FEASIBILITY STUDY FINDINGS

Bad River Band of Lake Superior Chippewa Ojibwe Hybrid Microgrid (OHM) Feasibility Study

Funded by Wisconsin OEI

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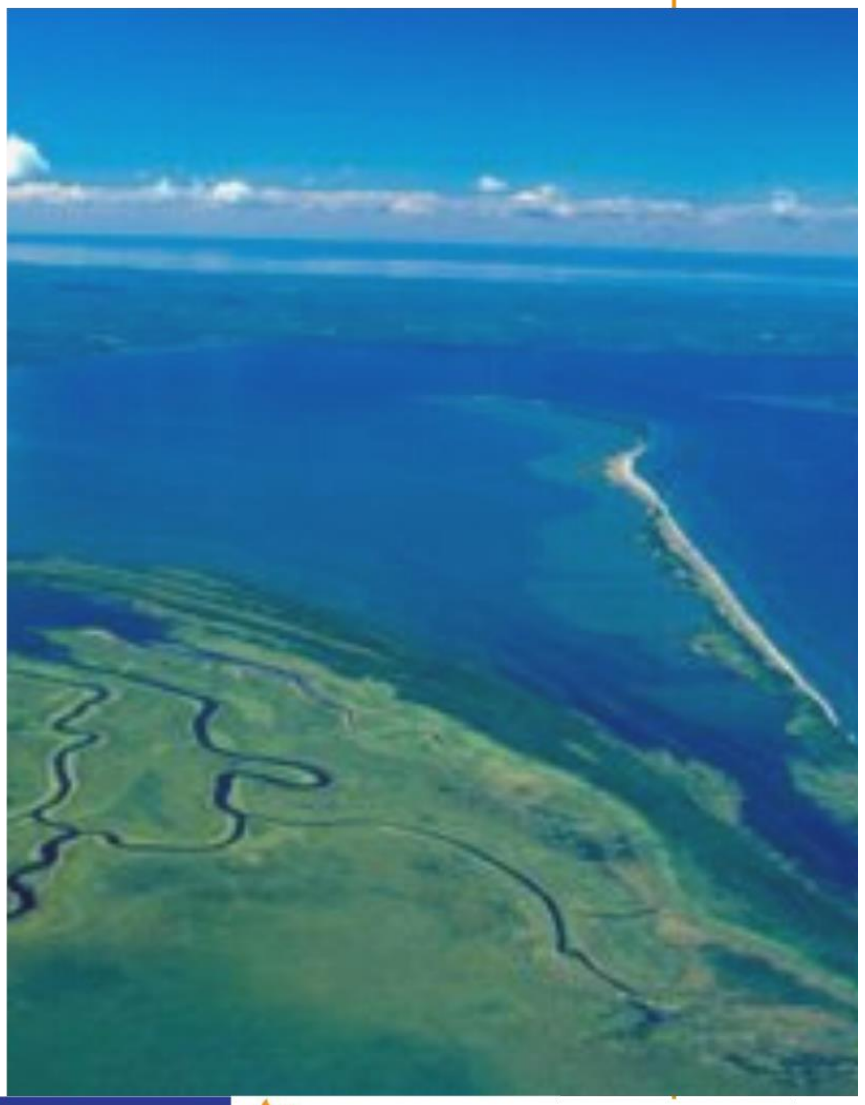
Rev E



Analysis provided by muGrid Analytics In partnership with Cheq Bay Renewables & Madison Solar Consulting

List of Acronyms

A	ampere
AC	alternating current
BEC	Bayfield Electric Cooperative
CHP	combined heat and power
COP	coefficient of performance, unitless (kW-thermal per kW-electric)
DC	direct current
DER	distributed energy resource
HVAC	heating, ventilation, and air conditioning
IRR	internal rate of return
kVA	kilovolt-amperes (apparent power only)
kW	kilowatt (1000 W)
kWh	kilowatt-hour (one kW over a period of one hour)
kWp	kilowatt photovoltaic (solar PV DC capacity)
LFP	lithium iron (Fe) phosphate (battery chemistry)
MBtu	million British thermal units, equal to 0.293 MWh
MW	megawatt (1000 kW)
MWh	megawatt-hour (1000 kWh)
NMC	nickel, manganese, cobalt (a lithium-ion battery chemistry)
NPV	net present value
O&M	operations and maintenance
PSC	public service commission
POC	point of connection
PV	photovoltaic (solar)
SPP	simple payback period
TOU	time of use
UPS	uninterruptible power supply
USDN	urban sustainability directors network
V	volt
W	watt
WWTP	waste water treatment plant

Executive Summary

The Bad River Band of the Lake Superior Chippewa is building a clean and resilient future with an advanced renewable energy community microgrid. The tribal energy team is investigating a community microgrid for both emergency services and critical infrastructure, studying expanding its existing building microgrids into a single Level 3 (as defined by Wisconsin Public Service Commission [PSC]) advanced community microgrid or several independently metered Community Resilience Centers. The Tribe is passionate about clean energy and intends to move quickly toward net zero carbon emissions.

In 2021 the tribal energy team and partners commissioned the first tribal advanced building microgrids: the Health and Wellness Center, Chief Blackhawk Administration Building, and their Waste Water Treatment Plant. Despite this successful pilot, many lifelines remain vulnerable such as durable medical devices at the Elderly Apartments, perishable food supplies at the IGA supermarket, and resilient back up for the Head Start Preschool.

muGrid Analytics conducted a thorough feasibility study to find a viable path to a larger community microgrid that meets the Tribe's clean resilience objectives, given the learnings of the pilot projects. An experienced team comprising muGrid Analytics, Cheq Bay Renewables, and Madison Solar Consulting were well prepared to support the Tribe on this project, as with the previous successful microgrids.

This study builds on the work begun in 2019 for the Tribe's Long Range Energy Planning effort. The study provides continuity, iteration, and a practical roadmap for future energy projects. We initiated data collection for 11 tribal buildings, providing the Tribe with significantly improved insight into their energy usage and needs. Conducting in-depth analysis of market opportunities for solar + storage and the associated economic impacts to a front-of-meter grid-connected community microgrid, we performed load profile synthesis, data cleaning, and aggregation using state-of-the-art statistical methods for load profile development. We demonstrated a pilot for dispatchable load control in conjunction with a solar-based microgrid on Tribal lands. Our commentary on business and policy considerations for tribal microgrid development is provided in the accompanying document, "Opportunities for De-Carbonizing the Bad River Band of Lake Superior Tribe of Chippewa Indians' Electricity Resources." We revealed the design tradeoffs between solar / battery capacity and generator tank size for two different microgrid configurations. Lastly, we discussed considerations for implementing distribution and operations for such a community microgrid.

To serve the New Odanah microgrid, we recommend 1 MW of battery inverter to pair with the existing 800 kW of generators to cover the instantaneous peak loads, along with 4 MWh of battery storage capacity. We recommend installing between 2-8MW of solar depending on economic projections and the Tribe's desires. The next steps are to consider the approach to implement such a microgrid – incrementally at the building level, or more rapidly as a front-of-meter energy project. Building a microgrid on the East Branch feeder may cover most of the critical facilities and provide an intermediary stepping stone to the full New Odanah microgrid. An East Branch microgrid would require 1 MW of battery inverter to pair with the existing 800 kW of generators, along with 2 MWh of battery storage capacity. We recommend a total of at least 500 kW of solar PV to support the East Branch microgrid, though the Tribe may choose to install more in anticipation of future needs.

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1 Introduction

A resilient, grid-connected microgrid or minigrid is composed of a collection of electrical generation, storage, and control assets that serve local loads. It can operate during grid-connected mode as an alternative to the grid. In grid-connected mode, operation is often focused on economics or carbon reduction. Every decision to use microgrid energy or not is driven by the economic or carbon alternative –purchasing from the grid. In resilience mode, the microgrid or minigrid provides its own power to local loads completely independently of the grid, so that the site has backup power for an anticipated duration.

Resilient, grid-connected microgrids often comprise renewable energy generation, fuel-based energy generation, and energy storage, along with a controller that can coordinate the operation of the different assets into a cohesive whole. Controllable loads and electric vehicles are increasingly recognized as components of microgrids as well.

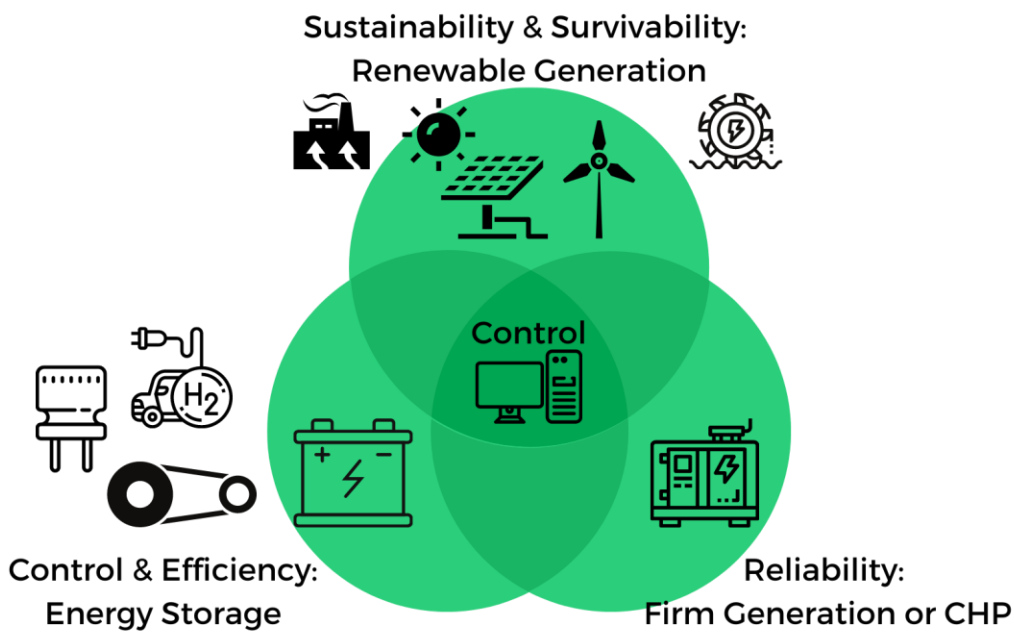


Figure 1. Resilient, grid-connected microgrid topology.

We distinguish between a microgrid and a minigrid based not only on the magnitude of the total electrical load and the capacity of the generation and storage assets required, but also based on the geographic dispersion of those loads. Geographically disperse minigrids require higher distribution voltages, more transformers, more attention to reactive power and voltage drop, and the meteorological conditions at each building can't be assumed to be identical. For example, a microgrid may be just one low-voltage building with backup power from a single generator and battery system. On the other hand, a minigrid could involve several buildings, medium-voltage distribution spanning many hundreds of feet, and several or more solar, battery, and generator assets. These two examples are so different in cost and complexity that we give them different names. A minigrid may even be composed of multiple, smaller microgrids.

Microgrids and minigrids provide multiple benefits. When they incorporate renewable generation (as the Bad River Tribe has previously done,) microgrids offer sustainability, or green power benefits. While a microgrid is grid-connected – that is, while purchasing electricity from the utility is an option – the microgrid offers economic benefits as an alternative to making those purchases. Finally, microgrids offer resilience, or backup power, allowing the facilities supported to ride through and recover from grid outages smoothly.

Due to the geographic dispersion of the Bad River locations, we would typically call this system a "minigrid." For the purposes of this report, however, we will use the more general term "microgrid" for common understanding.

One application of resilient microgrids could be turning one or more buildings into a Community Resilience Hub. As defined by the Urban Sustainability Directors Network (USDN), "Resilience Hubs are community-serving facilities augmented to support residents, coordinate communication, distribute resources, and reduce carbon pollution while enhancing quality of life. Hubs provide an opportunity to effectively work at the nexus of community resilience, emergency management, climate change mitigation, and social equity while providing opportunities for communities to become more self-determining, socially connected, and successful before, during, and after disruptions. Resilience Hubs can meet a myriad of physical and social goals by utilizing a trusted physical space such as a community center, recreation facility, or multi-family housing building as well as the surrounding infrastructure such as a vacant lot, community park, or local business."[1]

In addition to providing resilient infrastructure to support the work of each individual facility, the Bad River Tribe may wish to consider which buildings, particularly the Casino and Lodge, could function as Community Resilience Hubs to support the wider tribal community, including those not located in the New Odanah town core.

1.1 Purpose

The Bad River Band of the Lake Superior Chippewa desires an electric generation and distribution system that typically operates connected to the utility grid, but can also form an electric island when needed – a microgrid – using on site sources of electricity including existing generators, solar PV, and battery storage. This will also require adding new assets and buildings to their existing distributed energy infrastructure.

The Tribe commissioned a feasibility study of a microgrid comprising the Health and Wellness Center, Lodge & Casino, Elderly Center, New Elderly housing, Chief Blackbird Administration Building, Waste Water Treatment Plant, Fire Department, Moccasin Trail Gas Station and IGA Grocery Store, and the Elderly Housing facilities to achieve site resilience in islanded mode with economic benefits while in grid-connected mode.

Additional buildings that may also be considered, but are not as critical to resilience, are the new aquatic fitness center, Head Start, Pine Street Trailers, Lift Station, Bad River Transit Authority, and several residential housing areas.

[1] http://resilience-hub.org/

1.2 Approach

To understand all of the design options, we explore a *tradespace*. A tradespace represents all possible design options from minimum sizes of various technology options to the maximum size. We can quickly eliminate large sections of the tradespace due to cost or failure to meet resilience requirements. Then we focus on those designs that would meet requirements and perform trades between them.

To complete this study, we performed the following tasks:

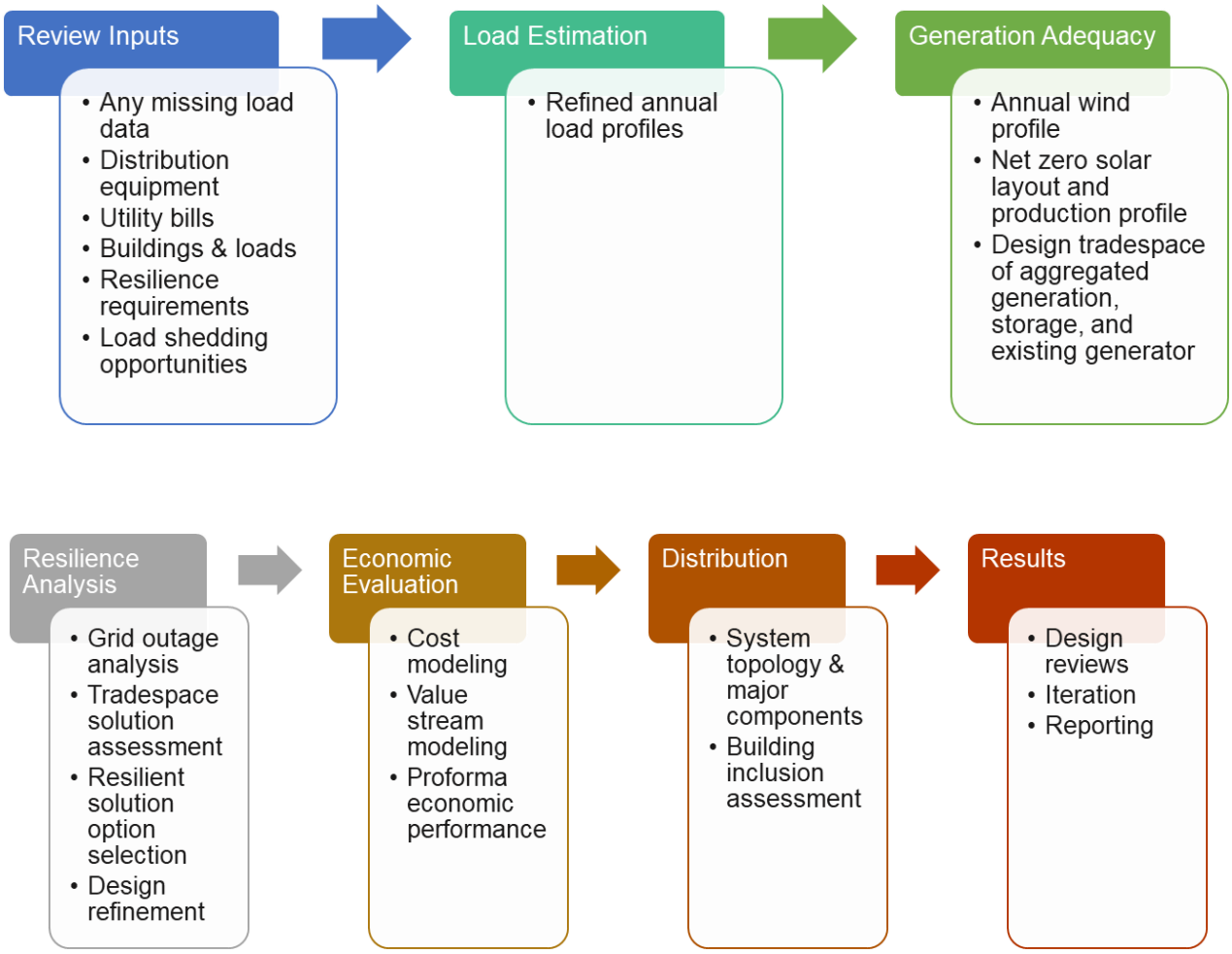


Figure 2. Project Approach.

2 Background

2.1 Previous Work

The Bad River Band has a long history of proactive planning and execution in the areas of energy and community resilience. Since 2011, the Tribe has been active in exploring new energy technologies. Studies commissioned by the Tribe have included:

- 2011 – Solar Energy Assessment
- 2012 – Energy Plan
- 2014 – Woody Biomass Feasibility Study
- 2017 – Health Clinic Energy Audit
- 2018 – Health Clinic Solar Assessment

In addition to planning for energy investments, the Tribe invests significant effort into protecting the lands and waters they steward through studies such as the Wetland Delineation Study (Ball Fields) of 2018, as well as into protecting their people with the Emergency Response and Pre-Disaster Mitigation Plans of 2018.

2.1.1 Ishkonige Nawadide

Building on this foundation of knowledge, the Tribe successfully applied for and won a Department of Energy (DOE) Office of Indian Energy (OIE) grant in 2019 to implement three single-building, resilient, grid-connected microgrids at the health clinic, the wastewater treatment plant (WWTP), and the Chief Blackbird Administration Building. Together, the project is called Ishkonige Nawadide, which means “It catches fire” in the Ojibwe language.

These three microgrids were commissioned in May 2021 and include over 500 kW of solar PV and over 1 MWh of battery energy storage – the largest stationary battery system in the state of Wisconsin at the time of its commissioning.

2.1.2 2019 Energy Plan

In the wake of the successful DOE grant application, the Tribe reconvened in December 2019 to build upon and revise their Energy Plan of 2012. They crafted a new, specific vision of what tribal energy could accomplish in the year 2030, and then developed a phased roadmap to get from the first three pilot microgrids to “energy sovereignty” in the form of a tribal utility authority.

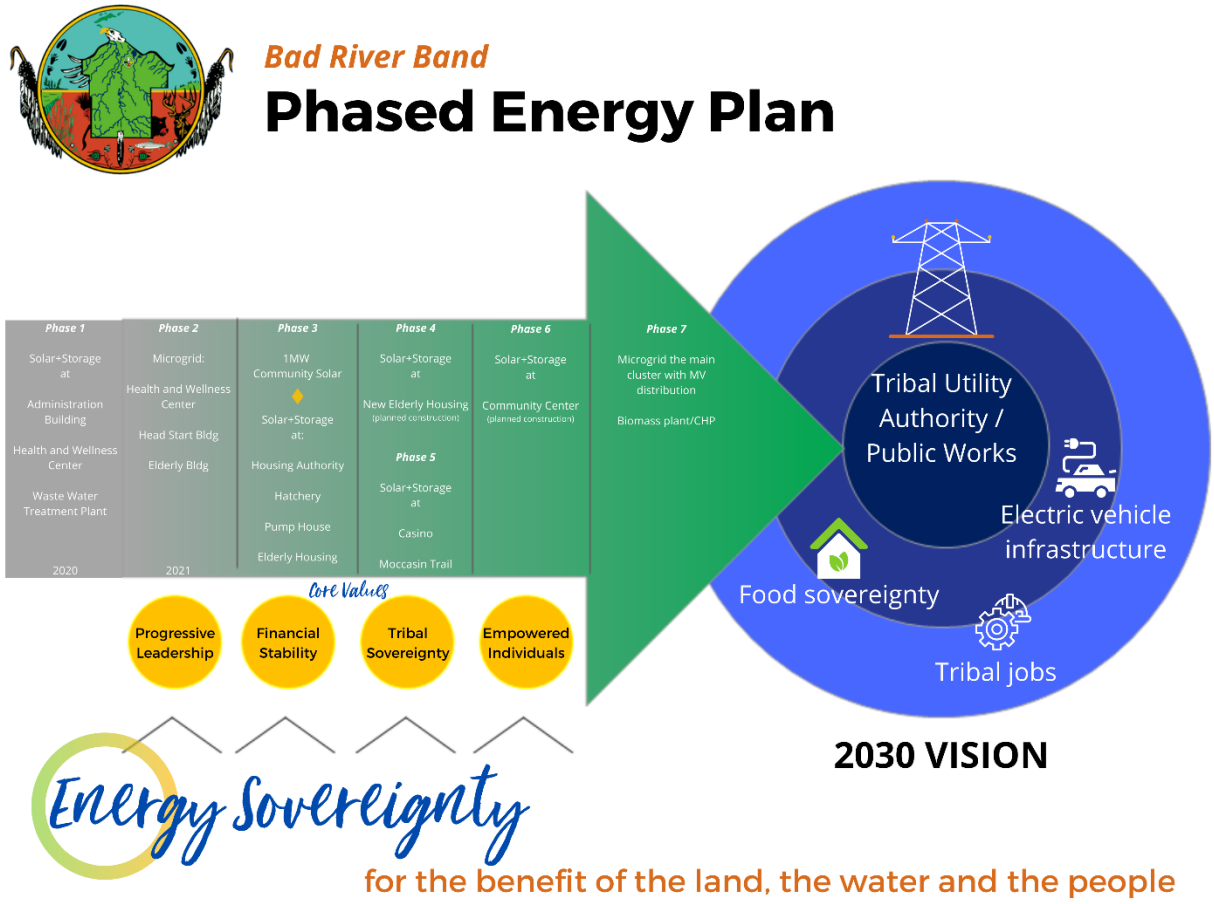


Figure 3. 2019 Energy Plan.

At the time the 2019 Energy Plan was developed, the Tribe recognized that a big hurdle in achieving their vision of energy sovereignty would be in making the leap from building-level microgrids to multi-building microgrids with more complex infrastructure, higher voltages, longer distances, and more control challenges. They acknowledge that in addition to implementing energy projects on the ground, the Tribe needs to understand the opportunities and challenges of developing a more complex microgrid.

Funded in 2021 by the Public Service Commission of Wisconsin's Office of Energy Innovation, this study serves to answer those questions. It also further provides the Tribe with the knowledge, and more importantly, the intuition required to continue pursuing their energy goals.

2.2 Site Overview

The Bad River Band wishes to develop a Community Resilience center Level 3 microgrid with both grid connected and islanding functionality. The New Odanah neighborhood of the Bad River Reservation is the site investigated by this study. It is shown in Figure 4 along with the relevant Bayfield Electric Cooperative's (BEC) electric distribution branches and main feeder. The branches connect to the same radial feeder (east circuit) of the Ashland substation, located 14.8 miles in driving distance to the west. The feeder effectively ends at the last three-phase branch, at which point the line along Route 2

becomes a single-phase branch. Feeder and branches are not distinguished in Figure 4, but the three-phase (purple) and single-phase (red, green, and blue) lines are. In this study, “microgrid” is understood to mean a collection of distributed energy resources (DERs), electric distribution at low and or medium voltage, and islanding capability. The terms “generator” and “genset” are interchangeable, and both refer to thermal combustion generation like a diesel engine with alternator.

Figure 4. Bad River Reservation site overview showing incoming BEC feeder line and focus area.

Some of the most critical buildings for providing community resilience are the Health and Wellness Center (clinic), Bad River Lodge and Casino, gas station and store, and the Elderly Center, which are all on one three-phase branch, referred to here as the “East Branch.” The administration building and WWTP are also significant and are on a separate three-phase branch, referred to as the “West Branch.” The elderly apartments and fire department are also important to consider, and are both on the same “Residential Branch B.” The concept of branches is important because they are a convenient location to island a part of the distribution grid. Table 1 below summarizes the facilities studied, critical loads, existing energy assets, and their relevant distribution grid branch according to this study’s designation.

Additional buildings that may also be considered, but are not as critical to resilience, include the Head Start education center, separate lift and pump stations for public wastewater, the Bad River Transit Authority, and several residential areas.

There are also a few areas of planned load growth which are currently in the planning phase. These comprise the aquatic center, more elderly housing, EV charging (fleet and/or public), and new heat pumps for cooling and heating.

The microgrid should utilize the generators and the Tribe should consider adding new wind, solar, and/or biomass generation, as well as battery storage, while using as much of their existing distribution infrastructure as possible. Assets that are nearing end of life and need to be replaced, such as the Lodge's generator, should be carefully considered.

Table 1. Identification of Critical Infrastructure.

Facility	Critical Loads	Existing Assets	Distribution Branch	Transformer kVa	Notes	BEC Rate Tariff
Critical Facilities						
Health and Wellness Center ("clinic")	In patient healthcare	Genset: 200 kW; 400 gal Solar: 300 kWp Battery: 568 kWh	East	300	Microgrid	6LP
Lodge & Casino ("casino")	HVAC, kitchen	Genset: 600 kW 500 gal	East	750	480 V	6LP
Moccasin Trail Gas Station	Gas pumps		East	N/A	Unmetered sub-circuit of casino, pays fixed % of electric bill	6LP
IGA Convenience Store ("store")	Perishable foods			N/A	Unmetered sub-circuit of casino, pays fixed % of electric bill	
Elderly Center	HVAC		East	75		6LP
Administration	IT and communications, kitchen	Solar: 20 kWp Battery: 72 kWh	West	300	Microgrid	6LP
Waste Water Treatment Plant ("WWTP")	Pumps, blowers, heaters	Genset: 500 kW line gas Solar: 200 kWp Battery: 435 kWh	West	300	Microgrid 480 V	6LP
Elderly Apartments	HVAC, personal medical devices	Genset: 40 kW	B	10	Single meter for 11 apartments	6LP
Fire Department	IT and communications, pumps		B	10	Unoccupied as of Feb 2022	6LP
Elderly Housing	HVAC, medical devices		B	10 (estimated)	Planned construction north of clinic PV field	
Non-Critical Facilities						
Head Start		Genset: 35 kW line gas Solar: 20 kWp	East	50 (estimated)	Possible microgrid	6LP
Residences			A, B	10, 15, 25		Residential
Pump House			West	25	480 V	5TPH
Lift Station 1			West	10	480 V	5TPH
Lift Station 2			A	10	240 V	5TPH
Aquatic Center			West	500 (estimated)	Planned construction north of clinic PV field	
Transit Authority			West	150		6LP

Considering Figure 4 and Table 1, the East Branch already has many of the critical facilities and existing energy assets. This isn't a coincidence as the Tribe has already taken steps to ensure resilient energy at their most critical facilities, and have installed gensets and microgrids in those locations. However, the Lodge genset is near end-of-life, a new elderly housing center is planned, and electric vehicle charging will increase the resilient energy need. Therefore, developing a microgrid on the East Branch could be a logical next phase for increasing the Tribe's resilience. The East Branch will be studied as a candidate community resilient microgrid along with the entire New Odanah neighborhood.

The New Odanah site has two primary physical constraints: low wetlands and forest cover. Avoiding impacts on wetlands and minimizing forest removal are two important objectives for all distributed energy resource (DER) design, although the Tribe recently cleared several acres for the Health and Wellness Center microgrid and is aware of the benefits and drawbacks of clearing land. Furthermore, recent catastrophic flooding underscored the importance of both protecting wetlands and keeping critical infrastructure above flood plains.

2.2.1 Critical Facilities

2.2.1.1 Health and Wellness Center (Clinic)

The Health and Wellness Center (HWC), or Clinic, is located at 53585 Nokomis Rd., Ashland, WI 54806. It is situated on the East Branch.

The HWC building microgrid is an emergency shelter and is an important Community Resilience Center, complete with heating and A/C, medical equipment, staff, and an open community space. A planned expansion could include a gym and additional health services.

The existing clinic microgrid has 300 kW solar PV and 568 kWh of battery storage capacity. The solar and storage are DC-coupled behind a single 250 kW inverter. The microgrid also has a sufficient diesel generator and modest fuel tank. Because the clinic may have life safety loads, it is absolutely critical that its resilience capacity is not reduced while supporting other microgrid loads. We recommend enabling the clinic to physically disconnect from the future community microgrid if required.

2.2.1.2 Lodge & Casino

The Bad River Lodge & Casino, located at 73370 U.S. Highway 2 Odanah, is also part of the East Branch. A critical part of a potential Community Resilience Hub, the Lodge can house people who are exposed to various hazards who may not reside in the New Odanah town core. It has a commercial kitchen and plans already exist for electric vehicle charging. The Lodge and Casino has a more than adequate 600 kW genset with a 500-gallon diesel tank, but both are nearing their end-of-life. As the equipment requires updating, this is an excellent opportunity to reevaluate all aspects of backup power for this building. The Tribe has already investigated an EPA grant for a new Tier 4 emissions genset, which would burn cleaner and allow for more running hours per year. The Tribe may also consider CHP here, as the Lodge and Casino may have a large heat load.

The Lodge is close in proximity to the BEC feeder where an eventual microgrid switchgear may be located, especially if only the East Branch is pursued in the next phase. In general, islanded distribution systems function best when the main sources of distributed generation are sited close to the point of disconnection. This can simplify and reduce costs of the protection and controls systems while creating a more reliable islanded network.

2.2.1.3 Moccasin Trail Gas Station and Store

The community gas station and convenience store are deemed critical because they can provide perishable and general food stuffs as well as gasoline during emergencies. The single building receives 480 V distribution from the Lodge and Casino's mechanical room, but without a submeter. Electricity costs are billed as a fixed percentage of the Lodge and Casino's electric bill, set at 25%.

2.2.1.4 Elderly Center

The Bad River Elderly Center is also part of the East Branch and is a critical site because of the vulnerability of its patrons, who are often the first to suffer during extreme events. The elderly often require life support or other general medical devices such as CPAP machines. In addition, the Elderly Center provides prepared meals (both onsite and delivered) to those in need.

2.2.1.5 Chief Blackbird Administration Building

The Administration Building, located at 72682 Maple St. Ashland, WI 54806, is in the Western Branch. Designated a critical building for the Community Resilience Hub, it is well-equipped to provide community services. The Administration building contains IT and communication equipment, as well as office space for tribal leadership. A small microgrid was completed in 2021, providing resilient power to an emergency load panel from a small amount of rooftop solar and battery storage. Unfortunately, this building has very little timeseries data available compared to the other previously built microgrids.

2.2.1.6 Waste Water Treatment Plant (WWTP)

The WWTP, located at 54173 Birch Street, Odanah, is in the West Branch. It is a critical facility because of health concerns created when it is not operating. Like most plants of this type, it has a dedicated genset. In times of need, certain plant operations can function at a reduced level or be delayed for some time, but typically this isn't necessary. The plant is also supported by a nearby lift and pump station which are included as separate, non-critical facilities in this study.

Additionally, the WWTP's microgrid has 200 kW of solar and 250 kW / 435 kWh of battery storage assets that could contribute to Community Resilience Centers for acute power needs. The three-phase-branch off the Bayfield Electric feeder make an efficient trunk to distribute power through the microgrid, so a Point of Connection (POC) near that area is reasonable.

Industrial facilities like the WWTP often suffer from having a few large loads created by large motors, often operating in a synchronized manner (several motors turn on together). This can create a load profile that has very large relative changes in load. The inrush current of motors is a separate but related problem. The future microgrid will benefit tremendously from intelligent load control if there is flexibility in the waste treatment process. However, the control systems for waste water plants are often difficult and expensive to reprogram and don't typically interface with existing building energy management software protocols.

2.2.1.7 Fire Department

The Fire Station is part of the Western Branch. It is a new building and as of February 2022, it was not yet occupied. This building is still a strong consideration to be part of the microgrid because of its emergency response role. This building's load was modelled using load data from a different fire department.

2.2.1.8 Elderly Housing (Planned Construction)

The New Elderly Housing facility is in the Eastern Branch, north of the Health and Wellness Center's PV field. Though it is not necessarily ideal for inclusion in the Community Resilience Hub, it is still considered a critical and priority building for the microgrid due to the sensitive population of its residents.

2.2.1.9 Department of Public Works

The Department of Public Works Facility data began in August 2019 and ended in April 2020, with a peak of 20 kW and average of 7 kW. The building's load is quite small. It does not have a generator. It is almost certainly worth including the Public Works building in the larger community microgrid rather than paying to isolate it.

2.2.1.10 Elderly Housing (Existing)

The existing Elderly Housing area is part of the Residential Branch B and it consists of 11 apartments on a single electric meter. The building is supported by a generator that provides about 40 kW.

This building would be an ideal location to add 20 kWp of rooftop PV. The Tribe recently released a RFP to solicit bids for the installation.

2.2.2 Non-Critical Facilities

2.2.2.1 Head Start

The Head Start educational center is a borderline critical facility. Deemed not critical because children can be sent home in case of an emergency, the facility already has a modest backup generator fueled by stored propane. This is an example of the microgrid's design being influenced by previous careful emergency planning.

However, it is possible that the emergency plan changes and the Head Start facility becomes a cooling center, due to the modern construction and existing energy resources. The building's emergency plan can also be, in turn, influenced by the microgrid design.

The Tribe is planning to install battery storage and increase solar PV capacity at the Head Start building in 2023.

2.2.2.2 Residences

There are a total of 35 distinct residential buildings between the Pine St., Kinnickinnick Rte., Maple St., Denomie St., and the Circle Dr. complex. In the Tribe's emergency preparedness plan, residences are not expected to have resilient backup power, although shelter-in-place warnings are not uncommon. For some vulnerable people, it may be safer to stay at home with available amenities and medical equipment. Furthermore, building a microgrid that specifically excludes residences from backup power can be costly if the residences are not all on one branch. And lastly, an important consideration is energy justice, such as the notion that the clean and affordable energy revolution should benefit everyone.

For these reasons, the New Odanah community microgrid specifically includes all the residences, which combined add a substantial but not overbearing load compared to the microgrid's other facilities.

One technical consideration for the residences is that they are all typical 120/240 V split-phase, and there are only two such branches: Residential A and B. Therefore, this would create a significant load imbalance on the microgrid, with phase C having much less load.

2.2.2.3 Pump House and Lift Stations

There is a pump house and two lift stations that support the local public works, although they are not deemed crucial for operation in the time periods discussed here. However, all three facilities have an average load below 10 kW, so they would not be a large burden for the community microgrid. The load factor for all three sites is quite low, but as discussed above the microgrid is likely to be limited by energy capacity and not power, so these facilities won't have an outsized impact.

Table 2. Pump house and lift station locations.

Facility	Location
Pump House	73047 Maple St.
Lift Station 1	54005 Birch St.
Lift Station 2	73428 Maple St.

