Minnesota Electric Utilities Energy Storage Activities Update

Legislative Energy Commission
November 9, 2017

GREAT RIVER ENERGY

OTTER TAIL POWER COMPANY

minnesota power

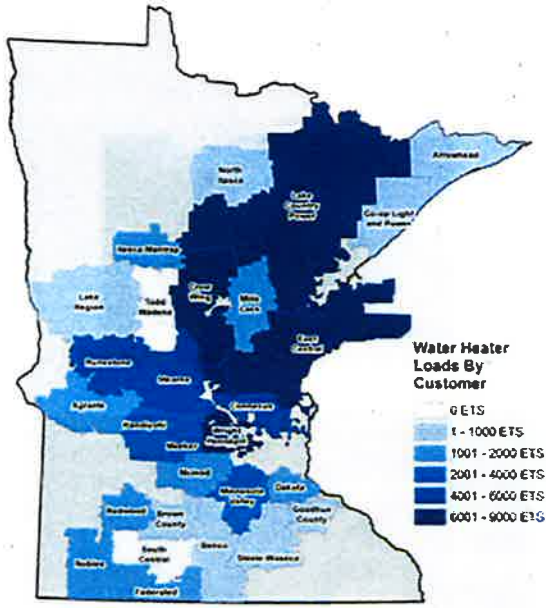
Xcel Energy

GRE Energy Storage Projects

- **Electric thermal storage**
- ReVolt electric vehicles
- Electric school bus
- **Grid-Interactive water heating**
  - Country Joe Homes
- Solar and battery storage
- Non-wire alternatives
  - Transmission investment deferral study

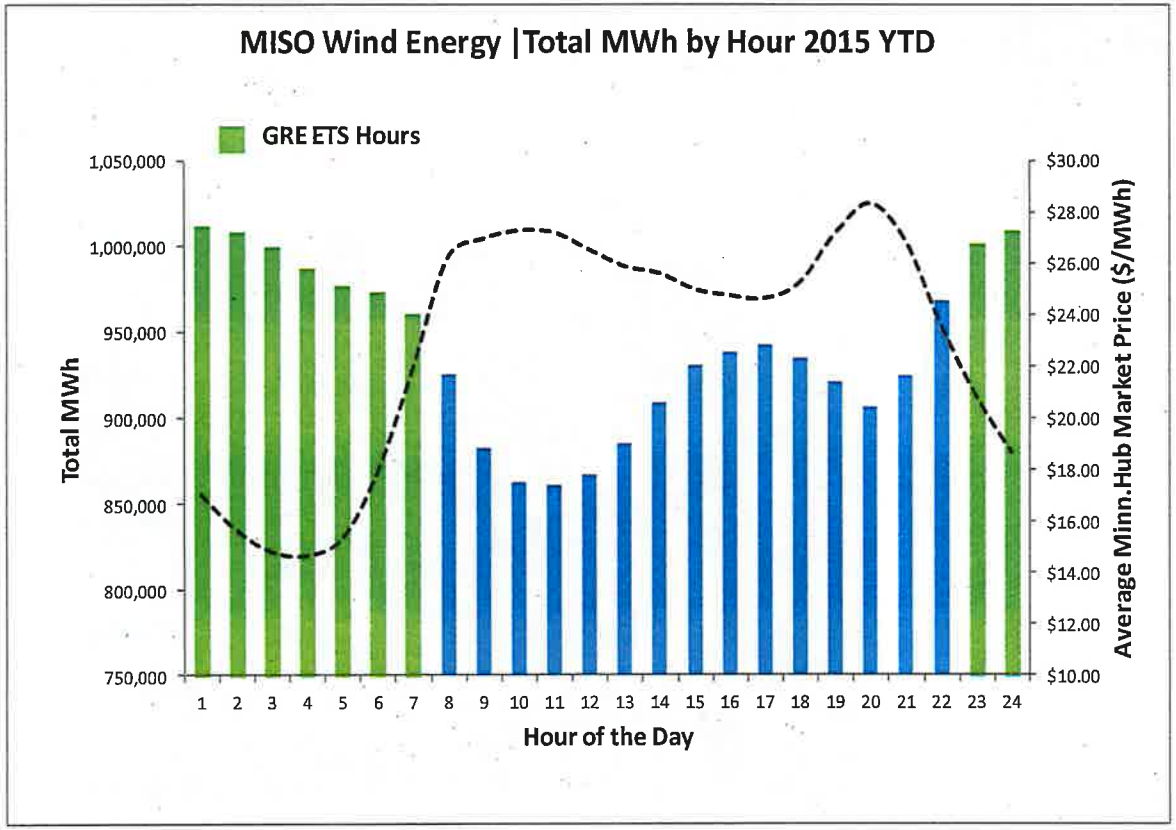
revolt
EMBRACE ELECTRIC VEHICLES

Electric Thermal Storage (ETS)



