DISCLAIMER

Preliminary Assessment of Renewable Energy Options at the Sravasti Abbey

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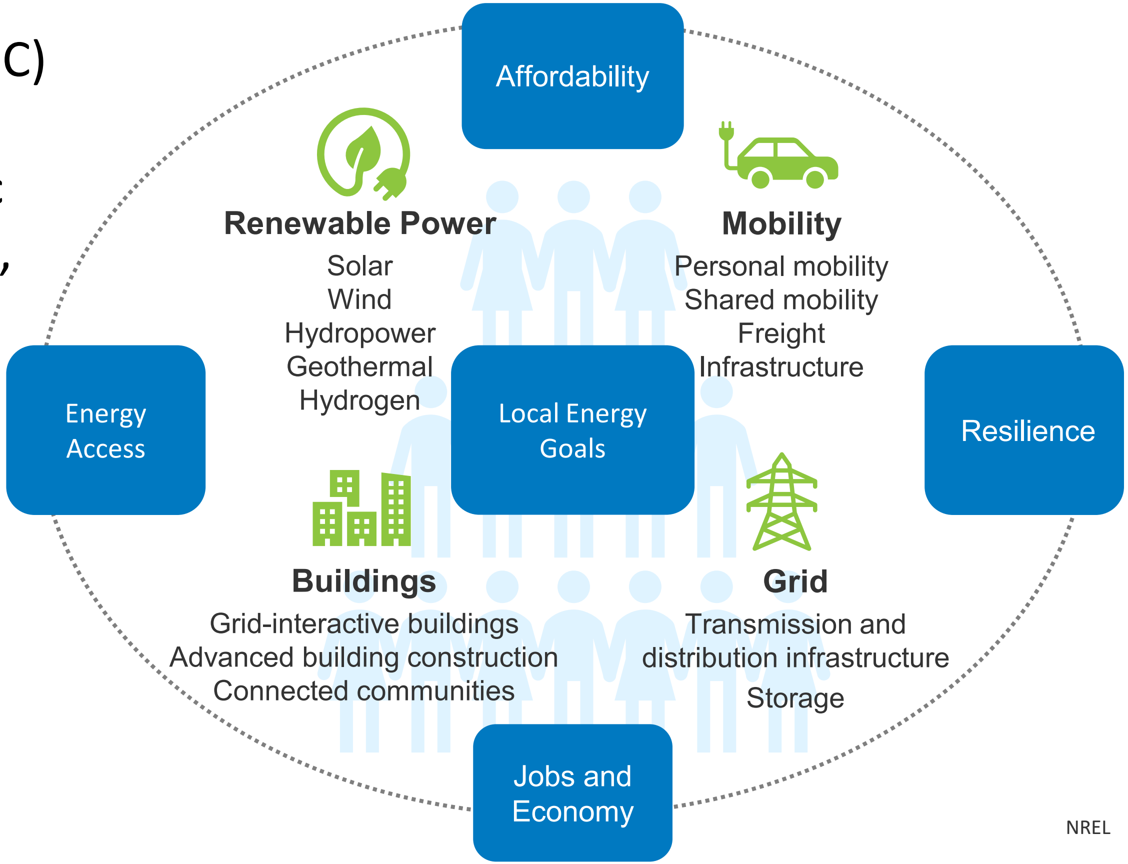
E2C Expert Match

February 2025

Energy to Communities (E2C)

Energy to Communities (E2C) is an **innovative, technical program** that helps electric utilities, local governments, and community-based organizations meet their **energy goals**.



