ENERGY TRANSITIONS INITIATIVE
U.S. Department of Energy

Partnership Project

Planning for a Sustainable and Resilient Energy System in Islesboro, Maine

Andrea Mengual, PNNL
Robert Broderick, Sandia
Andrea Mammoli, Sandia
Marcy Whitfield, PNNL
Laura Beshilas, NREL

April 2023

PNNL SAND2023-03039PE

Table of Contents

1. Executive Summary
2. Islesboro, Maine, Overview
3. Energy Transitions Initiative Partnership Project Overview
4. Existing Conditions in Islesboro
5. Hazard and Resilience Risk Assessment
6. Opportunity Assessment
7. Techno-Economic Analysis of Alternative Power Systems
8. Implementation Roadmap

Slide Deck Summary

- Islesboro is an island community in Maine served by one underwater transmission line. The community regularly experiences outages as well as high energy prices.
- Islesboro vision: “100% fossil-fuel free, in which inhabitants benefit equitably from low-cost, emergency resilient-electricity produced in large measure locally.”
- Islesboro received technical assistance from the Energy Transitions Initiative Partnership Program:
    - Collaborative development of energy goals for the community.
    - Assessment of conditions in Islesboro including existing energy systems, current energy use, and historical greenhouse gas emissions.
    - Assessment of risks and hazards.
    - Evaluation of four strategies to meet goals and mitigate risks.
    - Techno-economic analysis of alternative power systems.
- This slide deck serves as a summary of a report compiled by ETIPP for Islesboro, Maine.

Islesboro, Maine

Islesboro, Maine

- 600 year-round residents.
- 1,400 additional summer residents.
- 14-square-mile island in Penobscot Bay, Maine.
- Accessible by 30-minute ferry ride, or air taxi.
- Power is provided by Central Maine Power (CMP).
- Islesboro Energy Committee (IEC) was formed to identify and seek solutions to existing energy challenges on the island. The committee consisted primarily of full-time island residents who volunteer their time to this effort.

The ferryboat Margaret Chase Smith passing the Grindle Point Lighthouse in Islesboro (Photo by Bryan Bechtold/NREL).

Islesboro Energy Vision and Goals

Goal	Description
Achieve as close to 100% fossil-fuel-free energy systems on Islesboro as possible.	Transform Islesboro's energy systems and eliminate as much fossil-fuel use on the island as possible.
Enhance the resilience of the island's power system.	Enhance the resilience of the island's power system by lowering vulnerability to external hazards and increasing backup power capabilities on the island.
Ensure equitable access to low-cost, resilient energy on Islesboro.	Implement energy projects that provide equitable, low-cost access to resilient electricity for island residents.
Identify key actions for implementing Islesboro's energy vision.	Create an implementation plan for Islesboro energy projects that outlines crucial actions in the short-, medium-, and long-term time frames.

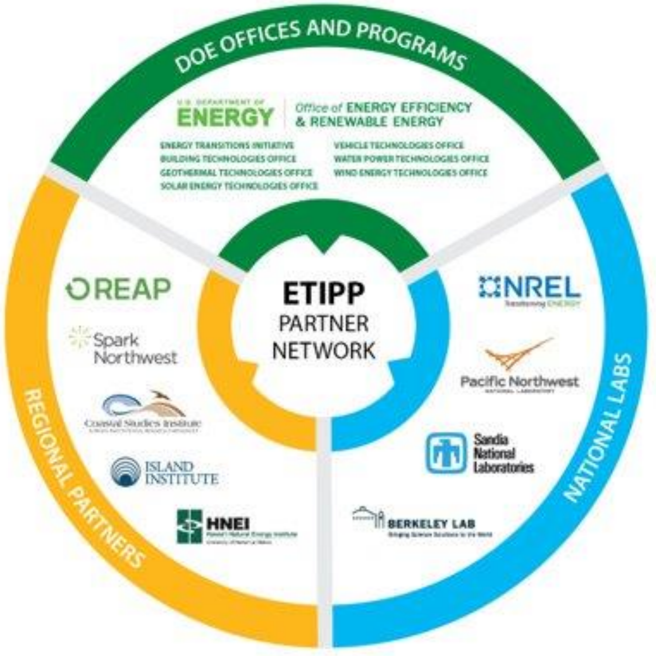
Energy Resilience

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.


The Narrows, Main Road in Islesboro (Photo by Bryan Bechtold/NREL).

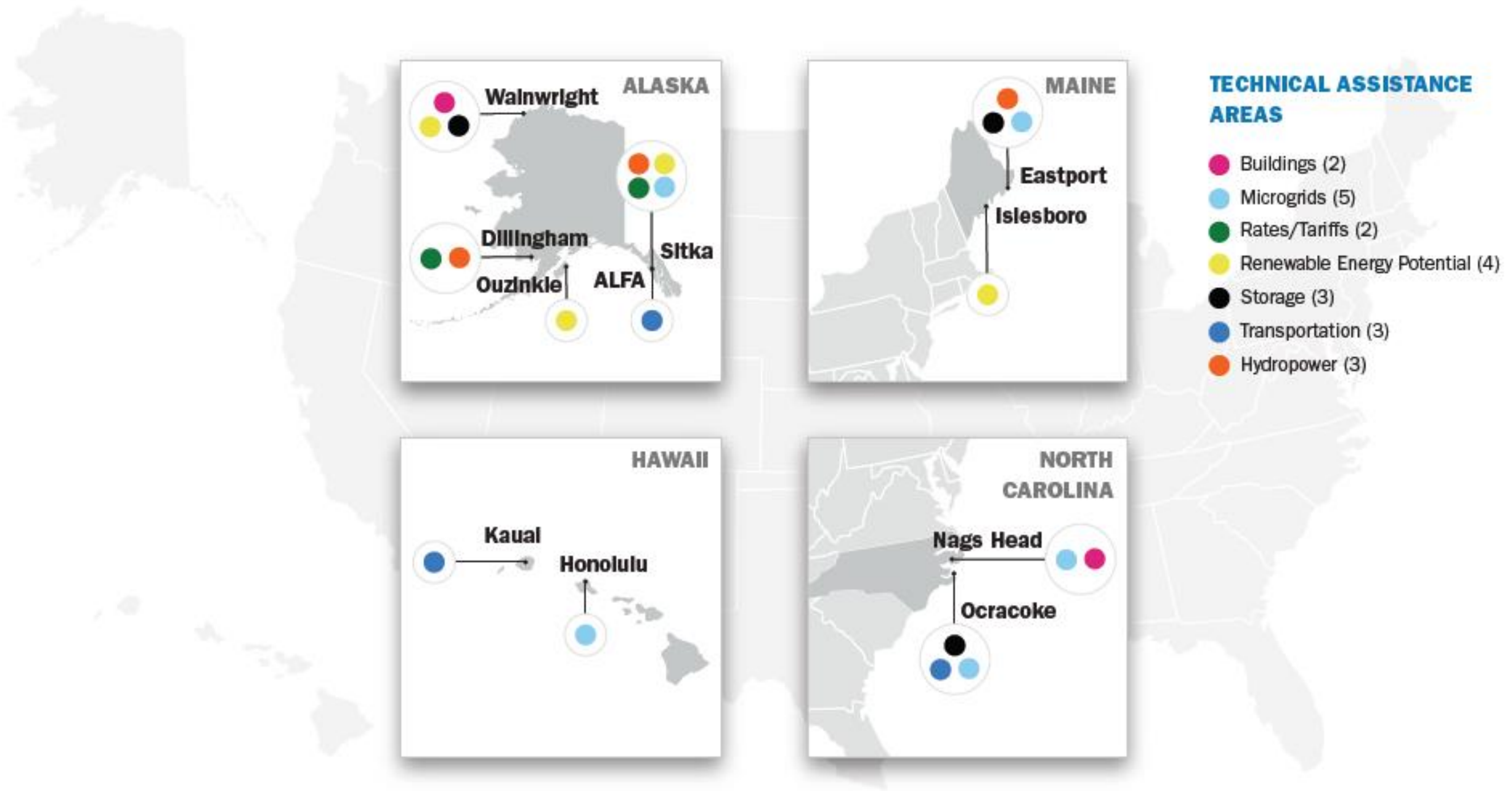
Energy Transitions Initiative Partnership Project (ETIPP)

Energy Transitions Initiative Partnership Project (ETIPP)



ETIPP connects remote and island communities with regional and national energy experts who can provide strategic energy analysis and planning for local energy resilience projects.

ETIPP Communities 2021



ETIPP in Islesboro

- Parties Involved
  - Islesboro Energy Committee: community liaison.
  - The Island Institute: local partner for providing technical assistance.
  - Technical assistance laboratories: National Renewable Energy Laboratory, Pacific Northwest National Laboratory, Sandia National Laboratories
- Islesboro received the following technical assistance:
  - Collaborative development of energy goals for the community.
  - Assessment of conditions in Islesboro including existing energy systems, current energy use, and historical greenhouse gas emissions.
  - Assessment of risks and hazards.
  - Evaluation of four strategies to meet goals and mitigate risks.
  - Techno-economic analysis of alternative power systems.

Marcy Whitfield (PNNL) asks for feedback on renewable energy from islanders during the Islesboro Energy Jamboree in 2022 (Photo by Bryan Bechtold/NREL).

