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DISTRIBUTED WIND CASE STUDY: LAKE REGION ELECTRIC COOPERATIVE

Renewable Energy and Rate Stabilization from an Innovative Wind-Solar Hybrid Project

RADWIND Project

This is the second in a series of case studies on distributed wind projects at electric cooperatives for NRECA Research's Rural Area Distributed Wind Integration Network Development (RADWIND) project. RADWIND's goal is to understand, address, and reduce the technical risks and market barriers to the adoption of distributed wind technologies by rural utilities. Distributed wind projects can use any scale of turbine from small kilowatt-scale units up to large multi-megawatt units, as long as they are connected on the distribution side of the electric grid. Turbines may be connected on the customer side of the meter to serve a local load, directly to the distribution grid as a utility generating asset, or directly powering an off-grid load. For more information on the project and additional resources, please visit the project landing page at www.cooperative.com/radwind.

The distributed wind project profiled in this case study is part of a front-of-meter wind-solar hybrid system, connected to the co-op's distribution grid.

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Project Snapshot

Cooperative	Project Ownership	Project Size	Turbine Size	Other System Equip.	Connection	Energy End Use
Lake Region Electric Cooperative	Juhl Energy	2 MW (limit set by inverter to avoid backfeed/curtailment)	2.3 MW	500 kW PV array, 2 MW joint inverter	Front-of-meter, distribution grid	LREC purchases 100% through PPA

Cooperative Profile

Lake Region Electric Cooperative (Lake Region/LREC)[1] is a distribution cooperative in western central Minnesota, with 28,000 residential, commercial, industrial, and seasonal home consumer-members. The

[1] https://www.lrec.coop/

74-employee electric co-op is headquartered in the town of Pelican Rapids in Otter Tail County, and their generation and transmission (G&T) cooperative is Great River Energy (GRE). See Figure 1,

Figure 1. Lake Region Electric Cooperative's Territory, shown in light green.
Courtesy of Lake Region Electric Cooperative.
https://www.lrec.coop

Lake Region's territory includes rural farmland, forests, prairies, and more than 1,000 lakes which are central to the region's identity. Through this, the co-op owns and maintains 5,600 miles of distribution lines and serves an average of 4.6 members per mile of line.

In March of 2019, LREC began operation of a first-of-its-kind 2 MW Wind-Solar Hybrid Project. Although the project is small by utility wind and solar farm standards, the energy world took notice. *Energy News Network* described the project as "trailblazing,"[2] and *Windpower Engineering* lauded it as "the first commercial integrated solar-wind power generation project in the U.S."[3]

Project Background

The 2 MW Wind-Solar Hybrid Project – connected to the distribution grid in front-of-the meter [4] – is LREC's largest renewable generating resource, but it is not their first. See Figure 2. The co-op has long had an initiative to respond to their members' interests in clean, local, renewable energy beyond the wind and solar that make up more than 25% of GRE's wholesale mix.[5] According to Steve Haiby, Lake Region's manager of energy services, "We definitely want to provide our members with clean, renewable energy in the most economical way, and we're always looking for new ways to do that."

Figure 2. Lake Region's 2 MW Wind-Solar Hybrid Project.
Courtesy of Lake Region Electric Cooperative.

[2] https://energynews.us/2019/03/07/midwest/wind-solar-pairing-cuts-equipment-costs-while-ramping-up-output/
[3] https://www.windpowerengineering.com/ge-juhl-partner-to-build-to-first-of-its-kind-solar-wind-hybrid-project/
[4] A wind turbine connected to a distribution grid as a generating resource is considered a front-of-meter installation. Front-of-meter wind projects provide energy and grid support to the distribution system and serve the interconnected local loads on the same distribution system. For more information, see https://www.cooperative.com/programs-services/bts/radwind/Documents/RADWIND-Use-Cases-Report-April-2021.pdf.
[5] https://greatriverenergy.com/making-electricity/

In 2013, the co-op built a 35 kilowatt (kW) research and demonstration photovoltaic (PV) solar array. They soon added another 18 kW solar array and made it directly available to members through a community solar subscription program, which sold out quickly.

Lake Region also has a novel program for member-owned solar — the GoWest Solar[6] program. Through the program, the co-op offers complete installations of residential PV arrays to members at competitive prices. The GoWest name refers to the fact that these systems face southwest instead of the standard southern orientation to optimize production during summer afternoon peaks.