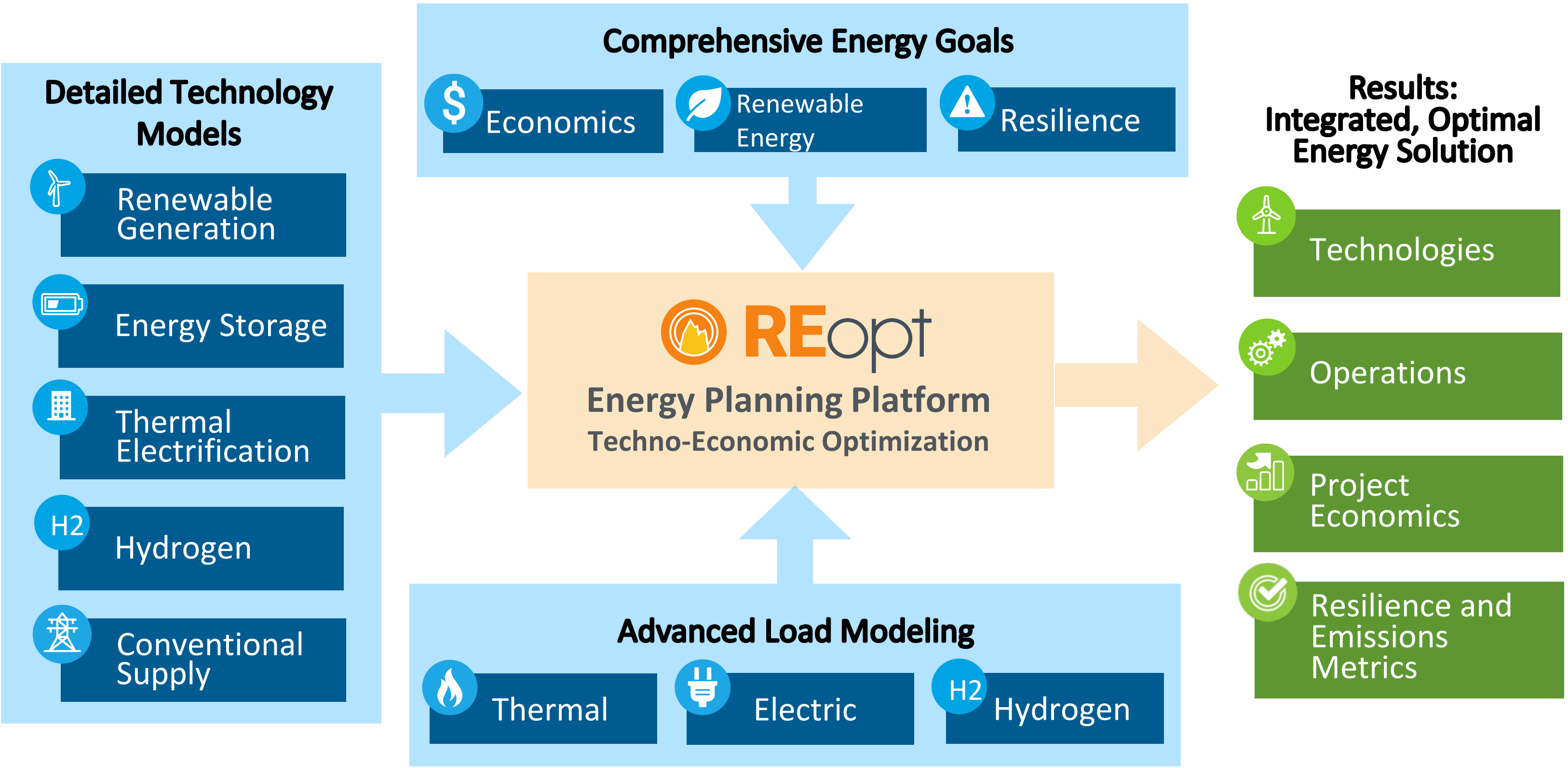
Contents

Background and Tool Overview

Analysis Overview

- The Sravasti Abbey is a Buddhist monastery in Washington state, requesting technical assistance to meet their energy goals.
- NREL used the REopt® platform to evaluate the technoeconomic potential of adding solar photovoltaics (PV), distributed wind energy, and electric storage at the Sravasti Abbey.
- The analysis goals focused on the ability of these technologies to increase carbon-free electricity at the site and improve the site’s energy resilience.

REopt Energy Planning Platform



REopt Minimizes the Lifecyle Cost of Energy

- **Life cycle cost (LCC)** of energy: The present value of all costs of energy at the site throughout the analysis period.

LCC = Capital Costs − Available Incentives + Operations and Maintenance (O&M) Costs + Electric Grid Purchases + Fuel Purchases

- **Net present value (NPV)** of distributed energy resource system: The life cycle cost savings (difference in LCC) between the business-as-usual (BAU) case and the optimized case.

$$NPV = LCC_{BAU} - LCC_{optimized}$$

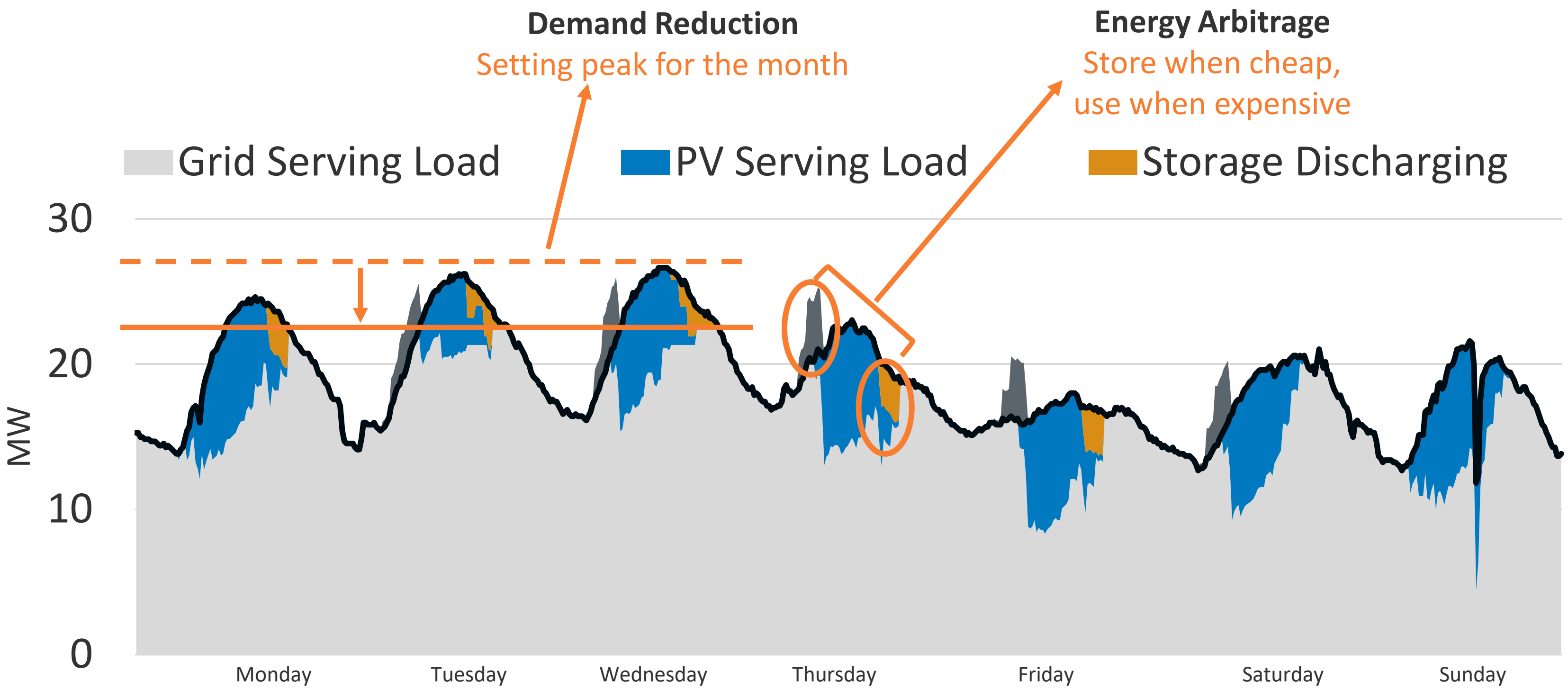
If NPV > 0, the project provides cost savings relative to the BAU case.