ETIPP Report Executive Summary

- Fossil fuel use in buildings represents approximately 75% of annual energy consumption in Islesboro, and around 50% of energy-related emissions. Electricity and wood consumption account for 34% and 13% of building energy-related emissions, respectively.
- Interventions such as energy efficiency and electrification projects in both year-round and seasonal residences are important for Islesboro to pursue its energy goals.
- Energy efficiency projects were found to be cost-effective for a typical residence in Islesboro.
- Electrification of space and water heating, combined with home weatherization and envelope improvements, can help reduce heating energy costs and emissions in Islesboro.
- To offset its current electricity demand, Islesboro needs to generate nearly 6,200 MWh of additional electricity annually, which is approximately 4.7 MW of solar. There is sufficient space on roofs and open ground for installing this amount of solar.
- The techno-economic analysis found that for all load cases, the least-cost system was one in which PV generation satisfied the entire island-wide load on an annual basis. This system does not include a battery, as the grid can be used as a "no-cost battery."
- The techno-economic analysis also found that implementing electrification and efficiency measures with a smaller renewable energy system is a better economic choice than installing a larger renewable energy system.

Existing Conditions in Islesboro

How much energy does Islesboro currently use?

What is that energy used for?

What renewable energy is already present on Island?

Existing Energy Infrastructure

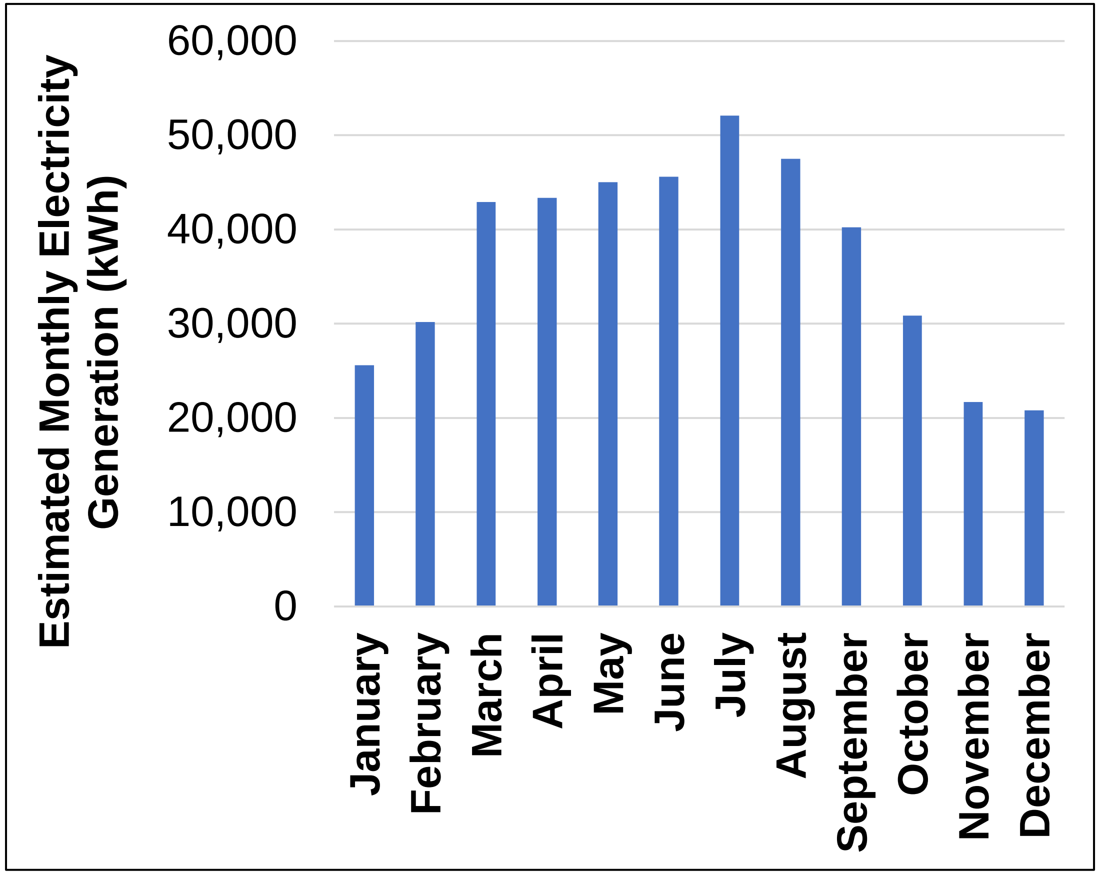
- Central Maine Power:
  - Provides electricity.
  - Owns, operates, and maintains all power distribution systems.
- Islesboro is fed by one underwater transmission feed from the mainland.
- There are no substations in Islesboro.
- Three-phase circuit spine

Three-phase circuits by CMP on Islesboro
https://www.arcgis.com/apps/Styler/index.html?appid=efb79ff9e99c448fb6683ad192324375

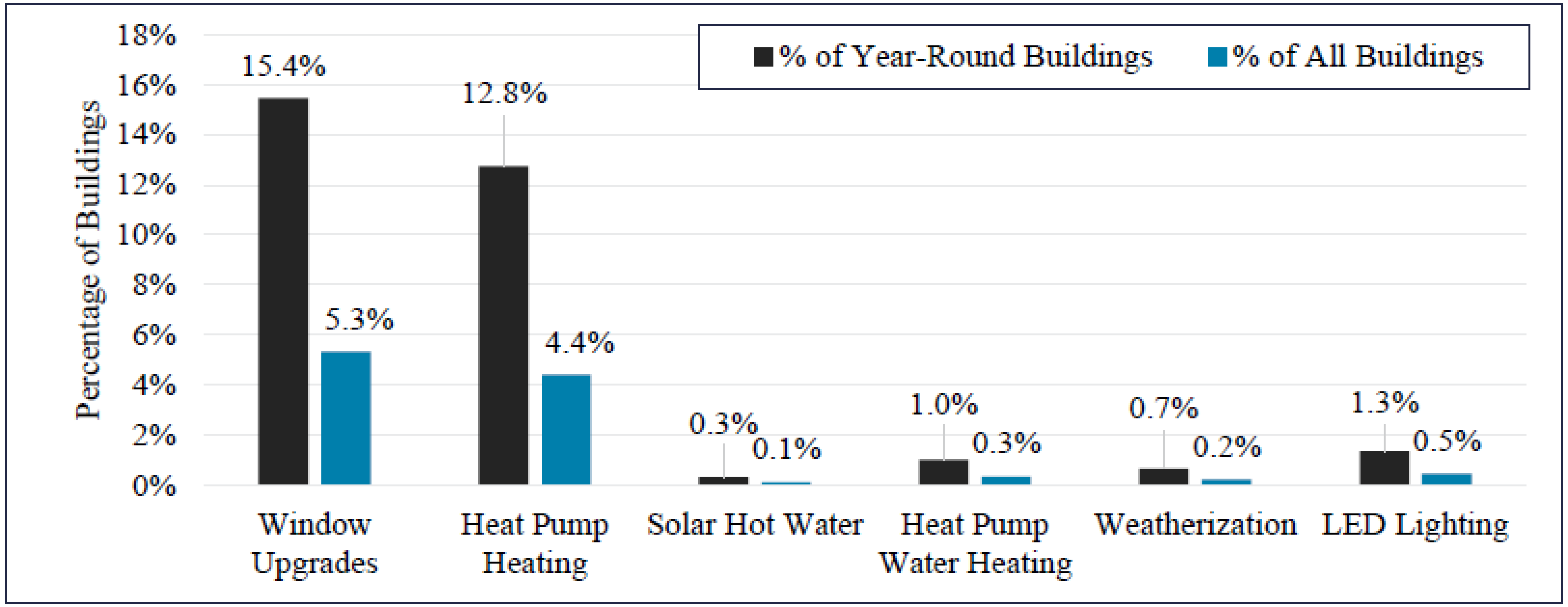
Existing Solar Photovoltaic (PV) Energy

Location	Array Size (kW)	Estimated Annual Generation (kWh/year)
Town hall/health center	46	58,000
School	68	85,000
North Transfer Station salt shed	32	41,000
Pendleton Yacht Yard	41	51,000
Residential arrays (24 total)	165 (total)	207,000 (total)
Total	**352**	**442,000***