2.2.2.4 Transit Authority

The Transit Authority is a relatively new building with garage space and a few offices. The load is relatively predictable with a consistent nighttime consumption of 2.8 kW, a steep increase upward with 5 to 9 kW at 7:00 am, a steep decrease at 6:00 pm, and typically flat weekends between 1 and 3 kW.

Table 3. New Odanah Transit Bus Route Schedule.

Shift	Route A 6-day	Route B 6-day	Evening 7-day	Sunday
1	122 mi End 11:30	122 mi End 12:30	162 mi End 22:30	108 mi End 11:45
2	108 mi End 16:00	108 mi End 17:00	81 mi End 2:00	108 mi End 16:00

While not a critical building for resilience at the time of this study, it may become more critical in the future. The Tribe is considering two electric busses, and would increase the electric load on the microgrid. Transit Authority staff indicate that the electric busses would operate on the routes between New Odanah and nearby Ashland. The bus routes indicate shifts (for example morning and afternoon) ranging from 81 mi to 162 mi. A recent study of city electric busses in Vermont calculated an overall efficiency of 2.4 kWh/mi. While this number is almost double what bus manufacturers suggest, it comes from real world measurements and can be used as a conservative estimate. The minimum bus battery capacity is therefore about 389 kWh, and a practical size closer to 450 kWh. While this represents a significant amount of added capacity for a small or medium microgrid if used to supplement the microgrid, it is capacity that isn't always available since the busses are often (a) not plugged in or (b) charging to be ready for the next shift. However, in the second case, charging could be temporarily halted for grid-connected economics such as peak shaving.

From this information, a "synthetic" (not based on any true measurements) load profile can be constructed, assuming that a bus returns and immediately begins charging the energy that it consumed in the last shift. The charging power could be fixed at the maximum power available. However, a reasonable assumption is that the chargers could be programmed to charge as slowly as possible, reaching 100% a short time before the bus is to be used again. This is a very small amount of dispatch

optimization, attempting to reduce the demand charge incurred by charging. Further optimization would be achieved in real time by a predictive algorithm, such as muGrid's RedCloud Real Time.

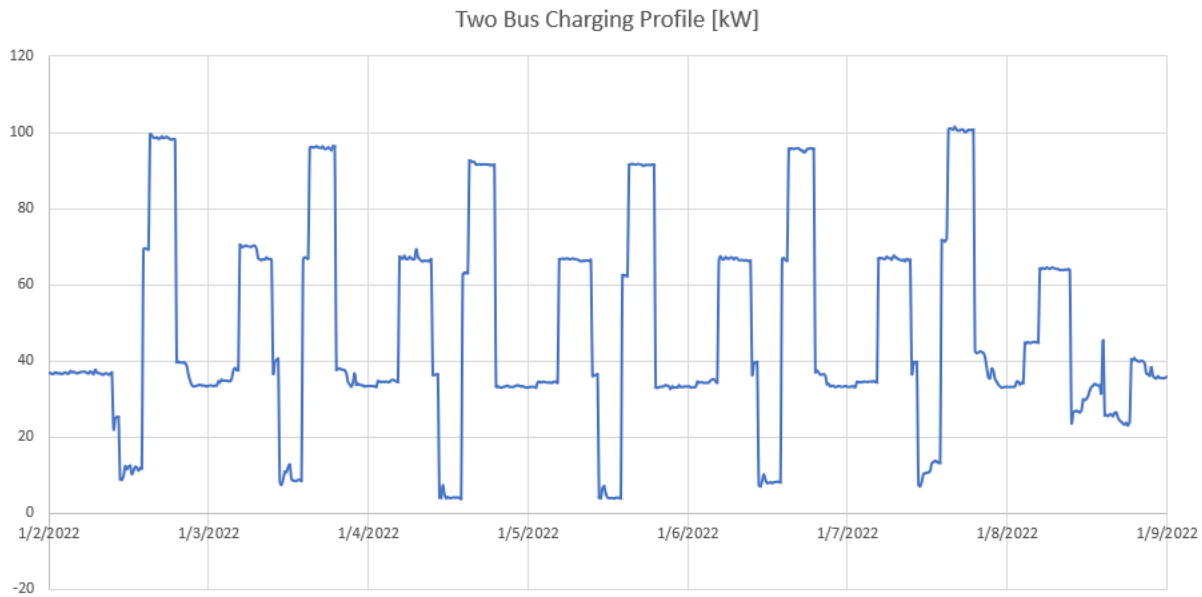


Figure 5. Transit authority bus charging synthetic load profile.

In an emergency, the electric busses could be left connected to their charging stations and be used as more battery capacity, increasing resilience of the whole microgrid. They could also be used during certain hours of the day when the extra battery capacity isn't needed. However, this active load management is a complex, non-linear problem that can only be solved on a case-by-case basis, and with knowledge of future load and solar production.

2.2.2.5 Aquatic Center (Planned Construction)

Near the Health and Wellness Center is the site of a new aquatic center, which is in its planning phase. The building's planned footprint is 71,000 sq-ft and the pool dimensions are estimated at 89 by 60 ft. The load profile was estimated using muGrid reference data and calculations from a published study.[2] This places the average electric load at 57.8 kW and peak at 115.8 kW. However, an additional average of 0.495 MBtu/h of heat (from gas or electric) is needed. If that heat comes solely from natural gas, then the previously estimated electric load doesn't change much, or perhaps even decreases some. On the other hand, if the heat comes entirely from a heat pump with assumed Coefficient of Performance (COP) of 3.5, then the extra average electric load is about 41.6 kW, for 99.4 kW total.

As the above calculations illustrate, pool heating can be an exceptionally large energy sink. And since the aquatic center is not deemed an important building for community resilience, the center will not island

[2] Saari, Arto, and Tiina Sekki. "Energy consumption of a public swimming bath." *The Open Construction & Building Technology Journal* 2.1 (2008).

with the microgrid. However, for economic and low carbon operation during grid-connected mode, we recommend that the building be well insulated and utilize a modern HVAC system to minimize heated or cooled air being exchanged with the outside environment. A dual source pool heating system may be of interest to the Tribe. The building will often cool or heat spaces and water with an air or ground source heat pump, taking advantage of the recent improvements in heat pump technology as well as energy efficiency incentives. This also allows the Tribe to utilize self-produced solar when available, but without increasing the backup load (which would in turn require more solar or genset capacity). The building could also switch over to a high efficiency natural gas furnace for especially cold periods, or when it's economically beneficial.

2.3 Project Resilience Objectives and Metrics

Resilience modeling is still nascent across the distributed energy industry. Many times, resilience performance is assumed to be deterministic – that there is a single number defining resilience at a site, perhaps as an average or minimum operating duration. However, we view resilience performance as stochastic, and we will characterize it with both expected outage survival duration and probabilistic confidence levels. Resilience performance is dependent upon several stochastic variables, including, but not limited to: weather, solar irradiance, cloud cover, time-of-day and time-of-year of the outage, and load at the facility. Some of these variables have characterizable but not fully predictable cross-correlation – solar conditions and building load may both be affected by the time of day or time of year of the outage, for example. But even if the relationships are characterized, the conditions at the beginning of an outage are never fully known well enough to calculate a deterministic resilience duration. Therefore, we analyze multiple descriptors of resilience performance, including probability, or confidence, for a given duration.

We define resilience duration as the amount of time the microgrid can support its dedicated loads after a grid outage before the microgrid fails due to lack of power, whether that lack of power is caused by battery depletion, fuel depletion in the generator, or lack of solar irradiance. This is our primary resilience metric. Other important resilience metrics include the time to recover functionality after the first failure (usually enabled by solar power recharging the battery) and the amount of time the microgrid can then run following that recovery, or the secondary resilience duration. All duration values – time to first failure or primary resilience duration, recovery duration, and secondary resilience duration – must be paired with confidence levels in order to be valuable analysis results. The confidence values are not randomly distributed – they are highly correlated to season of year and load conditions at the buildings and may also be correlated to the time of day.

Table 4. Types of outage problems and solutions.

Problem	Duration	Issues	Solutions
Power quality (e.g. low voltage, high voltage, harmonics)	< 1 minute	Electrical equipment damage, generator, or battery not effective	Power quality study and intervention, power conditioners and filters, UPS
Short interruption	< 1 minute	Generator or battery unable react fast enough	UPS, seamless transfer battery system
Long interruption	1 minute to 3 hours		UPS, microgrid, genset
Very long interruption	> 3 hours	UPS systems often only designed to a few hours or less	Microgrid, genset

The Tribe reports that they have many short duration (less than 1 minute) power quality problems, as well as occasional long duration outages for several hours at a time. However, the Tribe has also been impacted by low frequency, unpredictable "black swan" events, such as the 1-in-500-year river flooding event of 2016. A 1-in-500-year event is an event with a probability of happening in any given year of 0.2%. All three types of power outages can negatively impact the community, though the solutions to each problem may be different and not necessarily overlapping.

Since part of the microgrid decisions are impacted by questions regarding phases of the power system and by power quality concerns, the following is a very brief overview of how three phase electricity works.

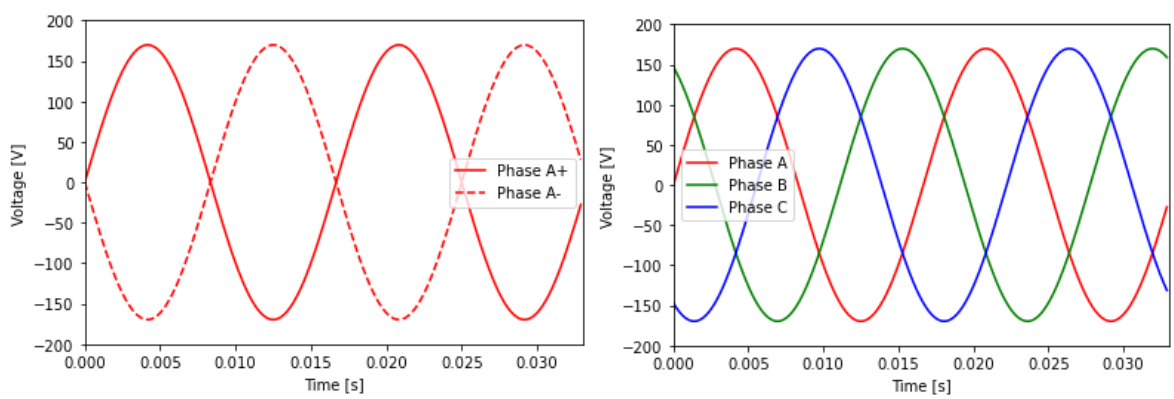
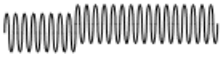
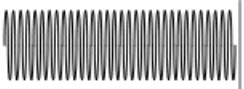


Figure 6: Split-phase 120/240 V power (left) and three-phase 120/208 V power (right)

Figure 6 shows perfectly functioning AC power at two common voltages, for the duration of two 60 Hz cycles. Note that 120 V (more accurately 120 Vrms) reaches 170 V peak, not 120. In reality the signal is always somewhat noisy and the voltage and frequency are not perfect. With these perfect waveforms in mind, Table 5 exhibits many typical power quality problems, some or many of which likely affect the Tribe. The Tribe also has lines and facilities with 277/480 V and 7.5/13 kV. The colors in Figure 6

correspond to the colors of distribution lines on Figure 4 and other similar figures, where the three phases split off into Phase A (red), Phase B (green) and Phase C (blue).

Table 5. Overview of power quality problems. (Source: Schneider Electric)

Disturbance category	Wave form	Effects	Possible causes	Possible solutions
1. Transient				
Impulsive		Loss of data, possible damage, system halts	Lightning, ESD, switching impulses, utility fault clearing	TVSS, maintain humidity between 35 – 50%
Oscillatory		Loss of data, possible damage	Switching of inductive/capacitive loads	TVSS, UPS, reactors/ chokes, zero crossing switch
2. Interruptions				
Interruption		Loss of data possible, damage shutdown	Switching, utility faults, circuit breaker tripping, component failures	UPS
3. Sag / undervoltage				
Sag		System halts, loss of data, shutdown	Startup loads, faults	Power conditioner, UPS
Undervoltage		System halts, loss of data, shutdown	Utility faults, load changes	Power conditioner, UPS
4. Swell / overvoltage				
Swell		Nuisance tripping, equipment dam-age/reduced life	Load changes, utility faults	Power conditioner, UPS, ferroresonant "control" transformers
Overvoltage		Equipment dam-age/reduced life	Load changes, utility faults	Power conditioner, UPS, ferroresonant "control" transformers
5. Waveform distortion				
DC offset		Transformers heated, ground fault current, nuisance tripping	Faulty rectifiers, power supplies	Troubleshoot and replace defective equipment
Harmonics		Transformers heated, system halts	Electronic loads (non-linear loads)	Reconfigure distribution, install k-factor transformers, use PFC power supplies
Interharmonics		Light flicker, heating, communication interference	Control signals, faulty equipment, cycloconverters, frequency converters, induction motors, arcing devices	Power conditioner, filters, UPS
Notching		System halts, data loss	Variable speed drives, arc welders, light dimmers	Reconfigure distribution, relocate sensitive loads, install filters, UPS
Noise		System halts, data loss	Transmitters (radio), faulty equipment, ineffective grounding, proximity to EMI/RFI source	Remove transmitters, reconfigure grounding, moving away from EMI/RFI source, increase shielding filters, isolation transformer
Voltage fluctuations		System halts, data loss	Transmitters (radio), faulty equipment, ineffective grounding, proximity to EMI/RFI source	Reconfigure distribution, relocate sensitive loads, power conditioner, UPS
Power frequency variations		System halts, light flicker	Intermittent operation of load equipment	Reconfigure distribution, relocate sensitive loads, power conditioner, UPS

Long and very long outages are typically uncommon, and most rural electric utilities don't keep sufficient statistics on their outages. For the Ashland substation, the best data source is total substation HV load, averaged over 15-minute intervals. The load typically ranges from 645 to 2211 kW, and the change in load in a single 15-minute step ranges from -299 to +303 kW, with a mean of 0 and standard

deviation of 34 kW. The distribution is quite normal (bell curve) so we can use the standard deviation to find statistical outliers. Where the decrease in load is greater than four standard deviations and is shortly followed by an increase in load of similar magnitude, we can be reasonably sure there was an outage somewhere in the distribution network served by the substation.

Table 6. Substation estimated outages and durations.

Date & Time CST	Load kW	Outage duration (in hours)
3/3/2021 12:30	997	2
7/27/2021 05:45	970	0.75
8/2/2021 08:30	900	0.5
9/7/2021 02:30	696	0.5
9/16/2021 02:00	864	2

This data set indicates a small number of long interruptions. Important equipment like servers and lab devices could be protected by individual uninterruptible power supplies (UPSs), which are inexpensive and very effective. Additionally, UPSs are double-conversion devices which help filter much of the low voltage and harmonics common in poor power quality. However, the interval load data we have at present is not of a fine enough resolution to show power quality or short interruptions, especially if they only occur on one phase. We recommend that the Tribe install a power quality meter to characterize the scope of power quality issues. Tribal maintenance staff are clear that the community faces many short and long power interruptions which harm equipment and interrupt work.

Considering very long interruptions, the 500-year flood of 2016 destroyed infrastructure and disrupted services for a week or more. The most recent Intergovernmental Panel on Climate Change report is clear that these kinds of extreme weather events are sure to increase, both in frequency and impact. Furthermore, the Global Facility for Disaster Reduction and Recovery data sets mark the Bad River reservation at medium risk (10-50% in any given year) of wildfire and medium risk (25% chance in next five years) of extreme heat.

Fortunately, the Tribe has already assessed many of these hazards and developed a Pre-Disaster Mitigation Plan, Emergency Response Plan, and the 2019 Long Range Energy Plan, which identify critical emergency functions such as the fire department, clinic, water and sewer, public works, and an emergency operations center. Furthermore, the Tribe inherently values longer term resilience and also would like to continue to move in the direction of energy sovereignty through a tribal utility authority in the future.

Informed by the data and previous planning exercises, muGrid helped the tribal leadership team develop resilient power backup targets for this study of three days of high confidence (98%) and one week at medium confidence (80%). This means that, in the first case, the microgrid should be designed to supply backup power for at least three days in 98% of simulated grid outage scenarios. muGrid can confirm from other rural electric service data sets that this resilience target is appropriate.

3 Analysis

3.1 Utility Analysis

3.1.1 Rate Tariff

The Bad River Band of the Lake Superior Chippewa Tribe is served electricity by Bayfield Electric Cooperative (BEC). Most of the buildings included in the proposed microgrid are on the 6LP (6 Large Power) rate tariff which consists of both a monthly demand charge, an energy charge, and a service charge.

Table 7. BEC 6 Large Power 6LP rate tariff.

	Energy [$/kWh]	Demand [$/kW]	Service Charge [$/day]
Winter (October-May)	0.10	10.10	2.52
Summer (June-September)	0.10	12.10	2.52

The pump house and lift stations are on the 5 TPH (5 General Three Phase) rate tariff. This rate tariff consists of an energy charge and a service charge. There is no demand charge.

Table 8. BEC 5 General Three Phase 5TPH rate tariff.

	Energy [$/kWh]	Demand [$/kW]	Service Charge [$/day]
All Year	0.15		2.52

BEC purchases electricity from Dairyland Power Cooperative (DPC). Excess energy exported to the utility grid by the Tribe's distributed energy resources is bought by DPC. This is discussed in detail below.

The Tribe has three existing microgrids on the reservation. These are operated by EnTech Solutions. The Tribe purchases electricity from these microgrids under an Energy Services Agreement (ESA) between the Tribe and the operator.

3.1.2 Value of Exported Energy

Energy exported to the grid is compensated at the day-ahead wholesale market rate at the Dairyland Power Cooperative (DPC) node of the Midwest Independent System Operator (MISO) network. Sometimes called the spot price, this rate reflects the market price of electricity on the wholesale market and varies based on market conditions during every hour of the day and year. The spot price is generally priced in $/MWh, but is easily converted to $/kWh.

As the name implies, the day-ahead spot price is set a day in advance, generally by about 9 pm Central Time. That means that it is possible to know with perfect certainty how much the power export will be worth during every hour of the next day. The Tribe can use this perfect near-term prediction to optimize the revenue potential of their electricity export by strategically scheduling the timing of the battery charging and/or discharging.

Figure 7 shows the daily average of the day-ahead spot prices at the DPC.DPC node since 2018. The past two years show both increased spot prices, and increased volatility. Also note that these are the daily averages, meaning that the hourly peaks are much higher.

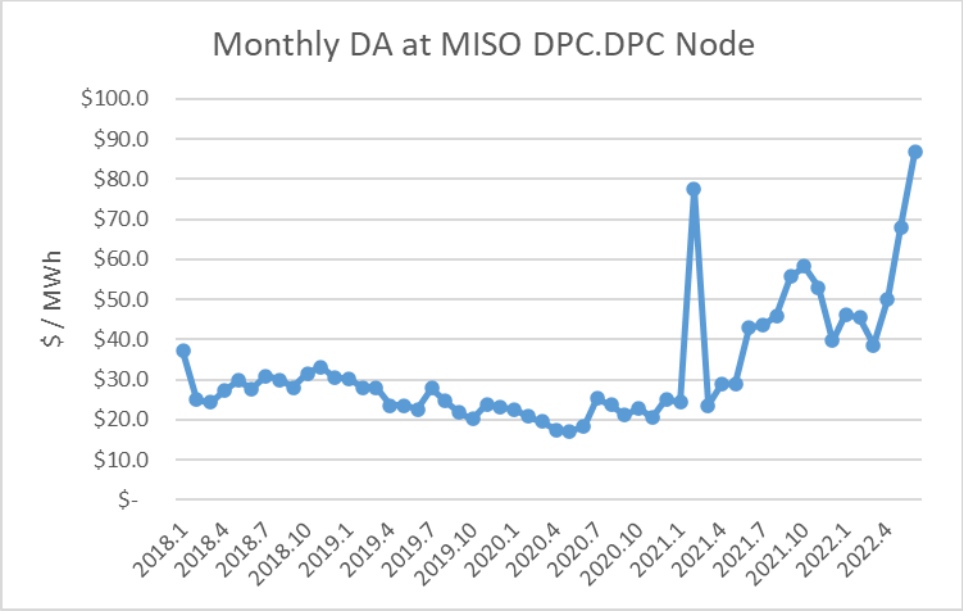


Figure 7. Daily average day ahead spot price.

Figure 8 shows the variation of the monthly average of the day-ahead spot prices at the DPC.DPC node. Spot prices have been trending up for the past two years, hitting their highest monthly average in June 2022.

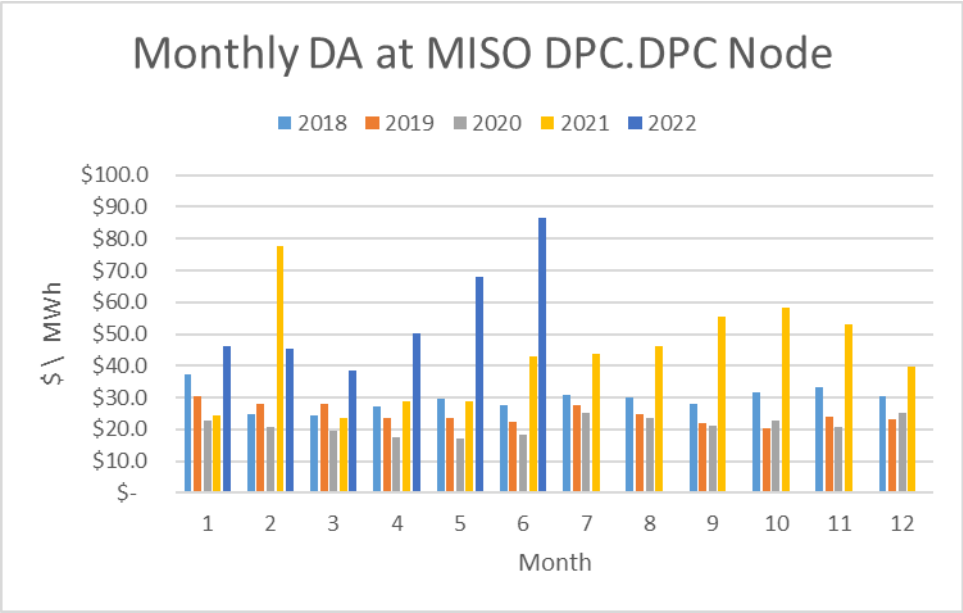


Figure 8. Variation of monthly average day ahead spot prices.

Figure 9 shows the hourly day-ahead spot prices for the week of June 23, 2022. During this week, the spot price exceeded 14 cents / kWh at one point. This means that the Tribe would receive 14 cents for each kWh exported to the grid during those hours.

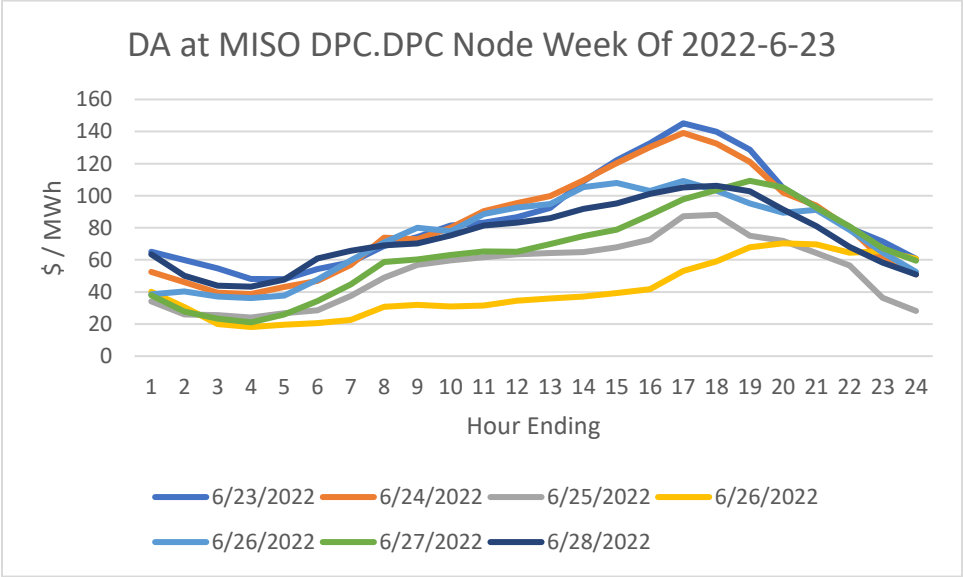


Figure 9. Hourly day ahead spot prices for week of June 23, 2022.

The spot price hit 31 cents per kWh from 4-5pm on June 21, 2022. This means that the Tribe would have received 31 cents for each kWh that they exported to the grid during that. Notably, this is more than they pay for energy from BEC on their scheduled rate tariff, and more than they pay for electricity from EnTech at the existing microgrids.

3.1.2.1 Waste water treatment plant exported compensation analysis

The waste water treatment plant has been exporting excess electricity to the grid since the summer of 2021. Table 9 shows the mechanics of how the exported solar is compensated for a day in September. The day-ahead hourly spot price is multiplied by the energy exported from the facility during every hour. The hourly export revenue is then summed each month. On the particular day shown in Table 9, the Tribe was compensated $40.22 for exporting energy to the grid.

Table 9. Example day of solar export.

Total	$ 40.22		554
Weighted Avg		$ 0.073	
Spot Price Avg		$ 0.060	
Date / Time	Value	Spot Price [$ / MWh]	Export [kWh]
	C =	A *	B
9/15/2021 0:00	$ -	$ 0.037	0.0
9/15/2021 1:00	$ -	$ 0.037	0.0
9/15/2021 2:00	$ -	$ 0.035	0.0
9/15/2021 3:00	$ -	$ 0.033	0.0
9/15/2021 4:00	$ -	$ 0.033	0.0
9/15/2021 5:00	$ -	$ 0.035	0.0
9/15/2021 6:00	$ -	$ 0.044	0.0
9/15/2021 7:00	$ -	$ 0.051	0.0
9/15/2021 8:00	$ -	$ 0.051	0.0
9/15/2021 9:00	$ -	$ 0.055	0.0
9/15/2021 10:00	$ 0.01	$ 0.061	0.2
9/15/2021 11:00	$ 0.66	$ 0.064	10.2
9/15/2021 12:00	$ 1.46	$ 0.064	23.0
9/15/2021 13:00	$ 7.13	$ 0.070	101.9
9/15/2021 14:00	$ 9.91	$ 0.073	136.7
9/15/2021 15:00	$ 7.62	$ 0.069	111.0
9/15/2021 16:00	$ 6.49	$ 0.078	83.6
9/15/2021 17:00	$ 5.23	$ 0.079	65.9
9/15/2021 18:00	$ 1.70	$ 0.080	21.3
9/15/2021 19:00	$ -	$ 0.082	0.0
9/15/2021 20:00	$ -	$ 0.078	0.0
9/15/2021 21:00	$ -	$ 0.080	0.0
9/15/2021 22:00	$ -	$ 0.072	0.0
9/15/2021 23:00	$ -	$ 0.072	0.0

We note that the average spot price over this 24-hour period is 6.0 cents / kWh. However, the weighted average export rate – calculated by dividing the total revenue ($40.22) by the total export (554 kWh) – is 7.3 cents. This indicates that the hours during which solar is exported have a higher spot price, on average, than the other hours of the day.

Table 10 shows the export compensation at the WWTP for the months during which data was available. The “reported” columns show the summarized data that is made available to the Tribe, while the

"Calculated from Time-Series Data" is our analysis using the time-series production data from the microgrid and the hourly day-ahead spot price from the DPC.DPC node.

Table 10. Monthly compensation at WWTP.

	Reported				Calculated from Time-Series Data			
Statement Month	Mwh	kWh Rate	Revenue		MWh	Revenue	Weighted Export Rate [$ / kWh]	Average Spot Price [$ / kWh]
Sep-2021	10.003	$ 0.0675	$ 675		9.881	$666	$0.0674	$ 0.056
Oct-2021	4.852	$ 0.0610	$ 296		4.587	$281	$0.0614	$ 0.058
Nov-2021	1.16	$ 0.0552	$ 64		1.070	$59	$0.0547	$ 0.053
Dec-2021	0.031	$ 0.0377	$ 1		0.000	$0		$ 0.046
Jan-2022	0		$ -		0.089	$5	$0.0531	$ 0.046
Feb-2022	3.437	$ 0.0462	$ 159		3.225	$149	$0.0463	$ 0.045
Total	19.483		$ 1,195		18.853	$ 1,160		
			$ 0.061				$ 0.062	$ 0.051

We note that the calculated weighted average export rate (6.2 cents) matches closely with the reported kWh rate (6.1 cents) and that the total exported energy matches reasonably closely. In fact, the reported exported energy is higher than that which we see in the data, a discrepancy which favors the Tribe. We also note the difference between the simple average of the spot price each month over the period (5.1 cents / kWh) and the weighted average export rate (6.2 cents). This confirms that the Tribe is being compensated at the hourly spot rate at the time the solar is actually being exported to the grid, not the simple average spot price for the month. This is as expected and is also favorable to the Tribe.

3.2 Data Collection

The availability of high-resolution time-series interval data is critical when designing a resilient microgrid. There are several reasons for this. First, it is important to understand when each building is using electricity, in order to understand how the load aligns with the variable generation such as wind or solar. Second, it is important to fully characterize the load, or to understand the peak demands that occur so that the resilient microgrid can be designed with sufficient power capacity to meet these peaks. These peaks can occur when multiple pieces of equipment turn on coincidentally.

In some cases, we are able to obtain historical time-series interval load data from the utility meter, particularly if the building has a smart meter. Many buildings on the reservation, particularly residences, do not yet have smart meters. In these cases, it is common to estimate a load profile from datasets of other buildings. This approach is obviously flawed in many ways, not the least of which is that the reference building profile that is being used may be located in a very different climate, and thus have very different usage patterns than far northern Wisconsin.

For these reasons, we opted to install a small fleet of data loggers at various buildings on the reservation that could potentially be included in the proposed microgrid. Although we were only able to collect a few months of data prior to performing this analysis, the actual interval data from the proposed microgrid will greatly enhance our confidence in the results of this study. Moreover, the loggers will

continue to collect data going forward. This should provide the Tribe and their future consultants with a rich dataset of load data from which to continue to design the process.

We selected the eGauge Core (EG4015) for the data logger due to its set of features and our previous familiarity with the device. Table 11 shows the eleven buildings where we installed a data logger.

Table 11. List of installed eGauges.

	Site	Address	Voltage	Phase	Service Amp	Main Service Cable Size	Conductors per phase	eGauge Core (EG4015)	J&D Split Core CTs 16mm 100a	J&D Split Core CTs 24mm 200a	J&D Split Core CTs 36mm 400a	Rogowski Rope Coil
1	Headstart	53552 Abinoojiiyag Rd	208	3	600	300 MCM	2	1	2	6		
2	Elderly Center	53508 Nokomis Rd	208	3	400	15mm	2	1				
3	Pump House	73430 US Hwy. 2	208	3	400	1/0	1	1		3		
4	Moccasin Trail Transit	73430 US Hwy. 2	208	3	400	250 MCM	2	1		6		
5	Lift Station by Food Sovereignty	Birch St.	240 Hi-leg	3	?	3/0 copper	1	1		2		
6	Casino/ Moccasin Trail Gas & Groc	Hwy 2	480	3	600	500MCM?	4	1				6
7	New Firehouse	Birch St.	208	3	400	2/0 copper	2	1		6		
8	Administration Building	Maple St.	208	3		250 MCM	4	1	3			
9	Elderly Apartments	Evergreen St.	120/240	1		TBD	2-(pair 500MCM)	1			4	
10	House		120/240	1		TBD		1		2		
11	WWTP	Birch St.	480	3		500 MCM					6	

eGauge data loggers record data at 1-second resolution. However, they only store the 1-second data for an hour, at which point they down-sample (average) it to 1-minute resolution to conserve storage space. Since we desired the finest resolution available for this study, but clearly could not task a staff person with downloading the data every 30 minutes around the clock, we developed an automated script to perform this task using the eGauge API. By querying the device twice per hour, we are generally assured of not losing the 1-second data. Occasionally network failures prevent us from communicating with the device. The 1-second data for these blips is lost.

Figure 10 shows the Elderly Center load as displayed on the eGauge web interface for the period May 3, 2022 at 1pm to May 3, 2022 at 2pm.

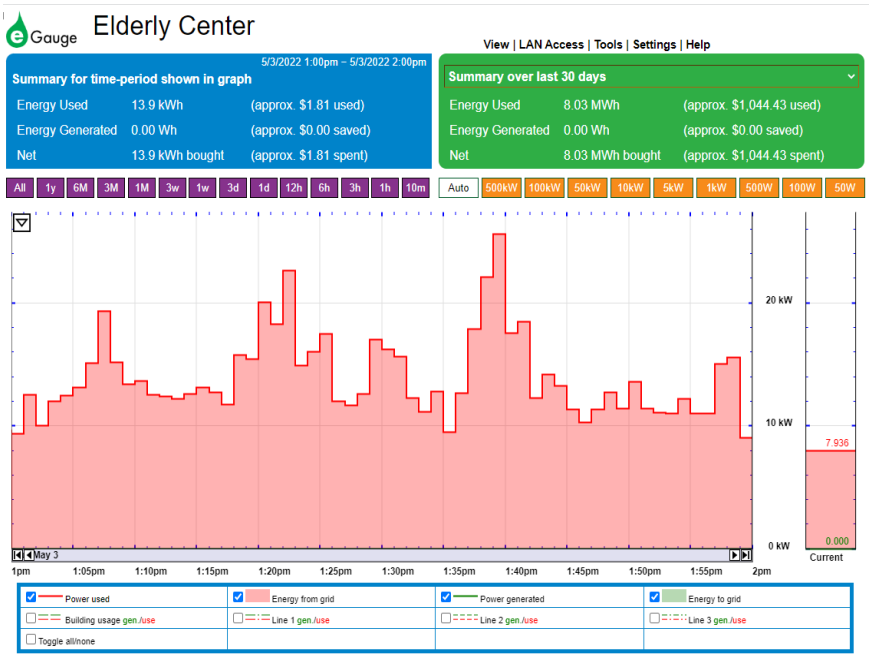


Figure 10. Example eGauge data collection from the Elderly Center.

3.3 Load Analysis

As described in section 283.2, the results of a feasibility study can vary significantly depending on the load, and sometimes in unexpectedly large ways. Therefore, a large part of the effort for this study was expended on load studies for each facility in the microgrid, as well as appropriate aggregation of those loads.

The first challenge is understanding the peak load, such that the combined generation and storage power capacity will always be greater than the peak. Given enough data, the peak load can be directly measured at a short-enough time interval, approximately 1 second. However, few sites have 15-minute interval data available, let alone 1-second data, and typically the peak must be estimated based on the available data and knowledge of the equipment.

The second challenge is called optimal asset sizing, where the goal is to find some combination of, for example, genset, solar array, and battery system sizing that minimizes operating cost, maximizes uptime, minimizes carbon emissions, or achieves other goals.

The third challenge arises once a system is built and the sizes are fixed. It involves determining the optimal dispatch strategy to meet those goals of minimal cost, maximum uptime, and minimum carbon emissions. In fact, the solution to the second problem also depends on the third. Both the second and third problems require an estimation of the load at regular time intervals, throughout the entire year, presumably for the lifetime of the investment.