If NPV < 0, the project is more expensive than the BAU case.

REopt identifies the **life cycle cost-optimal** distributed energy resource system that achieves the site’s energy goals (**cost savings**, **emission reductions**, and/or **resilience**).

How Does REopt Work?

REopt considers the trade-off between ownership costs and savings across multiple value streams to recommend optimal size and dispatch.



Example of optimal dispatch of PV and a battery energy storage system

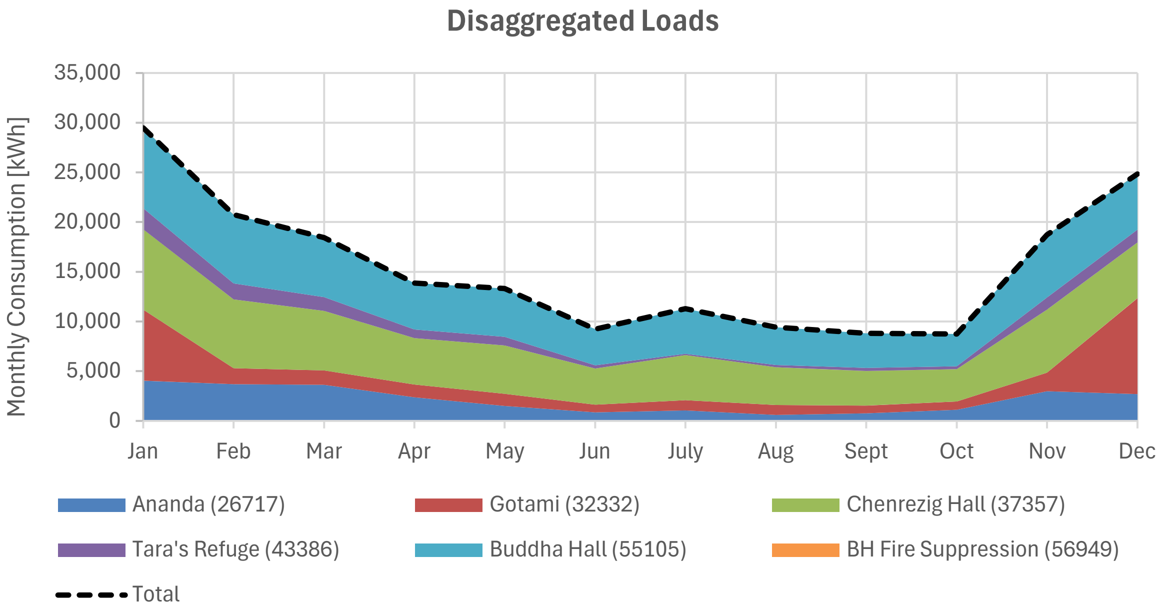
Inputs and Assumptions

Provided Load Data

- Monthly energy consumption values from July 2023 to July 2024 were provided for six meters (modeled as a single combined load due to a lack of demand charges in the utility rate).
- Analysis assumes that Buddha Hall's consumption after construction has finished will be similar to Chenrezig Hall.

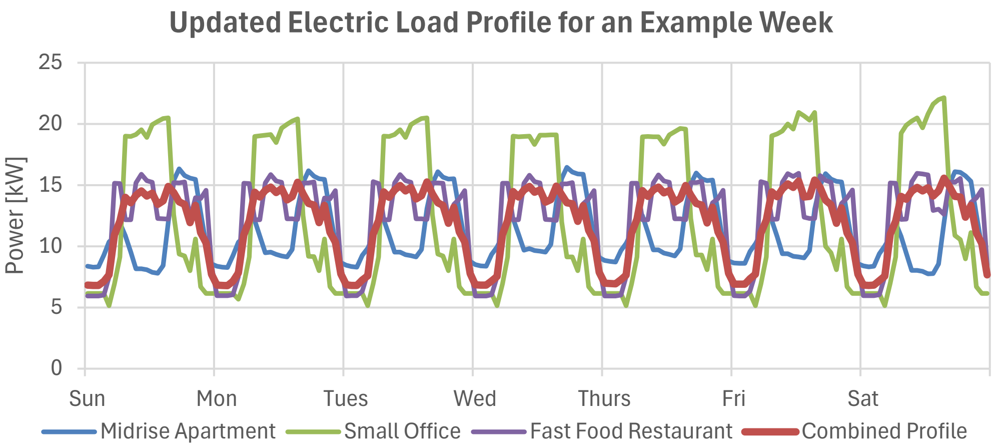
	Combined Total
Annual Load (measured)	186,947 kWh
Peak Load (estimated)	53.5 kW
Average Load (estimated)	21.3 kW
Minimum Load (estimated)	6.3 kW

Table shows values summed across all six meters.



Modeled Hourly Loads

- Hourly interval data was estimated using the DOE commercial reference buildings dataset.[1]
    - Monthly energy consumption was scaled to the site's billing data.
    - Modeled profile assumes 1/3 small office, 1/3 midrise apartment, and 1/3 fast food restaurant.
    - Weekend profiles were replaced with weekday patterns.



Building Type	Floor Area (ft^2)	Number of Floors
Large Office	498,588	12
Medium Office	53,628	3
Small Office	5,500	1
Warehouse	52,045	1
Stand-alone Retail	24,962	1
Strip Mall	22,500	1
Primary School	73,960	1
Secondary School	210,887	2
Supermarket	45,000	1
Quick Service Restaurant	2,500	1
Full-Service Restaurant	5,500	1
Hospital	241,351	5
Outpatient Health Care	40,946	3
Small Hotel	43,200	4
Large Hotel	122,120	6
Midrise Apartment	33,740	4

[1] https://www.energy.gov/eere/buildings/commercial-reference-buildings

Utility Rate Assumptions

- **Utility**: Pend Oreille Public Utility District
- **Net metering limit:** Customer-generators with a capacity of **100 kW** or less, supplying electricity from a fuel cell, solar, wind, or hydroelectric facility are eligible to participate in the public utility district's net metering program.[2]
  - Previous production-based incentives rates are shown here, but due to a lack of information since 2021, **no net energy metering compensation is modeled in this analysis**. This is a conservative assumption. Any compensation the site can negotiate with the utility will **lower** total lifecycle costs.