After the success of these smaller projects, LREC was interested in expanding and diversifying their renewable energy portfolio. The co-op's leadership began looking for the right opportunity.

Figure 3. GRE and LREC solar arrays.
Courtesy of Lake Region Electric Cooperative.

Concept, Planning, and Design

The seed was planted for Lake Region's 2 MW Wind-Solar Hybrid Project in 2017 when the co-op's CEO, Tim Thompson, learned about a similar project proposed in nearby Frazee, Minnesota. That project, which was to be developed by Minnesota-based Juhl Energy,[7] would have been the first of its kind in the U.S. However, it stalled due to pricing issues between the local utility and the Minnesota Public Utilities Commission.[8]

Despite the delays, Thompson was impressed with the Juhl Energy project's low price of energy, and there was room to add more locally generated energy under LREC's wholesale power supply contract with GRE, which allows LREC to generate up to 5% of its electricity peak demand or usage, whichever comes first.

[6] https://www.lrec.coop/products-service/solar/gowest-solar
[7] https://www.juhlenergy.com/
[8] https://energynews.us/2019/03/07/midwest/wind-solar-pairing-cuts-equipment-costs-while-ramping-up-output/

Because Juhl Energy's hybrid system was unique and fit LREC's needs, the co-op did not seek bids from other developer/owners or evaluate alternative technologies. Importantly, from the beginning, Juhl Energy was a trusted partner to both develop and retain ownership of the project. Thompson already knew Dan Juhl, Juhl Energy's owner, from a past position at another electric cooperative in Minnesota.

Keeping costs low was critical. Beyond supplying renewable energy, "another focus is rate stabilization, doing everything that we can to ensure our rates remain stable, so there are no dramatic cost increases for our members to worry about," said Dylan Aafedt, Lake Region's vice president of business solutions. One way the project kept costs down was by taking advantage of the complementary nature of wind and solar to maximize the value of a single point of interconnection with the utility. Wind turbines typically generate the most electricity during evening and night, whereas solar PV produces electricity during the day. By staggering production with a hybrid system, more total energy can be fed into a single substation over the course of a day compared to a single technology system. Furthermore, "the solar output will provide summer peak energy and the wind will provide winter peak energy."[9]

Although wind and solar are the featured elements, a key technology that enabled the project does not often make the headlines – the inverter. Juhl Energy collaborated with General Electric (GE) to develop a single, joint inverter that could accept energy from both the wind turbine and the solar array. This behind-the-scenes innovation increased system efficiencies and reduced the original $5 million price tag by about $500,000, or 10%.[10]

Another decision that kept upfront costs down and avoided potential regulatory hurdles was not to include a battery. However, in 2020, LREC began piloting a virtual battery of sorts with electric thermal storage (ETS) utilizing grid-interactive electric water heaters. Excess energy from the Hybrid Project is used to heat water in nearby members' homes, utilizing output that would otherwise have to be curtailed to avoid backfeeding, in accordance with LREC's contract with GRE.[11]

Technical Details

Lake Region's 2 MW[12] Wind-Solar Hybrid Project generates renewable energy through a combination of technologies:

- a 2.3 MW GE wind turbine (model GE 2.0-116),[13] with a 116-meter (380-foot) rotor diameter, 80-meter (262-foot) hub height, and an average capacity factor of 50% to 55%[14]
- a 500 kW photovoltaic (PV) solar array, which has an average 15% capacity factor[15]
- a 2 MW GE inverter. The 2 MW total system capacity is determined by the inverter's output capacity, which was sized to avoid backfeed or curtailment. Juhl Energy worked closely with GE to design the project's inverter, which utilizes GE's Wind Integrated Solar Energy (WiSE) technology platform. According to the manufacturer, the WiSE platform inverter "directly integrate[s] the solar panels through the wind turbine's converter, so both wind and solar share the

