MTERA
Midwest Tribal Energy Resources Association, Inc.

Solar and Battery Storage at the Lac du Flambeau Fish Hatchery

Example REopt® Results for a Tribal Application

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December 2024

Acknowledgements

The authors would like to thank Carri Chapman, Community Outreach Coordinator from the University of Wisconsin-Madison Grainger Institute for Engineering in partnership with MTERA for her work throughout the REopt training program.

The authors would also like to thank Kristen Hanson, Hunter Mayo, and Melinda Walker of the Lac du Flambeau Tribe's William J. Poupart, Sr. Fish Hatchery for their time and effort on this study.

Note: The results of this analysis are based on a desktop evaluation using the REopt modeling platform. This analysis utilizes assumptions regarding the cost of technologies, future loads, and future energy tariffs. Furthermore, the modeled battery dispatch assumes the battery control system can perfectly predict future loads and solar irradiance and can thus be considered an upper bound on performance. These initial findings should be considered preliminary and can serve as the basis for further viability analyses of solar and storage at this site.

Background

- One of the biggest barriers to Tribal solar deployment is staff energy-related technical capacity.[1]
- To help ameliorate this challenge, the U.S. Department of Energy (DOE) Solar Energy Technologies Office funded a hands-on, in-person training program for Tribes in 2024.
- The National Renewable Energy Laboratory (NREL) partnered with the Midwest Tribal Energy Resources Association to plan and host a workshop.
- The training program focused on using the REopt platform. Each participant modeled a specific solar project for their Tribe, following a step-by-step demonstration with one-on-one assistance.

[1] Beshilas, Laura, Scott Belding, Karin Wadsack, Elizabeth Weber, M.J. Anderson, Kelsey Dillon, Sara Drescher, Jake Glavin, and Reuben Martinez. 2023. "Addressing Regulatory Challenges to Tribal Solar Deployment." Golden, CO: National Renewable Energy Laboratory. NREL/TP-7A40-85741. https://www.nrel.gov/docs/ fy23osti/85741.pdf.

Purpose

- This slide deck is designed to:
  - Demonstrate how REopt can be used with a real-life example
  - Serve as a guide for Tribal staff who want to use the REopt platform to model a project
  - Be used as a template for presentations of REopt results.

This slide deck will demonstrate how REopt can be used by modeling the Lac du Flambeau fish hatchery in Lac du Flambeau, Wisconsin. Image from Hunter Mayo, LDF

Acronyms

BAU: business as usual

DOE: U.S. Department of Energy

ITC: Investment Tax Credit

kW: kilowatt

kWh: kilowatt-hour

LCC: life cycle cost

MACRS: modified accelerated cost recovery system

NPV: net present value

NREL: National Renewable Energy Laboratory

O&M: operations and maintenance

PV: photovoltaics

TOU: time of use

WPS: Wisconsin Public Service

Glossary

- **Array azimuth**: The angle clockwise from true north describing the direction the solar array faces.
- **Capital cost**: One-time costs required to make a generation system operational.
- **Critical load**: The power needed to maintain essential services at a facility during an emergency.
- **Discount rate:** Measures the time value of money and is used to calculate net present value (NPV). Discount rates are specific to each organization.
- **Internal rate of return:** The nominal discount rate at which the NPV of all the cash flows (both positive and negative) from the project equal zero.
- **Levelized cost of energy:** Unit cost of energy produced (or saved) over the full lifetime of a project.
- **Life cycle cost (LCC):** The present value of all costs of energy at the site throughout the analysis period.
- **Kilowatt (kW):** A unit of power.
- **Kilowatt-hour (kWh):** The amount of energy a kilowatt source produces in 1 hour.
- **Net billing**: Utility program that compensates solar panel owners for the excess power they send to the grid.
- **Net present value**: The total economic value of a system after subtracting life cycle costs (LCCs) from the energy bill savings the system will create.
- **Resilience**: The ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions through adaptable and holistic planning and technical solutions.

Contents

Executive Summary: Project Overview, Benefits, and Costs

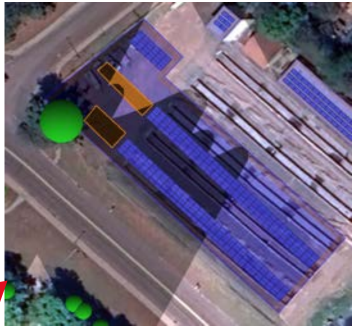
Project Overview

- The **Lac du Flambeau William J. Poupart, Sr. Fish Hatchery,** located on Pokegema Lake in Lac du Flambeau, Wisconsin, operates year-round. The hatchery raises walleye and muskellunge to stock reservation waters. The hatchery provides important ecological, economic, and cultural value for the local area and surrounding region.
- The hatchery is interested in pursuing **solar photovoltaics (PV) and battery storage** at the site to **reduce energy costs** and **improve resilience** to power outages.

Extended growth walleyes being weighed for stocking at the Lac du Flambeau Fish hatchery.
Image from Kristen Hanson, LDF Tribe

Potential Locations for Solar

Proposed system locations at the fish hatchery.
Image from Google Earth



Location 1: Max: 122 kW_{DC}

Location 2: Max: 49 kW_{DC}

- Hatchery personnel identified many potential locations in which solar PV could be installed.
- This analysis considered two of the potential siting locations:
  1. **Ground-mount PV over retired raceways**
  2. **Rooftop PV on the fish hatchery building.**
- This analysis assumes these PV systems would tie into the electric meter at the hatchery building.
- See Appendix and Assumptions slides for more information on the potential PV siting locations and the electric meters at this site.

Proposed System Sizing and Siting

Solar PV

- **49 kW rooftop** and **57 kW ground-mount (106 kW total)**

Battery Storage:

- **24 kW/383 kWh** (16 hours)

Without Diesel Generation

- This PV and battery sizing is expected to support all loads at the hatchery building for two days without use of the existing backup generator.

Utility Rate Switch

- It appears cost-advantageous to switch from the current electricity rate (Cg1) to the time-of-use (TOU) rate (Cg3).[1]

Proposed system location at the fish hatchery.
Image from Google Earth

How was this system sizing determined? Initial modeling using the REopt optimization platform indicates that the above system sizing will provide the most cost savings while also meeting the site's 48-hour resilience goal, without use of existing onsite backup generation. This initial proposed sizing and locations must be validated by detailed engineering and financial assessments.

[1] A TOU rate is currently required by Wisconsin Public Service (WPS) in order to net meter systems larger than 20 kW.

Project Benefits

Proposed system: 106 kW solar PV and 24 kW/383 kWh battery energy storage

Renewable generation: 108 MWh annually or 98% of facility load

Economics: $13.8k (97%) annual bill savings, and total net cost of $196,000, relative to current energy costs under the Cg1 rate[1]

Resilience: System designed to support 100% of facility loads through a 48-hour outage[2]

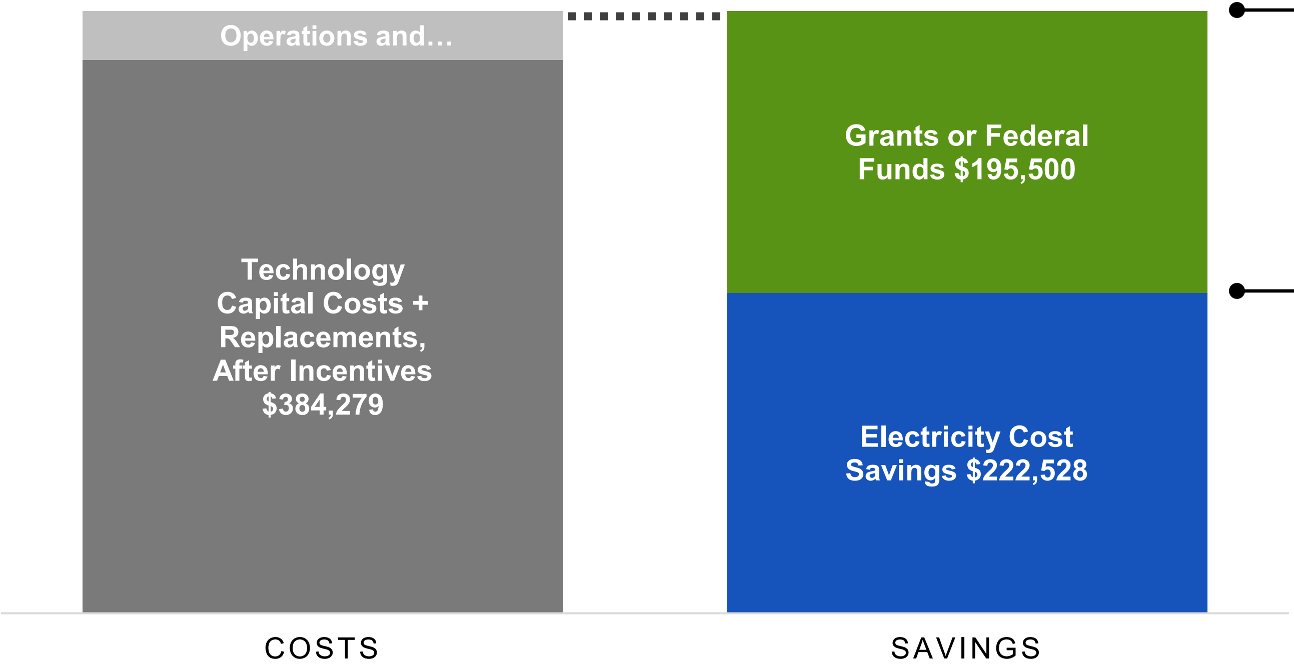
Climate: 461 metric tons avoided carbon dioxide-equivalent (CO_2e) emissions (equivalent to taking 110 cars off the road for a year [calculated using the U.S. Environmental Protection Agency's Equivalency Calculator])

Health: $54,000 in avoided public health costs

[1] Cost savings assume a switch to the Cg3 rate. Savings are based on battery dispatch with perfect foresight into future conditions and are thus an upper bound on expected savings.
[2] This resilience design criteria assumes perfect equipment reliability and one "design" outage in each season of the year. Expected probability of meeting critical loads for outages occurring any time of year and assuming imperfect reliability are shown in the appendix.

Costs and Benefits of Project

30-Year Costs and Benefits of Solar (106 kW) and Battery (24-kW, 16-hour) Project



With $196,000 Grant: Project is estimated to **break even**

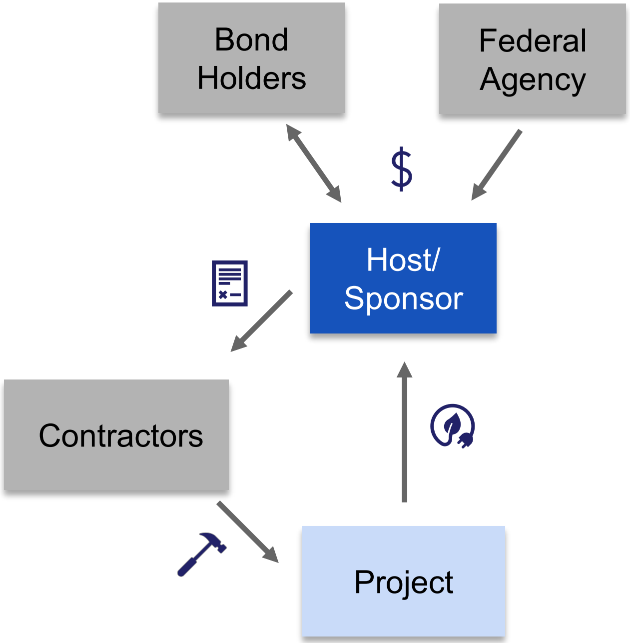
Without Grants: Anticipated net cost of **$196,000**

Electricity cost savings are relative to current costs under rate Cg1.

Project Structure

The Lac du Flambeau fish hatchery.
Photo from Hunter Mayo, LDF Tribe

Sponsor-/Host-Owned



Financial Summary

Potential Financing Sources for Direct Ownership

Grant Opportunities	Loan Opportunities
DOE Office of Indian Energy funding opportunities	U.S. Department of the Interior Indian Loan Guarantee and Insurance Program
U.S. Department of Agriculture Rural Development Energy Programs	U.S. Department of Agriculture Rural Energy for American Program Renewable Energy Systems and Energy Efficiency Loans
GRID Alternatives Tribal Solar Accelerator Fund	DOE Loan Program Office Tribal Energy Financing Program

Key Metrics

	Direct Ownership
Upfront Cost	$595,600 (before incentives) $309,000 (after incentives)
NPV	-$195,500
Internal Rate of Return	0.4%
Payback Period	29 Years
Levelized Cost of PV Generation	$0.15/kWh
Discount Rate	6.4%

Financials assume a switch to the Cg3 rate and are relative to current costs under the Cg1 rate.

Example Project Timeline

Phase 1: 1–2 years	Phase 2: 2–3 months	Phase 3: Through useful life

Development

- Community engagement
- Final technical design
- Secure offtake agreements, permits, and construction contract
- Finalize financing structure and commitments
- Target notice to proceed: 2026.

Construction

- Full engineering design
- Target commercial operations date: 2027.

Operations

- Regular systems O&M
- Year 10 battery energy storage system replacement
- Year 10 inverter replacement
- Year 25–35: End of panel lifetime.

This timeline is meant to serve as an example, assuming the fish hatchery begins the Development Phase in early 2025.

Analysis Approach and Key Assumptions

Modeling Overview

The optimal solar PV and battery sizing at the Lac du Flambeau Fish Hatchery, and the anticipated costs and benefits, were evaluated using NREL's **REopt** platform.

REopt is an extensively validated techno-economic model that identifies the cost-optimal combination and sizing of distributed energy resources for a site, accounting for site-specific characteristics and resilience goals.

Key model outputs include system sizing, dispatch, project economics, grid outage survivability metrics, and avoided emissions.

Learn more: https://reopt.nrel.gov/.

Key inputs are detailed on the following slides.

Modeling Overview

REopt identified the solar+battery system capacities that are expected to **minimize the life cycle cost (LCC) of energy** at the site while achieving the site's resilience goal.

- **LCC** of energy: The present value of all costs of energy throughout the analysis period.

LCC = Capital Costs − Available Incentives + Operating Costs + Electric Grid Purchases + Fuel Purchases

- **Net present value (NPV)** of the proposed system: The LCC savings between the business-as-usual (BAU) case and the optimized investment case.

