property

Securities, Franchises & Subdivided Lands

Fuel

Scales & Meters

Retailers

Telecom Provider

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 (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 (SB2030)
- $500,000 for the Clean Energy Resources Teams (CERTs) for community energy technical assistance and outreach.

RESOURCES

- CARD search
- CARD Webinars & Videos
- Request for Proposals
- Proposals & Evaluations

QUESTIONS?

For questions related to the CARD program, upcoming events, or if you'd like to provide feedback or suggestions, contact:

Department of Commerce
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Program Updates | Project Info | Stakeholder Info | Grantee Info

CARD Program Updates

FY 2017 CARD RFP

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

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

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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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