- **Tariff**:

Parameter	Existing rates[1]
Fixed Monthly Charge	$35.50
Energy Charge	$0.0623/kWh

- **Production-based incentive rates:**[3]

Fiscal year of system certification	Base rate residential-scale	Base rate commercial-scale	Base rate community solar	Base rate shared commercial solar	Made-in-Washington bonus
2018	$0.16	$0.06	$0.16	$0.06	$0.05
2019	$0.14	$0.04	$0.14	$0.04	$0.04
2020	$0.12	$0.02	$0.12	$0.02	$0.03
2021	$0.10	$0.02	$0.10	$0.02	$0.02

[1] https://www.popud.org/top-links/about-your-pud/our-rates

[2] https://www.popud.org/services/additional-services/customer-generated-powernet-metering

[3] https://www.energy.wsu.edu/RenewableEnergySystemIncentiveProgram/EligibilityIncentiveRates.aspx

Financial Assumptions

Economic Inputs	Assumptions
Analysis period	25 years
Ownership model	Direct ownership
Discount rate	6.38%
Electricity cost escalation rate	1.7%
Propane cost escalation rate	1.2%
O&M cost escalation rate	2.5%
Tax rate	0%

Solar PV and Wind Assumptions

Inputs	Solar PV Assumptions	Wind Assumptions
System characteristics	Array type: Ground-mount Tilt: 20° Azimuth: 180° DC-AC ratio: 1.2 Losses: 14% Degradation: 0.5%/year Resource data: Typical meteorological year data from the National Solar Radiation Database	Resource data: Wind Integration and National Dataset
Capital cost	$1,790/kW-DC	$4,760/kW
O&M cost	$18/kW/year	$36/kW/year
Incentives	30% ITC	30% ITC
Useful life	25 years	25 years
Space requirements	6 acres / MW	30 acres / MW
Area available	7.5 acres total	7.5 acres total

Battery Storage Assumptions

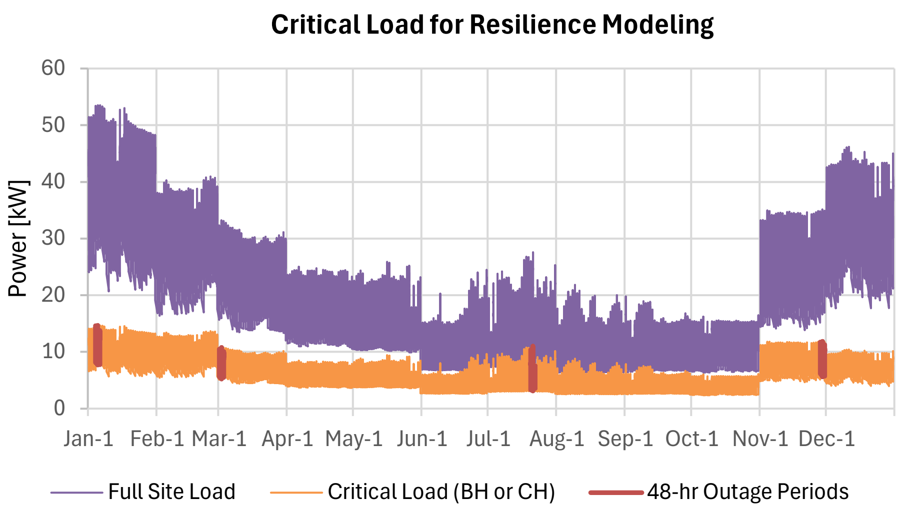
Storage Inputs	Assumptions
Chemistry	Lithium-ion
Capital cost	$455/kWh + $910/kW
Replacement cost	$318/kWh + $715/kW
Incentives	30% ITC
Replacement year	10
Charging/discharging efficiency	96%
DC-DC roundtrip efficiency	97.5%
Minimum state-of-charge	20%

Generator Assumptions

Generator Inputs	Assumptions
System type	Propane
Existing units	Three Generac systems: 130 kW (Buddha Hall) 16 kW (Prajna Cottage) 19.5 kW (Chenrezig Hall)
Electric efficiency	32.2%
Fuel higher heating value	26.8 kWh/gallon
Fuel cost	$2.60/gallon
Fuel availability	Buddha Hall: 1,000 gallons Prajna Cottage + Chenrezig Hall: 1,000 gallons
Fixed O&M	$20/kW
Minimum turndown	0%
Operational constraints	Only operates during outages

Resilience and Outage Survival

- To analyze the site's energy resilience, **12-hour**, **24-hour**, and **48-hour** outages were modeled to determine what technologies are needed to support critical loads for the full outage duration.
- In each scenario, outage timing was modeled as **four** outages of the specified length centered around the peak critical load of each season.
- Based on site feedback, critical loads are behind the **Buddha Hall** and **Chenrezig Hall** meters.
  - The full load at each meter was assumed to be critical. Buddha Hall's critical load was assumed to be the same as Chenrezig Hall.
  - Critical load was estimated by calculating what percentage of the full load is behind each meter based on breakdowns of monthly energy consumption from past utility bills



Critical load at Buddha/Chenrezig Hall as a percent of the full load for each month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
27.4%	33.3%	32.5%	33.7%	36.4%	39.4%	40.1%	40.3%	39.5%	37.1%	33.8%	22.5%

Results

Scenarios Modeled

Scenarios	Description	Technologies Considered	Targets
Business-as-usual	Site does not install any new technologies and continues purchasing electricity from the grid.	–	–
Cost optimal	New technologies are sized* to minimize the site's lifecycle cost over the analysis period while meeting any site goals (e.g., renewable energy (RE) or resilience targets)	Full technology set: PV, wind, battery storage PV-only scenario included	Renewable energy fraction: • 20%, 40%, 60%, 80%, 100%
Resilience	Technologies needed to survive outages of varying lengths along with their dispatch strategies are estimated.	Existing propane generators (optionally paired with PV, wind, or battery storage)	Outage survival: • 12 hours, 24 hours, 48 hours

*Technology sizes may be zero if they are not cost effective or necessary to meet the site's energy goal.

Full Technology Set Results

- Due to the low electricity rates at the site, RE systems have negative net present value.

	BAU	Cost-optimal	20% RE	40% RE	60% RE	80% RE	100% RE
PV Size (kW)	–	0	2.7 kW	21.2 kW	28.7 kW	35.4 kW	43.6 kW
Wind Size (kW)	–	0	11.7 kW	17.4 kW	27.3 kW	37.5 kW	47.1 kW
Battery Size (kW / kWh)	–	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
Year 1 Utility Cost ($)	$14,205	$14,205	$11,904	$9,885	$8,535	$7,695	$7,139
Year 1 Utility Bill Reduction (%)	–	0%	16.2%	30.4%	39.9%	45.8%	49.7%
Year 1 O&M Cost ($)	–	$0	$470	$1,009	$1,499	$1,987	$2,481
Initial Capital Expenses After Incentives ($)	–	$0	$43,469	$86,776	$130,197	$173,624	$217,037
Total Lifecycle Cost* ($)	$208,439	$208,439	$225,662	$247,950	$279,399	$318,301	$361,440
Net Present Value ($)	–	$0	-$17,223	-$39,511	-$70,960	-$109,862	-$153,001
Renewable Energy Fraction (%)	–	0%	20%	40%	60%	80%	100%

*Including electricity purchases from the utility

PV-Only Results

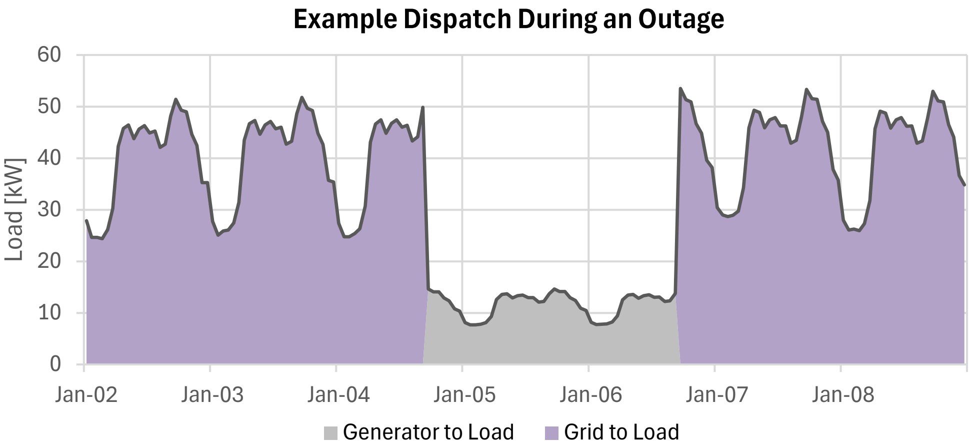
- When considering only PV, the cost to achieve RE penetration targets are 1.5–12.2% higher depending on the scenario when compared to a buildout of both PV and wind.

	BAU	Cost-optimal	20% RE	40% RE	60% RE	80% RE	100% RE
PV Size (kW)	–	0	33.6 kW	67.2 kW	100.7 kW	134.3 kW	167.9 kW
Year 1 Utility Cost ($)	$14,205	$14,205	$12,014	$11,019	$10,543	$10,252	$10,049
Year 1 Utility Bill Reduction (%)	–	0%	15.4%	22.4%	25.8%	27.8%	29.3%
Year 1 O&M Cost ($)	–	0	$604	$1,209	$1,813	$2,418	$3,022
Initial Capital Expenses After Incentives ($)	–	$0	$43,154	$86,308	$129,462	$172,616	$215,770
Total Lifecycle Cost* ($)	$208,439	$208,439	$229,105	$267,314	$313,148	$361,690	$411,530
Net Present Value ($)	–	$0	-$20,666	-$58,875	-$104,709	-$153,251	-$203,091
Percent increase in lifecycle cost compared to PV + wind results (%)	–	0%	1.5%	7.2%	10.8%	12.0%	12.2%
RE Fraction (%)	–	0%	20%	40%	60%	80%	100%

*Including electricity purchases from the utility

Resilience Results

- Based on results from an initial REopt resilience analysis, it is not cost effective to install RE technologies to increase site resilience due to the **existing generators** and **large fuel tanks**.
- Modeled results show **less than 100 gallons** of fuel consumed for outages of up to **48 hours**.
- Typically, RE systems can be paired with existing backup generators to extend outage survival, lowering emissions and fuel use. If the site chose to do this, battery storage would smooth PV and/or wind fluctuations to avoid extensively ramping the generators and reducing generator life.



	Fuel Use (gallons)			
Outage Length	**Winter**	**Spring**	**Summer**	**Fall**
12 hours	18.1	13.2	13.4	14.5
24 hours	32.7	23.8	32.7	32.7
48 hours	65.4	47.2	65.4	65.4

Conclusion

Conclusion

- Due to the low cost of energy from the Pend Oreille Public Utility District, PV, wind, and energy storage are not cost effective at the Sravasti Abbey.
    - The total lifecycle cost of energy over a 25-year analysis period could increase by **8%–97%** if the site chose to install RE generation to meet various RE targets:

LCC increase (%)	20% RE	40% RE	60% RE	80% RE	100% RE
PV + wind	8.3%	19.0%	34.0%	52.7%	73.4%
PV-only	9.9%	28.3%	50.2%	73.5%	97.4%