[9] https://www.lrec.coop/your-co-op/energy-sources/wind-solar-hybrid-project
[10] https://energynews.us/2019/03/07/midwest/wind-solar-pairing-cuts-equipment-costs-while-ramping-up-output/
[11] See also: https://www.cooperative.com/remagazine/articles/Pages/beneficial-electrification-lake-region-water-heater.aspx
[12] All MW and kW values in this section are alternating current (AC).
[13] https://www.ge.com/renewableenergy/wind-energy/onshore-wind/2mw-platform
[14] https://energynews.us/2019/03/07/midwest/wind-solar-pairing-cuts-equipment-costs-while-ramping-up-output/
[15] https://energynews.us/2019/03/07/midwest/wind-solar-pairing-cuts-equipment-costs-while-ramping-up-output/

same balance of plant, increasing system net capacity by 3 to 4 percent and annual energy production by up to 10 percent."[16, 17]

For the associated ETS pilot, LREC is evaluating Steffes Corporation's Dynamic Dispatch™, a Cloud-based water heater control system that utilizes grid-enabled thermal storage (GETS) controllers[18] installed on LREC member-owned 80- to 100-gallon electric water heaters. See Figure 4.

Figure 4. Steffes GETS controller on a member's water heater.
Courtesy of Lake Region Electric Cooperative.

According to Steffes, this system "precisely controls a large fleet of water heaters and makes them appear to the system operator as a single flexible fast-ramp asset (a virtual generator or battery)."[19] Currently, 40 LREC residential members on the same substation as the Wind-Solar Hybrid Project have this technology in their homes. The co-op plans to evaluate the impacts for a full year before releasing results.

Siting and Interconnection

The Hybrid Project is located on a member's farm two miles from the rural Erhard substation, a 10 MVA substation owned by LREC. The project is connected to the Erhard substation at 3-phase Y-connected 12.47 kV line voltage.

The custom inverter created an initial challenge at the point of interconnection (POI), which is owned by the project, not LREC. According to Al Fazio, Lake Region's vice president of engineering and operations, because the project team did not know exactly how the distribution grid would react to the hybrid, "the original POI, with simple cutouts, was not adequate to meet interconnection test requirements." To address this, they established a new POI utilizing a 3-phase recloser and this device allowed the GE system to meet interconnection test requirements.

Metering

LREC and Juhl Energy both meter the system's output on-site before the energy goes to the substation. LREC's metering allows them to see cumulative production, as well as minute-by-minute fluctuations in

[16] https://www.ge.com/news/press-releases/juhl-energy-partners-ge-renewable-energy-build-first-its-kind-solar-wind-hybrid
[17] Total output from 2019 (the first year of operation) reported to the U.S. Energy Information Administration was 6,026 MWh, for a total combined capacity factor of 34% when applied to the 2 MW total system capacity allowed by the invertor.
[18] https://www.steffes.com/2017/01/01/what-is-gets/#:~:text=Steffes%20GETS%20is%20the%20most,creating%20equity%20for%20all%20stakeholders.
[19] https://www.steffes.com/2017/01/01/what-is-gets/#:~:text=Steffes%20GETS%20is%20the%20most,creating%20equity%20for%20all%20stakeholders.

wind generation. The co-op uses this real-time data in the algorithm that determines when to dispatch the water heaters in the ETS GETS pilot.

Production

In its first twenty-three months of operation – from March 2019 through February 2021 – the Hybrid Project has produced more than 15 GWh (15,099,162 kWh). Most of that is used by the 1,200 members on the Erhard substation's 150 square mile distribution system.[20] Per their contract with GRE, LREC must avoid backfeed to GRE's transmission grid, which is why the GETS pilot is only for members served by this substation.

Figure , a report from the project's dashboard, shows the interplay of electricity supply to the Erhard substation and the GETS ETS pilot demand over the course of 48 hours. Wind speed (yellow line) and Temperature (purple line) are overlaid on hourly supply from the Wind-Solar Hybrid Production (green column – left axis) combined with GRE Supply (red column – left axis). In the background, the pilot's GETS ETS Charge (hourly demand) is shown in blue infill (right axis).

Note the 65 kW spike in GETS ETS charge on March 2nd at 5:00 PM. Total power supplied to the substation is just under 2,000 kW (2 MW). The majority of that is from the Wind-Solar system producing at near-maximum capacity. Supply from GRE at that time is almost zero. GETS ETS water heaters are charging to absorb excess Wind-Solar generation. Compare that to March 3rd at 6:00 AM. At this time, supply to the substation is nearly 3,000 kW (3 MW), with the majority of that coming from GRE and only a small amount from the Wind-Solar system. At this time, the GETS ETS water heaters are not charging.