NPV = **LCC Business-As-Usual** − **LCC Optimized Case**

If **NPV>0**, the project provides cost **savings** relative to the BAU case.
If **NPV<0**, the project is **more expensive** than the BAU case.

REopt
Renewable Energy Integration and Optimization

Modeling Overview

Resilience Goal

Electric Loads

Cost of Electricity

Net-Metering Policy

Technology Types and Costs

Detailed assumptions can be found in Appendix A.

Modeled Resilience Requirement

The system is initially sized to ensure critical operations can continue during a 48-hour power outage occurring during defined periods and assuming that the equipment is 100% reliable.

Results are then post-processed using REopt's Energy Resilience Performance Tool to assess the probability of surviving outages occurring **at any time**, accounting for expected equipment **reliability and availability**.

Resilience Inputs

Outage duration: 48 hours

Outage timing: Assumes outages are centered on the peak load for each of the four seasons.

Critical load: 100% of typical loads

Other Site and Cost Inputs:

Details on subsequent slides.

Optimal System Sizing From REopt

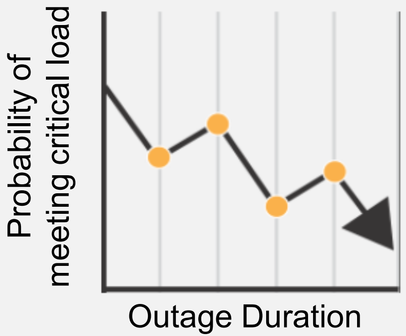
REopt

106 kW

24 kW/383 kWh

No existing backup generator

Advanced Outage Projections



Hatchery Meters and Associated Electric Loads

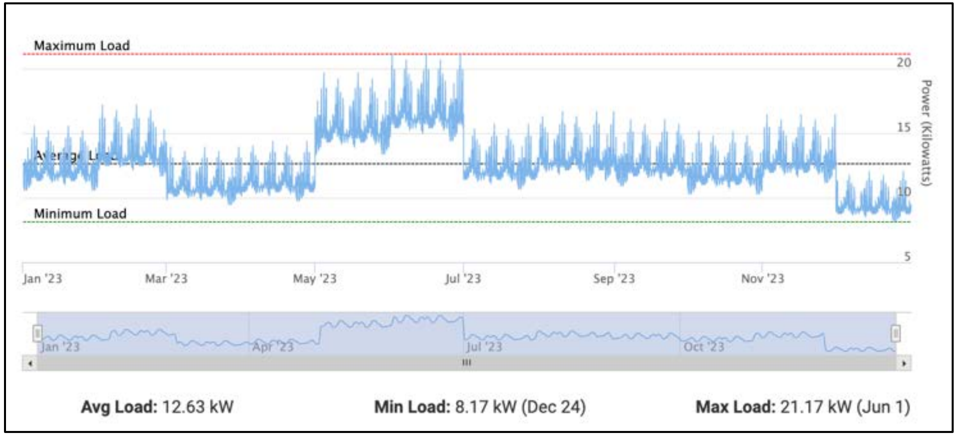
- The hatchery has three electric meters, each with a separate WPS utility account. Each meter serves different facilities and operations.
- This analysis used the **fish hatchery building meter (001)** for consideration of solar PV and battery storage due to the relative magnitude and importance of electric loads at this meter.
- Future analyses could consider solar PV and/or battery storage interconnected with the other meters at this site.

Last Digits of Account Number	Major Facilities or Operations Served	Annual Load	
		2022	2023
001	• Fish hatchery building and pumps.	110 MWh	90 MWh
003	• Aeration tower and raceways • Note: Raceways not operational 2023–2024, but will regain use of two raceways after hatchery upgrades.	50 MWh	8 MWh
004	• Pumphouse (feeds extended growth ponds operation) • Net storage poleman.	10 MWh	0.5 MWh

Typical and Critical Electric Loads

- Monthly electric loads were provided for January 2022–August 2024.
- Hourly interval data was obtained from WPS for September 2023–March 2024.
- Site personnel confirmed that 2022 is more representative of typical load than 2023 or 2024 loads, given equipment availability.
- Hourly loads from September 2023 were used to determine the typical load shape (timing of consumption).
- This hourly *load shape* was scaled to reflect the actual 2022 monthly *consumption totals* to obtain an hourly load profile for 1 year.
- 100% of typical loads were considered critical to meet during modeled grid outages.

Electricity Use at Fish Hatchery Building



Annual consumption: 110,640 kWh

Net Billing and Utility Rates

- The current net-billing policy of WPS differentiates between systems sized **less than and larger than 20 kW**.
- Systems sized larger than 20 kW must be on a TOU energy rate to participate in net billing (a rate with energy costs that vary by time of day or season).
- This analysis considers two distinct utility rate and net-metering policy pairings:
  1. The hatchery's **current non-TOU rate (Cg1)** paired with the "**less than 20 kW**" net-billing policy (systems sized over 20 kW under this policy are assumed to receive no compensation for exports to the grid)
  2. An alternative, **optional TOU rate (Cg3)** paired with the "**larger than 20 kW**" net-billing policy.
- Results indicate that switching to the Cg3 TOU rate and participating in the "larger than 20 kW" net-billing policy would be cost-advantageous for the hatchery. The solar PV and battery option highlighted in this deck assumes this rate and net-billing policy.

Net-Billing Policy

"Net billing" refers to the rate at which excess solar electricity exported to the grid is compensated.

The applicable WPS policy[1] depends on the installed system size and rate tariff. This analysis explores both net-metering policies and corresponding rate tariffs.

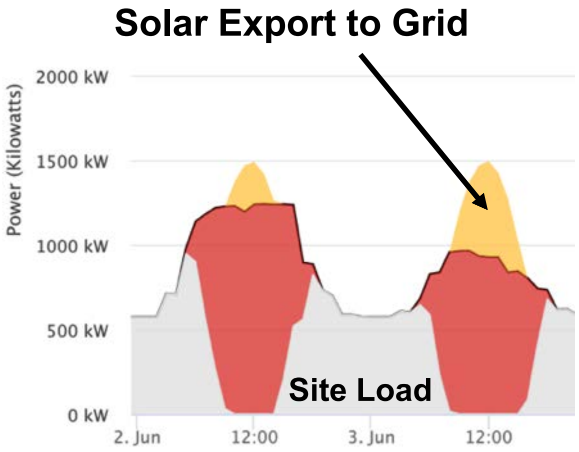
WPS net-billing policy for systems <20 kW:

- Compensated at full retail rate for all export up to monthly consumption
- Once export exceeds consumption, export compensated at $0.03532/kWh.[2]

WPS net-billing policy for systems >20 kW and <1 MW:

- Most applicable option for the hatchery appears to be PG-2B.
- Facility must use a TOU tariff.
- Compensated at an avoided cost of energy and capacity, which varies between defined on-peak and off-peak periods.

Treatment of "renewable credits": System owner keeps renewable credits and can claim environmental benefits.



Example of solar generation exporting to the grid. Image from REopt web tool

[1] WPS.N.d. "Customer-owned generation." Accessed October 2024. https://www.wisconsinpublicservice.com/environment/generation-wi.
[2] This compensation for excess generation is modeled on an annual, rather than monthly, basis due to limitations in the model.

Current Cost of Electricity (Cg1)

The Lac du Flambeau Fish Hatchery is currently billed under the WPS "**General Secondary Service (Cg1-Three Phase)**"[1] electric rate. The rate does not vary by time of day or year and does not include demand charges.

Rate Charge Category	Charge
Total Energy Charges	$0.1236/kWh
Fixed Charges	$1.4535/day

The hatchery has the **option** of enrolling in a **TOU energy rate,** detailed on the next slide.

[1] WPS. N.d. "Wisconsin standard electric rates for business service." Accessed August 2024. https://www.wisconsinpublicservice.com/payment-bill/business/wi-rates.
Energy charges above were calculated based on total charges August 2023–July 2024.

Potential TOU Rate Option (Cg3)

- The hatchery could enroll in the WPS "**Small Commercial & Industrial – Optional TOU Rate (Cg3-OTOU).**"[1]
- A TOU rate is required to participate in the PG-2B[2] net-billing policy, which can be applied to PV systems greater than 20 kW.
- The hatchery could select between three "On-Peak Period" options (shown in the screenshot below).

It appears that all TOU options would result in savings at the hatchery meter relative to current energy bills. **Option 2** is expected to produce the most savings (with or without solar PV), followed closely by Option 1.

On-Peak Periods
The following periods on Monday, Tuesday, Wednesday, Thursday, and Friday, excluding holidays:

1. Winter (Calendar Months of October – April)
   Option 1: 8:00 AM to 12:00 noon and 4:00 PM to 9:00 PM
   Option 2: 9:00 AM to 12:00 noon and 4:00 PM to 10:00 PM
   Option 3: 9:00 AM to 8:00 PM

2. Summer (Calendar Months of May – September)
   Option 1: 9:00 AM to 7:00 PM
   Option 2: 10:00 AM to 8:00 PM
   Option 3: 9:00 AM to 8:00 PM

Customer must choose the same option number during both the winter and summer periods. A customer requesting a change in the on-peak pricing period option must remain on the option previously selected until the next normal reading of the electric meter.

Off-Peak Periods
All hours not included as on-peak hours above.

Option 2: On-Peak Periods

	12 am	1 am	2 am	3 am	4 am	5 am	6 am	7 am	8 am	9 am	10 am	11 am	12 pm	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm	7 pm	8 pm	9 pm	10 pm	11 pm
Jan	2	2	2	2	2	2	2	2	2	1	1	1	2	2	2	2	1	1	1	1	1	1	2	2
Feb	2	2	2	2	2	2	2	2	2	1	1	1	2	2	2	2	1	1	1	1	1	1	2	2
Mar	2	2	2	2	2	2	2	2	2	1	1	1	2	2	2	2	1	1	1	1	1	1	2	2
Apr	2	2	2	2	2	2	2	2	2	1	1	1	2	2	2	2	1	1	1	1	1	1	2	2
May	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	2	2	2	2
Jun	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	2	2	2	2
Jul	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	2	2	2	2
Aug	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	2	2	2	2
Sep	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	2	2	2	2
Oct	2	2	2	2	2	2	2	2	2	1	1	1	2	2	2	2	1	1	1	1	1	1	2	2
Nov	2	2	2	2	2	2	2	2	2	1	1	1	2	2	2	2	1	1	1	1	1	1	2	2
Dec	2	2	2	2	2	2	2	2	2	1	1	1	2	2	2	2	1	1	1	1	1	1	2	2

Rate Charge Category		Charge
1	On-Peak Energy Charges	$0.22894/kWh
2	Off-Peak Energy Charges	$0.06541/kWh
Fixed Charges		$1.4535/day

[1] WPS. 2022. "Small Com'l & Indus Serv - Optional Time-of-Use." December 27, 2022. https://www.wisconsinpublicservice.com/company/wi_tariffs/cg3otou.pdf.
[2] WPS. 2023. "Parallel Generation-Purchase by WPSC." March 29, 2023. https://www.wisconsinpublicservice.com/company/wi_tariffs/PG-2B.pdf.

Technology Types and Assumed Costs

Solar PV

- **Type:** Ground-mount and rooftop, fixed tilt, standard modules
- **Capital cost:**
  - **Ground:** $3,164/kW
  - **Rooftop:** $2,440/kW
- **O&M cost:** $18/kW-DC

Battery Storage

- **Type:** Lithium-ion
- **Capital cost:** $445/kWh (battery pack) + $910/kW (inverter and Balance of Systems)
- **Replacement:** In Year 10 at $318/kWh + $715/kW

Assumed Incentives

- **Investment Tax Credit (ITC):** 40% (assumes 30% base and 10% Tribal Land Bonus) for both PV and battery
- **Modified accelerated cost recovery system (MACRS)**:
  - PV: 5-year schedule, 40% bonus depreciation
  - Battery: 5-year schedule, 40% bonus depreciation.

See Appendix A for additional information on cost assumptions

Scenarios Modeled (Sensitivity Analysis)

- Analysis considered several scenarios for solar and battery investment at the Lac du Flambeau Fish Hatchery.
- The sensitivity variables and their modeled values are shown below.
- The scenario highlighted in this slide deck includes the inputs circled.
- Results for all scenarios can be found in Appendix B.

Resilience Goal	With or Without Existing Generator	Solar Cost	Electricity Rate
12-hour outage	With 100-kW generator	**Ground:** $3,164/kW **Rooftop:** $2,440/kW	Cg1 (current flat rate)
48-hour outage	Without 100-kW generator	**30% Higher** **Ground:** $4,113/kW **Rooftop:** $3,172/kW	Cg3 (optional TOU rate)

Next Steps

Next Steps

- Verify all assumptions used in initial analysis with relevant stakeholders and partners
- Consult with engineers/renewable energy professionals to confirm site suitability (e.g., roof integrity, shading), potential need for electrical upgrades, and requisite controls and switchgear
- Discuss the project with the utility and understand any utility-related requirements or limitations
- Consider possible grant or other funding opportunities
- Assess zoning, permitting, and interconnection requirements
- Preview the project with likely financing partners.

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Thank you!

NREL/TP-5400-92528

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Solar Energy Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

Appendix A:

Detailed Assumptions and Model Inputs

Economic Assumptions

	Value Modeled	REopt Default
Analysis Period	30 years	25 years
Ownership Model	Direct purchase	Direct purchase
Off-Taker (Host) Discount Rate (nominal)	6.38%	6.38%[1]
O&M Cost Escalation Rate (nominal)	2.5%/year	2.5%/year[1]
Electricity Cost Escalation Rate (nominal)	1.7%/year	1.7%/year[2]
Generator Fuel Cost Escalation Rate (nominal)	1.2%/year	1.2%/year[2]
Host Effective Tax Rate	0%	26%

[1] NREL. 2023. "Annual Technology Baseline." https://atb.nrel.gov/electricity/2023/data.
[2] EIA (U.S. Energy Information Administration). 2023. "Annual Energy Outlook 2023." https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2023&region=1-0&cases=ref2023&start=2023&end=2048&f=A&linechart=ref2023-d020623a.3-3-AEO2023.1-0&map=ref2023-d020623a.4-3-AEO2023.1-0&sourcekey=0.

