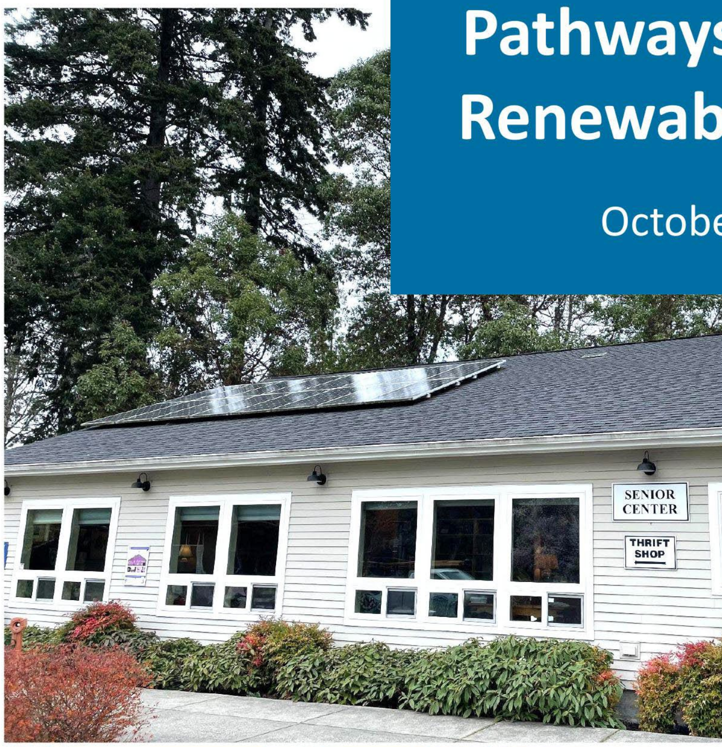
ENERGY TRANSITIONS INITIATIVE

U.S. Department of Energy

Bainbridge Island

Pathways to 100% Renewable Energy

October 2024



Energy Transitions Initiative Partnership Project: Bainbridge Island, Washington

Cohort 2 Technical Assistance: Pathways to 100% Renewable Energy

October 2024

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Table of Contents

The Energy Transitions Initiative leverages the experiences of islands, states, and cities that have established a long-term vision for energy transformation and are successfully implementing energy efficiency and renewable energy projects to achieve established clean energy goals. Through the initiative, the U.S. Department of Energy and its partners provide government entities and other stakeholders with a proven framework, objective guidance, and technical tools and resources for transitioning to a clean energy system/economy that relies on local resources to substantially reduce reliance on fossil fuels.

Figures

Tables

Acronyms

AC	alternating current
CAP	Climate Action Plan
CCAC	Climate Change Advisory Committee
COBI	City of Bainbridge Island
DC	direct current
DOE	U.S. Department of Energy
ETIPP	Energy Transitions Initiative Partnership Program
EV	electric vehicle
GHG	greenhouse gas
ITC	Investment Tax Credit
IRA	Inflation Reduction Act
NOAA	National Oceanographic and Atmospheric Administration
NREL	National Renewable Energy Laboratory
O&M	operations and maintenance
PNNL	Pacific Northwest National Laboratory
PSE	Puget Sound Energy
PV	photovoltaic
WTE	waste to energy

Executive Summary

Bainbridge Island aims to achieve 100% renewable electricity generation by 2040,[1] 5 years ahead of the Washington State goal, and increase its energy resilience in the face of natural disasters. To help address these goals, the City of Bainbridge Island (COBI) applied for and received technical assistance from the Energy Transitions Initiative Partnership Program (ETIPP) from 2022–2024. Supported by the U.S. Department of Energy (DOE), ETIPP provides technical assistance to remote coastal and island communities interested in approaches to renewable and resilient energy transitions. Pacific Northwest National Laboratory (PNNL) served as the technical lead for the ETIPP team, working in close collaboration with COBI, Spark Northwest, and the National Renewable Energy Laboratory (NREL).

The overarching goals of the technical assistance were: (1) to explore pathways for achieving 100% renewable energy through adoption of different technologies and programs; and (2) to assess the vulnerability of critical infrastructure and identify strategies for increasing energy resilience (Figure ES- 1). This report documents the goals, approach, and results for the pathways analysis. A separate report documents the resilience analysis (Rose et al. 2024), though it is important to note that local renewable energy generation can increase overall resilience.

The analysis of pathways for achieving 100% renewable energy involved collaboration among members of the ETIPP team and engagement with COBI partners, projection of future electric loads, and development and analysis of "pathways" for meeting future loads. We considered several technologies of interest to the Bainbridge Island community, including solar (rooftop, ground-mount, and carport[2]), anaerobic biodigestion for converting waste to energy, distributed wind, and marine energy. Various combinations of these technologies were explored through development and analysis of five pathways that describe different approaches that COBI could take toward achieving the 100% renewable energy by 2040 goal (Figure E1). The ETIPP team worked with public agencies and organizations on the Island throughout the technical assistance to incorporate input from various City departments, the Climate Change Advisory Committee, the Utilities Advisory Committee, public and private landowners, and Puget Sound Energy (PSE) in each stage of the analysis.

According to data from PSE for 2022, the current annual electric load for Bainbridge Island is 264,566 MWh. If the island adopts a more ambitious approach to climate action, the demand for electric sources of energy may increase by more than a third, to over 300,000 MWh annually in 2040. This electric load is higher than the 2022 load, even when accounting for ambitious energy efficiency measures, due to significant electrification planned by converting to electric heat pumps, electric vehicles (EVs), and electric ferry charging to reduce greenhouse gas (GHG) emissions.

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[1] For more information, see https://www.bainbridgewa.gov/1331/Climate-Action

[2] Rooftop solar includes all photovoltaic (PV) panels mounted to a building roof, whether residential or commercial. Ground-mounted solar is typically installed at the community scale in large, open spaces and can be fixed-tilt or axis-tracking. Carport solar is also typically community scale and includes all PV panels installed over parking areas on already-existing or added support structures.

Figure ES- 1. Description of pathways includes on-island energy generation from solar, small-scale wind, and marine energy technologies and off-island energy generation purchased from PSE Green Power,[3] Solar Choice,[4] or Community Solar.[5] Graphic created by PNNL Communications.

Analysis of the five pathways and associated renewable energy technologies demonstrates that rooftop solar has the greatest energy generation potential of the six energy technologies and that Pathway 2: Community-Led Solar is the most promising pathway for increasing on-island renewable energy generation (Figure ES- 2). Solar energy technologies and pathways are also the least costly per kW of electricity (Table ES- 1).

[3] For more information, see https://www.pse.com/en/green-options/Renewable-Energy-Programs/green-power.
[4] For more information, see https://www.pse.com/en/green-options/Renewable-Energy-Programs/solar-choice.
[5] For more information, see https://www.pse.com/en/green-options/Renewable-Energy-Programs/Community-Solar.

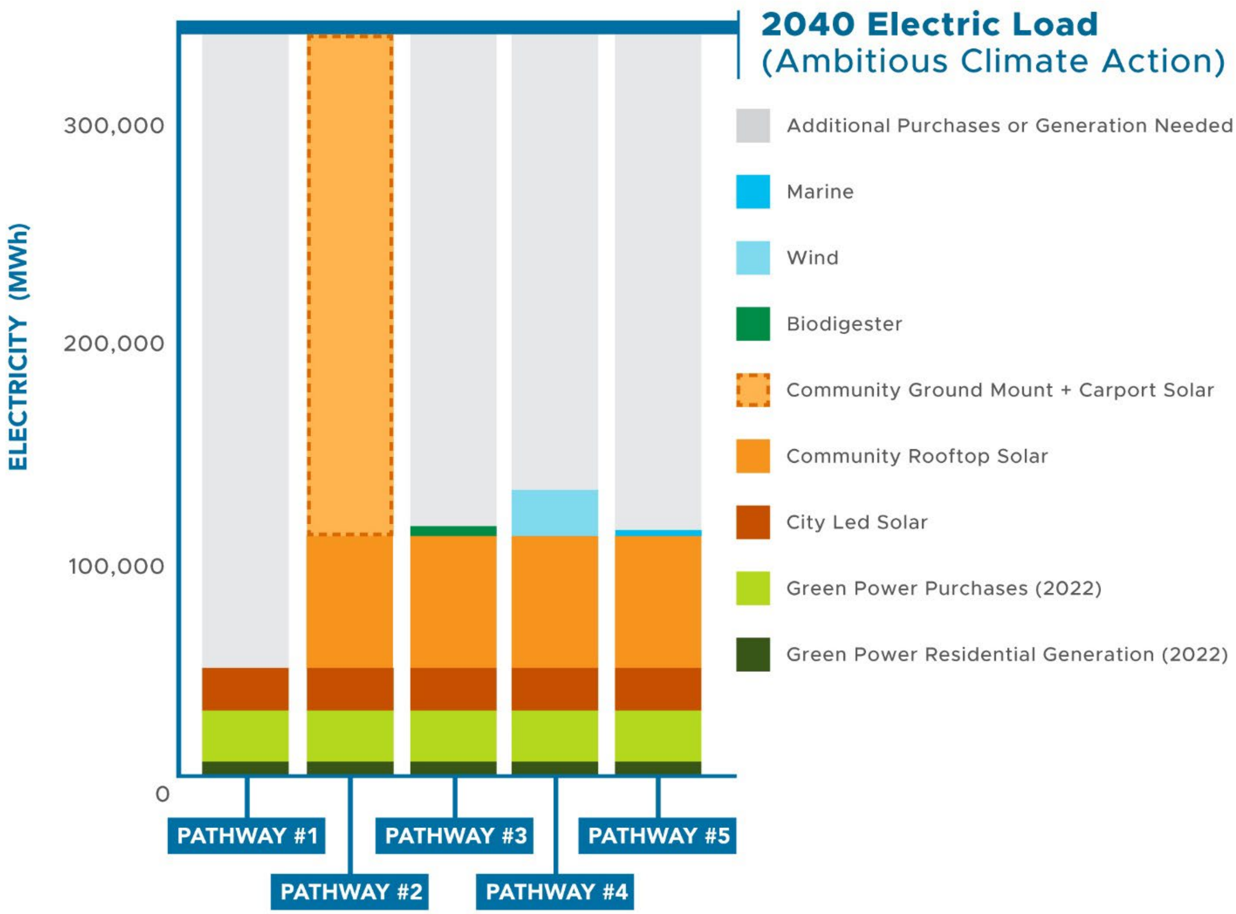

Figure ES- 2. Contributions of each pathway to 2040 energy consumption on Bainbridge Island. Pathway #1 includes from current purchases and rooftop, ground-mount, and carport locations listed in Appendix A. Pathway #2 includes current purchases and Pathway #1 solar plus all residential and commercial rooftops on the island, as well as a scalable amount of ground-mount and carport solar. Pathway #3 includes current purchases and Pathway #1 solar, rooftop solar from Pathway #2, and an anaerobic biodigester. Pathway #4 includes current purchases and Pathway #1 solar, rooftop solar from Pathway #2, and three 2-MW wind turbines. Pathway #5 includes current purchases and Pathway #1 solar, rooftop solar from Pathway #2, and one tidal energy device. Graphic created by PNNL Communications.

Table ES- 1. Summary of Technology Contributions to Bainbridge Electricity and Estimated Costs

TECHNOLOGY

	Rooftop Solar	Ground-mount Solar	Carport Solar	Biodigester	Wind	Marine
Potential Generation (MWh)	**82,500** *Pathways 1 & 2*	**7,200** *Pathway 1*	**3,300** *Pathway 1*	**3,500** *Impact Bioenergy 2017 estimate**	**16,000** *One 2-MW turbine each at three sites*	**130** *One turbine*
Estimated % of Bainbridge 2040 Load under Ambitious Climate Action	**25.4%**	**2.3%** *Potentially scalable with Pathway 2*	**1.0%** *Potentially scalable with Pathway 2*	**1.1%**	**4.8%**	**0.05%**
Technology Cost Estimate (USD 2023)	Residential: **$2,682/kW** Community: **$1,761/kW** *Source: Ramasamy et al. 2023*	**$1,161/kW** *Source: Ramasamy et al. 2023*	**$2,760/kW** *Source: Wood Mackenzie 2023*	**$61,600 - $93,800 per ton of waste**** *Source: Xiao et al. 2022*	Small distributed: **$7,850/kW** Midsize distributed: **$3,333/kW** *Source: Orrell et al. 2023*	**~$6,500 - $26,000/kW** Few commercial technologies, but significant government funding likely available *Source: OES Report 2015*

*** Rounded Impact Bioenergy estimate from 3,485 to 3,500 to display fewer significant digits, which is more consistent with the other potential generation estimates**

**** The cost estimate for the biodigester is not able to be converted to $/kW due to the high variability in the energy output depending on the waste composition**

Based on technical analysis and discussions with the Bainbridge Island community during site visits, the pathways that focus on solar were identified as the priority resource for the City to pursue. However, even with aggressive plans to implement multiple solar technology types with a variety of local partners, it is unlikely that the entire future electric load on Bainbridge will be met with on-island renewable energy generation. Approaching the goal will require identification of large sites for ground-mounted or carport solar, likely as part of a PSE Community Solar project, as well as developing as many residential and commercial rooftops as possible. Purchases of Green Power or other off-island renewable generation will likely be needed to meet the goal of 100% renewable energy generation by 2040.

Other renewable energy technologies provide smaller amounts of power that could be used to meet specific loads on Bainbridge Island and provide alternative sources of energy during times of year when solar generation is limited. These additional sources are unlikely to play a large part in helping Bainbridge Island achieve its 100% renewable energy generation goal; however, several steps can be taken by the City and community partners to pursue these options over the longer term. To move forward with an anaerobic biodigester, a detailed waste characterization study needs to be conducted. Such a study will help the City and community partners better understand the amount of electricity that could be generated and to site a project in a location that makes sense for waste transport as well as electric consumption. There is sufficient wind energy on the island to pursue several distributed wind projects for specific loads, but due to tree cover, sites are limited and would need to be identified and confirmed with on-site measurements. Specific loads would also need to be identified through collaboration with potential end users of the electricity. Generation of tidal energy is possible in Agate Passage, but our analysis using assumptions for a single generic tidal turbine suggests that tidal energy would not generate significant amounts of power. The available marine energy technologies are a long way from being ready to meet grid loads, though it is likely worth revisiting in the future as the technology improves and additional funding or research opportunities become available.

Next steps include engaging in various efforts to advance on-island solar pathways. This could include beginning to install solar on the remaining suitable City facilities; development of educational materials or outreach to residents, business owners, and the community around solar technologies or renewable power purchases; and continuing to partner with PSE on identifying and developing Community Solar projects on-island. Reaching 100% renewable energy generation on Bainbridge Island by 2040 is an ambitious goal, and it will take significant near-term investments in technology (primarily solar) and outreach to be able to approach it.

KEY TAKEAWAYS

NONE of the pathways identified, alone or combined, can achieve 100% of the electricity generation needed at present or in 2040 with on-island renewable energy alone.

Electric demand is likely to increase on Bainbridge Island, even considering aggressive energy efficiency measures, due to additional electrification (e.g., heat pumps, electric vehicles). Efficiency programs and actions are recommended to bring down the total consumption of electricity, though are not enough on their own to offset growing demand.

Solar Energy:

Solar energy (rooftop, ground-mount, and carport) is the most scalable, affordable, and near-term renewable energy option on-island for meeting Bainbridge Island's future electrical energy demand. There are numerous opportunities to develop smaller-scale solar projects in collaboration with public and private property owners and a limited number of opportunities for large-scale solar development on the island.

OTHER renewable energy options could provide smaller amounts of power that could help meet key loads, but are not likely to significantly contribute to meeting the 100% renewable energy goal for the Island in the near term.