All of these challenges greatly depend on measuring and estimating the electric load. For this reason, we work hard to collect as much billing and timeseries data (such as from a data logging device or smart utility meter) as possible, and then employ advanced methods to estimate the missing data and solve the above problems. Each facility (building or industrial load) is part of this process, but since this study has over a dozen buildings, some important aspects of the process are highlighted here.

Timeseries data almost always contains various types of bad data, such as gaps and outliers. In the below dataset from the Casino-Lodge, outlier detection based on *z-score* found 115 data points that were physically impossible based on the size of the main circuit breaker, or statistically unlikely because the value was more than three standard deviations away from the mean. A machine learning algorithm called *k-means clustering* also helps identify groups of outliers that z-score missed.

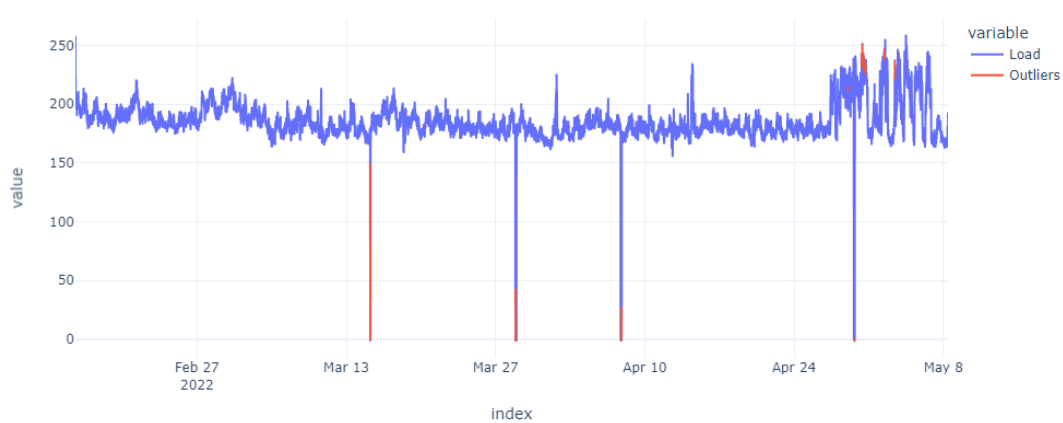


Figure 11. Casino-Lodge data outliers.

Typically, the outliers are replaced with data that is best-correlated with what the true measurement should have been. For this, the autocorrelation function is used to find where a timeseries is similar to itself. Typically, the same value from exactly 24 hours previous is very similar, but that wasn't the case with this dataset. Instead, the most recent 1 hour was used when available.

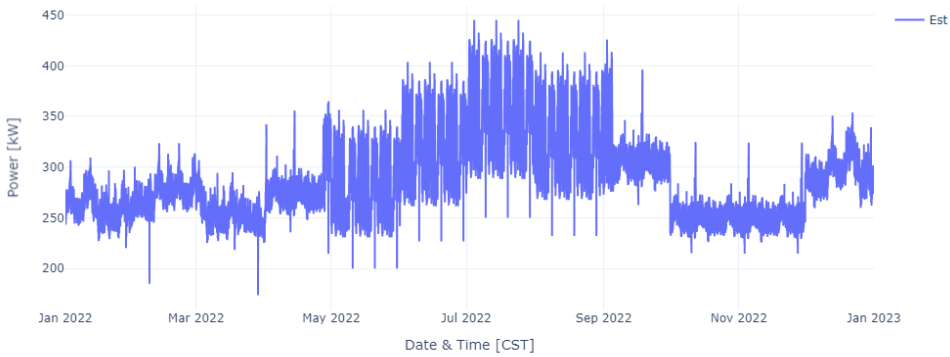


Figure 12. Casino-Lodge Profile and Scaling.

muGrid performs resilience simulations, computing how the battery, genset, and non-controllable sources like solar will serve the load in the case of a grid outage. On principle, a grid outage could happen at any hour of the year, so simulated outages also begin in every hour of the year. Rarely is a full year of load data available, so it is usually estimated based on available timeseries load and billing data. Because the available datasets don't perfectly overlap, there is usually a problem of imputation to solve, where effectively we are trying to predict the past on our way to predicting the future. The result of the imputation solution can look like Figure 12, where the data measurements have been shaped by the exponential function to more resemble the billing summary statistics of average load and peak load.

3.3.1 Load Summary

We conducted a load analysis at each site. Many sites have interval load data available, while other sites required partial or complete estimations.

Table 12 shows the main load profile statistics for the priority sites. Note that the aggregate Annual Demand is not equal to the sum of each site's Annual Demand. This is expected because each site's Annual Demand happens at different times.

In this report, usage or consumption refers to a quantity of energy consumed over a period of time and is measured in kWh or MWh. Usage is proportional to the area under the curve of a load-vs-time graph.

Table 12. Facility load summary.

Facility	Average Load [kW]	Peak Load [kW]	Load Factor
New Odanah all facilities	444.6	867.4	0.51
East Branch critical facilities	281.4	396.7	0.71
Critical Facilities			
Clinic	42.5	84.8	0.50
Lodge & Casino	141.6	300.5	0.47
Gas station and store*	47.2	100.2	0.47
Elderly Center	7.8	21.3	0.37
Administration	52.9	122.0	0.43
WWTP	30.0	64.1	0.47
Fire Department	8.3	17.3	0.48
Elderly Apartments			
Elderly Housing (Planned)	10.3	30.7	0.34
Non-Critical Facilities			
Head Start	12.4	40.9	0.30
Example Residence	1.2	10.6	0.11
Pump House	2.9	11.6	0.25
Lift Station 1	3.2	15.1	0.21
Lift Station 2	3.2	15.1	0.21
Aquatic Center (Planned)	57.8	115.8	0.50
Transit Authority	45.2	104.1	0.43

**The gas station and store pay a fixed 25% of the Lodge and Casino bill. Since all the loads on that meter are considered critical, it's less important to know exactly what the gas station and store consume.*

The load factor ratio is a measure of how much higher the peak load is than the average, where a smaller load factor means higher peaks. Buildings with low load factor are good candidates for load shedding or control to smooth out the demand. This reduces the amount of total backup power necessary and also reduces the billed demand charges. Industrial facilities and residences typically have low load factors, and aggregating facilities tends to increase the combined load factor compared to the individual buildings.

3.3.2 Interval Load Data

Interval data was collected over several months from eGauge data loggers specifically for this study. Data was also made available by EnTech Solutions, the operator of the Tribe's three existing solar-battery-genset microgrids. Some facilities had as much as multiple years of high-quality data from multiple sources, while others had only a few weeks of data from a single source.

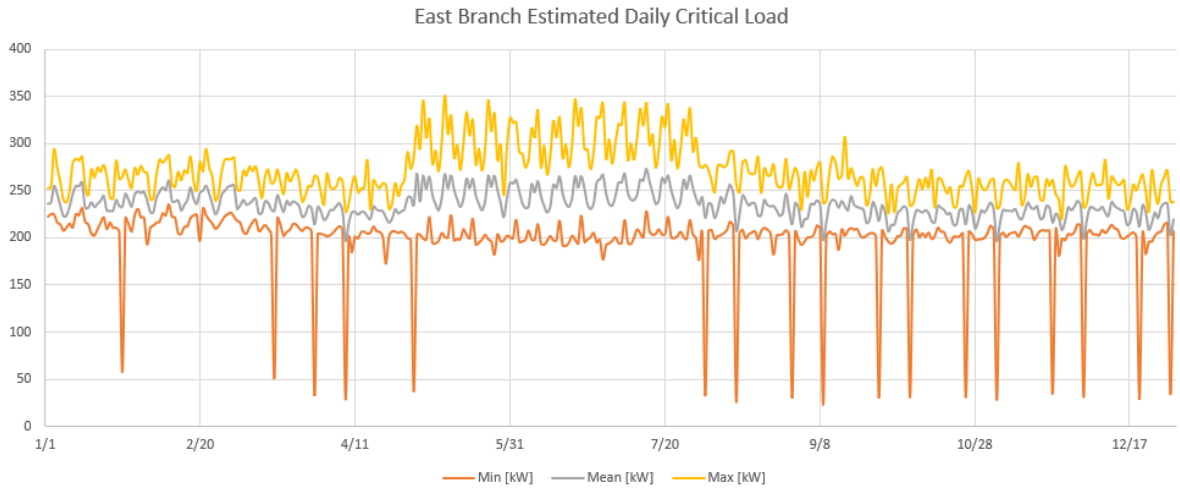


Figure 13. Aggregate load profile of the East Branch critical facilities.

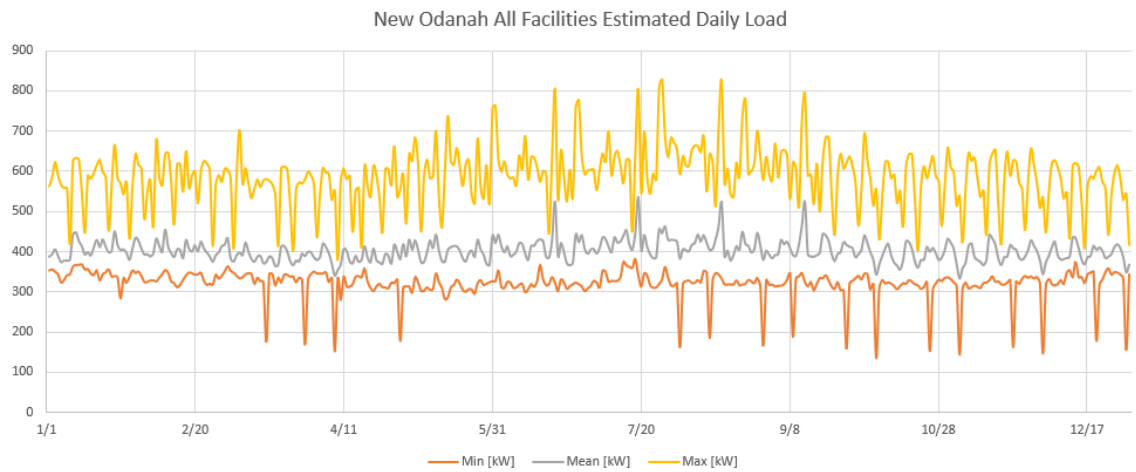


Figure 14. Aggregate load profile of all New Odanah facilities.

The East Branch critical facilities have a peak load of 397 kW and existing gensets totaling 800 kW plus a solar and storage inverter of 250 kW. Therefore, power capacity is not a large concern, except when the gensets are shut down.

All the New Odanah facilities have a combined peak load of 867 kW. The major gensets combined have 1300 kW of capacity, however one of those is the 500 kW WWTP utility line gas engine. In past analyses, the Tribe and muGrid have reasoned that utility gas is not a resilient fuel supply if a grid outage lasts long enough to depressurize lines, or if a floor or storm affects gas lines Therefore, the 500 kW WWTP genset is understood to be very useful for short outages, but not a long-term resilient asset.

Later analysis will show that the dynamics of this project are more about energy sufficiency than power, therefore peak load analysis is not a crucial component of the study. For example, the solar and battery

storage required to generate and time-shift energy will be in the range of a couple MWs, much higher than the 867 kW peak load.

The individual building load data has many different anomalies, which can generally be categorized as physically impossible values or statistically improbable values. An example of physically impossible load is a current value greater than the trip value of the main circuit breaker, given the time-current curve of the device. Some examples of statistically improbable values are in Figure 15 below where some peaks and zero-value events are more than 3 standard deviations away from the other values in that hour of day and that day of week. These are called outliers and are difficult to predict and model, so are usually removed from datasets and hedged against with a different method like an estimated factor of safety in capacity sizing.

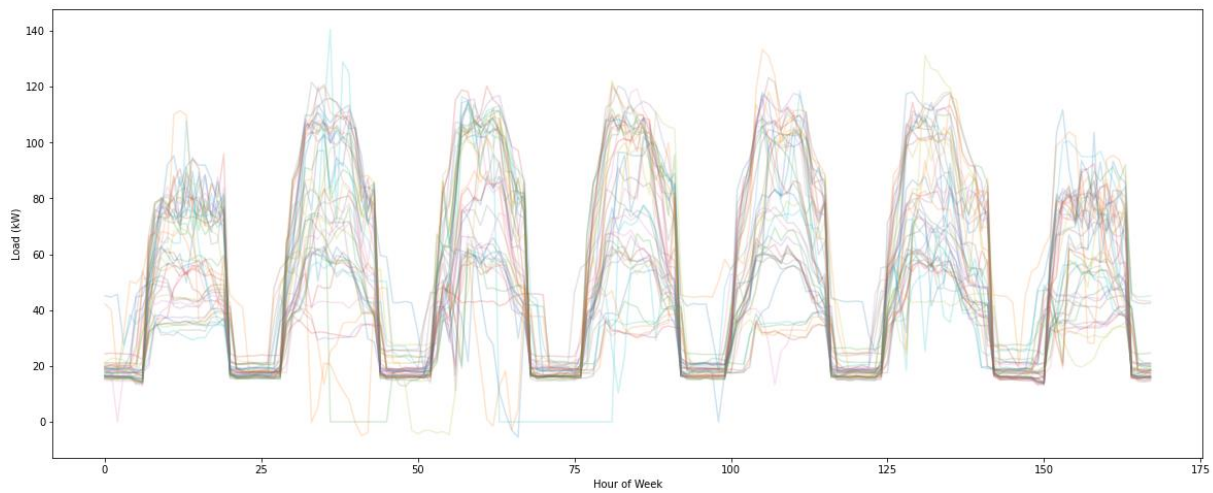


Figure 15. Clinic weekly load data superimposed, starting on Monday.

The operator of the three existing building microgrids, EnTech Solutions, has noted some issues in the data and in their ability to provide data, and these months were replaced with estimations or data from other sources. In Figure 15, the available clinic load measurements are superimposed on top of each other, week by week. The horizontal axis displays the hour of the week starting from midnight, so hours 24, 48, etc., are new days. The vertical axis shows load power in kW. Where the load lines are darker the data is more consistent, for instance at night near 20 kW. Some errant lines dip well below 20 kW and even go to zero. Visually these appear to be irregular, inconsistent with the rest of the data. Some of the errant dips may be short utility outages, but since this site has a microgrid and the meter measures true building load, the line segments near zero are probably just incorrect measurements. Other types of outlier data include missing measurements (which don't appear on the graph at all), and physically impossible data such as negative and extremely high values.

4 Design Considerations & Constraints

4.1 Business and Policy

We recognize that some of the most important constraints on the system are imposed, not by physical or technical limitations, but by regulatory or policy limitations. As a tribal organization, Bad River has more leeway than many site hosts, yet there are still constraints.

Niels Wolter of Madison Solar Consulting and Bill Bailey of Cheq Bay Renewables provided an in-depth discussion of business and policy considerations in their accompanying report to this study, *Opportunities for De-Carbonizing the Bad River Band of Lake Superior Tribe of Chippewa Indians' Electricity Resources.*

4.2 Distribution and Operation

An important objective for the Tribe is for the distribution network to eventually include microgrid topologies that serve the Community Resilience Centers, and an interconnection that islands the microgrid.

We began by documenting the system topology and location of major components. The relevant drawing and image sets are based on a Tribe-created .kmz distribution map, the BEC outage map available on the BEC website, shapefiles from Power System Engineering's distribution model, and publicly available satellite and street view imagery. We consulted with Power System Engineering and they provided an overview of the distribution network around New Odanah. All data sources are in good agreement with each other, except where satellite imagery is out of date.

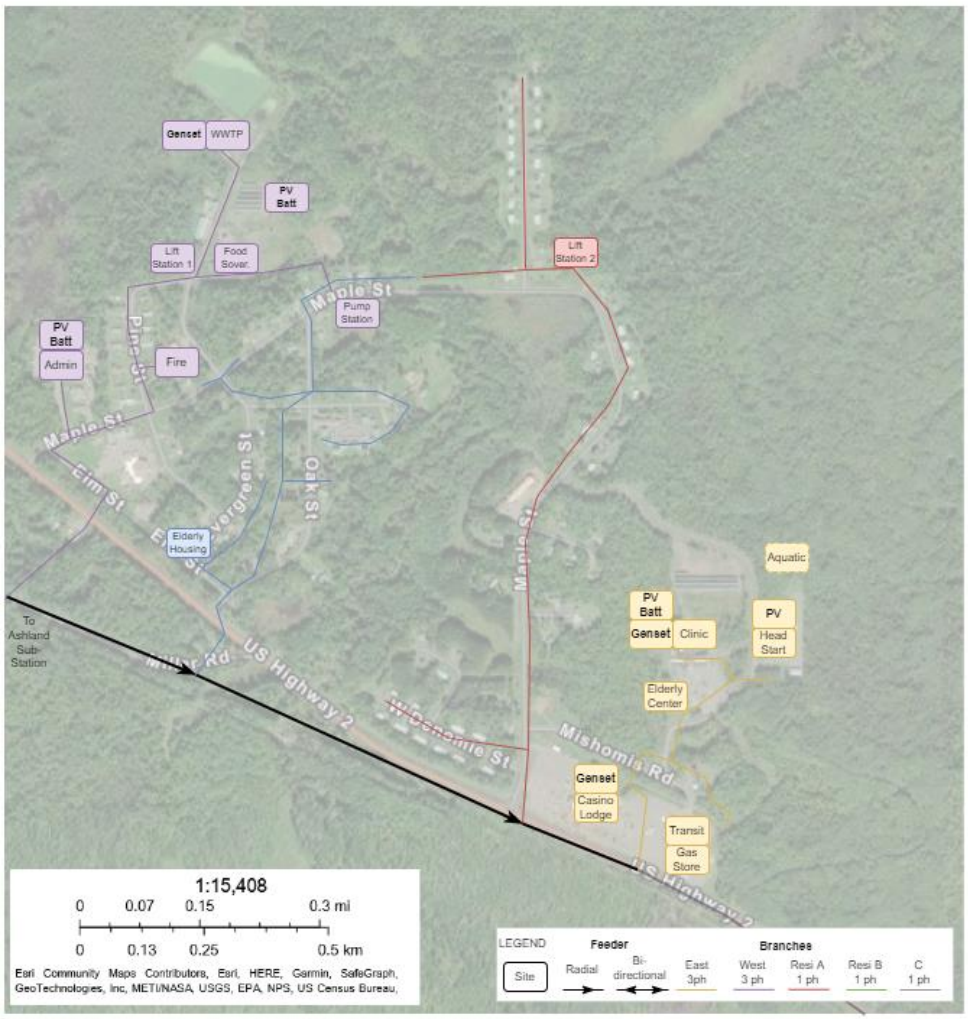


Figure 16. New Odanah existing electric distribution and major energy assets.

Transformers are likely the limiting asset for distribution capacity in every successful design case, since on principal, voltage could be supported at every generator or inverter. For this reason, large energy resources may need to interconnect at medium voltage. However, this is important for the second reason that protection coordination – determining which circuit breakers trip when and where – is much more difficult for bi-directional flows, such as both in and out of a building.

The Ashland BEC substation sends a radial three-phase feeder which meets Route 2 near the microgrid site. The New Odanah neighborhood is then served by four main branches: two three-phase and two single-phase. For the purpose of this study, the branches are referred to as East Branch, West Branch, Residential A, and Residential B (see Figure 16). The branches contain no non-customer metering and minimal control or network reconfiguration options. The microgrid needs to integrate with the reclosers but not necessarily the tie switches. The four branches serve a variety of three-phase and single-phase customer transformers, all of which are fused and solidly bonded to ground. The three-phase transformers are connected Y-Y.

The main feeder continues along Route 2, but only with the remaining phase C where other BEC customers are served. This is a consideration and a constraint for islanding any part of the feeder.

In the case of a short or open circuit, the BEC network protects against over voltages with an effective grounding strategy, similar to most of North America. While economic, this method is not conducive to changes in the network, including reconfiguration or a change in the short circuit capacity. Other more active strategies exist and are deemed in some markets to be cost effective, such as compensated networks.

With the distances under consideration, communication between energy resources and distribution automation could be fiber optic, wireless, or both. Wireless has the potential to be very cost effective and cover the entire New Odanah neighborhood, but bandwidth and fidelity vary with the protocol chosen as well as the practical challenges of noisy electrical environments.

4.3 Existing Energy Resources

The Tribe's energy team is passionate about moving to net zero carbon emissions alongside its resilience goals. The team has already studied most commercially available clean generation resources, and is piloting three solar PV, battery storage, and internal combustion engine (ICE) generator microgrids. Unfortunately, the wind and micro-hydro resources near the reservation are poor.

The Tribe has also begun preliminary consideration of a small-scale hydrogen electrolysis pilot. The purpose would be to see if longer-term storage provide by hydrogen might be economically feasible or at what price point it would be feasible. The Tribe is also studying the feasibility of biogas. Renewable natural gas could be used onsite or injected into the existing natural gas distribution system.

The relevant existing generators and renewable resources are listed along with the associated buildings and distribution branches in Table 1. A map of buildings and existing assets is shown in Figure 16.

4.3.1 Generators

We paid particular attention to the large 600 kW, 500 kW, and 200 kW generators at the Casino-Lodge, WWTP, and Clinic, respectively. The other generators are likely too small to be integrated in the microgrid, because of the cost required to convert the generator controller.

The Casino-Lodge's 600 kW diesel Caterpillar has a 500-gal tank and is nearing its end-of-life, although a specific age was not determined. The Tribe is aware of EPA grants to help pay for a more efficient and economic Tier 4 generator, also allowing to run the generator for more hours of the year than basic emergencies.

The WWTP's 500 kW natural gas generator is fed from a utility gas line. For this reason, the WWTP is both capable of running much longer than a comparable diesel generator with a fixed capacity of diesel storage, and at risk of not running at all due to a disruption in the gas service from an extended utility outage or failure in the gas distribution system. Furthermore, gas lines represent a relative safety concern compared to diesel, which is much less volatile at most temperatures. For these reasons, the WWTP generator is a useful energy resource for short term backup power, but is not considered a durable, resilient asset appropriate for a wide variety of hazards and durations. Its contribution to microgrid backup power is acknowledged but not modelled in this study. The WWTP is also the site of solar and battery assets which can microgrid along with the generator.

The Clinic's 200 kW diesel Generac with 400-gal of storage is appropriately sized for the building and has recently been made more resilient with a solar and battery microgrid. However, as a medical facility the clinic has an especially critical need for resilient backup power and may, in some circumstances, need to island itself from the larger New Odanah microgrid. These circumstances are not known specifically, creating a challenging modeling problem. However, the problem is noted here and the Clinic's 200 kW diesel Generac should not be considered as a primary or "backbone" asset to the microgrid. As such, extra emphasis is placed on the Casino-Lodge's generator and its imminent upgrade or replacement.

Existing generators will mostly remain and may be upgraded, but fossil fuel generation is not the focus for new capacity. However, the existing generators will be integrated with the microgrid, so a discussion of emissions and operating cost is relevant.

Natural Gas ICE generator: The Tribe is aware that a large portion of US national emission reduction is due to cheap natural gas, but doubt remains about the lifecycle emissions of extraction and transport. Transgressions such as ground water pollution from hydraulic fracturing are fundamentally at odds with tribal values. Also, utility line gas pressure cannot be guaranteed in many identified disaster scenarios, as was the case for a week in the 2016 flood.

Diesel ICE Generator: Although diesel is relatively expensive and polluting compared to natural gas, diesel generators lend to better resilience than line-fed natural gas because the fuel is stored in on-site tanks and can power some vehicles in an emergency. Additionally, any generator only produces emissions during maintenance runs or a grid outage. Furthermore, the power output technical low limit is much lower for diesel (typically 30% of maximum) compared to a gaseous fuel generator (50%).

In this report, *generator* and *genset* refer to fuel-based engine-alternator sets. Consistent with the industry, *generation* and especially *generating capacity* can mean any source of energy besides the grid and battery storage. For this reason, *genset* is generally preferred.

4.3.2 Renewables

Solar usually has zero local emissions, very low lifecycle emissions, technology maturity, and cost effectiveness, even in northern Wisconsin. For this reason, the Tribe has already invested in several solar PV arrays, most notably at the clinic (300 kWp) and WWTP (200 kWp). These plants are DC coupled with battery storage systems and then tie-in to the building electric systems at low voltage, behind the customer electric meter. The inverter in both cases is 250 kW. The battery capacity of the combined battery systems is just over 1 MWh – 568 kWh at the Clinic and 435 kWh at the WWTP.

Figure 17 shows the operation of the Clinic microgrid for the first four days of August 2021. The building load is met by a combination of the microgrid and the utility grid. The solar production is overlayed on the graph to show how solar often exceeds the load, while the energy not needed to meet the load is stored in the battery.

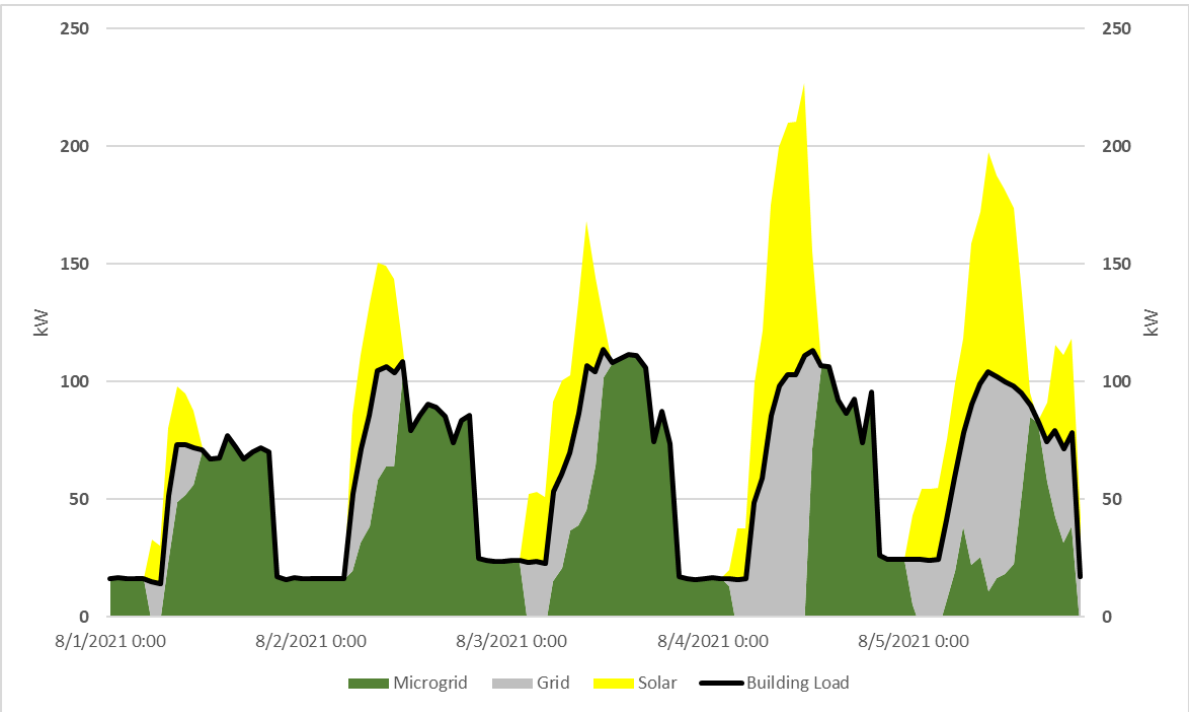


Figure 17. Real data from operating Clinic microgrid.

The study team spoke to the operator of the clinic and WWTP microgrids about interoperability with future systems several times during the course of this study. The operator confirmed that integration and interoperability with future microgrid assets would be possible. However, their comments were vague and did not present any details about interfaces or integration requirements that could inform this study or a future integrated microgrid design. They indicated that there would be an unspecified cost to develop an interface to the system, but did not provide an estimate. For purposes of this study, we have assumed that the existing WWTP and clinic microgrids can be integrated into a community microgrid. We did not estimate a cost for it.

The Administration Building also has a small solar plus storage microgrid installed behind the meter, which supports critical building loads only. Because of the small scale of this system, we ignore it as part of this study.

4.4 Additional Considerations

4.4.1 Energy Efficiency and Operations

This study has focused on the creation of a microgrid on the Bad River reservation, and the power generation and distribution requirements to support it. Before pursuing additional generation, we recommend that the Tribe conduct energy efficiency audits and implement additional energy efficiency measures across their portfolio of buildings. Many energy efficiency measures have faster paybacks than new generation, so it makes sense to explore these options first. Some of these "measures" can be as simple as changing the setpoint on building automation systems. Put another way, it is usually cheaper – and more sustainable – to not consume energy in the first place than it is to generate it renewably.

We examined the operations of the clinic as an example of a building operational analysis. Figure 18 shows the 15-minute load profile for each day during the period of March 21, 2020 to August 17, 2020. This is the "native load profile", meaning this is the energy consumption of the building itself, not factoring in the solar and battery microgrid. Graphs such as this can provide insight into macro-trends of the building, which we have annotated.

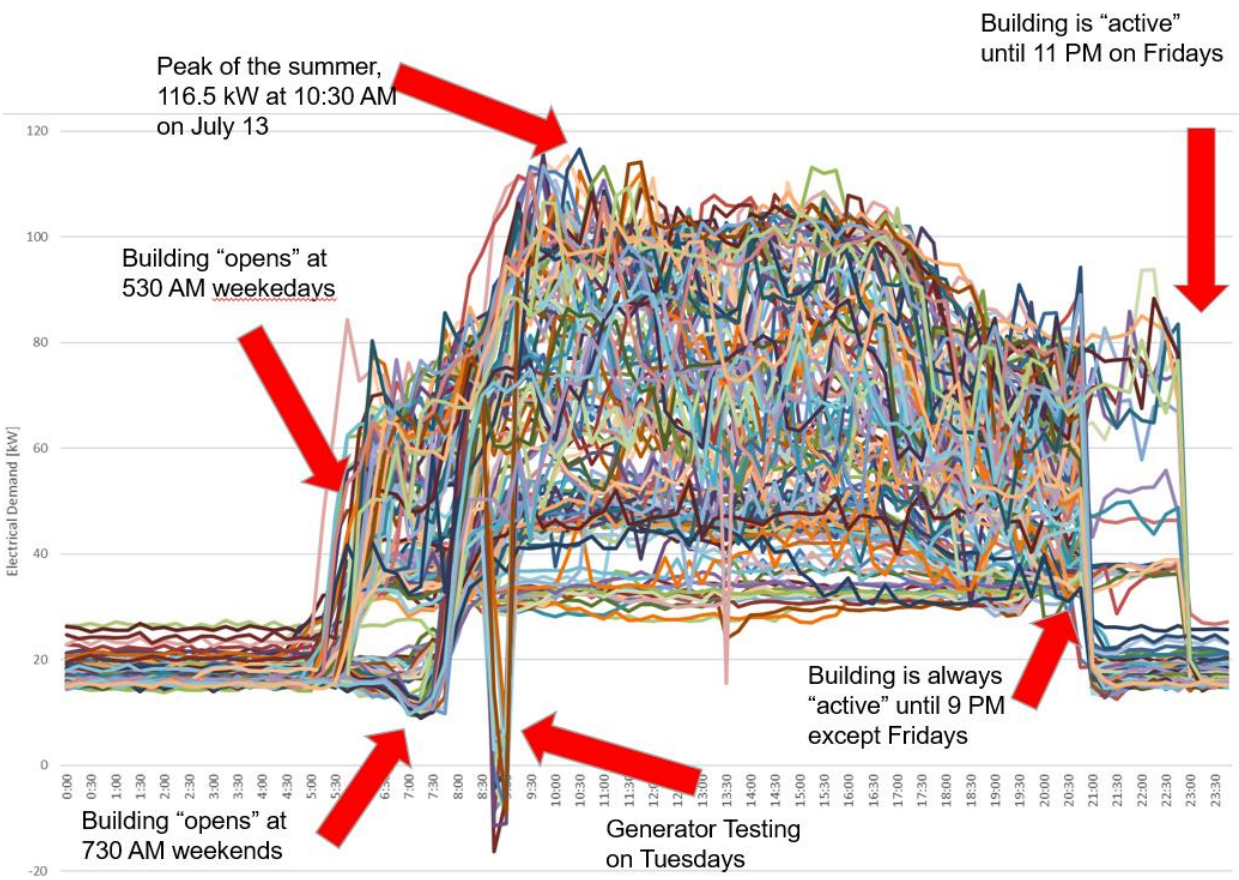


Figure 18. Clinic native load profile overlay.

We then plotted the electrical load profiles for a single week in August. Figure 19 shows the building electrical load profile for a week (Sunday to Saturday) in August 2020, but is generally representative of any week.

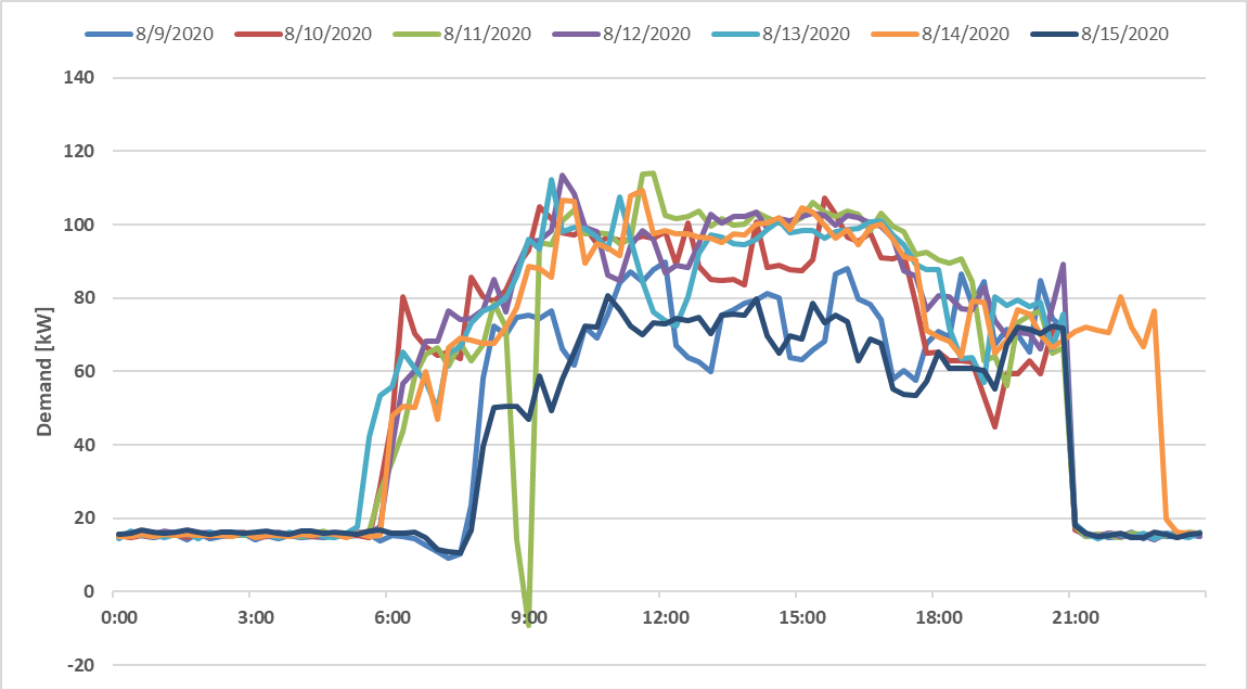


Figure 19. Sample weekly clinic load profile.