Solar PV Assumptions

	Value Modeled	REopt Default
PV Lifetime	30 years	25 years
System Type	Rooftop and ground-mount	Ground-mount, fixed tilt
Tilt	Rooftop: 18° Ground-mount: 27°	20°
DC-to-AC ratio	1.2	1.2[1]
Azimuth	SE roof: 238.6°, NW roof: 58.6°, ground: 222°	180° (south-facing)
Losses	14%	14%[1]
Technology Resource	NREL National Solar Radiation Database[2]	NREL National Solar Radiation Database[2] typical meteorological year data for this location
Capital Costs	**Ground:** $3,164/kW[3] **Rooftop:** $2,440/kW (Estimated based on cost data from 2021 – 2023)[3,4,5] **Sensitivity:** 30% higher costs	$1,790/kW-DC[4]
O&M Costs	$18/kW/yr	$18/kW/yr[4]
Incentives	40% ITC (assuming Tribal Land Bonus adder)	30% ITC, 5-year MACRS, 60% bonus depreciation (for projects in 2024)

[1] Dobos, Aron P. 2014. *PVWatts Version 5 Manual*. Golden, CO: NREL. NREL/TP-6A20-62641. https://www.nrel.gov/docs/fy14osti/62641.pdf.
[2] NREL. n.d. "National Solar Radiation Database." https://nsrdb.nrel.gov/.
[3] Lawrence Berkeley National Laboratory. N.d. *Tracking the Sun.* Data accessed April 29, 2024. https://emp.lbl.gov/tracking-the-sun.
[4] NREL. 2023. "Annual Technology Baseline." https://atb.nrel.gov/electricity/2023/data.
[5] Interactive U.S. Solar PV System Cost Model : 2023. 2023rd ed., Wood Mackenzie, 2023.

Battery Assumptions

	Value Modeled	REopt Default
System Type	Lithium-ion battery	Lithium-ion battery
AC-AC Roundtrip Efficiency	89.9%	89.9%[1]
Can Grid Charge?	Yes	Yes
Capital Costs	$445/kWh+$910/kW	$445/kWh+$910/kW[2]
Replacement Costs	$318/kWh, $715/kW	$318/kWh, $715/kW (In Year 10, assuming 5% annual cost decline)
Minimum State of Charge During Normal Operations	20%	20%[1]
Incentives	40% ITC (assuming Tribal Land Bonus adder)	30% ITC; 7-year MACRS, 60% bonus depreciation (for projects in 2024)

[1] Patsios, Charalampos, Billy Wu, Efstratios Chatzinikolaou, Daniel J. Rogers, Neal Wade, Nigel P. Brandon, and Phil Taylor. 2016. "An integrated approach for the analysis and control of grid connected energy storage systems." *Journal of Energy Storage* 5: 48-61. https://www.sciencedirect.com/science/article/pii/S2352152X15300335.
[2] U.S. Energy Storage Monitor: Q2 2023 Full Report. Wood Mackenzie Power & Renewables/American Clean Power Association, June 2023.

Incentives Assumptions

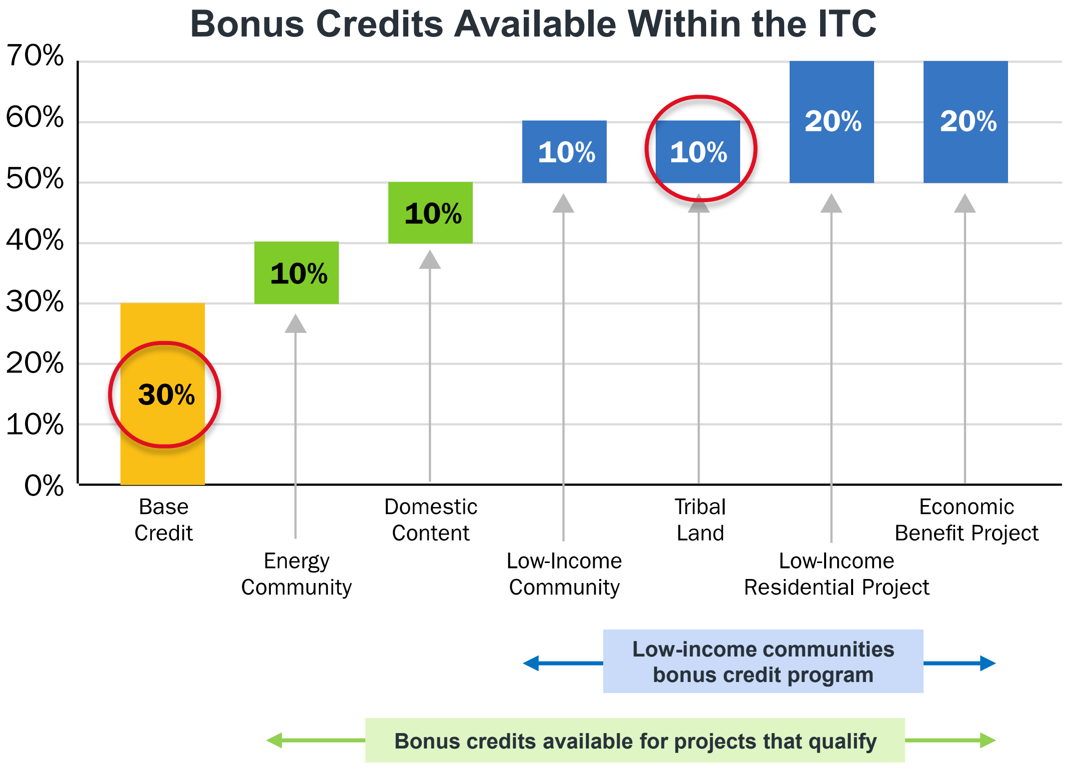


Illustration by NREL, adapted from Clean Energy Group

Resilience Assumptions

	Value Modeled	REopt Default
Outage Duration	12 hours and 48 hours considered	None
Outage Timing	Centered on peak loads in each of the four seasons	Centered on peak loads in each of the four seasons
Critical Loads	100% of typical loads	50% of typical loads
Existing Generator	100-kW existing generator and no generator considered	None
Diesel Fuel Cost	$3.51/gal[1]	$3.00/gal[2]

[1] AAA Wisconsin. 2024. “Fuel Prices.” Last modified November 27, 2024. https://gasprices.aaa.com/?state=WI.
[2] EIA. 2024. “Short-Term Energy Outlook Data Browser.” Last modified November 13, 2024. https://www.eia.gov/outlooks/steo/data/browser/#/?v=8&f=A&s=0&start=2018&end=2024&map=&linechart=~DSWHUUS&maptype=0&ctype=linechart.

Climate Emissions Assumptions

- Avoided emissions account for avoided purchases of grid electricity and avoided onsite fuel consumption for an emergency generator (if applicable).
- For grid electricity: Avoided emissions are estimated over the lifetime of the project using NREL's Cambium 2022 hourly emissions dataset with emissions rate inputs shown in the screenshot.[1]
- Emissions rate of diesel fuel: 22.58 lb CO_2e/gallon.

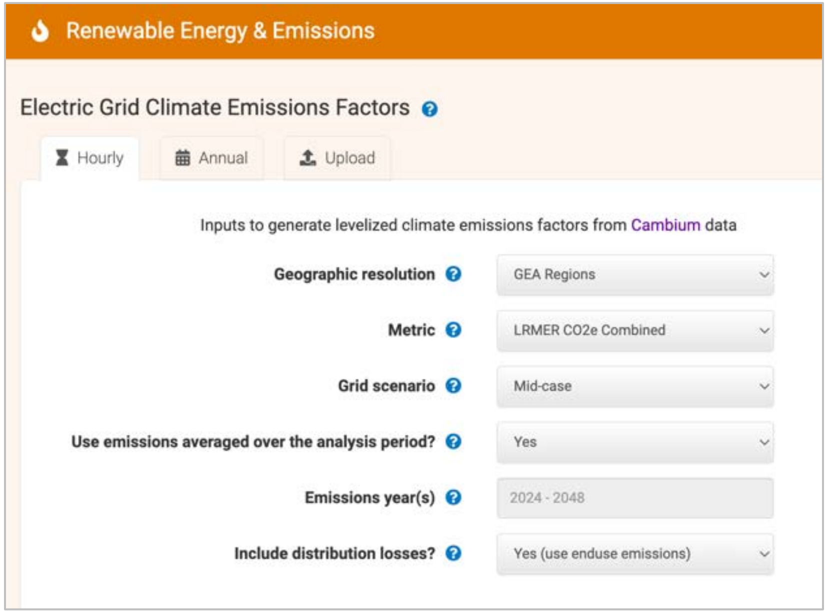


Image from REopt web tool

[1] Gagnon, Pieter, Brady Cowiestoll, and Marty Schwarz. 2023. *Cambium 2022 Scenario Descriptions and Documentation.* Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A40-84916. https://www.nrel.gov/docs/fy23osti/84916.pdf.

Health Emissions Assumptions

How are avoided public health costs calculated?

As the difference in health damage costs between the optimized (solar) case and BAU operations, based on avoided use of grid electricity.

Health costs = health-related emissions [tons $PM_{2.5}$, NOx, SO_2] x public health cost [$/ton]

Data source for emissions rate of grid-purchased electricity: Regional, hourly marginal health emissions rates from the U.S. Environmental Protection Agency's AVERT database.

Data source for health emissions costs: Location-specific, from EASIUR model. Quantifies impact of ambient[1] $PM_{2.5}$ on mortality for surrounding population.

[1] NOx, SO_2, and primary $PM_{2.5}$ all contribute to the formation of ambient $PM_{2.5}$
See the REopt User Manual for more details: https://reopt.nrel.gov/tool/reopt-user-manual.pdf.

Model Limitations

The following considerations are not accounted for in this initial analysis and should be further assessed prior to investment (not an exhaustive list):

- Potential required electrical upgrades at the site
- Interconnection rules and costs
- Land preparation costs
- Microgrid controller costs
- Land impacts
- Zoning and permitting requirements
- Site suitability (e.g., roof integrity for rooftop solar, soil composition for ground-mount solar, shading).

Additional Resources

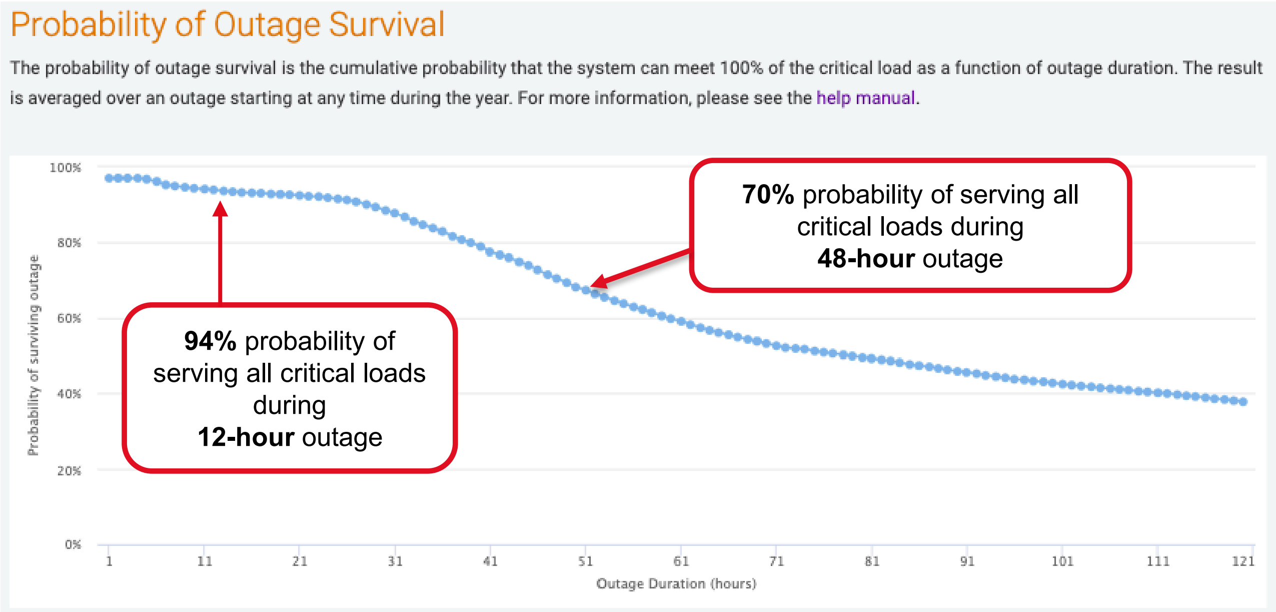
- **REopt web tool**: https://reopt.nrel.gov/
- **REopt User Manual**: https://reopt.nrel.gov/tool/reopt-user-manual.pdf
- **Energy Communities Tax Credit Bonus Map**: https://arcgis.netl.doe.gov/portal/apps/experiencebuilder/experience/?id=a2ce47d4721a477a8701bd0e08495e1d
- **Low-Income Communities Bonus Credit Program Map**: https://experience.arcgis.com/experience/12227d891a4d471497ac13f60fffd822/page/Page/.

Appendix B: Detailed Results and Sensitivity Analysis

Expected System Resilience

With a 106-kW solar array and 24-kW/16-hour battery, the hatchery facility is expected to have the following probability of surviving grid outages of increasing duration.

For more information on the REopt Energy Resilience Performance modeling, see the REopt User Manual.



Result obtained by utilizing the combined PV production profile of the rooftop and ground-mount system: https://reopt.nrel.gov/tool/results/8d024f5f-df2e-429d-bee5-abc6fc5b5fec.

Results Table for All Scenarios

Scenarios Modeled (Sensitivity Analysis)

- Analysis considered several scenarios for solar and battery investment at the Lac du Flambeau Fish Hatchery.
- The sensitivity variables and their modeled values are shown below.
- The scenario highlighted in this slide deck includes the inputs circled.
- Results for all scenarios can be found on the next slide.