* Represents approximately 6% of annual Islesboro electricity consumption

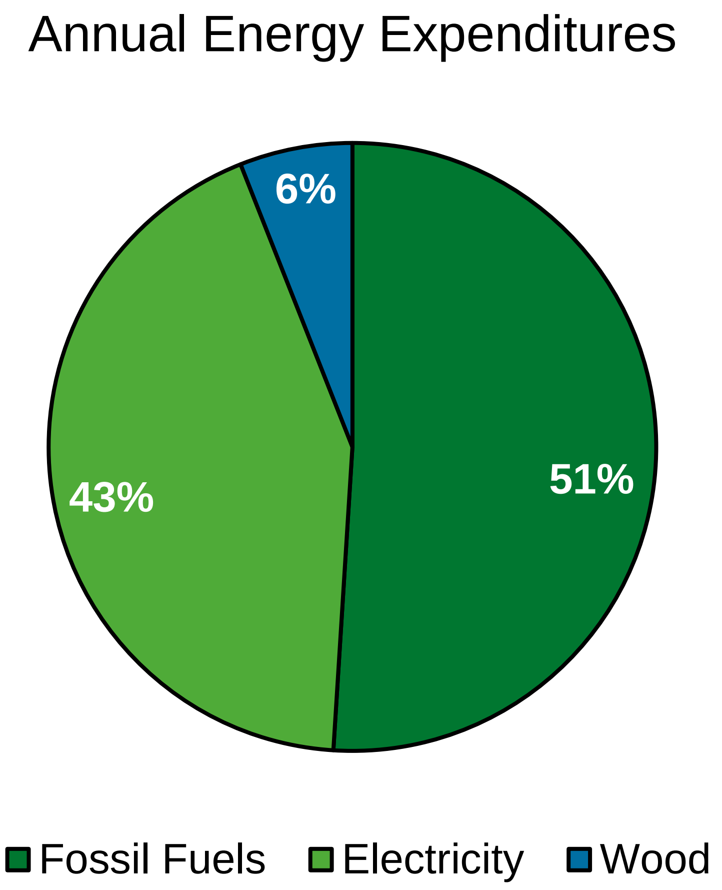


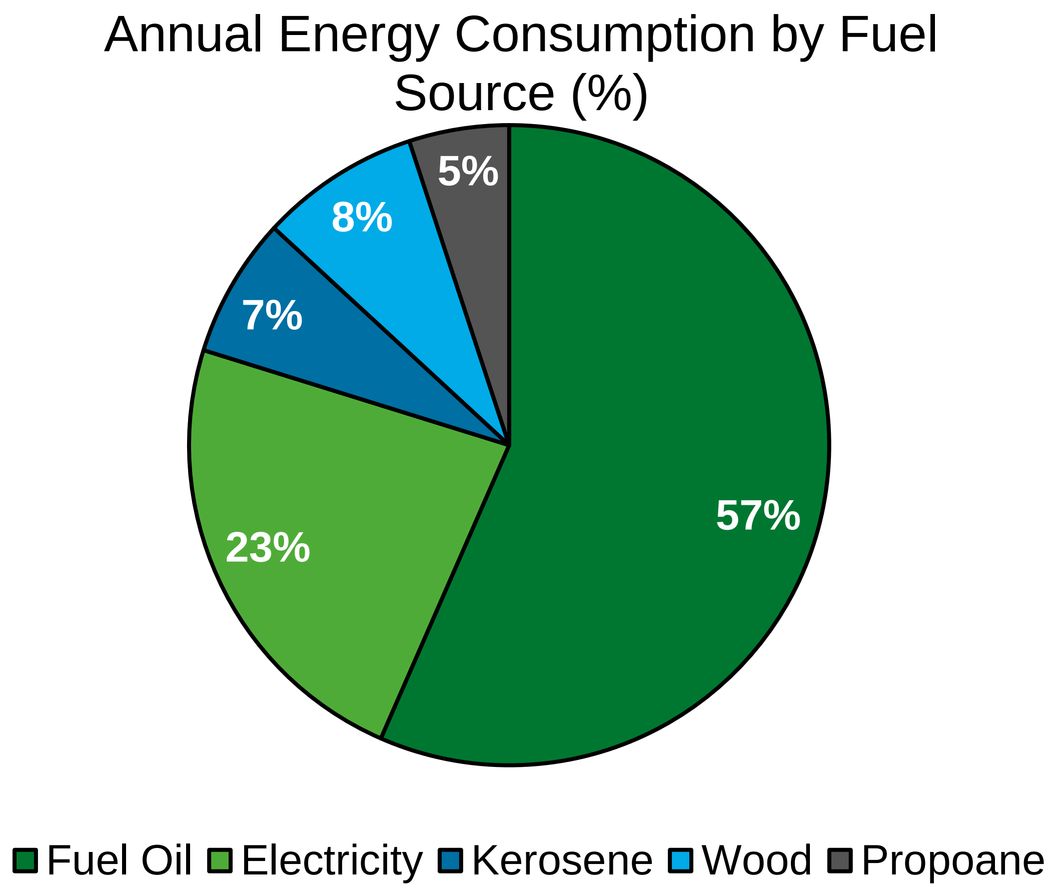
Energy Conserving Technologies



Installed energy-conserving technologies on Islesboro, according to data collected by the IEC and the Island Institute.

Current Energy Consumption

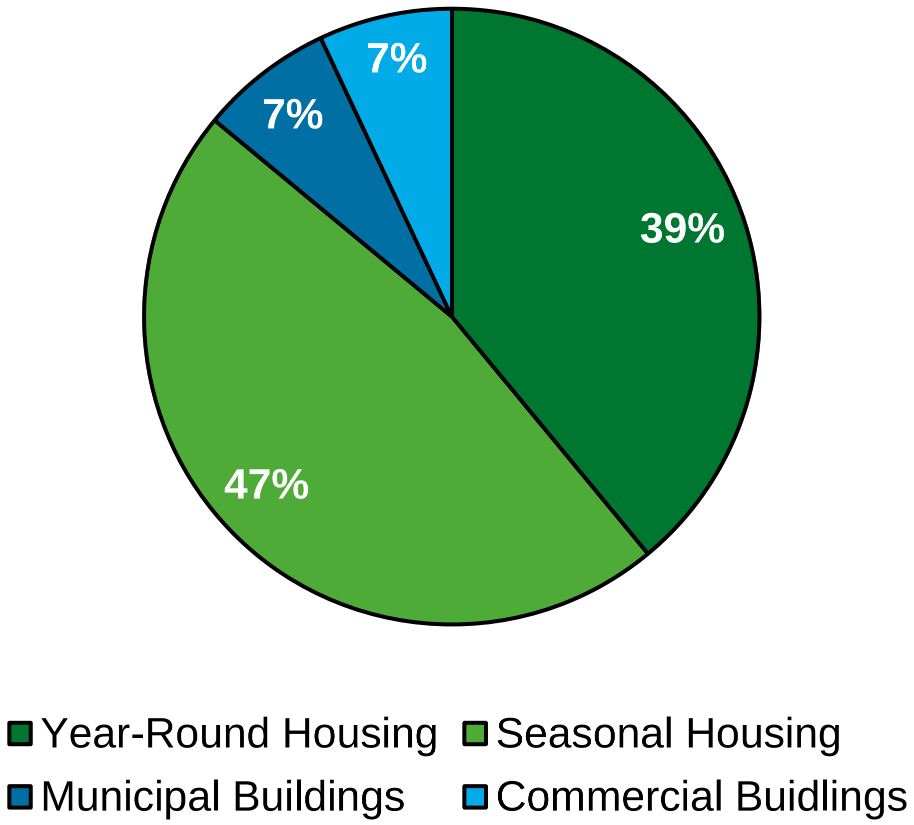




Source: Estimates based on data provided by Islesboro and energy modeling where data was not available

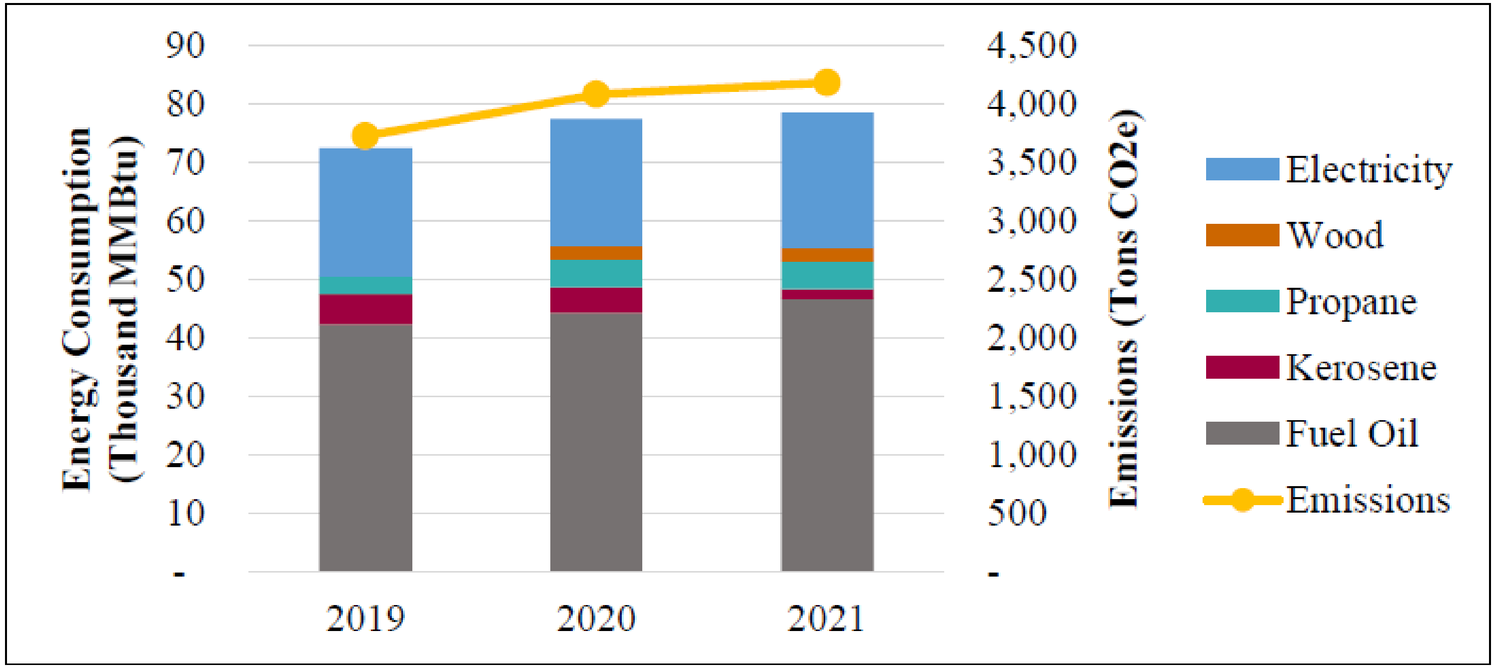
Current Energy Use in Buildings

Energy Consumption by Building Type



Building Type	Energy Use Intensity (kBTU/SF/year)
Year-round homes	67
Seasonal homes	31
Commercial	97
Municipal	78

Islesboro Historical Energy Consumption and Greenhouse Gas Emissions



Source: Energy consumption estimates based on data provided by CMP and transport documentation from the ferry. Emissions were calculated using emissions factors published by CMP and EPA.