From these graphs, we can observe many characteristics of the building operations by studying load profiles such as this. The baseline usage of the building is consistently 20 kW. Then the building "wakes up" at 5:30 AM on weekdays before "going to sleep" at 9pm every day, including weekends (except Friday, when it stays active for an additional 2 hours). The consistency of these profiles indicates that the building is operated using a building automation system, rather than manual control. The building automation system is likely controlling lights and HVAC equipment.

We note that the building is active (significant electrical load) until 9 pm every day (except Friday), though we believe that the clinic may only be open until 5pm. We therefore suggest that the Tribe consider closing the building earlier, at perhaps 6 pm or 7 pm. We calculate that closing the building at 6 pm (rather than 9 pm) would save at least 90 kWh each day, or $3285 per year.

We then note that the building is active on weekends, "waking up" at about 730-8am. We would advise the Tribe to verify that the building is actually in use during this period. If the building is not being used on the weekends, it could remain in the dormant during these two days each week. We estimate this would save about $3600 per year.

Finally, we note that the building is active an additional two hours on Friday evenings, closing at 11 pm, instead of 9 pm. Since this closing time does not follow the standard weekday pattern (closing at 9pm), we wonder if the building is actually in use during this time, or if by chance the "sleep" setpoint in the BAS was entered incorrectly. We calculate that these additional two hours of operation on Friday's cost the Tribe an additional $200 per year. This may not seem like much, but if in fact the building is not in

use during these hours, it is a very simple change. (Putting the building to sleep at 6pm, as noted previously, would clearly save even more.)

We recognize that the building may in fact be in use during each of these periods (weekdays until 9 pm, Fridays until 11pm, and on weekends) and as such the building automation system is programmed correctly. We simply suggest that the Tribe verify this operational schedule because these setpoint changes and resulting savings (about $7000 per year) can be achieved with virtually no cost to the Tribe. Similar operational analysis could be performed on other buildings.

4.4.2 Load Shedding and Rescheduling

There will be a pool at the new aquatic center that does not need to be backed up in resilience mode. The pool and additionally large chillers and condensers at the Casino can be rescheduled during high demand events and to reduce demand charges when grid-connected. The Casino gaming floor also likely could be shed in an emergency. Without sub-metering on these specific loads and a lack of Casino building electrical drawings, it's difficult to estimate the benefit of load shedding or load control such as inrush current reduction. However, the largest recorded 1 second change in power at the Casino-Lodge is 158 kW, so this is the approximate order of magnitude demand reduction that may be possible.

At the WWTP load rescheduling is difficult because of the industrial process and complex control systems which need to be reprogrammed. However, load scheduling at the clinic and other non-industrial buildings may be quite feasible, as described in section 4.4.1.

4.4.3 Dispatchable Loads

The Tribe's microgrid will potentially produce more electricity than it needs at various times of the day. This electricity can first be stored in batteries, but sometimes the batteries will be fully charged and the Tribe will still have excess electricity. The default option for this excess electricity is to export it to the utility grid and sell it to the utility. The downside of this is that the utility will only buy this excess electricity at the wholesale rate - the rate they would have paid on the spot market. This price varies, but is frequently less than half of the retail rate. It is therefore beneficial for the Tribe to explore ways to use this excess electricity onsite.

The Tribe is already experiencing this excess electricity scenario at the WWTP's building-level microgrid. The microgrid, which was commissioned in June 2021, consists of 200 kW-DC of solar and a 200 kW-400 kWh battery on a relatively continuous 35 kW load. This solar array brings the WWTP to net zero electricity over the course of the year, meaning that they produce as much solar onsite as they consume on an annual basis. However, since the building load is mostly flat, they end up producing more solar than the building needs during the day, especially in the non-winter months. This overproduction is first stored in the batteries for use at night. Yet, especially in the summer months, the batteries are often fully charged by 10 AM, at which point the overproduction is sold back to the utility grid and compensated at the wholesale rate.

Recognizing that this overproduction situation would only increase with the addition of even more distributed generation as part of a community-level microgrid, we wanted to help the Tribe explore alternative uses for this "low-value" electricity, and actually demonstrate how it would work using the WWTP as a testbed.

We considered charging electric vehicles, heating the building using electric resistive heaters, and rescheduling the plant's water / effluent pumps to operate during periods of excess solar. Each of these activities has the commonality of being somewhat asynchronous – they need to be done for a certain number of hours each day, but the specific timing of the operation does not matter much. In other words, these activities would allow the Tribe to perform work that they needed to do anyway, but it would essentially be performed using wholesale electricity rather than retail.

Along with the Tribe, we ultimately decided to deploy a simpler application that could still prove the concept of performing a non-trivial, valuable task using wholesale electricity. We elected to deploy a small Bitcoin mining system that operates exclusively when the WWTP is exporting low-value electricity to the utility grid.

The mining system consists of a single Bitmain Antminer S9 along with a Raspberry Pi controller running muGrid Analytics's Redcloud Real-Time supervisory control. The existing eGauge energy monitor at the plant is used to determine when the solar is exporting energy to the grid. muGrid Analytics provided the mining hardware for this mining-on-excess-solar demonstration project; no OEI funds were used.

Redcloud Real-Time continuously monitors the eGauge to determine when the plant is exporting electricity. When this condition is detected, Redcloud Real-Time then checks the current wholesale price of electricity and the profitability of mining Bitcoin to determine if mining should commence. If the conditions are determined to be favorable – that is the value of the Bitcoin produced is worth more than the spot price of electricity – Redcloud Real-Time activates the miner.

To summarize, the conditions which must be true to commence mining are:

1. The Wastewater Treatment Plant is exporting electricity to the utility grid
2. The incremental value of mining bitcoin is greater than the wholesale value of the electricity produced

Figure 20 shows the minute-by-minute operation of the Bitcoin miner for the period from May 16, 2022 to May 20, 2022.

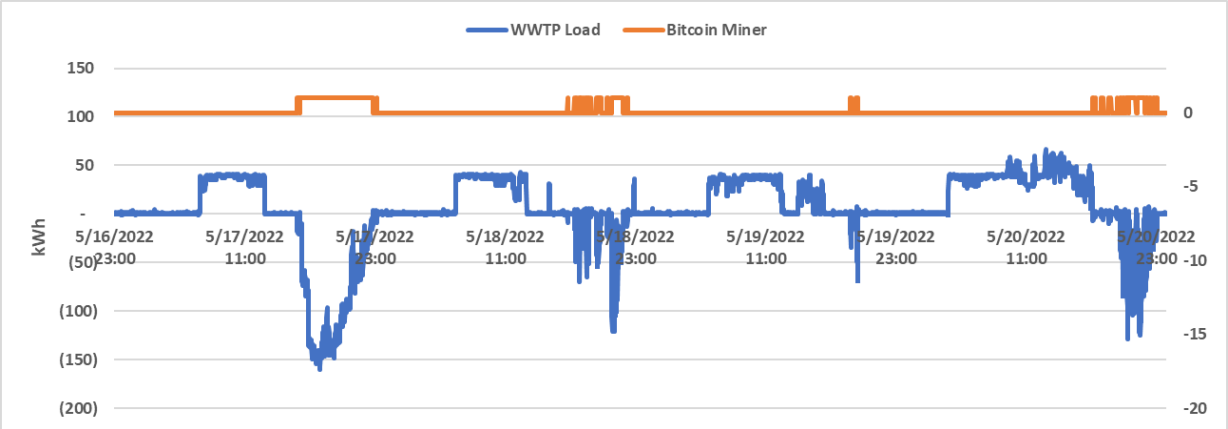


Figure 20. Sample miner operation.

The blue line shows the electricity flowing through the meter. When the values are positive, the utility is supplying power to the site (the load is relatively constant at around 40 kW). When the values are negative, the microgrid at the WWTP is exporting electricity to the utility grid. The orange line shows the on / off operation of the miner. When the WWTP is exporting power to the grid, the miner turns on. On May 17, the miner turned on and stayed on for much of the afternoon. However, on May 18, there were clouds passing through, causing the WWTP to export electricity only intermittently – the miner started and stopped accordingly, such that it was only operating during periods when the microgrid was exporting excess electricity.

Figure 21. The Antminer S9 bitcoin miner and associated power supply is on the shelf while the control system is in the enclosure below.

The excess solar powered mining pilot was activated on May 11, 2022. During the period between May 11, 2022 and June 18, 2022, the miner operated for 130.5 hours out of a possible 752 hours for a duty cycle of 17.3%. It consumed 175 kWh of electricity during this time. This indicates that the Wastewater Treatment Plant was exporting electricity for 17.3% of the time during this period.

The 175 kWh of excess energy consumed by the miner during this period represented 2.7% of the total 6477 kWh excess generation.

Figure 22. Mining-on-excess-solar demonstration.

We considered this Bitcoin-mining using exclusively excess solar energy to be a successful demonstration of muGrid's Redcloud Real-Time Supervisory control software. Although market conditions moved against us – including declining Bitcoin prices and soaring electricity spot prices – the underlying dispatchable control worked as expected and proved the concept of operating equipment during periods of excess solar. In the future, the same control scheme can be used to dispatch other asynchronous loads such as electric vehicle charging, water heating, space heating, and pumping water so that the Tribe can derive a higher value from their excess energy than exporting it to the grid (or curtailing it.)

4.4.4 New Assets Under Study

Solar (both PV and thermal): Solar usually has zero local emissions, very low lifecycle emissions, technology maturity, and cost effectiveness, even in northern Wisconsin. For this reason, the Tribe has already invested in several solar PV arrays, most notably at the Clinic (300 kWp) and WWTP (200 kWp). These plants are DC coupled with battery systems, and then tie-in to the building electric systems at low voltage, behind the customer electric meter. The inverter in both cases is 250 kW.

Battery Storage: Solar PV isn't inherently dispatchable, so electric energy storage is required for islanded operation. Of the many options, lithium ion, lithium iron phosphate (LFP), and lead acid chemical storage are the most economical and most technologically mature at this scale. The microgrids in place at the clinic, WWTP, and Administration Building include lithium ion battery storage technology.

Biomass Combined Heat and Power (CHP): Biomass can also reach low lifecycle emissions, especially if the heat has value, but the Tribe is concerned about local air quality and may not tolerate even fairly

low emissions. Furthermore, residue or waste cellulose sources may not always provide enough feedstock, and the Tribe is concerned about the carbon and ethical issues regarding energy crops.

Biogas: Biogas or renewable natural gas (RNG) could be an added renewable resource for the Tribe. A current feasibility study is underway. Potential biogas could be stored onsite or filtered and injected into the existing natural gas distribution system. Feedstocks are being identified and could potentially have the added benefit of improved water quality for the Tribe's wild rice ecosystem. This could be accomplished through removal and digestion of invasive species or digestion of manure within the local watershed.

Behind-the-meter energy resources like solar can offset most or all electric consumption, and therefore can be valued at the relatively high consumer electric tariffs (typically one rate for energy and one for demand). However, these projects are limited in size due to the building electric system and may have difficulty integrating with the control systems of a multi-building microgrid. For this reason, the study also considers plants that are interconnected on the distribution network, such as a community solar plant.

4.4.4.1 Solar

The Tribe has existing experience siting, designing, and installing solar PV with the help of consultants and engineering firms. The New Odanah neighborhood already has about 540 kWp of ground mount and rooftop capacity. A 1-2 MWp community solar plant has been under consideration for some time now, as in Figure 23.

Figure 23. Proposed sites for new solar.

For the identified resilience objectives, the total solar capacity will likely be on the order of megawatts and therefore interconnected at medium voltage instead of behind-the-meter. The land requirement will be around 4-5 acres per MWp. Exact equipment selection is out of scope of this study, but DC-coupling solar with battery storage may partially alleviate the complex control problem of balancing active and reactive power alongside power inverter and traditional generators. A possible detriment to DC coupling is a lower DC bus voltage (often 400 V) compared to AC string voltages increasing above 1000 V to decrease wiring and transformer costs. String-level DC-DC converters do not necessarily allow for higher DC string voltages.

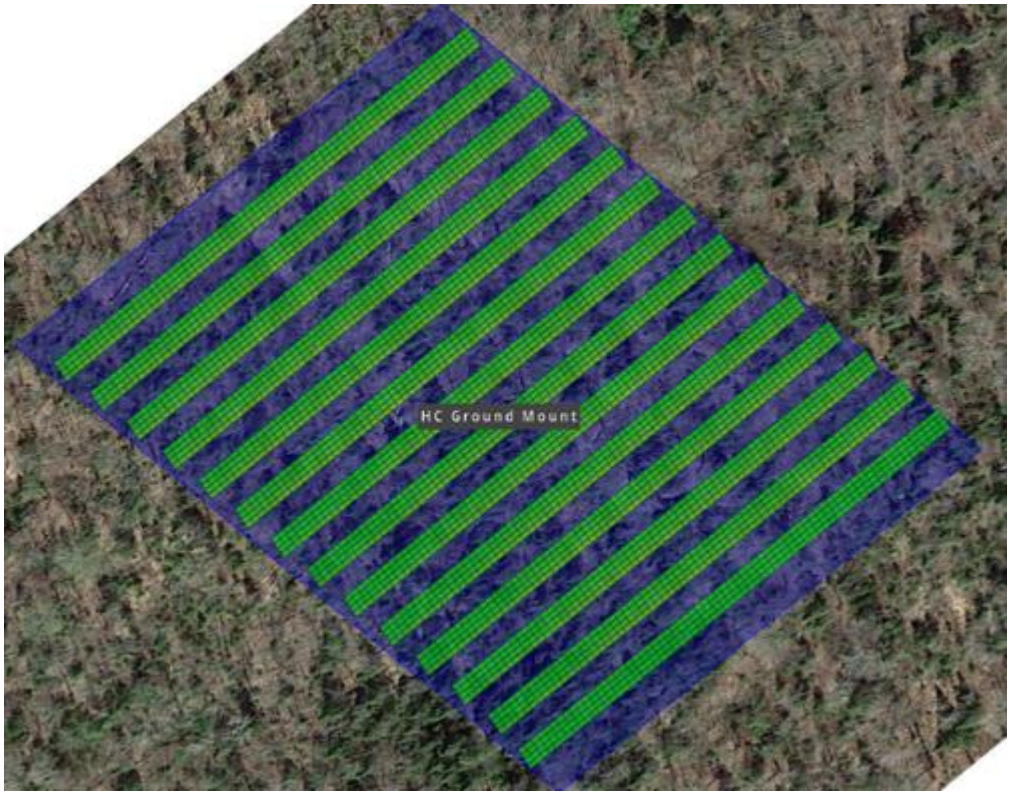


Figure 24. Example 1 MW solar array directly north of the Health and Wellness Center PV.

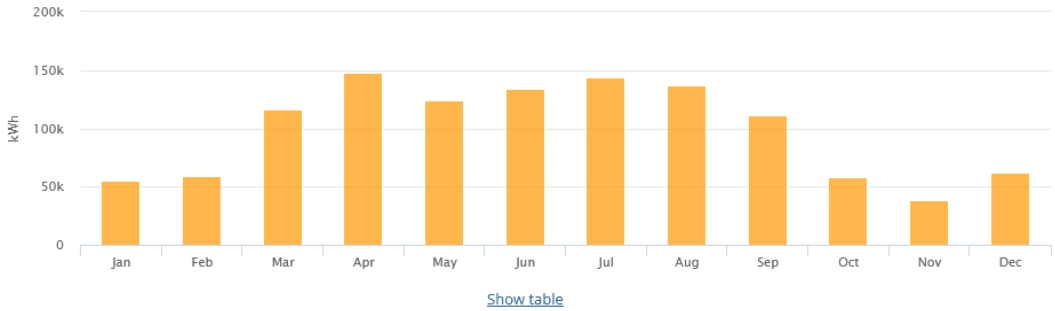


Figure 25. Projected energy production from a 1MW solar installation.

In addition to the community solar areas in Figure 23, the uncleared forest area north of the Clinic is generally adequate for a few MWp of solar. However, the Tribe also prefers to minimize new tree clearing, so solar carports at the casino area are also under consideration. Both locations are well positioned for interconnection, though with at least two new buildings in the planning phases it may be a complex site. In Figure 26, the flood map from the 2016 500-year flood event is shown, strongly suggesting that the area around the Clinic is one of the safest locations for new solar in New Odanah. The Clinic is the largest building just northeast of the Bad River Lodge and Casino, labelled in the flood map in Figure 26.

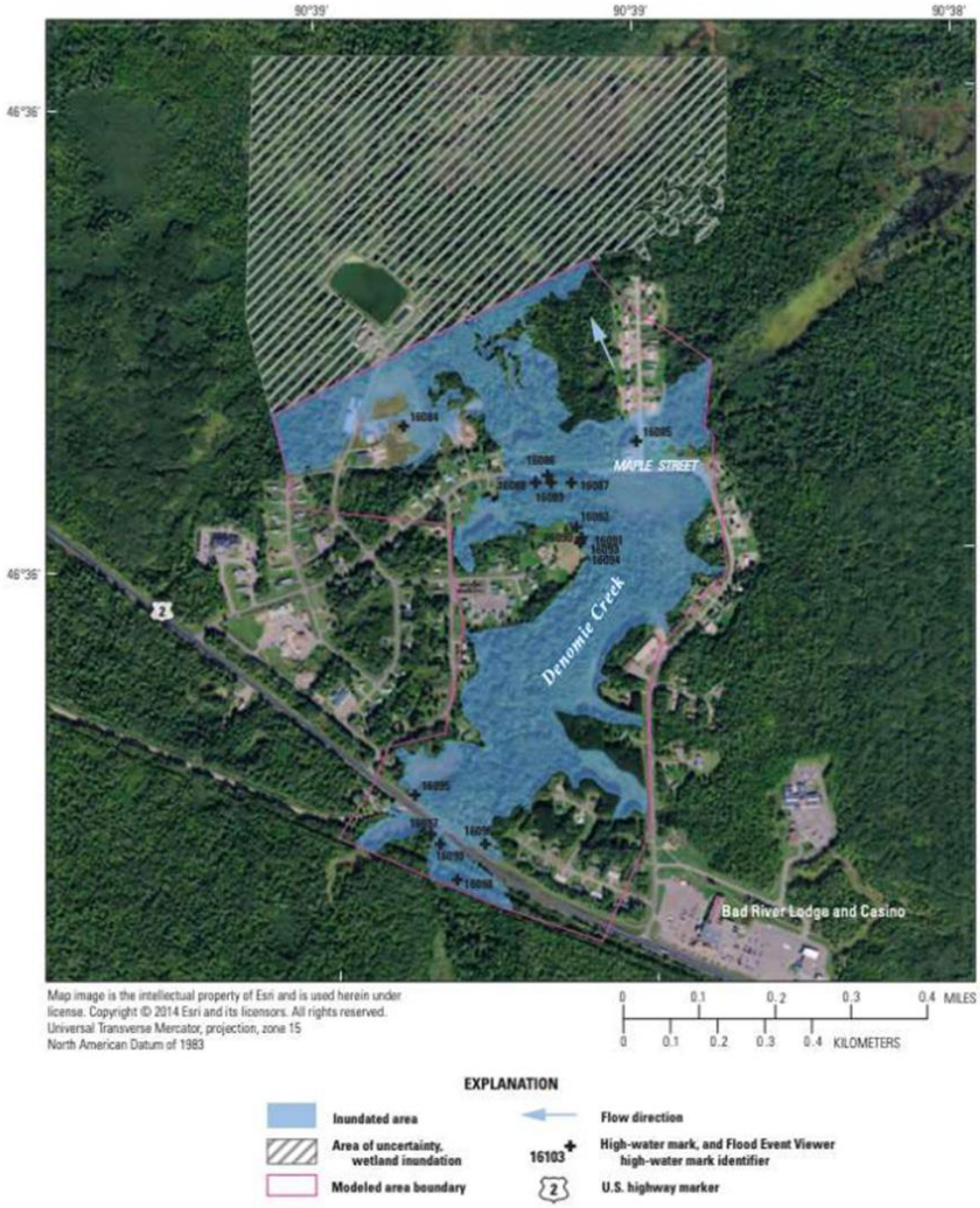


Figure 26. Flood map from the 2016 500-year flood event, with Clinic north-east of the Bad River Lodge and Casino.

While this solar siting is adequate for a medium-sized solar installation of 1-5 MW, if the selected solar capacity is larger, other sites will need to be evaluated, such as the remaining cleared or uncleared land around the WWTP. Medium and large energy assets should be located on one of the two three-phase branches, and as close as possible to any switchgear equipment (see design drawings).

4.4.4.2 Battery

We assume battery storage will be sited outside near the new solar PV. This is important to note because of the reduced cold weather performance of batteries and HVAC load in both summer and winter to cool or heat the battery cabinet.

Alternatively, batteries could be sited behind the meter to provide grid-connected operational benefits to each building. This presents a more difficult control problem in islanded mode, but nothing that couldn't be overcome. We assume for the purposes of this study, that the battery will be grid-tied, front-of-meter along with the solar. Economic opportunities could be available to the battery by exporting with the day-ahead market.

4.4.4.3 Generators

For this study, we assume that the generators provide backup power only. They run on diesel fuel (propane or natural gas could be alternatives.) This is representative of the asset cost we modeled.

That being said, anywhere there is a backup generator, there could be an opportunity for CHP. For CHP, the most likely fuels would be natural gas or propane, though woody biomass or biogas would also be possibilities. CHP can be an attractive option because it makes a fuel-burning generator much more efficient. Since northern Wisconsin has a long season where heat offtake is valuable and CHP can be run concurrently with the grid, CHP provides multiple revenue streams. It could also be a consideration for large heating loads, such as the future aquatic center pool.

CHP is a fuel-based solution and if it is run during grid-connected operations, emissions and subsequent air quality effects must be considered. Propane and natural gas CHP solutions are available at small scales, like the 600-800 kW required here, but alternative fuel options may not be available or may be prohibitively expensive at small scales.

5 Results

5.1 Generation and Storage Adequacy Assessment

An important first step in determining the feasibility of a microgrid is total power capacity, or adequacy. This is also the only step that most backup generator installers perform, and it is typically done by oversizing the asset substantially.

An example microgrid may have a peak load of 100 kW according to 15-minute interval average load measurements, but the 1-second power peak may be several times that value. Therefore, adequacy might require a 200 kW generator. Alternatively, it might require a 250 kW hybrid solar-battery inverter.

5.1.1 Solar

Solar was modelled similarly to the existing arrays with a 35-degree tilt and 30 ft spacing, for excellent comparison of real to modelled data. We recommend solar of at least 1 MW-dc and investigated solar sizes from 1 to 8MW in the tradespace.

5.1.2 Generators

The total genset capacity provided by the existing combustion engine generators is 800 kW, with 600kW coming from the Casino-Lodge and 200 kW from the Clinic. This does not include the 500 kW WWTP generator or generators below 50 kW. Both generators are on the East Branch.

The 800 kW is adequate for the East Branch's 15-minute peak load of 351 kW. However, it does not cover the 827 kW peak of the New Odanah neighborhood peak load.

The 600 kW Casino-Lodge generator is a large percentage of the total, so it will be a very important asset, especially in periods of high load or low solar. As these generators near end-of-life, the Tribe will need to decide whether to replace them with similar generators or retire them and invest instead in more battery or solar capacity. This will be easier to do with smaller generators rather than larger ones.

5.1.3 Battery Storage

We estimated the combined generation and storage capacities based on the aggregate load profile and estimated inrush current required. To do this, we summed the load of the seven priority buildings considered for the microgrid. The combined estimated 15-minute peak load is 351 kW maximum and 827 kW, for the East Branch only and New Odanah cases, respectively.

For both load profiles, we estimated the 1-second peak using eGauge timeseries data to be 135% of the 15-minute peak, a figure much lower than if any one building is concerned. This is due mostly to the spatial aggregation of loads, which tends to smooth out load profiles and increase the load factor. This results in 1-second peaks of 474 kW and 1116 kW for the two cases.

Battery systems included in a resilience-first design strategy typically are large enough to shut down the generator *often*. This does not necessarily mean the battery is capable of handling the 1-second peak load without the generator online. However, the more resilience is required of a site and the less tolerant the stakeholders are to even intermittent blackouts, the larger the battery power capacity should be. Therefore, the Tribe should consider battery inverter sizes of at least 500 kW to be paired with the available generator power of 800 kW. A battery inverter size of 1 MW will allow room for load growth and charge/discharge rate flexibility.

5.2 Resilience Analysis

To perform resilience analysis, we developed a tradespace of resilient backup simulations with generation and storage capacities. A tradespace represents options for design, including variations along all generation and storage sizing parameters and their associated performance and cost. The sizing tradespace is bounded by the generation and storage adequacy requirements, calculated in the previous task.

We define Time to First Failure (TTFF) as the length of time in hours until an islanded microgrid is unable to power the load. This can be due to any number of reasons: a drop in solar power, low battery state of

charge, or an empty fuel tank. In many cases when the solar resource returns, the microgrid comes back online. Minimum TTFF is the first time, in all of the simulated outages, that the microgrid failed. Average TTFF is the average time until the microgrid fails in the simulations.

It should be noted that these analysis runs were conducted with one year of load data (some of which we estimated) and with one year of solar production based on scaling the production for existing Bad River arrays. As such, both load and solar production for these resilience estimates are based on one single year of data, which may or may not be a typical year and may or may not have any outliers in the data. The analysis was conducted using a single outage simulation at each time step (every hour of the year) and statistics collected were based on the modeled performance of the system over that particular year. A more rigorous analysis would include monte carlo runs to statistically vary the weather and load conditions (which may be correlated). This is why we list all extremely-high confidence systems as "near-100%" or "99.99%+" instead of simply "100%." When our modeling results return "100%" successful, it means that the simulation was successful at achieving the desired duration at every one of the 8760 time steps that were run under the conditions described above. This is similarly true for confidence levels less than 100%.

Asset cost is estimated with a specific cost of installed solar of $1500/kW-DC and specific cost of battery storage of $1000/kWh. The error bar on the storage cost is quite high based on the relative immaturity of the industry, supply chain problems, and the rising cost of raw materials. Not included in the asset cost is the switchgear and controls cost, which vary significantly and depend on the result of a detailed engineering study of the required grounding and protection systems. However, many of those are fixed for the system sizes explored in the tradespace, so they can be ignored for this stage of the cost analysis. The additional amount required to build the microgrid, often called the balance of systems, is very roughly estimated at $250,000 for the East Branch case and $1,500,000 for the New Odanah case. The balance of systems should be added to the asset cost in Table 13 and Table 14.

As previously stated, this microgrid design is not lacking for power – the question is how to serve the energy. Therefore, the current aggregate generator power of 800kW works well, paired with at least a 500kW battery inverter. The energy required then can be provided by a combination of solar PV generation, battery energy storage to time-shift the energy produced by solar, and the amount of fuel in the generator tank. Generator tanks are easy and inexpensive to build, but they do not provide economic benefits in grid-connected mode, and they do not provide carbon-free energy generation. The Tribe must decide the trade between cost-effectiveness and sustainability.

We assume that batteries are generally available in a standard 2-hour or 4-hour configuration. That is, the energy capacity in kWh is 2 or 4 times the power rating in kW. These are standard battery configurations that are often available in the marketplace. Custom solutions at longer durations may be available, with higher energy capacities and lower inverter power ratings. However, at large scales, the energy capacity is often the cost driver for batteries, so reducing the inverter size may not have a big impact on cost.

We considered two hypothetical design cases:

- East Branch: a single recloser or small switchgear near the Casino can island most of the critical facilities for resilience,

- New Odanah all branches: all the branches and facilities are included in the microgrid, which segments the feeder when islanded

These could be viewed as two different options. Alternatively, the East Branch would make a good first step towards a smaller community microgrid, and has the benefit of having most of the "Critical Facilities" on it, with the New Odanah "all branch" solution as a later phase of expansion.

For each design case, we began by analyzing the base case – that is, what resilience could be achieved with only the existing assets. From there, we investigated the trades between solar + storage sizing and generator tank size.

5.2.1 East Branch Design Case

Table 13. East Branch Design Case Options.

Solar (kWp)	BESS (kW/kWh)	Generator (kW / gal)	Asset Cost	Resilience confidence at 3 days	Resilience confidence at 1 week
300	250 / 568	800 / 900	$0	12.6%	0%
500	1000 / 2000	800 / 3000	$1.26M	99.99%+	99.99%+
500	2500 / 5000	800 / 2000	$4.25M	99.99%+	82%
2000	3000 / 6000	800 / 900	$7.03M	99.99%+	84%

For the East Branch case, there is a clear trade between battery capacity and tank size. However, solar size remains the same for the large tank sizes, while leaping up at the smallest tank size. This makes it clear that the true required energy capacity for the East Branch is somewhere between the 900 and 2000 gallons of fuel, and the microgrids require solar to generate more energy only at smaller tank sizes.

Figure 27 shows detailed resilience performance for each case at durations up to 2 weeks (336 hours). Note that the large solar + storage / small generator tank shows significantly better performance at long outage durations.

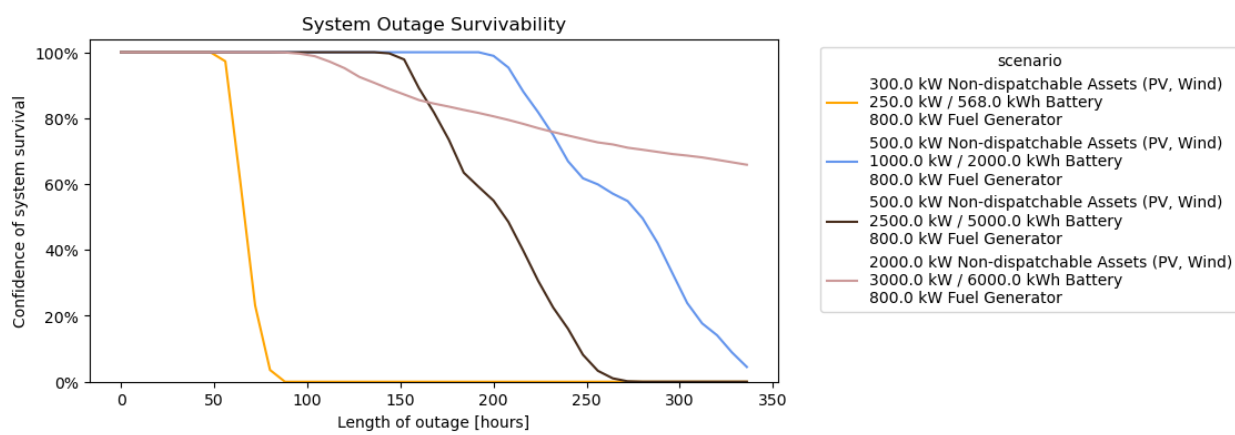


Figure 27. Resilience performance for East Branch Design Cases.

Figure 28 shows the large battery case specifically, and demonstrates how much of the resilience duration is supported by solar plus storage.

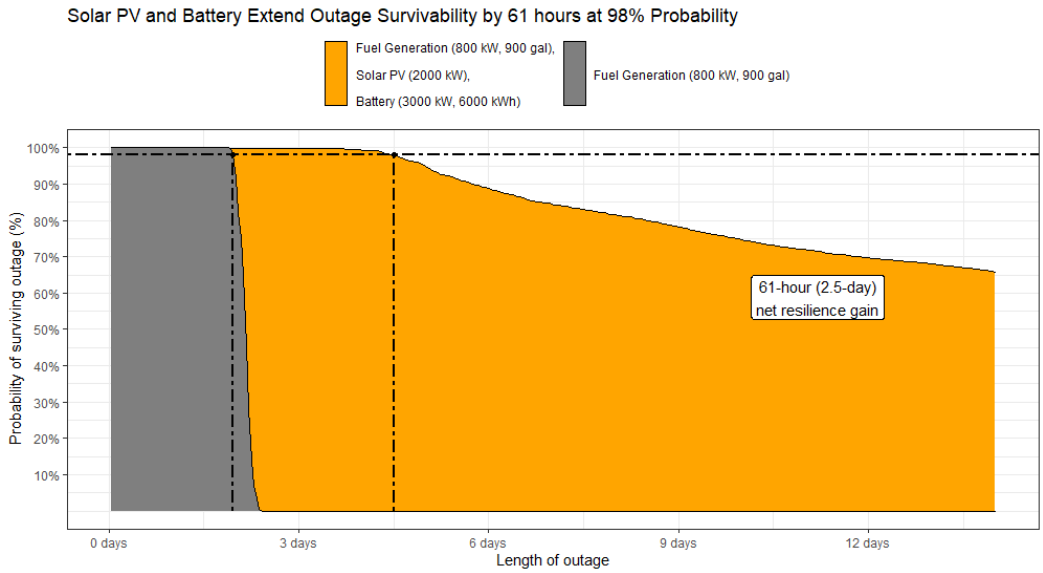


Figure 28. Solar + storage extend resilience performance of generator alone, large battery case.

On the other end of the spectrum, solar + storage still respectably extends the resilience duration of a large generator fuel tank with a smaller battery and solar plant, as shown in Figure 29.

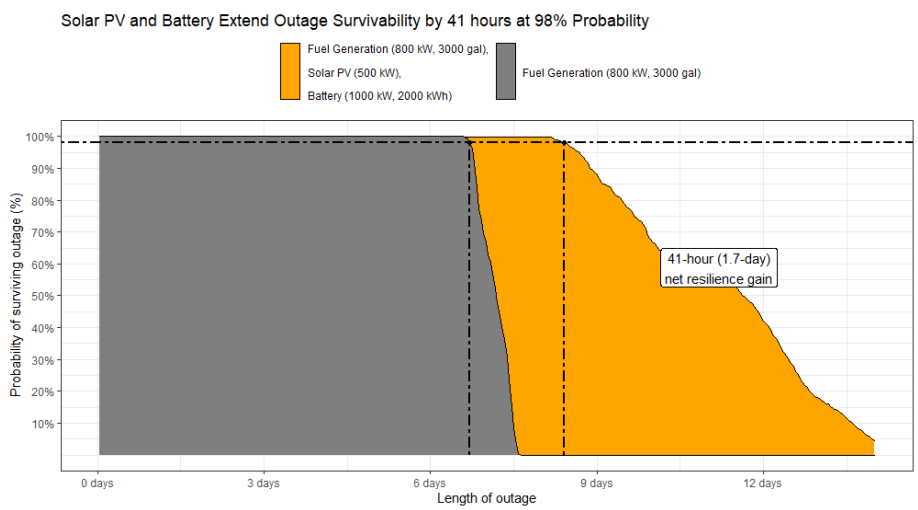


Figure 29. Solar + storage extend resilience performance of generator alone, small battery case.

Figure 30 shows seasonal resilience performance as simulated every hour of the year for each of the four design cases (including the base case) for the East Branch. The days of the year are placed along the x-axis of each plot and the time of day is on the y-axis. These images show that for the cases that meet the resilience requirement, while requirements are met year-round, they are exceeded in spring and summer when solar is plentiful, particularly in the large solar case.