Resilience Goal	With or Without Existing Generator	Solar Cost	Electricity Rate
12-hour outage	With 100-kW generator	**Ground:** $3,164/kW **Rooftop:** $2,440/kW	Cg1 (current flat rate)
48-hour outage	Without 100-kW generator	**30% Higher** **Ground:** $4,113/kW **Rooftop:** $3,172/kW	Cg3 (optional TOU rate)

Cost-Optimal Results Across Scenarios

Resilience Goal	With or Without 100 kW Generator	Solar Cost	Electric Rate	Ground-Mount PV [kW_{DC}]	Rooftop PV on SE Aspect [kW_{DC}]	Rooftop PV on NW Aspect [kW_{DC}]	Battery Storage [kW, hrs]	NPV[1]
12 hours	With Gen	High	Cg1 (current, flat)	-	-	-	-	$0
48 hours	With Gen	High	Cg1 (current, flat)	-	-	-	-	$0
12 hours	Without Gen	High	Cg1 (current, flat)	-	25 kW	19 kW	18 kW, 7 hr	-$82,966
48 hours	Without Gen	High	Cg1 (current, flat)	34 kW	25 kW	24 kW	25 kW, 19 hr	-$293,859
12 hours	With Gen	Mid-case	Cg1 (current, flat)	-	21 kW	-	-	$6,364
48 hours	With Gen	Mid-case	Cg1 (current, flat)	-	21 kW	-	-	$6,364
12 hours	Without Gen	Mid-case	Cg1 (current, flat)	1 kW	25 kW	24 kW	18 kW, 6 hr	-$61,346
48 hours	Without Gen	Mid-case	Cg1 (current, flat)	50 kW	25 kW	24 kW	27 kW, 15 hr	-$247,057
12 hours	With Gen	High	Cg3 (TOU)	-	17 kW	-	10 kW, 6 hr	$21,155
48 hours	With Gen	High	Cg3 (TOU)	-	17 kW	-	10 kW, 6 hr	$20,860
12 hours	Without Gen	High	Cg3 (TOU)	-	25 kW	3 kW	18 kW, 9 hr	-$21,425
48 hours	Without Gen	High	Cg3 (TOU)	31 kW	25 kW	24 kW	18 kW, 27 hr	-$241,918
12 hours	With Gen	Mid-case	Cg3 (TOU)	-	25 kW	-	10 kW, 5 hr	$31,124
48 hours	With Gen	Mid-case	Cg3 (TOU)	-	25 kW	-	5 kW, 6 hr	$32,842
12 hours	Without Gen	Mid-case	Cg3 (TOU)	-	25 kW	17 kW	18 kW, 7 hr	-$2,607
48 hours	**Without Gen**	**Mid-case**	**Cg3 (TOU)**	**57 kW**	**25 kW**	**24 kW**	**24 kW, 16 hr**	-$195,541

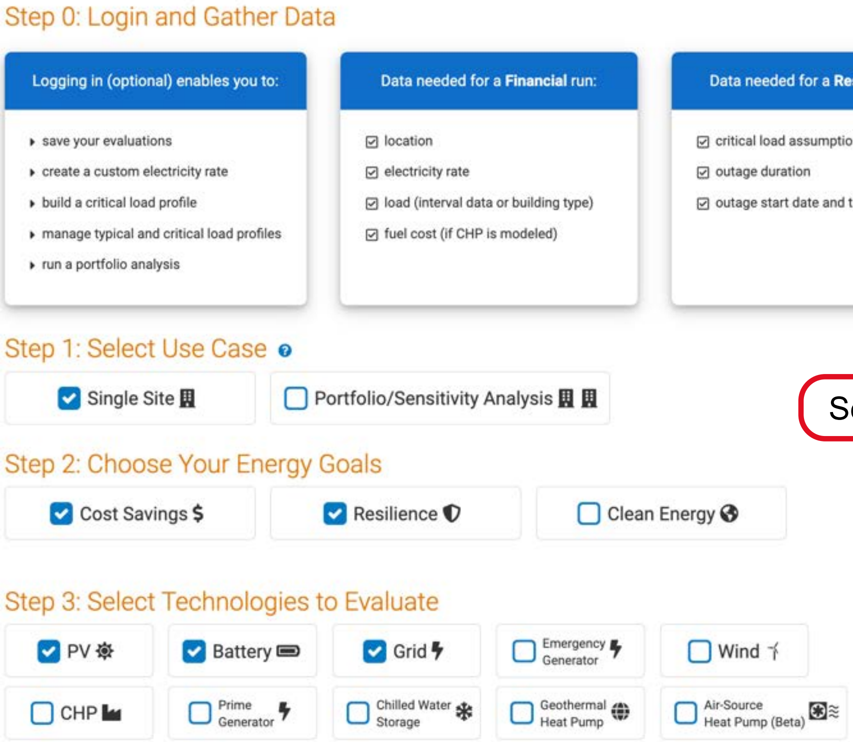
[1] NPVs for Cg3 cases are presented relative to current costs under the Cg1 rate.

Appendix C: Steps For Modeling in REopt

Modeling This System in the REopt Web Tool

- **The analysis presented in this slide deck was performed using the REopt Julia Package** to accurately capture the differing costs and expected production of the rooftop PV and ground-mount PV systems (modeling more than one PV system at a time is not currently feasible in the REopt web tool).
- However, **the following slides show the high-level steps that could be taken to model a simplified scenario** in the REopt web tool (reopt.nrel.gov): a single rooftop PV installation paired with battery storage at the Lac du Flambeau hatchery site.
- Each step includes instructions and tips.
- Prior to utilizing the web tool, key information was collected regarding the site's utility tariff, electric loads, net-metering policy, available space for solar panels, financial parameters, and site goals (as detailed in this slide deck).
- Remember: Users can review their results and inputs by saving and revisiting the URL to the results page of a REopt run.

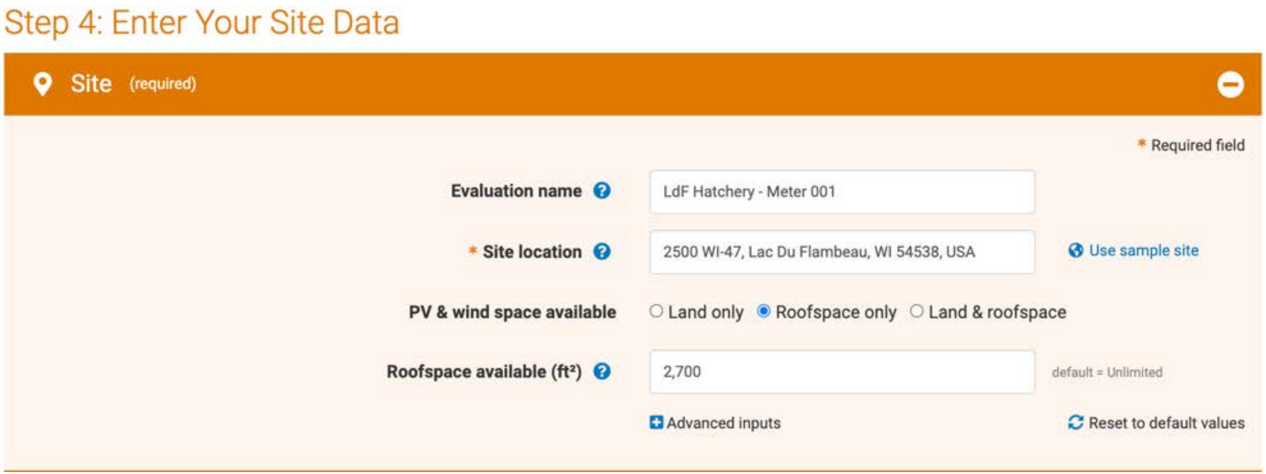
Goals and Technologies Inputs



Select all options shown here.

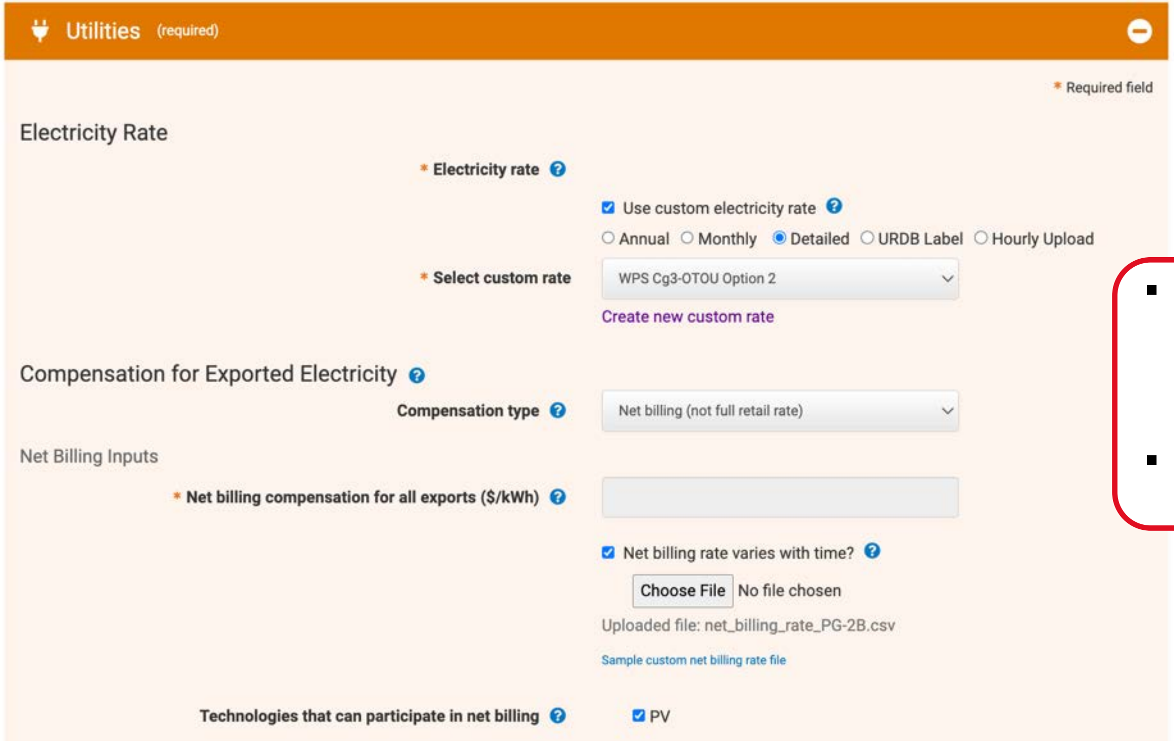
If hatchery staff wanted to consider the current backup generator in the technology solution, we would have also checked “Emergency Generator.” This scenario is only looking for the solar PV and battery system sizes that could support all critical loads.

Site Data Inputs



- Give the evaluation a useful name
- Enter a site location (this is used to determine the expected solar generation)
- Choose “Roofspace only” and enter the available roof space in square feet.

Utility Information Inputs



- Create the detailed rate using REopt's "Custom Rate Builder" and create the TOU net-billing file
- Select all options shown here.

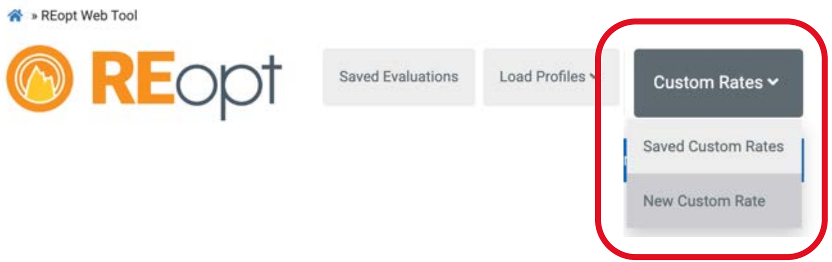
Creating the Custom Rate (1 of 5)

- How to identify available utility rates:
    1. Go to the WPS rate page: https://www.wisconsinpublicservice.com/company/wi-tariffs
    2. Scroll to view rates available for your chosen service class, in this case “Small commercial and industrial”
    3. Click through the rates and read the explanations to understand if the site qualifies and what the rates entail
    4. This analysis assumes the site switches to the Cg3-OTOU rate. Click the rate name to view the details.

Small commercial and industrial service	
Cg-1 (PDF)	12/21/23
Cg-5 (PDF)	12/20/23
Cg-20 (PDF)	12/20/23
Cg1-RR (PDF)	12/20/23
Cg5-RR (PDF)	12/20/23
Cg20-RR (PDF)	12/20/23
Cg3-OTOU (PDF)	12/20/23
Rules (PDF)	12/20/23
Direct control rider (PDF)	12/19/19
Renewable Pathway Pilot Program (PDF)	7/21/23

Creating the Custom Rate (2 of 5)

- The Cg3 rate offers customers a choice between three different options for the timing of "on-peak" charges.
- We need to use the REopt option "Custom Rates" > "New Custom Rate" to build this rate and use it in the REopt web tool.



Amendment 794 Schedule Cg3-OTOU

Small Com'l & Indus Serv - Optional Time-of-Use **Electric**

AVAILABILITY
This schedule is available upon written request on a voluntary basis for service to customers who qualify for rate Schedules Cg-1 or Cg-5.