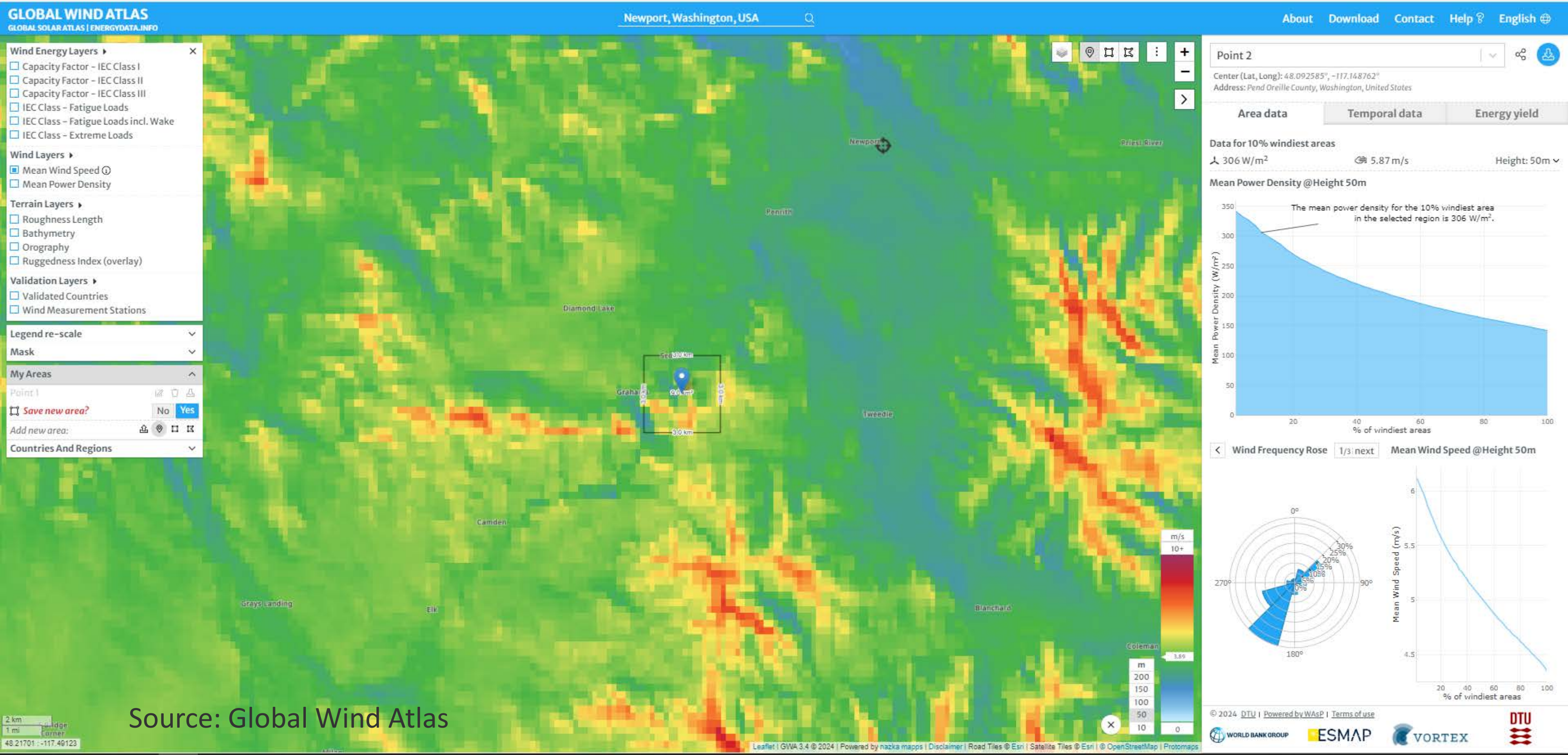
- Renewable energy systems are also not cost effective at the Sravasti Abbey for increasing resilience and outage survival due to the existing backup generators and large fuel tanks.
    - The site has **1,000 gallons** of fuel stored at each of the two meters serving critical loads while modeling results suggest that less than **100 gallons** is required to support the critical load at each meter for up to 48 hours.
    - Results may change if the Abbey is interested in powering other site loads during outages.

Additional Considerations for Distributed Wind Generation

Photos from Google Review images for Sravasti Abbey

Terrain: Somewhat complex; bucolic eastern Washington foothills with evergreens of modest height and grassy meadows; abbey appears to rest on a moderate slope with valley views

Wind resource appears to be strong per the Global Wind Atlas (annual average winds of greater than 5 m/s at a height of 50 meters), predominant winds from the SSW



Source: Global Wind Atlas

Environmental Considerations

Land Use, Wildlife, and Habitat

Land Use for Distributed Wind

- Distributed wind energy projects are typically installed in areas that have already been disturbed as they are sited close to the load they will serve.
- While construction can require access to a lot of land, very little land is actually displaced by wind turbine foundations. Land around the foundations can still be used for productive purposes (e.g., farming).
- Permanent land impacts can be remediated at end-of-life (e.g., through equipment decommissioning, foundation removal) and land restored to its original condition (e.g., through revegetation, seeding, topsoil replacement).


Photo from NeoCycle


Photo from Jill Schramm/MDN

Land Use for Small-Scale Distributed Wind

- Land use impacts may be nonexistent or marginal for small-scale wind systems.
  - General rule of thumb for spacing: a minimum of one acre is typically required to allow for setbacks from neighbors and property lines and from obstacles that could cause turbulence
- Turbulence can be a major issue for small turbines because of their lower tower heights and location near homes and other buildings.
  - Turbines need to be sited upwind of buildings/trees
  - General rule of thumb for tower height: approximately 30 ft. above anything within a 500 ft. horizontal radius
  - For tilt-up towers, enough space is needed to raise and lower the tower for maintenance; for guyed towers, space is needed to secure the guy wires


Photo from Bruce Hatchett / Energy Options

Wildlife and Habitat

- Siting is important to minimize impacts on birds, bats, and other migratory species.
  - Impacts to animals are primarily through collision and habitat disruption and, to a lesser extent, changes in air pressure caused by the spinning turbines.
- Studies have concluded that these impacts are relatively low, especially for smaller projects.
  - Impacts are species- and habitat- specific.
  - Micrositing is key to reducing impacts and some locations may not be suitable for development.
    - Micrositing is the process of identifying where an individual turbine will be located in a larger area.

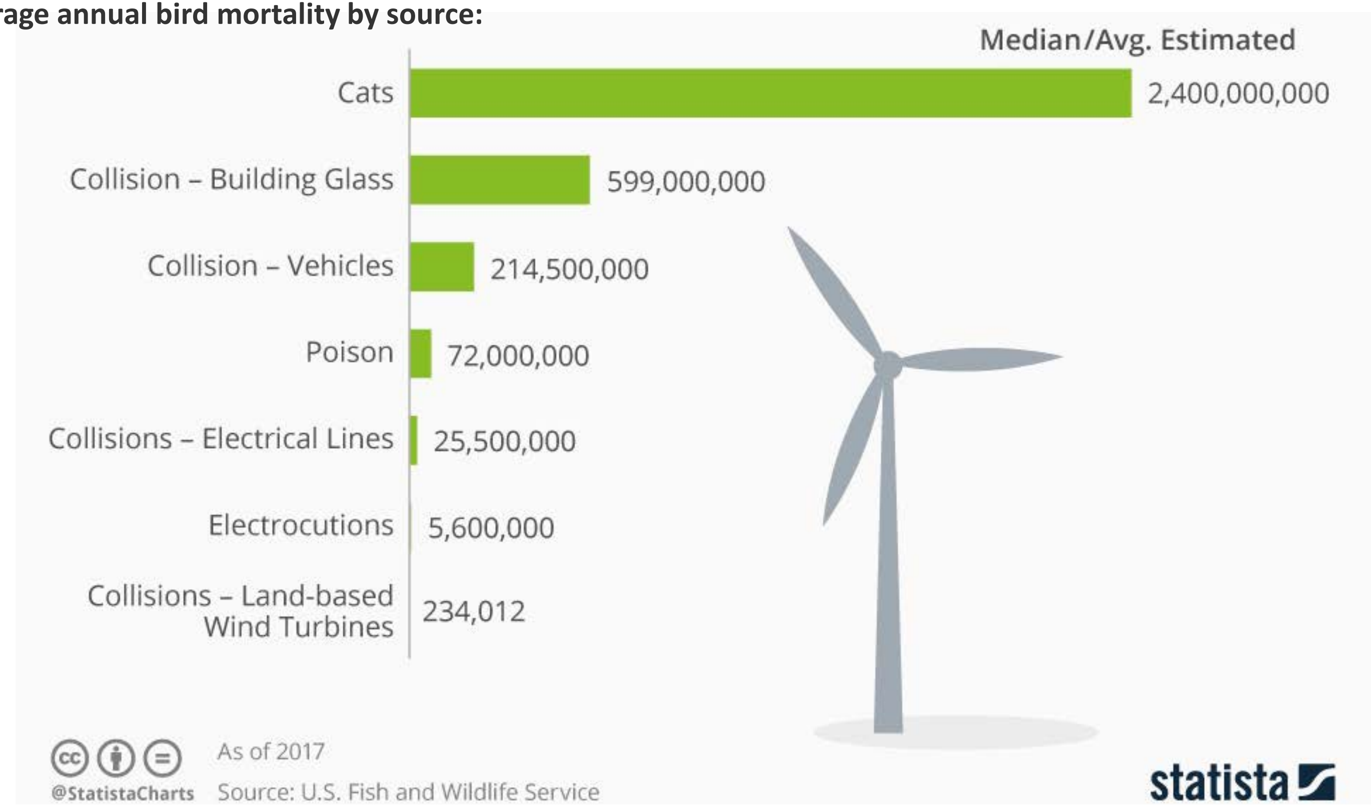
Photo from Windpower Monthly

Photo from Getty Images

Potential impacts at a large wind farm will be different than at a single, small wind turbine

Wildlife and Habitat

Estimated average annual bird mortality by source:



Wildlife and Habitat

- Small wind turbines are less likely to cause wildlife impacts
  - Findings suggest that small residential turbines have limited impacts on avian mortality/behavior.
  - No turbine-related avian fatalities were recorded during a 2007–2012 study on small wind turbines in Maine *(Morris and Stumpe 2015).*
  - Distributed wind projects are more likely to be sited in already disturbed areas, such as a manufacturing complex or an agricultural field.
  - The *U.S. Fish & Wildlife Service Land-Based Wind Energy Guidelines* provides a tiered approach for assessing potential wildlife impacts and does not expect distributed wind projects to need to go beyond preliminary site evaluations.
- Micrositing is critical to mitigating potential impacts regardless of project size.


Photo from Arterra / UIG via Getty Images


Photo from Edgar Figueiredo / Adobe Stock

Wildlife and Habitat Mitigation Strategies

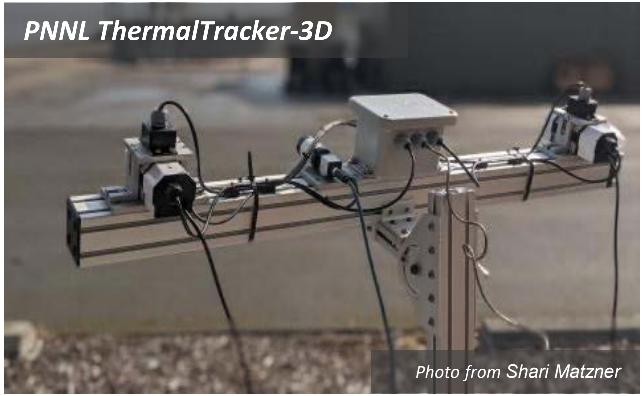
- There are many strategies and ongoing research to mitigate wildlife and habitat impacts:
  - Use of voluntary *U.S. Fish and Wildlife Service Land-Based Wind Energy Guidelines* to assess potential wildlife impacts prior to project development
  - Siting turbines away from known concentrations of avian species
  - Curtailment of operations during high-risk periods (e.g., when bats are most active)
  - Use of ultrasonic transmitters and novel lighting technologies to reduce bat activity (research still ongoing)
  - Replacing smaller low-capacity turbines with taller, higher-capacity turbines, which have fewer rotations per minute to limit collisions
  - Deployment of tracking technology to assess avian collision risk (e.g., Pacific Northwest National Laboratory's ThermalTracker-3D)

Photo from NREL

NREL research on Illuminating Turbines With Dim Ultraviolet Light ←

Bat Deterrent Units installed on wind turbine nacelle →

Photo from Harrison Gatos, NRG Systems



PNNL ThermalTracker-3D

Photo from Shari Matzner

Human-Environment Interactions

Sound

Sound Emissions

- Modern turbines do not produce sound at levels that can cause hearing impairment.
- There is evidence to suggest wind turbine sound annoyance is mostly a function of individual perception and experience.
  - There have been reports of increased annoyance, stress, irritation, and sleep disturbance, especially at wind turbine sound pressure levels greater than 40 dB(A).
- Modern turbines have features capable of controlling sound emissions such as:
  - Insulation of the nacelle* and gearbox
  - Blade serrations
- Sound concerns can also be mitigated with proper distances between turbines and nearby residences.

Acoustics testing at a wind farm
Photo from Acoustic Services

Blade serrations
Photo from Nordex

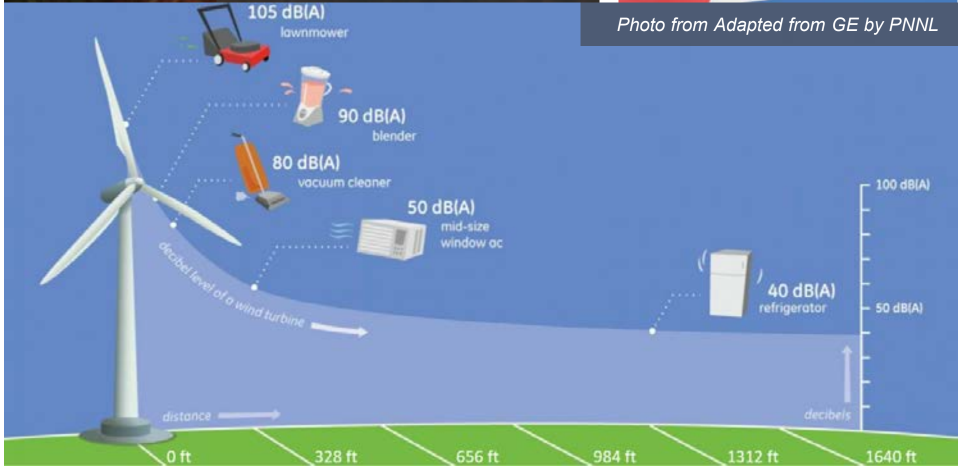


Photo from Adapted from GE by PNNL

*The nacelle houses all the generating components in a turbine (the generator, gearbox, drive train, and brake assembly).

Acoustic Testing and Sound Ratings

- Choosing a certified wind turbine is strongly recommended.

- For smaller-scale distributed wind turbines, which would be appropriate for the needs of the Abbey, acoustic testing is mandatory as sound level ratings are published.

- Turbines with a higher acoustic rating, such as the Kestrel, would need increased setback from observers to mitigate noise impacts.

ICC-SWCC Directory of Certified Turbines

ICC-SWCC labels, certificates and summary reports are accessible below for all current certified turbines. Turbines that have applied for, but have not yet been granted certification are also listed.

Show 10 entries Select Status Search:

ICC-SWCC Certification Number	Company	Turbine Model	Standard	Original Certification Date	Annual Energy Production	Sound Level	Rated Power	Peak Power	Status	Expiration Date
SWCC-11-04	SD Wind Energy, Ltd.	SD6	AWEA 9.1 (2009)	06/17/2019	8,950 kWh	43.1 dB(A)	5.2 kW	6.1 kW @ 17m/s	Certified	07/01/2025
SWCC-18-02	Hi VAWT Technology Corp	DS3000	AWEA 9.1 (2009)	05/10/2019	2,460 kWh	42.3 dB(A)	1.4 kW	1.4 kW @ 10.5 m/s	Certified	07/01/2025
SWCC-16-05	Bergey Windpower Co.	Excel 15	AWEA 9.1 (2009)	02/05/2021	29,800 kWh	48.5 dB(A)	15.6 kW	20.6 kW @ 16 m/s	Certified	01/01/2025
SWCC-10-20	Wind Resource, LLC	Skystream 3.7	AWEA 9.1 (2009)	04/12/2023	3,420 kWh	41.2 dB(A)	2.1 kW	2.4 kW @ 14.0 m/s	Certified	04/12/2025
SWCC-10-16	Eveready Diversified Products (Pty) Ltd.	Kestrel e400nb	AWEA 9.1 (2009)	02/14/2013	3,930 kWh	55.6 dB(A)	2.5 kW	3.0 kW @ 19.5 m/s	Certified	04/01/2025
SWCC-10-12	Bergey Windpower Co.	Excel 10	AWEA 9.1 (2009)	11/16/2011	13,800 kWh	42.9 dB(A)	8.9 kW	12.6 kW @ 16.5 m/s	Certified	01/01/2025

https://smallwindcertification.org/certified-turbines/

Regional Information

Dealer/Installer Options and Nearby Installations

Nearby Installations to Visit

- Visiting an existing distributed wind installation and having a discussion with the owner can be invaluable.
- **Walla Walla Community College** has two Bergey Excel 10 turbines (predecessor to the new Excel 15) and might be able to give an educational show & tell, but it is a 4-hour drive from Newport
  - https://www.wwcc.edu/

Thank You

www.nrel.gov

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