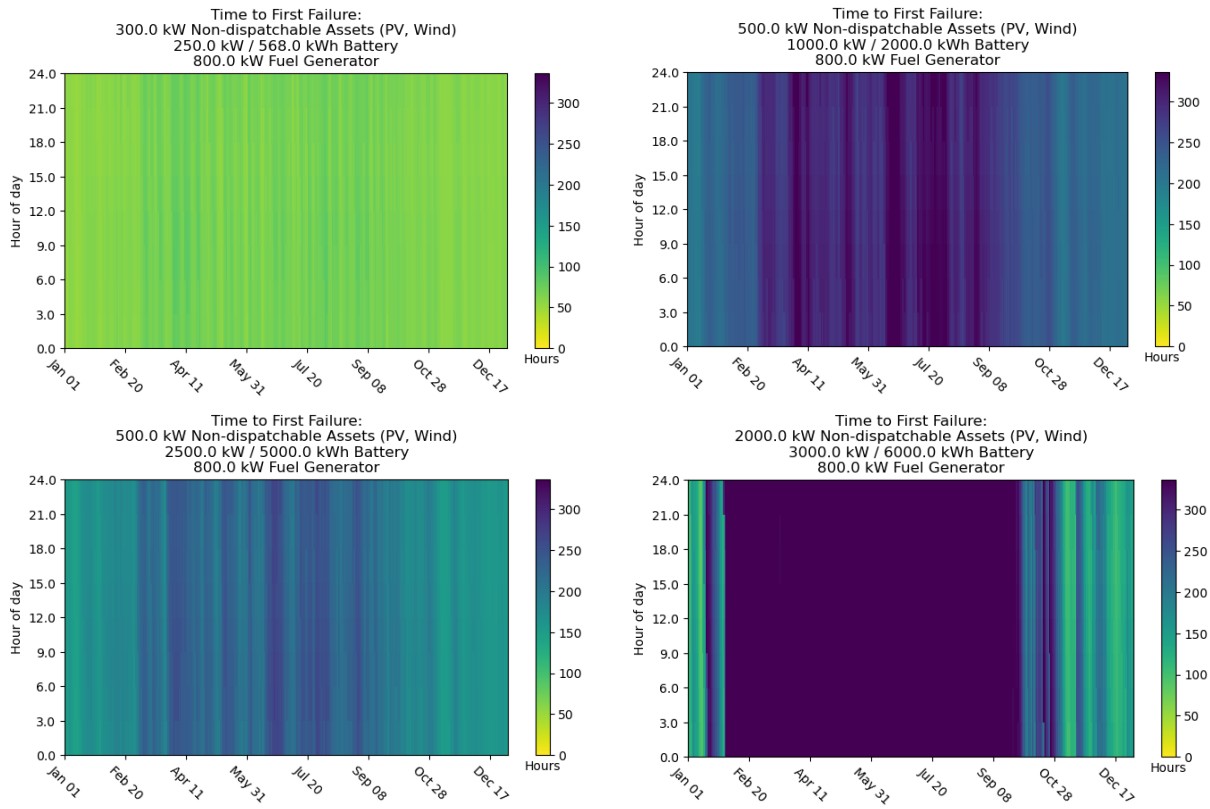


Figure 30. Seasonal Resilience performance for East Branch Design Cases.

5.2.2 New Odanah "All Branches" Design Case

Table 14. New Odanah "All Branches" Design Case.

Solar (kWp)	BESS (kW/kWh)	Generator (kW / gal)	Asset Cost	Resilience confidence at 3 days	Resilience confidence at 1 week
500	250 / 1003	800 / 900	$0	0%	0%
2000	1000 / 4000	800 / 3000	$4.96M	99.99%+	86%
4000	1500 / 6000	800 / 2000	$9.45M	99.99%+	87%
6000	2000 / 8000	800 / 900	$13.73M	99%	85%

For the New Odanah case, there is also a clear trade between battery capacity and tank size. Solar size also linearly increases as tank size decreases. This is because of the extra energy needed to consistently provide to the increased loads.

Figure 31 shows the detailed resilience performance for each case at durations up to 2 weeks (336 hours). Note that the large solar + storage / small generator tank shows significantly better performance at long outage durations, but since all of these cases have more reliance on solar than on the generator than the East Branch case, the difference is not as stark.

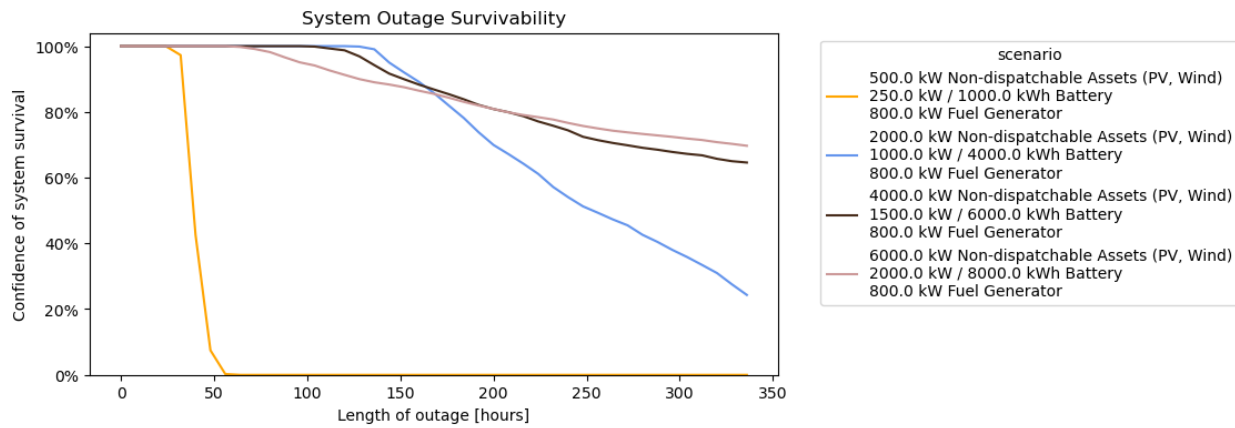


Figure 31. Resilience performance for New Odanah Design Cases.

Figure 32 shows the large battery case specifically, and demonstrates how much of the resilience duration is supported by solar plus storage.

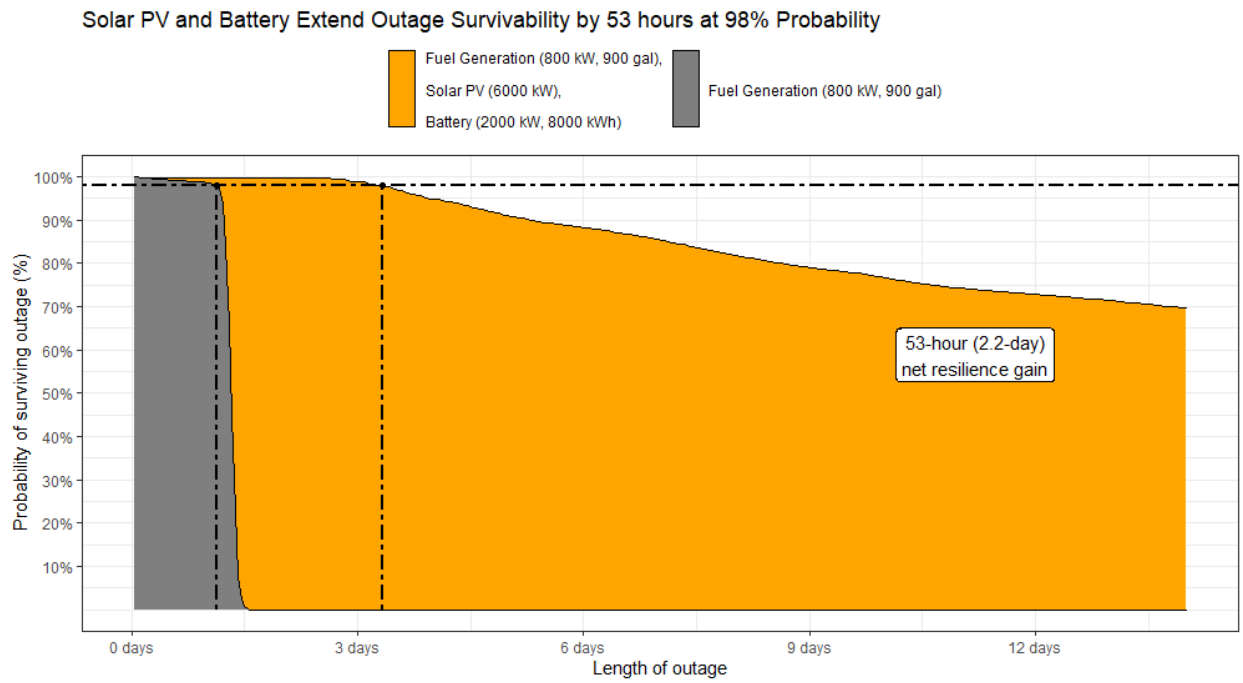


Figure 32. Solar + storage extend resilience performance of generator alone, large battery case.

On the other end of the spectrum, solar + storage still respectably extends the resilience duration of a large generator fuel tank with a smaller battery and solar plant, as shown in Figure 33.

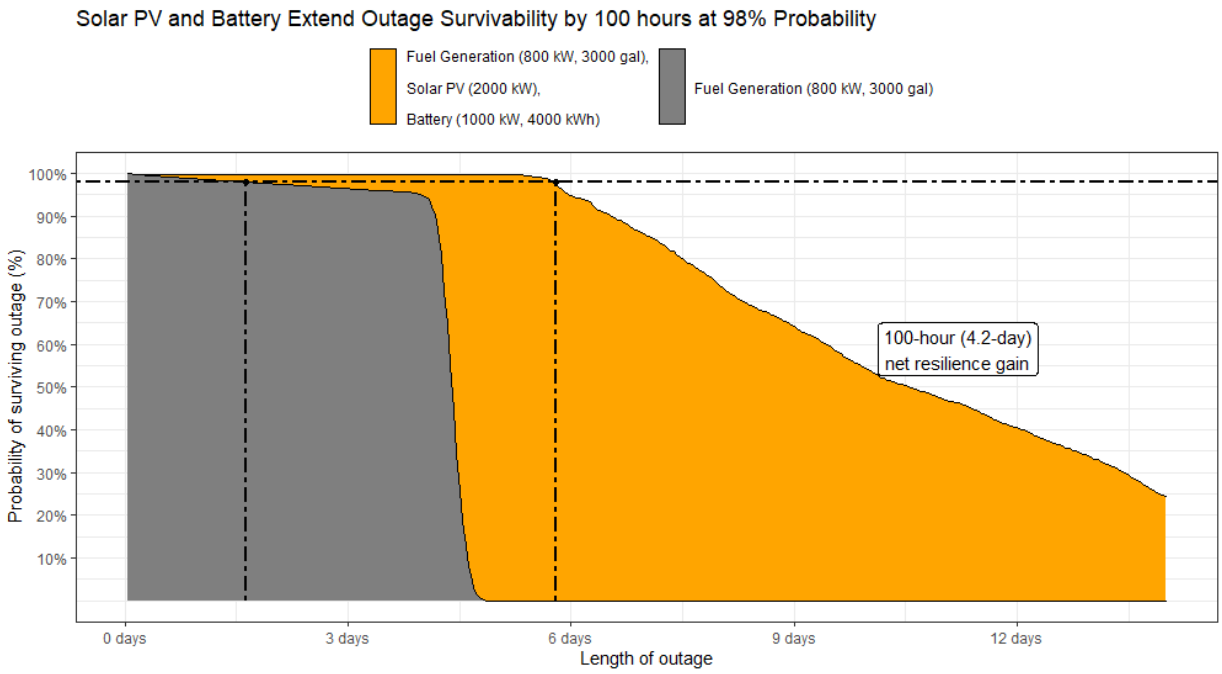


Figure 33. Solar + storage extend resilience performance of generator alone, small battery case.

Figure 34 shows seasonal resilience performance as simulated every hour of the year for each of the four design cases (including the base case) for the New Odanah "all branches" case. The days of the year are placed along the x-axis of each plot and the time of day is on the y-axis. These images show that for the cases that meet the resilience requirement, while requirements are met year-round, they are exceeded in spring and summer when solar is plentiful, particularly in the larger solar cases. Note that while Case 3 and Case 4 have very similar performance profiles, Case 3 is significantly less expensive.

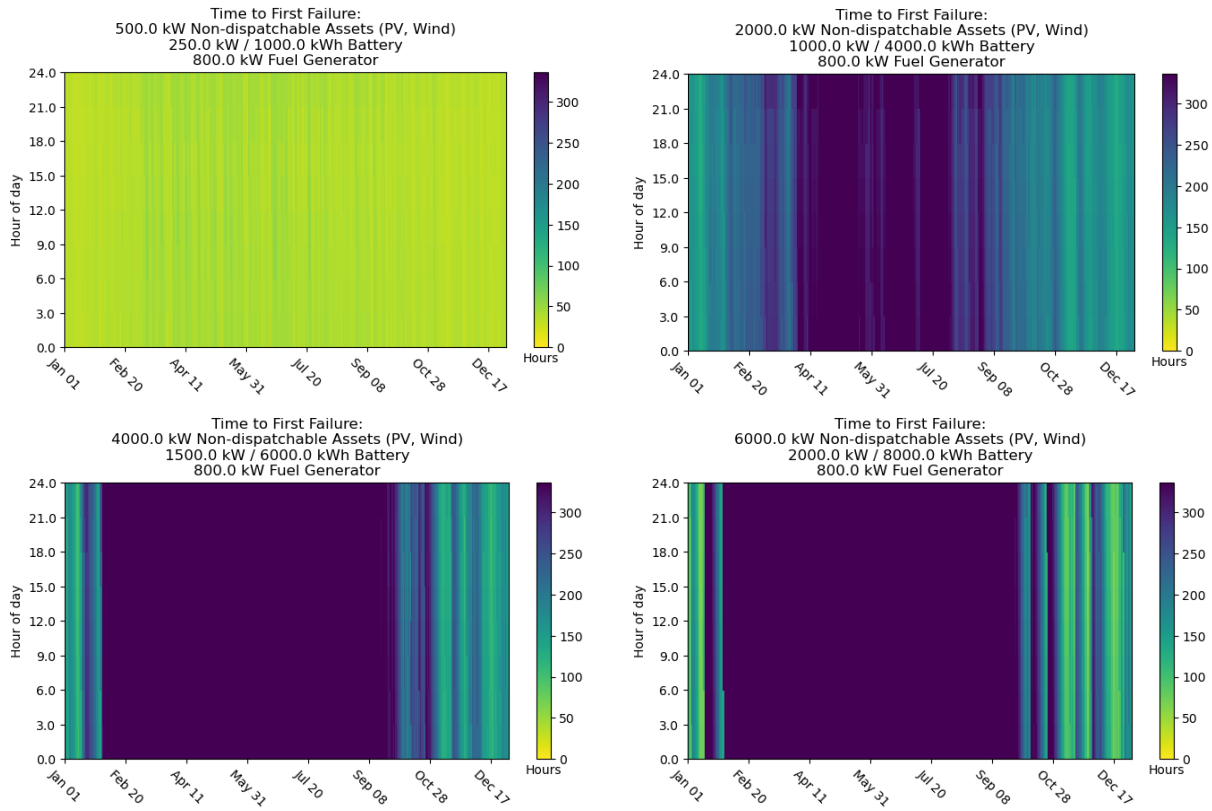


Figure 34. Seasonal Resilience performance for New Odanah Design Cases.

5.2.3 High level trends

Figure 35 shows a comparison between the battery capacity / tank size trade for both the East Branch and New Odanah cases. The East Branch case is, as expected, smaller than the New Odanah case, but both trendlines share a similar slope, meaning that this trade is relatively consistent and predictable and unlikely to have a knee in the curve.

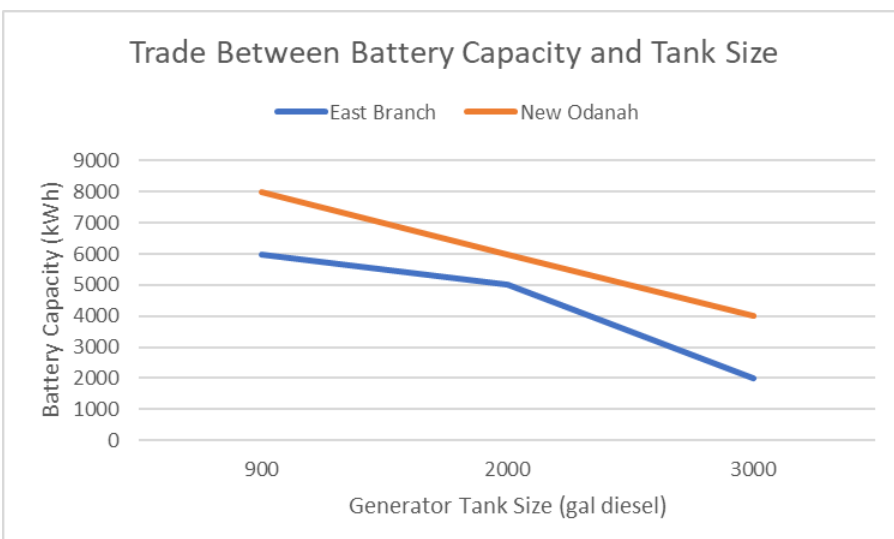


Figure 35. Trade between battery capacity and tank size.

Introducing solar size into the mix, we compare the ratio of battery capacity to solar power to the tank size. The East Branch case does not show a regular curve, because, as mentioned, the bigger tank sizes are in the range of the totally energy capacity that this collection of buildings need. A more interesting result is that the ratio of solar to battery capacity for the larger New Odanah case is linear, which shows a tight correlation between solar and battery sizing for a given tank size, when the load is large enough to require both renewable generation and fuel-based generation.

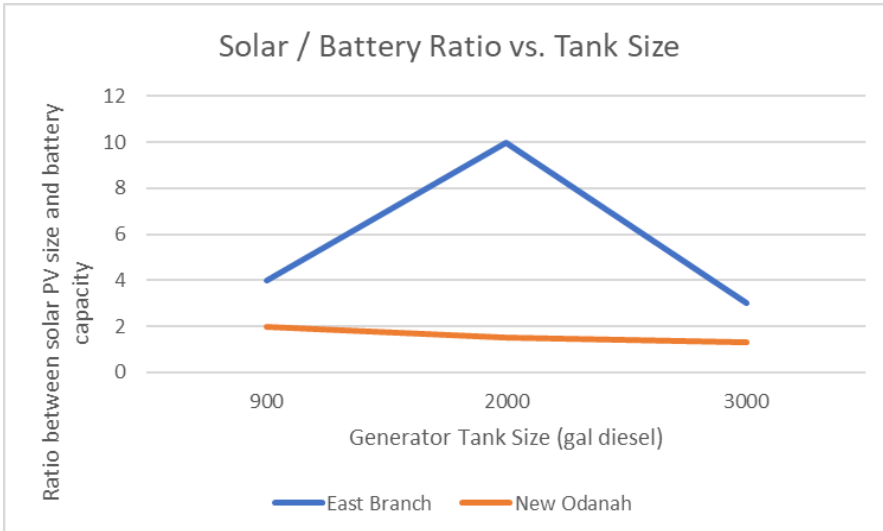


Figure 36. Solar-to-battery-capacity ratio vs. Tank Size.

In the following two figures, the New Odanah solution is shown for two example outages, one starting January 1st at midnight, and the other starting July 1st at midnight. Note that in the winter case, there is much less solar available and the generator (green) runs for longer periods. The opposite is true in the summer case. In winter there is little excess solar, and in the summer there is a substantial amount. In an islanded scenario, the excess solar is curtailed, and when grid connected it is sold back to Dairyland Power at the LMP rate.

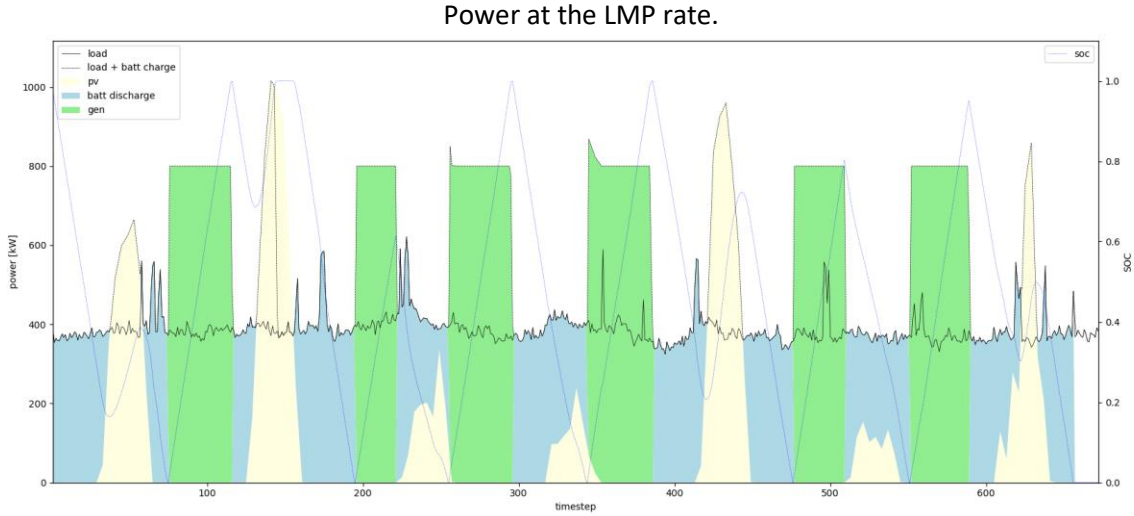


Figure 37. Outage Jan 1, New Odanah case, 4 MWh battery, 2 MWp solar, 800 kW genset 300 gal.

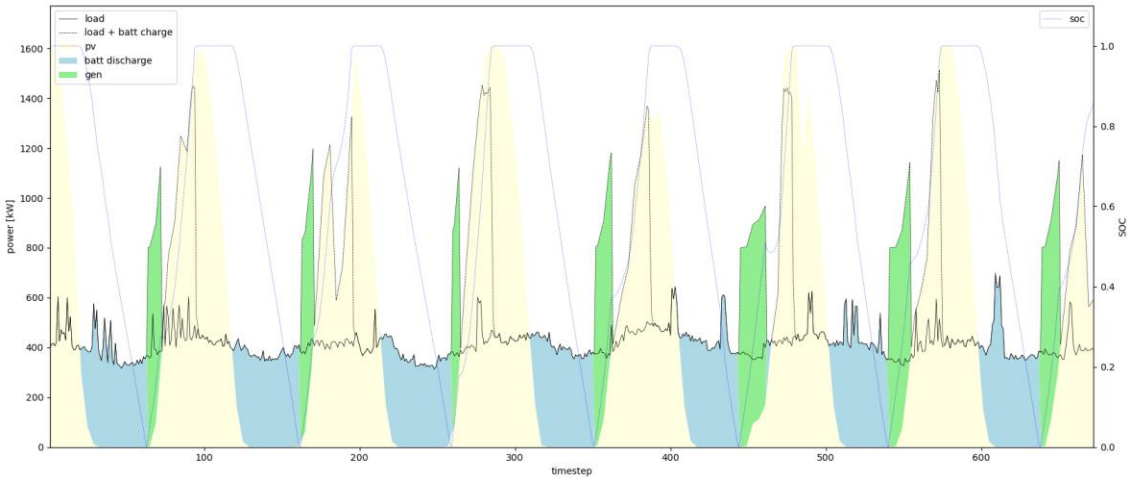


Figure 38. Outage Jul 1, New Odanah Case, 4 MWh battery, 2 MWp solar, 800 kW genset 3000 gal.

5.3 Microgrid Infrastructure

5.3.1 Microgrid Distribution Needs

A concept site plan for the New Odanah microgrid is shown below, where a section of the feeder (black) is interrupted by Switch 1 and 2 (switchgears), only during a grid outage, to connect the four branches of the microgrid. New solar PV and battery capacity is added at the Clinic, and possibly near the WWTP. Note that not all equipment and connections are shown, and the facilities including PV plants are not drawn to scale.

In the East Branch only case, only Switch 2 is required to isolate the branch from the feeder, which can re-energize at any time and supply downstream customers. A detail of the East Branch case is shown in Figure 39.

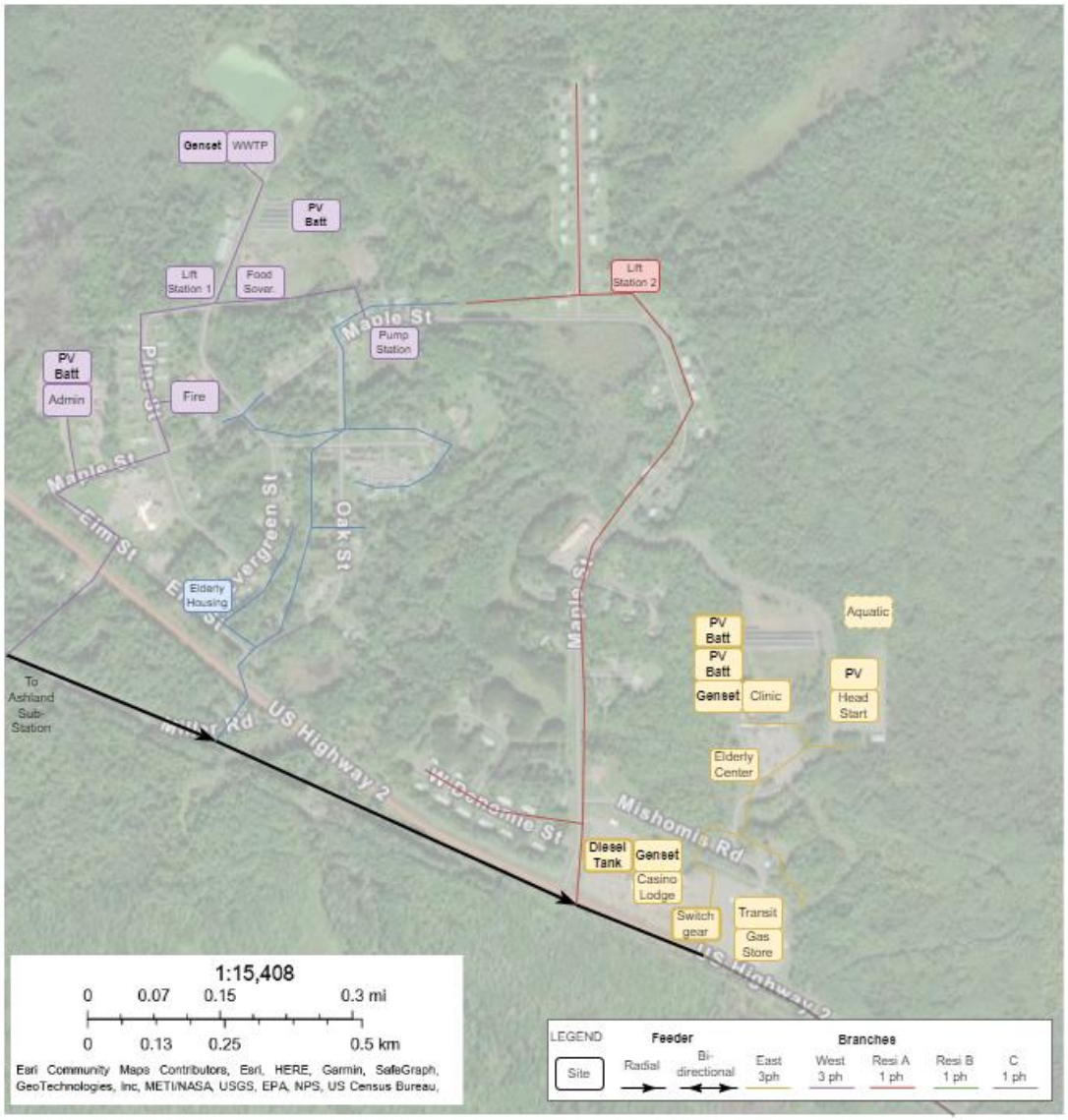


Figure 39. East Branch microgrid case.

New solar PV and battery storage are tied into the distribution network directly, not behind a meter. A microgrid controller is required to dispatch the battery and various generators, as well as continuously measure load power. While a “typical” microgrid controller may be adequate, more likely a basic distribution-level SCADA system will be required, for instance the SEL-3555 Real-Time Automation Controller. This is where the distinction between microgrid and minigrid becomes helpful.

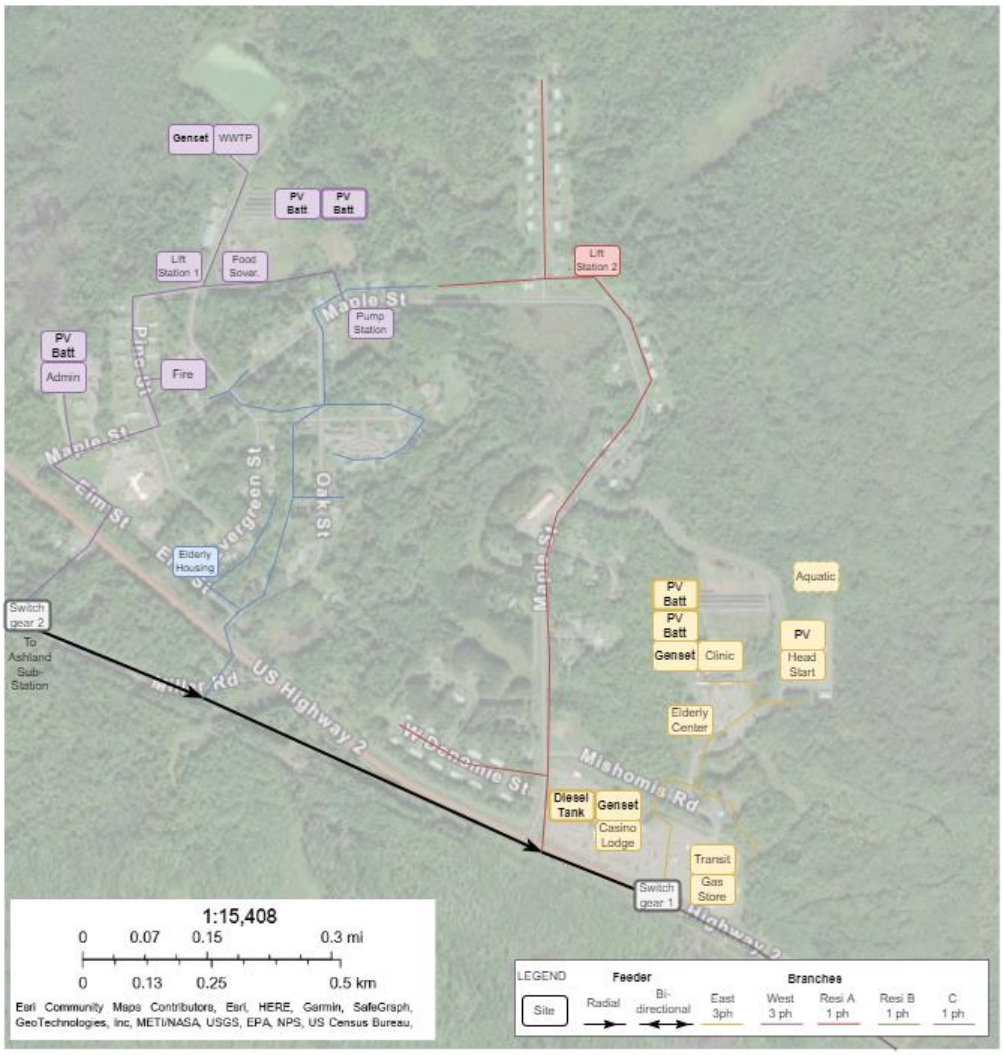


Figure 40. New Odanah microgrid case.

All or most buildings will be included in either microgrid topology. Any buildings that are connected to the distribution but will not be part of the microgrid must be switched-out with a motorized circuit breaker on the low voltage side, or a tie switch or recloser on the medium voltage side. An example is the aquatic center, which should be shed partially or entirely in a resilience scenario. The medium voltage switches will generally be more expensive; however, this will also mean fewer transformers on the microgrid in island mode. Transformers and large motors have a problem called inrush current, where it takes several times the normal operating current to initially energize the device. If the microgrid is temporarily de-energized – because the design involves an open transition of the switchgear, for instance – the generators and battery will need to supply all the normal operating load current plus the extra inrush current of all such devices.

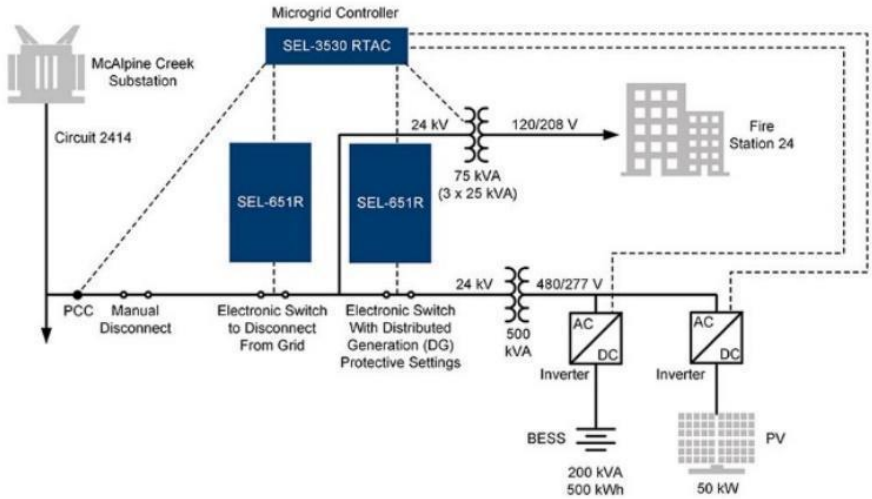


Figure 41. Example SEL-3555 Controller one-line.

Most buildings will need a power meter, or potentially entire branches can be metered. All these devices will need to be connected via a wired or radio comms network, with the protocol depending on the equipment chosen, but IEC61000 and DNP3 would be appropriate.

The distribution voltage is listed on some newer documentation as 13.2 kV, but the switchgear installation drawing references a 13200-4800 V transformer, so for the purposes of this study, the voltage is understood to be “medium”.

Figure 42. Example medium voltage switch.

On-load switches or reclosers will be required to isolate the parts of the grid that won’t be on the microgrid yet. The system will need meters to balance power flow, along with potentially some new circuit breakers. The system will require communication between most of the pictured devices, along with centralized control software and computers.

5.3.2 Microgrid in Islanded Mode

During a grid outage, or if another need exists, such as utility-requested demand response, the microgrid will disconnect from the BEC network at the switchgear or very nearby if that is not possible. The microgrid controller will change to island mode operation and open up any isolation switches included in the design (to remove buildings not in the microgrid). The microgrid controller will then begin to turn on the minimal possible number of generators, starting with the largest. At the point when the controller deems there to be enough solar power to serve the island load, it will stop turning on generators. Battery power will most likely be saved only for resolving peaks. This control strategy scales well for larger solar and battery plants, because simply fewer generators are turned on.

5.3.3 Microgrid in Grid-Connected Mode

Normally, without a grid outage, the microgrid controller will keep all isolation switches closed and not turn on the generators. In fact, most of the generators will not be capable of "paralleling" with the grid due to the Tribe's interconnection agreement. Instead, solar will be first dispatched to serve the load and next any available battery power, but only when the controller deems optimal. This would most likely be for demand reduction.

One technical issue affecting grid-connected operation is power quality. The Tribe reports many short outages, possibly lasting only a few seconds, and damage to equipment. Some of these outages also may be only one of three phases. For these reasons, the utility usually won't classify these problems as "blackouts" as defined by the regulator or have data on them, even if the power does go to zero briefly. Instead, these are often referred to as power quality problems. Power quality and short outages are summarized in section 2.3.

Depending on the type and duration of power quality problem, the microgrid switchgear relay may not detect a grid outage or may not be quick enough to make a difference. The microgrid relay can be adjusted to become more sensitive, but this often results in nuisance tripping of the relay. Therefore, muGrid's recommendation is to conduct a dedicated power quality study, dialogue with the utility, and the appropriate measures which may include specific devices such as UPSs, simple line filters, or more sophisticated electronic line conditioners. The Fluke 1770 series of three phase power quality analyzers are typical and appropriate for such a study.