Customer Charge	Daily
Single phase year-round customers	$0.9084
Single phase seasonal customers	$1.8168
Three phase year-round customers	$1.4535
Three phase seasonal customers	$2.9070

Energy Charge
On-Peak: All kWh at $0.22894/kWh
Off-Peak: All kWh at $0.06541/kWh

PRICING PERIOD DEFINITIONS

On-Peak Periods
The following periods on Monday, Tuesday, Wednesday, Thursday, and Friday, excluding holidays:

1. Winter (Calendar Months of October - April)
   Option 1: 8:00 AM to 12:00 noon and 4:00 PM to 9:00 PM
   Option 2: 9:00 AM to 12:00 noon and 4:00 PM to 10:00 PM
   Option 3: 9:00 AM to 8:00 PM

2. Summer (Calendar Months of May - September)
   Option 1: 9:00 AM to 7:00 PM
   Option 2: 10:00 AM to 8:00 PM
   Option 3: 9:00 AM to 8:00 PM

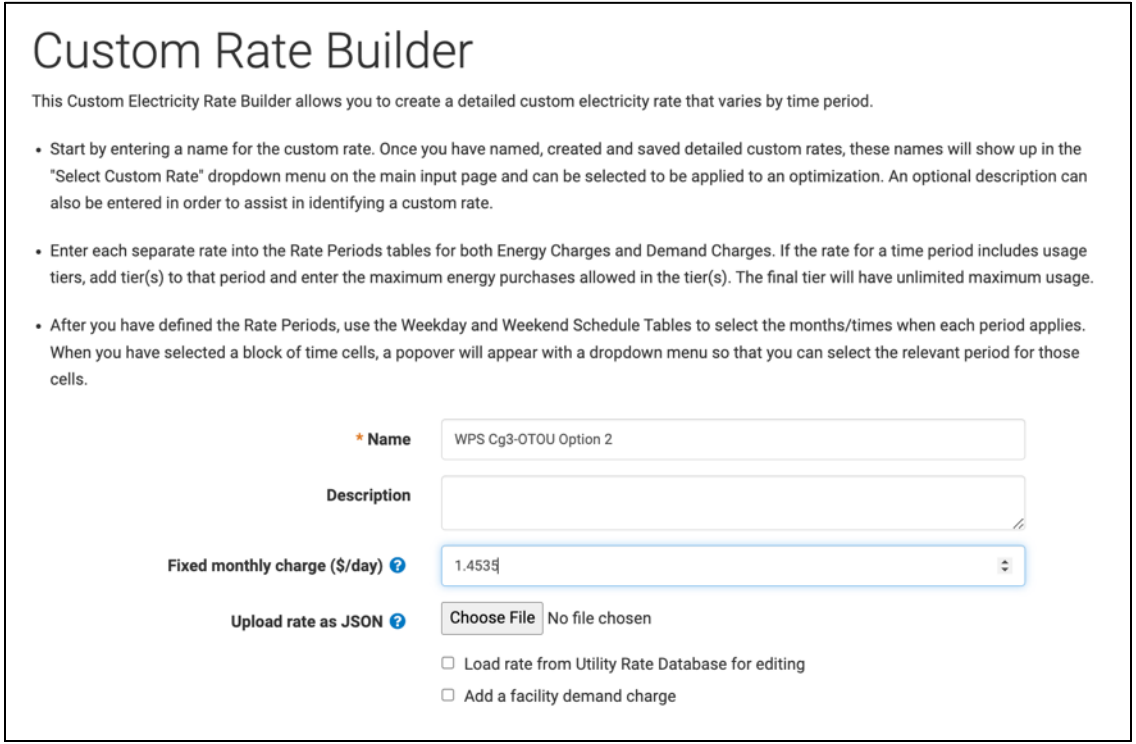
Customer must choose the same option number during both the winter and summer periods. A customer requesting a change in the on-peak pricing period option must remain on the option previously selected until the next normal reading of the electric meter.

Off-Peak Periods
All hours not included as on-peak hours above.

WPS. 2022. "Small Com'l & Indus Serv - Optional Time-of-Use." December 27, 2022. https://www.wisconsinpublicservice.com/company/wi_tariffs/cg3otou.pdf.

Creating the Custom Rate (3 of 5)

- In the REopt Custom Rate Builder, give the rate a useful name and enter the fixed charges as a daily rate (shown in previous screenshot).
- We are modeling TOU Option 2.



Creating the Custom Rate (4 of 5)

- Enter the peak and off-peak charges shown in the rate documentation
- Click and drag in the weekday and weekend tables to specify when the charges apply.

Time of Use Energy Charges

Time of Use Energy Charges - ***Rate*** *Periods*

Period	Tier in Period	Max. Energy Purchases (kWh/month)	Energy Charge ($/kWh)	
1	1	unlimited	0.22894	Add Tier to Period 1
2	1	unlimited	0.06541	Add Tier to Period 2

Add Rate Period

Time of Use Energy Charges - ***Weekday*** *Schedule*

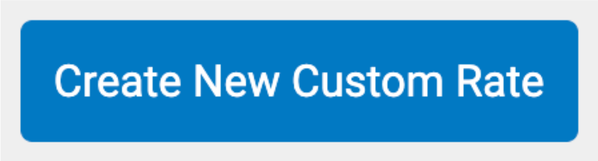
	12 am	1 am	2 am	3 am	4 am	5 am	6 am	7 am	8 am	9 am	10 am	11 am	12 pm	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm	7 pm	8 pm	9 pm	10 pm	11 pm
Jan	2	2	2	2	2	2	2	2	2	1	1	1	2	2	2	2	1	1	1	1	1	1	2	2
Feb	2	2	2	2	2	2	2	2	2	1	1	1	2	2	2	2	1	1	1	1	1	1	2	2
Mar	2	2	2	2	2	2	2	2	2	1	1	1	2	2	2	2	1	1	1	1	1	1	2	2
Apr	2	2	2	2	2	2	2	2	2	1	1	1	2	2	2	2	1	1	1	1	1	1	2	2
May	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	2	2	2	2
Jun	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	2	2	2	2
Jul	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	2	2	2	2
Aug	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	2	2	2	2
Sep	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	2	2	2	2
Oct	2	2	2	2	2	2	2	2	2	1	1	1	2	2	2	2	1	1	1	1	1	1	2	2
Nov	2	2	2	2	2	2	2	2	2	1	1	1	2	2	2	2	1	1	1	1	1	1	2	2
Dec	2	2	2	2	2	2	2	2	2	1	1	1	2	2	2	2	1	1	1	1	1	1	2	2

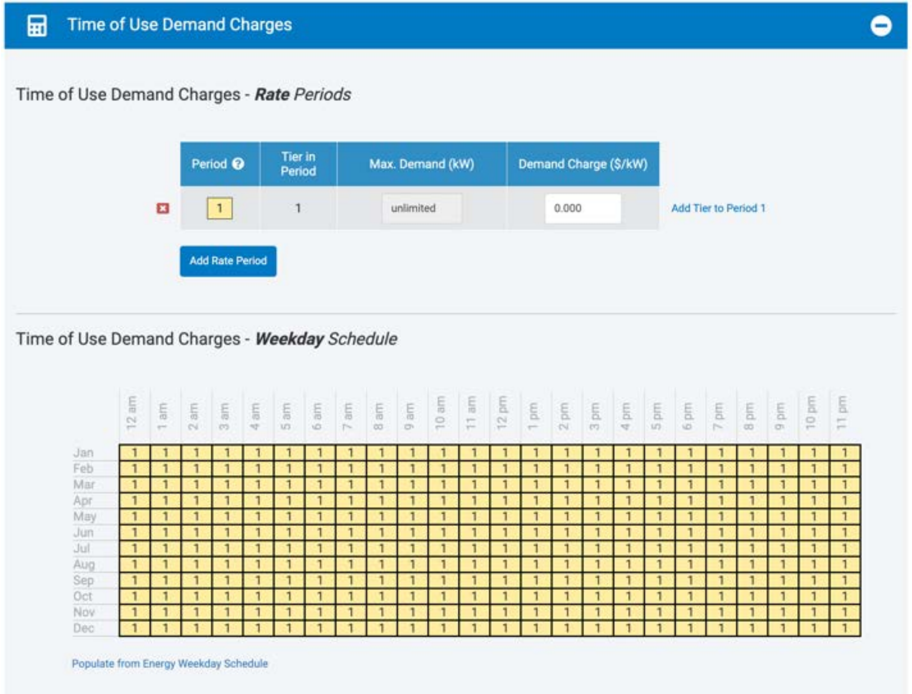
Time of Use Energy Charges - ***Weekend*** *Schedule*

	12 am	1 am	2 am	3 am	4 am	5 am	6 am	7 am	8 am	9 am	10 am	11 am	12 pm	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm	7 pm	8 pm	9 pm	10 pm	11 pm
Jan	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Feb	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Mar	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Apr	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
May	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Jun	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Jul	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Aug	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Sep	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Oct	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Nov	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Dec	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

Creating the Custom Rate (5 of 5)

- Set all demand charges to 0, as this rate does not have demand charges.
- Click “Create a New Custom Rate” when complete. This rate will save to your “Saved Custom Rates.”





Creating the Net-Billing Rate (1 of 2)

- Review the different net-metering policies offered by the utility: https://www.wisconsinpublicservice.com/environment/generation-wi.
- Note that there are different policies for systems under 20 kW and larger than 20 kW.

For systems greater than 20kW

1. For any questions regarding this process please contact:
   - CustomerGen@wisconsinpublicservice.com
2. Select parallel generation rate reference
   - No Purchase by WPS (PDF)
   - Purchase by WPS PG-2A (PDF)
   - Purchase by WPS PG-2B (PDF)
   - Purchase by WPS PG-2C (PDF)
3. Review and understand the rules and requirements
   - Customer-owned solar generation diagram – overhead primary service (PDF)
   - WPS Parallel Generation Rules (PDF)
   - WPS Interconnection Technical Requirements (PDF)
   - Wisconsin Administration Code Rules (PSC-119)
   - More information on Capacity Sizing from PSC 119 updated as of May 1, 2024 (PDF)

- This analysis assumes the PG-2B net-billing rate is used, with details shown below.

Avoided Energy Cost Rate:
The customer will receive a credit on their bill equal to the kilowatt hours supplied to the Company multiplied by the customer's Avoided Energy Cost Rate (shown below). The customer's Avoided Energy Cost Rate is not subject to any adjustments, such as the adjustment for cost of fuel, or any other miscellaneous surcharges or adjustments. This tariff is intended to provide payment for energy sent to the Company.

		Secondary	Primary	Transmission
On Peak				
	Winter	$0.04219	$0.04147	$0.04095
	Summer	$0.05338	$0.05247	$0.05182
Off Peak				
	Winter	$0.02904	$0.02855	$0.02819
	Summer	$0.03041	$0.02989	$0.02952

Creating the Net-Billing Rate (2 of 2)

- Translate the avoided energy and avoided capacity cost rates to a .csv file (a coded script can be useful for this process)
- Save this file and upload it as the REopt net-billing rate.

Avoided Energy Cost Rate:
The customer will receive a credit on their bill equal to the kilowatt hours supplied to the Company multiplied by the customer's Avoided Energy Cost Rate (shown below). The customer's Avoided Energy Cost Rate is not subject to any adjustments, such as the adjustment for cost of fuel, or any other miscellaneous surcharges or adjustments. This tariff is intended to provide payment for energy sent to the Company.

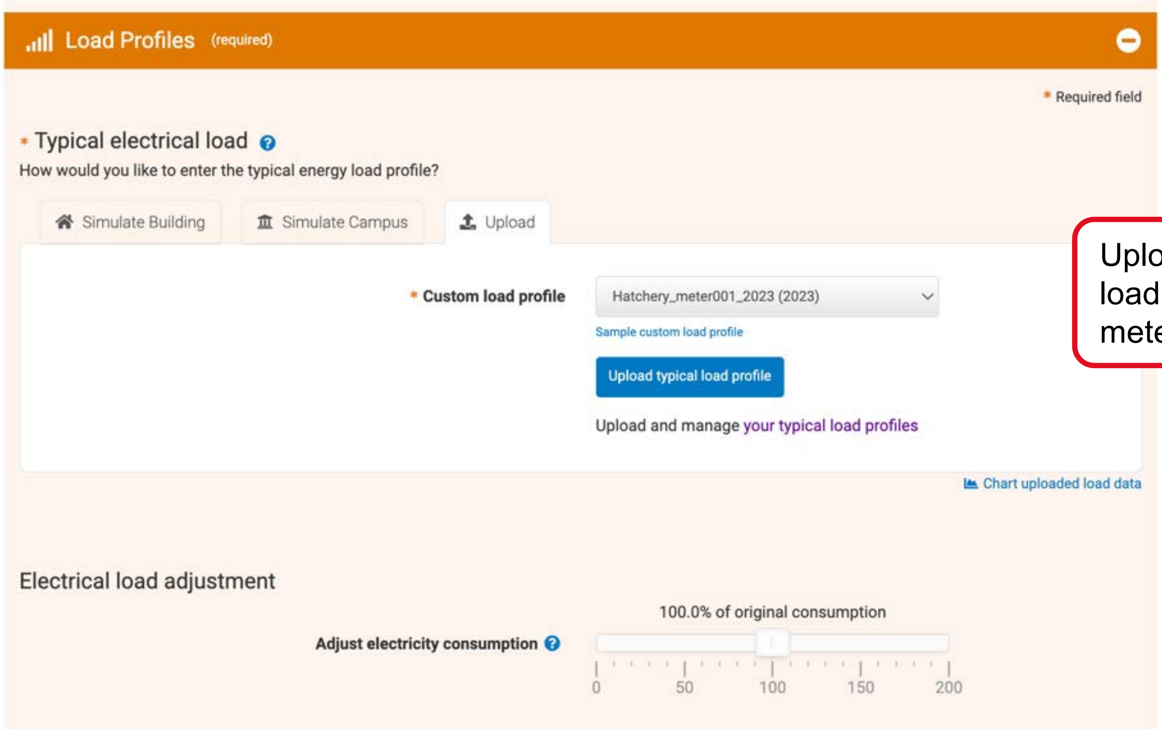
		Secondary	Primary	Transmission
On Peak				
	Winter	$0.04219	$0.04147	$0.04095
	Summer	$0.05338	$0.05247	$0.05182
Off Peak				
	Winter	$0.02904	$0.02855	$0.02819
	Summer	$0.03041	$0.02989	$0.02952

Avoided Capacity Cost Rate: The customer will receive a capacity credit equal to the amount of energy that is supplied to the Company during the designated on-peak period.