Hazards and Resilience Risk Assessment

Why are there power outages in Islesboro?

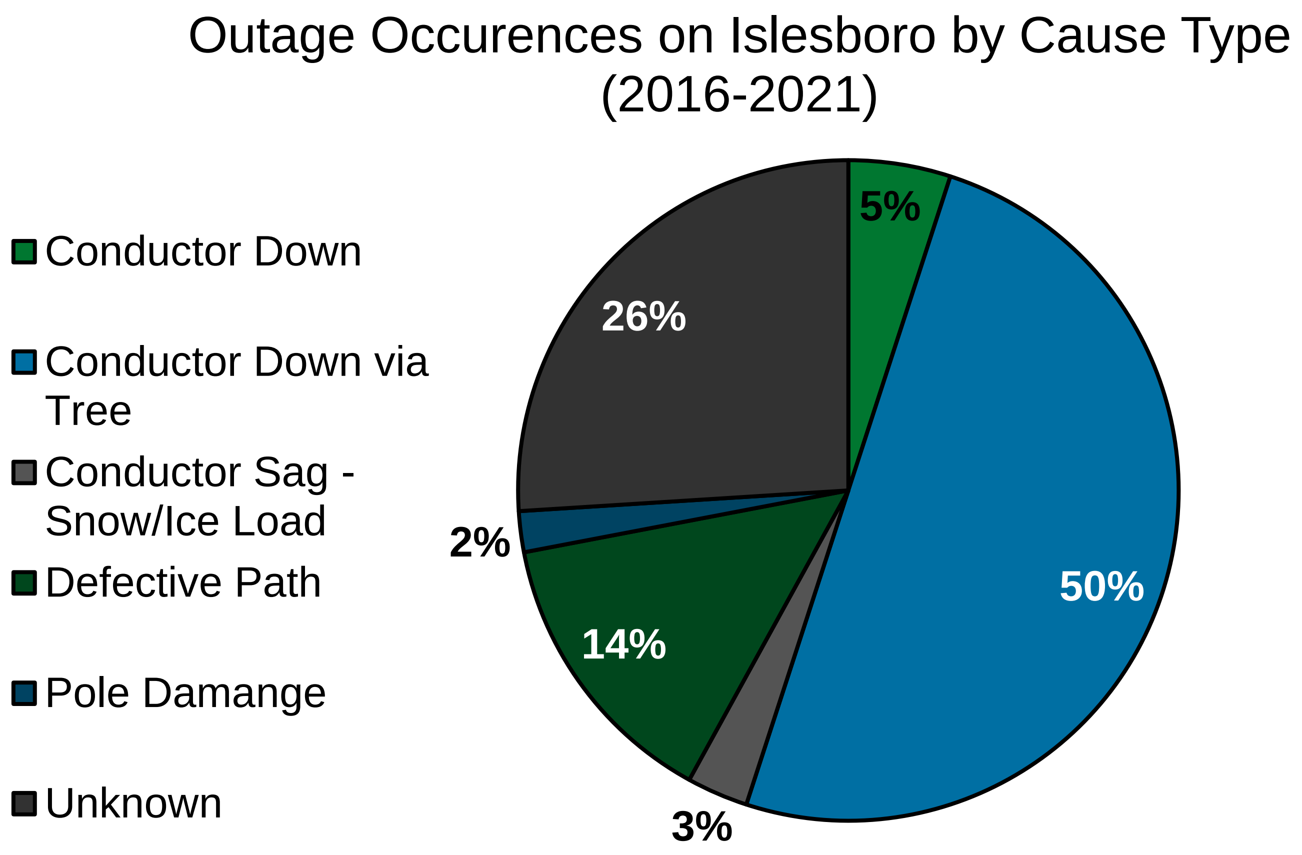
What are the vulnerabilities of the electric system in Islesboro?

Natural Hazards

Hazard	Annualized Frequency (Events/Year)	Expected Annual Loss Score	Electric Infrastructure Susceptance to Damage
Winter Weather	7.7	$36,527	Moderate
Lightning	6.7	$100,216	Moderate
Drought	5.8	$914,446	Low
Coastal Flooding	4.4	$40,665	Moderate
Ice Storm	1.2	$340,600	High
Hail	0.8	$27,701	Moderate
Riverine Flooding	0.8	$166,989	Moderate
Strong Wind	0.7	$53,708	High

Summary table of the most prevalent hazards for Waldo County, Maine
https://hazards.fema.gov/nri/report/viewer?dataLOD=Counties&dataIDs=C23027

Power Outages in Islesboro



Source: Outage data provided by CMP.

Electric System Vulnerabilities

Vulnerability	Islesboro
Critical facilities (see report for full list) lack adequate backup power.	12 of 18 critical facilities
Existing generators lack sufficient on-site fuel supply.	All
Single point of failure from transmission system (single transmission line or distribution substation).	Yes
Lack of automation in switching capabilities results in reliance on third party to transfer loads during an outage.	Yes
Electrical panel layout inhibits capability to strategically shed noncritical loads.	Yes
Generator maintenance protocols omit key requirements (fuel sampling, flushing of cooling system, battery replacement).	Unknown
Lack of emergency refueling plan for generators.	Unknown

Opportunity Assessment

What are the strategies that Islesboro can pursue to achieve goals and mitigate risks?

What are the potential costs and benefits of each strategy?

What are actions that Islesboro can take to implement these strategies?

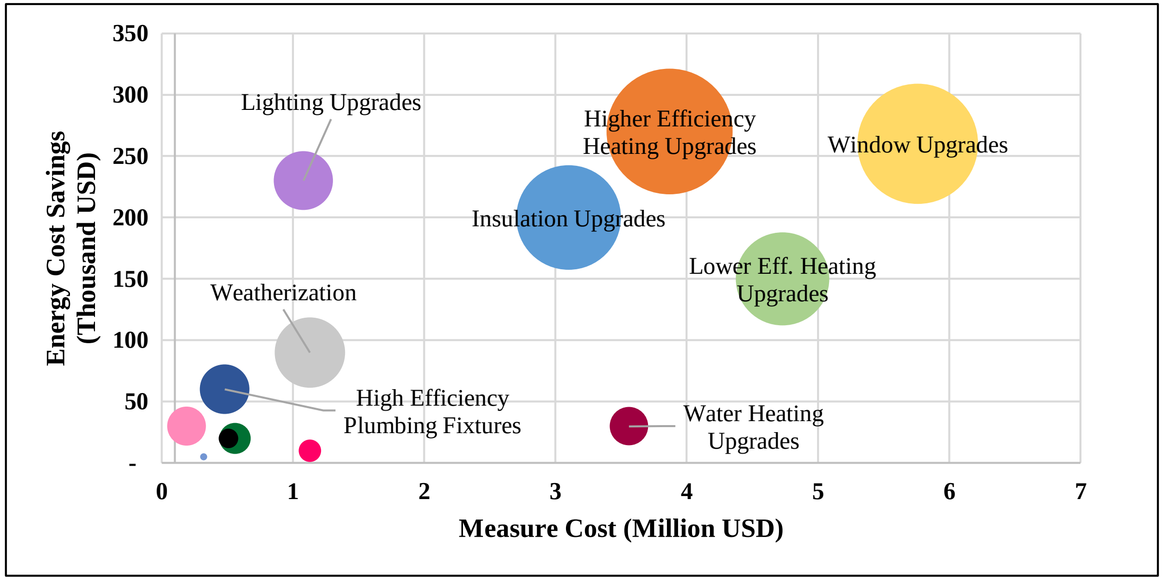
Strategies Evaluated

1. Reduce energy load through energy efficiency.
2. Electrify buildings.
3. Increase on-island energy generation.
4. Improve infrastructure conditions to enhance resilience.

Solar panels on the Islesboro Fire Department. (Photo by Bryan Bechtold/NREL)

1. Reduce Energy Load through Energy Efficiency

- Implementation of energy efficiency measures (EEM)
- EEMs evaluated:
  - Lighting system and control upgrades.
  - Envelope upgrades.
  - Heating and hot water efficiency upgrades.
- Evaluated for three different building types:
  - Year-round housing.
  - Seasonal housing.
  - Commercial and municipal buildings.



Distribution of the rough order of magnitude of energy cost savings and implementation costs for all measures evaluated if they were to be implemented on all buildings in Islesboro. The size of the bubble represents the amount of energy savings for each measure.