Marine Energy:

Tidal energy is possible, but is a long way out from commercial viability and the potential site in Agate Passage would likely generate very small amounts of power at a very high cost.

Waste-to-Energy:

To move forward with an anaerobic biodigester, a waste characterization study needs to be conducted. Although the value of the electricity would be minimal, a biodigester could provide other benefits such as waste management and a source of local fertilizer.

Wind Energy:

A small distributed wind project will be most useful in an area of high relative wind resource that is adjacent to and can directly offset a specific energy load. Once a site and load are selected, the next step is to conduct a site study to assess tree cover and collect wind energy measurements.

NEXT STEPS for the City of Bainbridge Island could include:

- **Continue** to make progress on 120kW publicly hosted solar site as part of the carbon offset associated with the new Ted Spearman Justice Center.
- **Partner** with PSE and others in the community to maximize the installation of solar at public and private facilities on the island. This could include a Community Solar project (see Appendix A), but most locations analyzed are too small to qualify.
- **Explore** installing solar on the remaining suitable City facilities: the Operations and Maintenance Yard rooftop, the existing Police building, and the new Ted Spearman Justice Center parking lot.
- **Develop** educational materials and conduct outreach to promote renewable energy technologies and programs to the community to encourage more on-island renewable energy projects.

Introduction

Bainbridge Island aims to achieve 100% renewable electricity generation by 2040, 5 years ahead of the Washington State goal, and to increase its resiliency in the face of natural disasters. To help address these goals, the City of Bainbridge Island (COBI) applied for and received technical assistance from the Energy Transitions Initiative Partnership Program (ETIPP) from 2022–2024. Supported by the U.S. Department of Energy (DOE), ETIPP provides technical assistance to remote coastal and island communities interested in approaches to renewable and resilient energy transitions. The program is community-driven and leverages local partner networks and national laboratories to provide technical assistance tailored to the specific energy needs and challenges of a particular community. The Bainbridge Island ETIPP project is led by Pacific Northwest National Laboratory (PNNL)[6] with administrative support from the National Renewable Energy Laboratory (NREL)[7] and regional nonprofit partner Spark Northwest.[8]

Bainbridge Island is an incorporated island city in the Puget Sound region of western Washington, located adjacent to the Kitsap Peninsula, about 7 miles west of Seattle in Kitsap County. Bainbridge Island has an area of 26 square miles, with 52 miles of shoreline, dense forests, mostly rural development patterns, and an estimated population of 25,000. One bridge connects Bainbridge Island to the Kitsap Peninsula at the north end of the island at Agate Passage, and a single ferry route connects the downtown area to Seattle. As a result, the island has limited means for evacuation or access during emergencies.

Electricity is a main focus on Bainbridge Island, as there is no natural gas on the island. Current energy sources include electricity provided by Puget Sound Energy (PSE), the local utility, via a single transmission line at Agate Passage; carbon-intensive fuels such as propane and gasoline; wood stoves for some residential heating; and a few rooftop solar projects on residential, commercial, and public buildings. PSE's 2020 fuel mix comes primarily from nonrenewable sources such as natural gas and coal (Table 1) (PSE 2023). However, Washington's Energy Independence Act requires PSE to meet a renewable portfolio standard as a percentage of customer load.[9] The current target is 15%, which PSE is meeting through incremental hydropower efficiency upgrades, eligible wind, and biomass. By 2045, PSE electricity will need to be free of greenhouse gas (GHG) emissions or 100% renewable under the Washington Clean Energy Transformation Act.[10] As such, some of the electricity provided to Bainbridge Island by PSE, both now and increasingly into the future, comes from renewable sources, but none is locally generated.

[6] For more information, see https://www.pnnl.gov/projects/ETIPP/communities.

[7] For more information, see https://www.nrel.gov/state-local-tribal/etipp-technical-assistance.html.

[8] For more information, see https://sparknorthwest.org/.

[9] For more information on the Energy Independence Act (I-937), see https://www.commerce.wa.gov/growing-the-economy/energy/energy-independence-act/.

[10] For more information on the Clean Energy Transformation Act, see https://www.commerce.wa.gov/growing-the-economy/energy/ceta/.

Table 1. 2020 PSE Fuel Mix

Fuel	Percentage
Coal	23%
Hydroelectric	24%
Natural Gas	27%
Nuclear	<1%
Other (biomass, non-biogenic and petroleum)	1%
Solar	1%
Unspecified	14%
Wind	9%

Bainbridge Island's 2019 GHG inventory identified energy generation as contributing 55% of overall GHG emissions on the island (COBI 2019). The Climate Action Plan (CAP) was developed to help reduce these GHG emissions by 90% by 2045, inspire community action and partnership for additional climate mitigation and adaptation measures, and serve as the main driver for climate action on Bainbridge Island (COBI 2020). The Climate Change Advisory Committee (CCAC)[11] was a key leader in developing the CAP as well as supporting the Bainbridge ETIPP application. The City is active in involving the community and CCAC in various programs to implement the CAP, including Climate Smart Bainbridge[12], energy efficiency efforts, and other activities described on their Climate Action webpage.[13] According to the 2022 CAP Progress Report, existing City facilities are powered by 100% Green Power (91% wind and 9% biogas) under an existing PSE program (Climate Smart Bainbridge 2022). There is additional interest in generating renewable energy on-island for all consumers to meet the goal of 100% renewable by 2040.

This report begins by describing the approach to technical assistance in the ETIPP project, followed by the development of future scenarios for electricity demand based on current use. Potential pathways to 100% renewable energy are identified and analyzed by technology contributions from solar energy, anaerobic biodigestion, distributed wind, and marine energy. The combinations of these technologies and contributions to meet demand are discussed, along with potential policies and programs for implementation of the most relevant technologies moving forward. The report concludes with recommendations for next steps for the City to meet the goal of 100% renewable energy generation by 2040 on- and off-island and key caveats to consider.

[11] For more information about the committee, see https://www.bainbridgewa.gov/922/Climate-Change-Advisory-Committee.
[12] For more information about the Climate Smart program, see https://www.climatesmartbainbridge.org/.
[13] For more information about Climate Action on Bainbridge, see https://www.bainbridgewa.gov/1331/Climate-Action

The second goal of increasing energy resilience is discussed in Rose et al. (2024), though it is important to note that local renewable energy generation can increase overall resilience.

Approach to Technical Assistance

PNNL completed the technical analysis aspects of the project, supported by the community partner Spark Northwest and the program administrator, NREL. All partners met on a biweekly basis with the community lead from COBI, with additional technical experts or community representatives invited as relevant. Prior to selection of PNNL as the technical lead, NREL and Spark Northwest met with the City in-person in August and September 2022 for ETIPP onboarding activities. The ETIPP team conducted several activities throughout the project that involved the community, including:

- A scoping phase that included participation of a wide variety of community partners across several virtual meetings, including Bainbridge Island School District, Bainbridge Prepares, Bainbridge Island Fire Department, Bainbridge Island Parks & Recreation, the Climate Change Advisory Committee, Kitsap County Sewer District #7, PSE, the Utilities Advisory Committee, Washington State Ferries, and Washington State Department of Transportation
- A virtual community kickoff meeting[14]
- In-person site visits in May 2023 and September 2023 to present preliminary results and solicit feedback
- A presentation of the results of the analysis at the November 2023 Climate Change Advisory Committee meeting.

Input from the city and community partners was integrated throughout each step of the technical analysis (Figure 1). The technical analysis included a collection of information to project the future electric load that Bainbridge will be experiencing in 2040, as well as assessment of the potential technology contributions to meeting that load from solar (rooftop, ground-mount, and carport), an anaerobic biodigester to convert waste to energy (WTE), distributed wind, and marine energy. These technologies and various combinations were explored through the development of pathways or scenarios to describe approaches that COBI could take toward meeting their 2040 goal of 100% renewable electricity.

[14] A recording of the virtual kickoff meeting is available at https://www.youtube.com/watch?v=jpTxKe5412Q.

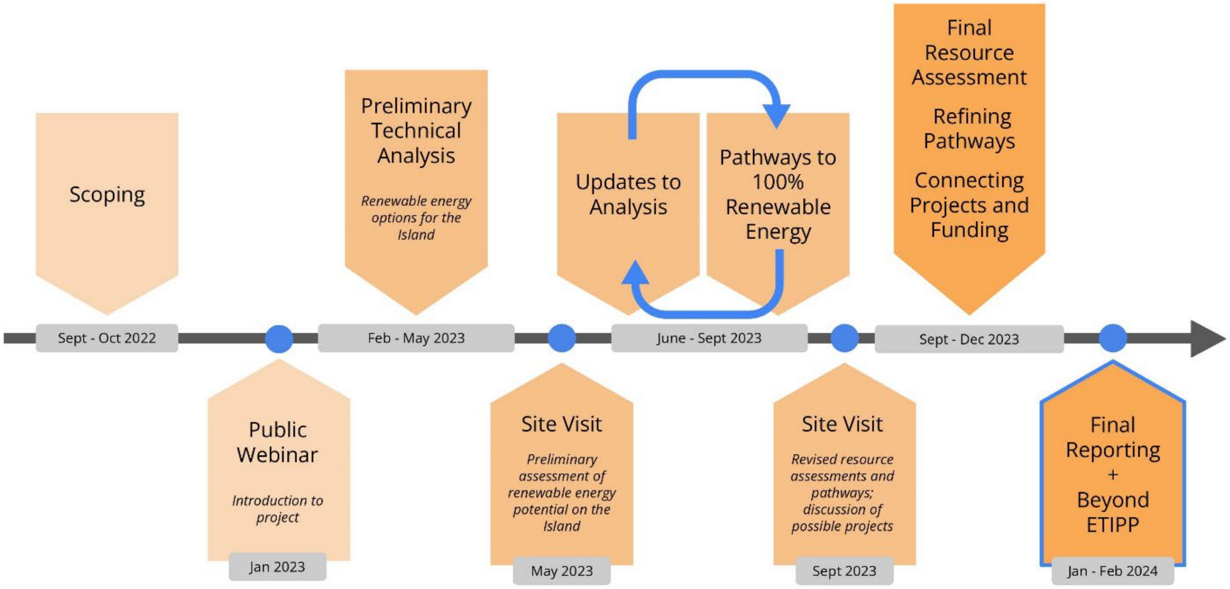

Figure 1. Timeline of technical assistance provided for the ETIPP Bainbridge project

Future Loads on Bainbridge

To predict future loads, we gathered data on current energy use on Bainbridge Island, identified factors that may influence electricity demand in 2040, and developed a range of scenarios to explore potential variation in this demand. The following section outlines our methods and results for each of these steps. The estimates of energy use for 2040 can help the City determine whether electricity demand is likely to increase or decrease in the future, and what kinds of policies and interventions may influence variation in demand.

To understand current electricity use on Bainbridge Island, PSE provided the ETIPP team with load information for the island's three substations: Port Madison, Murden Cove, and Winslow. The data were available in 15-minute intervals for 2022. The total annual electricity consumption for 2022 was 264,566 MWh with a peak load of 86 MW in December. The monthly electricity consumption and peak electricity demand varies seasonally, with approximately double the energy use in the winter than the summer months (Figure 2) due to heating demand.

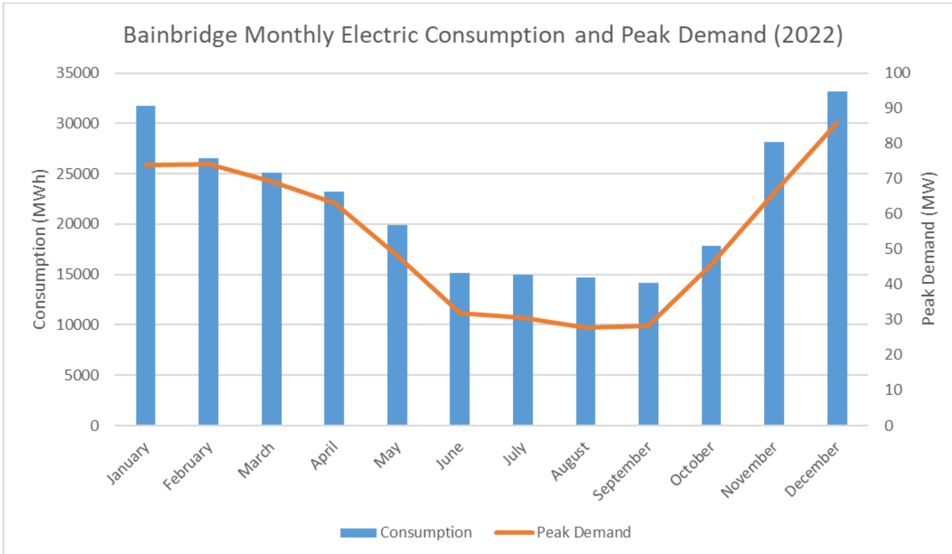

Figure 2. Bainbridge monthly electric consumption (MWh) and peak demand (MW) in 2022 (data from PSE)

Based on conversations with the City and community partners, we considered three factors that may influence energy demand: realistic population growth, energy efficiency, and electrification. We then made assumptions about how these factors may differ under three different scenarios for 2040.

1. Business as Usual: only assumes population growth.
2. Moderate Climate Action: assumes population growth, ferry electrification, 50% adoption of electric vehicles (EVs) by 2045; 25% adoption of heat pumps for space heating/cooling and water heating by 2040; and 8% additional electric efficiency by 2040.
3. Ambitious Climate Action: assumes population growth, ferry electrification, 80% adoption of EVs by 2045; 75% adoption of heat pumps for space heating/cooling and water heating by 2040; and 14% additional electric efficiency by 2040.

The scenarios are an attempt to capture realistic future conditions, rather than theoretical maximum or minimum future demand. We did not attempt to predict major future changes in technologies. We assumed linear change, except for the addition of ferry electrification estimated to occur in 2026.

These scenarios predict a 13%–35% increase in electricity use from the present (Figure 3), with both the Moderate and Ambitious Climate scenarios leading to more than twice the electric demand than the Business-as-Usual scenario. Nine percent of the increase in the Moderate and Ambitious Climate Action scenarios is due to ferry electrification.

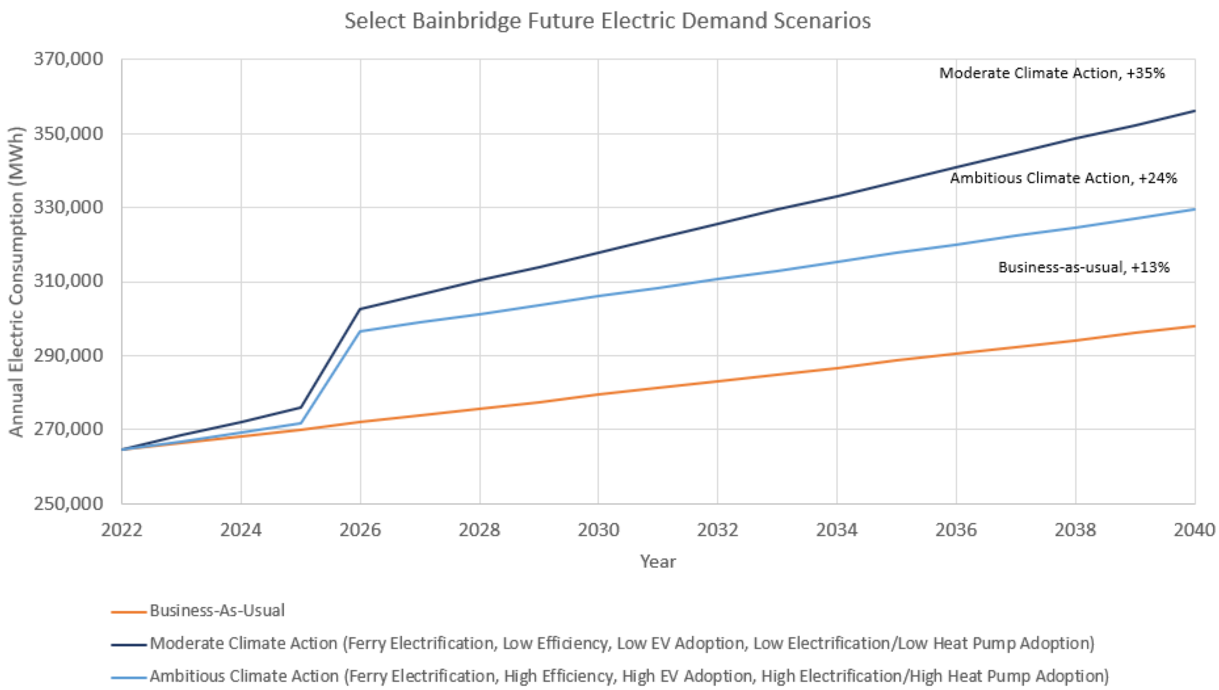

Figure 3. Projected future electricity loads on Bainbridge Island, based on information from PSE, further electrification, and efficiency plans

The Ambitious Climate Action scenario is associated with a smaller increase in electricity use than the Moderate Climate Action scenario. This is because the increased electricity use due to additional EV adoption is offset by decreased electricity use associated with replacing existing electric resistance heaters with more efficient heat pumps (see Figure 4 for breakdown of contributions to the projected load).

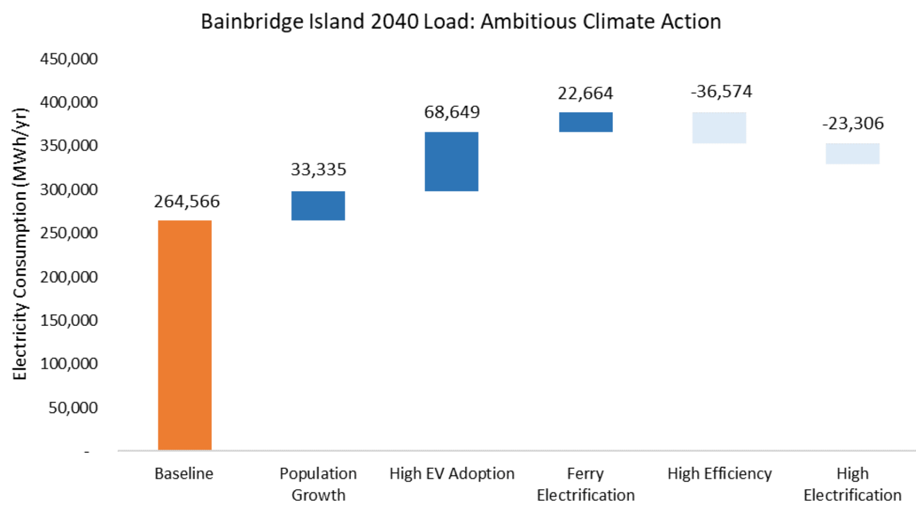

Figure 4. Breakdown of the Ambitious Climate Action scenario for 2024, showing effects that increase the future load (electrification in dark blue) and decrease the future load (efficiency in light blue)

Based on Bainbridge's goals, we only evaluated electricity demand and did not include an analysis of other fuels. While electrifying buildings and vehicles increases electricity demand, it is important to note that other fuel use will decrease. If electricity is carbon-free, or has a lower emissions rate than other fuels, this also reduces carbon dioxide and other GHG emissions and air pollutants, in alignment with the CAP.

Assumptions

In order to build these scenarios, we made a few key assumptions concerning population growth, ferry electrification, EV adoption, and building electrification (including electric heat pumps).

- The population of Bainbridge Island is expected to increase at a rate of approximately 0.7% annually (COBI 2017a; COBI 2017b). Electricity demand is estimated to increase approximately proportional to population.
- Ferry electrification demand was estimated based on the Washington State Department of Transportation's Ferry System Electrification Plan (WSDOT 2021). We assumed that the ferry charges equally at the Bainbridge and Seattle terminals. Ferry electrification is on track to start charging on Bainbridge in 2026 (WSDOT n.d.).
- Bainbridge provided current EV registration numbers. As of 2023, 908 battery EVs and 343 plug-in hybrid EVs were registered on the island, an estimated 5% of the current passenger vehicles. We assumed 0.94 vehicles per person that travel an average of 30 miles per day (Caporal 2024). We assumed that a typical EV that travels 30 miles per day uses 11.81 kWh of electricity (EVBox n.d.). Bainbridge has a goal to achieve 80% electric passenger vehicles by 2045. We scaled this linearly to estimate the number of EVs required in 2040 to meet this goal. For context, Washington State has a goal that all new light-duty vehicles sold, purchased, or registered must be electric by 2030.
- Building electrification encompasses any change from using fuels to electricity in buildings. This is dominated by space and water heating. Heat pumps are the most efficient method of providing heat with electricity; by design, heat pumps for space heating also add air conditioning.[15] Therefore, we evaluated the change in electric demand from non-electric or less-efficient electric space and water heating and no air conditioning or standard air conditioners to heat pumps. Based on Census heating fuel data (U.S. Census n.d.), Washington heat pump data (Weinberger 2022), and a recent COBI heat pump survey, we estimated that Bainbridge's current residential heating distribution is 25% non-electric, 60% electric resistance, and 15% heat pumps; cooling is 50% none, 35% standard air conditioners, and 15% heat pumps; and water heating is 20% non-electric, 80% electric resistance, and 0% heat pump water heaters. We modeled the change in electricity demand from this baseline to the scenarios described above based on typical home values for Bainbridge and the Pacific Northwest region using Census data and the Residential Energy Consumption Survey (EIA n.d.) with the PNNL Facility Energy Decision System modeling tool.[16] We did not have sufficient information on

[15] https://www.energy.gov/energysaver/heat-pump-systems
[16] See https://feds.pnnl.gov/.

commercial buildings to estimate existing or potential heat pump installations. PSE reported that commercial buildings represent 13% of customers and 37% of electric load (COBI 2017a).

We consider the 2040 goal of meeting future loads with renewable energy fulfilled when the total annual renewable energy generation on-island combined with off-island purchased power matches the total annual electric demand. This does not mean that every electron consumed on the island at any time is from a renewable generation source, but rather that the electricity generated by renewables and consumed over the course of the year nets out to zero. This allows for accounting of seasonal resources (such as solar) and seasonal consumption (such as heating) and limits the amount of overbuilding and massive amounts of storage that a community would need to meet the instantaneous load at all times with distributed renewables.

Pathways to 100% Renewable Energy

Current electricity provided by PSE to Bainbridge Island is from a mix of renewable and nonrenewable sources (Table 1). PSE's electricity is required to become more renewable over time under Washington's Clean Energy Transformation Act[17] and emission-free by 2045. In order to meet the projected electric load increases by 2040 with 100% renewable energy, we identified and analyzed several different pathways that include various renewable energy technologies for on-island generation that are based on the interests of Bainbridge Island community members, and off-island purchases through PSE Green Power,[18] Solar Choice,[19] or Community Solar[20] programs.

First, we assessed the preliminary technical feasibility and potential amount of energy that could be generated by solar, an anaerobic biodigester, wind, and marine energy at an island-wide scale and seasonally. Then, we developed pathways that leverage and combine different renewable technologies with the aim of supporting 100% of the 2040 electric load under the Ambitious Climate Action future scenario. Finally, we analyzed the pathways to determine their potential for actually meeting the Bainbridge Island goal. These pathways are considered storylines or scenarios that describe a possible future, are usually plausible approaches to implementation, and reflect important choices that need to be made moving forward to leverage a finite amount of capacity and resources. The pathways we selected are described below and were iteratively developed in partnership with the City to reflect community values and priorities.

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[17] For more information on the Clean Energy Transformation Act, see https://www.commerce.wa.gov/growing-the-economy/energy/ceta/.
[18] For more information, see https://www.pse.com/en/green-options/Renewable-Energy-Programs/green-power.
[19] For more information, see https://www.pse.com/en/green-options/Renewable-Energy-Programs/solar-choice.
[20] For more information, see https://www.pse.com/en/green-options/Renewable-Energy-Programs/Community-Solar.

- *Pathway #1: City-led solar on-island*
  All reasonable City properties are developed for solar (rooftop, ground-mount, carport). Then, the City shares lessons learned, sparks interest, explores incentive programs, etc., to engage other nonresidential property owners to install solar.
- *Pathway #2: Community-led solar on-island*
  All reasonable public and private properties (residential and nonresidential) are developed for rooftop solar in the near term, as well as all properties from Pathway #1. The amount of remaining ground-mount and/or carport solar needed to meet 2040 loads is identified.
- *Pathway #3: Solar + biodigester + buy the rest*
  All reasonable Pathway #1 properties and all rooftops from Pathway #2 are developed for solar. An anaerobic biodigester of the size to match the existing Bainbridge waste stream is installed. Additional power needed to meet goals is purchased off-island from PSE Green Power, Solar Choice, or Community Solar if generation is not sufficient.
- *Pathway #4: Solar + wind + buy the rest*
  All reasonable Pathway #1 properties and all rooftops from Pathway #2 are developed for solar. The permitting process for three 2-MW wind turbines is started. Additional power needed to meet goals is purchased off-island from PSE Green Power, Solar Choice, or Community Solar until generation is sufficient.
- *Pathway #5: Solar + marine + buy the rest*
  All reasonable Pathway #1 properties and all rooftops from Pathway #2 are developed for solar. The permitting process for one marine energy converter is started. Additional power needed to meet goals is purchased off-island from PSE Green Power, Solar Choice, or Community Solar until generation is sufficient.

Key locations that align with each pathway were identified for further analysis in conversation with the City and other stakeholders during the September site visit and the November CCAC meeting. The technology contributions, including approach and findings for each pathway, are described in the following section and the combinations are summarized at the end.

Technology Contributions: Solar

Solar power, also known as solar energy, is a renewable source of electricity generated by harnessing the radiant energy emitted by the sun. Solar power is primarily generated through the use of PV solar panels, which convert sunlight into electricity. These panels consist of semiconductor materials that release electrons when exposed to sunlight, generating direct current (DC) that can be converted into alternating current (AC) for use in homes, businesses, and industries. Solar power can allow communities to generate their own electricity, reducing reliance on fossil fuels and utility providers, while lowering the GHG emissions associated with electricity generation.

Solar PV is installed in different size ranges. Residential rooftop PV capacity typically ranges between 5–20 kW. Community-scale PV can be installed on rooftops, carports (over parking lots), or be ground-mounted, and can range widely in capacity, from 20 kW to over 2 MW. Utility-scale projects have arrays that are either single-axis tracking (the array follows the sun as it travels across the sky to maximize energy production) or fixed axis, and tend to have capacities ranging from 1 MW to over 1 GW for the largest projects.

Operations and maintenance (O&M) for solar PV is relatively simple, especially for fixed-axis systems because they have no moving parts. O&M tasks include periodic cleaning of the modules, vegetation management, system inspection, and corrective maintenance.

Relying only on solar for electricity production can be challenging, due to the resource's inherent intermittency and variability. As a result, integrating other generation technologies, such as small-scale wind and battery storage, can help smooth out these fluctuations in electricity generation.

This report investigates seasonal variability in the island-wide solar resource and two pathways to achieving Bainbridge Island's 100% renewable energy goal by 2040: city-led solar and community-led solar. In both cases, the results should be used as guidance, as estimates are based on technical potential, not economic or market potential.

Solar Resource

Solar estimates for Bainbridge Island come from the NREL National Solar Radiation Database,[21] which contains decades of solar radiation data covering the United States and some international locations. The National Solar Radiation Database distills many years of radiation data into a single typical meteorological year, which is a year of hourly data that represents median weather conditions over many years and is used as a general estimate for a particular region. The PVWatts® calculator uses these data to estimate the energy production of more specific user-defined solar PV systems.[22]

Bainbridge Island has a solar resource that averages 4.0 kWh/m^2/day. This resource is seasonal; more solar energy is available during the summer and less during the winter when cloud cover is more frequent and days become shorter (Figure 5).

[21] For more information on the National Solar Radiation Database, see https://nsrdb.nrel.gov/.

[22] For more information on PVWatts, see https://pvwatts.nrel.gov/.

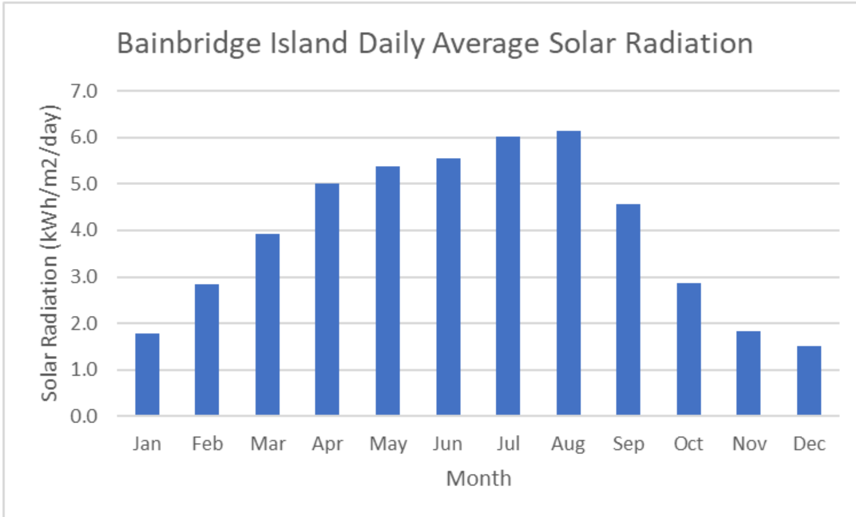


Figure 5. Monthly variation of solar radiation available on Bainbridge Island (from National Solar Radiation Database)

Existing Solar and Green Power Purchases

According to Bainbridge Island's 2022 Environmental Protection Agency Green Power Partnership Reporting Form, there is 3.5 MW_{DC} of existing on-island solar generation, from 379 interconnected residential customers, 38 interconnected commercial customers, and two City-owned accounts/facilities. In 2022, these generated 4,049 MWh. According to the same form, there were 24,435 MWh of green power retail purchases in 2022, through a combination of PSE's Green Power, Solar Choice, and Community Solar programs. Combined, the existing solar and Green Power purchases offset 8.6% of Bainbridge Island's projected 2040 electricity consumption based on the Ambitious Climate Action scenario.

Pathway 1: City-Led Solar

For this pathway, we assumed all reasonable City properties could be developed for solar (rooftop, ground-mount, carport). We then assume that the City shares lessons learned, sparks interest among community partners, explores incentive programs, and collaborates on projects to engage other nonresidential property owners to install solar with the aim of meeting Bainbridge Island's 100% renewable energy by 2040 goal.

To explore the potential for the City-led solar pathway to meet Bainbridge Island's 100% renewable energy goal, we compiled a list of properties through conversations with the City and discussions with the community during the first site visit. These properties include: City-owned buildings such as the O&M yard and police stations; other public entities like schools, fire stations, and parks; private for-profit businesses; and private nonprofit churches. A full list of these properties is available in Appendix A.

Each property was assessed using Google Maps satellite imagery to estimate available area for PV. This preliminary analysis made the following assumptions:

- Rooftop
    - Whole roof available for PV
    - Only included flat, south-, east-, and west-oriented roof area; assumed orientation was due south, east, west
    - Included small reduction or avoided mechanical equipment, sharp changes in roof angle, small outcrops
    - Does not include space between panels for existing equipment or maintenance access.
- Carport
    - Assumed installation over whole parking area
    - Measured only parking stalls or included reduction to account for space between stalls
    - All panels are oriented due south.
- Ground-mount
    - Assumed all ground area is available for solar
    - Assumed solar could be mounted everywhere
    - All panels are oriented due south.
- Did not avoid measuring shaded areas or include a shading loss factor.

Due to these assumptions, some areas we included in our analysis may not actually be appropriate for solar because of shading, existing mechanical equipment, or limits to which areas can fit rectangular panels. As such, our estimates for the area of rooftop available for solar should be considered as the upper limit. Next, we used NREL's PVWatts tool to estimate the technical potential for PV on each property. PVWatts estimates the electricity output of a PV system based on the location, available area, module and type, tilt angle, azimuth, and other user-defined inputs.

The results of our analysis suggest that developing all available properties could result in up to 19 MW_{DC} of PV capacity, which could generate up to 20,000 MWh/year, or 6.1% of Bainbridge Island's projected 2040 electricity consumption based on the Ambitious Climate Action scenario. Our estimates suggest the greatest contribution to 2040 demand could come from solar PV development on private for-profit and non-City-owned public entities (Table 2). Most of this solar PV development would be rooftop (9,500 MWh/year) followed by ground-mount (7,200 MWh/year) and carport (3,300 MWh/year) (Figure 6). A table containing estimated nameplate capacity PV for each property can be found in Appendix A.

Table 2. Summary of Properties in Pathway #1 by Ownership Type

Ownership	Properties	Number of Properties	DC System Size (MW)	Annual Electric Output (MWh/yr)	% of 2040 Ambitious Load
Other Public Entity	Schools, fire stations, recreation center, parks, ferry terminal parking lot	14	8.5	9,000	2.7%
Private For-Profit	Lynwood Center, downtown Winslow, Safeway, pavilion/movie theater, Copper Top, transfer station	8	8.5	9,000	2.7%
Private Non-Profit	Churches	3	1.4	1,500	0.5%
City-Owned	O&M yard, police stations	3	0.5	500	0.2%
	Total:	**28**	**18.9**	**20,000**	**6.1%**

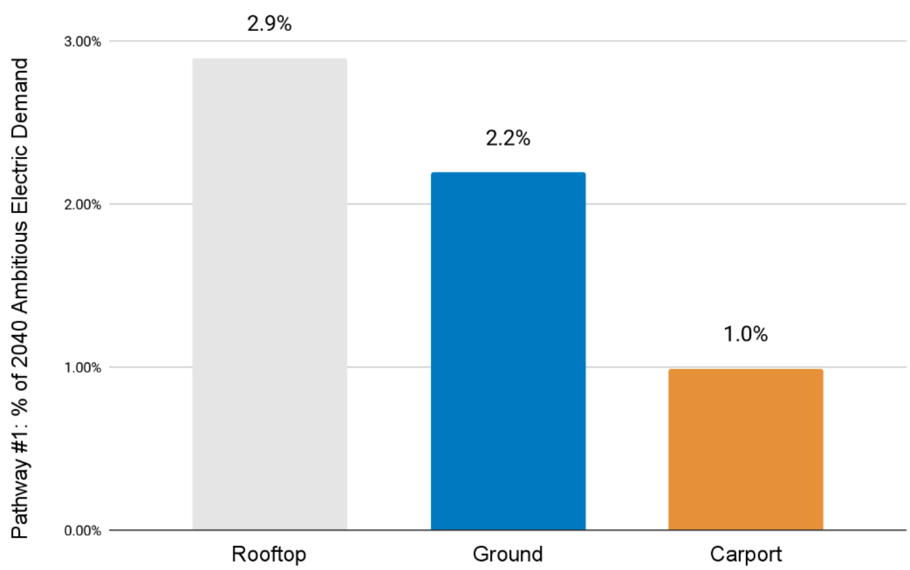


Figure 6. Percentage of 2040 load generated from Pathway #1 sites by solar technology type

Pathway 2: Community-Led Solar

For this pathway, we assumed that all reasonable public and private properties (residential and nonresidential) would be developed for solar (rooftop). For nonresidential solar, we used the estimates from the City-led solar pathway.

For residential solar, this pathway utilized existing studies that estimate rooftop potential based on satellite and LIDAR data. We used NREL's Rooftop Solar Photovoltaic Potential in the U.S. (Gagnon, Margolis, and Phillips 2019) to estimate rooftop PV based on building area from the American Community Survey (U.S. Census Bureau 2024) and Kitsap County tax data (Kitsap County n.d.). These results were validated by comparing them to Google's Project Sunroof.[23]

Our results suggest that developing all reasonable public and private rooftops (residential and nonresidential) could result in up to 82 MW_{DC} of PV capacity. This capacity could generate up to 73,000 MWh/year, or 18.1% of Bainbridge Island's projected 2040 electricity consumption based on the Ambitious Climate Action scenario.

Together, existing on-island solar, Pathway #1, and Pathway #2 could meet up to 25.4% of the 2040 demand. To meet the remaining demand with on-island solar, our results suggest Bainbridge Island would need to develop at least 226 MW_{DC} of ground-mount or carport PV (Figure 7). This would require developing at least 760 acres of ground-mount PV, or at least 554 acres of carport PV. Thus, if the aim is to meet Bainbridge Island's 2040 electricity demand with on-island solar, the city and public and private entities around the island will need to work together to develop all reasonable public and private rooftops on the island and hundreds of acres of ground-mount or carport PV.

[23] For more information on Google's Project Sunroof, see https://sunroof.withgoogle.com/.

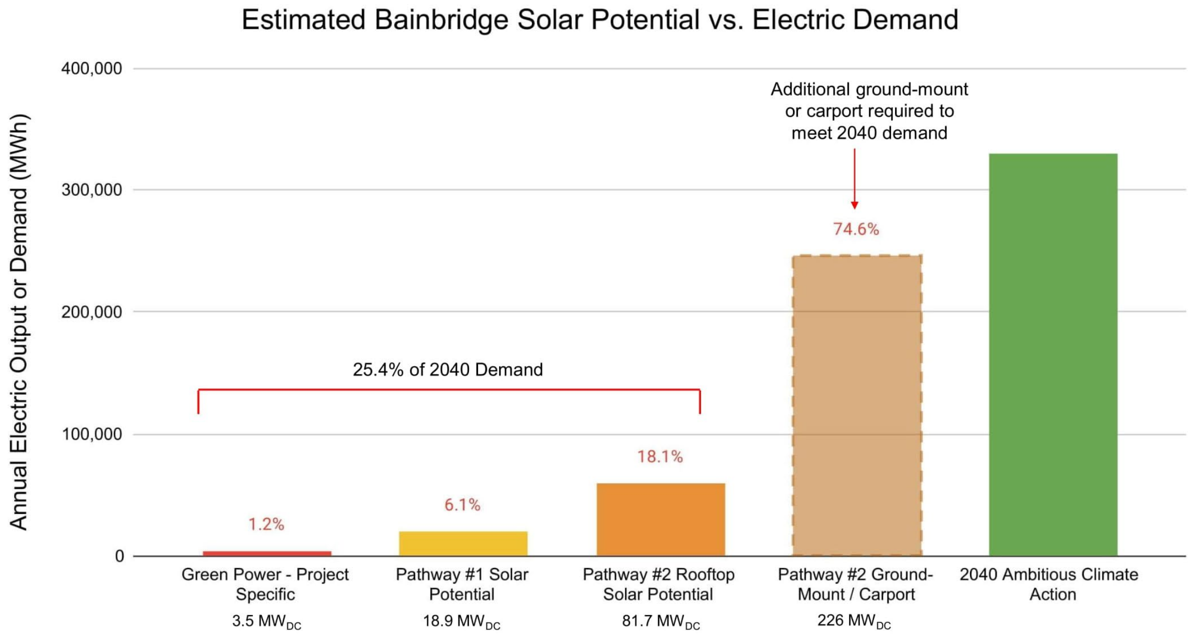


Figure 7. Existing solar and possibilities for Pathway #1 and Pathway #2 compared to current and future electric demand

Next Steps

Meeting Bainbridge Island's goals with on-island solar would require developing all reasonable public and private rooftops on the island as well as developing an additional minimum of 226 MW_{DC} of ground-mount or carport PV. To identify and prioritize these sites to pursue developing, it will be important to consider several factors:

- Capacity and scale of PV that can be installed: Larger arrays will be less expensive (per kW) to install.
    - Capital costs for installing solar PV typically range around $3,000/kW for residential rooftop solar, $2,000/kW for community fixed-tilt ground-mount solar, and $1,000/kW for utility-scale one-axis tracking ground-mounted solar (Ramasamy et al. 2021).
    - In 2020, the average levelized cost of utility-scale ground-mount PV ranged from $0.035 to $0.05 per kilowatt-hour, and was $0.12 per kilowatt-hour for residential PV (SETO 2021).
- Existing relationships with COBI: It is likely easier to work with locally owned and operated facilities or public agencies than to work with larger chains or national corporations.
- Proximity to existing infrastructure: The fewer electrical or structural updates that are needed to connect solar, the less installation costs will be incurred, especially for carport PV.

If sufficient space for Pathway #2 ground-mount or carport PV is not available on-island, 100% renewable energy will need to be procured through a combination of feasible on-island renewable generation and additional purchases from PSE.

The City could support residential and commercial rooftop solar with incentives or educational resources and continue to document successes with communications and outreach. This is already underway with the request for proposals released on January 4, 2024, for hosting a 120-kW solar project (rooftop, ground-mount, or carport) on a public agency property, funded by COBI as part of carbon offsets for the new Ted Spearman Justice Center (COBI 2024). The City could also continue working with PSE to evaluate additional sites for Community Solar projects. Until there is enough on-island generation to meet Bainbridge Island's goals, the City could supplement on-island generation with additional solar and Green Power purchases from PSE. A tracking system may need to be developed to measure progress toward the 2040 goal, with voluntary reporting of generation or enrollment of participating residents and commercial properties. The City will also need to keep working with PSE to understand and update annual power consumption on the island to ensure that the estimates for future load are matching reality. Additionally, COBI should continue to encourage adoption of energy efficiency measures, as decreasing energy consumption reduces the amount of on-island renewable energy generation needed to meet goals.

Technology Contributions: Biodigester

To support Bainbridge Island's goal of 100% renewable energy by 2040, PNNL assessed the feasibility of WTE using organic waste (biomass) as the primary feedstock. WTE is defined as energy recovery from waste by the conversion of nonrecyclable waste materials into usable heat, electricity, or fuel through a variety of processes; anaerobic digestion is a specific WTE process in which microorganisms breakdown organic material in the absence of oxygen, producing biogas and digestate (nutrient-rich solid/liquid mix). The biogas can be used to generate heat and/or power; some heat will be used internally for preheating the feedstock.

Approach

To begin the analysis, PNNL reviewed any previous studies that involved WTE on Bainbridge Island. The primary study is a PSE-funded effort prepared by Impact Bioenergy (2017) that was used as a baseline for anaerobic digestion on the island. The findings from the Impact Bioenergy study were compared to updated information and assumptions about feedstock availability, and deemed to be reasonable based on available information. Potential sources of waste used to validate the Impact Bioenergy assumptions were identified from a combination of commercial demographic research and community feedback.

The estimated amount of feedstock was then evaluated against assumptions for anaerobic digestion technology processing to determine potential outputs for Bainbridge Island. Different requirements such as scale, installation, waste type, and cost were considered to select the most relevant options. Further information was compiled through case studies and vendor-provided information from 10 different locations.

Findings

Impact Bioenergy evaluated anaerobic digestion opportunities in 2016 and 2017, and found that the total usable amount of waste on Bainbridge Island was 8,750 tons/year. This value could be increased to 11,000 tons/year when waste from Poulsbo is included along with future growth. These values assume waste stream capture in addition to Bainbridge Disposal collection from food waste, paper waste, landscape waste, manure, and bedding. Additional potential sources of waste on Bainbridge Island are summarized in Table 3. Food waste was identified to be the most common among commercial sectors on the island due to tourism.

Table 3. Potential Waste Streams From Industries on Bainbridge Island

Industry on Bainbridge	Probable Waste Types
Wastewater Treatment	Biosolids/sludge
Fisheries	High-water-content fish waste
Hotels	Food waste from restaurants, other non-organic waste
Restaurants	Food waste
K-12 Schools	Paper and food waste
Supermarkets	Food waste
Farms	Farm waste (agricultural, manure)
Vineyards	Cultivation waste
Brewery	Food waste slurry
Wineries	Grape seeds and other grape-based organic waste
Distilleries	Distillery stillage

Using the waste sources available in Bainbridge as reference, we calculated the expected biogas output from different feedstocks. We analyzed feedstock contents because biogas output can vary by over 100% within the same waste category, depending on its composition (Levis and Barlaz 2013; Li, Chen, and Li 2009; Browne and Murphy 2013). As an example, Figure 8 shows three mixed-food waste streams from different sources, with a range of about 50 to about 125 m^3/day of methane output potential. PNNL found outputs in the range of Impact Bioenergy results, and for simplicity and consistency at this early stage of analysis, used these values for further calculations.

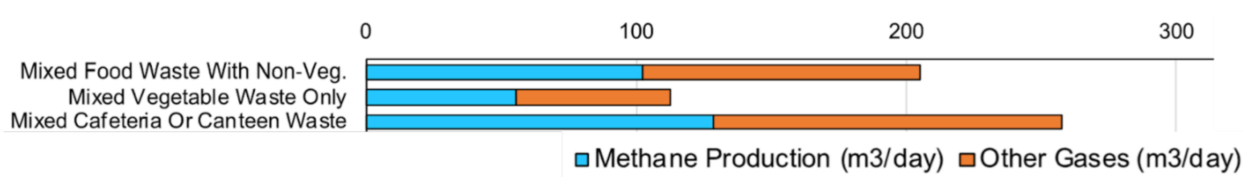


Figure 8. Biogas output difference for food waste

Our analysis indicates that meeting 100% of Bainbridge Island's electricity needs with biomass alone is not feasible. The estimated feedstock volume of 8,750 tons/year would generate nearly 3,500 MWh/year (Impact Bioenergy 2017) in a 0.5-MW system, providing only about 1% of the island's total annual electricity consumption. The biomass required to meet current annual electricity consumption is 963,000–2,644,000 tons/yr, depending on the biogas yield of the anaerobic digestion technology used. This is over 100 times the amount of feedstock available.

In addition to analyzing and further developing the research from Impact Bioenergy, PNNL performed preliminary research on the costs of commercial anaerobic digestion systems and potential benefits (Table 4). Anaerobic digestion systems have specific costs that differ from other energy projects. Most of these costs come from managing the feedstock, which needs to be collected, processed, and stored. However, as the proposed feedstock is generated on the island, the costs for waste transport and disposal off-island could be avoided.

Table 4. Cost Categories and Further Considerations for Anaerobic Digestion

Capital Cost Categories	O&M Cost Categories	Potential Cost Benefits
• Material pre-processing equipment • Storage space/structure • Digester • Boiler and/or generator • Infrastructure to interconnect energy outputs and utility supplies.	• Feedstock collection/segregation • Education for waste segregation • Typical energy plant O&M • Waste disposal costs.	• Avoided waste shipping/landfill fees • Avoided purchased electricity/heat • Sale of compost/effluent.

To better understand the specific cost implications of an anaerobic digestion system, we synthesized information from several vendors and case studies of a similar scale as Bainbridge for reference. Most of the examples are for systems on farms using manure as feedstock. These projects range from $650k–$12M in cost after conversion to 2023 USD (AgSTAR 2012), with the variability due to size. In a prototype assessment evaluating the feasibility of several renewable energy components in Tunisia, the total capital cost of a 1-MW anaerobic digestion system was estimated to be approximately $5.2M with a total annual O&M cost of about $8k per year (Herrera et al. 2020). A reference study evaluating the outputs of different feedstocks with high and low water content estimated an approximate capital cost range of $61,600–$93,800 per ton of waste per day with a range of $31–$40 per ton for annual O&M costs (Xiao et al. 2022). These estimates would result in a capital cost of $1.5M–$2.3M for a Bainbridge-sized system. The International Renewable Energy Agency estimates $1.8–6.3/W for anaerobic digestion systems (IRENA 2012), or $1.2M–$4.2M for a 0.5-MW system for Bainbridge in 2023 USD.

Larger anaerobic digestion systems are custom-built and require multiple acres. Bainbridge would use a smaller fixed-capacity system (such as the one shown in Figure 9) to process its smaller waste stream. These smaller systems can be modular, allowing for ease of installation and scalability, and process ~200-18,000 tons/year. However, they typically target a single waste stream and have difficulty processing mixed wastes. PNNL explored several commercially available examples that may be feasible on Bainbridge Island (Table 5).

Figure 9. Small plant digester system (Photo from Bekon)

Table 5. Example Commercial Anaerobic Digestion Technologies

Vendor	Technology	Waste Type	Capacity	Output	Comments
Chomp	N/A	Food waste	22–16,000 tons/year	11.7–200 kWe	Capital cost of $5.3M for 4,500 wet tons/year at 12% total solids
Gaia	N/A	Dairy effluent and cheese factory case studies	-	-	May not be suitable for Bainbridge waste streams
Qube Renewables	Bioqube, Dryqube	Food waste (Bioqube) Agricultural waste (e.g., wheat) (Dryqube)	444 tons/year (per 40 ft system)	30 kWe	Other non-modular technologies also available
Harp Renewables	N/A	Organic waste such as food, agricultural and horticultural biomass, green waste, cardboard, etc.	9–940 tons/year (for food waste*)	-	-
SeaB Energy	Flexibuster	Food waste	78–391 tons/year	-	-
Bekon	BekonMini	Farm waste	3,000–10,000 tons/year	100–300 kWe	Non-modular design

Dashes indicate information is not available or applicable.
* Per U.S. Environmental Protection Agency, food waste density is 22–45 lbs/ft^3(EPA 2016).

Next Steps

Due to the limited availability of waste, anaerobic digestion would have a small contribution to Bainbridge Island’s overall renewable energy portfolio. However, it can still provide value through waste reduction, peak demand reduction, and/or energy supply for designated critical infrastructure.

The next steps required to determine the potential for anaerobic digestion should revolve around better understanding the available waste (including quantity, composition, and collection and separation efforts) and potential locations for the system (including how the output will be used and acceptability of the site to the public). Characterizing the energy content and amount of available feedstock is critical to accurately estimating power generation potential and identifying overall system requirements and limitations. A waste characterization study will provide these values. Feedstock logistics, including purchasing/shipping costs, processing requirements, and storage volumes, are also important to characterize. The availability of feedstock over time and the potential for supply disruptions will inform storage requirements.

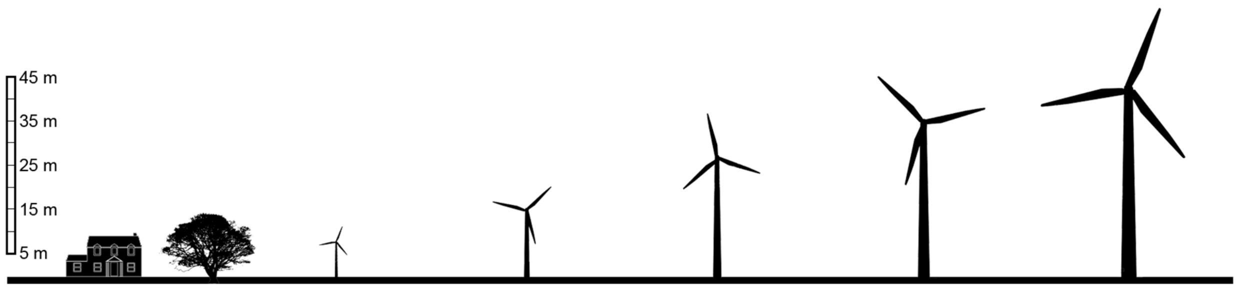
Potential end uses that can consume the energy produced need to be identified. End uses may consider thermal versus electrical loads and timing of energy needs versus energy production, both daily and seasonally. As noted, a biodigester can generate heat or power, but as with all energy conversion processes, power generation is less efficient. Therefore, thermal loads should be prioritized over electric loads for efficiency. On the other hand, the baseload generation capability of a digester provides a resilience benefit that COBI may want to leverage for critical electrical loads; in this case, pairing with an electrical load may be preferable.

The profile of the connected load, whether thermal or electric, should match the output of the system to optimize efficiency and avoid the need for energy storage. An efficient system will generate the same amount of energy, day and night, throughout the year. Systems that must be turned off or down at night or seasonally to match feedstock availability or the energy need will not have optimal operation and therefore will be less cost-effective.

An anaerobic digestion system that can use on-island waste materials, reduce electrical and thermal needs from other sources, and provide dedicated energy during times of disruption to a critical facility may be the optimal use for this technology on Bainbridge.

Technology Contributions: Wind

Wind energy is the kinetic energy of the wind converted into electrical energy using a wind turbine with a rotor and an electrical generator. Wind turbines are diverse in terms of size (height aboveground and blade length) and generating capacity (less than 1 kW to greater than 10 MW) and are therefore customizable to the energy needs of homeowners, businesses, communities, and utilities (Figure 10). Utility-scale wind energy tends to involve wind farms (on-shore or off-shore) composed of many turbines, and the energy generated can be transported long distances to centers of demand. Distributed wind energy can involve one or more wind turbines of any size that are sited near the infrastructure to which they supply energy. Distributed wind customers include remote off-grid cabins, residences, farms, industrial facilities, and local utilities. Both utility-scale and distributed wind energy projects depend on available wind resources. Distributed wind also requires optimizing the locations of turbines so they are close to where the energy is needed but far enough away from obstacles that reduce the available wind resource, such as buildings and trees.



Height (m)	up to 15	up to 25	up to 50	up to 65	65 +
Rated Power (kW)	0-1.5	1.5-15	15-60	60-200	200-500
Applications	House	House or farm	Farm or business	Business	Business or community

Figure 10. Scales and applications of distributed wind

To illustrate the wide-ranging applications of distributed wind, we share two case studies. The first starts at the small end of the distributed wind size/capacity scale in Hawaii. Three 20-m tall, 10-kW capacity wind turbines are currently deployed at the Central Maui Landfill Refuse and Recycling Center in Puunene (Figure 11a). The turbines generate 27–45 MWh of energy per year and offset between two-thirds and 90% of the Center's annual energy consumption, saving the facility approximately $18,000 annually. On the other end of the distributed wind size/capacity scale, the community of Grayland, Washington, developed the Coastal Energy project, consisting of four 80-m tall, 1.5-MW capacity wind turbines that generate 12,000–16,000 MWh annually (Figure 11b). Through the Coastal Community Action Program, the wind energy produced by the Coastal Energy wind project is sold to a local utility. All revenue goes to the Grayland community, which was economically impacted by the decline of the timber industry.

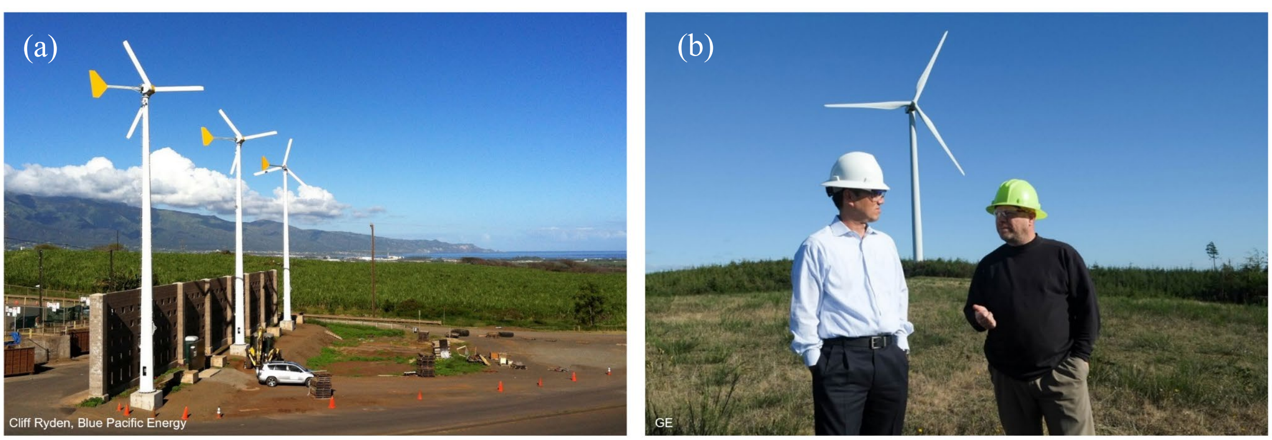


Figure 11. (a) Central Maui Landfill Refuse and Recycling Center wind turbines in Puunene, HI (left, photo credit: Cliff Ryden); (b) one of the Coastal Energy project wind turbines in Grayland, Washington (right, photo credit: GE)

Wind Resource

To explore the potential for distributed wind to support Bainbridge in meeting its 100% renewable energy goal, we first assessed the wind resource across the island. Next, we selected nine potential locations, based on interest from community partners and the island-wide results. Lastly, we estimated wind energy generation at these sites using five different turbines. The complete set of analyzed sites and recommendations for siting provides COBI with information to weigh advantages and disadvantages at each location in terms of wind resource quality, wind generation potential, proximity to infrastructure, and site quality.

First, we assessed the wind resource across the island using three high-resolution wind models (Global Wind Atlas [DTU 2023], WIND Toolkit [NREL 2023], and Wind Report [Bergey Windpower 2023]). The three models provide the ranges of wind speed estimates across Bainbridge Island (Figure 12). These wind speeds can be used to identify areas of higher relative wind resource to be analyzed for energy potential and lower relative wind resource to be disregarded for further investigation. Most of Bainbridge Island has lower wind resource as compared with locations in Washington where wind energy is more commonly deployed, particularly east of the Cascades. However, some areas on Bainbridge Island (along coasts and on elevated locations) are more promising for wind. In addition to providing insight into the ranges of wind speeds, the island-wide wind assessment also provides an initial look into the seasonal (fastest in winter) and diurnal (fastest at night) trends in the wind resource and where the wind is predominantly coming from (north and south-southwest).

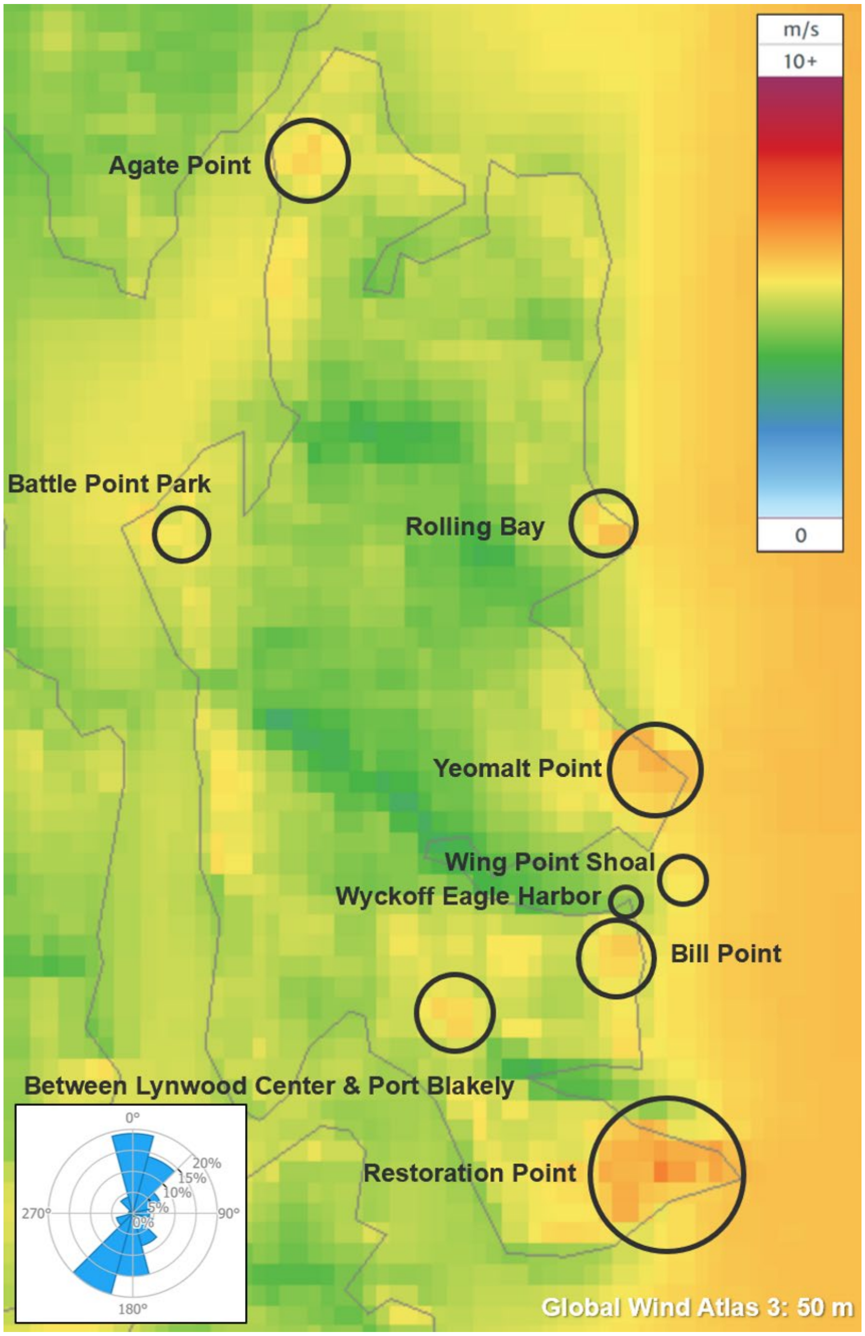


Figure 12. Wind speed and direction at 50-m aboveground level from Global Wind Atlas at Bainbridge Island

We also explored some of the physical challenges for wind energy deployment during the initial island-wide assessment. All wind energy projects experience energy loss for a variety of reasons, including downtime for maintenance, weather impacts, and line and transformer loss. We created a custom set of loss assumptions for Bainbridge Island that were incorporated into the wind energy generation estimates in this report (Table 6).

Table 6. Typical Wind Energy Project Losses and Assumptions Used for the Bainbridge Island Wind Analysis

Loss Category	Typical Range	Bainbridge Assumption	Notes
Availability	4%–6%	6% (higher-end average, due to accessibility of maintenance personnel and components)	Downtime for maintenance (planned or unplanned)
Wake (array)	0%–15%	1% (wakes accounted for in turbine spacing recommendations)	Dependent on quantity of turbines and arrangement of array relative to predominant wind directions
Turbine Performance	1%–3%	2% (average)	Dependent on state of technology
Electrical	2%–3%	3% (average)	Line and transformer losses
Environmental	1%–10%	6% (higher-end average, due to coastal conditions)	Weather impacts (icing, pausing during extreme winds); downtime due to wildlife migration
Curtailment	0%–3%	1% (lower-end expectations)	When generation exceeds demand; potentially necessary for grid balancing
Total	**12%–25%**	**19%**	

In addition, nearby obstacles including buildings and trees can create turbulence that reduces the amount of available wind resource that turbines can utilize. According to David Barts' *Common Trees of Bainbridge Island* (2018), the maximum heights of many of the trees meet or exceed typical distributed wind turbine hub heights (Figure 13). PNNL recommends that turbine hub heights be at least 10-m taller than the height of any obstacles within a 150-m radius.

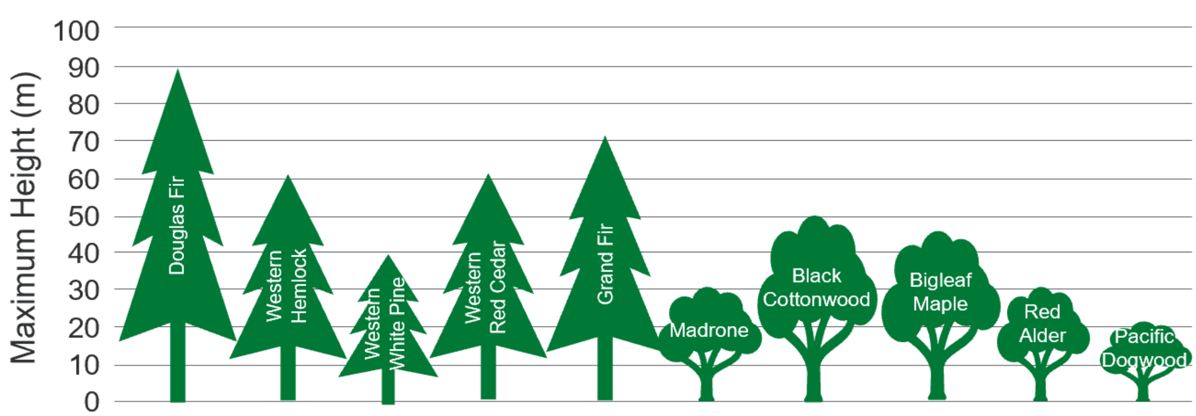


Figure 13. Maximum tree height based on number reported in Barts (2018)

Finally, we considered the influence of co-locating multiple turbines. To minimize the impact of turbulence generated by upwind turbines, PNNL recommends a spacing of eight rotor diameters (the diameter of the circular area swept by the turbine blades) between turbines in lines parallel to the predominant wind direction and three rotor diameters between turbines in lines perpendicular to the predominant wind direction.

Locations of Interest

Next, we leveraged the island-wide resource assessment to select nine locations at which to estimate wind generation potential. The selection of locations for wind analysis was a collaborative process. COBI provided PNNL with initial locations of potential wind deployment that have the advantages of open space and proximity to generation or transmission infrastructure. These locations include Battle Point Park, Wing Point Shoal, and Wyckoff Eagle Harbor, shown in Figure 12. PNNL performed the wind resource and energy generation estimates for these sites, along with a selection of additional sites that were identified based on results of the initial wind resource assessment indicating high relative wind resource on Bainbridge Island. Some of the additional sites have high forest and/or infrastructure density (both of which act to reduce the available wind resource), highlighting the necessity of detailed siting and potentially clearing at these locations. A rule of thumb for wind resource screening is an annual average wind speed of 5.0 m/s as a threshold for economically feasible wind energy development at a turbine hub height of 50 m above the ground.

Because distributed wind can support a variety of applications using a wide range of different-sized turbines (Figure 10), we analyzed five commercially available wind turbines for Bainbridge Island. These range from the 15-kW Bergey Excel 15 turbine to the GE 2.3-MW-116 turbine (Table 7). The turbine hub heights (the height at the center of the turbine blades) range from 24–80 m above the ground, and the turbine tip heights (the maximum height of the turbine, the hub height plus the length of the blade) range from 32–138 m.

Table 7. Nameplate Capacities and Typical Hub Heights and Tip Heights for Turbines Evaluated

Manufacturer /Model	Bergey Windpower Excel 15	Eocycle EOX S-16	Northern Power Systems NPS 100C-28	EWT DW 54-900	GE 2 MW-116
Nameplate Capacity	15 kW	25 kW	100 kW	900 kW	2.3 MW
Typical Hub Height	37 m	24 m	37 m	50 m	80 m
Tip Height (base to blade tip)	42 m	32 m	51 m	77 m	138 m
Rotor Diameter	10 m	16 m	28 m	54 m	116 m

For locations of community interest and/or high relative wind resource on Bainbridge Island (circled in Figure 12), Table 8 presents the ranges of annual average wind speed at 50 m above ground level, according to each wind resource dataset. The estimated annual average wind speeds from the Global Wind Atlas, the highest-resolution model, are at or above the threshold at all sites except Wyckoff Eagle Harbor, while WIND Toolkit and Wind Report tend to place the annual average wind speeds slightly below the threshold for feasibility. This disagreement among the models at annual average wind speeds so close to the threshold for feasibility urges the gathering of on-site wind measurements at locations of potential wind deployment interest.

Table 8. Annual Average 50-m Wind Speed According to Wind Resource Model

Site	Global Wind Atlas	WIND Toolkit	Wind Report
Battle Point Park	4.9 m/s–5.3 m/s	4.4 m/s	4.3 m/s
Wing Point Shoal	5.3 m/s–5.5 m/s	5.1 m/s–5.2 m/s	4.7 m/s
Wyckoff Eagle Harbor	4.4 m/s	4.6 m/s	4.6 m/s
Agate Point	5.2 m/s–5.6 m/s	4.4 m/s	4.4 m/s
Rolling Bay	5.3 m/s–5.8 m/s	4.7 m/s	4.7 m/s
Yeomalt Point	5.5 m/s–6.1 m/s	4.9 m/s	4.6 m/s–4.7 m/s
Bill Point	5.5 m/s–5.7 m/s	4.7 m/s	4.6 m/s
Lynwood Center/Port Blakely	5.2 m/s–5.6 m/s	4.6 m/s	4.4 m/s
Restoration Point	5.6 m/s–6.7 m/s	4.9 m/s	4.6 m/s–4.7 m/s

Figure 14 presents the monthly and hourly average wind speed ranges across the three wind speed models, Global Wind Atlas, WIND Toolkit, and Wind Report, and across the evaluation sites shown in Figure 12. Wind speeds on Bainbridge Island will be fastest in the winter and slowest in the summer. Diurnally, wind speeds on Bainbridge Island will be fastest at night and slowest during the day, thus complementing solar energy, which generates the most energy during daylight hours.

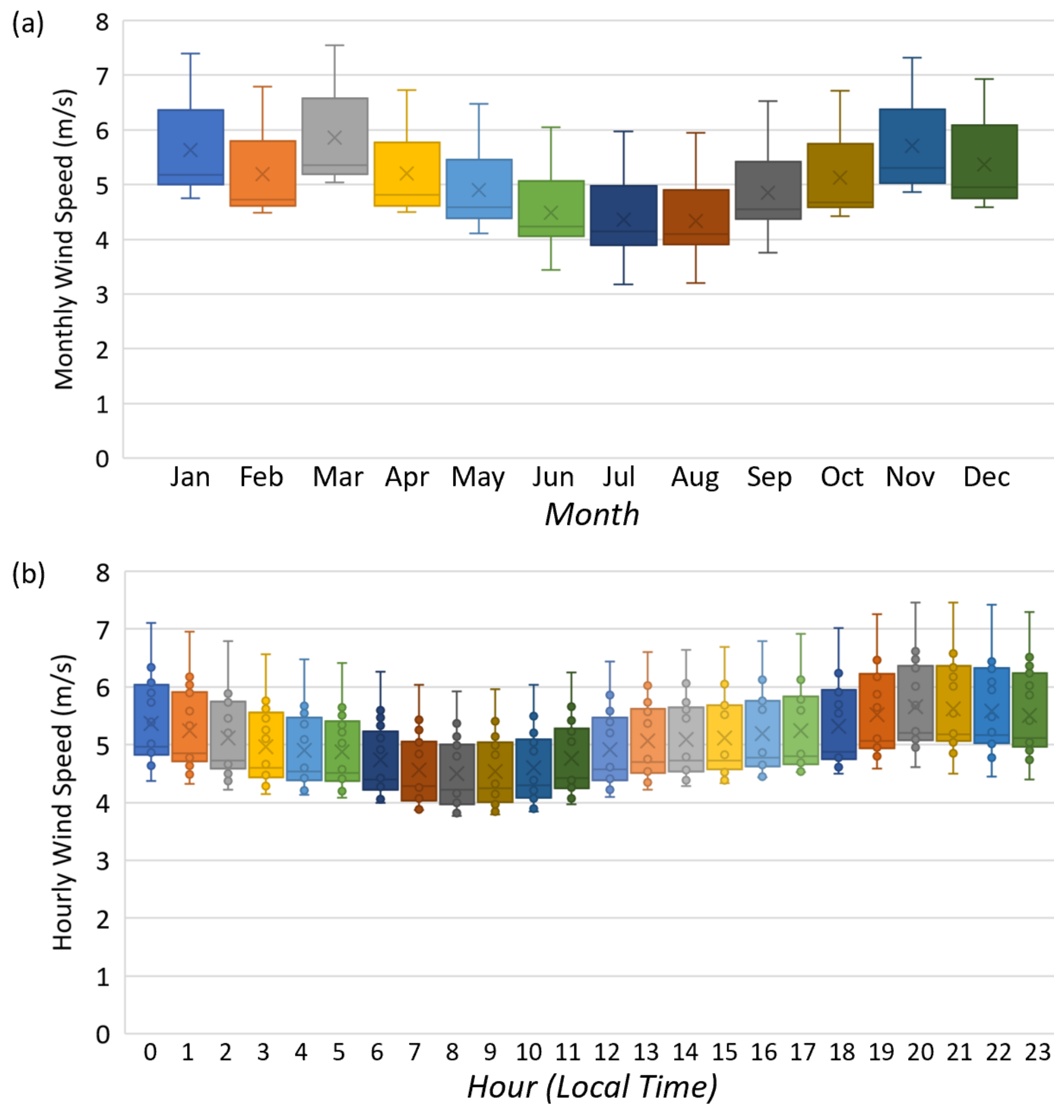


Figure 14. (a) Monthly and (b) hourly average wind speed ranges across the three wind resource models used in this analysis (Global Wind Atlas, WIND Toolkit, and Wind Report) and across the sites evaluated in Figure 12

Using the same three wind resource models, Global Wind Atlas, WIND Toolkit, and Wind Report, Table 9 presents the ranges of annual average wind speeds at hub height, the ranges of annual energy estimates for an average wind resource year, and the percentage of Bainbridge Island's current energy demand (264,566 MWh) that a single turbine would offset. Restoration

Point has the highest potential for wind energy generation, with annual energy production estimates ranging between 4,000–8,000 MWh for the largest turbine in the analysis, the GE 2.3-MW-116. One GE 2.3-MW-116 wind turbine at each of the three sites of interest (Battle Point Park, Wing Point Shoal, and Wyckoff Eagle Harbor) has the potential of producing nearly 16,000 MWh during an average wind resource year.

Table 9. Annual Average Hub Height Wind Speed, Annual Energy Production Estimate, and Percentage of Annual Bainbridge Demand That a Single Turbine Would Meet

Site	Bergey Excel 15 37-m Hub Height	Eocycle EOX S-16 24-m Hub Height	NPS 100C-28 37-m Hub Height	EWT DW 54-900 50-m Hub Height	GE 2 MW-116 80-m Hub Height
Battle Point Park	4.0–5.0 m/s 17–27 MWh <0.1%	3.7–4.9 m/s 33–51 MWh <0.1%	4.0–5.0 m/s 135–194 MWh <0.1%	4.3–5.3 m/s 854–1,363 MWh 0.3%–0.5%	4.8–5.9 m/s 4,000–5,638 MWh 1.5%–2.1%
Wing Point Shoal	4.5–5.3 m/s 18–27 MWh <0.1%	4.2–4.9 m/s 39–55 MWh <0.1%	4.5–5.3 m/s 153–213 MWh <0.1%	4.7–5.5 m/s 883–1,324 MWh 0.3%–0.5%	5.1–6.0 m/s 4,260–5,796 MWh 1.6%–2.2%
Wyckoff Eagle Harbor	4.0–4.2 m/s 14–16 MWh <0.1%	3.5–3.7 m/s 24–27 MWh <0.1%	4.0–4.2 m/s 120–133 MWh <0.1%	4.4–4.6 m/s 758–856 MWh 0.3%	5.0–5.2 m/s 4,136–4,535 MWh 1.6%–1.7%
Agate Point	4.0–5.1 m/s 15–27 MWh <0.1%	3.5–4.4 m/s 26–45 MWh <0.1%	4.0–5.1 m/s 126–198 MWh <0.1%	4.4–5.6 m/s 839–1,459 MWh 0.3%–0.6%	5.0–6.4 m/s 4,297–6,319 MWh 1.6%–2.4%
Rolling Bay	4.4–5.4 m/s 17–29 MWh <0.1%	3.9–4.8 m/s 30–51 MWh <0.1%	4.4–5.4 m/s 143–219 MWh <0.1%	4.7–5.8 m/s 895–1,500 MWh 0.3%–0.6%	5.2–6.5 m/s 4,543–6,575 MWh 1.7%–2.5%
Yeomalt Point	4.4–5.7 m/s 17–33 MWh <0.1%	4.1–5.3 m/s 34–64 MWh <0.1%	4.4–5.7 m/s 143–243 MWh <0.1%	4.6–6.0 m/s 834–1,613 MWh 0.3%–0.6%	5.0–6.6 m/s 4,160–6,763 MWh 1.6%–2.6%
Bill Point	4.2–5.3 m/s 15–27 MWh <0.1%	3.7–4.6 m/s 27–47 MWh <0.1%	4.2–5.3 m/s 132–207 MWh <0.1%	4.6–5.7 m/s 832–1,420 MWh 0.3%–0.5%	5.2–6.4 m/s 4,368–6,449 MWh 1.7%–2.4%
Lynwood Center/Port Blakely	4.1–5.2 m/s 14–27 MWh <0.1%	3.6–4.6 m/s 26–46 MWh <0.1%	4.1–5.2 m/s 123–201 MWh <0.1%	4.4–5.6 m/s 778–1,407 MWh 0.3%–0.5%	5.0–6.3 m/s 4,077–6,228 MWh 1.5%–2.4%
Restoration Point	4.3–6.3 m/s 16–39 MWh <0.1%	3.8–5.6 m/s 30–69 MWh <0.1%	4.3–6.3 m/s 137–275 MWh 0.1%	4.6–6.7 m/s 837–2,000 MWh 0.3%–0.8%	5.1–7.4 m/s 4,230–7,891 MWh 1.6%–3.0%

The average installed cost (including equipment purchase, installation, foundation, permitting, zoning, transportation, taxes, inspection, engineering and design, and financing) for new small wind turbines (≤100 kW capacity) between 2020–2022 ranged from $4,000/kW to nearly $8,000/kW; O&M costs for small wind turbines are ~$35/kW/year (Orrell et al. 2023). The average installed cost for new midsize and large wind turbines (>100 kW) between 2020–2022 ranged between $2,000–$3,500/kW; O&M costs are ~$20/kW/year. Scheduled maintenance activities for wind projects can include inspecting the turbine, controller, and tower; adjusting blades; checking the production meter and communications components; and providing an overall biannual or annual scheduled maintenance visit per manufacturer owner's manual. Unscheduled maintenance can include activities ranging from responding to a customer complaint of noise from the turbine to replacing the generator, electrical components, inverter, blades, anemometer, or furling cable. The skills and supplies required for wind turbine maintenance may not be available on Bainbridge Island, which may increase O&M costs and turbine downtime.

Returns on investment for distributed wind vary widely according to a number of factors, including local electricity prices, availability of incentives, wind resource, turbine technology, and accessibility of parts and maintenance. The following case studies from the National Rural Electric Cooperative Association provide examples of distributed wind returns on investment. In Oklahoma, a state known for good wind resource, residential owners were able to recoup their investment in a 10-kW wind turbine in 12 years. The residents achieved this by using state and federal tax credits and also likely benefited from their nearby proximity to the turbine manufacturer (NRECA 2022). In Illinois, the Rural Electric Convenience Cooperative invested in a 900-kW wind turbine sited on an abandoned coal mine, with electricity going to the cooperative's members. In 2019 and 2020, the wind turbine has saved the electric cooperative around $100,000 per year after project expenses were deducted because the per kWh generation cost was cheaper than the wholesale power purchase price. The turbine was financed with state and federal grants, with the remaining balance financed over 15 years using the federal zero-interest Clean Renewable Energy Bonds program available at the time (NRECA 2021).

According to the Distributed Wind Energy Futures Study, in order for a distributed wind project to be profitable in Kitsap County, the capital expenditure would need to be limited to $474/kW for front-of-the-meter systems and $7,253/kW for behind-the-meter systems (McCabe et al. 2022). A behind-the-meter wind turbine is one that is connected to the local distribution grid behind a customer's utility meter—typically to offset all or some of the on-site energy needs. Front-of-the-meter wind projects provide energy and grid support to the distribution system and help serve the interconnected local loads on the same distribution system (Orrell et al. 2023). It is important to note that, while the current version of the Distributed Wind Energy Futures Study accounts for the federal Investment Tax Credit (ITC) and state and utility net-metering policies, more recent investments in clean energy, such as the Inflation Reduction Act (IRA), are not included in the threshold capital expenditure calculations.

Next Steps

The above wind resource assessment for Bainbridge Island showed that wind energy would not significantly offset current and future Bainbridge energy loads, but could be advantageous for offsetting the energy of a specific local load, particularly if multiple turbines are deployed. The next steps include first identifying potential local entities (schools, industrial facilities, agriculture) that combine an interest in wind energy with being advantageously located in areas of high relative wind resource (Figure 12). Second, once areas of wind interest are identified, on-site wind measurements are recommended at or near the anticipated turbine hub height in order to refine energy generation estimates. These on-site wind measurements are generated by installing a meteorological tower with anemometers or by deploying LIDAR, and it is recommended that 1 year of wind observations are gathered to accurately capture the seasonal cycle of wind resource. Additional challenges to consider in selecting a site for a wind turbine include the feasibility of transporting and installing turbine components on-island, assessing environmental concerns such as bird/bat collisions and other common stakeholder concerns (e.g., operational noise, shadow flicker, lighting, and aesthetics).

Technology Contributions: Marine

Marine energy is an emerging technology with a lot of research interest in the Puget Sound area. Marine energy encompasses many technology designs and different ways to harvest energy from moving water, including waves, tides, temperature gradients, or salinity gradients. Wave energy devices often capture energy from the up and down motion of waves using buoys that rise and fall; however, wave power can be harnessed from a variety of different aspects of wave movement and motion. This technology has not yet converged on one particular design and can have many different archetypes. Tidal energy typically refers to capturing energy from the current that is generated as the tide pushes water from one place to another. Tidal generators often look like wind turbines underwater (called axial-flow turbines, Figure 15a, b), but can have different numbers of blades. Another tidal generation technology looks more like lawnmower blades (called cross-flow turbines, Figure 15c, d).

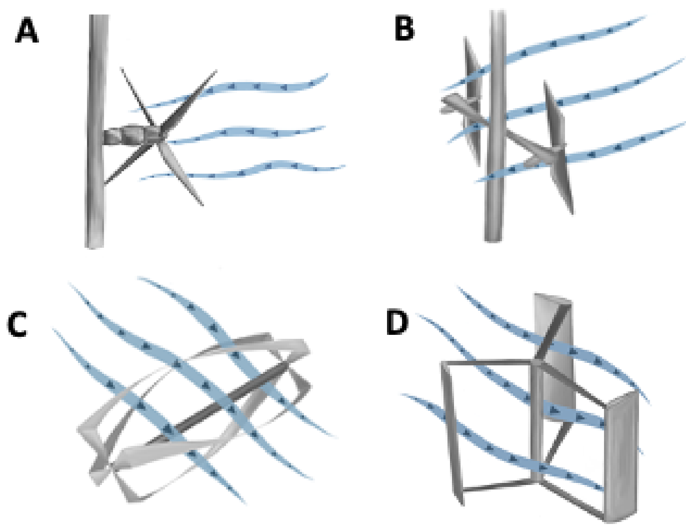


Figure 15. Axial-flow turbines (a, b) rotating on the axis of the incoming water flow, while cross-flow turbines (c, d) rotate across the flow

Tidal Energy Resource

First, we narrowed down which marine energy resource to focus on for Bainbridge Island. A good wave energy resource is at least 30 kW/m, and all of Puget Sound has wave power much lower than that. In contrast, tidal energy typically requires around 1 m/s of average current speed, which is more in line with speeds observed in Puget Sound. We used NREL's Marine Energy Atlas[24] to identify the overall hotspots for tidal energy around Bainbridge Island (Figure 16). Agate Passage has about 1 m/s currents, and Rich Passage has currents that are even higher. However, during the first site visit, COBI and community partners noted that Rich Passage is a very busy environment with ferries and naval uses occurring in a constricted channel. Because of these conflicts, we considered Rich Passage to be unsuitable for marine energy development so we excluded the passage from further analysis and focused on Agate Passage.

[24] To access the Marine Energy Atlas, see https://maps.nrel.gov/marine-energy-atlas/.

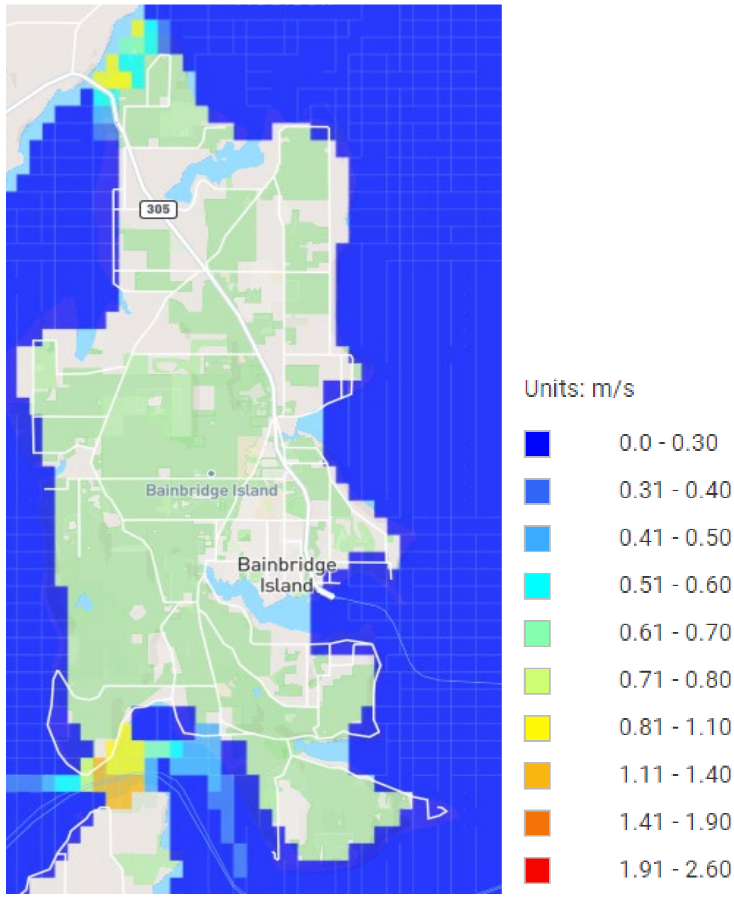


Figure 16. Annual depth-average tidal current speed (m/s) (from NREL's Marine Energy Atlas, data from Haas et al. [2011]).

Locations of Interest

To assess the potential for marine energy at Agate Passage to contribute to meeting Bainbridge Island's 100% renewable energy goal, we combined tidal modeling with empirical measurements. For the modeling, we used a canonical turbine, called Reference Model 2.[25] This model was created by DOE to represent a typical turbine, including cost estimates and performance for modeling purposes. We coupled the turbine model with measurements from the National Oceanographic and Atmospheric Administration (NOAA) across the tidal cycle at various depths to calculate annual power production. Tidal measurements were taken in the Agate Passage over a 2-month period from July 27 to September 9, 2015, with an acoustic Doppler current profiler. These measurements are used by NOAA to predict tidal currents around Puget Sound. Because tidal currents vary with the position of the moon and sun, 2 months of data are enough to understand how the shape of the bottom of the ocean influences tidal currents. Using these types of measurements, tidal currents can be predicted indefinitely into the future. These predictions are posted on the NOAA website (https://tidesandcurrents.noaa.gov/) for

[25] For more information on Reference Model 2, see https://tethys-engineering.pnnl.gov/signature-projects/reference-model.

recreational or commercial use. We used the reference model turbine and the velocity measurements to estimate marine energy generation for both shallow water and deep water deployment, at 8.7 ft and 21.9 ft, respectively. A community may want to install a tidal turbine at different heights in the water column based on their desire to see or not see the turbine from the surface. Generally, there are faster currents higher in the water column.

Reference Model 2 provides a power curve that describes the power output of this turbine at different current speeds. The power curve was applied each time in the acoustic Doppler current profiler dataset, then summed to determine an approximate annual power output. The modeling analysis resulted in fairly low annual power outputs for both a shallow deployment and a deep deployment, 132 MWh and 79 MWh, respectively (0.05% and 0.03% of the total 2022 Bainbridge annual electric demand). There may be areas of Agate Passage that are faster than the currents measured by NOAA, so a more precise estimate of the velocity may be able to get higher generation numbers. Further, a different turbine more optimized to perform in this precise location may also allow for higher generation. Still, tidal turbines are an emerging technology that is unlikely to meet significant amounts of Bainbridge's generation in the near future at Agate Passage.

Next Steps

Our results suggest that marine energy is not likely to be a technology that contributes significantly to reaching the goal of 100% renewable energy by 2040, but is still an approach that could be viable on Bainbridge Island for meeting the demand of a particular load and is likely worth revisiting as the technology improves. At this stage, if Bainbridge were interested in exploring tidal energy, the most viable option would be to pursue federal funding for a research project in collaboration with DOE's Water Power Technologies Office. The purpose of the project would be to understand energy needs for particular facilities on Bainbridge Island that could be served by the tidal device and to analyze, design, and test particular devices in the water to help advance the knowledge and technology around tidal energy for community-based applications. However, the application would not be suitable for contributing to Bainbridge's 100% renewable energy goal in the near term. An example of a recent funding opportunity through DOE is the tidal Funding Opportunity Announcement for the first of five phases totaling $35 million in investment in tidal demonstration projects. One of the projects chosen is led by Orcas Power and Light Cooperative that proposes to place a turbine in Rosario Strait that can produce 2 MW of power, which would be a significant amount of power for a community like Bainbridge Island (DOE 2024).

Pathway Combinations

None of the pathways identified, alone or combined, can achieve 100% of the electricity generation needed with renewable energy on the island, even if pursued concurrently and immediately (Figure 17). The solar pathways have the potential to contribute the most to renewable energy generation. Ground-mount and carport solar are found to be the most scalable options, but viable space needs to be found to achieve the possibilities described in Pathway #2. Additional off-island purchases are likely required to meet the goal, at least in the near term.

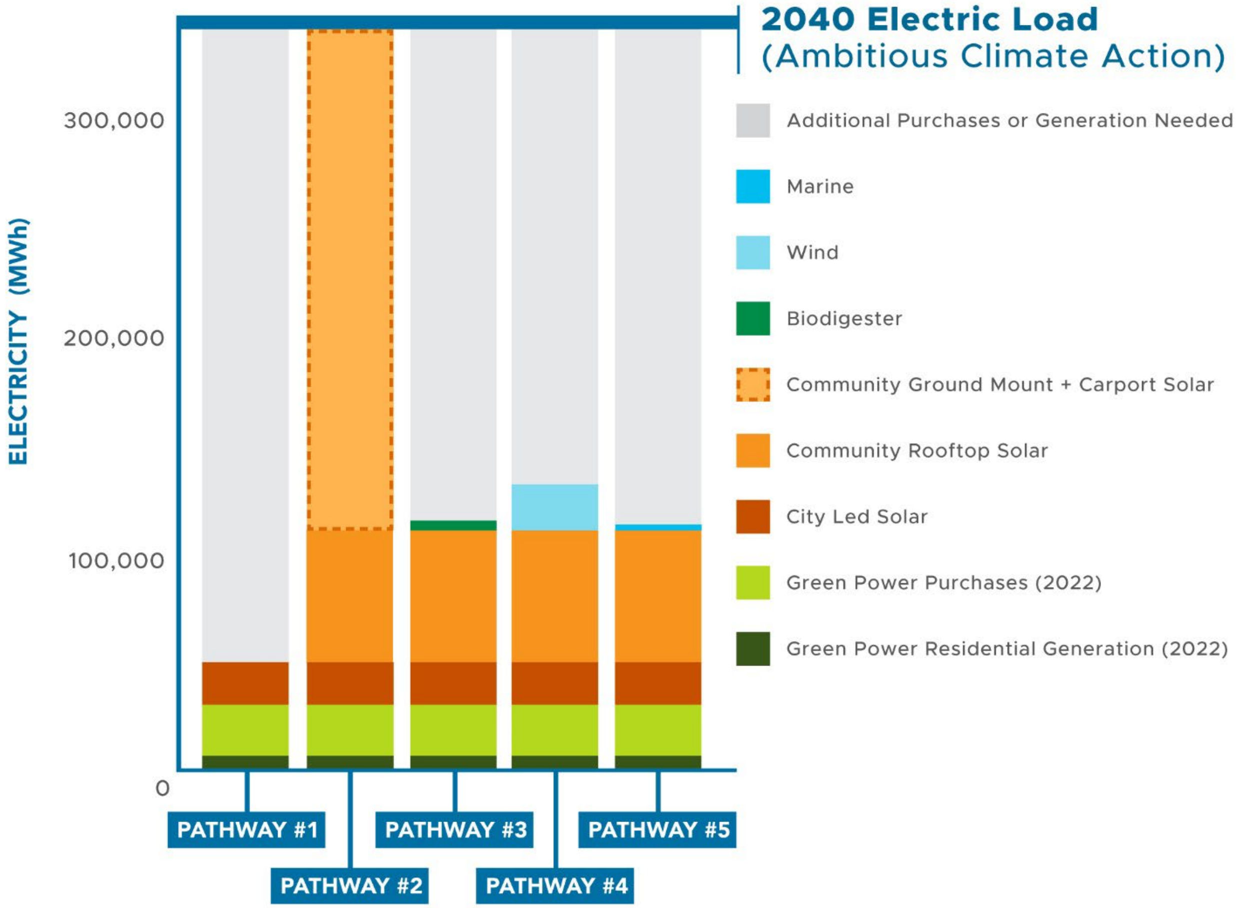


Figure 17. Contributions of each pathway to 2040 energy consumption on Bainbridge Island. Pathway #1 includes contributions from current purchases and rooftop, ground-mount, and carport locations listed in Appendix A. Pathway #2 includes current purchases and Pathway #1 solar plus all residential and commercial rooftops on the island as well as a scalable amount of ground-mount and carport solar. Pathway #3 includes current purchases and Pathway #1 solar, rooftop solar from Pathway #2, and an anaerobic biodigester. Pathway #4 includes current purchases and Pathway #1 solar, rooftop solar from Pathway #2, and three 2-MW wind turbines. Pathway #5 includes current purchases and Pathway #1 solar, rooftop solar from Pathway #2, and one tidal energy device. Graphic created by PNNL Communications.

In considering a path forward, it is also important to consider the cost of each technology. At present, rooftop and ground-mount solar are the most commercially established and cost-effective options to generating electricity. Table 10 summarizes the estimated costs by each technology as well as their potential generation on Bainbridge.

Table 10. Summary of Technology Contributions to Bainbridge Electricity and Estimated Costs

TECHNOLOGY	Rooftop Solar	Ground-mount Solar	Carport Solar	Biodigester	Wind	Marine
Potential Generation (MWh)	**82,500** *Pathways 1 & 2*	**7,200** *Pathway 1*	**3,300** *Pathway 1*	**3,500** *Impact Bioenergy 2017 estimate**	**16,000** *One 2-MW turbine each at three sites*	**130** *One turbine*
Estimated % of Bainbridge 2040 Load under Ambitious Climate Action	**25.4%**	**2.3%** *Potentially scalable with Pathway 2*	**1.0%** *Potentially scalable with Pathway 2*	**1.1%**	**4.8%**	**0.05%**
Technology Cost Estimate (USD 2023)	Residential: **$2,682/kW** Community: **$1,761/kW** *Source: Ramasamy et al. 2023*	**$1,161/kW** *Source: Ramasamy et al. 2023*	**$2,760/kW** *Source: Wood Mackenzie 2023*	**$61,600 - $93,800 per ton of waste**** *Source: Xiao et al. 2022*	Small distributed: **$7,850/kW** Midsize distributed: **$3,333/kW** *Source: Orrell et al. 2023*	**~$6,500 - $26,000/kW** Few commercial technologies, but significant government funding likely available *Source: OES Report 2015*

*** Rounded Impact Bioenergy estimate from 3,485 to 3,500 to display fewer significant digits, which is more consistent with the other potential generation estimates**
**** The cost estimate for the biodigester is not able to be converted to $/kW due to the high variability in the energy output depending on the waste composition**

In addition to generating renewable energy on-island, there are several options for purchasing off-island credits or offsets to meet the goal of 100% renewable energy by 2040, listed below. COBI already participates in several purchase programs and made 24,435 MWh of Green Power retail purchases in 2022 through a combination of PSE's Green Power, Solar Choice, and Community Solar programs.

- *PSE Green Power*: Offers all PSE customers an option to match up to 100% of their electricity use with renewable energy. Green power projects include wind and solar in the Pacific Northwest region.
- *PSE Solar Choice*: Allows all PSE customers to match all or a portion of their electricity usage with renewable energy generated through independent solar projects. Customers can purchase "blocks" of the independent solar projects or choose to offset a portion of their monthly usage.
- *PSE Community Solar*: Allows customers to purchase shares in semi-local solar power projects and receive credits generated by their shares on their electricity bill. No projects currently exist on Bainbridge Island, but they have been discussed and some initial assessments have been completed by PSE.

In deciding how much to purchase, individuals, businesses, or COBI will need to decide when to begin meeting the 2040 goal, as well as calculate the balance of renewable energy that needs to be purchased, given the on-island renewable energy generation at that time. This calculation can be easily done if individuals and businesses offset their own consumption, or can be done at a higher level to cover the consumption of those not participating in an offset program or generate their own renewable energy. It is important to begin tracking renewable energy generation, consumption, and purchases ahead of the 2040 goal to have accurate numbers for the deficit at that time and a baseline by which to assess the impact of actions taken toward meeting the 100% goal.

In addition to PSE's purchase programs, the overall mix of energy provided by the utility is expected to become cleaner in alignment with the requirements of Washington's Clean Energy Transformation Act,[26] which requires electricity provided to be coal-free by 2025, GHG-neutral by 2030, and free from GHG emissions by 2045. Bainbridge will need to decide if this cleaner mix contributes toward meeting the goal of 100% renewable energy, as well as be able to assess the electricity provided on a regular basis to determine if additional purchases are needed for a defined period of time or indefinitely.

Though it may require less effort and be more cost-effective to purchase renewable energy credits or offsets to meet Bainbridge Island's goal, there are additional benefits to generating renewable energy on the island. These benefits include fostering the resilience of residents, critical infrastructure, and emergency services, especially if the power supply to the entire island is lost (due to an earthquake or bridge failure). In that event, having solar and battery storage at key locations (such as Community Disaster Hubs) could allow for continued provision of emergency services for longer, without relying on emissions-intensive fuels. More information on these resilience aspects is discussed in the *Bainbridge Island ETIPP Resilience Report* (Rose et al. 2024). On-island generation also allows for renewable power credits to be purchased by other PSE customers that may not be as resourced or suitably located to install their own renewables.

[26] For more information on the Clean Energy Transformation Act requirements for PSE, see https://www.cleanenergyplan.pse.com/.

Conclusions and Implications for City Priorities

Based on technical analysis and discussions with the Bainbridge Island community during several site visits, the pathways that focus on solar were identified as the priority resource for the City to pursue. However, even with aggressive plans to implement multiple solar technology types with a variety of local partners, it is unlikely that the entire future electric load on Bainbridge will be able to be met with on-island renewable energy generation. Approaching the goal will require identification of large sites for ground-mount or carport solar, likely as part of a PSE Community Solar project, as well as developing as many residential and commercial rooftops as possible. Purchases of Green Power or other off-island renewable generation will be needed to meet the goal of 100% renewable energy generation by 2040.

Additional energy sources provide smaller amounts of power that could be used to meet key loads, but are not likely to play a large part in meeting 100% renewable energy generation. To move forward with an anaerobic biodigester, a waste characterization study needs to be conducted to better understand the amount of electricity that could be generated, and to site a project in a location that makes sense for waste transport as well as electric consumption. There is sufficient wind energy on the island to pursue a few distributed wind projects for specific loads, but sites are limited due to tree cover, and a suitable site would need to be identified and confirmed with on-site measurements. Tidal energy technologies that were assessed are possible in Agate Passage, but do not generate significant amounts of power; additionally, the technologies are a long way from being ready to meet grid loads, though it is likely worth revisiting in the future as the technology improves and additional funding or research opportunities become available.

Next steps for COBI include any efforts to advance on the solar pathways. This could include beginning to install solar on the remaining suitable City facilities, proactively partnering with other public and private institutions to develop solar at identified locations, developing educational materials or outreach to residents and the community around solar technologies, renewable power purchases, leveraging existing incentive programs, and continuing to partner with PSE on identifying and developing Community Solar projects on-island. Additionally, COBI should continue to encourage adoption of energy efficiency measures, as decreasing energy consumption reduces the amount of on-island renewable energy generation needed to meet goals. Relevant funding resources and tax incentives to aid in taking these next steps are described in Appendix C. Reaching 100% renewable energy generation on Bainbridge by 2040 is an ambitious goal, and it will take significant near-term investments, primarily in solar energy, to be able to approach it.

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Appendix A. Pathway #1 Properties

Full list of properties included in Pathway #1.

Table A- 1. Properties Included in Pathway #1

Solar Type	Location	Ownership	Area (m2)	Acre (Acre)	DC System Size (kW)	AC Energy (kWh/yr)
Rooftop	O&M Yard	City-Owned	1,706	0.4	273	250,840
Carport	Ted Spearman Justice Center	City-Owned	724	0.2	116	126,150
Carport	Existing Police Station	City-Owned	737	0.2	118	128,415
Rooftop	Bainbridge High School	Other Public Entity	10,637	2.6	1,702	1,843,223
Rooftop	Woodward Middle School	Other Public Entity	5,805	1.4	929	911,054
Rooftop	Sonoji Sakai Intermediate School	Other Public Entity	2,075	0.5	332	300,792
Rooftop	Commodore Options School	Other Public Entity	4,373	1.1	700	757,667
Rooftop	Captain Johnston Blakely Elementary School	Other Public Entity	3,410	0.8	546	590,798
Rooftop	Ordway Elementary School	Other Public Entity	3,423	0.8	548	593,137
Rooftop	Xalilc Elementary School	Other Public Entity	3,963	1.0	634	686,709
Rooftop	Fire Station 21	Other Public Entity	1,237	0.3	198	214,347
Rooftop	Fire Station 22	Other Public Entity	939	0.2	150	137,755
Rooftop	Fire Station 23	Other Public Entity	345	0.1	55	59,782
Rooftop	Recreation Center	Other Public Entity	2,093	0.5	335	313,852
Carport	Battle Point Park Parking	Other Public Entity	1,474	0.4	236	256,830
Carport	Ferry Terminal Parking Lot	Other Public Entity/Private For-Profit	9,979	2.5	1,597	1,738,741
Rooftop	Lynwood Center	Private For-Profit	3,515	0.9	562	542,304
Rooftop	Downtown Winslow	Private For-Profit	939	0.2	150	145,537
Rooftop	Safeway	Private For-Profit	3,713	0.9	594	643,389
Rooftop	Pavilion/Movie Theater	Private For-Profit	1,832	0.5	293	317,449
Rooftop	Copper Top	Private For-Profit	6,270	1.5	1,003	960,603
Ground	Bainbridge Transfer Station	Private For-Profit	24,344	6.0	3,895	4,241,699
Ground	Vincent Road Triangle	Private For-Profit	9,702	2.4	1,552	1,690,476
Carport	Lynwood Center Parking Areas	Private For-Profit	2,474	0.6	396	431,070
Rooftop	Grace Episcopal Church	Private Non-Profit	1,001	0.2	160	146,850
Rooftop	St. Cecilia Parish	Private Non-Profit	631	0.2	101	101,703
Ground	Bainbridge First Baptist Church	Private Non-Profit	7,353	1.8	1,176	1,281,187

Appendix B. Spatial Data Sources

The spatial data sources for the marine energy and wind energy are available as individual map PDFs (https://drive.google.com/drive/folders/1MMb6P9nNh5OcjeZQy4PGLZH7yMdqtlev) and are included in the Resilience GIS Map Package from Google Drive at https://tinyurl.com/56txyutd.

Appendix C. Funding and Tax Incentives

This section describes current relevant resources for advancing the work identified in this report, as compiled by Spark Northwest.

Relevant Funding Resources

Implementing any combination of the pathways is expected to involve multiple projects and funding sources. Leveraging these funding sources, in particular, federal incentives, can help bring down the costs of meeting the goal of 100% renewable energy. The funding landscape is dynamic; this section provides a snapshot of near-term opportunities based on current information in Table C- 1. Note that this section provides initial information and is not tax or financial advice. Individual circumstances will vary, and it is recommended to consult the guidance and regulations associated with each opportunity and work with a lawyer or other professional as needed.

Table C- 1. Summary of Select Currently Open or Announced Funding Opportunities

Funding Opportunity	Agency	Scope Summary	Timing
Building Resilient Infrastructure and Communities	Federal Emergency Management Agency	Pre-disaster hazard mitigation activities that increase resilience.	Current application period closed in February 2024 but expected to be a recurring program subject to availability of funding.
Community Change Grants Program	U.S. Environmental Protection Agency	Environmental and climate justice projects, including clean energy and climate adaptation.	Application period open until November 21, 2024.
Rural Energy for America Program	U. S. Department of Agriculture	Cost share for rural small businesses to purchase and install renewable energy or efficiency technologies.	Applications due quarterly.
Washington Clean Energy Grants	Washington Department of Commerce Energy Programs in Communities	Funds to implement energy efficiency retrofits, solar PV, and grid resiliency/reliability.	Overburdened/vulnerable community deadline April 5, 2024. General solicitation deadline expected in late spring 2024.
Grid Resilience and Reliability Grants	Washington Department of Commerce	Projects to strengthen and modernize the power grid against wildfires, extreme weather, and other natural disasters exacerbated by the climate crisis.	To be announced in 2024.
Washington Home Electrification and Appliance Rebates Program	Washington Department of Commerce	Grants to eligible third-party administrators to provide rebates and incentives to households and small businesses to purchase and install high-efficiency electric equipment and appliances.	Currently open, will remain open until June 30, 2025, or until the available funding is allocated.

At the federal level, the 2021 Bipartisan Infrastructure Law and 2022 IRA established and expanded numerous funding opportunities. Many of these will be recurring in coming years. Several Bipartisan Infrastructure Law funding opportunities are expected to recur through Fiscal

Year 2026. At the state level, the Washington Department of Commerce has established the Energy Program in Communities unit within the Energy Division and State Energy Office. Through this initiative, a variety of new funding opportunities will launch in 2024. Philanthropic resources, though not covered here, can also provide valuable support.

Tax Incentives

The IRA established and expanded clean energy tax credits. The IRA also made these credits available to certain entities like local governments that have not previously been able to directly access them. IRA clean energy tax credits are expected to be available through at least 2032.

The ITC is the main tax credit expected to be of interest for clean energy projects described in this report.[27] In general, the ITC is a sliding scale of 6%–70% of the eligible basis, which is generally the capital cost of the qualifying project. Solar PV energy, energy storage, and certain other technologies may qualify.

In 2025, the current ITC (Section 48 ITC for Energy Property) transitions to a technology-neutral credit (Section 48E Clean Electricity Investment Credit), which is expected to apply to electricity generation and energy storage with zero GHG emissions. This credit may be able to support emerging clean energy technologies contemplated in this report, like marine renewable energy, that have not conventionally benefited from the ITC. Forthcoming regulations are expected to further clarify which technologies will qualify. The value of the ITC depends on the criteria met in a series of base and bonus credits. It is theoretically possible to attain a credit of 70%, but a range of 30%–50% appears more likely for most projects. Projects with capacity under 1 MW have fewer requirements for attaining the full value of the credit. Elective pay is the mechanism that makes the ITC (and certain other IRA tax credits)[28] available to tax-exempt organizations and local governments (and certain other related applicable entities).[29] In general, elective pay allows the ITC value to be received directly as money from the government. It is new and has specific regulations. The preregistration portal[30] and instructions[31] were developed in December 2023.

Considerations with elective pay tax credits:

- A successful payment may come several years after the start of project procurement and construction. Payment comes after a project is placed in service and has filed a return claiming the payment. Other funds are therefore needed for upfront construction costs.

[27] DOE discusses considerations about the choice between the ITC and Production Tax Credit at https://www.energy.gov/eere/solar/federal-solar-tax-credits-businesses. Other tax credits may be available for other specific project types.

[28] Elective pay-eligible tax credits are described in IRS Publication 5817-G (6-2023), available at https://www.irs.gov/pub/irs-pdf/p5817g.pdf.

[29] Definition of tax exempt organizations is provided in https://www.irs.gov/credits-deductions/elective-pay-and-transferability-frequently-asked-questions-elective-pay, Question #4.

[30] See https://www.irs.gov/credits-deductions/register-for-elective-payment-or-transfer-of-credits.

[31] See https://www.irs.gov/newsroom/irs-opens-free-ira-and-chips-pre-filing-registration-tool-for-organizations-to-register-to-monetize-clean-energy-credits.

- When using elective pay, projects over 1 MW capacity may have their credit value reduced if domestic content requirements are not met. There are separate regulations describing domestic content requirements, which generally require a certain portion of manufactured components, steel, and iron be sourced from the United States.
- Entities using elective pay may be audited by the IRS. It is a new mechanism and many entities using it will be new to some aspects of tax credits. It may be especially helpful to work with a tax professional.

A business may be eligible for the 30% ITC without going through the elective pay option. Likewise, a homeowner who owes federal income tax may be eligible for the Residential Energy Tax Credit. If the federal tax credit exceeds tax liability, the excess amount may be carried forward to the succeeding taxable year. In addition, under the federal Modified Accelerated Cost-Recovery System, businesses that owe taxes may recover investments in renewable energy projects by reducing their income through depreciation losses. A number of renewable energy technologies are classified as 5-year property under the Modified Accelerated Cost-Recovery System, including wind, solar, geothermal, and combined heat and power. The Modified Accelerated Cost-Recovery System improves the economic viability of a project by reducing the tax liability in the initial years of production.