	Secondary	Primary	Transmission
All on-peak excess energy, per kWh	0.03228	$0.03134	$0.03095

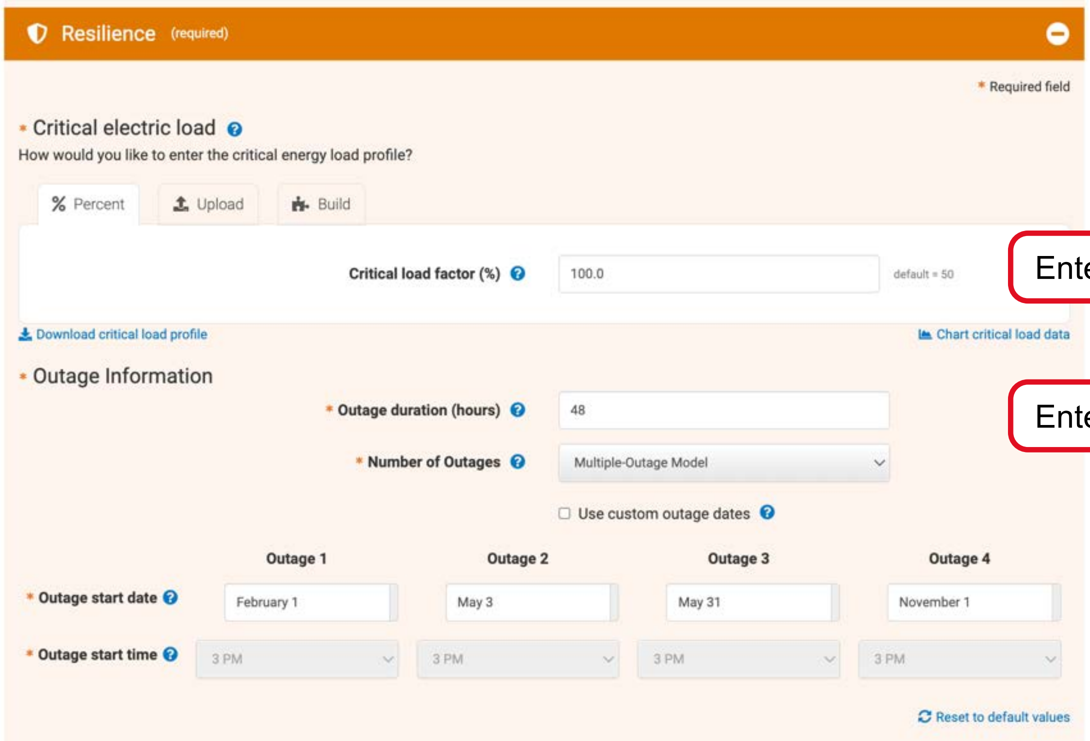
	A	B	C
1	Hour	Net Billing Rate ($/kWh)	
2	1	0.02904	
3	2	0.02904	
4	3	0.02904	
5	4	0.02904	
6	5	0.02904	
7	6	0.02904	
8	7	0.02904	
9	8	0.02904	
10	9	0.02904	
11	10	0.02904	
12	11	0.02904	
13	12	0.02904	
14	13	0.02904	
15	14	0.02904	
16	15	0.02904	
17	16	0.02904	
18	17	0.02904	
19	18	0.02904	

Load Profile Input



Upload the custom-generated load profile, created based on metered data.

Resilience Inputs

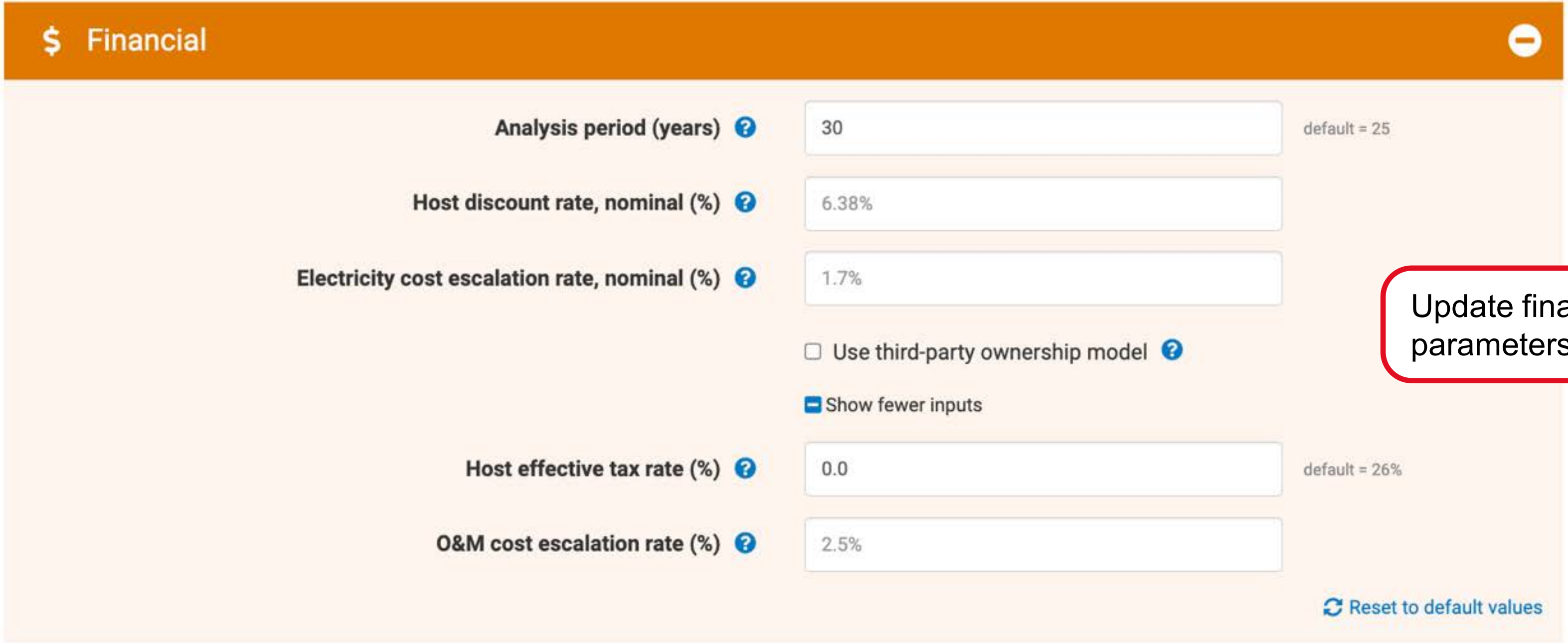


Enter the critical load.

Enter the outage duration.

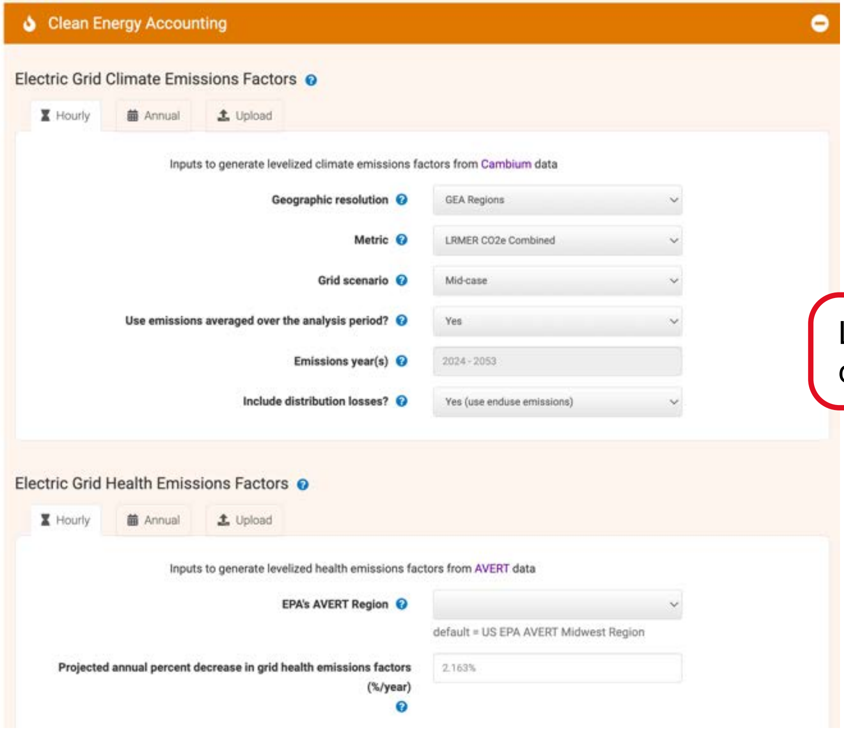
The outage timing will automatically populate.

Financial Inputs



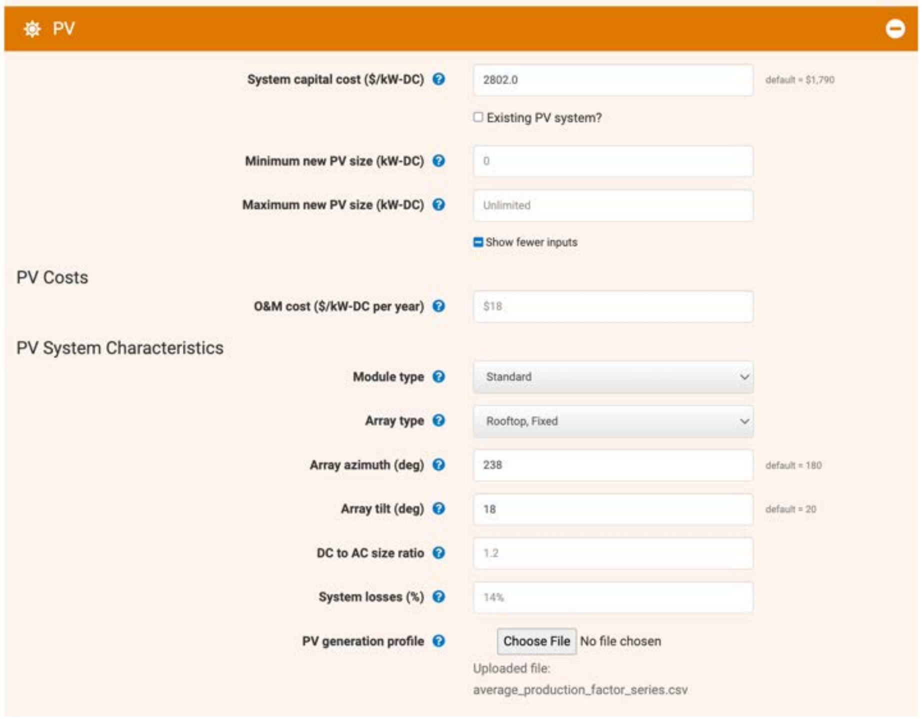
Update financial parameters.

Clean Energy Accounting Inputs



Leave emissions defaults.

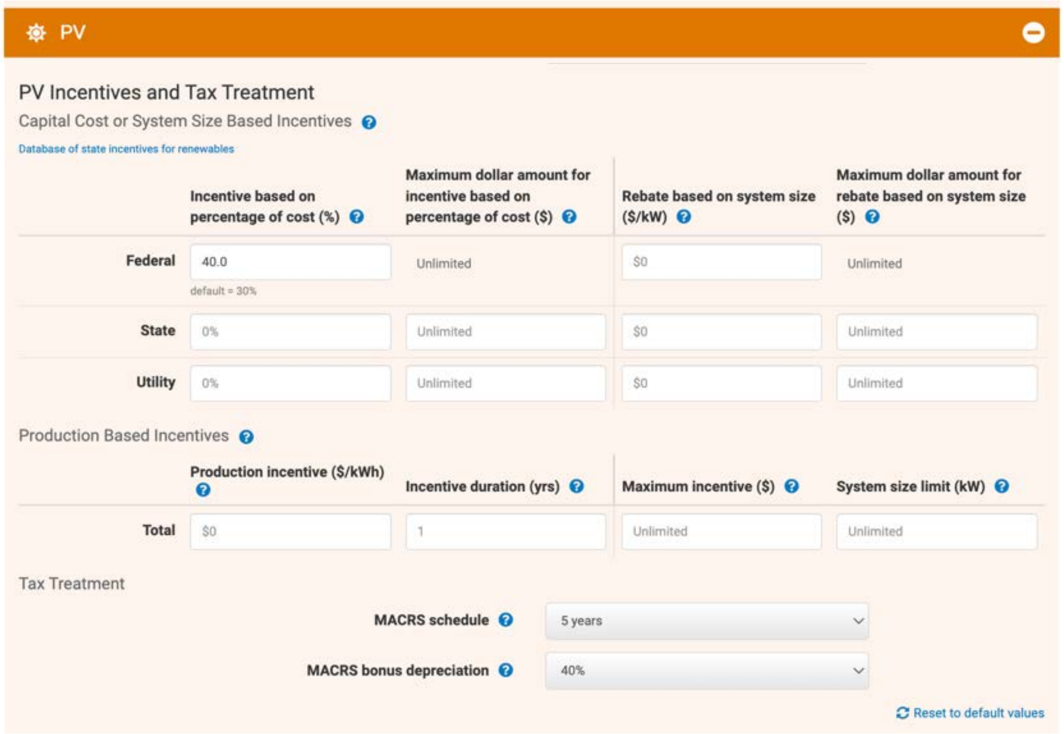
Solar PV System Inputs



- Show Advanced inputs
- Update the PV capital cost to align with the system type and size
- Update the array azimuth and tilt to align with the planned location.

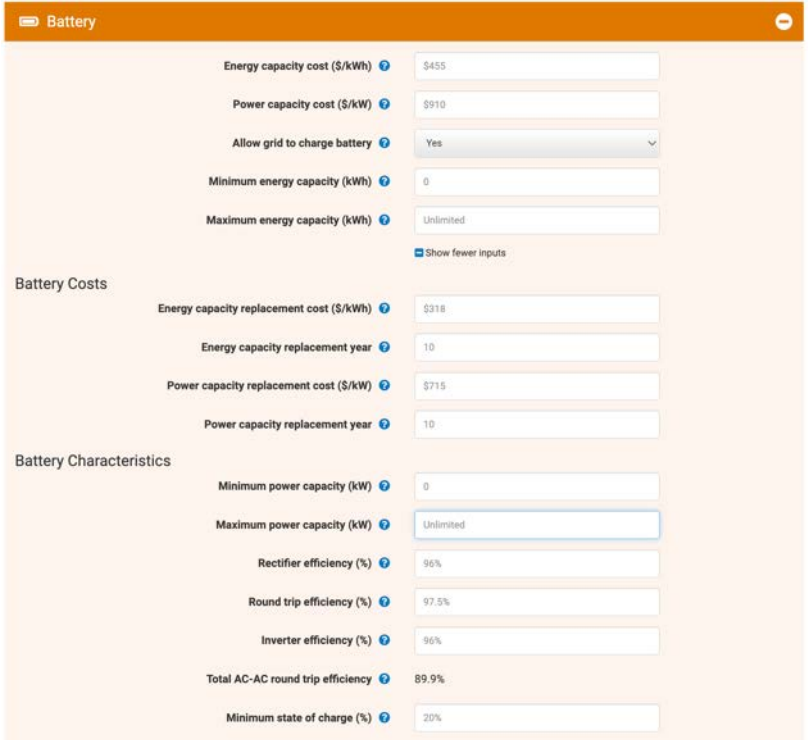
This example assumes solar PV is being considered for this section of the roof on the hatchery building.
Image from Google Earth

Solar PV Financial Inputs

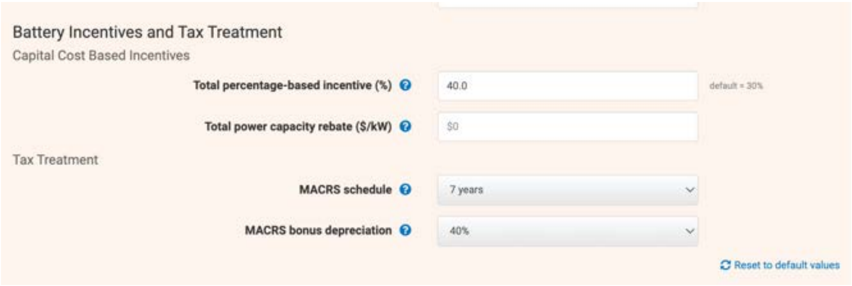


- Update the PV incentive to reflect anticipated ITC bonus adders
- Update the MACRS bonus depreciation to reflect 2025 incentive levels.