Potential Next Steps for Load Reduction Implementation

Step	Responsible Party	Description	Time Horizon
Promote energy efficiency locally.	IEC	Begin promoting and socializing the benefits of adopting EEMs to island residents.	Short
Connect with neighboring communities.	IEC	Research and connect with neighboring island communities in Maine making efforts toward energy transformation and decarbonization. For example, the organization A Climate To Thrive on Mount Desert Island has implemented programs around building retrofits and solar energy that may be a useful model for Islesboro.	Short
Identify applicable incentives and application processes.	IEC with Island Institute support	Investigate in more detail available incentives and the application process for each. A conversation with Efficiency Maine as an incentive provider may also be useful to learn whether the incentive process can be streamlined for a larger number of applications.	Short
Identify contractor(s) for EEM implementation.	IEC with Island Institute support	Hold discussions with local contractors that may be able to implement EEM projects on Islesboro to better understand costs and available programs. Consider discussing options for deploying an EEM at scale on the island (e.g., lighting retrofits in both year-round and seasonal homes).	Short
Implement EEMs.	Residents	Begin implementing selected EEMs where possible.	Medium
Track progress.	IEC	Track the implementation of EEMs through periodic surveys and review of utility bills.	Medium

2. Electrify Buildings

- Majority of building related-energy emissions in Islesboro come from building heating, hot water production, and cooking.
- Options evaluated:
    - Convert heating to heat pump systems.
    - Convert heating to resistance-based systems.
    - Convert water heating to resistance-based systems. Note: heat pump water heaters were not evaluated in this analysis.
    - Convert cooking systems to electricity.

Induction stoves use electricity. (Photo by Dennis Schroeder/NREL)

Electrify Buildings

Electrification Option	Annual Energy Cost Savings ($)	Total Energy Savings (%)	Full Capital Investment ($)	Estimated Incentives ($)	Simple Payback without Incentives (Years)	Simple Payback with Incentives (Years)
Convert heating to heat pump systems	360K	35%	6.2M	1M	17	15
Convert heating to resistance-based systems	980K Increase	11%	4.8M	-	No payback	-
Convert water heating to resistance-based systems	300K Increase	3%	5.1M	2.5M	No payback	No payback-
Convert cooking systems to electricity	60K Increase	-	1.6M	-	No payback	-

Estimated annual energy and cost savings, full investment, incentives, and simple payback in years for each of the system conversion options if implemented in all buildings in Islesboro.

- Note: resistance-based options result in additional costs due to lower system efficiencies and the cost of electricity.
- Note: the best system type and configuration will vary by building.

Potential Next Steps for Building Electrification

Step	Responsible Party	Description	Time Horizon
Engage a contractor to evaluate electrification requirements.	IEC	Engage a contractor to evaluate typical homes on Islesboro to obtain a better estimate of costs and actions that would be required to electrify heating and hot water systems. Islesboro could also request the contractor provide recommendations for enabling homes to be ready for electrification, such as upgrading the electrical wiring, service, etc. Islesboro residents can use this information to evaluate electrification in their own homes and prepare for potentially installing an electric system during an emergency replacement or a planned upgrade.	Short
Identify contractors for building electrification.	IEC	As for EEMs, hold discussions with local contractors that may be able to assist in building electrification. Examples of contractors that may be needed include electricians; heating, ventilation, and air conditioning (HVAC) contractors; and plumbing specialists. Create a list of potential contractors and make it available to island residents to support their preparation for electrification.	Short
Review local ordinances.	IEC / Town	Review local ordinances or applicable building codes to identify and address barriers (if any) to the installation of electric systems on Islesboro.	Medium
Make a plan.	Residents	Encourage Islesboro residents to make a plan for existing equipment replacement. If interested in electrifying, what preparations does each home need to make?	Medium
Track progress.	IEC	Track the progress through periodic surveys and review of utility bills.	Medium

3. Increase On-Island Renewable Energy Generation

- Approximately 6% of total Islesboro electricity is supplied by local solar PV.
- 6,200 MWh of additional electricity (~4.7 MW PV) needed to offset all current demand.

PV Type	Total Available Area	Total Potential Capacity (MW-DC)
Rooftop PV	Approximately 250,000 square feet of available rooftop area for solar PV across all buildings on Islesboro.	3.6
Ground PV	Approximately 300,000 square feet (7 acres) of available open ground area that can be used for PV. Note: This is a conservative estimate based on a few selected sites, and there is more than this amount of open space on Islesboro.	4.6


Solar panels at the Islesboro Central School. (Photo by Bryan Bechtold/NREL)

Why Solar? (Why Not Other Renewables?)

- Wind generation potential in Maine along the coast ranges from fair to outstanding, but ETIPP analysis did not consider wind due to:
    - Community concerns about land-based wind.
    - Maine law prohibiting offshore wind in state waters used for recreation and fishing.
- Tidal energy is a possibility in Maine but is not feasible for Islesboro because the tide flow velocity is not strong enough.
- Wave energy is not substantial in the region and therefore was not considered for this analysis.

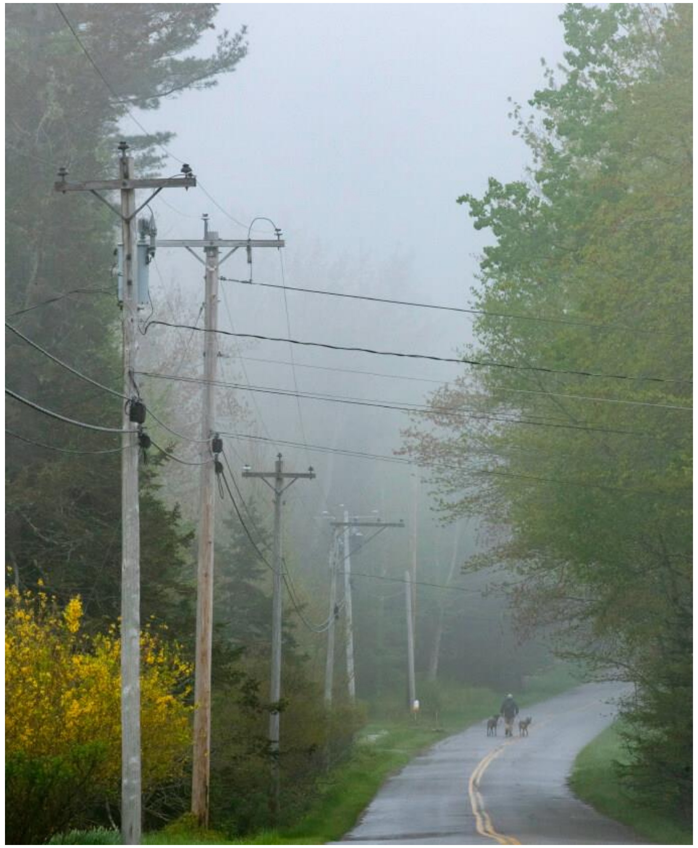
Solar panels on the Islesboro Fire Department. (Photo by Bryan Bechtold/NREL)

Potential Next Steps for On-Island RE

Step	Responsible Party	Description	Time Horizon
Engage and educate community stakeholders on renewable energy.	IEC / Town	Continue engaging with and educating local stakeholders on the benefits and pathways for installing renewable energy projects on Islesboro.	Short
Connect with neighboring communities to learn best practices.	IEC	Research and connect with neighboring island communities in Maine making efforts toward energy transformation and decarbonization. For example, the organization A Climate To Thrive on Mount Desert Island has implemented programs around building retrofits and solar energy that may be a useful model for Islesboro.	Short
Investigate the possibility of community solar projects.	IEC / Town	Islesboro residents can further investigate the possibility of community solar on the island. This process can involve activities such as identifying viable locations for a large-scale solar project, conducting outreach, obtaining consensus from residents on project options, engaging with potential vendors, and others.	Medium

4. Improve Infrastructure Conditions to Enhance Resilience

- Potential measures to improve the resilience of the power supply:
  - Supply side
  - Access options
  - Proactive utility engagement.



Main Road, North Island in Islesboro.
(Photo by Bryan Bechtold/NREL)

Supply Side and Access

- Install permanent backup generation at critical facilities.
- Utilize mobile backup generators.
- Work with utility to identify opportunities to enhance the existing electric infrastructure.
- Only six of 18 critical facilities have backup generators installed.

An emergency generator nicknamed "Big Buck" at NREL.
(Photo by Werner Slocum/NREL)

Access

- Work with utility to identify opportunities to enhance the existing electric infrastructure.
  - Add loops to current radial layout to minimize number of customers impacted by faults.
  - Include automation in switching capabilities.
- Explore option of placing a generating asset at the end of the radial circuit.
- Explore dual fueled equipment when replacing equipment at the end of its life.

Main Road at Seal Harbor, Islesboro. (Photo by Bryan Bechtold/NREL)

Proactive Utility Engagement

- Develop emergency operating and outage recovery plans with the utility and emergency response teams.
- Exercise plans and procedures annually to ensure preparation.
- Hold periodic meetings with utility to build relationships and explore resilience options.
- Engage with utility on electrical distribution and transmission maintenance including:
  - Vegetation management
  - Circuit inspection
  - System review and planned system improvements.

Why Not an Underground Distribution System?

Most outages were caused by downed power lines and poles, so why not an underground distribution system?

- Expensive
- Requires utility approval and funding
- Operations, maintenance, and repairs more time consuming.

Techno-Economic Analysis of Alternative Power Systems

Assessment of feasible alternatives that can advance Islesboro's goals

Techno-Economic Analysis

- Evaluate energy technologies by examining the following:
  - Costs
  - Benefits
  - Risks
  - Uncertainties
  - Timeframes.
- Techno-economic analysis conducted by Sandia used HOMER Pro.