- Requires a large capacity water heater
  - 85 to 105 gallons
- Heat water between 11 pm and 7 am
- More than 65,000 ETS & 45,000 peak shave water heaters controlled
- Each ETS water heater stores an average of 13 kWh each night
- Combined program stores over 300 GWh a year

Delivering Value & Utilizing Wind Energy



- MISO Market as storage
- Take advantage of overnight wind generation

Grid-Interactive Water Heating

GREAT RIVER ENERGY

Non-Wire Alternative: ICE Storage Study

- Evaluate DER and energy storage as means to reduce feeder outages on transmission system
- Used DOE Interruption Cost Estimator (ICE) tool to determine avoided costs of interruption
- Battery costs vs. transmission upgrade costs
  - Conclusion: battery storage not cost effective at this time
- Transmission group increasingly considering non-wires alternatives in project evaluation

Country Joe Homes

Grid-interactive water heating project

Context

Great River Energy (GRE) has a long history of working with its members to implement electric thermal storage (ETS) technologies to take advantage of low, off-peak prices. One of the most successful programs has been the ETS water heating program, which limits the charging of large capacity (80 to 105 gallon) water heaters to the hours of 11 p.m. to 7 a.m. A graphical depiction of this strategy is shown in figure 1.

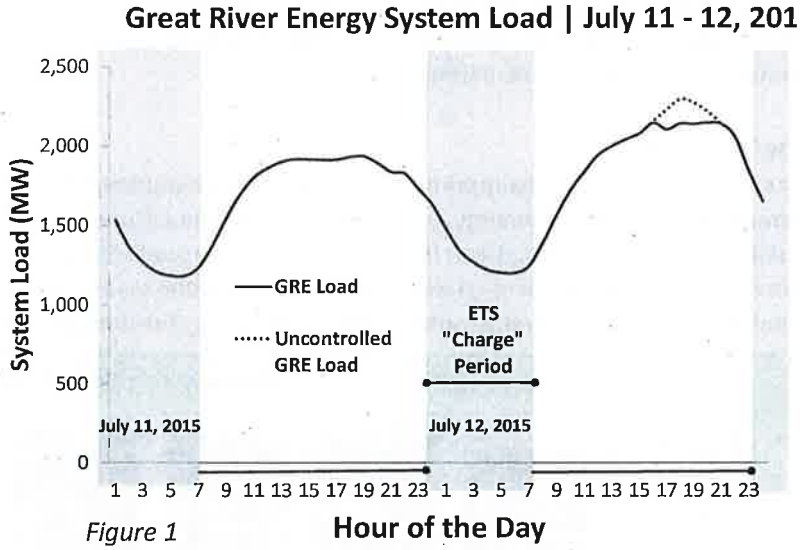


Figure 1

While this strategy has worked well to lower the wholesale cost of energy and pass these savings onto our members, the dynamics within the MISO market continue to evolve. With increased renewable energy, prices are being pushed lower outside of the off-peak hours. In addition, the ability to use water heaters to provide ancillary services within the market is gaining traction within other wholesale markets as technology and communications continue to evolve.

Description

Dakota Electric Association (DEA), GRE, and housing developer Country Joe Homes (22260 Dodd Blvd, Lakeville) will install large-capacity, grid-interactive water heaters in all 81 units of the Legacy 2 housing development in Lakeville. In aggregate, the homes will provide over 360 kW of grid-interactive resources represented by the ETS heaters. This would be the first community storage development of its kind in Minnesota. In addition to the ETS resources, DEA and GRE will work with Country Joe Homes to install electric vehicle chargers, advanced air source heat pumps, Wi-Fi thermostats, comprehensive LED lighting technologies, and energy efficient appliances where possible. Such a development, built to new energy code requirements, should provide a glimpse of what is possible when new housing developments combine advanced electric technologies and communications to shape end-use load curves that can better utilize variable generation resources.

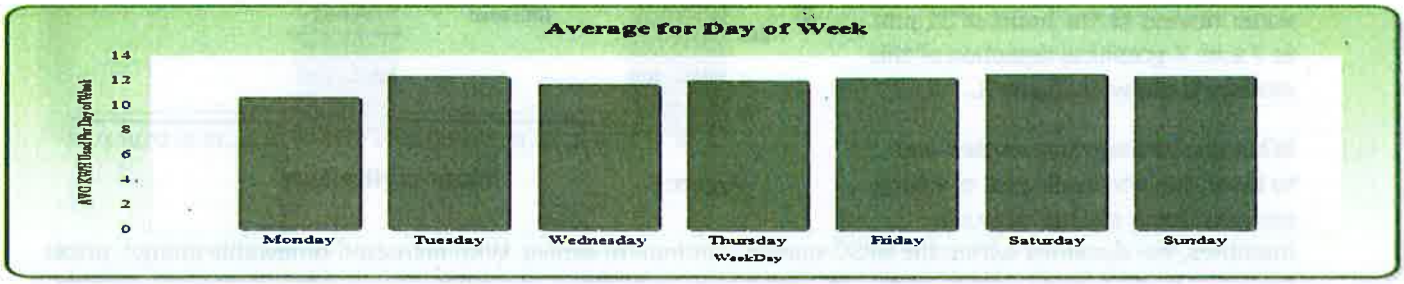
DEA worked with the developer to incorporate the full complement of technologies into the first model home, which was built in September. The remaining 81 homes will be built over a three-year period from 2017 to 2019. DEA and GRE would anticipate having information available from the

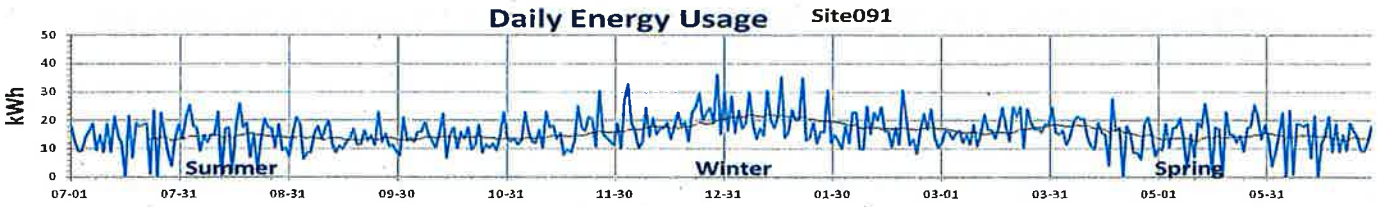
projects prior to the end of 2018, which could be used to disseminate project challenges and successes for other cooperatives throughout the United States.

The homes will feature the Steffes Grid-Enabled Thermal Storage (GETS) Hydro Plus 80 gallon storage water heater. These water heaters represent an advancement over typical 80-gallon thermal storage water heaters in that the units have thermocouples and communications technology built into the unit, which allows utilities to see the state of charge of single units or a group of water heaters in aggregate. When coupled with rapid two-way communications, facilitated by cellular or Wi-Fi technology, utilities have the ability to very granularly control the water heaters, opening up the possibilities of renewable energy tracking or providing ancillary services within a wholesale market.

Why it matters

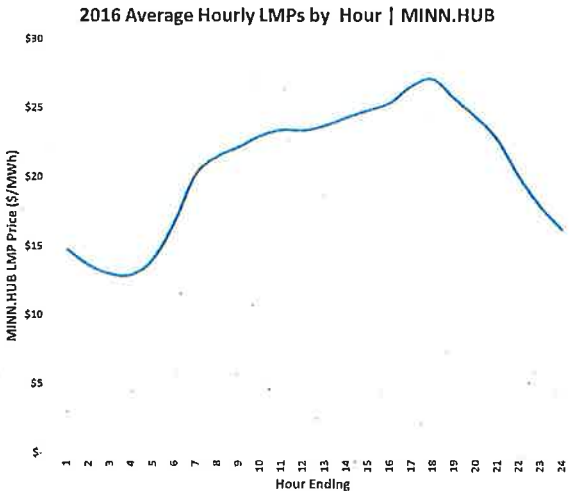
Water heater energy consumption is often generalized at about 12 to 14 kWh daily. With a typical 4.5-kW element, this amount of energy can be delivered within a three-hour period. However, there is significant variability in consumption driven by a number of factors within the home. The 11 pm to 7 am ETS charging time frame provides nine hours of charging to ensure all of the water heating energy needs of the home are met, even when there are extreme outliers in water heating consumption.

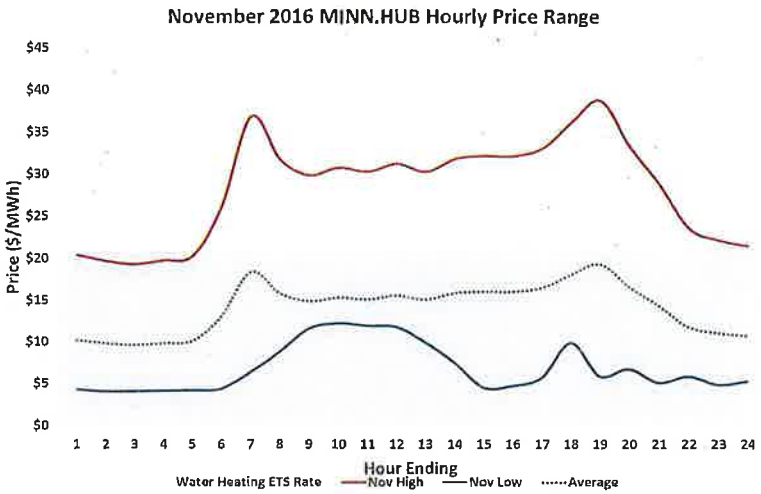




Even though the hours targeted by the program are typically the lowest cost energy hours in the MISO market, the LMP costs typically decrease in the early morning hours, bottoming out around 4 a.m. Without having visibility into the state of charge of the water heaters, it is difficult to take advantage of the lowest price hours in the market, as the average heater will typically be "full" by the time these prices are available.

The ability to use water heaters to provide ancillary services within a wholesale market also requires visibility into the water heater to ensure the utility can meet the daily water heater needs of the household. In addition, this visibility is required to also understand how much a group of water heaters can contribute to an ancillary services market. Due to the speed at which ancillary services are provided, there is another requirement for high speed communications to the water heaters that can enable rapid, four-second communications to the water heater. This level of communications can allow for the water heater load to be varied in response to an Area Control Error (ACE) signal, or to follow the rapid fluctuations of renewable generation such as solar.





Next steps

GRE will continue to work with DEA and Steffes to ensure delivery of the Steffes water heaters meets the expectations of Country Joe Homes.

GRE, DEA, and Steffes are developing a communications solution that will enable high-speed communications to each of the 81 grid-interactive water heaters in the development. This is expected to be finalized by the fourth quarter of 2017. In the interim, DEA will be controlling all of the water heaters installed in the development under the peak shave strategy. Once the communication plan has been finalized, DEA will convert existing water heaters from a radio-controlled system to the interactive communications system. Once all communications have been established, DEA and GRE will begin to evaluate and implement various control strategies that can lower the overall cost of energy being delivered to the aggregate group of water heaters.

In 2018, EPRI will be involved in the project as part of an advanced energy communities supplemental project. As part of this work, EPRI will provide technical support in understanding communications options for frequency regulation from hot water heaters, monitoring water heater operation in response to signals, and gauging the project's effectiveness at supporting GRE in its bidding for MISO. EPRI will also monitor a sample of homes in the new home community to understand load operation and the possibility of load shaping for grid services.

Project costs/schedule

Great River Energy costs

- Staff time and incremental cost of 81 water heaters: $81,000
- Communications: Cellular data plan

Member cooperative

- Staff time and ETS water heater cost share: $81,000

Project start: November 2016
Project end: December 2019

For more information

Jeff Haase
Strategic Energy & Efficiency Program Representative
Great River Energy
jhaase@grenergy.com

Powering what's possible

GRE and its members continue to seek new ways to use advanced technologies and data to help serve its members better. GRE and its members are well into updating critical systems and implementing new technologies for metering, telecommunications, demand response management, and meter data management.

GREAT RIVER ENERGY

Community storage

Energy and environmental stakeholders are uniting around "community storage" to solve the electric industry's energy storage challenge. The Community Storage Initiative has received the support of key industry groups, including the nation's utility trade associations, environmental groups, manufacturers and more than a dozen individual utilities.

Both Great River Energy and the Minnesota Rural Electric Association are members of the initiative. Community storage refers to a spectrum of utility-sponsored programs which aggregate electric storage resources available throughout the community, such as water heaters and electric vehicles, to improve the efficiency of electric energy services for consumers. Community storage programs offer the industry the practical steps to rapidly increase the amount of energy storage available.

Initiative members have been implementing community storage programs and, through the Initiative, will work together to evolve those programs. Like community solar, community storage enables consumers and utilities to share the system-wide benefits of energy storage – environmental benefits, lower costs and grid optimization – in communities large and small across the country. Such programs maximize the value of distributed energy resources, many of which are already available to participate in energy storage programs through simple retrofits and program design.

The Initiative's advisory council includes representatives from the American Public Power Association, Edison Electric Institute, Natural Resources Defense Council, National Rural Electric Cooperative Association, and Peak Load Management Alliance. The Initiative is chaired by Gary Connett, director of member services at Great River Energy.

A list of founding supporters and brief descriptions of their community storage efforts is available on the Initiative's website: communitystorageinitiative.com. Initiative members are conducting a range of innovative community storage programs, including grid-interactive water heating, electric vehicle charging, grid-interactive space heating, ice storage technology, and residential battery storage.

Research conducted by The Brattle Group and sponsored by the Initiative's founding members recognized that the nation's 50 million residential electric water heaters collectively represent a significant and vastly underutilized energy storage resource capable of leveraging substantial environmental and cost benefits. An article in the November 2015 edition of Public Utility Fortnightly introduced the community storage concept. Links to both the report and the article can be found on the Community Storage Initiative's website.

The Initiative hosted a two-day forum in July 2016 at the University of Minnesota Law School campus where attendees heard group members explain their mission and guiding principles. Those in attendance also discussed where they fit into the growing collaborative and how to help further its vision.

Connett participated in a summit at the White House where federal and private sector organizations gathered to discuss scaling renewable energy and storage with smart markets and spoke about the Initiative. He also educated those on Capitol Hill about the Initiative during a congressional briefing about community storage, introducing the concept of how the energy industry can use tried-and-true household technologies to help meet consumer energy needs in a new era.

Electric thermal storage water heating

Electric thermal storage (ETS) water heating is a load control strategy that provides households with their daily hot water needs by charging their water heaters only during the lower-cost, off-peak hours. Member-consumers participating in the ETS program heat their water from the hours of 11 p.m. to 7 a.m. In exchange for this level of control, Great River Energy provides discounted wholesale energy to its member cooperatives for energy sales associated with the ETS program. The strategy requires that a household install a "large capacity" storage water heater, which is typically between 85 and 105 gallons in size, with the larger water heaters provided to households that have more family members.

Great River Energy's ETS resource

Great River Energy is able to store a gigawatt of energy each night by controlling the ETS water heaters of more than 65,000 end-use members. This effective form of community storage aggregates distributed energy technologies increases energy efficiency and allows for better integrate renewable energy resources onto the grid and reduce customers' monthly electric bill.

Electric vehicles

Electric vehicles provide another valuable form of community storage. Great River Energy continues to look at ways to make it easier for consumers to drive electric vehicles and currently offers rebates for residential charging stations that encourage off-peak or time-of-use vehicle charging. This strategy enables consumers to use more electricity during night-time hours when prices are typically lower and when the electricity is frequently produced from the region's abundant wind resources.

re-volt℠
EMBRACE ELECTRIC VEHICLES

Great River Energy in 2015 launched Revolt, a first-of-its kind program that allows members of its 28 cooperatives to upgrade the electricity they use to fuel their PEVs to wind energy at no additional cost. While the PEVs enrolled in Revolt will be powered by wind energy, standard or offpeak rates still apply for the electricity used to charge them.

This program extends to members who already own or lease a PEV and members who purchase or lease one by Dec. 31, 2017.