5.4 Economic Analysis

5.4.1 Capital Costs

We assessed the capital cost of each proposed design. DER asset costs scale with the capacity (kW or kWh) of the asset, at least within the range considered in this study. Controls costs however do not scale in this way, but are considered fixed costs for a given distribution topology and complexity.

5.4.1.1 Assets

We estimated battery capex at $1000/kWh and ground mount solar at $1500/kWp. The battery cost is especially volatile, possibly ranging +200/-50% depending on the specific project and battery size. Further complicating battery cost estimates is uncertainty in what balance of systems is included –

wiring, panels, foundation, etc. In our estimate, we assume a container with HVAC and commissioning but no other balance of systems. The solar cost should be much more accurate, as the industry matures and cost data becomes public. More information about the distribution system, a detailed engineering design, and vendor quotes will result in a better cost estimate.

5.4.1.2 Controls

The controls and switchgear costs can vary significantly and depend on the result of a detailed engineering study of the required grounding and protection systems. Controls costs don't scale with the solutions presented in this section, unless the distribution area changes substantially. That is only the case when considering the entire New Odanah neighborhood rather than just the East Branch circuit. Therefore, two very rough budgetary estimate costings are provided, but a further engineering study is required considering the unique requirements (especially of the New Odanah case) and the remote location.

Table 15. Controls capital costs.

	Capital cost [$]
East Branch	250,000
New Odanah Neighborhood	1,500,000

5.4.2 Behind-the-meter savings analysis

There are generally two options for interconnecting distributed energy resources such as solar and storage – they can be connected behind-the-meter or front-of-the-meter.

Behind-the-meter assets generate savings by allowing the customer to generate some of their own electricity, and thus avoid buying that amount from the utility. The amount of electricity that they would have normally bought, but didn't, is the savings. These assets can also reduce the peak demand charges at the site, and similarly the lower peak demand charges on the monthly bills are the savings. The key to a behind-the-meter asset is that there needs to be an existing electrical load such that the load can be reduced.

The savings from a behind-the-meter asset depends on which rate tariff the meter is on. For the 6LP rate tariff, the savings is 10 cents per kWh. Meanwhile for the 5 TPH rate tariff, the savings would be 15 cents per kWh. The assets could also reduce demand charges, and the savings there would be $10.10 for each kilowatt reduced per month in the winter, and $12.10 per kilowatt in the summer months. A key point to keep in mind here is that BEC does not offer net metering for systems of this size. Therefore, any electricity exported to the grid is compensated at the spot price, which varies by the season, day, and hour.

5.4.3 Front-of-meter savings analysis

As the name implies, front-of-meter assets are connected in front of the customer meter. These assets have no load associated with them; they export 100% of their production to the grid, and the utility pays them for this energy. (Technically, these assets will be located with a production meter, which is used to accurately measure the amount of electricity produced. The key is that this is a dedicated meter, with no inherent load associated with it).

The compensation rate for front-of-meter systems is not so straightforward to estimate because it is often negotiated with the utility. Utilities generally buy the electricity that they distribute from suppliers (such as Dairyland Cooperative, in the case of BEC) so the energy being injected onto their grid from a front-of-the-meter system allows them to avoid buying some of that electricity, similar to how a behind-the-meter system allows the customer to avoid buying some amount of electricity from the utility.

The value of the electricity to the utility depends then on what the cost would have been for them to buy this electricity from their supplier, or on the market. A good proxy for this would be the day-ahead spot market at the DPC.DPC node. This is the rate that BEC and Dairyland compensate for exported solar from the existing microgrids.

We would expect that the spot rate would be the starting point *from the utility's perspective* during negotiations. In other words, it should be a lower bound on the possible compensation rate. It may be possible for the Tribe to negotiate a higher rate for the compensation.

5.4.3.1 Example front-of-meter compensation analysis (solar only)

To begin to quantify the monetary value of production from a front-of-meter array, we considered the actual hourly DC production of the solar at the WWTP from May 2021 to Feb 2022 (which is all the data that EnTech provided). We converted this to AC by assuming the inverter is 86% efficient. We then assumed that this production was entirely and immediately exported to the grid and compensated at the day-ahead spot price. To calculate the monthly compensation, we simply multiplied the hourly production (kWh) by the hourly day-ahead spot price at the DPC node.

Table 16 shows the actual solar production from the WWTP for the 10 months during which data was available. The second column shows the compensation, while the third column shows the average $ / kWh compensation rate. (Note that this is simply the average).

Table 16. Actual solar production data from WWTP.

Month	DC Production [kWh]	AC production [kWh]	Compensation at the spot price (if 100% exported)	Avg $ / kWh
May-21	26,061	22,412	$ 731	$ 0.033
Jun-21	32,566	28,007	$ 1,594	$ 0.057
Jul-21	33,067	28,437	$ 1,494	$ 0.053
Aug-21	29,561	25,422	$ 1,434	$ 0.056
Sep-21	26,470	22,764	$ 1,443	$ 0.063
Oct-21	33,067	28,437	$ 1,863	$ 0.066
Nov-21	9,606	8,261	$ 464	$ 0.056
Dec-21	4,082	3,511	$ 136	$ 0.039
Jan-22	6,212	5,343	$ 252	$ 0.047
Feb-22	14,552	12,514	$ 602	$ 0.048
Mar-22				
Apr-22				
Total	194,479	167,252	$ 9,156	$ 0.055

The overall average for the 10 months where data is available is 5.4 cents / kWh.

To simulate a complete year, we then copied the data from September and October into the missing April and March rows, respectively. We note that this is a very crude approximation, but in the absence of the actual data, it seems reasonable.

Now we see that the average compensation over the course of the year – assuming that 100% of the production is immediately exported to the grid and compensated at the hourly day-ahead spot price – is 5.6 cents / kWh. We should reemphasize that this is a market rate, meaning that it will have significant volatility. The key question is whether the current upward slope (the spot price has doubled in the past 2 years) is an anomaly or a trend.

Finally, we note that the production factor is 1,182 kWh / kWp. (Again, this is an approximation because we did not receive the production data for March and April).

Table 17. Estimated full year analysis for solar only market export.

Month	DC Production [kWh]	AC production [kWh]	Compensation at the spot price (if 100% exported)	Avg $ / kWh
May-21	26,061	22,412	$ 731	$ 0.033
Jun-21	32,566	28,007	$ 1,594	$ 0.057
Jul-21	33,067	28,437	$ 1,494	$ 0.053
Aug-21	29,561	25,422	$ 1,434	$ 0.056
Sep-21	26,470	22,764	$ 1,443	$ 0.063
Oct-21	33,067	28,437	$ 1,863	$ 0.066
Nov-21	9,606	8,261	$ 464	$ 0.056
Dec-21	4,082	3,511	$ 136	$ 0.039
Jan-22	6,212	5,343	$ 252	$ 0.047
Feb-22	14,552	12,514	$ 602	$ 0.048
Oct-21	33,067	28,437	$ 1,863	$ 0.066
Sep-21	26,470	22,764	$ 1,443	$ 0.063
Total	194,479	167,252	$ 9,156	$ 0.055
kWh / kWp	836			

5.4.3.1.1 Front-of-meter solar + storage savings analysis

The preceding analysis assumed that 100% of the solar production was immediately exported and sold to the utility at the day-ahead spot price at the DPC node. But there is actually significant variability in the spot price, meaning that the Tribe could potentially make more money if they were to strategically discharge the battery during hours when the compensation is higher. This is possible because the compensation rate is the *day-ahead* spot price, meaning that the Tribe would know the night before,

with full certainty, which hours will have the highest spot price the next day. Then it is a matter of having the battery charged and ready to discharge during the most lucrative hours.

This is illustrated in Figure 43 where the blue line shows the solar production curve for October 8, 2021. The yellow dots show the DPC day-ahead spot price. The solar production peaks before the spot price peaks for the day, indicating that if the solar energy was stored in the battery, it could be discharged later the same day when the spot price is higher.

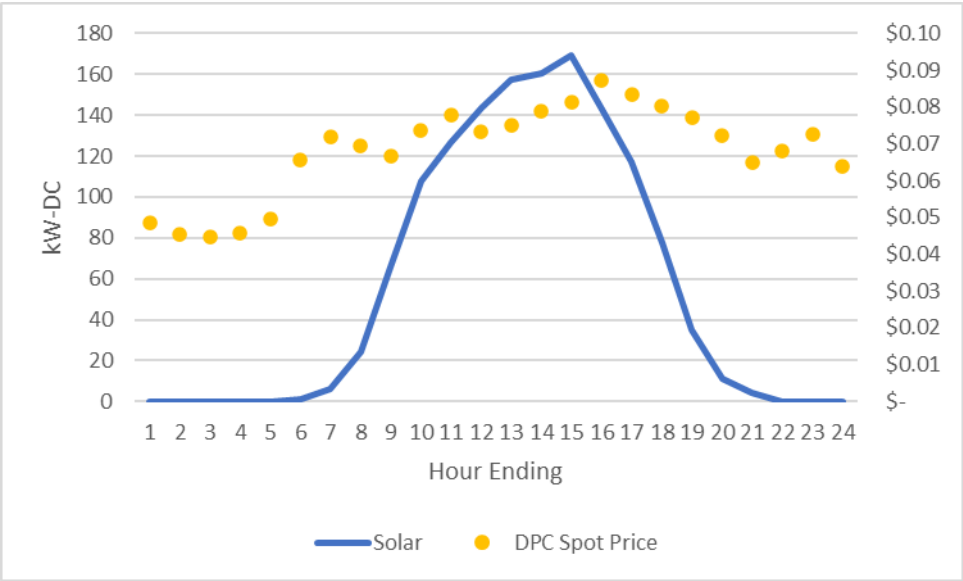


Figure 43. Solar availability vs. Spot price.

5.5 Environmental Impact

5.5.1 Renewable Generation

At first blush, estimating environmental impact and carbon savings for renewables-based microgrids seems simple: solar generates zero-carbon energy. Calculate the estimated solar production from the array and use the EPA Greenhouse Gas Equivalencies Calculator to estimate carbon reductions. Indeed, this is the method with which we begin.

Carbon offset generally scales linearly with solar size for the same geographic location, spacing, and tilt. Therefore, we can show the curve for carbon offset at New Odanah in Figure 44.

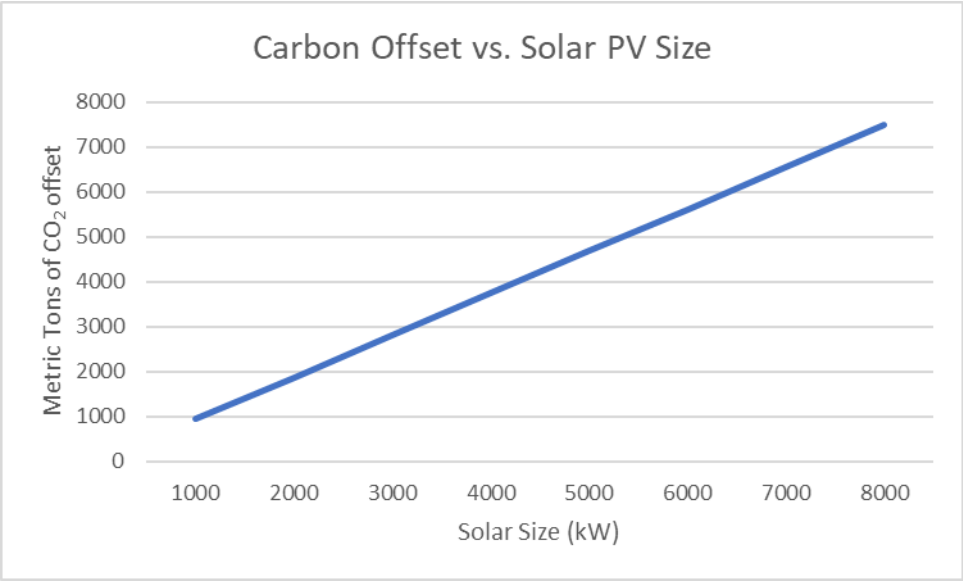


Figure 44. Carbon offset vs. Solar PV size.

5.5.2 Holistic Impact Analysis

In addition to simple energy accounting, however, the objective of environmental impact assessment is to consider the broader community involved in the microgrid, and as such, we must consider a broader perspective of environmental impact. Tribal members already promote a culture and ethos of stewardship – a responsibility and dedication to working in symbiosis with the resources of land and water. The Tribe will think holistically about the systems-level environmental impacts instead of limiting the scope to the source of their kilowatt hours.

When setting holistic carbon goals, the first and most important thing to consider is the system boundaries. We may calculate the site's environmental impact as the impact of its electricity alone, the building as a whole, the building plus the people in it, the cars in the parking lot, etc. Impacts stemming from these various system boundaries may include:

- Total building usage and building efficiency
- Emissions from building heating and cooling systems
- Emissions from other processes internal to the building such as cooking or manufacturing
- Emissions due to the length of building occupants' commutes
- Emissions due to the number of electric vehicles using the facility
- The mix of technologies (fuels-based vs. renewable vs. carbon free) of the generation coming from the utility to the building
- And more.

Some of these items, like the length of occupants' commutes, may seem hard to control or even to accurately quantify. However, behavioral items can become part of overall community goals by allowing and encouraging carpooling, public transit, and work-from-home.

When setting carbon goals for a community, it is easier to take these holistic effects into account. It is important for the community to clearly define its boundaries, to identify what the community "counts" in its own carbon footprint and circle of responsibility.

Sources of electricity generation are certainly a part of this holistic analysis – and may be an increasing part as building and vehicle electrification continue – but it is not the only part to consider.

As with any metric, we recommend starting with a baseline – what is the carbon footprint today? How was that footprint measured? What was included and what was left out? From that baseline, and knowing what was included to derive it, the Tribe can set carbon targets and develop strategies for both technical and behavioral solutions to meet those targets.

We highly recommend conducting energy efficiency studies at all buildings and performing building management or load balancing optimization at the large buildings to ensure that the building is running at peak performance before layering on technological solutions. This may include load scheduling similar to that which is discussed in section 4.4.1.

5.5.3 Circular Economy

Another component of holistic environmental impact, especially when it comes to technological solutions like microgrids, is the total life cycle of the equipment. That is, we must ask where the raw material came from and how the equipment was manufactured. We must also ask where the equipment will go after it is no longer needed or no longer working.

Asking where the material comes from has long been a question in the lithium-ion battery industry, especially for NMC chemistries that rely on cobalt, which is rare and often unethically sourced. Luckily, lithium iron phosphate (LFP) along with other non-lithium chemistries on the horizon use more abundant materials with lower extraction impacts and also higher recyclability. Solar panels and battery modules are still largely manufactured in China, where a large percentage of power is still produced using coal and other fossil fuels. This is also changing, as the global interest in renewable energy generation increases and global awareness of manufacturing sustainability increases. The Tribe may or may not yet be able to select all technologies that have a "clean" supply chain. Yet, an awareness of the issues and a willingness to stay at the forefront of technology developments will help, both of which the Tribe has already demonstrated in spades.

End-of-life planning for energy projects is something that is much more controllable. Some in the energy industry now believe that all projects should have an end-of-life plan included as part of their initial design documentation. This is relatively new thinking for the industry, even since the Ishkonige Nawadide projects of 2020. For end-of-life planning we ask:

- Can any equipment be reused? (If yes, what is the path to reuse?)
- Can any part of this equipment be recycled?
- Of the parts of this equipment that go to a landfill, is there anything that could be toxic?
- Of the parts of this equipment that go to a landfill, how fast will they break down?

It is not clear how participating in the circular economy can be accounted in a "carbon target". However, it is undoubtedly an important part of considering the environmental impact of a technological solution.

6 Conclusions

6.1 Key Takeaways

The following are the most important takeaways from this study:

-- Before pursuing additional generation, we recommend that the Tribe conduct energy efficiency audits, implement load scheduling, and implement additional energy efficiency measures across their portfolio of buildings.

-- The dynamics of meeting the resilience requirements for this microgrid project are more about energy sufficiency than about power.

--The Tribe will need to decide on a strategy going forward in the near term: whether to continue deploying individual microgrids at each building, which can be aggregated together, or to take a more central-plant approach with a single feeder-level solar plus storage plant that can back up the entire feeder. We generally think a consolidated front-of-meter central plant microgrid makes sense.

-- If considering a single feeder level solar plus storage installation, the Tribe should consider battery inverter sizes of at least 500 kW to meet power requirements, given the sizing of existing generators already located on the feeder. Larger battery inverter sizes will allow for more load growth in the future, and we generally recommend a battery inverter of 1 MW for both the East Branch microgrid and the full New Odanah microgrid.

-- If considering individual microgrids at each building to aggregate later, we will need to pay close attention to the aggregation to ensure adequate peak coverage as well as synchronization between dispersed battery systems.

-- To meet the energy needs of the microgrid and the resilience duration, there is a clear trade between the battery capacity / solar PV plant size and generator tank size. Enlarging the generator fuel tank will always be less expensive, but the Tribe may value the benefits of solar and storage more highly. This is a trade that should be made with community discussion. There is no apparent “knee in the curve” for meeting the resilience requirements as written. These options are also not mutually exclusive – the generator fuel tanks could be enlarged along with adding additional solar.

-- That being said, solutions that favor more solar and storage generally have better resilience performance at durations longer than 1 week versus those with a larger fuel tank. Higher confidence at longer durations may be of interest to the Tribe, along with greater sustainability from renewable generation.

-- The revenue potential of a front-of-meter solar plus storage system will depend on selling electricity back to the grid and being compensated at the day-ahead spot price. Strategic control of the battery discharge will allow the Tribe to maximize revenue potential by time-shifting some of the solar energy to more lucrative hours of the day (such as the evening.) Other revenue streams for the battery may include providing demand response or other grid services and being compensated for doing so. These opportunities are not yet available with BEC and Dairyland, but may soon be an option.

-- When the Tribe eventually forms a Tribal Utility Authority, they will be generating their own power on the reservation and importing additional power as needed that they buy on the wholesale market. This

front-of-the-meter microgrid project would then be located inside the TUA, but would still be offsetting wholesale rate electricity that the Tribe would otherwise purchase on the market.

-- While we were able to install a fleet of data loggers to collect actual operating data for this study, due to the time constraints of the study, we only collected a few months of data. It would be beneficial to revisit the study results after a full year of high-resolution interval load data has been collected.

-- Additionally, data transfer processes for the existing microgrids from EnTech to the Tribe and to the analysis team have not been fully developed. We believe the Tribe would benefit from a smoother, more consistent data transfer process.

-- To move this study forward into implementation, especially as the Tribe considers forming a Tribal Utility Authority, we acknowledge that basing analysis on load data from a single year may have limitations. We recommend statistically varying load and production estimates to ensure coverage of outliers in future studies.

-- In addition to the deployment of data loggers, other advanced metering technology would also be helpful. Bayfield Electric Cooperative has begun the roll out of smart meters at tribal facilities, but it has not been completed at the time of this writing. Smart meter installation would provide validation to the load data itself as well as to billing.

6.2 Next Steps

Building on the success of this initial site assessment study, the Tribe is well positioned to advance their long term energy vision and to move toward more comprehensive energy sovereignty. The work performed in this study can form the foundation of a phased plan to gradually deploy energy systems that work together so that the whole is greater than the sum of the parts. Developing the physical, distribution, and operational architectures, rough asset mix and system sizing, and control methodology for these community microgrids is a critical step toward realizing the tribal vision of energy sovereignty "for the land, the water, and the people."

muGrid Analytics looks forward to supporting the Bad River Band in continuing to achieve their energy goals.

6.2.1 Next Data Collection Steps

The effort to collect and aggregate data is not yet complete. We recommend that the Tribe:

- Advocate for the accelerated rollout of smart meters by BEC
- Advocate for collection and timely sharing of high-resolution interval data at the three existing building-level microgrids from EnTech
- Continue to monitor and collect data from the eGauge data loggers that were installed as part of this study
- Acquire a power quality analyzer to conduct a dedicated power quality study, dialogue with the utility, and install appropriate mitigation measures which may include specific devices such as UPSs, simple line filters, or more sophisticated electronic line conditioners. The Fluke 1770 series of three phase power quality analyzers are typical and appropriate for such a study.

6.2.2 Next Policy Steps & Architectural Decisions

The most important next steps are those around policy and the broad architectural decisions that represent the Tribe's overall energy goals and desires. A major design decision will be to choose which buildings are included in the microgrid, a decision which is guided by overall tribal goals and the capital costs to implement. A phased approach plan to gradually incorporate facilities could be considered, but integration into a larger, feeder-based microgrid will be an important design consideration. Based on the large amount of existing fuel-based generating capacity, we recommend planning to include all buildings in the microgrid in the near term. Compared to the high fixed cost of the controls, switchgear, and networking to install a community level microgrid, the incremental cost to include individual buildings is low.

Other imminent policy discussions may include

- Identifying funding sources for project implementation. Funding sources and levels may influence how energy project implementation is phased.
- Identifying siting opportunities for larger-scale solar. The location for a multi-megawatt solar plant has already been an area of discussion for the Tribe. We recognize that the Tribe is considering not only generation adequacy, avoidance of flood plains, and proximity to loads as described in this study, but also considering impacts to the land and natural environments that they steward.
- Heating strategy. In this study, we focused primarily on electricity generation, storage, and distribution, including maximizing use of previously existing assets. Because heat is an important component of energy consumption on the shores of Lake Superior, we recommend that due consideration is given to heating strategy (including potential electrification of heating and/or combined heat and power generation), especially in light of these study results.
- EV charging approach. In this study, we considered the impact of fleet EV charging for public transit busses. A broader discussion including further fleet electrification as well as public EV charging would help shape the future EV charging needs and can be included in the next iteration of more detailed design.

6.2.3 Next Analytical Steps

Once architectural decisions are made about solar PV and battery siting and placement with relationship to the meter, as well as the potential inclusion of other revenue streams like CHP, more detailed economic analysis may be conducted, which could shed light on another potential "knee in the curve" that could guide the design trades.

The Tribe may desire refined analysis once comprehensive interval load data is collected from the data loggers (installed as part of this study) for at least one year. As the Tribe continues to move toward a goal of forming a Tribal Utility Authority, which will require increased reliability, they may also consider conducting analysis with statistical variations in load and renewables production.

6.2.4 Next Implementation Steps

In order to move the implementation of the New Odanah microgrid forward, the Tribe may consider whether it would be advantageous to continue rolling out DERs at individual facilities, in preparation for integration into a larger, feeder-based microgrid. We recommend continuing to work with facilities on the East Branch, as well as expanding DERs at identified critical facilities on the West Branch as well.

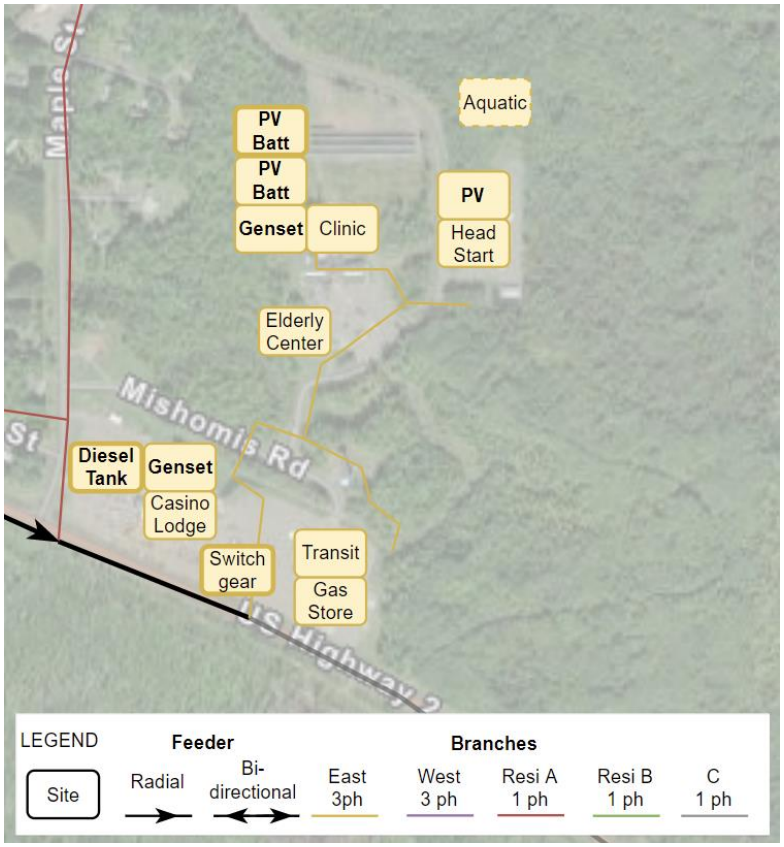


Figure 45. East Branch Community Microgrid.

Moving forward to install a larger scale solar array has been a near-term item on the implementation plan for a while now, and we recommend moving forward with identification of siting for such an installation, since it will form a critical piece of the future microgrid, and can provide economic benefits now.

The rest of the implementation strategy is highly dependent on the policy decisions made in section 6.2.2, so we recommend determining concrete implementation plans and actions as part of the outcome of all policy and architectural discussions.

Once key architectural decisions are made, the next step towards implementation is a detailed engineering study to design the major energy assets, interconnections, switchgear, centralized controller, and communication networking needs. Such a study will provide a more refined cost estimate and help the Tribe match up the project to available grant opportunities.

Opportunities for De-Carbonizing the Bad River Band of Lake Superior Tribe of Chippewa Indians' Electricity Resources

June 2022

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Abbreviations

AC	Alternating Current
BEC	Bayfield Electric Cooperative
BESS	Battery energy storage system
DA	Day ahead
DC	Direct Current
DG	Distributed Generation (terminology used by BEC)
DPC	Dairyland Power Cooperative
DR	Distributed Resources
FERC	Federal Energy Regulatory Commission
FMV	Fair Market Value
IRS	Internal Revenue Service
ITC	Investment Tax Credit (federal)
kW	Kilowatt (1000 watts)
kWh	Kilowatt hour (1000 watts used for an hour)
LLC	Limited Liability Corporation
LMP	Locational Marginal Price
LNG	Liquified Natural Gas
MISO	Midwest Independent System Operator (operates the central US transmission grid)
MW	Megawatt (1000 kW)
MWh	Megawatt hours (1000 kWh)
PPA	Power Purchase Agreement
PV	Photovoltaic (solar electric system)
Tribe	Bad River Band of Lake Superior Tribe of Chippewa Indians
TUA	Tribal Utility Authority
TUP	Tribal Utility Partnership
RE	Renewable or Renewable Energy
RECs	Renewable Energy Credits
ROW	Right of Way
UPS	Uninterrupted Power Supply
WWTP	Wastewater Treatment Plant

Definitions

Ancillary grid services = distributed resources can provide a host of valuable services (i.e., ancillary services) to the grid to better ensure it safe and reliable operation. These services include active power control or frequency control and reactive power control or voltage control, on various timescales. Some utilities pay DR owners for these services.

Avoided cost (of electric power) = The cost the electric grid avoids, including generating, transmitting, and distributing electric power, when a behind the meter distributed resource (DR) puts power onto the grid. The avoided cost is generally set, by the electric utility industry, equal to the locational marginal price (LMP).

Behind the meter = Electricity generating, and storage distributed resource (DR) systems located behind the utility owned electric meter at the electricity customer's site or building. The generation and/or storage system is connected into the building's/site's electric panel and offsets the site's power use. If the generation meets all site power needs, it then supplies any excess to the grid.

Beneficial electrification = The decarbonization of the energy sector will require all consumers to stop using fossil fuels while increasing their use of renewable-sourced electricity as efficiently as possible. The conversion to efficient electrical devices is called "beneficial electrification". Examples of beneficial electrification technologies include heat pumps (air, ground and water-sourced) for space and water heating and air conditioning, and electric vehicles.

Clipping = When a generator produces more power than the inverter can use. That power is lost to "clipping". Photovoltaic (PV) systems commonly have clipping losses, particularly on cold clear bright sunny days – when the PV modules operate at maximum efficiency and wire losses are minimized.

Community distributed resource = Distributed resource development strategy that allows groups of consumers to purchase "subscriptions" to a central DR facility and receive credit on their electric bills for the energy it produces. The central DR facility is constructed for multiple customers, who each subscribe to a portion of the project. These consumers continue to purchase their electricity from their utility but receive a credit on their utility bills for the energy that is produced by their portion/ownership-share of the solar facility. To date, the majority of the community distributed resource projects are PV systems (aka solar gardens).

Community scale = Distributed resource (DR) projects of roughly 1 MW to 5 MW AC

Distributed resources = Smaller generating systems (generally under 10 MW), storage systems and other resource (e.g., demand reduction opportunities) which are distributed within the

electric distribution system. In contrast to utility-scale power plants, which are usually much larger (e.g., 100 to 1000 MW) and connected to the electric transmission system. Distributed Resources may include:

- Solar photovoltaic (PV), power generation
- Wind, power generation
- Biomass firing/gasification boilers, heat and/or power generation (combined heat and power)
- Biogas firing, heat and/or power generation (combined heat and power)
- Biogas cleaning, producing renewable natural gas (RNG) suitable for pipeline injection, boiler firing, heating, power generation, combined heat and power, and storage
- Hydrogen production, using electrolysis to create hydrogen from splitting water[1].
    - Hydrogen use: fired in a boiler for space heating, water heating, industrial or in a combined heat and power plant or used in a fuel cell to generate electricity
- Electricity storage, batteries, and similar, power storage, demand cost reduction, arbitrage, providing ancillary grid services, resilience
- Cryptocurrency mining and sales – using excess/low-cost electricity to create income
- Nuclear, safe, small, modular, power generation and heat production
- Demand reduction opportunities, such as air conditioning systems that can turn off or reduce their operation when the electric grid is taxed

Electric meter aggregation = Electric meter aggregation allows multiple meters on one premise, owned by one customer, to be aggregated for net metering or parallel generation purposes.

In-front of the meter = Electricity generating, and storage distributed resource (DR) systems connected in front of the utility-owned electric meter. The generation and/or storage system is connected directly to the electric utility's distribution system not to a customer's electric panel.

Locational marginal price = The real time cost of providing one more kilowatt hour kWh of electricity to the power grid. It depends on the location and thus reflects transmission constraints. Commonly used to determine the avoided cost of electricity.

Net metering[2] = A policy that values the electric power that behind the meter renewable DR to put onto the utility grid at the customer's retail electric rate. Typically, the amount of power put onto the grid is limited. Example net metering limits include no more than 120% of the site's use, no more that the site's monthly use, or no more than the site's annual use. Excess generation is typically valued at an avoided cost/LMP related price. In Wisconsin, the net metering cap is typically 20 kW AC but can be as high as 100 kW AC (Xcel and Madison Gas and Electric) and 300 kW AC (We Energies). The Bayfield Electric Cooperative recently changed their net metering cap from 0 kW DC (i.e., net metering is not available) to 90% of the site's annual electricity use.

[1] Tribes in the Southwest USA are starting to talk with hydrogen producers about selling their water rights.
[2] Can also be called net energy billing

Net metering tariff = The electric rate sheet that described the utility's net metering policies.

Master metering = When one utility-owned electric meter, typically in tenant occupied buildings, measures the electricity use of multiple apartments, condos, or other leased or rented units and common area. The whole building's power use is metered using the master meter. The building's electric bill is based on that meter. The building owners becomes responsible for paying the electric bill.

Microgrid = A group of interconnected electricity consumers with their own distributed resource able to operate separately from the electric utility grid (e.g., when the grid is down).

Parallel generation = A generator that is sited behind a customer's electric meter and generates power while the grid is also generating power. Thereby, generating power in parallel with the electric grid.

Power purchase agreement = The legal contract detailing the price at which, and other details, the distributed resource provides power to the power purchaser (customer). The distributed resource can be owned by the Tribe, a third-party owner, other owners, or a partnership. The power purchaser, or customer, is typically the transmission utility if the DR is connected to the transmission system, the distribution utility if connected to the distribution system, or the site owner if connected to a site's electric panel (on the customers side of the meter).

Parallel generation tariff = The electric utility rate description for power that the customer-sited generator provides to the grid for a distributed resource that is larger than net metering. Typically, power provided to the grid is valued at an LMP/avoided cost related price, negotiated with the utility, or zero.

Renewable energy credit (REC) = Every megawatt hour (MWh) of renewable power produces both 1000 kWh of power and 1 REC. A REC values that the power was generated from a renewable source. RECs can be sold separately from the power itself often under longer term contacts (10 to 20 years). But then the power originally sourced from a RE generator is no longer renewable (as that attribute was sold).

Third-party ownership (of distributed resources) = An ownership strategy that allows the initial owners of the DR to make use of Federal tax benefits, including the Investment Tax Credit and Accelerated Depreciation, to improve the DR project's economics. The third-party owners are neither the site owner or the utility, and thus a third party). The third-party owners typically oversee the projects installation for behind the meter projects or team with the project's developer (as tax equity investors) for in front of the meter projects. For behind the meter projects, the third-party owner often leads the project's installation, financing, and operation during their ownership period. After the tax benefits are consumed, per the IRS after year 5.5, the third-party owner often steps out of the project selling their ownership. Their ownership is sold for the project's fair market value (FMV) per IRS rules. The contract between the third-

party owner and the site owner may use a lease, power purchase agreement, or service agreement.

Tribal utility authority = Tribes may legally purchase and operate the utility infrastructure on the Tribes' property. The Tribal body that operates that infrastructure is the Tribal Utility Authority. This report takes a broader view, which includes the Tribe developing a more of a complete understanding of their utility infrastructure so that they are better able better manage their utilities. The Tribe may not need to own everything but rather better understand and regulate the electric providers operations on Tribal property.

Utility scale= Distributed resource (DR) projects of typically 100 MW to 1000 MW

Value of solar = An electric rate design methodology that determines the value of solar PV power generated by customer-sited, behind the meter, installations. Factors that may be included in the value of solar include:

- Utility variable costs (fuel and purchased power)
- Utility fixed costs (generation capacity, transmission, and distribution)
- Distribution system and transmission line losses
- Ancillary services (to maintain grid reliability)
- Environmental impacts (carbon and criteria pollutant emissions)

Virtual net metering = Uses the utility's billing system to allow a customer-generator with multiple utility-owned electric meters at different geographic sites to offset power consumption on one utility owned meter with on-site RE generation from another site's electric meter. All meters must be with the same utility.

Wheeling = Using the electric distribution and or transmission system to move a customer's power from the site of generation to the site of use. Typically, the distribution/transmission utilities charge a fee for this service.

1. Summary and Recommendations

It is critical to honor the Tribe's long-term goals of increasing:

- Use of renewable resource
- Resiliency
- Self sufficiency

While being socially and economically beneficial to all Tribe members.

The power sector is undergoing a significant transformation to reduce carbon emissions, with surging fossil fuel prices, and new technologies, thus creating significant opportunities for the Tribe to meet these goals.

Distributed resource (DR) technologies will play a key role in this transformation. DR are small (typically under 10 MW), modular, energy generation and storage technologies that provide electric capacity or energy where it is needed. DR includes everything from solar PV to batteries, to producing and storing hydrogen.

