CITY OF BAINBRIDGE ISLAND

Climate Change Advisory Committee
Regular Meeting
February 21, 2024
5:30 PM
Council Conference Room
280 Madison Avenue N
+ Zoom Webinar

The Climate Change Advisory Committee will hold this meeting
in person and using a virtual, Zoom webinar platform

Members of the public will be able to attend at City Hall
or by calling in to the Zoom webinar

Please click the link below to join the webinar:
https://bainbridgewa.zoom.us/j/91390380790
Or Telephone: 1-253-215-8782
Webinar ID: 913 9038 0790

AGENDA

5:30 Call to Order/Roll Call/Accept of Modify Agenda/Conflict of Interest Disclosure

5:35 Approve December 20, 2023 and January 17, 2024 Meeting Minutes (attached)

5:40 Public Comment

5:45 Climate Manager Staffing Updates and Transition Plan (Autumn Salamack)

6:00 Review draft ETIPP Report (attached)
- Do you have any feedback or clarifications you would like to see in the report?
- How do you think the committee, city and community can leverage this work to take next steps towards achieving Bainbridge's 100% renewable energy goal?
- Are there any action items for the CCAC you would like to see mentioned or discussed in the report?

6:30 Climate Manager Updates (Autumn Salamack)
- EVSE grant and fleet charging update.
- Heat pump pilot program update.
- Solar PV/carbon offset project update.

6:45 Draft Dashboard (attached)

7:15 Updates
- Advisory Committees Status (Council Members)
- Home Electrification Fair (Mike/Kevin)
- Discuss endorsing Fossil Fuel Non-Proliferation Treaty https://fossilfueltreaty.org/endorsements/#governments
- Other

7:30 Adjourn

Materials
1. December and January minutes
2. ETIPP Draft Report
3. Draft Dashboard

Climate Change Advisory Committee
Meeting Minutes
December 20, 2023

Meeting called to order at 5:31 PM by Kevin

Roll Call

- Committee members: Derik Broekhoff, Julie Matthews, Steve Richard (online), Sanjay Bhat, Michael Cox, Kevin Thomas, Jens Boemer, Ray Victurine
- City Staff: Autumn Salamack
- City Council: Kristen Hytopoulos and Leslie Schneider

Agenda
Accepted as is by those present.

Conflicts of Interest
Jens provided standard disclosure that he works for an institute that occasionally does business with PSE. Sanjay likewise provided his standard disclosure (he is marketing director at Kitsap Transit, which has a contract with COBI to promote transit, which is managed by Autumn's group at the city; he also serves on the Board with Courtyards on Madison, working with Department of Energy on community solar grant projects).

Minutes from Last Meeting
Julie moved, Steve seconded, unanimously approved.

Public Comment

- None

Updates from Autumn

- The city is working finalizing the 2023 annual climate action plan progress report for City Manager to share at January meetings.
- Update on heat pump pilot program (1 year pilot program to install energy efficient heat pumps in island homes).
    - Solicited qualifications and received responses from two firms (Spark NW and Kicking Gas).
    - They were invited to submit full proposals – due January 11.
    - Kevin from CCAC is helping to review proposals.
- The city is soliciting bids for solar carbon offset installations, working with consultant to apply criteria (including for additionality). Hoping to have a set of sites to review in early February. The city has budget to review up to 4 sites (which could be at public facilities, including Washington State Ferries).
- Hannah (Sustainable Transportation Coordinator) just submitted a grant application to Washington Dept. of Commerce for funding to install level 2 EV chargers for city fleet vehicles, as well as at the new justice center and in Lynwood center. Should know by January 16 if application is successful.
- Hannah will be holding a discussion on January 10 on sustainable transportation.
    - Committee also discussed whether it has been continued with school district.

- On January 27, the ETIPP team will be back to discuss solar + battery options for community disaster hubs.
- City has updated waste reduction regulations:
    - CCAC members discussed educating community about recycling basics, and ensuring recycling options are made available at different facilities.

Discussion of CCAC Priorities and Goals for 2024

Autumn also shared her thoughts on top 10 priorities for where CCAC could contribute in the coming year (while cautioning that it would probably be infeasible to form subcommittees for all 10), including:

- Taking forward ETIPP work to explore & develop renewable energy & storage options.
- Further helping with implementation & outreach on heat pump pilot program.
- Looking at electric landscaping tool requirements or incentive programs.
- Sustainable transportation plan implementation – including public EV charging program
- Helping promote e-bike incentive program.
- Updating GHG inventory for 2023 (in anticipation of 2025 CAP update).
- Helping outreach on tree cover, planting guidance.
- Responding to city requests.

Autumn also shared feedback on what has worked well in terms of CCAC input/assistance, including:

- Staffing outreach events.
- Analysis & assessment for carbon offset project.
- Heat pump program research.
- Guiding communications & materials.
- All the work to develop CAP.

Sometimes there has been tension between what people want to do vs. what city needs to prioritize (there are 100s of items in CAP, so we need to be selective).

Committee members and others shared and discussed ideas for what the committee could work on in 2024, assisting Autumn with her suggested priorities. Topics discussed included:

- More community outreach, education, communication of progress, and “marketing”.
- Assisting with grant writing.
- Developing “data dashboards” that could help communicate climate action priorities and progress in achieving them.
- Helping with inventory update.
- Helping with review of Climate Action Plan (CAP) .

Members discussed delegating CAP sections to individual(s) on committee to review & provide status updates – and communicate this to community (including through a dashboard). Mike to develop a framework, Kevin will distribute, people can sign up for sections and go from there.

The meeting was adjourned at 7:17 PM. Julie motioned; Sanjay seconded.

Climate Change Advisory Committee
Meeting Minutes
January 17, 2024

Meeting called to order at 5:31 PM by Kevin

Roll Call

- Committee members: Derik Broekhoff (online), Julie Matthews, Steve Richard (online), Sanjay Bhat, Michael Cox, Kevin Thomas, Jens Boemer (online – left early), Ray Victurine (online)
- City Staff liaison: Autumn Salamack
- City Council liaisons: Kirsten Hytopoulos, Leslie Schneider

Agenda
Julie noted there were no minutes from the last meeting. To be provided at the February meeting.

Conflicts of Interest:
Sanjay disclosed he is marketing director at Kitsap Transit, which has a contract with COBI to promote transit, which is managed by Autumn's group in the city. He also serves on the Board with Courtyards on Madison, working with Department of Energy on community solar grant projects. Jens provided standard disclosure that he works for an institute that occasionally does business with PSE.

Public Comment
None

ETIPP Project Update

Project representatives from Pacific Northwest National Laboratory (PNNL) provided an update to the committee on the progress of the ETIPP project. Highlights:

- They will complete project reports in mid-February.
- Two reports to be delivered: One on their assessment of the potential for Bainbridge Island to achieve 100% renewable energy from on-island power generation, and another on enhancing power system resilience.
- The "100% RE" report will be discussed at the next CCAC meeting, February 21.
- The resilience report will be reviewed in March.

Climate Officer Updates

Autumn provided updates on city activity related to the climate action plan (CAP).

- Climate Friendly Trees
  - City is working with Drue (the city arborist) to identify priority tree species (fulfilling CAP goal).
  - There is a new webpage for climate friendly trees on the city website (link is in the meeting agenda).
- Heat Pump Pilot Program
  - Issued RFQ late in 2023. Two organizations submitted (see minutes from last meeting).
  - They were invited to submit proposal for how to design and implement a heat pump. rebate program, focusing on low-income & senior homes (looking, for example, at what are they key barriers to heat pump uptake).
  - One firm submitted a proposal. Reviewing now. Should have decision by next meeting (February).

- Police and Municipal Court building (Ted Spearman Justice Center) offset project update
  - Recently put out public request to apply for funding to install 120kW system (https://www.bainbridgewa.gov/1479/2024-Solar-PV-Application-for-Public-Pro)
  - Have heard from WSF that they are looking at maintenance yard as an option
  - Heard interest from others as well
- EV charger update
  - Process moving forward for grant city is seeking from state to support level 2 EV charger deployment
  - Town & Country got a permit and is looking to start installation this month, in the lower level of parking lot. If it goes ahead, this will be the first DC fast charger on the island.
- Annual CAP progress report submitted to designer – should be available next week.
  - Will be shared in the city manager's report out in February.

Dashboard Update

Committee members continued discussion of development of a climate dashboard. Mike, Ray, and Jens presented ideas they developed as members of a dashboard subcommittee.

- The dashboard would show community how BI is progressing in achieving goals of the CAP
- Mike presented a template for the dashboard, along with summary of what other city dashboards contain
- Discussion centered around:
  - How to select key data to present?
  - Who is the audience? (What data to present?)
  - How to make the dashboard useful for decision making
- Committee members raised the issue of update frequency and how to ensure the dashboard gets ongoing attention. One possibility might be to develop it as more of a storyboard, with narrative updates.

Action Items

- Subcommittee will reconvene and consider feedback
- The proposed approach is to have different committee members take charge of different sections

Other Updates

- Planning is underway for a home electrification expo, which would bring speakers, equipment demos, info on rebates, etc. related to home electrification and efficiency upgrades. However, there was a decision to move the expo to September to give more time to plan.

The meeting was adjourned at 7:26 PM. Sanjay motioned; Julie seconded.

DRAFT

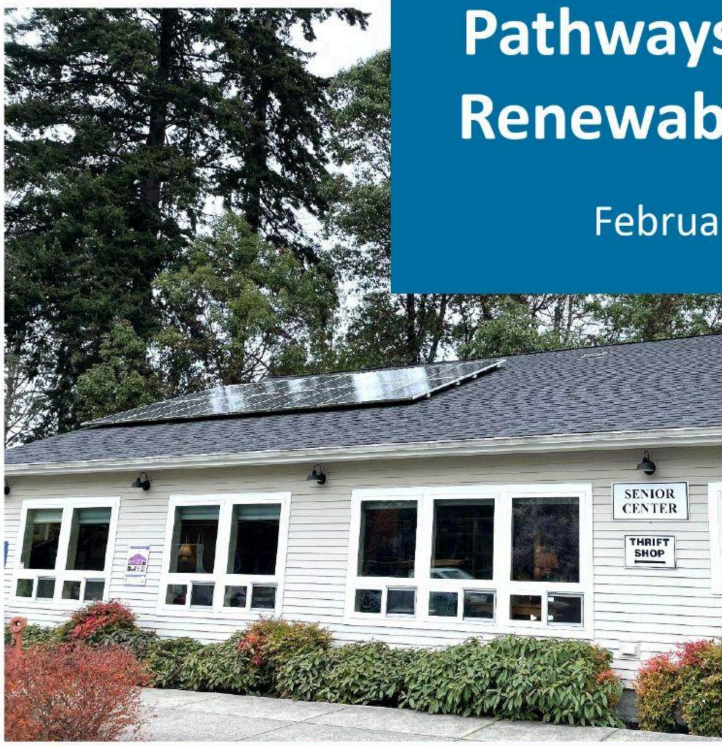
ENERGY TRANSITIONS INITIATIVE

U.S. Department of Energy

Bainbridge Island

Pathways to 100% Renewable Energy

February 2024



Energy Transitions Initiative Partnership Project: Bainbridge Island, Washington

Cohort 2 Technical Assistance: Pathways to 100% Renewable Energy

February 2024

Katie Arkema[1], Deborah Rose[1], Malcolm Moncheur de Rieudotte[1], Lindsay Sheridan[1], Orlando Garayburu Caruso[1], Amy Solana[1], Alisha Piazza[1], Molly Grear[1], Mia Devine[2], Sean Esterly[3], Autumn Salamack[4]

1. Pacific Northwest National Laboratory
2. Spark Northwest
3. National Renewable Energy Laboratory
4. City of Bainbridge Island

Suggested Citation: Arkema, K.; Rose, D.; Moncheur de Rieudotte, M.; Sheridan, L.; Caruso, O.; Solana, A.; Piazza, A.; Grear, M.; Devine, M.; Esterly, S.; Salamack, A. 2024. ETIPP Report: Bainbridge Island Pathways to 100% Renewable Energy. PNNL-35643.

Report Cover Photo Credits: Clockwise from top left, solar panels at Senior Center photo by Autumn Salamack; ferry photo by City of Bainbridge Island; Crystal Springs Road photo by Autumn Salamack, and EV Charging at City Hall by Autumn Salamack.

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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.

Tables and Figures

Acronyms

AC	Alternate Current
CAP	Climate Action Plan
CapEx	Capital Expenditure
CCAC	Climate Change Advisory Committee
CO_2	Carbon Dioxide
COBI	City of Bainbridge Island
DC	Direct Current
ETIPP	Energy Transitions Initiative Partnership Program
EV	Electric Vehicle
GHG	Greenhouse Gas
IRA	Inflation Reduction Act
ITC	Investment Tax Credit
NREL	National Renewable Energy Laboratory
NSRDB	National Solar Radiation Database
O&M	Operations and Maintenance
PNNL	Pacific Northwest National Laboratory
PSE	Puget Sound Energy
PV	Photovoltaic
USD	United States Dollars
WTE	Waste-to-Energy

Executive Summary

Bainbridge Island aims to achieve 100% renewable electricity generation by 2040[1], five years ahead of the Washington State goal, and to 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) during 2022-2024. Supported by the U.S. Department of Energy, 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. This report documents the goals, approach, and results for the pathways analysis. A separate report documents the resilience analysis[2], 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 the 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), anaerobic biodigestion for converting waste-to-energy, distributed wind, and marine energy. Various combinations of these technologies were explored through the development and analysis of five pathways that describe different approaches that COBI could take towards achieving the 100% renewable energy by 2040 goal (Table 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, public and private land-owners, and Puget Sound Energy (PSE) in each stage of the analysis.

[1] https://www.bainbridgewa.gov/1331/Climate-Action

[2] Rose, D.; Arkema, K.; Moncheur de Rieudotte, M.; Devine, M.; Esterly, S.; Salamack, A. 2024. ETIPP Report: Bainbridge Island Improving Resilience. DOI.

Table E1. Description of five pathways.

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 non-residential property owners to install solar.
Pathway #2	Community-led solar on-island	All reasonable public and private properties (residential and non-residential) are developed for solar in the near term.
Pathway #3	Solar + Biodigester + Buy the rest	All reasonable Pathway #1 properties are developed for solar. An anaerobic biodigester of the size to match existing Bainbridge waste stream is installed. Additional power needed to meet goals is purchased 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 are developed for solar. The permitting process for one wind turbine is started. Additional power needed to meet goals is purchased 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 are developed for solar. The permitting process for one marine energy converter is started. Additional power needed to meet goals is purchased from PSE Green Power, Solar Choice, or Community Solar until generation is sufficient.

According to data from PSE for 2022, the current annual electric load for Bainbridge Island is 264,566 MWh. If Bainbridge 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 due to significant electrification planned by converting to electric heat pumps, electric vehicles, and electric ferry charging to reduce greenhouse gas emissions.

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 (Table E2, Figure E1). Solar energy technologies and pathways are also the least costly per kW of electricity.

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-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 likely be needed to meet the goal of 100% renewable energy generation by 2040.

Table E2. Summary of technology contributions to Bainbridge electricity and estimated costs.

Technology:	Rooftop Solar	Ground-mount Solar	Carport Solar	Biodigester	Wind	Marine
Potential Generation (MWh)	83,602 (Pathway #1 and #2)	7,143 (Pathway #1)	3,175 (Pathway #1)	3,485 (Impact Bioenergy estimate)	15,969 (one 2MW turbine at 3 sites)	132 (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%
Cost estimate (2023 USD)	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 H2 2023 US Solar PV system pricing	$61,600 - $93,800 per ton of waste Source: Xiao et al. 2022	Small distributed: $7,850/kW Midsize distributed: $3,333/kW Utility scale: $1,370/kW Source: Distributed Wind Market Report: 2023 Edition	~$6,500 - $26,000/kW Few commercial technologies, but significant government funding likely available Source: OES Report 2015

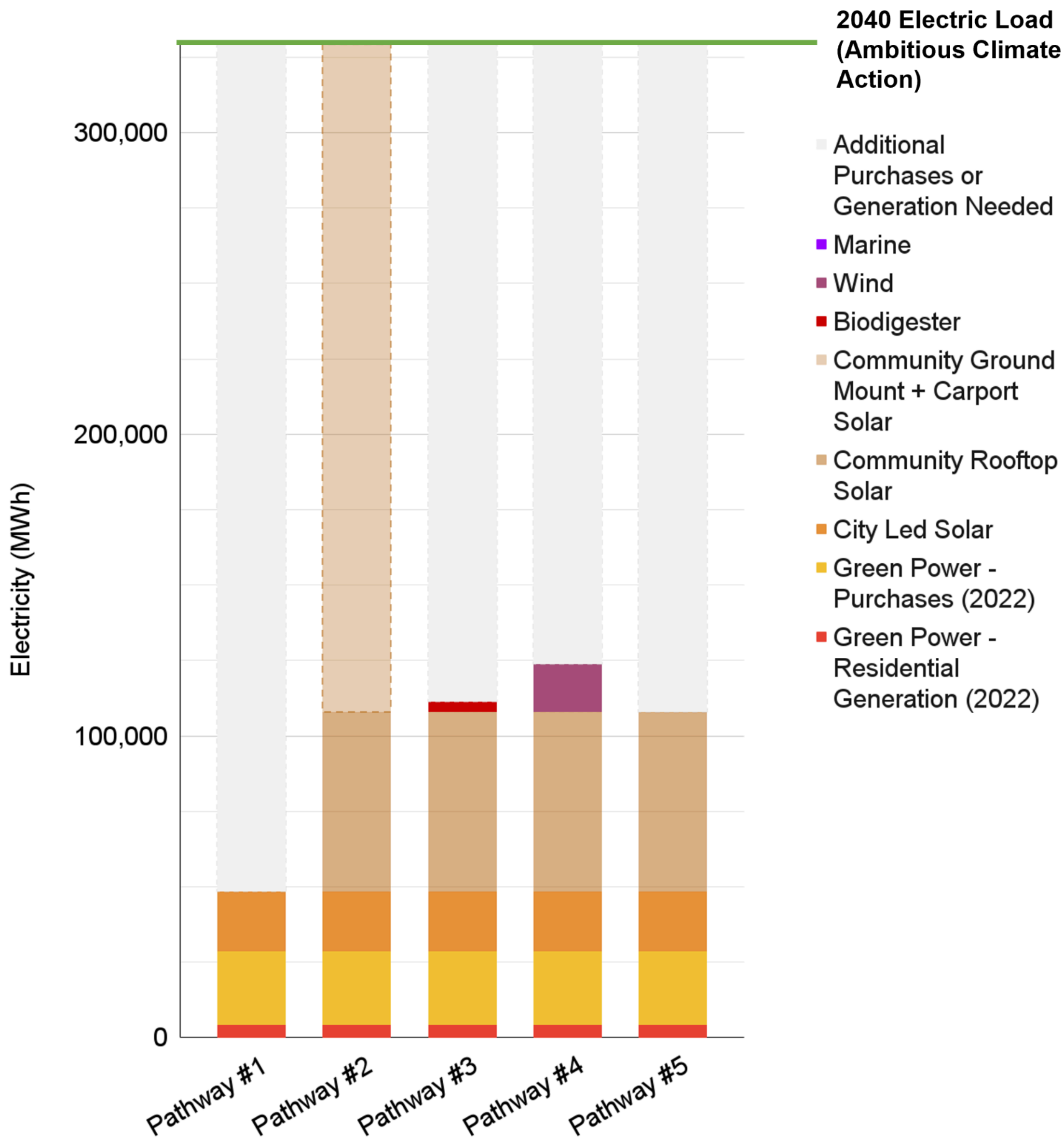

Figure E1. Contributions of each pathway to 2040 energy consumption on Bainbridge Island.

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 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 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 in Agate Pass. 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 for the City of Bainbridge Island include engaging in various efforts to advance on 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 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 the goal of 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.

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 energy, though are not enough on their own to offset growing demand.
- Solar energy (rooftop, ground-mount, and carport) is the most promising 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.
  - *Waste-to-Energy*: To move forward with an anaerobic biodigester, a waste characterization study needs to be conducted to better understand the quantity and quality of waste generated on the island to serve as feedstock.
  - *Wind Energy*: A small distributed wind project will be most useful in an area of high relative wind resource tied to a specific energy load. Once a site and load are selected, the next step is to conduct a site scale study to assess tree cover and collect wind energy measurements.
  - *Marine Energy*: Tidal energy is possible, but is a long way out from commercial viability and the potential site in Agate Pass would likely generate very small amounts of power at a very high cost.

- Purchases of Green Power or other off-island renewable generation will be needed to meet the goal of 100% renewable energy generation by 2040.
- Next steps for the City of Bainbridge Island could include:
    - Continuing to make progress on 120kW publicly hosted solar site as part of the carbon offset associated with the new Ted Spearman Justice Center.
    - Partnering 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, but most locations analyzed are too small to qualify (Note: our analysis suggests the Transfer Station could have sufficient area to be a possibility (see Appendix A).
    - Exploring 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.
    - Developing educational materials and conducting 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, five years ahead of the Washington State goal, and to increase their 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, 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)[3] with administrative support from the National Renewable Energy Laboratory (NREL)[4] and regional nonprofit partner Spark Northwest[5].

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 miles, with 52 miles of shoreline, dense forests, mostly rural development patterns, and an estimated population of 25,000. There is one bridge connecting Bainbridge Island to the Kitsap Peninsula at the north end of the Island at

[3] https://www.pnnl.gov/projects/ETIPP/communities
[4] https://www.nrel.gov/state-local-tribal/etipp-technical-assistance.html
[5] https://sparknorthwest.org/

Agate Passage, a single ferry route that connects the downtown area to Seattle, and a single transmission line serving the island at Agate Passage. As a result, the island has limited means for evacuation or access during emergencies, and the community can be slow to have power restored in storm events.

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, and carbon-intensive fuels such as propane and gasoline, as well as a few rooftop solar projects on residential, commercial, or public buildings. PSE's 2020 fuel mix comes primarily from non-renewable sources such as natural gas and coal (Table 1)[6]. However, Washington's Energy Independence Act requires PSE to meet a renewable portfolio standard as a percentage of customer load[7]. The current target is 15%, which PSE is meeting through incremental hydropower efficiency upgrades, eligible wind, and biomass. As such, some of the current electricity provided by PSE to Bainbridge Island comes from renewable sources, but none is locally generated.

[6] https://www.pse.com/en/pages/energy-supply/electric-supply

[7] Washington State Department of Commerce. Energy Independence Act (I-937). https://www.commerce.wa.gov/growing-the-economy/energy/energy-independence-act/

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%

Energy generation was identified from the Greenhouse Gas Inventory[8] as contributing 55% of overall greenhouse gas (GHG) emissions on the island. The Climate Action Plan (CAP, 2020)[9] was developed to help reduce these GHG emissions by 90% by 2045, support adaptation to climate change, and inspire community action and partnership for additional climate mitigation and adaptation measures, and serves as the main driver for climate action on Bainbridge. The Climate Change Advisory Committee (CCAC)[10] 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[11] and other activities described on their Climate Action webpage[12]. According to the 2022 CAP Progress Report[13], existing City facilities are powered by 100% Green Power (91% wind and 9% biogas) under an existing PSE program. 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 electric 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

[8] COBI. 2019. Bainbridge Island's Greenhouse Gas Inventory Results Fact Sheet. https://www.bainbridgewa.gov/DocumentCenter/View/12812/BainbridgeGHGFactSheet3_11-22-19
[9] COBI. 2020. Climate Action Plan: A Plan for Mitigating and Adapting to Climate Change on Bainbridge Island. https://www.bainbridgewa.gov/DocumentCenter/View/14354/Final-Bainbridge-Island-Climate-Action-Plan-November-12th-2020
[10] https://www.bainbridgewa.gov/922/Climate-Change-Advisory-Committee
[11] https://www.climatesmartbainbridge.org/
[12] https://www.bainbridgewa.gov/1331/Climate-Action
[13] Climate Smart Bainbridge. 2022. Climate Action Plan Annual Progress Report. https://www.bainbridgewa.gov/DocumentCenter/View/16973/2022-Annual-CAP-Progress-Report?bidId=

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.

The second goal of increasing energy resilience is discussed in a separate report[14], though it is important to note that local, renewable energy generation can increase overall resilience.

Approach to Technical Assistance

Pacific Northwest National Laboratory (PNNL) completed the technical analysis aspects of the project, supported by the community partner Spark Northwest and the program administrator, the National Renewable Energy Laboratory (NREL). All partners met on a biweekly basis with the community lead from the City of Bainbridge Island (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 team 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, Puget Sound Energy, the Utility Advisory Committee, Washington State Ferries, and Washington State Department of Transportation;
- a virtual community kickoff meeting[15];
- in-person site visits in May 2023 and September 2023 to present preliminary results and solicit feedback;
- and a presentation of the results of the analysis at the November 2023 Climate Change Advisory Committee meeting.

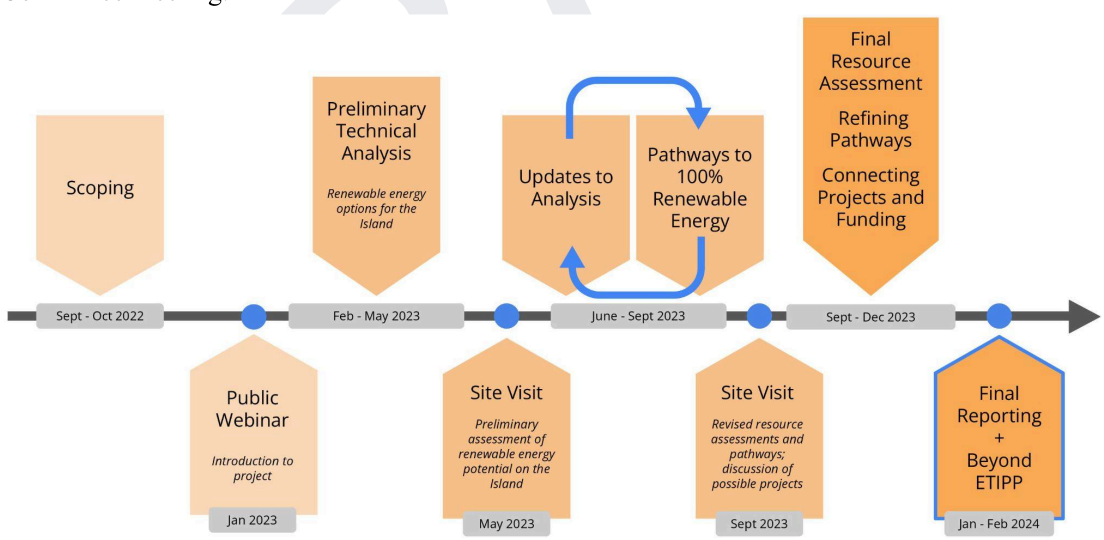

Figure 1. Timeline of technical assistance provided for the ETIPP Bainbridge project.

[14] Rose, D.; Arkema, K.; Moncheur de Rieudotte, M.; Devine, M.; Esterly, S.; Salamack, A. 2024. ETIPP Report: Bainbridge Island Improving Resilience. DOI.

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

Input from the City and community partners was integrated throughout each step of the technical analysis (Figure 1). The technical analysis included 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, distributed wind, and marine energy. These technologies and various combinations were explored through the development of pathways or scenarios to describe approaches that the City of Bainbridge Island could take towards meeting their 2040 goal of 100% renewable electricity.

Future Loads on Bainbridge

To predict future loads, we gathered data on current energy use on Bainbridge Island, identified factors that may influence electric 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 electric 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, Puget Sound Energy 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 the year 2022. The total annual electric consumption for 2022 was 264,566 MWh with a peak load of 86 MW in December. The monthly electricity consumption and the peak electricity demand varies seasonally, with approximately double the energy use in the winter than the summer months (Figure 2) due to heating demand.

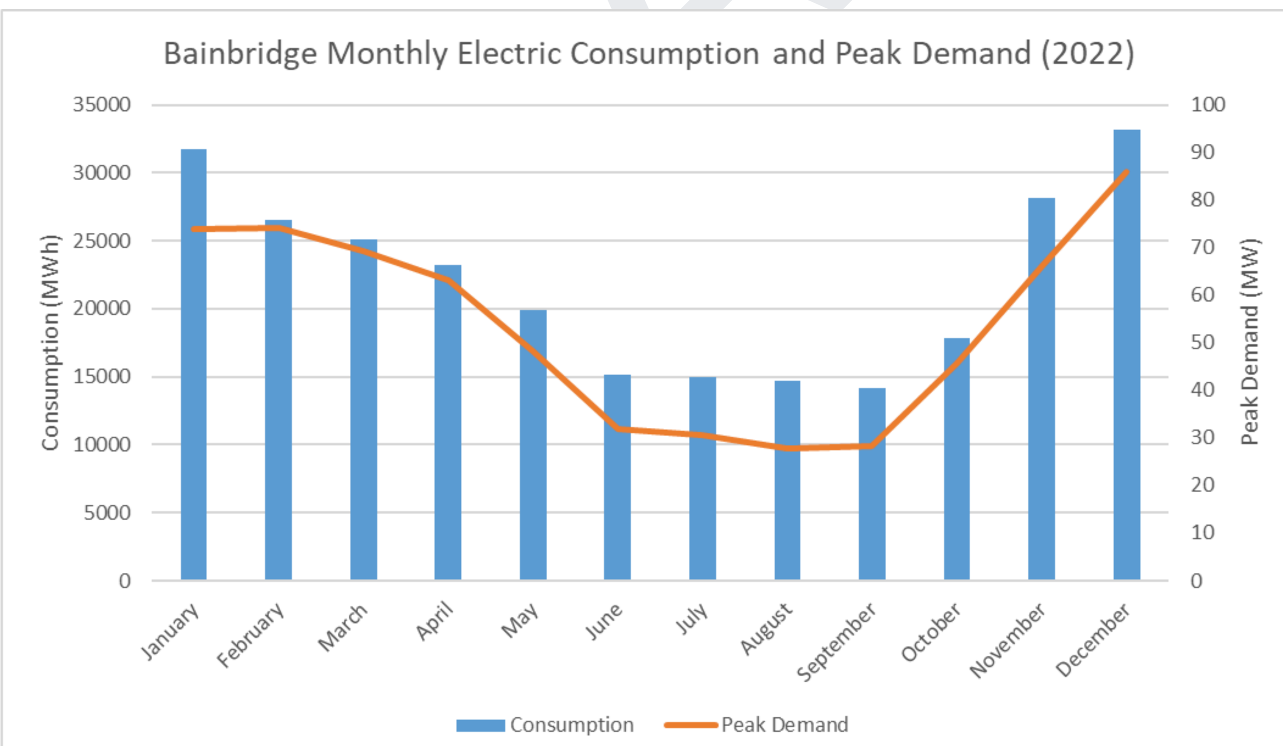

Figure 2. Bainbridge monthly electric consumption (MWh) and peak demand (MW) in 2022. Data from PSE.

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 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 electric vehicles 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 13% - 35% increase in electric 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. 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 electric vehicle 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).

Based on Bainbridge's goals, we only evaluated electric demand and did not include an analysis of other fuels. While electrifying buildings and vehicles increases electric 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 CO_2 and other greenhouse gas emissions and air pollutants, in alignment with the Climate Action Plan.

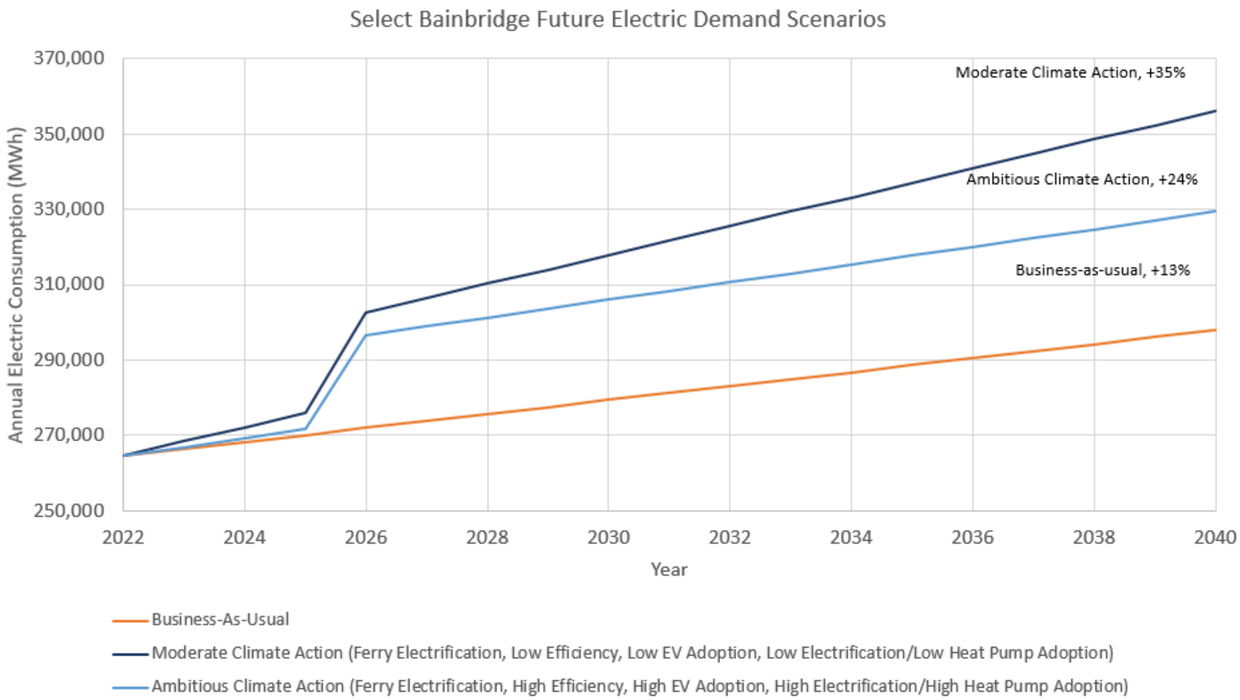

Figure 3. Projected future electric loads on Bainbridge Island, based on information from PSE, further electrification and efficiency plans.

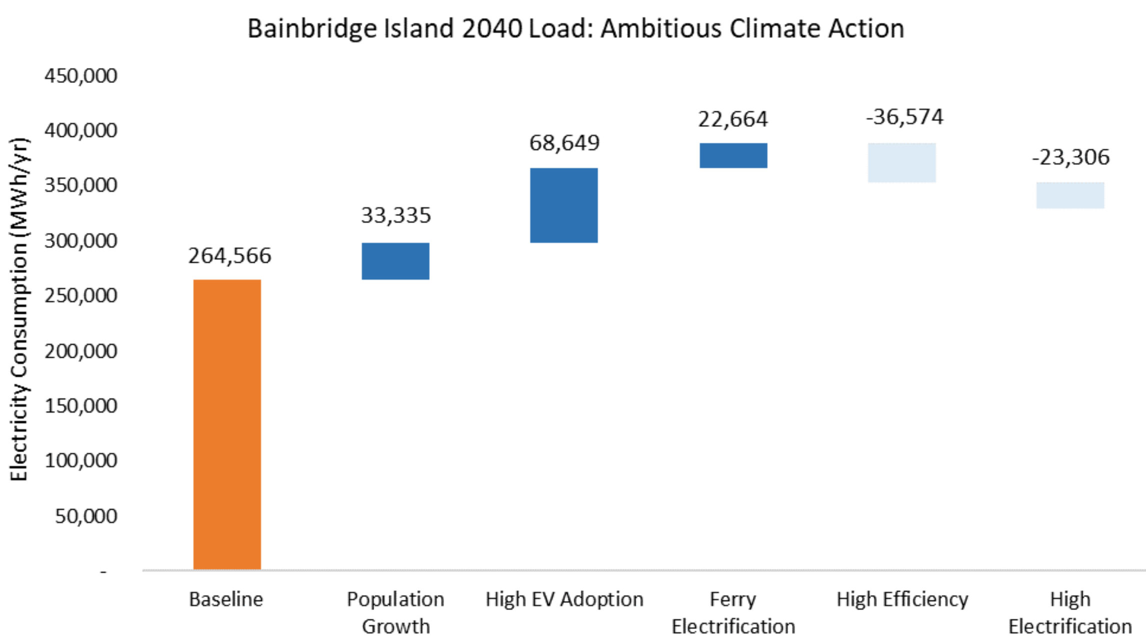

Figure 4. Breakdown of the Ambitious Climate Action scenario for 2024, showing effects that increase the future load (electrification, dark blue) and effects that decrease the future load (efficiency, light blue).

Assumptions

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

- The population of Bainbridge is expected to increase at a rate of approximately 0.7% annually[16,17]. Electric demand is estimated to increase approximately proportional to population.
- Ferry electrification demand was estimated based on Washington State Department of Transportation's Ferry System Electrification Plan[18]. 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[19].
- Bainbridge provided current EV registration numbers. As of 2023, 908 battery EVs and 343 plug-in hybrid EVs were registered on Bainbridge. This is estimated to be 5% of the current number of passenger vehicles on Bainbridge. We assumed 0.94 vehicles per person that travel an average of 30 miles per day[20]. We assumed that a typical EV that travels 30 miles per day uses 11.81 kWh of electricity[21]. 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[22].
- 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 heating with electricity; by design, heat pumps for space heating also add air conditioning[23]. Therefore, we evaluated the change in electric demand from shifting from non-electric or less-efficient electric space and water heating, and from no air conditioning or standard air conditioners to heat pumps. Based on Census heating fuel data[24], Washington heat pump data[25], and a recent City of Bainbridge Island 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 electric demand from shifting from this baseline to the scenarios described above based on typical home values for Bainbridge and the Pacific Northwest region based on Census data and the Residential Energy Consumption Survey[26] using the PNNL Facility Energy Decision System

[16] City of Bainbridge Island Electric Utility Municipalization Feasibility Study. 2017. https://www.bainbridgewa.gov/DocumentCenter/View/7983/Bainbridge-Island---Preliminary-Draft-Report---012317?bidId=

[17] COBI. 2017. Comprehensive Plan. https://www.bainbridgewa.gov/162/Comprehensive-Plan

[18] WSDOT. 2021. Washington State Ferries System Electrification Plan, Appendices. https://wsdot.wa.gov/sites/default/files/2021-11/WSF-System-Electrification-Plan-Appendices.pdf

[19] https://wsdot.wa.gov/construction-planning/major-projects/ferry-system-electrification

[20] https://www.fool.com/the-ascent/research/car-ownership-statistics/

[21] https://evbox.com/en/ev-home-charger-electricity-usage

[22] https://afdc.energy.gov/laws/all?state=WA

[23] https://www.energy.gov/energysaver/heat-pump-systems

[24] https://www.census.gov/programs-surveys/acs

[25] Weinberger, H. 2022. Seattle is no longer the U.S.'s least air conditioned big city. *Crosscut PBS.* https://crosscut.com/environment/2022/12/seattle-no-longer-uss-least-air-conditioned-big-city

[26] https://www.eia.gov/consumption/residential/

modeling tool[27]. We did not have sufficient information on commercial buildings to estimate existing or potential heat pump installations. Puget Sound Energy reported that commercial buildings represent 13% of customers[28] and 37% of electric load[29].

We consider that the 2040 goal of meeting future loads with renewable energy to be met 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 do to meet the instantaneous load at all times with distributed renewables.

[27] https://feds.pnnl.gov/

[28] Puget Sound Energy 2022 Count of Customers by Class

[29] City of Bainbridge Island Electric Utility Municipalization Feasibility Study. 2017. https://www.bainbridgewa.gov/DocumentCenter/View/7983/Bainbridge-Island---Preliminary-Draft-Report---012317?bidId=

Pathways to 100% Renewable Energy

In order to meet the projected electric load increases by 2040 with renewable energy, we identified and analyzed several different pathways that include various renewable energy technologies and are based on the interests of Bainbridge Island community members. First, we assessed the preliminary technical feasibility and potential amount of energy that could be generated by solar energy, an anaerobic biodigester, wind energy, and marine energy at an island-wide scale and seasonally. Then, we developed pathways that leverage and combine different renewable energy 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.

- *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 non-residential property owners to install solar.
- *Pathway #2: Community-led solar on-island*

  All reasonable public and private properties (residential and non-residential) are developed for solar in the near term.
- *Pathway #3: Solar + Biodigester + Buy the rest*

  All reasonable Pathway #1 properties 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 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 are developed for solar. The permitting process for one wind turbine is started. Additional power needed to meet goals is purchased 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 are developed for solar. The permitting process for one marine energy converter is started. Additional power needed to meet goals is purchased 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 photovoltaic (PV) solar panels, which convert sunlight into electricity. These panels consist of semiconductor materials that release electrons when exposed to sunlight, generating a 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 greenhouse gas emissions associated with electricity generation.

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[30]. 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[31].

Operations and maintenance (O&M) for solar PV is relatively simple, especially for fixed-axis systems, since 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, along with battery storage, can help smooth out these fluctuations in electricity generation.

This report investigates seasonal variability in the island-wide solar resource for Bainbridge Island 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 National Renewable Energy Laboratory's (NREL) National Solar Radiation Database (NSRDB)[32], which contains decades of solar radiation data covering the United States and some international locations. The NSRDB 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 (https://pvwatts.nrel.gov/) uses these data to estimate the energy production of more specific user-defined solar PV systems[33].

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

[30] U.S. Solar Photovoltaic System and Energy Storage Cost Benchmark: Q1 2020 (2021)
[31] https://www.energy.gov/eere/solar/articles/2030-solar-cost-targets
[32] https://nsrdb.nrel.gov/
[33] https://pvwatts.nrel.gov/

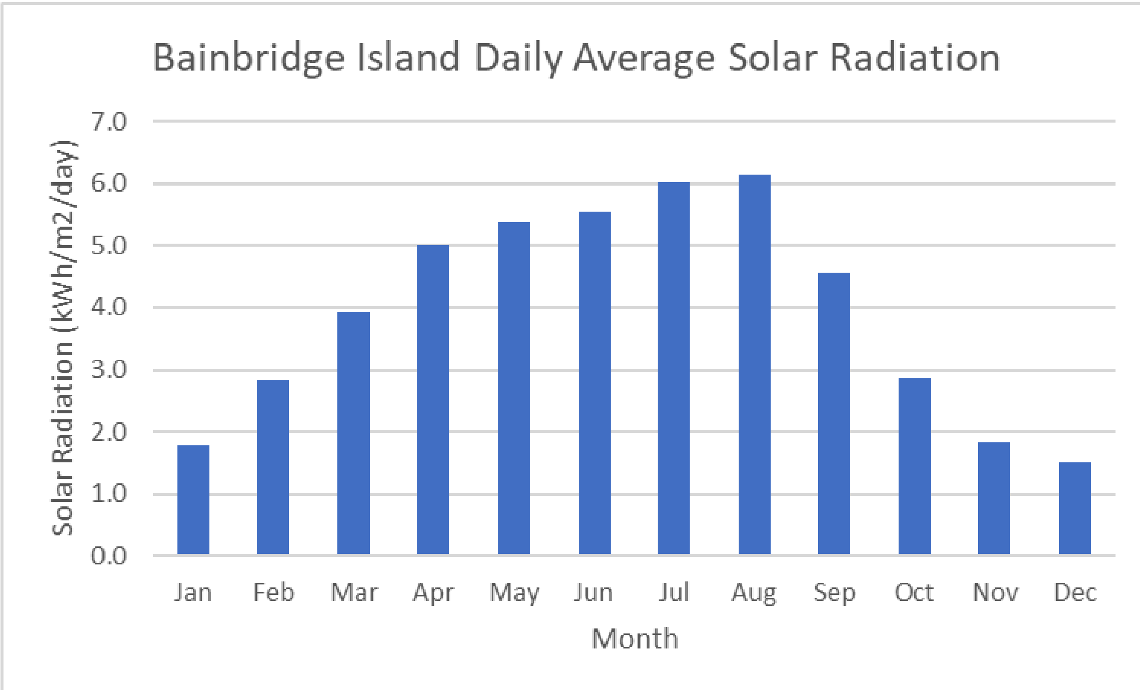

Figure 5. Monthly variation of solar radiation available on Bainbridge Island (from NSRDB).

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 2 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 non-residential 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 operations and maintenance yard, and police stations; other public entities, like schools, fire stations, and parks; private for-profit businesses; and private non-profit 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 carports could be installed 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-mounted followed by ground-mount and carport solar PV (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, Pavillion/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%**

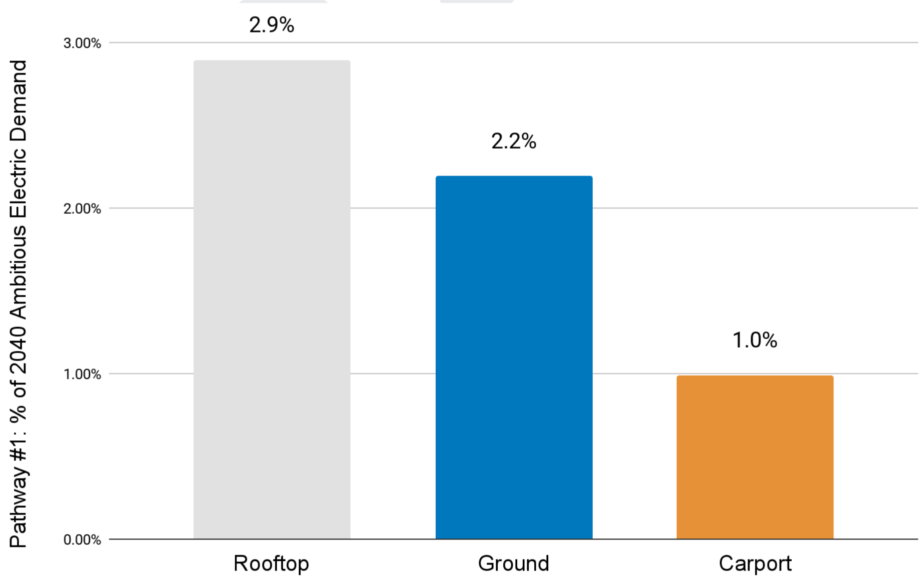

Figure 6. Percent of 2040 load generated from Pathway #1 sites by solar technology type.

Pathway 2: Community-led solar

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

For residential solar, this pathway utilized existing studies that estimate rooftop solar potential based on satellite and LIDAR data. We used NREL's Rooftop Solar Photovoltaic Potential in the U.S.[34] to estimate potential rooftop PV based on building area from the American Community Survey[35] and Kitsap County tax data[36]. These results were validated by comparing them to Google's Project Sunroof[37].

Our results suggest that developing all reasonable public and private rooftops (residential and non-residential) could result in up to 82 MW_{DC} of PV capacity. This PV 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 25.6% of the 2040 demand. To meet the remaining 2040 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.

[34] https://data.nrel.gov/submissions/121

[35] https://www.census.gov/programs-surveys/acs/data.html

[36] https://www.kitsapgov.com/assessor/Pages/DataDownload.aspx

[37] https://sunroof.withgoogle.com/

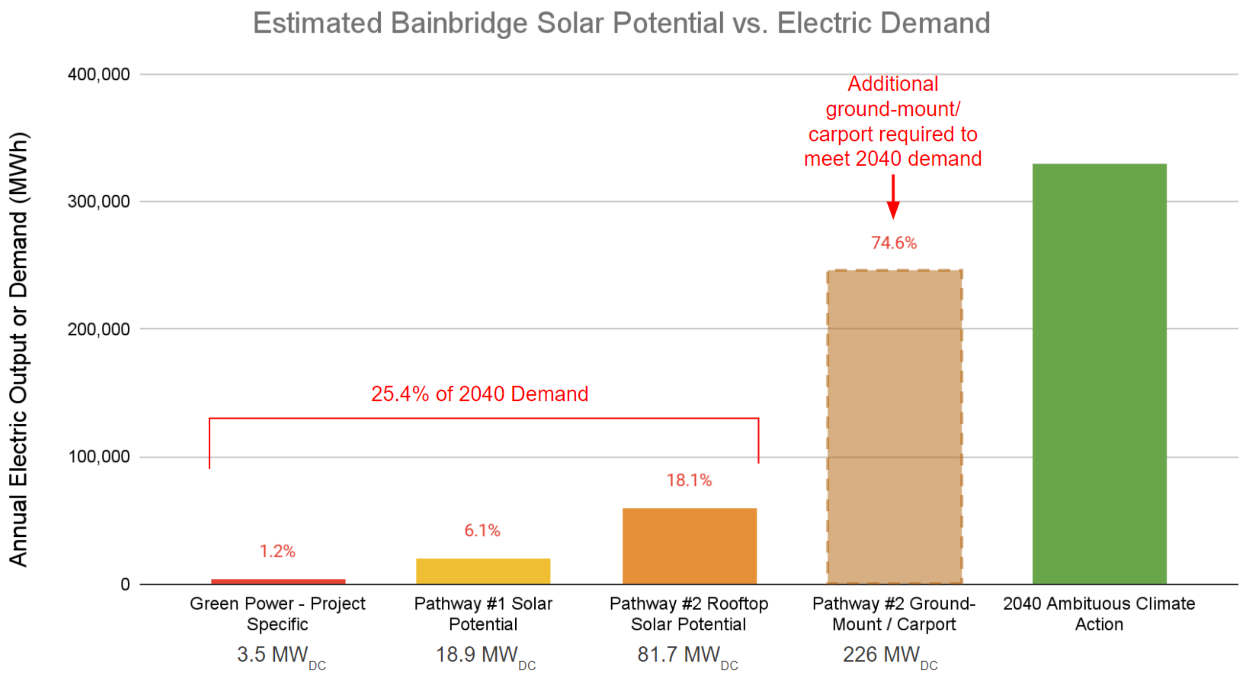

Figure 7. Existing solar and possibilities for Pathway #1 and Pathway #2 compared to current and future electric demand.

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. Alternatives to this approach could include procuring 100% renewable energy through a combination of on-island renewable generation and additional solar and green power 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 120kW solar project (rooftop, ground-mount, or carport) on a public agency property, funded by the City as part of carbon offsets for the new Ted Spearman Justice Center[38]. 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, the City should continue to encourage the adoption of energy efficiency measures, as

[38] COBI. 2024. Soliciting Public Properties to House a Solar PV Project on Bainbridge Island. https://www.bainbridgewa.gov/1479/2024-Solar-PV-Application-for-Public-Pro

decreasing energy consumption reduces the amount of on-island renewable energy generation needed to meet the Bainbridge Island goals.

Technology Contributions: Biodigester

To support Bainbridge Island's goal of 100% renewable energy by 2040, PNNL assessed the feasibility of waste-to-energy (WTE) using organic waste (biomass) as the primary feedstock. WTE is defined as energy recovery from waste by the conversion of non-recyclable waste materials into usable heat, electricity, or fuel through a variety of processes; while anaerobic digestion is a specific WTE process in which microorganisms break down 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 to the system for pre-heating 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 estimate 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 Bainbridge in 2016 and 2017 and found that the total usable amount of waste on Bainbridge 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

Utilizing the waste sources available in Bainbridge as reference, we calculated the expected biogas output from different feedstocks. We analyzed different feedstock contents because biogas output can vary by over 100% within the same waste category, depending on its composition[39,40,41]. As an example, Figure 8 shows three different mixed food waste streams from different sources, with a range of about 50 m^3/day of methane output potential 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 Impact Bioenergy values for further calculations.

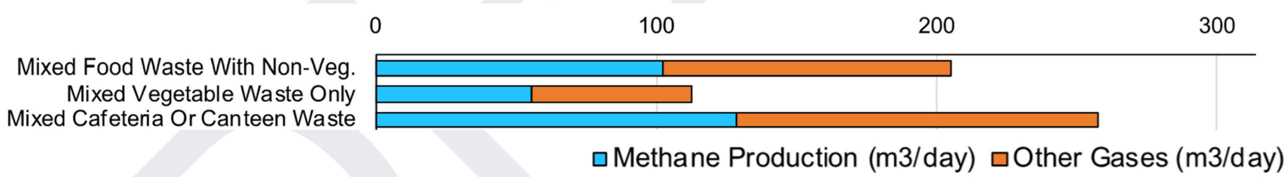

Figure 8. Biogas output difference for food waste.

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 Bainbridge annual electricity consumption is

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[39] Levis, J. and Barlaz, M. 2013. Anaerobic Digestion Process Model Documentation. Raleigh, NC: North Carolina State University. Available at https://silo.tips/download/anaerobic-digestion-process-model-documentation-james-w-levis-and-morton-a-barla

[40] Li, R., Chen, S., Li, X. 2009. Anaerobic co-digestion of kitchen waste and cattle manure for methane production". *Energy Source Part A: Recovery, Utilization and Environmental Effects* 31(20):1848–1856. https://doi.org/10.1080/15567030802606038

[41] Browne, J. and Murphy, J. 2013. Assessment of the Resource Associated with Biomethane from Food Waste. *Applied Energy* 104(C): 170–177. https://doi.org/10.1016/j.apenergy.2012.11.017

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 performed by 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 associated with them 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[42] (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 operation and maintenance cost of approximately $8k per year[43]. 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 operations and maintenance costs[44]. These estimates would result in a capital cost of $1.5M to $2.3M for a Bainbridge-sized system. The International Renewable Energy Agency estimates $1.8-6.3/W for anaerobic digestion systems[45] (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.

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[42] AgSTAR. 2012. Funding On-Farm Anaerobic Digestion. https://www.epa.gov/sites/default/files/2014-12/documents/funding_digestion.pdf

[43] Herrera et al. 2020. Sustainability assessment of a hybrid CSP/biomass. Results of a prototype plant in Tunisia. *Sustainable Energy Technologies and Assessments* 42: 100862. https://doi.org/10.1016/j.seta.2020.100862

[44] Xiao et al. 2022. Comparative environmental and economic life cycle assessment of dry and wet anaerobic digestion for treating food waste and biogas digestate. *Journal of Cleaner Production* 338: 130674. https://doi.org/10.1016/j.jclepro.2022.130674

[45] IRENA. 2012. Renewable Energy Technologies: Biomass for Power Generation. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2012/RE_Technologies_Cost_Analysis-BIOMASS.pdf

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. Picture 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 @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 & 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 EPA, food waste density is 22-45 lbs/ft^3

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 on Bainbridge Island 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 the available feedstock is critical to accurately estimate power generation potential and identify 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 the feedstock over time and the potential for supply disruptions will inform storage requirements.

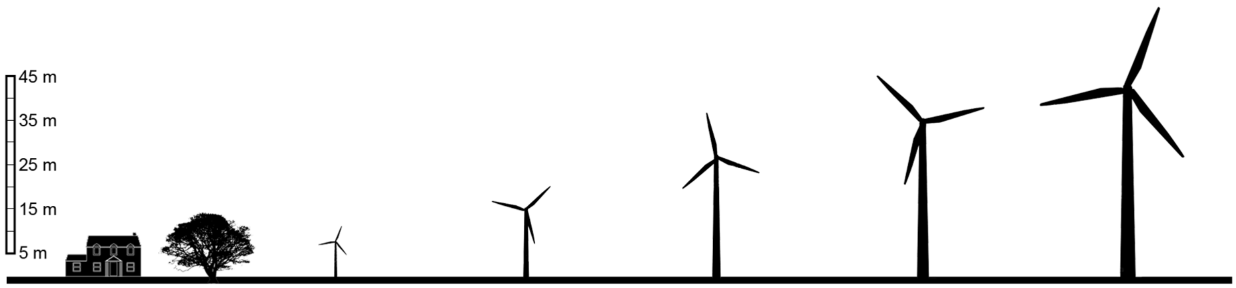
Potential end uses that can consume the energy produced need to be identified. End uses may consider thermal versus electrical loads and timing of energy needs versus energy production, both daily and seasonally. As noted, a biodigester can generate heat or power, but as with all energy conversion processes, power generation is less efficient. Therefore, thermal loads should be prioritized over electric loads for efficiency purposes. 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 above ground 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 (onshore or offshore) 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 they supply energy to. 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 that 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 case starts at the small end of the distributed wind size/capacity scale and is located 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, Hawaii (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.

(a) (b)

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, WA (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 the City with the information to weigh the 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[46], WIND Toolkit[47], and Wind Report[48]). The three high-resolution wind models provide the ranges of wind speed estimates across Bainbridge Island (Figure 12). These wind speeds can in turn be used to identify areas of higher relative wind resource to be analyzed for wind 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 on 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 on Bainbridge Island and where the wind is predominantly coming from (north and south-southwest).

[46] DTU. 2023. Global Wind Atlas. https://globalwindatlas.info/en
[47] NREL. 2023. WIND Toolkit. https://www.nrel.gov/grid/wind-toolkit.html
[48] Bergey Windpower. 2023. https://www.newrootsenergy.com/wind-report-modeling-tools

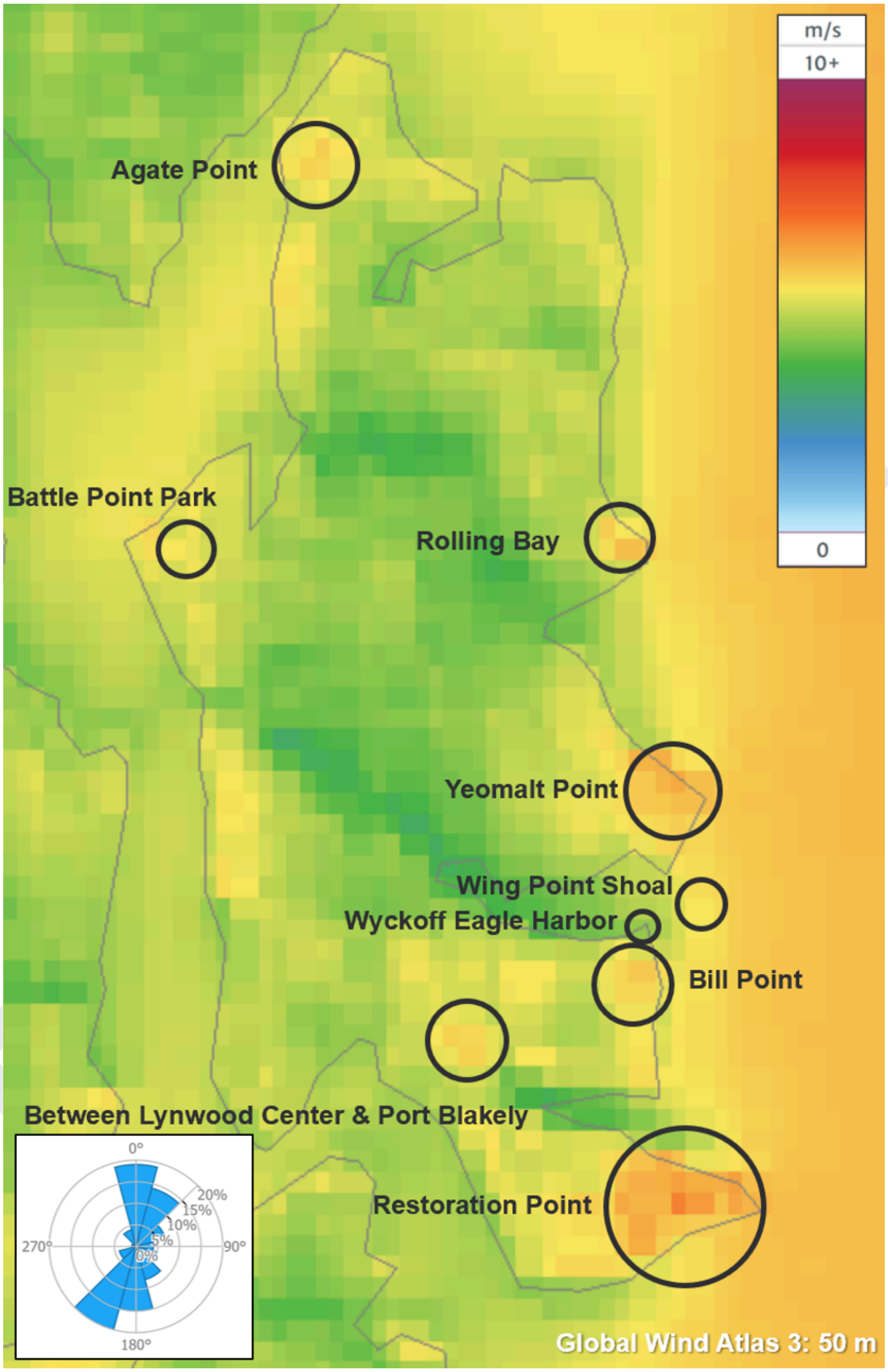


Figure 12. Wind speed and direction at 50 m above ground level from Global Wind Atlas at Bainbridge Island.

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

In addition, nearby obstacles, including buildings and trees, can create turbulence which reduces the amount of available wind resource that wind turbines can utilize. According to David Barts' *Common Trees of Bainbridge Island*[49], the maximum heights of many of the trees on Bainbridge Island 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.

[49] Barts, D. 2018. *Common Trees of Bainbridge Island*. Available at https://bainbridgenature.files.wordpress.com/2018/11/ctobi_draft_preview.pdf

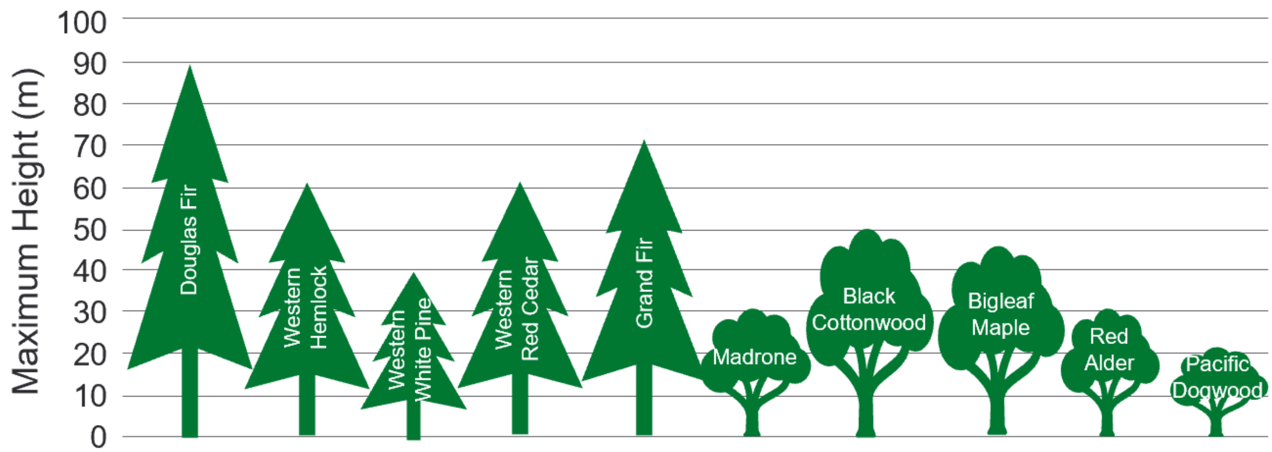


Figure 13. Maximum tree height based on number reported in *Common Trees of Bainbridge Island*.

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 8 rotor diameters (the diameter of the circular area swept by the wind turbine blades) between wind turbines in lines parallel to the predominant wind direction and 3 rotor diameters between wind 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. The City provided PNNL with initial locations of potential wind deployment which have the advantages of open space and proximity to generation or transmission infrastructure. These initial locations include Battle Point Park, Wing Point Shoal, and Wyckoff Eagle Harbor (Figure 12). PNNL performed the wind resource and energy generation estimates for those sites, along with a selection of additional sites that were identified based on the results of the initial island-wind 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.

Since 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 m to 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 m to 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	27 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 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 onsite 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.

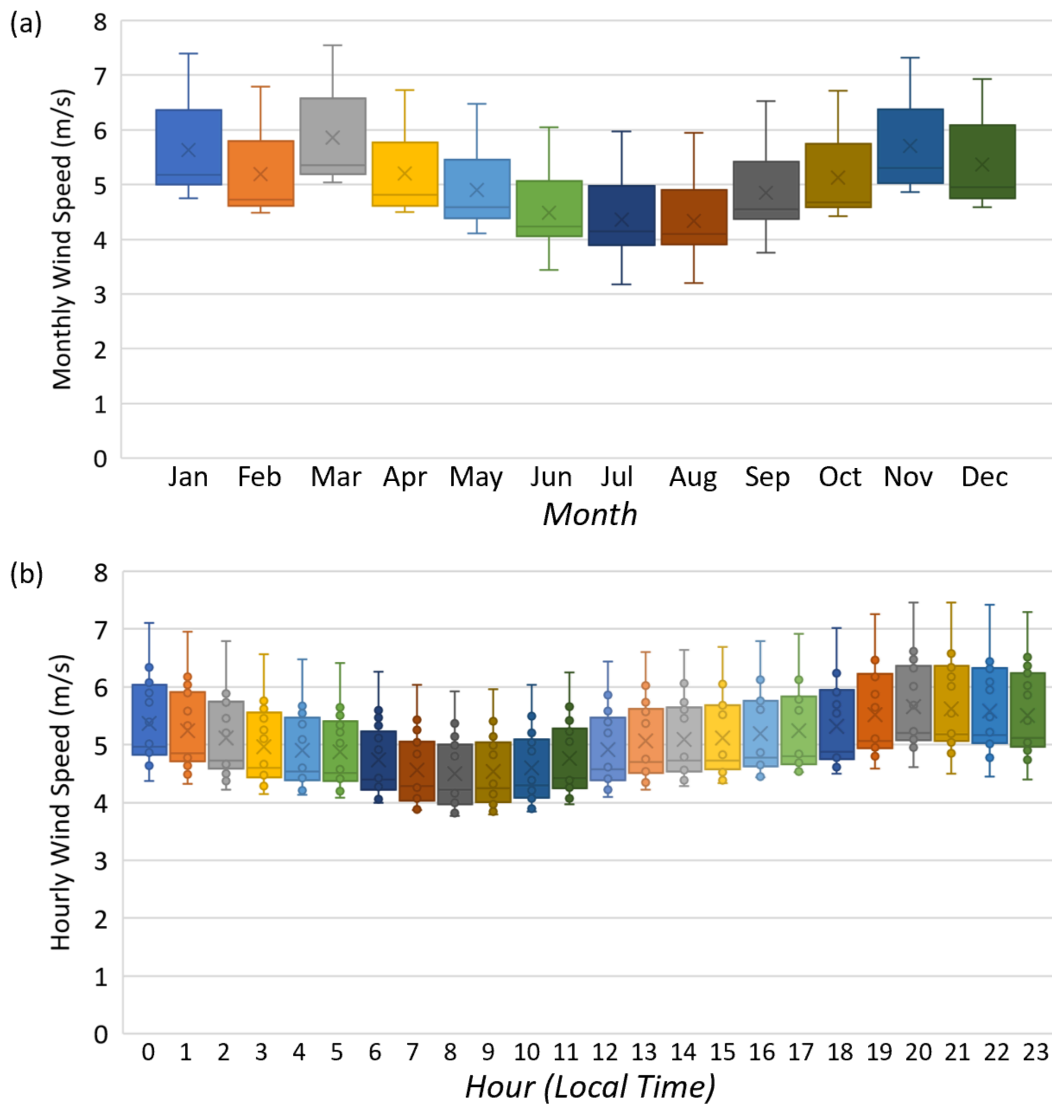


Figure 14. (a) Monthly and (b) hourly average wind speed ranges across the three wind resource models used in this analysis (Global Wind Atlas, WIND Toolkit, and Wind Report) and across the sites evaluated in Figure 12.

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 percent 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 4000 and 8000 MWh for the largest turbine in the analysis, the GE 2.3 MW-116.

Table 9. Annual average hub height wind speed, annual energy estimate, and percent of annual Bainbridge demand that a single turbine would meet.

Site	Bergey Excel 15	Eocycle EOX S-16	NPS 100C-28	EWT DW 54-900	GE 2 MW-116
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 - 1363 MWh 0.3 - 0.5%	4.8 - 5.9 m/s 4000 - 5638 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 - 1324 MWh 0.3 - 0.5%	5.1 - 6.0 m/s 4260 - 5796 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 4136 - 4535 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 - 1459 MWh 0.3 - 0.6%	5.0 - 6.4 m/s 4297 - 6319 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 - 1500 MWh 0.3 - 0.6%	5.2 - 6.5 m/s 4543 - 6575 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 - 1613 MWh 0.3 - 0.6%	5.0 - 6.6 m/s 4160 - 6763 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 - 1420 MWh 0.3 - 0.5%	5.2 - 6.4 m/s 4368 - 6449 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 - 1407 MWh 0.3 - 0.5%	5.0 - 6.3 m/s 4077 - 6228 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 - 2000 MWh 0.3 - 0.8%	5.1 - 7.4 m/s 4230 - 7891 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 and 2022 ranged from $4,000/kW to nearly $8,000/kW; and operations and maintenance costs for small wind turbines are ~$35/kW/year[50].

Renewable energy incentive programs are beneficial to reducing the cost of deploying renewable energy systems. At the state level, California provides the last remaining state cash incentive program that regularly provides funding for distributed wind systems. Funding opportunities for Bainbridge Island do exist, however, at the federal level. The U.S. Department of Agriculture Rural Energy for America Program provides grant funding and loan financing to agricultural producers and small businesses for renewable energy systems or efficiency improvements[51]. Additionally, the federal Business Energy Investment Tax Credit (ITC) and the Residential Renewable Energy Tax Credit are federal policy mechanisms that offset some of the capital costs of qualified renewable energy projects. The Inflation Reduction Act (IRA) extended the Residential Renewable Energy Tax Credit at 30% through 2032, after which the credit value is phased down until it expires in 2035. The IRA also extended the Business Energy ITC at 30% through 2024. Provisions allow for additional, stackable bonus credits for communities with brownfields, high fossil fuel employment or tax revenue with higher-than-average unemployment rates, or that have recently closed coal mines or coal-fired electric generation plants. Beginning in 2025, the ITC will be replaced by the Clean Electricity ITC, which will be available to all energy generation technologies with zero or net-negative carbon emissions, and for which the same bonus credits will be available[52].

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 utilizing state and federal tax credits, and also likely benefited from their nearby proximity to the turbine manufacturer[53]. 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 coop around $100,000 per year after project expenses were deducted, since 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[54].

While the above wind assessment for Bainbridge Island focuses mainly on the wind resource availability, turbine size options, and recommended considerations, the Distributed Wind Energy Futures Study[55] provides additional techno-economic guidance to assess the feasibility of distributed wind deployment at the county level. The Futures Study employs a metric called threshold capital expenditure (CapEx), which is an indicator of the amount of capital

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[50] Orrell, A. C., Sheridan, L. M., Kazimierczuk, K., & Fensch, A. 2023. Distributed Wind Market Report: 2023 Edition. Pacific Northwest National Laboratory, Richland, WA, USA. PNNL-34661. https://doi.org/10.2172/1996555

[51] https://www.rd.usda.gov/programs-services/energy-programs/rural-energy-america-program-renewable-energy-systems-energy-efficiency-improvement-guaranteed-loans

[52] Orrell, A. C., Sheridan, L. M., Kazimierczuk, K., & Fensch, A. 2023. Distributed Wind Market Report: 2023 Edition. Pacific Northwest National Laboratory, Richland, WA, USA. PNNL-34661. https://doi.org/10.2172/1996555

[53] NRECA. 2022. