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MiEnergy Cooperative

Residential Battery Pilot Summary

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Project Description

MiEnergy Cooperative partnered with Iowa Economic Development (IEDA) and National Rural Electric Cooperative Association (NRECA) on a pilot project related to residential energy battery storage. MiEnergy is an electric distribution cooperative procuring power supply services from Dairyland Power Cooperative and provides retail electric service to about 24,000 meters in Iowa and Minnesota. MiEnergy purchased 6 battery storage unit of which four are in Iowa and two are in Minnesota.

MiEnergy's pilot project study is in conjunction with three other Dairyland Power Cooperative electric distribution cooperatives which also partnered with NRECA. The following Cooperatives purchased residential battery systems from Sonnen Batterie as well as MiEnergy.

Jo-Carroll Energy, Elizabeth, Illinois

Oakdale Electric Cooperative, Oakdale, Wisconsin

Richland Electric Cooperative, Richland Center, Wisconsin

MiEnergy has 531 distributed energy resources (DERs) on its system, 212 in MN and 319 in IA. The DERs on MiEnergy's system are a combination of solar, wind and manure digestors. With MiEnergy relying more on DER systems, it raises the concern on reliability. Can a residential battery backup system be the answer to a more resilient grid? Can Sonnen Batterie optimize the energy supply and demand to such a degree that an integration of 100% renewable energy within a community is possible 24/7?

Typically, electrical use for a household is high in the morning, drops off midday and increases early evening. Peaks are in early morning and evening. The electrical power production cycle of a solar photovoltaic (PV) system peaks midday when household consumption drops off. Power production and use simply don't match time wise.

One of the purposes of the pilot program is to look at battery storage to see if it is a realistic tool for energy management, like load control projects in the early 1980's. First, it is necessary to understand residential battery technology on a small scale. This pilot tests to see if switching a home's electricity source from the grid to a battery and back can help manage electricity during peak periods. It can help the cooperative determine if there are benefits to members being on a time of use electric rate with options when combined with a battery to avoid peak times.

MiEnergy has a very diverse sales mix compared to a lot of rural Cooperative. Most rural Cooperatives are heavily loaded on residential sales. MiEnergy's sales mix from 2013 through 2017 included 41 to 44 percent of sales being to residential users; 41 to 46 percent to large and small commercial and 13 to 15 percent to municipal resale. Generally, large and small commercial accounts peak during midday whereas residential peaks late afternoon early evening when families arrive home from school and work.

MiEnergy has installed four of the units in Iowa residential homes. The first two battery units, which were Sonnen ECO 16 battery units (16 kWh storage, 8 kW discharge), were installed in November of 2018. The next two battery units were Sonnen ECO 10 battery units (10 kWh storage, 7 kW discharge). These units were installed in March of 2019. Two of the units are near Decorah and the other two are in Ridgeway and New Hampton. The installation process was more complicated than first thought. There was also difficulty in finding homes that the battery could potentially cover most of the members electrical use.

Purchasing

The ECO 16 units cost $19,672 and the ECO 10 units cost$14,522.25. The ECO 10 units were purchased through Werner Electric and the ECO 16 units were purchased in conjunction with the other pilot cooperatives through NRTC. The recommended shelf time for the units is 6 months. The average installation cost for the electricians was $3,363.35. In summary, the purchase price along with installation averaged $23,035.35 for the ECO 16 units and $17,885.60 for the ECO 10 units.

Screening Sites

It was decided upfront that MiEnergy wanted these units to be in the members' homes. This is the real-life experience that the co-op pursued for this pilot project. The members that were interested in participating in the project had to be willing to work with MiEnergy through this learning curve. MiEnergy's marketing strategy was to make the membership aware of the project and allow them to contact the co-op. The battery pilot project was introduced in the monthly newsletter as well as at MiEnergy's annual meeting. This was the best practice to spike members' interest that might be actively involved in the process. MiEnergy had a lot of inquiries but in the end, it was 24 members that were interested in being part of the project.

The first step was to learn what limiting criteria there were for the battery units. The main factors that were identified were:

1. **Internet Connection:** Internet availability is the main reason why most of the households weren't suitable locations. Not only did the member need to have internet, but the internet needed to be hardwired into the unit. It was identified that a lot of members either had no internet or wireless only. This communication is required for the unit so Sonnen can still speak to the unit in order to check the current state, change the charge/discharge times, troubleshoot issues, install software updates, and have the ability for the member to view the unit in real time.
2. **Conditioned Space:** The battery units needed to be installed in close proximity to the member's service panels. The service panels varied from being on the utility pole, in the garage, in the basement, ~~and/or~~ to being outside on a banner board. The unit needed to be in a controlled environment that ranges from 41º to 113º Fahrenheit. Temperatures that would be higher or lower than the acceptable range would shorten the unit's 20-year life span.
3. **Adequate Spacing:** The battery unit is 26"L x 14"W x 75"H require an additional 3 feet on each side for ventilation. The units weigh 800 lbs, sit on the floor, and requires wall supports. There also needs to be adequate spacing in front of the unit to safely inspect and repair it.
4. **Service Panel:** There were multiple issues identified with the various service panels. Multiple service panels/subpanels and CT services were eliminated as candidates. The ideal situation is a 200-amp service panel with an existing subpanel near the main service panel. The member had to agree to have an electrician remove circuits from the main service panel and transfer them to a critical load panel. After the pilot project is completed an electrician will wire the circuits back into the main service panel if the member so chooses.
5. **Pilot Project Term (5-10 years)**- The members had to be willing to allow the unit to stay in their house for a minimum of 5 years with an option up to 10 years after the first 5-year term. The members were required to sign an agreement before installation. After the pilot project has concluded the members will have the option to purchase the units at market value or removed with all of the electrical work put back.
6. **Control Periods-** One of the goals of this pilot project is to explore the possibility of the co-op being able to control the battery during high demand times to try to shed peak and reduce peak demand on the system. Members had to agree to allow MiEnergy to control the battery charge and discharge time periods at its discretion.

After reducing the sites from 24 to 11, MiEnergy used another round of measures to reduce the remaining sites yet allow for a variety of site~~s~~ locations for the project. MiEnergy had interested members send photos of the proposed room and service panels. This provided a visual to help identify the best site. MiEnergy's goal was to install the units in the most ideal homes.

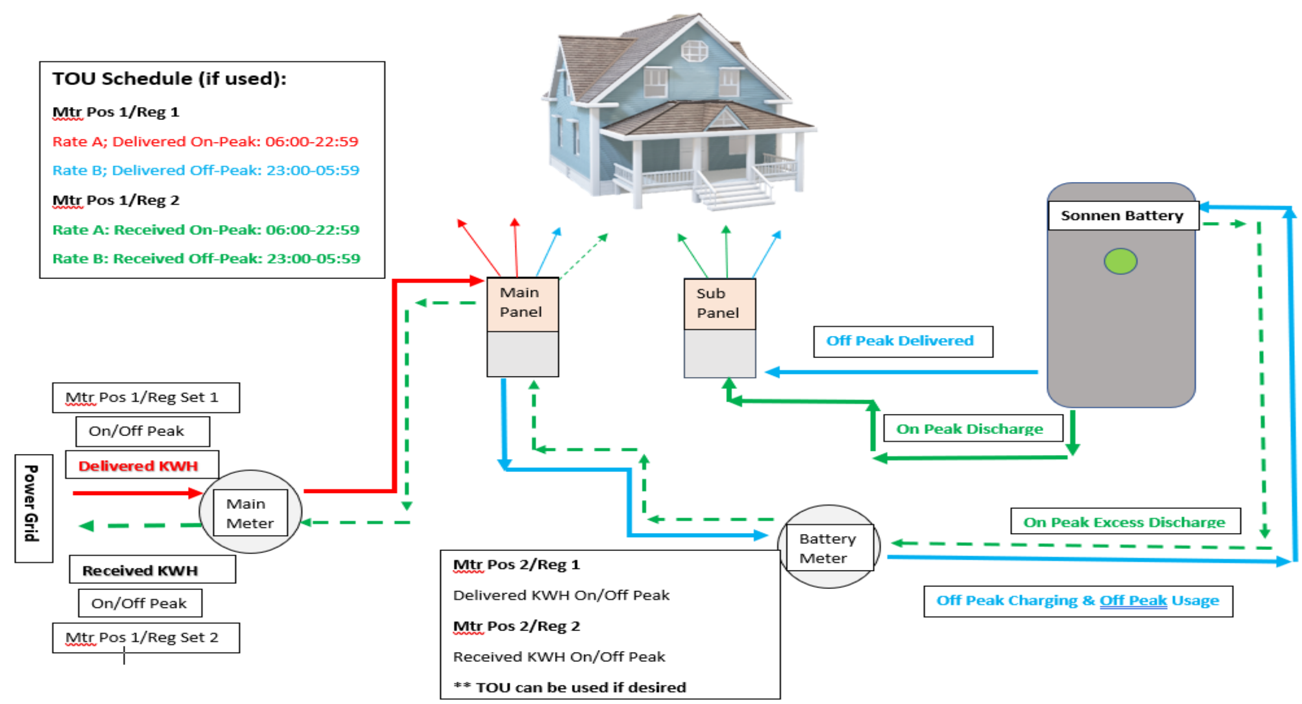
1. **Distributed Generation**- 6 out of the 11 applicants had an existing PV system. The battery unit has three different types of operation (see section on modes of operation). Self-consumption is designed to store excess solar production and discharge that energy at night or when the solar array is not producing more than the member is consuming.

Having a system installed in a member's home with a DER system was crucial for the project.

2. **Monthly Use**- The applicants varied from 263 kWh per month to 10,030 kWh per month. The applicants were narrowed down to households with 1,100 or fewer kWh per month. MiEnergy wanted to stay away from larger loads since the intent of the project was residential battery storage.
3. **Peak kW**- Peak kW ranged from 6.56 kW to 45.6 kW. The battery units were designed with 7 and 8 kW inverters. The goal was to not overload the inverter and have the breaker trip, so the chosen households had to be relatively close to the inverter's kW rating
4. **Generator-** One of the remaining 11 households had an existing 14 kW generator. Another goal was to see how the battery ran in place of a generator and possibly how it ran in conjunction with a generator.

Installation

Certified Sonnen Installer- Sonnen requires the installer to be a licensed electrician in that state as well as receive a certification from Sonnen. There is a pre-test that needs to be completed



before taking the final exam. Past electricians that have taken the exam, have emphasized how difficult it is to get certified. These added certifications/licenses are a great safety check for cooperatives. This allows not just anyone to install a system and to connect with the grid without working with MiEnergy. In order to commission the units, the installer needs to call Sonnen and walk through their testing procedures or have a Sonnen representative come on site for the commissioning. It was determined that we also wanted to install a second meter to track how much the Sonnen unit was going to charge.

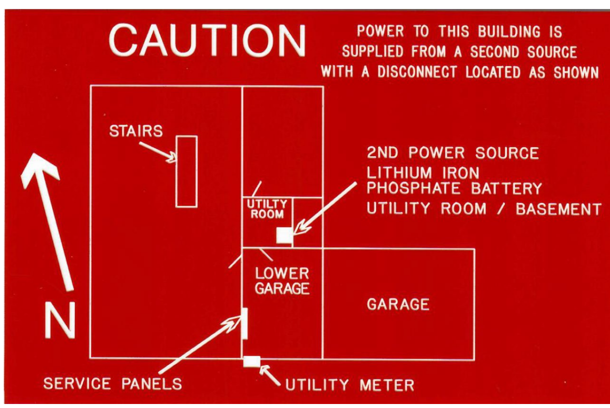
Subpanel- Electricians worked with members in deciding which circuits they wanted on the battery unit. Those circuits were then re-wired from the main service panel to the subpanel which was on the load side of the battery unit. Most of these circuits were for lighting, bedrooms, kitchens, and other small peak usage circuits. AC units were left off from the battery units in order to not overload the battery and trip the breaker.

Safety

The number one question asked from the members, regarding battery safety is, "will these batteries start on fire in our home." Obviously, MiEnergy can't 100% guarantee this, but they are the safest battery chemistry available. The cell makeup is lithium-ion iron phosphate ($LiFePO_4$). These batteries are manufactured to stay at room temperature.

Outside of being the safest chemistry battery, MiEnergy wanted to take extra steps. One of the pilot members is a member of the fire and rescue and suggested that the local fire and rescue departments be notified of the location of these battery units.

Placards- Placards were placed at the main service meter, the utility disconnect, and the service panel. The placards identified the battery unit's location, make-up, and the potential 2nd power source.



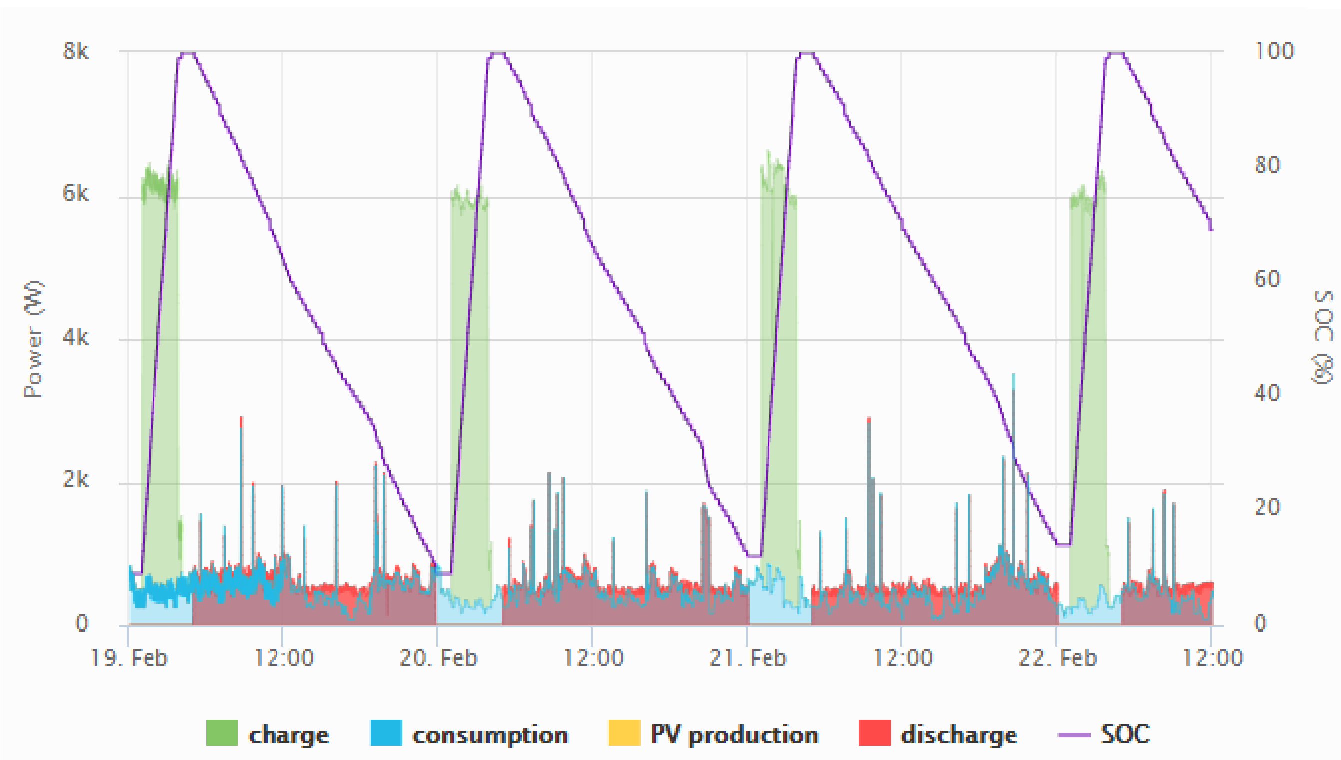
E-Stop- Emergency stops were installed at all four sites. Three of the four were installed outside of the house with one being near the doorway that enters the utility room. The E-stop allows anyone to quickly turn off the battery unit without having to open the battery unit or entering the room and using the utility disconnect.

Modes of Operations

1. Back-Up. In this setting the unit will act as a generator. It will retain a 100% state of charge (SOC) and only discharge when there is no grid power (outage). After the unit sees the grid power return it will begin to charge back to 100% SOC. If tied with a PV system, then the unit would charge from the solar. The unit would allow the PV system stable power, which would allow the array to continue to produce power to feed the home. MiEnergy didn't see much reason to test this mode, especially since during an outage in either of the other two modes the unit would operate the same. If a member's concern is backup power, then MiEnergy would recommend a generator.

2. Time-of-Use (TOU). Currently, MiEnergy has all units in this setting. One of the main goals was to see how much of the house could be powered by off-peak charging. This mode allows MiEnergy to choose the discharge and charge times of each unit. This also allows members to select a charge time when the utility has off-peak rates and possibly a cheaper kWh cost. The discharge time would then be during on-peak times when the utility possibly charges a higher kWh rate. MiEnergy has run into two different scenarios with TOU schedules. What should the TOU schedule be with solar and without solar?

1. The units that don't have solar tied in currently discharge from 11 a.m. to 10 p.m. and 6 a.m. to 11 p.m. These times were chosen based on previous TOU schedules. Originally, the units were set to discharge from 2 p.m. to 8 p.m. This was based on MiEnergy's peak times. The units were only discharging 40%-60% of their charge capacity. MiEnergy adjusted the discharge schedules to get the full charge out of the units. The goal was to see what these units would do and then run them to their full capacity. The charging times are set to begin 12 a.m. Midnight was chosen because of the low demand on the system.



*Pictured is a 3-day cycle of a battery on the TOU schedule with no PV system.

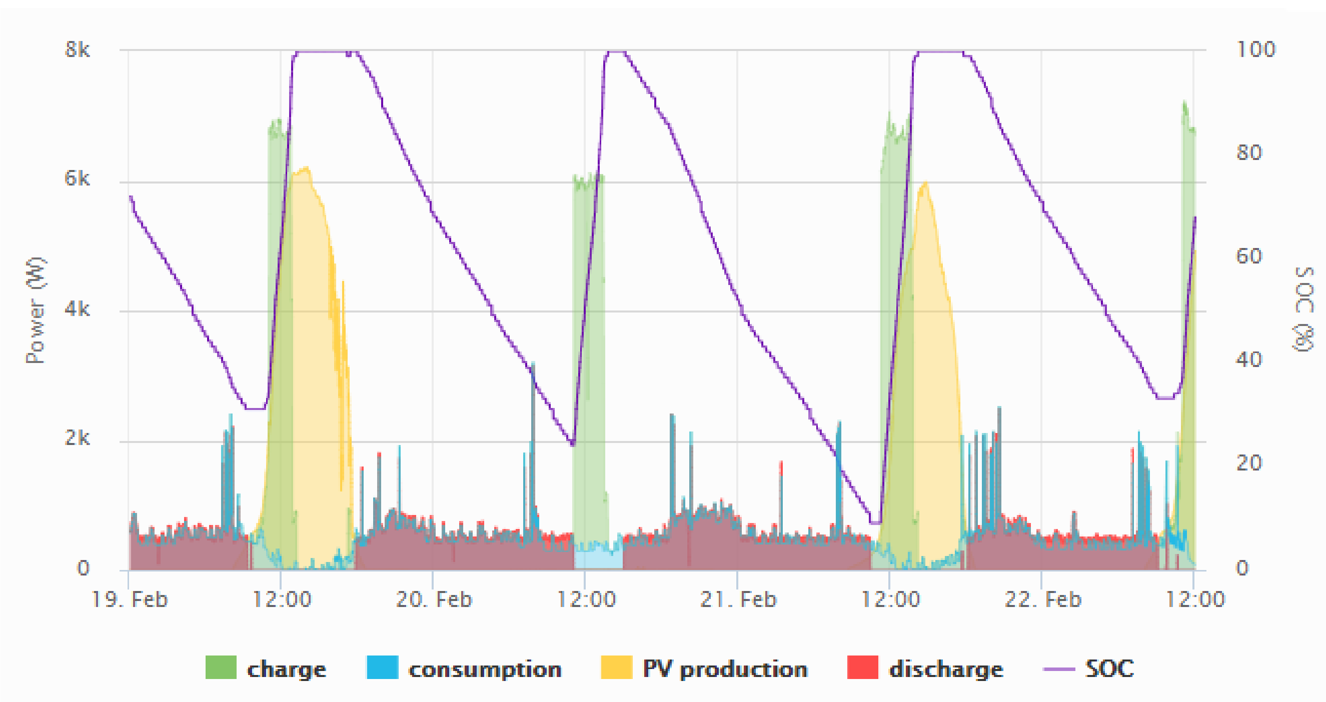
-Purple indicates the state of charge % (SOC) of the unit. The units are set to a minimum SOC of 5% (this depends on what the user sets it at) and when it hits that minimum threshold it stops discharging and remains at that SOC until the unit begins to charge at its preset charge time.

-Green is the unit charging in watts. This unit charges at a 6-kW rate. The SOC increases significantly during the charging time. Once charged the units does not discharge until it hits the set discharge time.

-Blue is the consumption/load of the subpanel. It is visible that the consumption is always being monitored. The consumption is all the electricity being used on the subpanel that the unit is tied into.

-Red indicates the discharge of the battery. When looking at the above graph you can see that the discharge is always greater than the consumption. The unit is designed to monitor the demand on the subpanel and discharge more wattage than the consumption. The minimal discharge is 400 watts. When the load on the subpanel is less than 400 watts, then the discharge will go back to the main service panel. If that discharge still isn't used up by the load on the main service panel, then the excess wattage will go back onto the grid.

2. The units with solar are set on different TOU schedules. These units are set to charge when solar is producing and discharge when there is no solar. These two units start to charge at 10 a.m. and begin to discharge at 6 p.m.

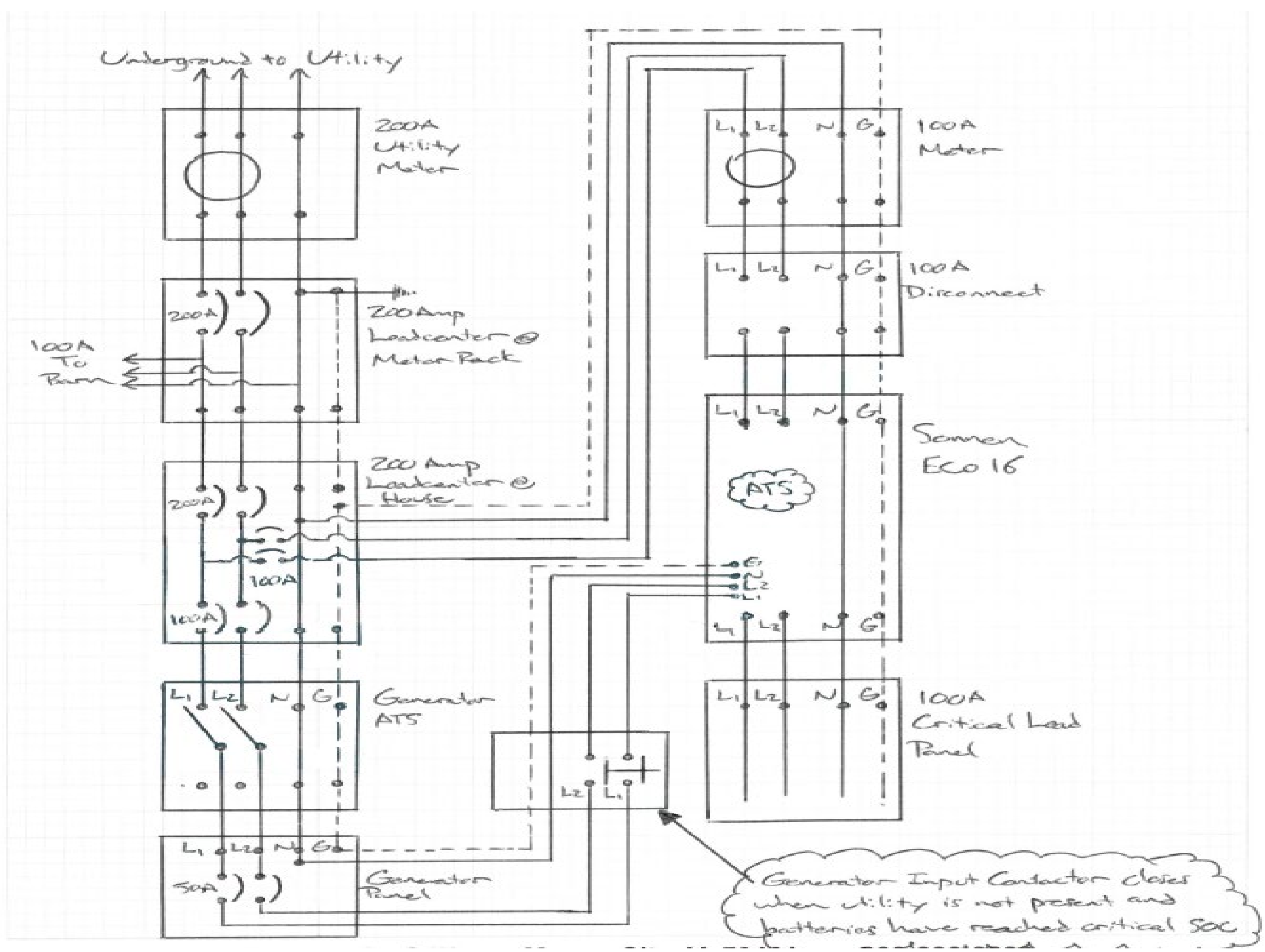


-Yellow is the PV production. In these TOU schedules the solar is designed to charge the unit. On February 20th it is visible that there was no solar production and on the 19th the solar charged the majority of the batteries.

3. Self-Consumption. In this setting the unit will allow the homeowner to use as much solar production as possible to cover their load. The unit will not discharge watts when the solar is producing enough to cover the members consumption. When the solar production isn't enough to cover the load, the unit will discharge the needed amount to cover the load. When there is more production from the solar than there is consumption, then the batteries will charge from the solar.

Neither of the members with solar wanted to be on this mode of operation. MiEnergy offers net metering for solar in the form of kWh credits. In this case, the members didn't want to see their solar production go into the battery and be affected with the efficiency loss from converting from AC to DC and back to AC voltage. This will be talked more in depth in the net metering section.

Generator



The one-line drawing above shows how a generator can be tied into the system. The owner in the pilot project had already purchased a 14 kW Generac and wanted to make sure it didn't go to waste. The above one-line shows the meter and a 200-amp panel outside. The service panel in the house feeds the battery and has a tie to the transfer switch. On a normal operation, without the battery the transfer switch would open when there is no utility power and would feed the circuits on the subpanel. When the utility power returns the transfer switch would close back in and the subpanel would be fed by the grid. With the battery the generator operates the same way. The difference is there is a contactor on the load side of the Generac panel that closes when the unit needs to be charged (reaches 5% SOC). This setup is like a PV system where during an extended outage the owner could use the generator to charge the battery, and then run off that battery until the unit gets to a low enough SOC that the contactors close.

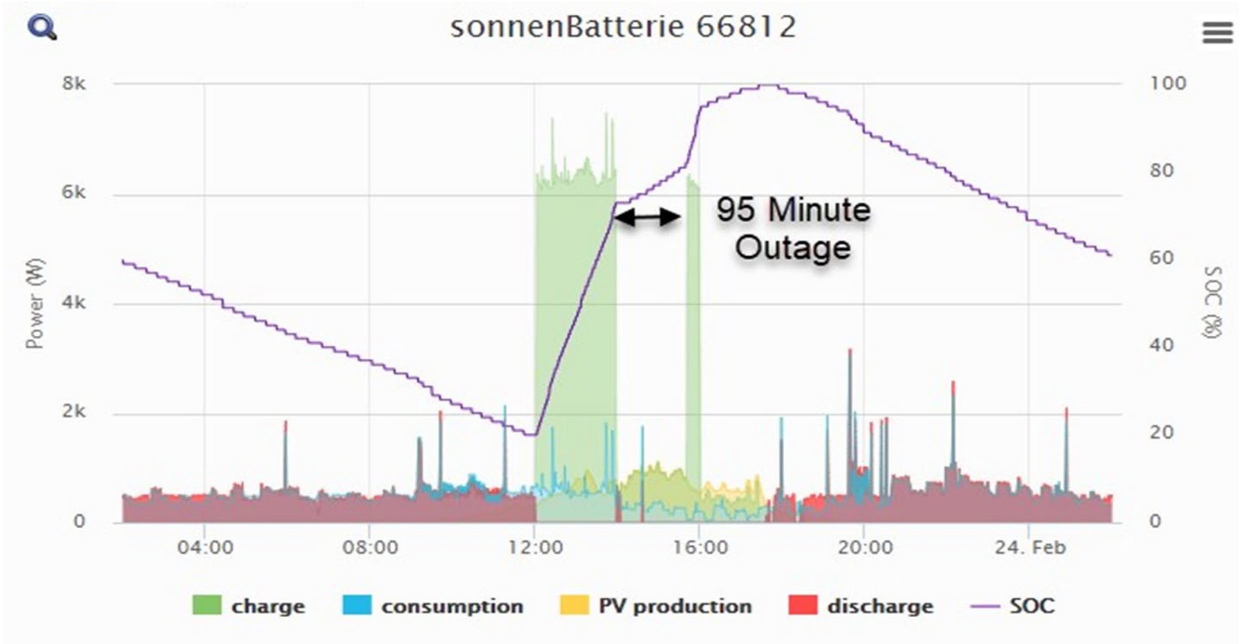
Depth of Discharge

MiEnergy looked at what SOC is best for the battery units. If the units continually discharge to 0% or 1% and sit for hours every day before recharging, then the units could fall into deep discharge. Deep discharge is when the unit's SOC continually gets too low for an extended time period. Deep discharge can damage the unit. Other than deep discharge (0%-1%), the minimal set SOC can be flexible to what the homeowner would like. At the same time MiEnergy wants the unit to have some charge in case of a short outage. 5% SOC may be re-evaluated later in the pilot project. The first half of the pilot project, MiEnergy wanted to see how much load could be covered and monitor the efficiency losses. Most manufacturers will recommend a maximum depth of discharge (DoD). The higher the DoD the more you'll be able to maximize your storage capacity.

Outage Operation

Operation during an outage is different than everyday discharge. When the unit is discharging or charging there is no separation from the grid. The unit sensing the consumption on the panel and discharges. In order to know how the unit is operating, someone would have to read the display on the unit. The unit will act differently during an outage. Once the unit senses no grid power for 30 seconds the transfer switch opens and disconnects itself from the grid. When the transfer switch opens, you'll hear a loud clunk. After hearing the "clunk", and power returns the unit will be powering the subpanel. The Sonnen light on the front of the unit will be green, indicating the house/panel is being powered by the battery unit. After the grid returns power, the inverter will take 5 minutes before the transfer switch closes. The "clunking" noise will be an indicator of this. IEEE requires the inverter to not return power to the grid for a minimum of 5 minutes after seeing grid power. This is a safety issue, so no power is back fed onto the lines during an outage.

Outage incident- One of the units with a PV system had a 95-minute outage. There was a squirrel that blew the fuse on the transformer. The unit was charging at a 6 kW rate when the outage happened. It must have been a cloudy day because the solar production was minimal



(roughly 1 kW). The unit stops charging from the grid but continues to charge (SOC%) but at a much slower rate. The solar(yellow) is covering the members consumption and charging the battery slightly. You can see two larger spikes just shy of 2 kW that happened during the outage. It's visible that the demand was higher than the solar was supplying, so the unit discharged the amount of wattage to cover that demand above what the solar couldn't. After that consumption spike, the unit went back to charging from the solar because the solar production was enough to cover the consumption and slightly charge the unit. Once the outage ended, the unit began to recharge at the 6-kW rate.

Firmware & System Update

The main purpose of the unit being hardline to the internet is for firmware and system updates. There is no set schedule for the updates and the number of updates varies annually. The battery unit will not update while operating (charging or discharging). If the unit is updating while an outage occurs, then the unit will operate, and the update will start over after the system isn't operating. The unit does identify when there is an update occurring. On the front of the unit there is a display under the Sonnen logo that identifies the status the unit is in. Below are the different statuses:

Pulsing White: Normal operation

Pulsing Green: Off-grid operation

Pulsing Orange: No Internet connection

Pulsing Yellow: Firmware/System Update

Solid Red: Error

Percentage of Whole Home Battery Covers

MiEnergy really wanted to see how much of the total home these units could power. The units have been fully charging and almost completely discharging on a daily schedule. MiEnergy looked at the members' total use (Apr.-Sept.) and the total discharge of the battery. This showed us how much of the members' use was powered by the battery.

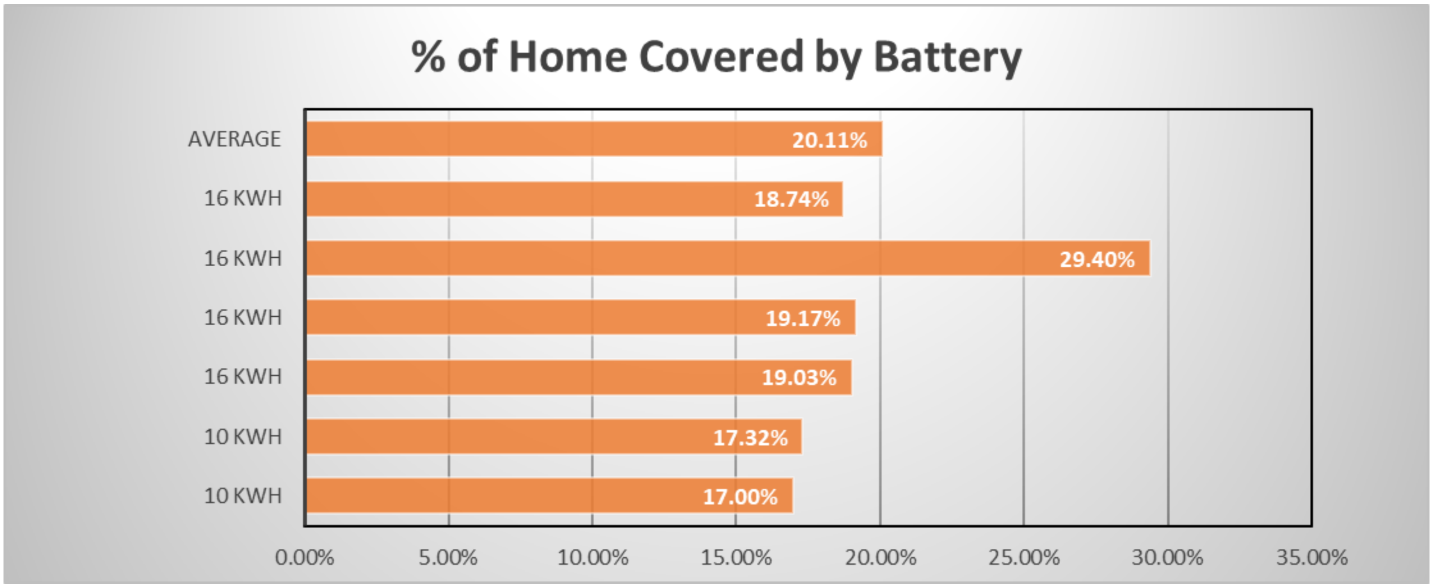
There are a few factors that affect the whole home percentage. The first, is the member's electric use. If a member has a high use, then the battery will cover a smaller percentage of that use. The battery discharge is a fixed number monthly, but the members' electric use will vary. Below is the members' monthly electric use during this period.

808 kWh, 797 kWh, 1550 kWh, 1116 kWh

Secondly, the size of the battery unit will affect how much of the home the unit can cover. The units were 16 kWh storage capacity and 10 kWh battery storage. These sizes, from the above kWh use, show that the two smaller units were installed in homes with less use. This will increase the percentage of the home they can cover.

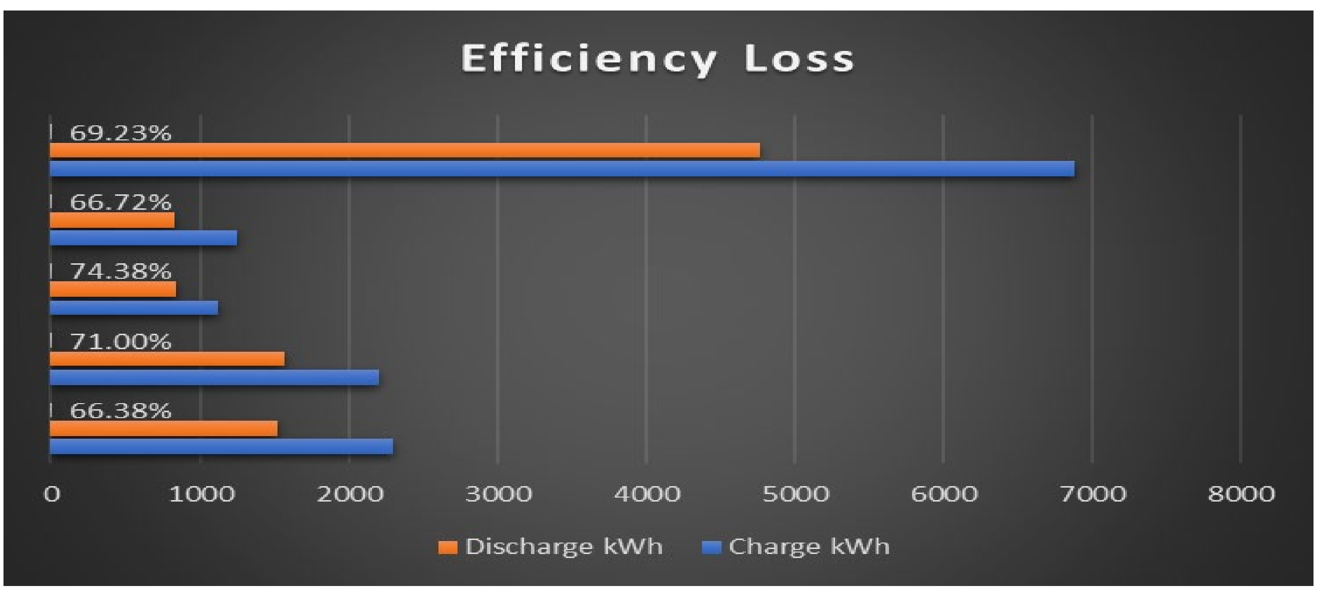
Thirdly, two of the systems have solar arrays. The size of the array and the time of the year will directly affect the percentage of the home's electric use the battery unit covers.

The below graph shows that the average battery covered 18.13 % of the home. The 16 kWh battery units covered about 19% with a 29.4% outlier. The 10 kWh battery units covered about 17% of the home.



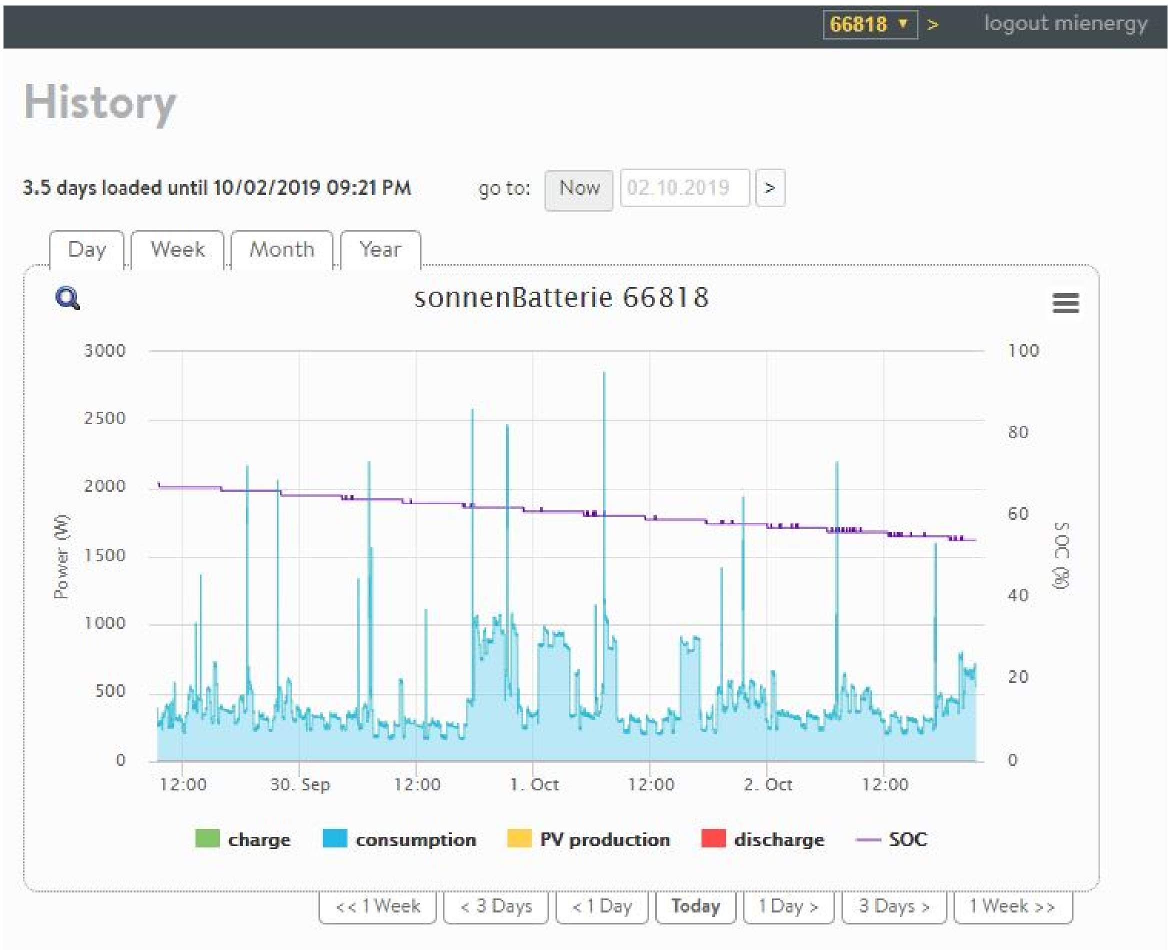
Efficiency Loss

Another one of the aspects MiEnergy Cooperative wanted to look at was the efficiency conversion. The maximum inverter efficiency on the specifications sheet states 93% which means there is 7% efficiency loss on the inverter. The inverting conversion loss is the conversion from alternating current to direct current. This process includes two inverter conversions which is AC to DC and then back to AC current. It was expected the efficiency loss for round trip would be around 14%.



MiEnergy Cooperative used the total kWh that went to charge the battery unit, and then the total kWh that were discharged to calculate the efficiency loss. The numbers we found were much higher than initially expected. The efficiency in total was 69.23%. Keep in mind this loss is only on the battery unit. There would be extra loss from the two systems that have separate inverters for their solar array. The conversion for the energy produced from the solar that gets stored on the battery is DC/AC/DC/AC. That is 3 conversions between AC and DC when adding a battery unit to an existing solar array.

MiEnergy reached out to Sonnen to see if they knew of any possible causes for the high efficiency loss. Sonnen had a few small suggestions but no answer to account for the extra 15% loss. One of the issues is the initial charging rate. The systems were charging at 6,000 watts and Sonnen suggested that high charge rate may affect the efficiency. The charge rate for all the systems has been reduced. The other issue is the storage loss. There is a little power loss from storing the energy in the battery. MiEnergy set one unit to not discharge for a week to see what it did to the SOC percentage. There is a 2% daily energy loss on the energy stored in the batteries.



That 2% daily loss ends up being .2 kWh on the 10 kWh unit and .32 kWh on the 16 kWh unit. Over a year those losses equate to 116.8 kWhs & 73 kWhs. Sonnen is looking into other possible reasons for the high efficiency loss.

Discharge Times & Rates

The main reason for having the battery units discharging fully and daily was to gain some knowledge on how much of the whole home the battery units could power. After running/discharging the batteries every day and learning how much the unit can power a household, MiEnergy has changed the discharge time for summer season to 2 p.m.-6 p.m. and winter season to 5 p.m.-8 p.m. This time frame lines up with the peak load times of our wholesale energy provider (Dairyland Power Cooperative). MiEnergy is going to look at how to implement the battery units into our load management program. The intent is to not only discharge the amount of use that member is using on their subpanel but to discharge extra kW to feed back onto the grid and reduce system-wide demand. These can be great load shedding resources.

Until MiEnergy has a time of use rate schedule that would benefit the members, there is no reason to continue to discharge the entire capacity of the battery unit. A TOU rate will factor in the efficiency loss on the unit and will help compensate the member back for that energy loss.

Net Metering & PV Storage Strategies

Every state has a different policy on net metering. MiEnergy has territory in both Minnesota and Iowa. Minnesota has a net metering policy, for cooperatives, any DER system 40 kW and under qualifies for retail rate. What this means is if a resident of Minnesota builds a system larger than their use then the electric utility must purchase it back at the same rate in which they purchase a kWh for. In Iowa, the excess production from a DER system is paid back at avoided cost.

MidAmerican Energy and IPL are required to reimburse their Iowa customers with a kWh credit for all over production (IOU). MiEnergy handles excess production the same in Iowa. The excess production gets paid back as a kWh credit that carries over indefinitely.

There are two strategies when a DER system is over producing for the members. Either store the excess generation for later consumption or sell it back to the electric utility.

Storing of the excess generation is the original schedule the battery units were programmed. Per members' request they wished to use their excess production at a later time in order to cut back on using grid power. The battery units would begin to charge at 11 a.m. which is close to peak solar generation. Other than environmental purposes, the financials work better in this situation for net metering policies that pay avoided cost for excess production. If the retail rate is $.12 for a kWh and avoided cost is $.03 for a kWh, then it makes more sense to store that generation and use it later when you would be paying $.12 for a kWh.

The two solar sites on this pilot project have since changed their stance on the charging times. Both members wanted the batteries to be changed to charge off the grid during low demand times. These members receive kWh credits for their excess production and would prefer not to have their production go into the battery and lose out on the efficiency loss. This is the similar stance most members would take if the electric utility paid back retail rate for excess production.

Whole Home Battery vs Subpanel

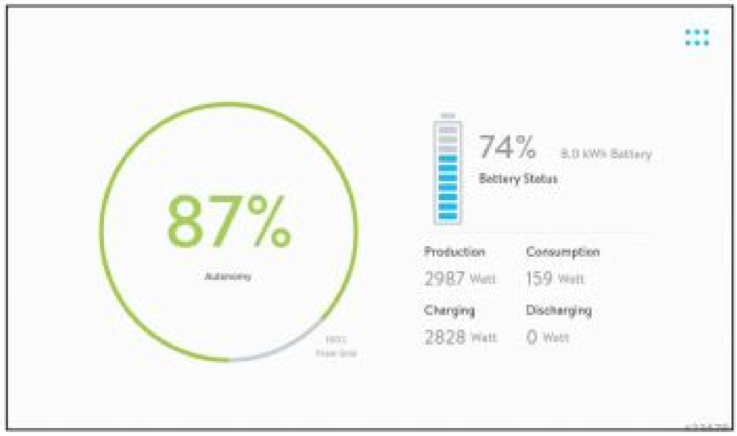
One of the installs is wired into the entire home. What that means is, the other are setup like one would install a generator. Critical loads and lighting circuits were moved over into a subpanel. During an outage the battery unit will power that subpanel. With the whole home install, the battery unit is on the line side of the main service panel which means every circuit in the house will be powered by the battery during an outage.

Cons of Whole Home Battery

Outage time can be an issue if its extended. If the unit is on the entire home, then typically you'll have more consumption. This consumption will drain the battery quicker. For example, a 16-kWh battery would typically last 16 hours if you were using 1,000 watts per hour or 1 kWh. Now, if you had the entire home on the battery during an outage, then you would theoretically be consuming more than 1,000 watts. Let's say the consumption is 4,000 watts, then the battery unit would last 4 hours. So, capacity can be an issue if the entire home is one the battery unit.

Time of outage also influences the life on the battery unit. None of the battery units that are on the subpanel have large loads or any load that would exceed 8 kW (this would trip the breaker). Tripping a breaker on the battery units won't be as common for the systems that are not on the whole home. If the outage happens during the day, when you're not around to control the circuits, then the batteries would drain and or the breaker could trip. With the breaker tripping, nothing would be powered during the outage. If the outage occurred at 11 a.m. on a 90-degree day and the homeowner worked 8-4, then the AC unit would most likely have drained the entire storage before you got home. Another scenario would be if you have the AC running, electric water heater (because all the kids took long showers in the morning), dehumidifier, etc. and there was an outage. All this load would exceed 8 kW and the breaker on the battery unit would trip and it would require someone to turn the breaker back on and remain under 8 kW.

Knowledge of Sonnen unit follows up on the last con of a whole home battery unit. If the consumption exceeds 8 kW the breaker will trip. The homeowner must be comfortable enough to open the unit, find the breaker, and flip it back on. MiEnergy did training with the homeowner that has the whole home battery unit.



Pros of Whole Home:

Availability to entire electrical system. This alone is the biggest benefit and greater significance than any of the cons. Having the entire home at your disposal during an outage would make an outage a minimal inconvenience. If the outage is for an extended amount of time, then you would need to do some load management.

Solar Production. With solar tied into the battery unit the excess production will go into the battery and the rest would go towards the consumption of the home. If the battery unit wasn't on the whole home, then the homeowner would not be able to capitalize on all the solar production.

Flexibility to control electric use. The consumption does need to be monitored or controlled for the breaker to not trip or drain the storage. The battery unit will display how many watts are being used and the remaining battery life. Again, if the system exceeds 8 kW and trips then the homeowner will need to turn off some of their load in the service panel and then flip the breaker back on in the battery unit. Likewise, if the homeowner knows the outage will be for an extended period and the expected battery life will run out before the outage is restored, then the homeowner will have to turn off some luxury circuits or reduce their consumption. Either way this very much empowers the homeowners and educates them on conserving electricity.

Load management – Almost don't need to control. The amount of load on the battery plays a big role of controlling load on the grid. When the battery unit is set on a daily schedule (like it is now) it will discharge up to the amount of consumption on the subpanel. If the only loads on the subpanel are minimal loads, then the battery is not reducing much of the homeowner's load and essentially not reducing the load on the entire system. If the full home were on the battery unit, then essentially the entire home would be taken off the grid on daily discharge times. This is a much greater tool for load management. Otherwise, with minimal load on the subpanel

MiEnergy would want to send a discharge command in order to maximize the amount of load they can take off the home.

API system

MiEnergy has installed a program (Postman) that allows direct communication to the battery unit (HTTP API commands). There were two options in communicating with the units. One is through a local LAN in which MiEnergy is required to setup a VPN to access the homeowner's LAN. In order to have a smoother communication line and not have to continue to VPN into the homeowner's network, MiEnergy chose to go the direct URL command route. The API system allows server request URL command. This enables sending control commands through Sonnen's backend. Some of the URL commands include set discharge rate, charge rate, status, consumption, production, grid feed watts, state of charge, AC frequency, AC voltage, battery voltage in volts, system time, and manual control.

3 Controlling the storage system

3.1 API commands

ID	URL	Description
1	/setpoint/charge/1000	Charge the system with value in watts
2	/setpoint/discharge/1000	Discharge the system with value in watts
3	/status	Returns the battery status in a response in JSON format

Table 1: API commands

Below is an example of a curl command that MiEnergy would send in order to have the unit charge at a set rate. The first required information in the curl command is the serial number of the battery unit. This is unit specific. The second information is the value. Ahead of this value, you can see that this is a charge command. The value is the wattage in which MiEnergy wants the battery unit to charge at. The last part of this curl command is the token. This is an authorization token that Sonnen has setup that allows access into their backend system. This token is the same for every command on every unit. The token is 64 base GUID. So, it's a mix of 64 numbers letters. MiEnergy plans to eventually purchase or write their own script/program in order to control the units.

Charging:

```
curl -X "GET" "https://core-api.sonnenbatterie.de/proxy/SERIAL/api/v1/setpoint/charge/VALUE" -H "Accept: application/vnd.sonnenbatterie.api.core.v1+json" -H "Authorization: Bearer TOKEN" -H
```

SERIAL – Serial number of the system to connect

VALUE – Charging or discharging value in watts

TOKEN – Bearer authentication Token

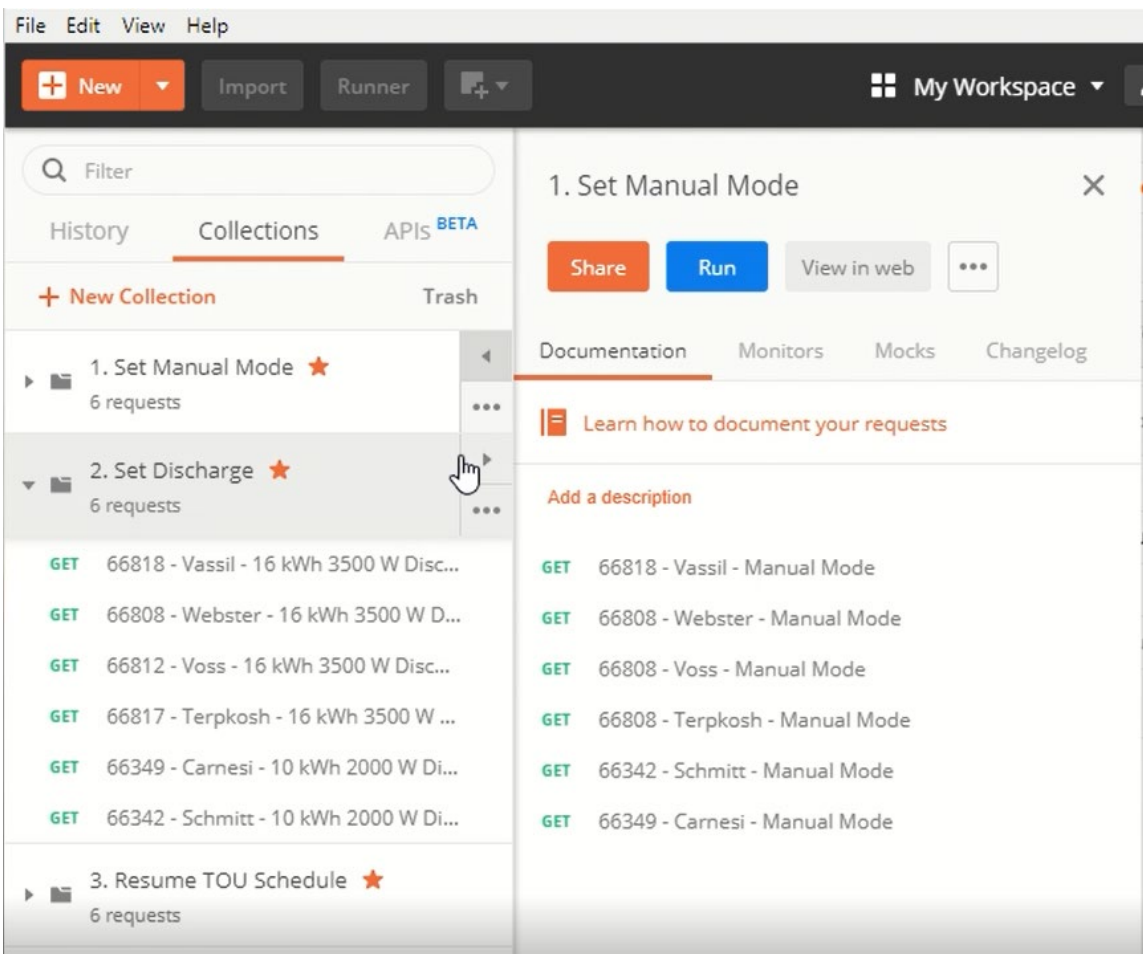
Load Management

Dairyland Cooperative has been given permission by MiEnergy to control one of the batteries for their own piloting purposes. The units are on a daily discharge schedule of 2 p.m. – 6 p.m. On average the batteries are only discharging about 20% of their capacity. The plan is during the next peak alert (when there is a high energy demand and the cooperative will be charged based on their peak load) Dairyland (through their own software) and MiEnergy will send out commands to the units to discharge at 2kW (10 kWh system) and 3.5 kW (16 kWh system) for a 4 hour time period. This is regardless of the members' consumption. If the member is consuming 5 kW then only 2 kW or 3.5 kW would be from the battery and the rest from the grid. If the member is only consuming 1 kW, then all the excess will go back onto the grid and shave peak elsewhere.

Peak Alert Example

MiEnergy usually receives the peak alert from Dairyland around 11 a.m.. This means that when 2 o'clock comes around the battery units need to be sent a curl command. All the units are setup into folders with unique commands.

1. **Set manual mode** is the first folder. This is done before 2 p.m.. This folder needs to be opened and the command needs to be run. By hitting run, all the commands in this folder will be sent. So, the curl commands are all saved and can be run at the same time. This makes a 20-minute process be completed in 20 seconds.
2. **Set discharge rate** is the second folder/command. This is done right before 2 p.m.. In the photo below you can see all the units are listed with serial number, name, size of the storage, and the discharge amount that is programmed in for each command. Again, this



was all setup prior in order to make this process as seamless as possible. When you run this folder each of those commands will be sent and the units will start to discharge at those specific discharge rates.

3. **Resume TOU schedule** is the last command that needs to be sent. The units will continue to discharge until they're down to their minimal state of charge. If nothing is done after this, then the battery would sit at this state of charge for the rest of time. The last command that needs to be sent is to have the unit revert to its last time of use schedule. The battery units begin to charge at midnight. The end goal would be to send this command before midnight (any time after 6 p.m.) in order for the battery unit to charge that night and have the storage to discharge the following day.

Lessons Learned

Efficiency loss. Calculating efficiency loss on these unit was surprising. The battery units averaged an efficiency loss around 30% round trip. It was expected 7.5% efficiency loss. This greatly affects the feasibility. This has an adverse effect with actually causing the homeowner to increase their electric use.

Solid Red Display on the unit is bad.

Installation Certification. Sonnen and Telsa have certification in order to be an installer. As a homeowner and utility/cooperative not any electrician can install battery units. Sonnen will not commission the unit unless it is done by a certified Sonnen installer. Sonnen's certification involves a pre-test and what has been said a very difficult exam.

Installation costs can vary in every home. Yes, they can be wired in but depending on the service size and location of the unit, the installation cost could be much more than typical homes. It's highly recommended that before purchasing a unit to get the installation estimate from a certified Sonnen installer. Advise members and/or customers to get quotes from electricians before purchasing battery units. This can make it difficult for utilities and cooperatives to offer such a product.

Installing bi-directional meters is important because if there is excess discharge that goes back onto the grid the member/customer needs to be compensated. At what rate the member is compensated depends on the State policy and the utilities/cooperatives polices.

Emergency circuits vs Whole home. This will depend on what the member/customer is looking for in the battery unit and how much they would like to spend. With a smaller storage unit, the goal would be selecting critical loads. With larger capacity the goal would be towards having the entire home available and educating the user how to control their load during an outage. From a cooperatives standpoint the larger the capacity the more significant load management can be. Excess discharge compensation would also play a role.

Requirements include hard-wired ethernet from modem, conditioned space that ranges from 41º to 113º F, adequate spacing for ventilation.

SOC% or DoD are very important. Fully discharging the unit continuously will deter the life expectancy of the unit.

Location of Storage from cooperative. Cooperatives and utilities will want to standardized battery installations. This will be very difficult being a behind the meter install. Does it make the most sense to have the battery on the line or load side of a production meter? Every install is going to be different and won't be standardized until more development and the market has matured.

Net metering. The policies can vary amongst utilities and cooperatives but have a plan together on how this may work with a time of use rate. With a 30% efficiency loss, the members didn't want the excess production of their solar to go into the battery. Financially, it makes more sense to sell all the excess back at retail rate then store their own generation for later use.

Benefits of Residential Storage

Homeowners

1. **Back-up power**- At this point the biggest benefit is for electric resiliency. This can also be done with a generator at a much lower price. Though as technology advances, owning a storage unit can open the door down the road to solar and allow flexibility with electric rates.
2. **Flexibility in electric rates-** As battery technology advances the price for the units should decrease, capacity increase, and power increase. With that said utilities and cooperatives will continue to develop time of use rates. The rates would allow homeowners to purchase power at off-peak times and consume that power during on peak times. In doing this the utility/cooperative would reduce the off-peak kWh price. Residential demand will become more mainstream in the future. Solar alone doesn't usually produce during the peak times and can't be relied on daily. Having a storage unit would allow a homeowner to shave their peak on a daily schedule which on a monthly basis would reduce their demand payment.
3. **Green energy**- Relying mostly on a homeowner's own production as consumption does reduce their carbon footprint. The homeowner can store their excess generation on the battery and consume it at a later time rather than from the grid. These benefits are becoming less significant as wholesale power is becoming much greener.
4. **Grid dependence-** For homeowner wanting to rely minimally on the grid for their consumption these units can be put on a self -consumption mode. Solar would need to be tied in with the system. This would allow homeowners produce and consume the majority of their use while still having the grid available in need be.

Cooperatives/Utilities

1. **Reducing Peak Demand-** The biggest benefit to the utilities and cooperatives would be reducing the system peak demand. MiEnergy was able to control the units to discharge during a February peak alert. This had a reduction of 21 kW on the system. This has a very minimal impact on the entire grid, but it's on a very small scale.
2. **Incentivize Homeowners-** The above comparison made will be between utility scale versus residential scale battery. With having a program in place to promote residential storage, the homeowners would have the option and reap some of the benefits. A utility scale battery would have a greater impact on peak load reduction and those savings would be spread amongst the members/customers. With residential storage, there would be two levels of savings. The homeowner themselves would have a direct benefit whether that's a TOU rate, capacity credit, power credits, etc. and then the overall membership would have a benefit from wholesale savings. Most cooperatives/utilities will have to have a blend of large-scale and small-scale storage systems.
3. **Possible Market-** This could be a new market for utilities to participate in. Whether that participation includes being a distributer of the storage units, installer, and/or form a partnership with a local contractor.

Rate Structures

Incentivized Programs

1. **Continued Capacity Credit** based on the kWh and kW rating of the system. Our cooperative is charged on capacity during a possible 12 peak alerts between winter peak and summer peak times. If the homeowner allowed the cooperative to control the battery storage unit then said homeowner would receive a monthly credit. This credit would be based on a percentage of the capacity charge per kW that the distribution cooperative gets charged from the wholesaler. For example, if the capacity charge for a winter peak and summer peak were $25 and $60 per kW, then the member could receive an average monthly credit. This would be based on the number of annual peak alerts.

   The homeowner could also receive back X % of the wholesale capacity charge per each event. The capacity credit would have to be limited to the homeowner's peak load or x % above that load. Below would be an example.

	# of Days	% of Capacity Charge	Capacity Charge	Continued Capacity kW	
Winter Peak	3	0.25	$25	3	$56
Summer Peaks	9	0.25	$60	4.5	$608
				Annual Savings Member	$664
				10 Year savings	$6,637.50

Rate-Based Methods

1. **Time of Use** has been the most talked about rate structure tied with battery storage. The concept here is to have the homeowner shift their usage from on-peak to off peak by offering a lower off-peak kWh charge. The battery would charge during off-peak (lower kWh charge) and then discharge during on peak times (higher kWh charge). If the homeowner continues to have a large amount of their electric use during on-peak times, then this rate would not work for them.

Description	Fee - TOU	Fee - Rural
Basic	$35	$35
Summer-on	$0.200	$0.120
Non-summer on	$0.180	$0.120
Off-peak	$0.056	$0.120

The cooperative looked at roughly 6 months of electric use for each site to calculate the kWh use. We estimated what their on- peak use was. The on-peak time frame that was used was 9 a.m. to 9 p.m. year-round. The rate was different for summer on peak ($.20 kWh) and non-summer on peak ($.18). Summer included the months of June, July, and August with all other months be non-summer. The off-peak rate was $.056 kWh. The left graph shows what the homeowner would pay without a time of use rate. Those numbers are based off an average usage of our members prior to the battery. The right graph would be their calculated savings if they were on a time of use rate. With these savings from a TOU rate the payback period would be 33 years for the 10 kWh units and 43 years.

Description	Units	Units Rural	Fee - Rural
Basic	12		$420
kWH charge	4,397	0	$0
Summer-on	955	955	$114.54
Non-summer on	2,979	2,979	$357.43
kWH off	7,567	7,567	$908.06
Total		11,500	$1,800

Description	Units charge & use	Battery kWH discharge	Units TOU	Fee - TOU
Basic			12	$420
kWH charge	4,397		4,397	$246
Summer-on	955	747	207	$41.42
Non-summer on	2,979	2,242	736	$132.53
kWH off	7,567	0	7,567	$423.76
Total		2,990	12,907	$1,264
Save/year				$536

2. **Peak alert rate-**The homeowner would receive an annually lower electric rate (cheaper kWh) if they eliminated their demand during a peak alert. If the member didn't eliminate their demand, they would be charged a causation charge. Most likely a pass-through cost of the wholesale kW charge. This would be a similar rate to the co-op's existing generators that are on a peak alert rate.

Applicability

Is residential battery storage feasible? It depends on if the homeowner or utility/cooperative are purchasing the storage units. Different rate structures are being rolled out as we speak across the country. The technology is here to establish an API communication to control the storage units. MiEnergy's wholesaler is also creating a program to remotely control the storage for their distribution cooperatives. They've done one test trial which was successful. The blueprints are being created. The concern isn't technology in terms of installing, monitoring, charging, and discharging the units. The technology is going to get to a point that makes the storage feasible from a financial standpoint. The warranty on the Sonnen units and others are 10-year warranties. On the rate structures discussed above, none of those allow a payback period under 10 years. Batteries must continue to increase with capacity to size ratio. With this advancement the price of the units will also need to come down. An ECO 16 (16 kWh, 8 kW) unit would need to be around $3,000-$4,000 to be financially feasible. This would assume a newer home install as well to avoid expensive installation costs. Controlling EVs batteries at this point are more feasible from a financial standpoint than home battery storage units. The time will come.