This report has two main areas of focus:

- BEC Tribal policy recommendations for supporting the adoption of DR located behind the meter at BEC's Tribal members
- Options for siting community scale DR technologies in front of the meter located on-reservation land and perhaps owned or co-owned by the Tribe

Behind the Meter Options

Recommended behind the meter policy options, that support the implementation of renewable DR on the reservation include:

- Changes to net metering and parallel generation rates
- Master metering of multi-tenant buildings
- Electric meter aggregation
- Virtual net metering
- Campus metering for microgrids
- Third-party financing
- Grid demand support tariff
- On bill financing of DR and electrification

Behind the Meter Recommendations

<u>Master Metering:</u> the requirement for individual electric metering of homes and businesses is state law. However, state law does not govern the Tribe. Thus, the Tribe could consider master metering (having one utility meter at) new or existing multi-tenant buildings. Master metering would require the Tribe to find alternative methods of billing tenants for their power use.

Third-Party Ownership, Leases, and Power Purchase Agreements: The Bayfield Electric Cooperative (BEC) allowed the third-party owned EnTech microgrids sited on the Tribe's property to interconnect. Utilities that oppose third-party ownership, argue that it is against state law. The Tribe could consider asking BEC if they would allow other third-party owned PV system or other DR projects. Tribal members could use third-party financing for PV/DR on their homes, businesses, and Tribal facilities. Ideally, the financing payments would be less than customer's electric bill would have been.

In Front of the Meter Options

There are many technology, ownership, and business model options for in-front of the meter DR. BEC, Dairyland Power Cooperative (DPC) and Xcel are each looking toward increasing their reliance on renewable DR and are activity making renewable DR investments.

In front of the meter DR sited on Tribal land is complex, as it is bound by:

- The technical specifications of the Miller Road stepdown transformer substation
- The type of DR, its costs, benefits, and ownership
- The Tribe's power use (now and in the future)
- The BEC distribution grid and its upgrade costs
- The value DPC will pay for power (kWh and KW) the DR puts onto the BEC distribution system
- The project's ownership, contracts, business model
- The willingness of BEC and DPC to work in partnership with the Tribe

DR projects are put together by the involved parties with a goal of optimizing the project's financing while minimizing risks. The projects are formed by their legal contracts. Contracts can offer great flexibility if all parties agree and the contracts follow the law.

Recommended in front of the meter utility policy options to help the Tribe site DR projects include BEC and DPC allowing Tribal ownership and co-ownership of:

1. Community-scale DR
2. Community DR gardens

The most common, and recommended DR project contact option is a power purchase agreement (PPA). Utilities have experience with PPAs. Under a PPA, the project's developer does all the work developing the project, including siting, construction, permitting, financing, interconnection, commissioning, and operation and maintenance, while covering almost all the project's risks. The local distribution provider signs the PPA with the developer to purchase the power produced by the generator/DR.

The Tribe, BEC and DPC would ideally work together to determine the DR project's most cost-effective and low-risk ownership strategy. Different project partners bring different

resources/benefits to the project. For example, the project's developer can take advantage of DR's tax benefits (which DPC, BEC and the Tribe cannot).

In Front of the Meter Recommendations

PPA Structure: If the Tribe wants to be the owner or part-owner of a DR project, the PPA structure using a third-party developer is recommended. The Tribe could be a common equity owner and participate in the board of the DR project's LLC. The Tribe could increase its ownership share over the life of the DR.

Solar at BEC's Ashland Substation: BEC is currently exploring community-scale solar projects at several substations within its service territory. The Tribe could engage with BEC during their early discussions to determine if adding solar at the Ashland Substation offers any beneficial options, including co-ownership, for the Tribe. This project would not be on Tribal land nor have significant resilience benefits for the Tribe.

DPC Utility-Scale BESS Pilot Project: DPC is currently looking for a site to host a utility-scale BESS project for improving grid reliability. The Tribe could consider asking DPC to site the pilot utility-scale BESS on the Tribe's property. The Tribe and DPC could consider innovative funding, ownership, and operational strategies.

Outage Monitoring System: The Tribe suffers from regular outages of varying length but data about the outages is generally lacking. An outage monitoring system would offer many benefits including better understanding the current situation, designing better solutions (from a microgrid to uninterrupted power supplies to BEC distribution system improvements), providing data showing BEC needs to make distribution system investments, better understanding the value of the BEC infrastructure, and providing the data needed to support funding applications or requests for reliability investments by BEC or DPC.

How to Proceed: The Tribe should be patient in their energy planning efforts. The Tribe doesn't need to have all the answers today. Rather the Tribe should start with projects that make sense now and where funding is available, while ensuring that the projects are adaptable to likely future conditions. It is important for the Tribe to stay abreast of developments in the electricity market, and pilot interesting ideas. The Tribe will learn important lessons many of which will help inform future decisions.

2. Tribe's 2017 Strategic Energy Plan (excerpts[3])

Tribe's Energy Vision: To empower and enable the community to move toward energy independence.

Energy Goals

- Goal 1: Improve energy management system
- Goal 2: Exercise Tribal energy sovereignty and promote economic development by building capacity to plan and execute energy projects, increase the resiliency of energy infrastructure
- Goal 3: Reduce energy costs compared to current baseline by 10% by 2025
- Goal 4: Generate 10% of the Tribe's electricity with RE technologies by 2025

Goal 4 Details: Generate 10% of the Tribe's electricity with renewable energy technologies by 2025.

The Tribe is interested in meeting energy demands with renewable energy (RE). One of the most promising RE technologies for Bad River is solar photovoltaic systems (PV). The Tribe is also interested in utilizing smaller scale biomass for building heating.

Specific activities and energy saving measures identified include:

- Implement PV at individual facilities, as funding becomes available
- Assess feasibility of RE for each facility
- Install PV on wastewater treatment plant by December 2019 for 80% utility bill reduction and increased disaster resiliency

Table from 2018 Strategic Energy Plan, Tribal Energy Project Timeline showing selected projects (energy efficiency and other projects unrelated to RE were removed)

Years 0-2	Years 2-5	Years 5-10
• Solar PV on Facilities • Solar PV system at the Solid Waste Facility • Solar PV on WWTP (larger scale) • Energy accounting software (Building Automation Systems and metering) • Work with utility to incentivize RE for residences	• Microgrid for disaster response • Tribal representative on utilities (Bayfield & Xcel) • Update forest management plan	• Biomass – smaller scale for heating facilities

[3] Source: Bad River Band of the Lake Superior Tribe of the Chippewa Indians Strategic Energy Plan 12/18/2017

• Create Tribally owned utility commission • Communicate with utility representative		

Tribal Resiliency

Climate change increasingly impacts tribal homes, food, and overall lifestyle of American Indians. Current and future impacts from climate change threaten native communities' access to traditional food such as fish, game, wild and cultivated crops which have an impact on cultural, economic, and community health life. Additionally, climate change challenges the integrity and stability of ecosystems on which native people live by changing ecosystem processes and biodiversity. Decreases in water quality and quantity affect Indian drinking water supplies, food cultures, ceremonies, and traditional ways of life. Climate change affects native populations in various and impactful ways which threaten traditional ways of life.

To combat climate change within native populations, native traditional knowledge has emerged. Traditional knowledge involves a "cumulative body of knowledge, practice, and belief, evolving by adaptive process and handed down throughout generations by cultural transmission, about the relationship of living beings with one another and with their environment" (CTKW, 2014). Traditional knowledge strives to create a symbiotic relationship between native people and their environment. Therefore, as climate change increasingly threatens Tribal Nations, cultural characteristics, and practices, documenting the impacts on traditional lifestyles may strengthen adaptive strategies.

The Tribe has made progress toward Goal 4 and resiliency goals by installing solar photovoltaic systems (PV) and battery electric storage systems (BESS) at:

- Wastewater treatment plant: 200 kW DC PV and 426 kWh BESS
- Health and Wellness Center: 301.6 kW DC PV and 568 kWh BESS
- Chief Blackhawk Administrative Center: 24 kW DC PV and 44 kWh BESS
- Head Start Building: 20.5 kW DC PV

For a total of 546.1 kW DC PV and 1038 kWh BESS

Long Range Planning (excerpts)[4]

The Bad River Band's mission statement:

[4] Workshop and Summary Report completed by muGrid, July 2020

To work toward a more progressive, financially stable government, to maintain tribal sovereignty, and enable members to progress individually towards a more fulfilling life culturally, spiritually, and economically.

The workshop participants identified that each of the values in the tribe's mission statement manifested in a particular way specific to energy vision:

Progressive and Financially Stable

- Maximize resources at minimum cost
- Achieve 100% sustainability: assisting the region with the same endeavors
- Add RE every year to tribal programs
- Adopt clean energy – reduce carbon footprint
- Reduce carbon emissions
- Establish freedom from fossil fuels and fossil fuel companies

Tribal Sovereignty

- Create independence and resiliency under tribal control for the strength and benefit of the people, land, and water
- Increase energy independence
- Develop tribe's energy commission: control electric energy on the reservation
- Produce energy on their own as a Tribe

Enable Members to Progress Individually

- Create good paying jobs
- Establish independence and resiliency for the strength and benefit of the people, land, and water

The Tribe defined their driving objective as energy independence and the establishment of a Tribal Utility Authority (TUA). There are several versions of what a TUA might be. Two basic types are:

1. Totally independent - "Cut the cord" and develop a microgrid that is entirely independent and not tied into the grid at all.
2. Stay connected to the grid but develop an alternative means of interconnection that the Tribe owns.

The long-range plan document embraced the first definition, developing a reservation-wide microgrid or mini-grid with all necessary power generation and distribution infrastructure. (This may not be the most cost-effective method for the Tribe to achieve 100% carbon-free electricity use and it may add risk by reducing energy resilience.)

To progress toward the vision of a TUA, the workshop participants identified microgrid and pure solar projects that can provide economic and resilience benefits now while taking advantage of various funding opportunities. These assets will then eventually become part of the TUA and enable energy sovereignty for the Tribe.

3. Change and the Time Element

Decarbonizing and taking increased control of the electric distribution grid sited on the Tribe's property will take years to decades.

Between today and ~2050, as the grid decarbonizes, there will be very significant technical power sector innovations, technology price changes, electricity cost changes, utility policy changes, incentive changes, state and federal policy changes, possible carbon taxes, new business models, etc.

The future will be very different than today, providing both unexpected solutions and challenges.

Thus, a power sector plan (Plan) cannot be very specific or accurate. The Plan cannot solve every issue. Rather the Plan should identify what makes sense now and what initial steps also make sense for, and could be adapted to, likely future scenarios. The Tribe can then consider and act on those initial steps. Some initial steps/projects could pilot likely solutions on a small scale. The Tribe's three microgrids are all pilots.

The power sector Plan need not know exactly how its goals will be achieved. All reasonable options should be considered on an ongoing basis. This includes considering all distributed resource (DR) technology options, as well as ownership options, funding options, financing options, and other related opportunities (e.g., carbon trading, ancillary grid services, etc.), and costs/risks.

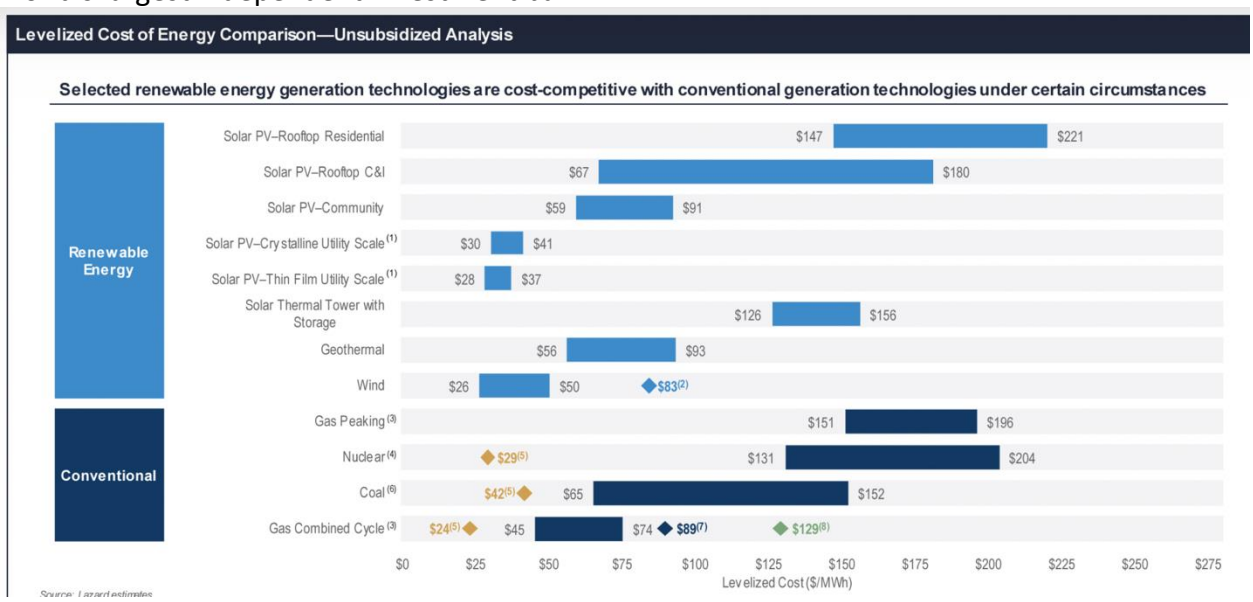
Today, for the Tribe to be 100% self-sufficient, 100% carbon free, and disconnected from the region's electric grid would be very costly and financially impractical. Consider, using current technologies and pricing, cutting all oil, propane, and natural gas use, and then having a few weeks of negative 20° weather with no wind or sunshine. It simply would not work. However, the future will be very different.

Recommendation: Be patient, don't need to have all the answers today, start with projects that make sense now (the low hanging fruit) and where funding is available, attempt to ensure that the projects are adaptable to likely future conditions, stay abreast of developments in the electricity market, pilot interesting ideas on a smaller scale, lessons will be learned, and honor the Tribe's long-term goals.

4. Current Electric Power Sector Landscape

The US electricity sector is in a major state of flux

The Table, below, provides the cost of new power generation in the US as developed by Lazard, 2021[5]. Lazard is a well-respected financial advisory and asset management firm and is the world's largest independent investment bank[6].



In the Table above, note that utility-scale solar and wind are significantly less costly than new natural gas power generation. Community solar (i.e., 1MW to 5 MW of PV) can cost less than new coal fired power generation.

Natural gas prices have been surging since the Lazard analysis, was completed. Solar PV system prices have also recently increased due to a pending Commerce Department trade case, inflation and post-pandemic shipping, manufacturing, raw material, and labor constraints.

The Table, below, shows US natural gas prices over the last five years (source: Trading Economics, May 9 2022[7])

[5] https://www.lazard.com/perspective/levelized-cost-of-energy-levelized-cost-of-storage-and-levelized-cost-of-hydrogen/
[6] Source: Wikipedia, 05.09.22
[7] https://tradingeconomics.com/commodity/natural-gas

Note the recent surge in natural gas prices. One key question is if this uptrend will continue or if it is short-term price spike.

Natural gas is more expensive in much of the industrialized world. For over a decade the US has been racing to build liquefied natural gas (LNG) facilities, export terminals and buy LNG tankers, to export cheap US natural gas. Events in Ukraine and Europe are only amplifying this trend. This is increasing the price of natural gas in the US.

The natural gas rig count, the number of drilling rigs looking for new natural gas reserves in the us, has not spiked as much as natural gas price (see Figure below). Thus, it is unlikely that significant US natural gas reserves will be added, rather reserves are likely to be depleted, further driving up US natural gas prices.

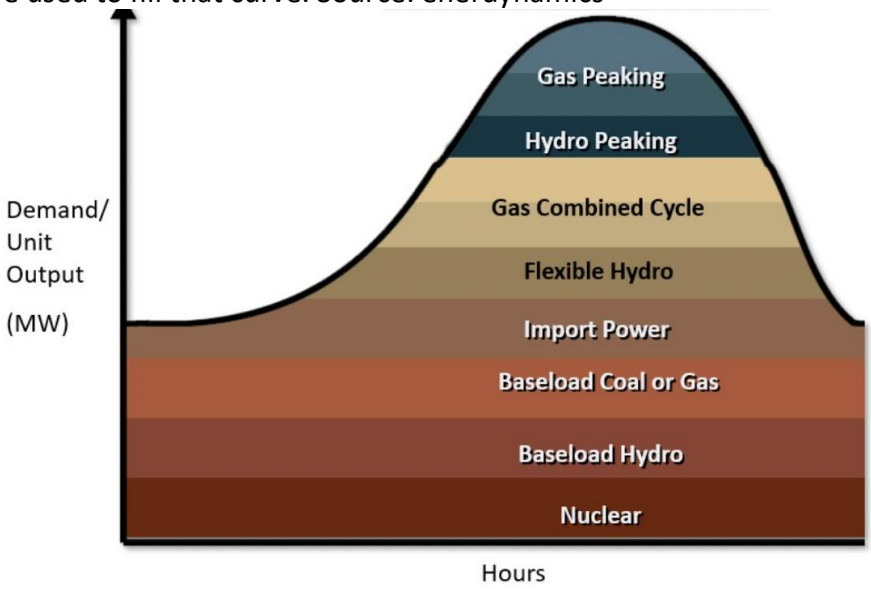
Figure 5-year US natural gas rig count through May 9, 2022 (Source: YCharts[8])

[8] Link https://ycharts.com/indicators/us_gas_rotary_rigs#:~:text=Basic%20Info,from%2096.00%20one%20year%20ago . Accessed: 05.09.22

Increasing exports and reduced exploration for new reserves suggests that natural gas prices will remain high for some time.

The location marginal price (LMP) price of power is set by the power generators on the edge or margin of being turned on. Those plants are commonly natural gas-fired generators (often called "peakers"). Natural gas power plants are usually operated to meet the fluctuating load, and the peak loads, of the grid. This is because they can be quickly turned off and on, unlike a nuclear or coal-fired power plant. Thus, they are typically the marginal power generator and drive the grid's LMP price.

The table, below, shows an example utility load curve and the types of generation sources that are used to fill that curve. Source: enerdynamics[9]



Generally, electric utilities propose that the value of RE power generation provided by customer-owned DR system (when the RE system is larger than net metering) should be valued at the LMP. Thus, the LMP price ties directly into the economics of customer-sited/behind the meter RE systems.

[9] Link: https://www.enerdynamics.com/Energy-Currents_Blog/The-Electric-Load-Curve-Once-Predictable-Now-Fickle.aspx accessed 05.16.22

With increased natural gas prices, the LMP prices are also increasing. Thereby making the power produced by renewable generators more valuable.

Carbon Reduction Goals – the need to replace fossil-fired generators

States, including Wisconsin, and electric utilities including Xcel and We Energies (Wisconsin's largest electricity utility) have pledged to be carbon neutral by 2050. As climate change is increasingly acknowledged, the need to reduce the emissions of carbon dioxide and other greenhouse gases will also increase.

Given the need to de-carbonize power generation, much of the current generation stock (i.e., all coal and natural gas fired power plants) will have to be replaced. And given the economics of power generation the new power generators are very likely to be renewable (RE).

Or rephrased: all fossil-fuel generated electric power generation will have to be replaced with carbon-free generation (by 2050), with storage.

5. The Tribe's Electricity Providers

The Bad River Tribe's electricity providers are Bayfield Electric Cooperative (BEC) which provides most of the electricity used by the Tribe, and Xcel Energy, which provides electricity to the area west of the Bad River.

Most the Tribe's power needs are provided by the Dairyland Power Cooperative (DPC) using the BEC distribution system. Xcel provides about 10% of the Tribe's power needs, including power generation, transmission, and distribution. Since DPC and BEC provide about 90% of the Tribe's power needs, this report focuses on them.

DPC is beginning the process of replacing their fossil fuel fired power plants. In 2021, DPC generated 75% of its power from fossil fuels (natural gas and coal). Their goal is to reduce their reliance on fossil fuel fired power generation to 63% by 2031. During the same time-period, DPC forecasts wind and solar generation to increase from 22% to 36% (of their generation fleet's nameplate capacity).

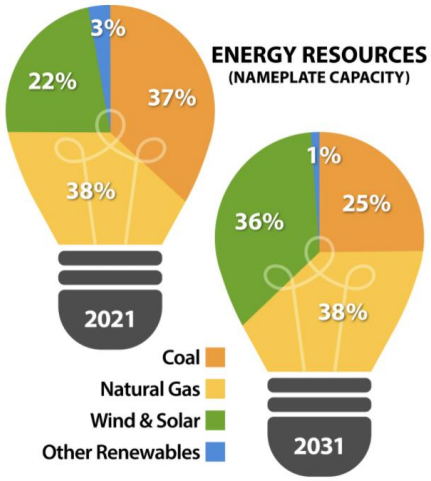


Image source: DPC website[10]

DPC is actively working to reduce its carbon emissions. Over the last year, their press releases[11] included the following:

- DPC member cooperative, MiEnergy, has a power purchase agreement (PPA) with OneEnergy Renewables for the 9 MW of electricity generated by solar arrays in Minnesota's Rushford Village, Fountain, Lanesboro, and Stockton.
- DPC's President Brent Ridge attended Jackson Electric Cooperative's ribbon cutting ceremony for the 1.5 MW Strobus Solar Site in Black River Falls, WI. OneEnergy Renewables is the solar owner and developer.

[10] https://www.dairylandpower.com/energy-resources accessed 4/13/22
[11] Found at https://www.dairylandpower.com/Posts

Image below, person on the far right is Eric Udelhofen of One Energy Renewables the project PV development company (of community and utility scale PV projects)

- DPC acquired the RockGen Energy Center, a 503 megawatt (MW) natural gas power plant located in Cambridge, WI.
- DPC's 345 MW Genoa coal-fired Station #3 (G-3) will be retired June 1, 2022, following 52 years of providing safe, reliable power to the region.
- DPC signed an MOU with NuScale who has a small modular reactor technology. NuScale's VOYGR™ power plants are flexible and able to perform load following maneuvers to meet grid capacity needs. DPC considers this due diligence process for their evaluation of affordable, reliable, and carbon-free energy solutions.
- As a part owner of the planned Cardinal-Hickory Creek transmission line. DPC's COO Ben Porath note that it "is an essential 345-kV backbone interconnection that will provide a vital link to the future of our region's renewable energy developments"
- The Dane County Circuit Court has affirmed the approved Certificate of Public Convenience and Necessity... for the planned Nemadji Trail Energy Center in Superior WI. The combined-cycle natural gas plant will deliver up to 625 MW of reliable, renewable-supporting energy to the electric grid. It will perform on-demand in any weather conditions and to back-up wind and solar facilities.

6. Strategies for Increasing RE Generation and Resilience

This Report considers the options for empowering and enabling the Tribe to move toward energy independence, while improving resilience. This report focuses on RE and carbon-free electric power generation and other supporting technologies such as electricity storage, and electric power conversion to other valuable products (e.g., hydrogen, heat, etc.)

The report has two main areas of focus:

- BEC Tribal customer policy recommendations for supporting the adoption of behind the meter RE and carbon-free DR technologies
- Options for siting small-scale utility (aka community scale) RE and carbon-free DR technologies in front of the meter. This could be located on-reservation land at key points along BEC's radial line feeding the tribe, for example, at the Tribe's step-down transformer/substation on Miller Road or off-reservation land near the BEC's Ashland substation.

Do note that as the Tribe implements more behind the meter RE projects, their BEC electricity use falls and less community-scale DR is required. However, it is expected that other energy uses will be converted to electricity over the next several years, including space and water heating and vehicle travel, increasing the Tribe's electricity use.

To determine if it is more cost effective for the Tribe to invest in behind the meter or in-front of the meter small utility scale projects, or a mix of both, depends on many factors including:

- The willingness of DPC and BEC to work with the Tribe
- The Tribe's resources, goals, risk tolerance
- Funding opportunities

Recommendations

It is important to begin understanding the Tribe's cost of behind the meter and in-front of the meter community-scale utility DR options as well as their risks and how the Tribe's resilience is affected. This will require working with BEC, DPC and Xcel.

Consider the lessons learned while doing this work as a pathway for the Tribe to better understand how to manage the reservation's electric utility resources.

7. Distributed Resources (DR)

It is important for the Tribe to consider the full breath of the technical solutions available to meet their power sector goals. DR goes beyond generation and storage.

DR are smaller power generating (generally under about 10 MW), electricity storage systems and other resources which are distributed within the electric distribution system. In contrast to utility-scale power plants, which are usually much larger (e.g., 100 MW to 1000 MW) and connected to one point of the electric transmission system. DR can provide either or both power (kWh) and demand (kW) benefits.

Distributed Resources include:

- Solar photovoltaic (PV), power generation
- Wind, power generation
- Biomass firing/gasification boilers, heat and/or power generation (combined heat and power)
- Biogas firing, heat and/or power generation (combined heat and power)
- Biogas cleaning, producing renewable natural gas (RNG) suitable for pipeline injection, boiler firing, heating, power generation, combined heat and power, and storage
- Hydrogen production, using electrolysis to create hydrogen from splitting water[12].
    - Hydrogen use: fired in a boiler for space heating, water heating, industrial or in a combined heat and power plant or used in a fuel cell to generation electricity. Hydrogen can be stored and transported (although currently difficult and expensive) and sold.
- Nuclear, safe, small, modular, power generation and heat production
- Electricity storage, batteries, fly wheels, pump hydro, etc., power storage, demand cost reduction, arbitrage, providing ancillary grid services, resilience
- Load control, reducing electricity use during critical, typically high-cost, periods. For example, using an automated system to reduce air conditioner use on hot summer afternoons.
- Cryptocurrency mining and sales – using excess/low-cost electricity to create income

Note on Nuclear Power
Converting all the world's energy use to renewables with current technologies is a very significant challenge. Some believe that safe nuclear power using distributed micro-reactors could be an important source of carbon-free generating capacity. Nuclear could support the transition to the carbon-free future. Westinghouse is planning on having commercial units available as soon as 2027.

[12] Tribes in the Southwest USA are starting to talk with hydrogen producers about selling their water rights.

8. Bayfield Electric Cooperative (BEC) Policy Recommendations Supporting the Tribe's Adoption of Behind the Meter DR

In March 2020, BEC changed their net metering policy for all BEC customers per Policy 300.11 (source: Bill Bailey, personal communication, 5/23/22)

BEC's net metering policy was changed for all new solar installations. Currently, all solar installed since March 2020, any energy exported to the grid is credited at Dairyland's monthly averaged day-ahead (DA) local marginal price (LMP) essentially equating it to the parallel generation tariff. On May 14th, 2022, at BEC's annual meeting, a revised draft policy was announced which includes the following:

- Existing solar installations are grandfathered in at 100% net-metering until December 31, 2024
- After December 31, 2024, all solar is net metered at 90% of retail value up to the member's annual usage
- Excess exported energy beyond annual usage is credited at DPC's averaged annual DA LMP
- Net metering capacity limit is raised to 40 kW AC
- Starting January 1, 2025, existing solar installations will enter a 20-year contract guaranteeing the 90% pay-back rate
- New solar Installations will enter a 25-year contract guaranteeing the 90% payback rate

This policy, or something similar, is expected to get final approval, by BEC, in the third quarter of 2022.

Policy recommendations for supporting DR projects for BEC or Xcel customers on Tribal land. These policies go beyond what BEC and Xcel currently offer their customers.

1. Net Metering Electric Tariff

- Net metering at full retail-rate to 120% of the customer's annual kWh use
    - The 120% of annual use is per Xcel Minnesota net metering rate
    - Net metering agreements between BEC and the customer/RE system owner should be for 25 years
    - When site ownership changes new owners can continue the existing net metering agreement
    - Other resources

- Interstate Renewable Energy Council's Model Net Metering Rules[13]
- Solar Energy Industry Association's Principles for the Evolution of Net Energy Metering and Rate Design[14]

2. Parallel Generation Electric Tariff

- For customer-generators with DR systems larger than net metering (i.e., DR capacity above 40 kW AC), the parallel generation tariff should value generation exported to the grid at:
  - 90% of avoided costs, where avoided costs include:
    - Avoided energy costs (kWh)
    - Avoided capacity cost (kW)
    - Avoided transmission cost
    - Avoided distribution costs
    - Avoided environmental costs
    - These costs would be determined on an annual basis by DPC
  - 20-year fixed price contracts are between the BEC customer-generator DPC. The contracts should value of RE generation based on the avoided cost of the year of interconnection
  - When site ownership changes, the new owners can continue the existing parallel generation contract

Table, Summary of the "Value of (behind-the-meter) Solar" based on avoided costs proposed by RENEW Wisconsin and Xcel Wisconsin during the Xcel Wisconsin rate case at the Public Service Commission of Wisconsin (Spring 2022). Note, that BEC's avoided costs differ from those shown below. This is an example of recently proposed avoided costs.

Summary – Value of Solar

	Xcel Energy – After customer self-supply (Pg2-b)	RENEW Wisconsin plus sited studies
Avoided Energy Costs	2.24 cent/kWh	2.7 cents/kWh
Avoided Capacity Costs	None	3.6 cents/kWh
Avoided Transmission Costs	None	1.4 cents/kWh
Avoided Distribution Costs	None	0.16 cents/kWh
Avoided Environmental Costs	None	4.2 cents/kWh
Total	2.24 cents/kWh	12.26 cents/kWh

3 Multiple DR System interconnected a Building or Premise

Multiple DR systems are permitted at an individual building/premise, serving multiple electric meters. Some Wisconsin electric utilities permit only one DR system per building.

[13] Link: https://irecusa.org/resources/model-net-metering-rules/
[14] Link: https://www.seia.org/sites/default/files/NEM%20Future%20Principles_Final_6-7-17.pdf

This would allow a building owner or tenant occupied buildings with multiple electric meters to interconnect DR systems to more than one electric meter.

4 Master Metering of Multi-Tenant Buildings

Chapter 119 of the State of Wisconsin's Administrative Code's Service Rules for Electric Utilities requires that utility-owned electric meters be installed for each residential dwelling and commercial unit. The Rules' rationale is that each tenant pays their own electric bill to encourage them not to waste electricity. However, with modern, inexpensive metering and billing technologies – that can now be done using non-utility-owned meters and billing systems.

BEC's Bad River distribution grid was built following this rule however the Tribe is not under the jurisdiction of Wisconsin's administrative code.

For example, under Wisconsin's residential electric rates, multi-family building tenants pay the same monthly fixed charge as any other residential customer, including single family homes. At a multifamily building, the fixed charge[15] can account for more than 25% of the tenant's annual electricity bill. Meanwhile, in a large single-family home, the fixed charge may account for 5% of their monthly electric bill. So, the fixed charge is very regressive.

With master metering, the multi-tenant building is often on a medium commercial electric rate with an all in kWh cost[16] significantly less than a residential or smaller commercial electric rate. Thus, the site owner's and tenant's electric bills drop.

Currently, most PV installations on multi-tenant buildings are connected to the building's common area meter, which is owned by the building owner. To offset tenant loads, a separate PV system would have to be connected to each tenant's electric meter. This is costly, impractical, and sometimes technically difficult. Also, as the electric meter use increases, with master metering, larger more cost-effective DR system can be installed on the master meter and both the building owner and tenants' benefit. Master metering allows more DR to be sited more cost effectively on multi-tenant buildings.

However:

a. The re-metering of an existing multi-tenant building has a cost
b. Some other metering method and billing system for tenant electricity consumption will be needed. Companies offer this service for a fee.[17]
c. The master meter owner is responsible for paying for all the tenants on that meter's electricity costs.

Recommendation: For the next multi-tenant building built on Tribal property consider master metering. If the utility says they are required to install one electric meter per unit, reply that PSC rules do not apply on Tribal property.

[15] The monthly charge to be connected to the electric grid.
[16] The "all in kWh cost" is the site's total electric bills for a year divided by the site's kWh use over the same year.
[17] For example: https://www.yardi.com/products/yardi-energy-solutions/

5. Electric Meter Aggregation

Electric meter aggregation allows multiple meters on one premise, owned by one customer, to be aggregated for net metering or parallel generation purposes. The bill aggregation and billing would be done by the BEC billing system. Providing this functionality in the BEC billing system may be expensive for BEC. BEC will also have administrative costs to set up and maintain the aggregated metering customers.

The customer-generator designates the rank order for the additional meters to which the net metering credits are to be applied. If in a monthly billing period, the net metering facility supplies more electricity to BEC than the energy usage recorded by the customer's designated meter, then BEC will apply credits to additional meters in the rank order as provided by the customer. Any remaining credits (i.e., additional kWh of onsite generation/storage) after doing so will be rolled over for use during the subsequent billing period[18].

6. Virtual Net Metering

Virtual net metering allows a customer-generator with multiple BEC electric meters at different geographic sites to offset power consumption on one BEC meter with on-site RE generation from another site and BEC electric meter. All BEC meters must be on Tribal land. Providing this functionality on the BEC bills may be expensive for BEC. BEC will also have administrative costs to set up and maintain the virtual net metering customers.

7. Campus Metering for Microgrids

For microgrids, composed of multiple buildings, to work, DR and onsite backup generation need to be integrated into a single system. This can only be done by replacing individual BEC building meters with one "campus" BEC meter. There are sites in Wisconsin that already have campus metering (e.g., university campuses). This is very similar to Xcel Energy WI Resiliency Services pilot tariff[19], which is currently being implemented by Bayfield County, where the Courthouse and Jail will be combined and metered with one Xcel electric meter.

9. Third-Party Financing

The Tribe could ask BEC to permit all forms of third-party financing including leases, service agreements, and power purchase agreements (PPAs) for behind the meter and in front of the meter DR systems sited on Tribal property. The Tribe's three Entech microgrids are third-party financed by Entech. Thus, this should not be an issue for BEC.

Recommendation: Consider offering PV system leases to the Tribe's residential or smaller commercial customers.

10. Grid Demand Support Tariff

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[18] Source: see IREC 2009 Model Interconnection Standards. See page 6, for additional details

[19] Link: https://www.xcelenergy.com/staticfiles/xe-responsive/Admin/We_Section_3.pdf page 47

The Tribe could ask BEC to develop a tariff to pay DR, sited on Tribal property, for providing power to the BEC distribution grid during the grid's peak/high-cost periods with day ahead notification based on LMP prices.

11. On-Bill Financing of DR and Beneficial Electrification

The decarbonization of the energy sector will require all customers to stop using natural gas, propane, gasoline, and other fossil fuels while increasing their use of renewable-sourced electricity as efficiently as possible. The conversion to efficient electrical devices is called "beneficial electrification". Examples of beneficial electrification include heat pumps (air, ground and water-sourced) for space and water heating and air conditioning, and electric vehicles.

Electric utilities generally actively support beneficial electrification because it adds to their electricity sales.

BEC could be asked to provide on billing financing of beneficial electrification as well as DR measures installed at Tribal member's homes, businesses, offices, etc. that are cost effective. The on-bill financing could cover PPA or lease costs or simply the measure's financing payments. Outside financial resources could be used to co-finance these projects and reduce costs to Tribal members. Again, it may be difficult for the BEC billing systems to provide this service and it will increase BEC's costs and risks.

9. Siting Megawatts of In-front of the Meter Carbon-free Distributed Resources (DR) on Tribal Lands

As DPC-owned existing fossil power generation is replaced by carbon-free generation, some of the new DR capacity could be sited on the Tribe's property at or near the stepdown substation on Miller Road, serving the Tribe's main electricity loads.