HOMER

- HOMER: Hybrid Optimization Model for Electric Renewables
- Finds the least cost combination of components to meet electrical and thermal loads specified.
- Produces a list of possible system options, sorted by lifecycle cost.

Assumptions for Techno-Economic Analysis

Assumption	Notes
6% discount rate, 3% inflation	Discount and inflation rates can vary, these are typical long-term values.
25-year analysis period	Representative of a typical investment time horizon as well as representative of a typical PV panel lifespan.
CMP flat rate, $0.215/kWh purchase, $0.00 sell back	Flat rate, with no demand charges is typical of a local residential service tariff.
Net metering assumed with each discrete system capped at 2MW, annual true-up of net energy consumption	
Cost of PV $2,569/kW	NREL's Annual Technology Baseline used to estimate the cost to install.
One outage event each year: 5-day/year loss of grid power	Based on information from the IEC.
86% of full capacity derating of PV system	Based on the NREL PVWatts® Calculator estimate to account for losses due to soiling, shading, material degradation, etc.
Inverter sized at 100% of peak PV size	
Emissions are assumed zero if there is an annual net export of energy to the grid.	

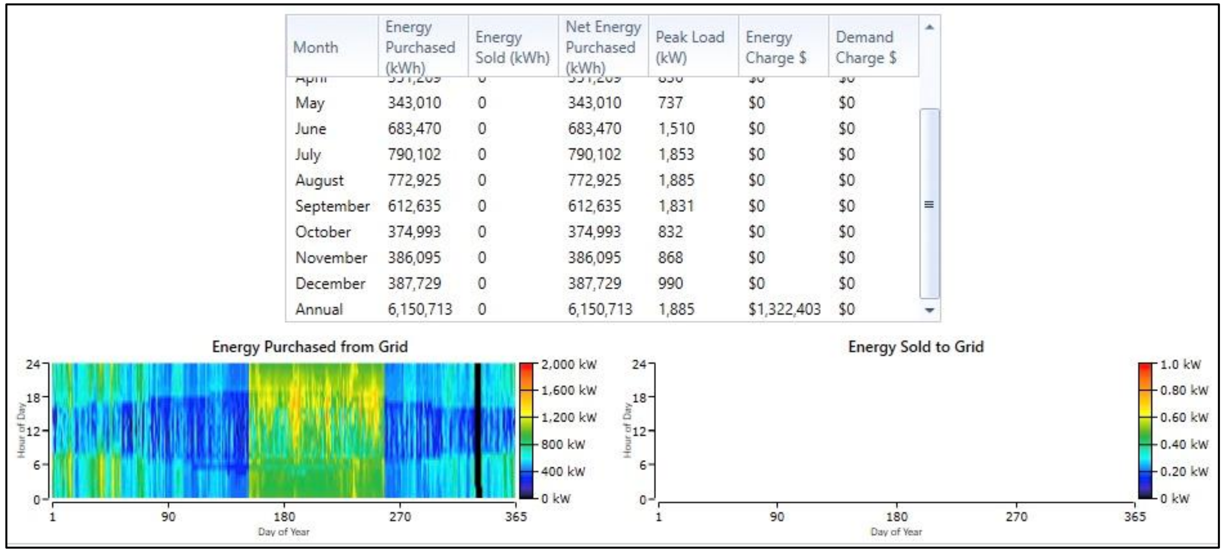
Scenarios

ETIPP used HOMER to evaluate eight potential scenarios:

1. Island-Wide Scenario Baseline
2. Island-Wide Scenario Baseline with PV
3. Island-Wide Scenario of High Electrification with PV
4. Island-Wide Scenario of High Electrification, High Efficiency with PV
5. Island-Wide Scenario High Electrification, High Efficiency, Renewable Microgrid
6. Island-Wide Scenario of High Electrification and a High Efficiency Diesel Backup Microgrid
7. Multiple Building Microgrid at Islesboro Town Center: Renewable Energy Microgrid
8. Multiple Building Microgrid at Islesboro Town Center: Diesel Back Up Microgrid

1. Island-Wide Baseline Scenario: Grid Connected Only

- 2021 electric load, supplied by CMP
- Business as usual
- Notes:
  - Strong summer peak due to summer residents.
  - Current cost of power (slightly lower than CMP due to existing PV).
  - Emissions resulting from published CMP estimated average.



Month	Energy Purchased (kWh)	Energy Sold (kWh)	Net Energy Purchased (kWh)	Peak Load (kW)	Energy Charge $	Demand Charge $
May	343,010	0	343,010	737	$0	$0
June	683,470	0	683,470	1,510	$0	$0
July	790,102	0	790,102	1,853	$0	$0
August	772,925	0	772,925	1,885	$0	$0
September	612,635	0	612,635	1,831	$0	$0
October	374,993	0	374,993	832	$0	$0
November	386,095	0	386,095	868	$0	$0
December	387,729	0	387,729	990	$0	$0
Annual	6,150,713	0	6,150,713	1,885	$1,322,403	$0

Energy exchange for Case 1. Because existing PV on the island only supplies approximately 6% of the island's energy needs, the net draw of power from the grid is always positive. Energy is not sold to the grid (as seen in the "Energy Sold to the Grid" panel).

2. Island-Wide Scenario with PV

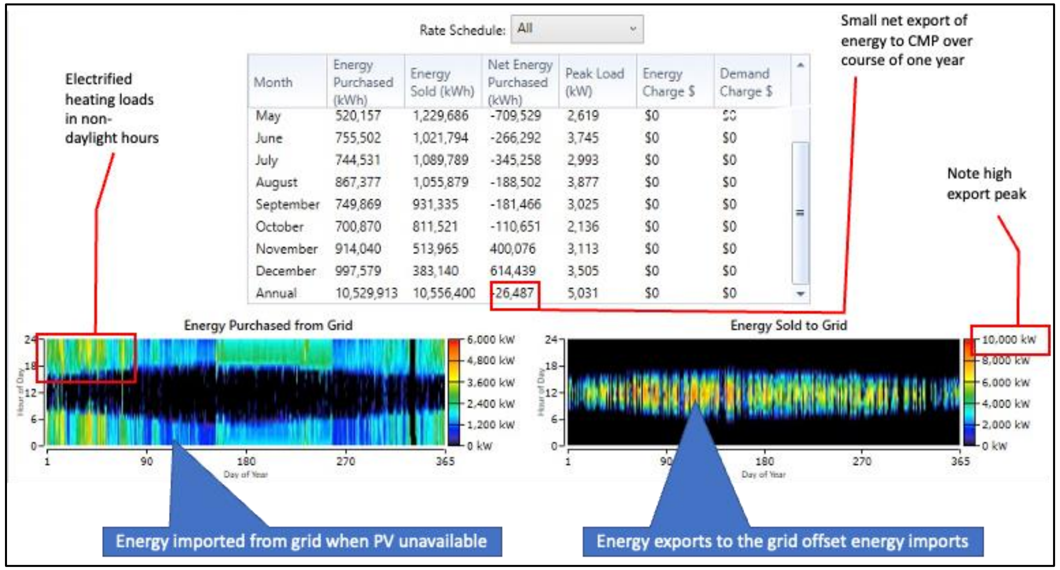
- Same load scenario as Case 1.
- Installation of additional PV to offset *all* purchases from CMP.
- Techno-economic analysis recommends the installation of a PV array with total of 4.75 MW peak capacity.
- Notes:
  - Levelized cost of energy reduced by 35% compared to Case 1.
  - High upfront investment but lower long-term energy cost.
  - PV alone does not provide resilience and eliminate loss of power during a grid outage.

Goal	Would this scenario help Islesboro achieve this goal?
Fossil-fuel-free*	Yes
Resilience	No
Low-cost	Lowest-cost option assessed

*The fossil-fuel-free concept is nuanced: The grid still runs on fossil fuel and could not run without it. However, PV displaces the island's fossil fuel use in an average (net) sense, if we assume that CMP does not sell the renewable energy credits in the carbon offset market.

3. Island-Wide Scenario of High Electrification Load Case With PV

- Electric load is much higher due to a forecasted electrification of heating loads and transportation.
- Techno-economic analysis recommends adding a total of 12.2 MW of PV capacity.
- Notes:
  - LCOE reduced by 32% compared to Case 1 (per unit energy).
  - High upfront investment.
  - PV alone does not eliminate loss of power during a grid outage.



Month	Energy Purchased (kWh)	Energy Sold (kWh)	Net Energy Purchased (kWh)	Peak Load (kW)	Energy Charge $	Demand Charge $
May	520,157	1,229,686	-709,529	2,619	$0	$0
June	755,502	1,021,794	-266,292	3,745	$0	$0
July	744,531	1,089,789	-345,258	2,993	$0	$0
August	867,377	1,055,879	-188,502	3,877	$0	$0
September	749,869	931,335	-181,466	3,025	$0	$0
October	700,870	811,521	-110,651	2,136	$0	$0
November	914,040	513,965	400,076	3,113	$0	$0
December	997,579	383,140	614,439	3,505	$0	$0
Annual	10,529,913	10,556,400	-26,487	5,031	$0	$0

Energy exchange for Case 3. Energy is imported from the CMP grid when PV is unavailable (at night, for example). Energy is exported to the grid when the on-island solar PV produce more electricity than is demanded. There is a net export of energy at the end of the year.