LREC makes a customizable version of this dashboard available at: https://hybrid.lrec.coop/.

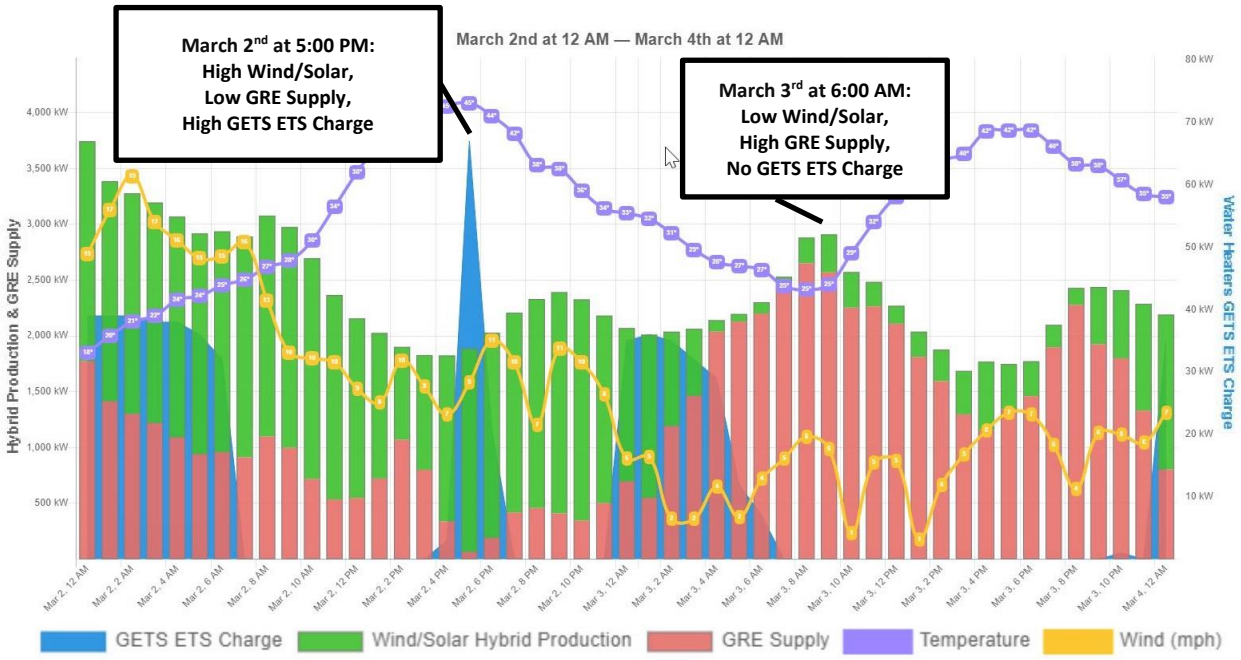

Figure 5. Screenshot of LREC Wind-Solar Hybrid Project Production Dashboard, March 2nd at 12 AM – March 4th at 12 AM. Courtesy of Lake Region Electric Cooperative.

[20] https://www.mprnews.org/story/2019/09/20/new-power-generation-rural-coop-makes-bet-on-wind-solar-hybrid

Planning & Engineering

The planning and engineering phase involved collaboration of all project parties – LREC, GRE, Juhl Energy, and GE. GE needed information about Lake Region's distribution system to design the inverter. LREC needed to understand all system details, because Juhl Energy purchased much of the required distribution grade equipment for the project through LREC.

Engineering studies were completed prior to project development, and minor improvements were made on both the distribution and transmission systems as a result of these studies. LREC conducted the distribution studies as part of its own due diligence. GRE required LREC to conduct transmission studies. Juhl Energy reimbursed LREC for all engineering study costs, as well as costs for improvements needed on the transmission system.

Operations & Maintenance

As the developer and system owner, Juhl Energy is responsible for all operations and maintenance (O&M) on the Wind-Solar Hybrid Project. The system currently has a functional availability of greater than 95%, and the co-op expects this to increase over time as initial system bugs are addressed.

Economic Details

Financing

The co-op did not need to secure financing, because it entered into a power purchase agreement (PPA) with Juhl Energy. LREC felt that this approach reduced risk for their membership. Juhl Energy, project developer and owner, secured their own financing. As a taxable entity, they were able to take advantage of the federal Production Tax Credit (PTC) for the wind portion, as well as the Investment Tax Credit (ITC) for the solar portion.

Power Purchase Agreements and Renewable Energy Credits

LREC purchases all system generation through a 20-year power purchase agreement (PPA) with Juhl. Lake Region expects to save $200,000 annually by offsetting energy purchases and reducing demand charges from GRE.[21] The co-op also sees value from the project in being able to "lock-in low-priced energy" for the 20-year PPA term as a hedge against increased power supply costs.[22]

Bank of America purchases all of the project's renewable energy credits (RECs).[23] This arrangement helped lower the PPA price that LREC pays Juhl Energy, but means that neither Juhl Energy nor LREC can claim the project's renewable attributes. Instead, the RECs support Bank of America's initiative to purchase 100% renewable electricity.[24]

[21] https://www.lrec.coop/your-co-op/energy-sources/wind-solar-hybrid-project
[22] https://www.cleanenergyresourceteams.org/combining-wind-solar-and-thermal-storage-beneficial-electrification
[23] Annual value of this project's RECs is not public information.
[24] https://www.ge.com/news/press-releases/juhl-energy-partners-ge-renewable-energy-build-first-its-kind-solar-wind-hybrid

Members and Community

"Member satisfaction is our primary goal of the whole project," explained Haiby, and it appears this goal has been achieved. The farmer who leases land to the project is happy with the arrangement, and the surrounding neighbors also have a positive view of the project. Members on the Erhard substation's feeders, where the project is interconnected, have the opportunity to participate in the GETS pilot, which reduces their own bills and also helps the co-op utilize the wind energy overnight when loads are low. Additionally, all members benefit from the project's significant savings that help the co-op keep rates stable. "We hear at our annual meeting and our district meetings very positive feedback from our membership, both in the financial aspect and the progression towards clean, renewable energy," said Haiby.

Figure 6. Lake Region's Wind-Solar Hybrid Project, located on a member's farmland.
Courtesy of Lake Region Electric Cooperative.

Project Experience, Opportunities, and Challenges

Overall, project development went smoothly, and the savings to date – more than $446,000 in just under two years – are exceeding the original savings estimate of $200,000 per year. But like any project, it was not without challenges. The main issues LREC encountered were related to:

- **Securing the site** – The first potential site LREC identified fell through after neighbor objections. The second was disqualified, because it was too close to a municipal airport. The third, offered by a member, met all the requirements with no objections or restrictions. Coincidentally, it is also close to LREC's headquarters; co-op staff can see the wind turbine out their windows.
- **Addressing G&T concerns** – GRE was supportive of the project, but they did have concerns about backfeed onto their transmission grid in the absence of battery storage. LREC began the GETS ETS pilot to mitigate this risk. The G&T also wanted to ensure the system's output would not exceed the 5% generation allowance in LREC's wholesale contract with them.
- **Integrating new equipment** – LREC noted that, given the system's custom components, more consideration should have been given early on to the type of device utilized at the point of interconnection.

At some point, LREC may add battery storage to the project, but that has not been decided yet. The co-op is watching as battery technology evolves and prices come down to see if and when it makes sense to add.

Key Lessons and Insights

LREC's Wind-Solar Hybrid project has been a success with multiple benefits for the co-op and its members, because the project was built by the right people at the right time for the right reasons. The co-

op wanted to be responsive to the strong member interest in clean, renewable energy, while keeping costs low. GRE, Lake Region's G&T, was supportive. Both wind and solar were established, cost-effective technologies when the project was developed, and still are. And a reputable developer customized an innovative system at a price and scale that fit the co-op's needs.

Contacts for Questions:

Steve Haiby
Manager of Energy Services
Lake Region Electric Cooperative
SHaiby@lrec.coop
Ph: 218.863.9815

Michael Leitman (Project Manager)
Director, System Optimization
National Rural Electric Cooperative Association
Michael.Leitman@nreca.coop
Ph: 703.907.5864

Dylan Aafedt
Vice President of Business Solutions
Lake Region Electric Cooperative
DAafedt@lrec.coop
Ph: 218.863.9856

This case study was researched and written by Laura Moorefield, Moorefield Research & Consulting, LLC, lmoorefield@gmail.com, Ph: 970.903.3044.

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