9.1. At the End of a Radial Feeder – Reliability

The Tribe's electric loads are on the end of a long radial distribution feeder. This results in higher maintenance costs per customer and reliability issues when compared to more urban distribution feeders. Providing power generation and/or storage at the Tribe's Miller Road stepdown substation would reduce distribution-system maintenance costs while improving electric service reliability. Thus, benefiting both BEC and the Tribe.

Example Utility Funded Microgrid in the Village of Boaz, Wisconsin
In 2021, Alliant Energy agreed to install a $3 million 250-kW 8-hour, or 2 MWh BESS (without any generation) creating the Village of Boaz Wisconsin's microgrid[20]. The Village has about 120 Alliant customers and is on the end of a long radial feeder with regular reliability issues (3 to 4 times a year).

The Alliant project creates a community-scale utility grid with "islanding" capability and a dedicated power source (the BESS). It is one of several research pilot projects Alliant Energy is implementing as they develop their RE portfolio and energy storage solutions. The Public Service Commission of Wisconsin allowed Alliant Energy to have the microgrid's cost paid by Alliant's customers.

As noted in the Ojibwe Hybrid Microgrid Feasibility Study outages of varying length are relatively common, yet data about the outages is sparse. The outages have significant costs that including everything from backup generator fuel use, to lost services, to damaged equipment. The Tribe should consider installing the technology and processes need to monitor and collect grid outage data. As part of this OEI funded Feasibility Study outage tracking and data collection technologies and processes are starting to be put into place.

Improved outage data could be used to:

- Better designing and understanding the optimal microgrid
- Making the case for outside funding to support reliability investments
- Encouraging BEC and DPC to make reliability investments either by upgrading the distribution system or by placing DERs that support the Tribe's reliability

[20] Source: https://www.alliantenergy.com/alliantenergynews/newscenter/28-boazmicrogrid and https://www.usnews.com/news/best-states/wisconsin/articles/2022-01-08/boaz-to-host-wisconsins-first-community-scale-microgrid Accessed 05/18/22

- Better understanding how to harden Tribal assets to survive the outages using technologies such as uninterrupted power supply (UPS)
- Better understanding value the of the BEC grid if the Tribe were ever interested in forming a partnership with BEC or TUA

9.2. The "Deal" for an In-front of the Meter DR Project

Any in-front of the meter DR project will require a set of contracts. These contracts must be legal. Otherwise, anything goes. Neither BEC or the Tribe are regulated by Public Service Commission of Wisconsin's rules and the Tribe is not governed by State laws. This should open a larger number of implementation options for the project's parties (I.e., Tribe, DPC, BEC, third-party developers, etc.).

The final legal, ownership, financial, engineering, and operational design of the project is up to the parties, their creativity and willingness to work together, and share the project's risks.

So, for questions such as:

- Could the Tribe own or co-own an in front of the meter project?
- Could the Tribe purchase the project at year ten for fair market value (FMV)?
- Could the Tribe be on the board that operates the DR?
- Could the Tribe pay a fee to BEC to move "their" electric power from in front of the meter DR capacity they own to the Casino (this is called wheeling power)?
- Could the Tribe operate the DR, whenever the BEC grid goes down, to optimize their resilience?

The answer is "Yes" if it is legal, and all parties agree.

Understandably, a small cooperative electric utility and its board of directors may be unwilling to enter far-ranging and perhaps innovative DR negotiations on many topics or to pay the cost of hiring the expertise needed for such negotiations. Similarly, the Tribe would need to have the expertise and financial resources to participate in such negotiations.

However, BEC's CEO Christopher Kopel has experience with utility-scale solar projects, ownership models, power purchase strategies, and has been involved in 1000's of MW of front of the meter solar. He is receptive to explore solar projects. Also, there are existing well-understood community-scale DR project strategies, that the Tribe can use in partnership with BEC. Some of these are discussed below.

Recommendation: The Tribe should capitalize on the DR expertise of BEC's CEO to develop and move forward on jointly beneficial projects and pilot project.

9.3 The Tribe's In-front of the Meter DR Potential at the Miller Road Stepdown Transformer Substation

The Tribe's DR system would ideally be sized to the Tribe's power needs. The Tribe is estimated to use about 5 million kWh/year. The DR's size is also limited by the BEC distribution system). If the DR is owned by BEC its size is limited by BEC's contact with their power provider DPC.

Size of the Tribe's Miller Road Stepdown Transformer Substation
Michael Wood, of muGrid, estimates that about 2 MW AC of generation could be sited at the Tribe's stepdown transformer substation on Miller Road. That generation could be intermittent, like solar, or wind, or a DR technology that operates more hours of the year such as biomass, or biogas power generation[21]. See Annex 1 for an image of the substation and a concept for siting 1 MW of PV nearby.

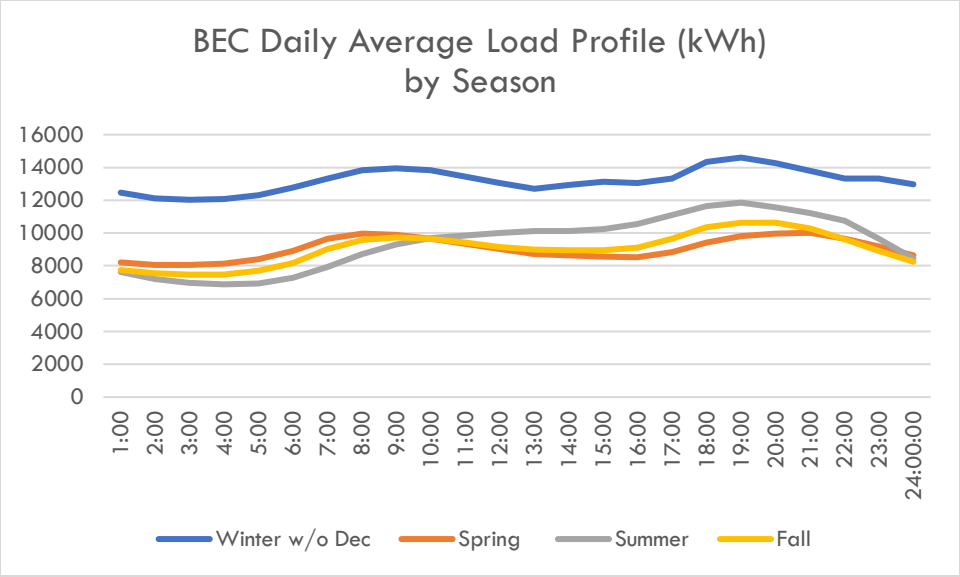
2 MW AC of fixed tilt PV would generate about 2.4 million kWh per year, roughly half the Tribe's current use, while a 1 MW biomass/gas power plant with an 85% capacity factor would generate 14.9 million kWh per year, roughly three times current use.

Limiting power delivered to the BEC distribution grid

A substation's electricity throughput when plotted (hour of the day vs amount of electricity that passes through the substation) creates a load curve. That load curve is likely to be roughly bell shaped with use peaking during the day and decreasing at night (particularly in the early morning hours).

Figure, BEC's Seasonal Electric Use Load Curves (using 2020 data provided by BEC). Note that electricity use is highest in the winter and there's more of an afternoon peak in the summer. This data is for all BEC's customers. The Tribe's load shapes are likely to be different.

[21] Basically, burning biogas or biomass to boiler water to spin a steam turbine and generates electric power



Ideally the Tribe's DR project's power output would stay under the substation's load curve, thereby meeting only the Tribe's loads, and limiting power delivered to BEC's distribution system. Power should only be put back on the BEC grid if it is safe and cost effective.

If the DR puts power back into the BEC distribution grid from the Miller Road stepdown substation (i.e., pushing power back toward Ashland) then:

- There may be an added cost for distribution system upgrades needed to safely permit the power flow. This is determined through BEC's distribution system engineering study (per state law PCS.119). Although PCS rules don't apply to the Tribe this analysis is needed. The Tribe should pay for their fair share of any required upgrades. Generally, the more power that is put into the distribution system the greater the distribution system's upgrade costs.
- The amount BEC or DPC pays (per kWh) for the power the DR puts into BEC's distribution system must be considered. The value is likely to be based on LMPs and will change over time. These costs are difficult to forecast and thus add risk to the project's economics.
- The amount BEC or DPC pays for ancillary electricity services that support the operation of the BEC and DPC grids (if any). For example, the DR could provide power to BEC to reduce BEC's demand charges from DPC or it could provide frequency services.

Increasing the Tribe's Electricity Use

More DR generation could be added, without increasing power delivered to the BEC distribution system, if the Tribe:

- Increases electricity use
- Implements beneficial electrification, converting natural gas, gasoline, and propane using technologies to electric technologies

- Adds electricity storage, to store excess electric power instead of sending it to the BEC grid
- Adds new electric loads that generate value (e.g., cryptocurrency mining, electrolysis for hydrogen production)
- Allows some of the generation to be lost (e.g., clipping losses)

Contractual Limitation on the DR size

Per BEC's contract with DPC, BEC can self-generate their own power supply up to 1.5 MW AC of generation capacity. DPC provides all BEC's other power needs. BEC currently has 300 kW AC of generation capacity (a community solar project). BEC can self-generate power up to an additional 1.2 MW AC of generation capacity. This amount could increase if BEC negotiates with another DPC member to get their share of DPC's self-generation allowance.

If the generation is owned by DPC, a private third-party developer, or the Tribe, then there is no contractual limit on the size of the DR.

9.4. Who Owns the In-front of the Meter DR?

The Tribe, BEC and DPC would ideally work together to determine the DR project's most cost-effective and low-risk ownership strategy.

Different project partners bring different resources/benefits to the project. For example, outside tax-equity investors can make use of the Federal Investment Tax Credit (ITC) and the accelerated or even one-year federal and state depreciation schedules. The Tribe can provide land for siting the DR project and waive BEC's fees (e.g., property tax and right of way fees). A utility owner can often provide financing resources with lower interest rates.

Options to consider when identifying the optimal project implementation strategy, include:

- Ownership options
  - Ownership over time
    - Who builds/commissions
    - Who owns the DR
    - Who owns the land/site
    - Who operates the DR
    - Is ownership transferred at some time (e.g., when tax credits are consumed)
    - Is operation transferred at some time
  - Project Partner options
    - Tribe
    - Utility (DPC, BEC, Xcel)
    - Third-party developers

        - Third party investors
        - Third-party operators
        - Financiers/bonding, loans, etc.
    - Ownership and partnership options
        - Ownership can be shared between the utility, Tribe, and third-party developers
        - Ownership shares can change over the life of the asset
            - The Tribe could take full ownership or increase their ownership, at some point
    - Tribe could just own the land where the generating asset is sited
- Operation, one party should be the assets' operator
        - The operator does not have to be the owner

A third-party operator, the utility, or the Tribe could operate the asset for the partnership or for one owner. That owner could be the Tribe, the utility, or the third-party developer

9.5. BEC and DPC Policy Recommendations for In-front of the Meter Community-scale DR

The Tribe can consider asking BEC and DPC for allowing the following:

1. Permit Tribal Ownership and Co-Ownership of Community Scale DR

The Tribe could own, or co-own community-scale DR systems connected the BEC distribution grid without any associated customer electric meter (i.e., in-front-of-the-meter DR). These projects could be co-owned with BEC, DPC, third party developers, or other parties. Importantly, BEC and perhaps DPC would need to approve of the Tribe's ownership, and interconnection to the BEC distribution grid.

For example, a 1 MW AC DR project could be installed with 700 kW AC serving and "owned" (e.g., contracted for using a PPA) by BEC and 300 kW AC "owned" by the Tribe.

2. Permit Community DR Gardens

Tribe, and its partners could develop, own/co-own and operate community DR gardens like the Minnesota Community Solar Garden Program. BEC customers located on Tribal property could be eligible to participate in the program. The Community DR Gardens would be sized appropriately for the BEC distribution system and interconnected to the BEC distribution system. BEC would permit the community DR garden to successfully operate, this includes, signing the PPA with the community DR garden (as appropriate), and crediting participating customer's electric bills (both for kWh and kW benefits) through virtual net metering.

3. Explore future options to allow Tribal DR assets to participate in FERC ancillary energy service markets.

FERC has issued rules that for paying customer-sited and owned DR to help balance the transmission system. These markets are active in the PJM[22] transmission service territory. PJM operates several markets for ancillary services, such as: the Synchronized Reserve Market, the Non-Synchronized Reserve Market, the Day-ahead Scheduling Reserve Market, and the Regulation Market. These is no reason why Tribal DR assets should not be allowed to participate in these markets.

9.6. In-front of the Meter DR Implementation Strategies

1. Power Purchase Agreements (PPAs)
DPC and its member utilities have installed several community-scale, of 1 to 5 MW, PV projects using PPAs. DPC member cooperatives currently have PPAs with OneEnergy Renewables for the 9 MW of operating PV projects.

Under a PPA, a private third-party developer does all the work developing the project, including siting, construction, permitting, financing, interconnection, commissioning, and operation and maintenance. The developer covers almost all the project's risks and headaches. The local distribution provider (BEC) or power provider (DPC) signs the PPA with the developer to purchase the power produced by the generator typically for the generators' expected life but there can be future buy-out options.

The Developer arranges the financing and makes use of, or finds investors able to make use of, all the tax benefits. PPAs work well when the utility owners cannot take advantage of the tax benefits. The Federal ITC and state and federal accelerated deprecation can cover over half of a PV system's cost. DPC and BEC are not for-profit organizations, and thus pays no taxes, and cannot take advantage of tax benefits.

The Tribe could also sign the PPA with the project's developer (if permitted by BEC/DPC). This is similar to the Tribe's three microgrid projects which were developed and financed by EnTech (who used the tax benefits). The main difference is that the EnTech DR projects are behind the meter, not in-front of the meter.

After all tax benefits are used (typically after year 5.5) there is often the first buyout option. As this time the Tribe, DPC or BEC could take ownership or increased ownership, and if desired operation of the DR. The new owner(s) would need to pay fair market value (FMV) for the project (per the Internal Revenue Service's (IRS) ITC rules).

The financing of a PPA project is typically done as follows:

[22] PJM coordinates the transmission of electric power in Pennsylvania, New Jersey, and Maryland as well as Illinois.

- Common Equity - provided by the project's developer, utility, or Tribe (typically covers about 20% of project cost)
    - The common equity could be raised from party's cash reserves, debt, or other sources (grants, donations, low-cost land lease, etc.)
    - During the project's recapture period (the typically project's first 5.5 years during which the tax equity investor captures the tax benefits) common equity ownership share is 1%. After the recapture period, the common equity ownership flips to 95%.
    - The common equity holders receive a return on invest on the project (of 5% to 15%/year)[23]
- Tax Equity - sourced from outside investors able to use/monetize the project's tax benefits (typically covers about 30% of project costs)
    - During the recapture period, the tax equity investor owns 99% of the project. After the recapture period their ownership falls to 5%.
    - Step out of the project after the recapture period (after tax benefits are consumed) typically occurs after year 5.5[24]. Their share, then 5%, is normally sold to the common equity owners for FMV. The FMV is usually determined based on the project's discounted[25] cashflow and expected remaining life.
    - They are the "preferred" investor and thus are the second to be repaid if the project fails
- Debt/loan financing (typically covers about 50% of project costs)
    - Debt financing is first to be repaid if the project fails
    - Debt financing is typically relatively long-term
    - A reduced interest rate has a significant role is improving project's economics

The Tribe could be a common equity investor. Individual Tribal members could also be investors. But because the project is not registered with the Security Exchange Commission individual investors must be "accredited". To be classified as accredited, the investor must meet one of two criteria:

- The investor must have earned income exceeding $200,000, or $300,000, during each of the previous two full calendar years, and a reasonable expectation of the same for the current year. The same method (single or joint) must be applied to the income test in all three years.
- The investor must have a net worth greater than $1 million excluding, for individual investors their primary residence.

Pros

- Very commonly used for these types of DR projects and well understood in the utility industry

[23] If a common equity holder uses debt financing with an interest rate that is less than the project's expected return, then they could make a profit. However, the DR project's return is not guaranteed. And common equity holders are the last investor repaid if the project fails.

[24] Per the 5.5-year federal recapture period expiration.

[25] Recently, discount rates of 5% to 6% were used. Eric Udelhofen personal communication 5/24/22

- Project investors carry the project's risks. As noted above, in case of the project's failure, debt financing is paid off first, then the tax equity investor and lastly the common equity investor(s)
- Project developer's tax equity investor makes use of the tax benefits
- Project developer leads the entire process
- The tax equity investor typically relinquishes their ownership after the tax benefits are used and sells them to the common equity investor(s).
- Usually,[26] after the tax equity investor steps out of the project the common equity investors ownership can also change. For example, the Tribe could increase their ownership or take full ownership. Purchases would have to be made using the project's FMV.
- When the DR project's ownership is restructured, it has an operational history. This informs the next owner about the technical reliability and viability of the project (reducing risks).
- The new owner must purchase the project for at least its FMV (per IRS rules). FMV[27] is typically significantly less than (i.e., 25% to 85% depending on the technology and years of operation) the project's installed cost. The simple payback periods for PV projects purchased at FMV can be under 5 years. Yet, the DR may have many (10 to 30) years of remaining cost-effective operational life.

Cons

- The project developer builds the project for their own best interest
- Contracts are significant, important and must be reviewed carefully
- The Developer can have high fees and income requirements

Electricity Price Stability – Reducing the Risk of Price Shocks

Renewable projects are typically financed using long-term low-interest rate financing. Given that most of the renewable project's cost is the initial installation cost and financing (and both those costs are known at time of construction) the cost of generation is very stable over the life of the generator. Variable costs, including operation and maintenance, replacements, taxes, insurance, administration, etc. are a small share of the project's total cost.

Thus, RE generation costs are stable, and should increase slower than general inflation.

Note that RE project PPAs often include an annual purchase price escalator – this is done to be competitive with current electricity prices. As a result, the PPA investors returns should increase over time (often roughly similar to general inflation).

Utility DR Ownership

When electric utility customers pay their monthly bill, a significant share of that bill goes to pay off the financing used to pay for the power grid (power plants, transmission lines, distribution lines, utility trucks, etc.). The financing is typically long term, often lasting up to the expected life of the asset (30 to 40 years or more), and at low interest rates. Utilities are considered a very low-risk business and as such able to get low interest rates. This is how the electric grid is financed.

The Federal government offers tax benefits, the ITC and depreciation, for RE generation projects. However, these benefits can only be used by tax-paying businesses. DPC and BEC are both a 501(c)12 not for profits, and thus exempted from income tax, and thus unable to use the Federal tax benefits[28]. So, using the PPA structure for not-for-profit utility owned RE projects makes a lot of sense[29].

Pros

- The utility is in control of all aspects of the project

Cons

- Not-for-profit utilities cannot make use of the Federal tax benefits
- Utilities tend to "gold plate" their projects, partly because they are very risk adverse and partly because their rate of return (i.e., income/profit) is based on the value of their capital stock[30].
- Utilities tend to like to hold their generating plants for long periods of time. So, buyouts of DR assets by third parties (i.e., the Tribe) is less likely, unless the Tribe forms a true TUA.

[28] The Tribe is also unable to use the Federal tax benefits.
[29] Xcel Wisconsin can make use of Federal Tax benefits. However, under Wisconsin state law those benefits must be returned to their utility rate payers over the term of the generation project's financing (double check this).
[30] DPC and BEC do not rely on rates of return for their income

Tribal DR Ownership

The Tribe could own the in-front of the meter DR project. The Tribe could go as far as owning all utility assets on Tribal lands by creating a Tribal Utility Authority (TUA). But, as noted, the Tribe cannot make use of the Federal tax benefits. And the Tribe has no experience with developing, building, financing, etc. community-scale DR projects.

Recommendation
If the Tribe wants to be the part-owner of a DR project, the PPA structure with a third-party developer is recommended. The Tribe could be a common equity owner and participate in the board of the DR project's LLC. After the project is up and running, the Tribe could consider increasing their ownership share when the tax equity investor drops out and/or purchasing ownership shares from common equity owners. Participating in the DR project would be a good experience for the Tribe and be used to better inform decisions regarding the TUA.

9.7. DPC and BEC In-Front of the Meter DR Opportunities

BEC and DPA In-front of the Meter DR

BEC is currently exploring community-scale solar projects at several substations within their service territory. This includes BEC's Ashland substation, which could technically handle up to 7 MW AC of DR[31]. For this project, an electricity purchaser(s) or off-taker(s) is required. The Tribe could be one of the off takers. Bad River could also co-offtake with BEC, DPC or Xcel. The Tribe could also be one of the Project's owners. The most likely initial DR project owner is a third-party developer who has a PPA with DPC.

Recommendation: The Tribe should engage with BEC during their early discussions to determine if adding solar at the Ashland Substation offers any beneficial opportunities for the Tribe.

DPC is Looking for a Site to Pilot a BESS Reliability Project

Eric Udelhofen noted[32] that DPC is looking for site to host a utility-scale BESS project for improving grid reliability. It would be considered a pilot project and not have to pencil economically. This could be an option for the Tribe to pursue.

Recommendation: Ask DPC about siting the pilot utility-scale BESS on the Tribe's property. The Tribe and DPC could consider innovative funding, ownership, and operational strategies.

[31] Typically, the substation transformer's size limits the size of the DR because they are very costly to replace.
[32] Personal communication 05/18/22

9.8. Example Implementation Strategies for In-front of the Meter DR Options

SolarShare Wisconsin Cooperative[33]

The SolarShare Wisconsin Cooperative (Cooperative/Coop) was incorporated in late 2021. The Coop intends to own all or portions of community- scale solar energy projects in Wisconsin, sell electricity, using the PPA structure, and sell renewable energy credits (RECs) to utility and other customers. The Cooperative's solar projects are expected to have a capacity of 1 to 5 megawatts (MW) and be located on approximately 5 to 40 acres of land.

Renewable Energy Credits (RECs)

Every MWh of RE power produces both 1000 kWh of power and 1 REC. A REC values that the power was generated from a RE source. RECs can be sold. But then the RE owner can no longer claim to be using renewable power.

The REC market is complex. Some state's (e.g., Illinois) have REC markets created by state regulations. Other states such as Wisconsin have a voluntary market (i.e., state laws do not place a value on RECs).

A commodity-type RECs price (e.g., from a large Texas wind farm) in voluntary market is about $1/REC (or about 0.1 cents/kWh). However, a "feel good" REC from say a community solar project or a Tribal project could be much more than that. Perhaps twenty times more (i.e., 2 cents/kWh) (source Eric Udelhofen, personal communication 05/18/22). The REC contracts are typically long term for 10 or more years. Thus, providing significant income to the project's owner.

The Cooperative maintains its principal office in Madison, Wisconsin. The initial board of directors include Heather Allen, president of RENEW Wisconsin and Eric Udelhofen director, project development, One Energy Renewables.

Eric Udelhofen roughly estimates that a PPA for 2 MW PV SolarShare's project in northern Wisconsin would cost roughly 5 to 7 cents per kWh. As the Tribe provides more value to the project (e.g., grant funding, a low/no-cost land lease, etc.) the PPA price would decline. The PPA price would be higher if installation costs are higher (e.g., shallow bed rock requires more expensive foundations for the racking system, or if PV component or installation labor costs increase).

[33] All information in this section is from the SolarShare website: https://solarshare.coop/ accessed 05/11/22 and personal communications with Cory Neely and Eric Udelhofen (May 2022)

The Cooperative provides its investors a low-cost way to privately invest in local renewable energy projects in their community. The Cooperative uses private capital investment for renewable energy projects in their communities. The initial funding round raised $500,000. Some of that initial funding can be used for common equity financing of their projects. Investors into the Cooperative (not the solar projects) can include individual residents of the State of Wisconsin and legal entities with their principal place of business in the State of Wisconsin. Thus, the Tribe and its members could be Coop investors.

As the community-scale solar projects, owned/co-owned by the Coop, generate revenue, dividends are distributed to Member Investors (as the Coop's board deems appropriate). Some of the project income generated by the Coop's common equity investments would be used to further the business goals of the Coop.

SolarShare RE project strategy

- The Coop leads the development of the project
- Each project is its own limited liability corporation (LLC)
- The Coop leads the project's LLC. The LLC board includes its investors. This could include the Tribe
- The project uses a PPA which is typically signed with the distribution utility but for the BEC, DPC would sign the PPA.
- The Project uses the financing structure as described in the PPA section of this report
- The Coop arranges the project's operation and maintenance services
    - The Coop could work with the Tribe to help train and then hire Tribal members to provide these services

The Tribe could participate by

- Being a member investor of the SolarShare Coop
- Being a common equity investor in a SolarShare Coop developed DR LLC project
- Hosting a PV/DR LLC project
- Serving on the project LLC's board of directors
- Providing a low/no-cost lease for use of the land required for siting the DR project
- Bringing in grant funding
- Providing other support to the project, for example in negotiations with BEC, DPC and other parties, supporting project siting, etc.
- If allowed by BEC/DPC, sign the PPA for purchasing some or all the power generated by the project

Community Solar Gardens[34]

Community Solar Gardens are a successful method for getting RE projects online in Minnesota. As of the April 2021, over 750 megawatts of electricity are being produced by community solar gardens around the Twin Cities.

Community solar gardens allows groups of consumers to purchase "subscriptions" to a central solar facility and receive credit on their electric bills for the energy it produces. The central solar facility is constructed for multiple customers, who each subscribe to a portion of the project. These consumers continue to purchase their electricity from their utility but receive a credit on their utility bills for the energy that is produced by their portion/ownership-share of the solar facility.

The monetary value of the bill credit is based on Minnesota's value of solar determination[35] and paid per kWh generated by the subscribers share of the PV system[36]. The value of solar determination includes the different benefits of solar including avoided costs (i.e., energy and its delivery, generation capacity, transmission capacity, transmission and distribution line losses, and environmental value). The distribution utility is not compensated for the needed billing changes or wheeling[37] of power.

The payment for subscribing to the renewable garden is either made upfront or paid via the customer's monthly electric bill (those costs would be financed by the project developer using long-term financing). There could be a mix of pre-pay and as you go for subscribers.

A Tribal community RE garden does not need to mimic the Minnesota program. Rather it should be modified to meet the needs of the Tribe. For example, the program should consider including a carveout with reduced charges for low to moderate income residential customers.

In General Community Solar Gardens have higher costs

- Community Solar Gardens are more costly than a simple PPA project. This is for a few reasons:
    - They are more complex
    - The host utility must make significant investments in their billing systems to manage the virtual net metering
    - The developer or host utility needs a significant and ongoing marketing budget and administrative budget to find, sign up, and manage the subscribers
        - For example, the local utility needs to deal with subscribers moving or leaving and then find new subscribers over the life of the project.

[34] This idea is from Minnesota's Solar Gardens program. DPC has two members in Minnesota, so they are familiar with the policy. And Xcel knows Minnesota better than any other electric utility.
[35] For more information visit: https://mn.gov/commerce-stat/pdfs/vos-methodology.pdf
[36] Stacy Miller, City of Minneapolis – Coordinator, Division of Sustainability, personal communication, 5/23/22
[37] I.e., moving power from the Community Solar Farm to the end user.

- In Minnesota about 90% of the subscribers are homeowners and account for 10% of the subscribed kWh while 10% of the subscribers are commercial customer, and account for 90% of the kWh. Yet each customer's on-going administration costs are similar.

10. The Tribe's Carrots and Sticks when Negotiating with BEC, DPC and Xcel

When negotiating with electric utility companies it is important to consider the Tribes leverage and what the utilities may gain from cooperating with the Tribe. Some of the Tribe's carrots and stick are summarized below.

Carrots that the Tribe can offer

- Provide mutually beneficial partnership opportunities/business model options for each of the DR project's stages:
    - Development
    - Co-funding
    - Financing
    - Ownership
    - Operations
        - Energy resources: wood, biogas, water.
- Support in de-carbonizing DPC/Xcel generation stock
    - Power generation site(s) and siting ease (i.e., land)
- Improving grid resilience and reliability (Tribe is on the end of a long radial feeder)
- Piloting end of radial feeder DR.
- Reduced need for distribution system investments
    - The BEC distribution system is depreciated and has not seen significant upgrades since it was installed, investments are likely in the short term. DR sited at the stepdown substation could reduce the need for future upgrades
    - Since the Tribe proposed significant right of way fees, five years ago, little to no significant distribution system investments have been made on Tribal property
    - For future upgrades there could be a partnership between that Tribe and BEC
- DR assets could supply power to BEC and Xcel during MISO peak LMP cost periods
- The Tribe could waive the property tax on utility infrastructure
- The Tribe could waive the right of way (ROW) fees on utility infrastructure
- The effort could enhance the relationships between the Tribe and BEC and DPC which could influence and be mutually beneficial, as the Tribe considers forming and/or forms a TUA
- The project could pilot DR options/strategies that other Xcel and DPC customers and other community and Tribes could use/consider across the region
- By working together perhaps improving communications and trust, the Tribe and Xcel could find a win- win so that Xcel doesn't have to move their transmission line. It is likely that the cost of moving their transmission line off Tribal property has increased significantly.
- The Tribe is legally able to form at TUA. However, the Tribe is likely to prefer win – win partnership strategies with BEC and Xcel (while meeting the Tribe's goals). Working

together on DR projects today may help both parties improve their relationship and trust, and thus better find win-win solutions.
- Good public relations on joint projects

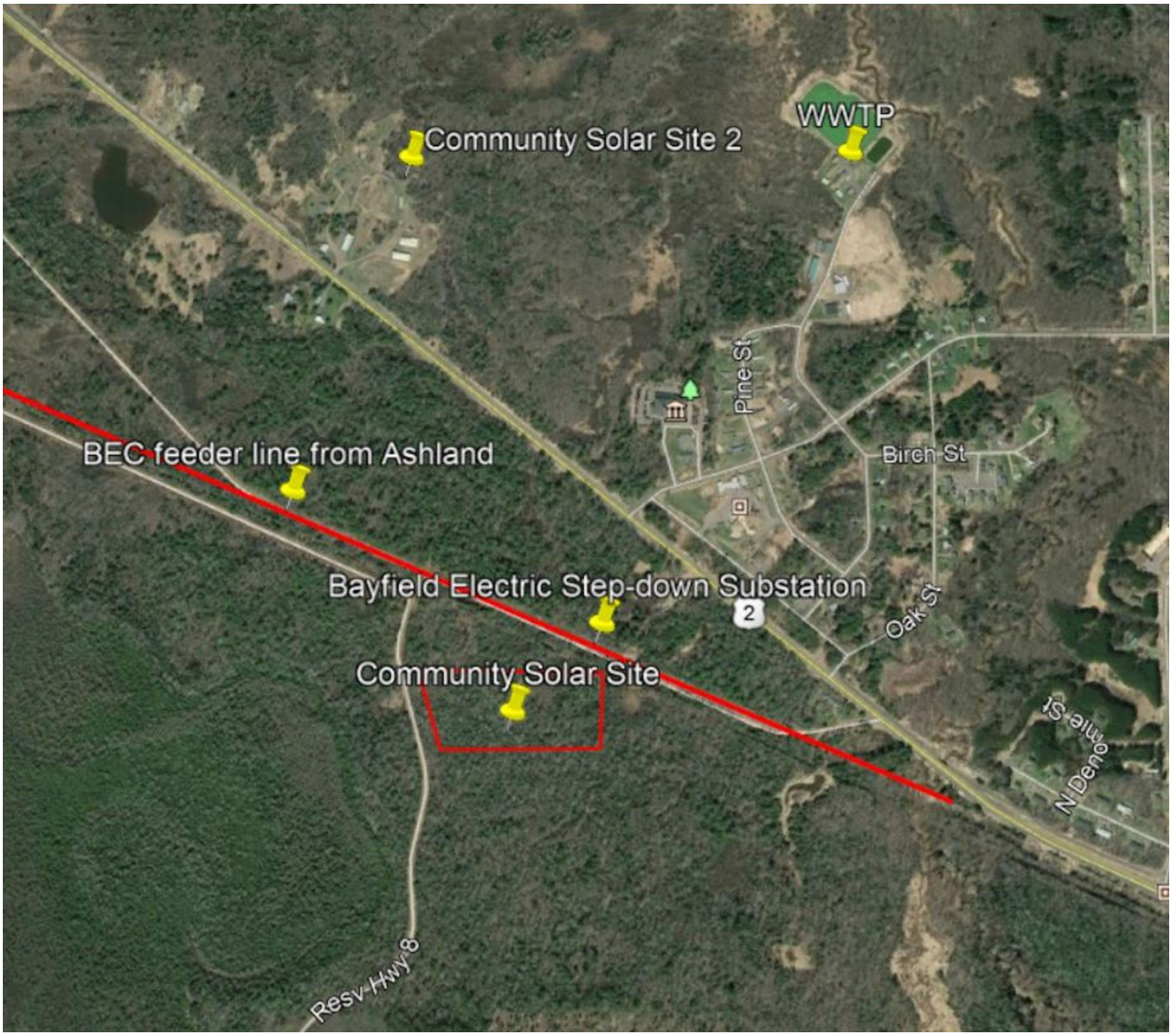
Sticks that the Tribe can offer
- Charging property tax on utility infrastructure
- Charging ROW fees on utility infrastructure
- Creating the TUA
- Demanding distribution infrastructure be updated
- Tribe could purchase power from the wholesale market if they owned a point of connection (substation) or become an aggregated qualified facility under new FERC rules

11. Tribe's Strategic Energy Plan Suggestions for Consideration

To be clear about the Tribe's intentions regarding updating their electric utility service, improving resilience, and becoming carbon free while benefiting all tribal members, the Tribe could consider adding the following to their strategic energy plan, the Tribe will

- Be carbon neutral electric by 2040(?)
- Electrify current fossil fuel (natural gas, oil, propane) use (vehicles, space heating, water heating, etc.) as it makes financial sense, and the needed resources are available
- Consider on-bill financing of DR and electrification (of projects with payback periods of less than 6(?) years
- Consider all viable DR technologies for meeting the Tribe's goals
- Equally support behind the meter and in-front of the meter DR but determine what mix is most beneficial to the Tribe
- Demand fair treatment of behind the meter and in-front of the meter DR per policy recommendations summarized in this report (Sections 8 and 9)
- Better understand the number, length and impacts of the Tribe's electric power outages
- Test likely solutions by implementing pilot projects
- Begin discussions with electric utility providers regarding the Tribe's DR implementation options, strategies, and potential partnership.
- Investigate current opportunities including:
    - Testing master metering at a multi-tenant building
    - Requesting campus metering for an expanded microgrid
    - Piloting a lease financing program for smaller Tribal BEC customers
    - DPC's interest in piloting a utility-scale BESS for grid reliability
    - BEC's interest in siting PV at the Ashland substation
    - BEC's CEO's interest in DR
    - The ability to sell high value RECs from Tribal-owned DR
- Pursue co-ownership and partnerships for in front of the meter DR projects and, in the process, gaining experience, trust and insights with DR technologies, the power grid, implementation strategies, and implementation partners (electric utilities, developers, contractors, consultants, etc.). These are useful experiences to be applied toward the Tribe's consideration of forming a TUA.

Annex 1 Potential Siting of a Community Solar PV Project



Source: Bill Bailey Cheq Bay Renewables

PV system size: 1,000 kW DC (total module DC rating)

Array Type	Acres	Acres Plus 20%	kWh/kW DC	Total kWh
Fix mounted, due south, 30° tilt, 30 ft row spacing	4.1	5.1	1,256	1,255,500

1 MW PV system using a fix mounted racking system with 30-foot row spacing. A single axis tracking array has about the same area requirements (and looks the same but the module rows are oriented north-south and move during the day). Source Helioscope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