Battery Inputs

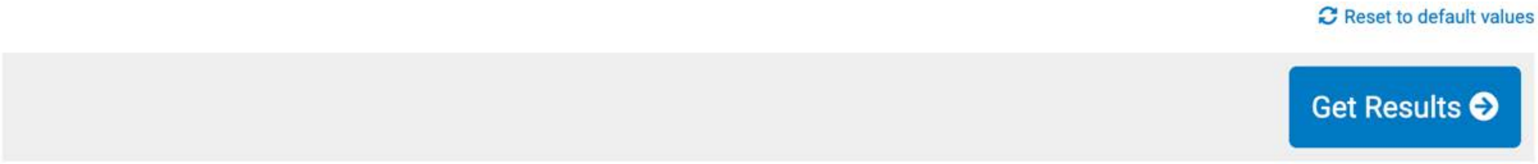


- Leave battery defaults unless you have preferred cost or technology characteristics inputs
- Update the battery incentive to reflect anticipated ITC bonus adders
- Update the MACRS bonus depreciation to reflect 2025 incentive levels.

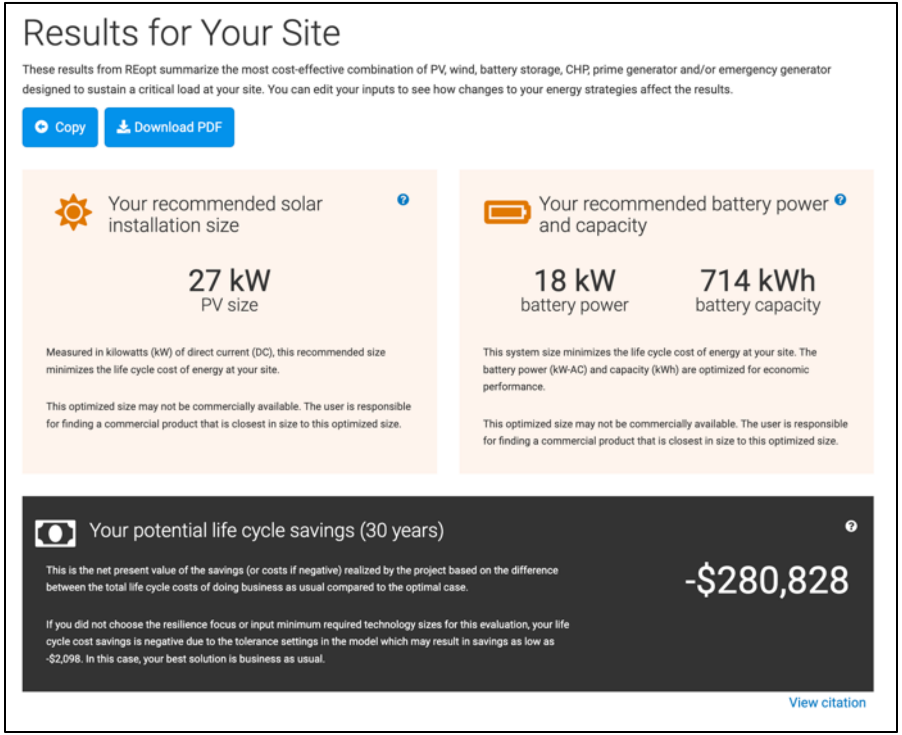


Get Results

Click “Get Results” when all inputs are finalized.



Explore the Results



- The **system sizes** shown are those that are expected to be the most financially beneficial over the 30-year analysis period.
- The **life cycle savings** shown are the expected total savings compared to BAU operations over 30 years.
  - The negative value indicates that this system is expected to cost the hatchery $280,828 *more* than BAU costs.
  - Note that this cost *does not* account for the value of being able to power critical loads through a grid outage.
- The results shown here are for a simple example, and therefore do not align with the more detailed results presented in this slide deck.
- Link to results: https://reopt.nrel.gov/tool/results/f5f17de4-1fc5-49da-a8d4-8b2e71f3446e.

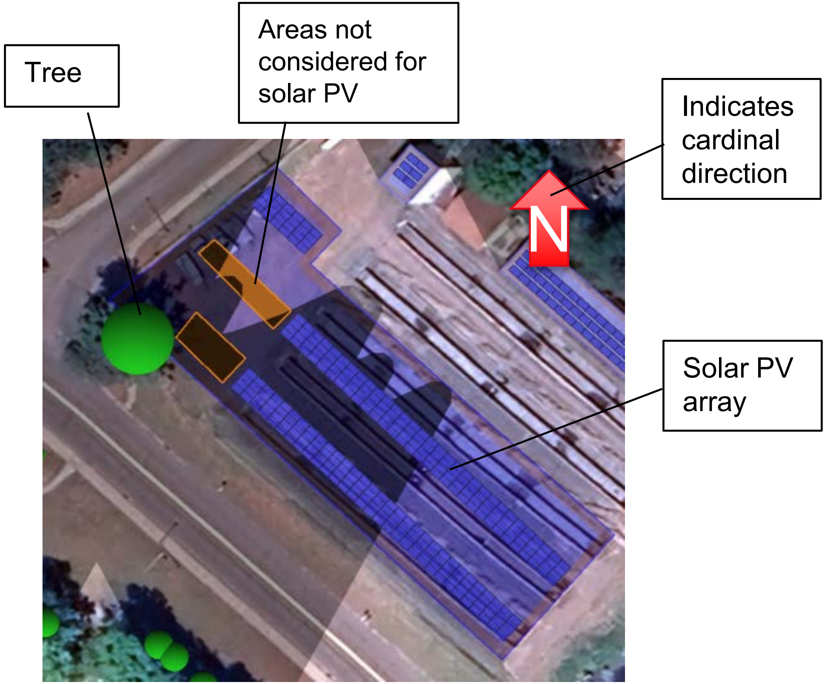
Appendix D: Other Siting Considerations

Context for Additional Solar Siting Options

- The analysis highlighted in this deck focuses on two potential siting locations for solar PV and assumes that PV in these locations serves electric loads on the hatchery building meter (#001).
- However, other locations for solar PV are also of potential interest to the Lac du Flambeau Hatchery. Solar PV in these locations could potentially serve electric loads behind other meters on the hatchery property or adjacent properties.
- The following slides present a **preliminary desktop estimate of the amount of solar PV that could potentially be sited in different locations**. The analysis does not give any indication of cost nor actual feasibility of solar implementation in each location.
- These estimates should be followed by an onsite engineering feasibility assessment, accounting for site constraints, shading, interconnection points, structural requirements, potential groundwork, total installation costs, etc.

HelioScope Overview

- HelioScope is a software tool for designing solar projects.
- This analysis provides a preliminary desktop analysis for 15 potential locations for solar projects, identified by hatchery staff.
- In this preliminary analysis, solar PV modules were <u>not</u> added to areas that are estimated to receive more than 10% shading annually.
  - Note: Heights of modeled obstructions (e.g., trees), which cause shading, are based off HelioScope LiDAR data. **Actual heights of modeled obstructions (and therefore actual shading) may differ in reality**.

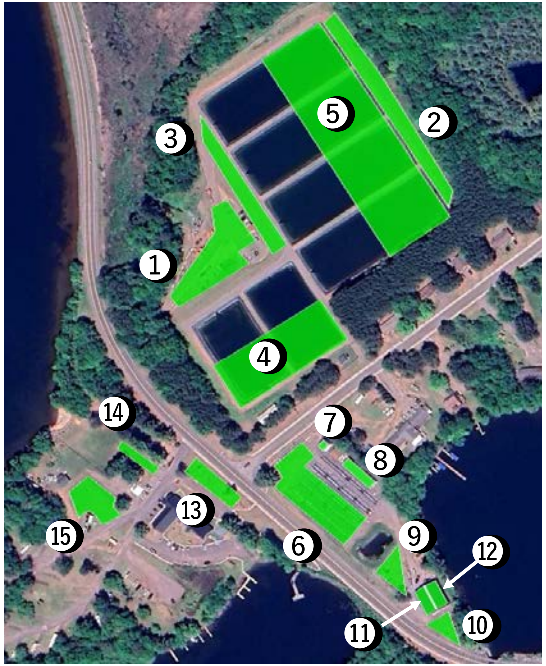


HelioScope analysis example with labels.
Image from HelioScope

Potential PV Locations

The Lac du Flambeau team identified 15 potential locations for solar PV on or near the Fish Hatchery property. The image identifies these locations and the table summarizes data for the locations.

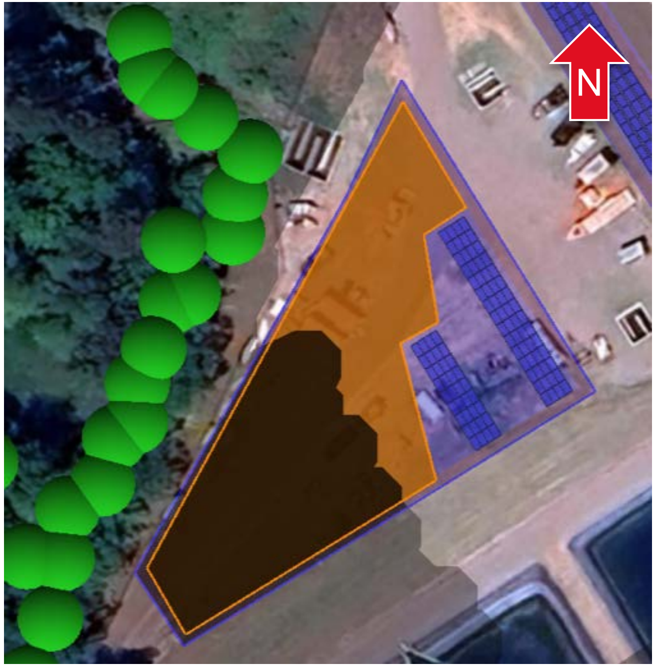
ID	Area (m^2)	Estimated Maximum PV Size (kW)
1	2,518	43.2
2	2,380	104
3	1,528	75.6
4	4,337	453.6
5	11,347	1,036
6	2,611	122.4
7	39	3.2
8	230	18.9
9	502	14.4
10	329	0
11	202	25.2
12	218	24.3
13	689	0
14	290	0
15	951	48.6



Locations identified by Lac du Flambeau staff for potential solar PV installations. Image from Google Earth

Location #1

- **Likely PV type**: Flat ground-mount
- **Approximate maximum PV size:** 43.2 kW
- **System tilt:** 27°
- **System azimuth:** 238°
- **Estimated energy production:** 50,586 kWh/yr



Potential solar PV array location #1. Image from HelioScope

Location #2

- **Likely PV type**: Angled ground-mount
- **Approximate maximum PV size:** 104.0 kW
- **System tilt:** 15°
- **System azimuth:** 236°
- **Estimated energy production*:** 121,126 kWh/yr

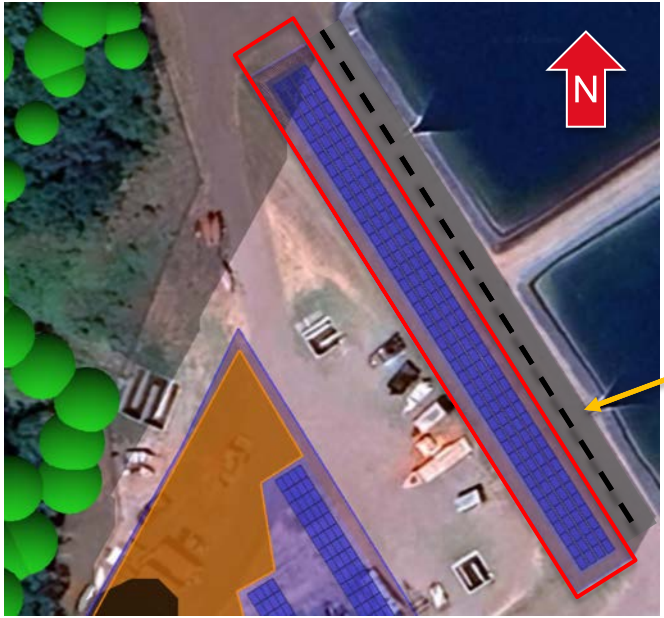
Note: If the canopy PV (Location #5) is constructed, it will most likely shade the majority of this area and greatly impact annual energy production.

Potential solar PV array location #2.
Image from HelioScope

Location #3

- **Likely PV type**: Angled ground-mount
- **Approximate maximum PV size:** 75.6 kW
- **System tilt:** 15°
- **System azimuth:** 238°
- **Estimated energy production:** 87,709 kWh/yr

Note: This area is a steep slope.



This area leaves ~10 ft for vehicle driving access.

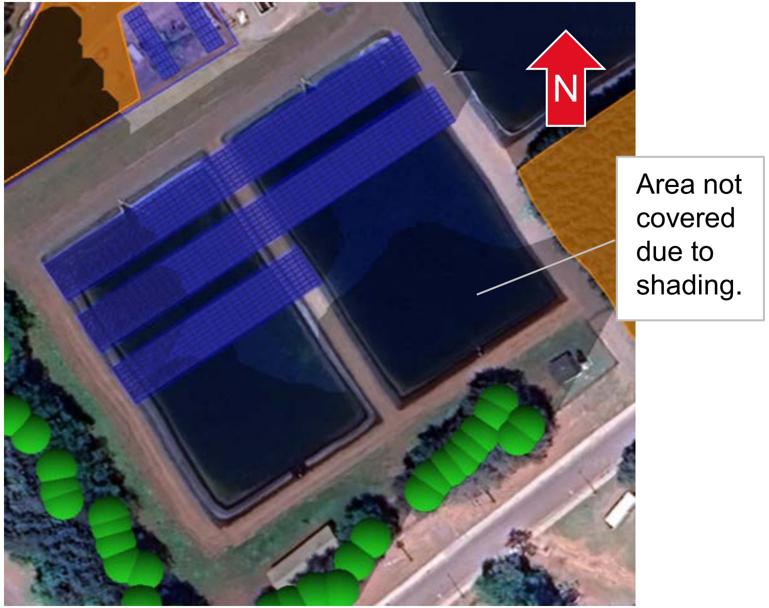
Potential solar PV array location #3. The red box indicates the array studied for this example. Image from HelioScope

Location #4:

- **Likely PV type**: Canopy PV
- **Approximate maximum PV size:** 453.6 kW
- **System tilt:** 5°
- **System azimuth:** 147°
- **Estimated energy production:** 511,774 kWh/yr

Notes:

- The canopy structure presented is a conceptual design that may not reflect practical or achievable implementation and needs to be confirmed with solar developers as realistic. This canopy might require additional support structures, which will add to the total installation cost.
- Birds are often in this area. The impact that birds may have on a solar array in this location is unclear.
- If the PV canopies were on the south side of the pond, they are expected to receive more shading from surrounding trees.
- To continue using the road between the ponds, ensure no canopy supports are added along the dividing road.



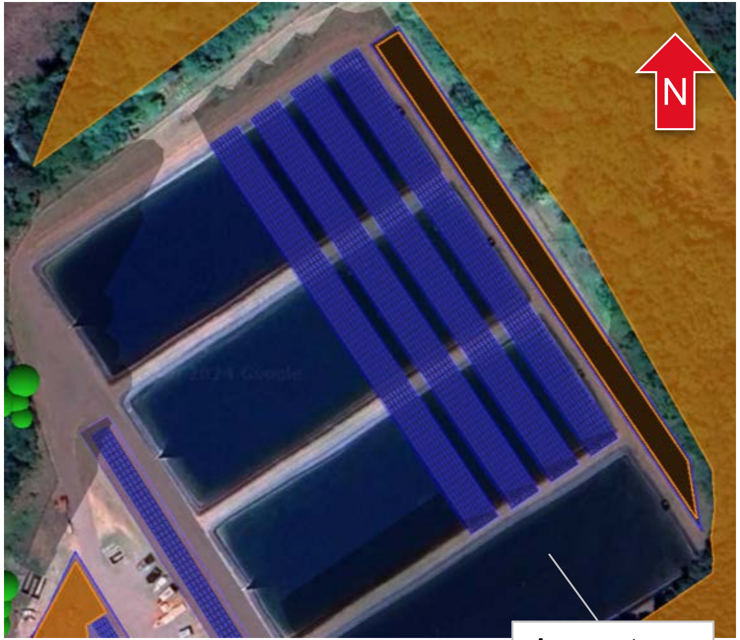
Potential solar PV array location #4. Image from HelioScope

Location #5:

- **Likely PV type**: Canopy PV
- **Approximate maximum PV size:** 1,036 kW
- **System tilt:** 5°
- **System azimuth:** 236°
- **Estimated energy production:** 1,157,210 kWh/yr

Note:

- The canopy structure presented is a conceptual design that may not reflect practical or achievable implementation and needs to be confirmed with solar developers as realistic. This canopy might require additional support structures, which will add to the total installation cost.
- To continue using the road between the ponds, ensure no canopy supports are added along the dividing road.



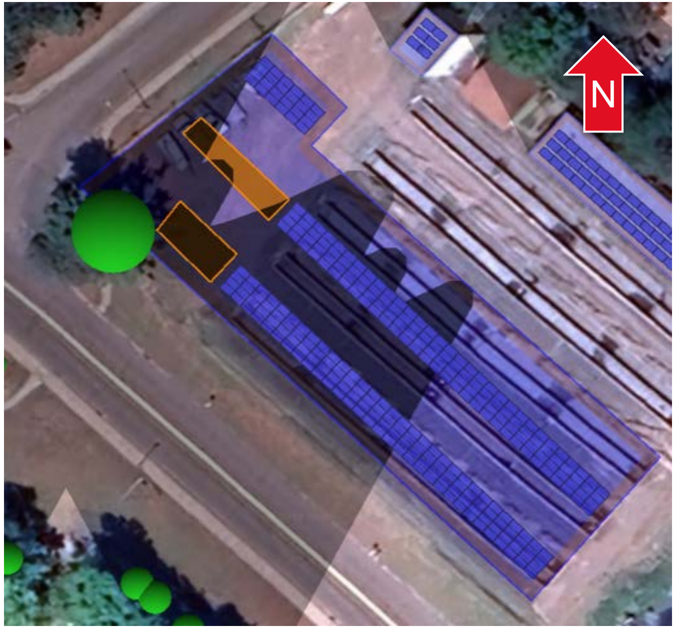
Area not covered due to shading.

Potential solar PV array location #5.
Image from HelioScope

Location #6

- **Ground-mount area:** 27,313 ft^2
- **Likely PV type**: Flat ground-mount
- **Approximate maximum PV size:** 122.4 kW
- **System tilt:** 27°
- **System azimuth:** 222°
- **Estimated energy production:** 149,482 kWh/yr

Note: These solar arrays are assumed to be over the two fish raceways on the left, which are retired.



Potential solar PV array location #6. Image from HelioScope

Location #7

- **Likely PV type**: Rooftop flat-mount
- **Approximate maximum PV size:** 3.2 kW
- **System tilt:** 15°
- **System azimuth:** 222°
- **Estimated energy production:** 3,826 kWh/yr

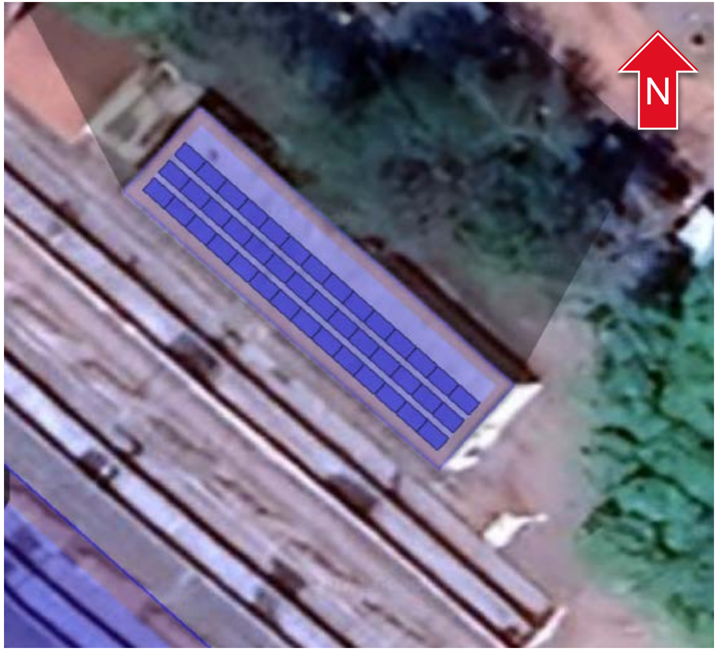
Potential solar PV array location #7. The red arrow points to the roof for the array. Image from Google Earth

Potential solar PV array location #7. Image from HelioScope

Location #8

- **Likely PV type**: Flat rooftop
- **Approximate maximum PV size:** 18.9 kW
- **System tilt:** 15°
- **System azimuth:** 222°
- **Estimated energy production:** 22,549 kWh/yr

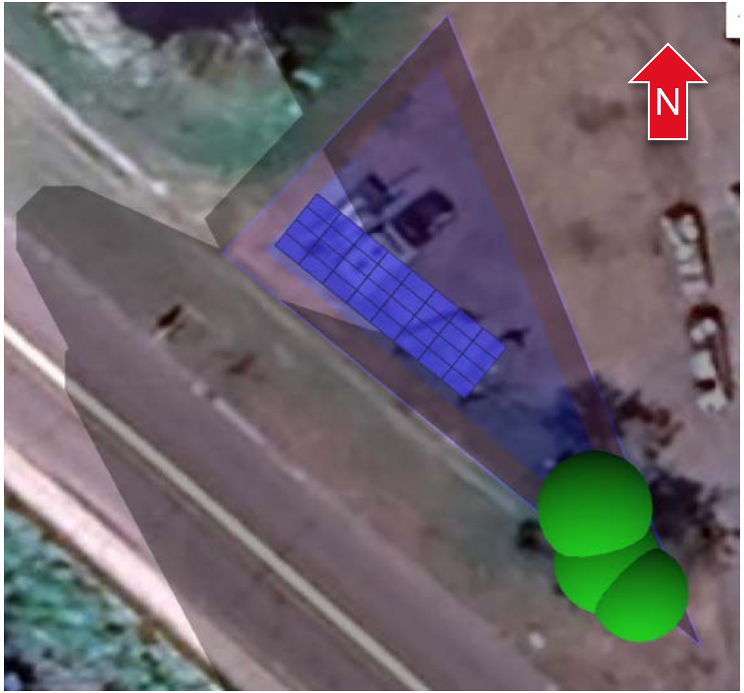
Potential solar PV array location #8. The red arrow points to the roof for the array. Image from Google Earth



Potential solar PV array location #8. Image from HelioScope

Location #9

- **Likely PV type**: Flat ground-mount
- **Approximate maximum PV size:** 14.4 kW
- **System tilt:** 27°
- **System azimuth:** 219°
- **Estimated energy production:** 17,776 kWh/yr



Potential solar PV array location #9. Image from HelioScope

Location #10

- This potential location appears to be where vehicles would drive to enter the building; therefore, this location was not analyzed for estimated annual energy production.

Potential solar PV array location #10 is likely not viable due to use by vehicles. Image from HelioScope

Location #11

- **Rooftop area:** 2,744 ft^2
- **Likely PV type**: Angled rooftop
- **Approximate maximum PV size:** 25.2 kW
- **System tilt:** 18°
- **System azimuth:** 238.6°
- **Estimated energy production:** 29,375 kWh/yr

Potential solar PV array location #11; the red arrow points to the south-facing rooftop on the hatchery building for the array studied in this example. Image from Google Earth.

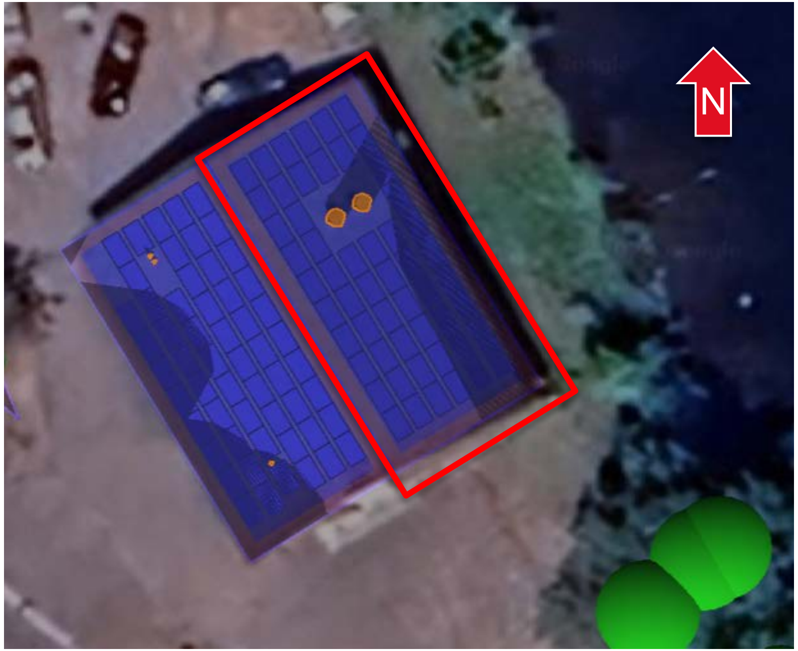
Potential solar PV array location #11; the red box outlines the array studied in this example. Image from HelioScope

Location #12

- **Rooftop area:** 2,773 ft^2
- **Likely PV type**: Angled rooftop
- **Approximate maximum PV size:** 24.3 kW
- **System tilt:** 18°
- **System azimuth:** 58.6°
- **Estimated energy production:** 22,967 kWh/yr

Note: North-facing rooftops are less desirable for solar PV installation.

Potential solar PV array location #12; the red arrow points to the north-facing rooftop on the hatchery building for the array studied in this example. Image from Google Earth



Potential solar PV array location #12; the red box outlines the array studied in this example. Image from HelioScope

Location #13

- This potential location is greatly shaded by surrounding trees; therefore, this location was not analyzed for estimated annual energy production.

Potential solar PV array location #13 is greatly shaded. Image from HelioScope

Location #14

- This potential location is greatly shaded by surrounding trees; therefore, this location was not analyzed for estimated annual energy production.

Potential solar PV array location #14 is greatly shaded. Image from HelioScope

Location #15

- **Ground-mount area:** 13,301 ft^2
- **Likely PV type**: Flat ground-mount PV
- **Approximate maximum PV size:** 48.6 kW
- **System tilt:** 27°
- **System azimuth:** 180°
- **Estimated energy production:** 62,303 kWh/yr

Potential solar PV array location #15. Image from HelioScope

Floating Solar PV

- Hatchery personnel were interested in the possibility of floating PV on the fish ponds.
- The team investigated the opportunity but did not consider floating PV for the hatchery:
  - Higher cost: A floating PV system is estimated to have a higher installed cost, about 25% greater per watt than a ground-mounted system.[1]
  - Draining: The fish ponds are drained annually. Standard floating PV floating equipment is not designed for water bodies that are dried.
  - Impact on fish: The technology is nascent, and the impact on aquaculture is unclear. The fish hatchery is important to the Tribe's economy, and pursuing a project with unclear implications for the fish is not feasible.

Floating solar array on a water retention pond in Colorado.
Photo by Dennis Schroeder, NREL

[1] Ramasay, Vignesh and Robert Margolis. 2021. *Floating Photovoltaic System Cost Benchmark: Q1 2021 Installations on Artificial Water Bodies.* Golden, Co: National Renewable Energy Laboratory. NREL/TP-7A40-80695. https://www.nrel.gov/docs/fy22osti/80695.pdf.