Goal	Would this scenario help Islesboro achieve this goal?
Fossil-fuel-free*	Yes
Resilience	No
Low-cost	No

4. Island-Wide Scenario of High Electrification, High Efficiency With PV

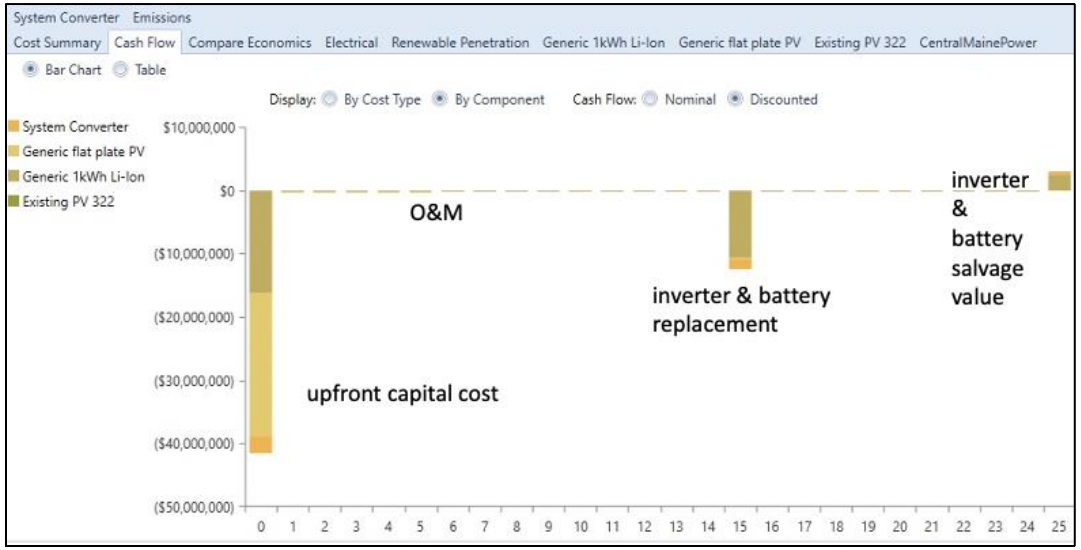
- Increase in electric load due to electrification of heating loads and transportation is largely offset by energy efficiency measures.
- Techno-economic analysis recommends adding a total of 6.3 MW of PV capacity.
- Notes:
  - LCOE reduced by 33.5% compared to Case 1.
  - Total cost of energy slightly higher due to increased electricity costs, but likely offset by reduced fossil fuel energy costs.
  - High upfront investment ($18 million).
  - PV alone does not eliminate loss of power during a grid outage.

For Case 4, the techno-economic analysis recommends adding 6.3 MW of PV, which covers approximately 25 acres.
For comparison purposes, this is illustrated near the Islesboro airstrip.

Goal	Would this scenario help Islesboro achieve this goal?
Fossil-fuel-free*	Yes
Resilience	No
Low-cost	No

5. Island-Wide Scenario of High Electrification, High Efficiency, Renewable Microgrid

- High electrification, high efficiency case.
- Zero tolerance for loss of service.
- Emissions-free resources only are considered.
- Techno-economic analysis recommends 8.8 MW of PV and a 29.5 MWH LI-ion battery.
- Notes:
  - It is possible to ensure 100% availability of service with a RE-only system.
  - LCOE double that of Case 1.
  - Optimal battery management necessary to optimize battery life.
  - Battery could provide grid services and potentially offset some high costs of the system.

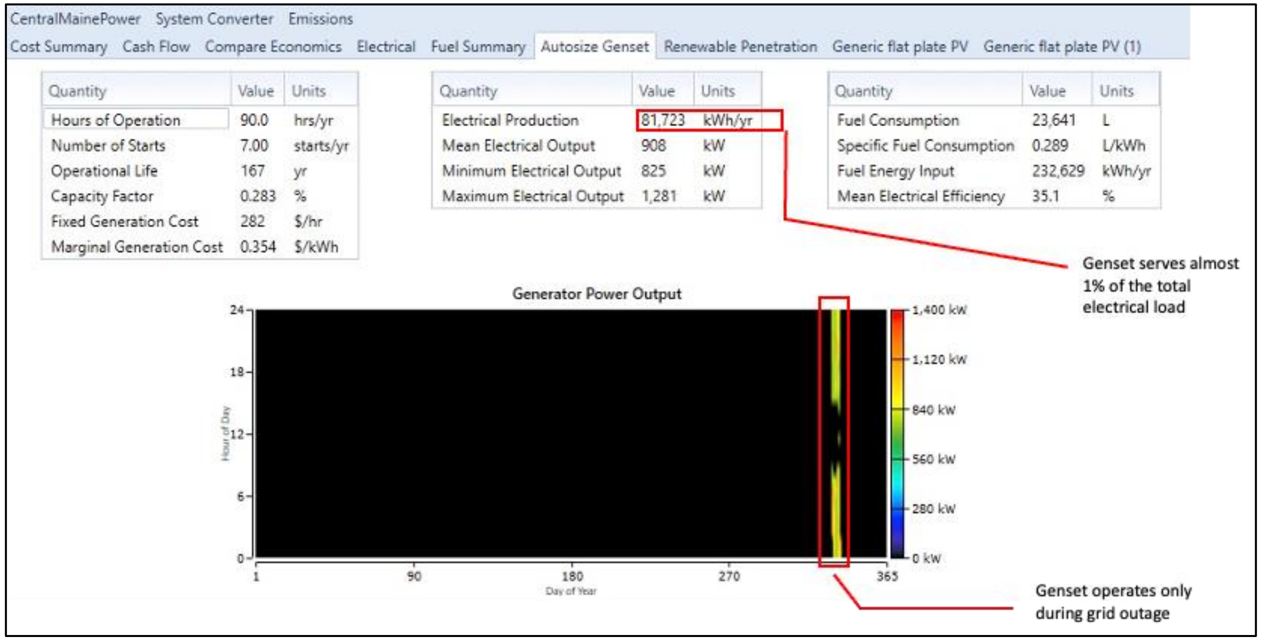


The cash flow for Case 5 is dominated by capital cost for initial installation and replacement of components (PV, battery, and inverter).

Goal	Would this scenario help Islesboro achieve this goal?
Fossil-fuel-free*	Yes
Resilience	Yes
Low-cost	No

6. Island-Wide Scenario of High Electrification, High-Efficiency Microgrid With Diesel Backup

- High electrification, high efficiency case.
- Zero tolerance for loss of service.
- Diesel backup generation was considered as an option, along with battery and PV.
- Techno-economic analysis recommends 6.3 MW PV and 3.3 MW diesel genset, with no battery storage.
- Notes:
  - PV array and diesel genset can support the town’s load during a 5-day grid outage.
  - Diesel backup generator only operates during grid outages.
  - Emissions are non-zero, but a small fraction of the grid-only scenario.

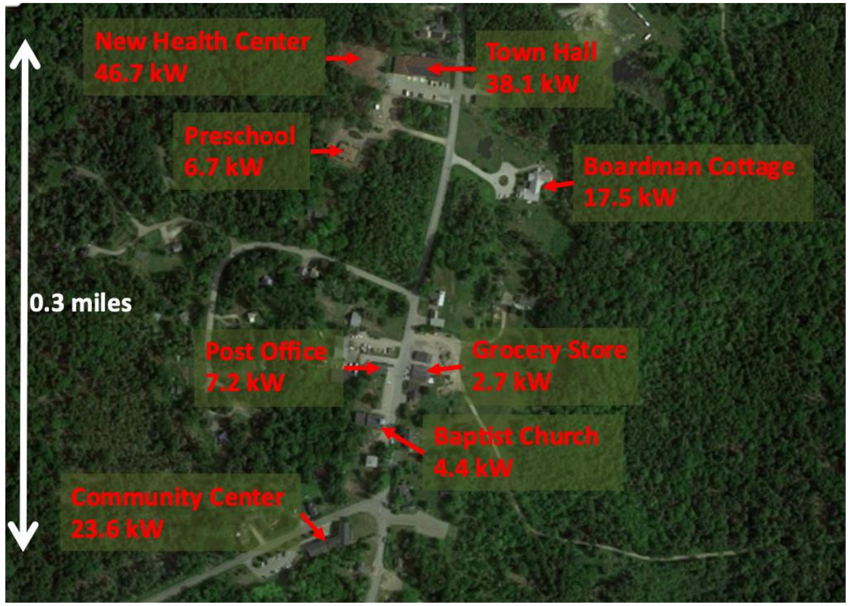


The diesel backup generator is used in Case 6 only during grid outages.
It serves approximately 1% of the total electrical load.

Goal	Would this scenario help Islesboro achieve this goal?
Fossil-fuel-free*	Yes (except for outages)
Resilience	Yes
Low-cost	No

7. Multiple Building Microgrid Islesboro Town Center: Renewable Energy Microgrid

- Enhance the resilience of a group of buildings that could provide critical services during grid outages of up to five days.
- Eight buildings along Main Street, including a community center, a grocery store, and the town hall.
- 100% RE, no fossil-fuel backup allowed.
- Techno-economic analysis recommends an addition of 738 kW PV and 1,647 kWh Li-ion battery storage.
- Cost of power for the buildings is very high due to larger PV and addition of battery storage.



Town Center Resilience Cluster for Cases 7 and 8.

Goal	Would this scenario help Islesboro achieve this goal?
Fossil-fuel-free*	Yes
Resilience	Yes
Low-cost	No

8. Multiple Building Microgrid at Islesboro Town Center: Diesel Backup Microgrid

- Enhance the resilience of a group of buildings that could provide critical services during grid outages of up to five days.
- Eight buildings along Main Street, including a community center, a grocery store and the Town Hall.
- Techno-economic analysis recommends 333 kW PV and 160 kW diesel genset.
- Notes:
    - Diesel genset only runs during grid outages.
    - Cost of power to the buildings only slightly higher than with PV only, but still lower than with grid only.

Scale and potential location of a new 333 kW PV array located near the town center building cluster for Case 8.

Goal	Would this scenario help Islesboro achieve this goal?
Fossil-fuel-free*	Yes (except for outages)
Resilience	Yes
Low-cost	No

Key Takeaways

- Lowest-cost solution is a grid-tied 4.75 MW PV array.
  - Assumes net-metering with 12-month true-up.
- State net-metering limits the size of individual PV arrays.
- It is unclear if CMP has capacity to allow power back feed to mainland.
- All-renewable resilient microgrid is expensive due to batteries and large PV array.
- Diesel option for resilience adds a small cost premium to the PV-only option.
- Typically, CO_2 emissions from using a diesel backup generator amount to about 4% of the grid-only emissions for the same case.
  - PV array could be sized to export more electricity to CMP to eliminate net emissions.
- Up-front investment costs are high, but financing arrangement could turn upfront cost into annual payments that are lower than corresponding grid-only electric bills.
- Implementing efficiency measures in the high-electrification scenario is likely a better economic choice than upsizing PV system to serve a larger load.

Implementation Roadmap

Islesboro Implementation Roadmap

- Islesboro can begin improving its energy resilience immediately through operational planning.
- Initial steps to socialize and promote the adoption of EEM and electrification can advance Islesboro’s energy vision.
- More capital-intensive solutions will take more time.

Islesboro Preschool. (Photo by Bryan Bechtold/NREL)

Reduce Energy Load Through Energy Efficiency

Action	Short-Term Priority (2023)	Medium-Term Priority (2024-2028)	Long-Term Priority (2028+)
Promote energy efficiency locally.	✓		
Connect with neighboring communities.	✓		
Identify applicable incentives and application process.	✓		
Identify contractor(s) for EEM implementation.	✓		
Track EEMs.		✓	
Track progress.		✓	

Electrify Buildings

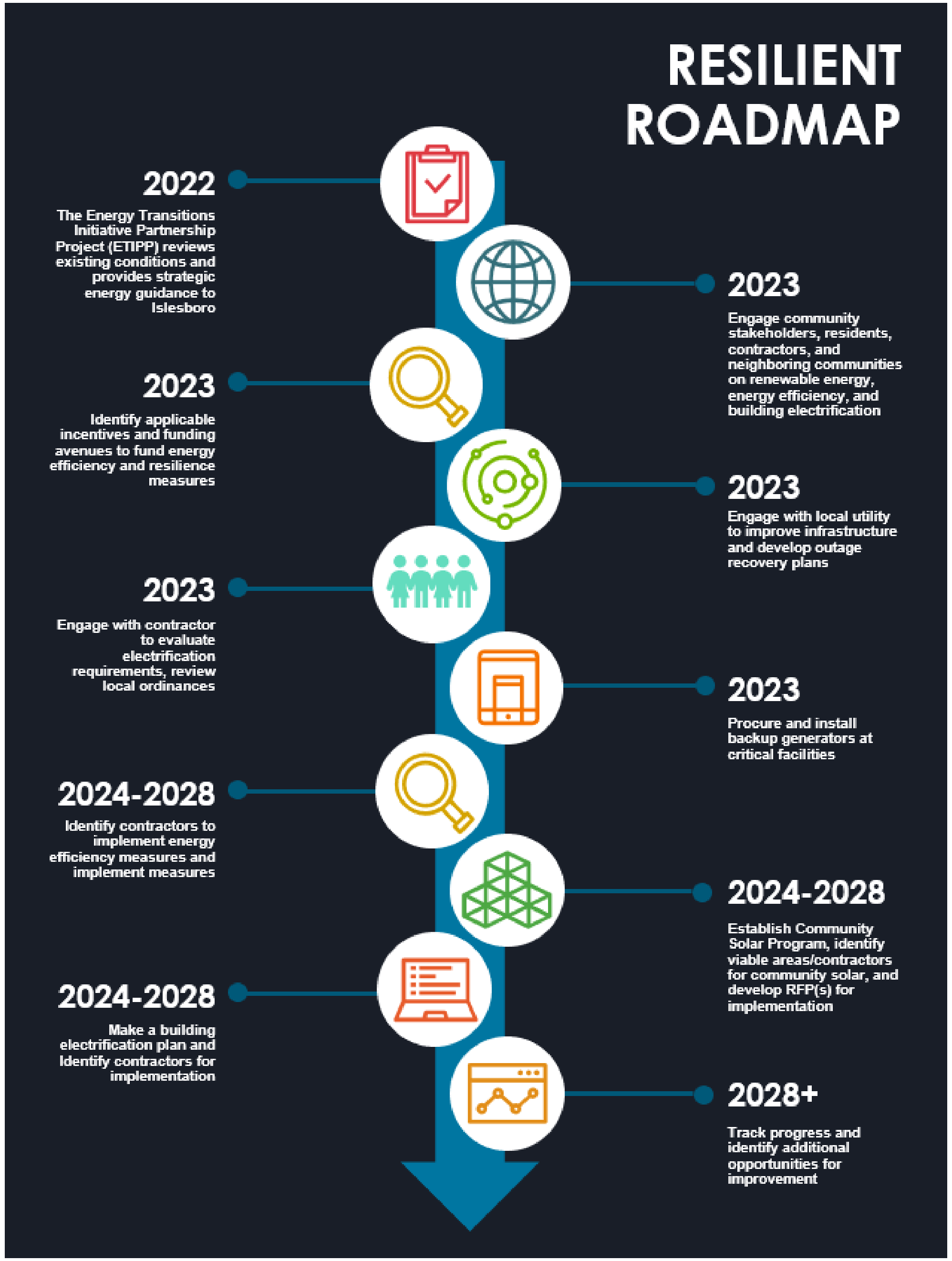
Action	Short-Term Priority (2023)	Medium-Term Priority (2024-2028)	Long-Term Priority (2028+)
Engage a contractor to evaluate electrification requirements.	✓		
Identify contractors for building electrification.		✓	
Review local ordinances.	✓		
Make a plan for building electrification.		✓	
Implement and track progress.			✓

Increase On-Site Renewable Energy Generation

Action	Short-Term Priority (2023)	Medium-Term Priority (2024-2028)	Long-Term Priority (2028+)
Engage and educate community stakeholders on renewable energy.	✓		
Connect with neighboring communities to learn best practices.	✓		
Investigate the possibility of community solar projects.		✓	

Improve Infrastructure Conditions to Enhance Resilience

Action	Short-Term Priority (2023)	Medium-Term Priority (2024-2028)	Long-Term Priority (2028+)
Install permanent backup generators.		✓	
Procure mobile backup generators.		✓	
Install generator quick-connect panels.		✓	
Install dedicated generator fuel storage.		✓	
Engage with utility to add loops to distribution.	✓		
Procure dual-fueled equipment at end of life.		✓	
Explore placing generating asset at end of radial circuit.	✓		
Develop/exercise robust emergency outage recovery plan.	✓		
Engage with utility on distribution and transmission system maintenance.	✓		



RESILIENT ROADMAP
2022
The Energy Transitions Initiative Partnership Project (ETIPP) reviews existing conditions and provides strategic energy guidance to Islesboro
2023
Engage community stakeholders, residents, contractors, and neighboring communities on renewable energy, energy efficiency, and building electrification
2023
Identify applicable incentives and funding avenues to fund energy efficiency and resilience measures
2023
Engage with local utility to improve infrastructure and develop outage recovery plans
2023
Engage with contractor to evaluate electrification requirements, review local ordinances
2023
Procure and install backup generators at critical facilities
2024-2028
Identify contractors to implement energy efficiency measures and implement measures
2024-2028
Establish Community Solar Program, identify viable areas/contractors for community solar, and develop RFP(s) for implementation
2024-2028
Make a building electrification plan and Identify contractors for implementation
2028+
Track progress and identify additional opportunities for improvement

Acronyms and Glossary

Acronyms

- CMP: Central Maine Power
- CO_2: Carbon dioxide
- EEM: Energy Efficiency Measures
- ETIPP: Energy Transitions Initiative Partnership Project
- HOMER: Hybrid Optimization Model for Electric Renewables
- IEC: Islesboro Energy Committee
- LCOE: Levelized cost of energy
- NREL: National Renewable Energy Laboratory
- PNNL: Pacific Northwest National Laboratory
- PV: Photovoltaic

Glossary

- **Distributed Energy Resource:** Small-scale energy resource, typically near where the energy is used. Examples include rooftop solar and storge.
- **Levelized Cost of Energy:** The price at which the generated electricity of a system should be sold for the system to break even at the end of its lifetime.
- **Load:** The amount of electrical power that users demand.
- **Microgrid:** Interconnected demand and distributed energy resources that act as a single controllable entity with respect to the grid. It can connect and disconnect from the grid to operate in grid-connected or island mode.

Thank You

This work was authored in part by the Pacific Northwest National Laboratory, Sandia National Laboratories, and 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, Energy Transitions Initiative, Geothermal Technologies Office, Solar Energy Technologies Office, Water Power Technologies Office, and Wind 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.

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525. **SAND2023-03039PE**