Contact information

Gary Connett, director of member services
Great River Energy
gconnett@grenergy.com

OTP load control history

- Time clocks deployed since the 1940s for control of water heaters
  - A long history of utilizing storage and demand response to avoid peaks and maintain low rates for customers.
  - Added radio frequency controls in the 1970s (ability to respond more quickly to Grid needs – "grid intelligent")
- OTP has three thermal storage rates today (See below)
  - In total OTP can control roughly **15%** of our total load
  - Nearly 1/3 of our customers are on a load-control rate AC Cycling rate also a small "storage" resource (~1 MW)
- OTP performs economic control in addition to demand control
  - Load controlled during high market prices. Savings flow back to customers

Rate	Customers	Peak MW Available	Control Description
Controlled Water Heating	30,000	30	Up to 14 hours in a 24 hr period
Deferred Load	1,800	14	Up to 14 hours during a 24 hr period
Fixed Time of Service	1,000	~10	10 PM to 6 AM, 8 hours of electric service daily

Smart Water heater Pilot

- A storage research team was developed and reviewed many storage alternatives to meet future market needs (i.e. volatility, low energy prices, demand costs)
  - Reviewed both **load and supply** side resources as storage options (i.e. thermal, ice, battery, hydro, pumping, etc.)
  - Thermal storage exhibited lowest customer cost
  - Recognized electric battery storage as "emerging"; will become more economical as prices continue to decline.
- The research team recommended a thermal storage pilot that would be more refined and "smarter" than traditional control.
  - Started working with a technology vendor in the summer of 2017.
  - Expect the software and hardware to be in place in Q1 2018 for the pilot.
  - Intend to replicate electric battery storage with aggregated thermal resources via software and virtual power plants.
  - Evaluating both retrofit and new water heater technologies.
  - Two way communication to devices for more granular and predictable control algorithms and programs.
  - All savings passed back to customers to help maintain low electrical rates
  - Intend to evaluate market potential of aggregated thermal resources for all market products
  - Ability to expand to other resources such as residential heating/cooling, building management systems, etc.

minnesota power
AN ALLETE COMPANY

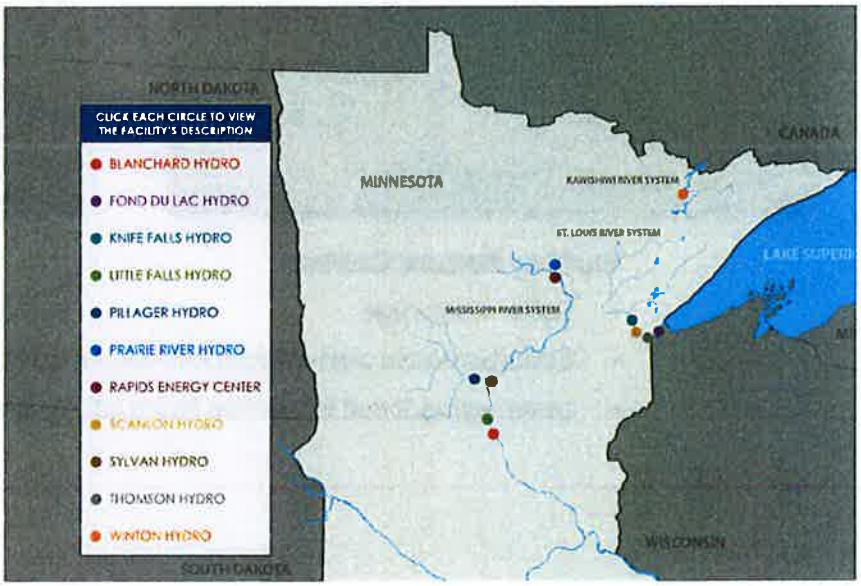
EnergyForward

Longstanding Storage in Our Region

Hydroelectric Resources as Storage

- Since company founding in 1906
- Reservoir storage provides essential electric services to northeastern MN

Minnesota Power Hydropower Stations



minnesota power
AN ALLETE COMPANY

Manitoba Hydro

SIEMENS

GREAT NORTHERN TRANSMISSION LINE
Connecting Manitoba and Minnesota

Innovative All-Renewable Storage

- High volume clean storage collaboration with Manitoba Hydro
- Efficient, cost effective storage application
- Hydro balances wind energy across ND, MN and Manitoba

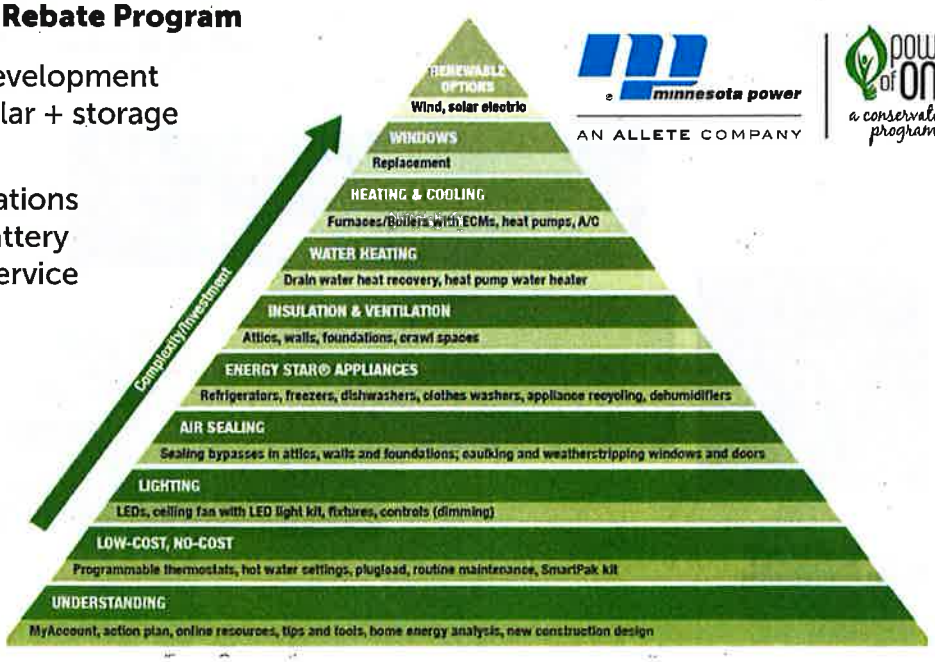
Energy Storage in Our Communities

Hartley Nature Center

- Solar + storage
- Collaboration and education within our community
- Leveraging local expertise from utility and university resources

MP's SolarSense Customer Rebate Program

- Provided research and development funding for residential solar + storage application
- 3 Tesla PowerWall installations in Duluth; 6-10 legacy battery storage systems across service territory

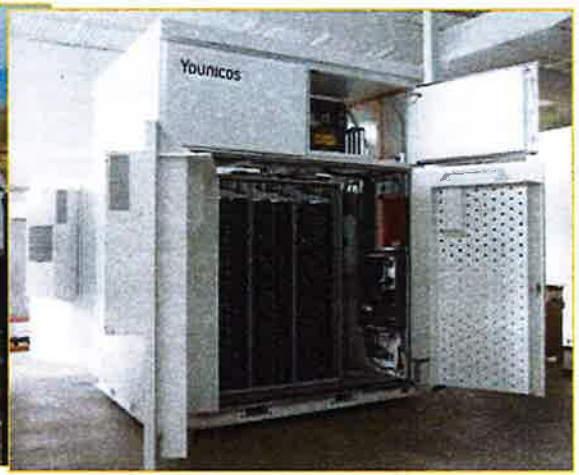


minnesota power
AN ALLETE COMPANY

power of one
a conservation program

Peña Station Pilot

- Utility-sited 1 MW, 2 MWh Battery Storage System
- 1.6 MW carport solar PV system
- 260 kW customer-sited rooftop PV system
- Switching and control systems, owned by Xcel Energy.
- Microgrid capabilities: During a grid outage, battery powers Panasonic facility
  - Panasonic's building management system prioritizes energy usage based on battery state of charge and expected length of outage
  - Panasonic's 240 kW rooftop PV also able to operate
  - 10% of battery capacity reserved for Panasonic



Xcel Energy®

Site Photo

Xcel Energy®

Stapleton Battery Project

- 6 utility-sited batteries
- 6 customer-sited, utility-owned, behind-the-meter batteries
- 2015: Feeder ~18.5% PV penetration

Xcel Energy®

Stapleton Battery System Overview

- Utility-sited (six total)
  - Range in 18 to 54 kW in size
  - Four hours of storage
- Residential (six total)
  - 6 kW/15.5 kWh
- Use Cases:
  - Peak Demand Reduction
  - Voltage Regulation
  - Solar Time Shifting
  - Energy Arbitrage
  - Back-up Power

Xcel Energy®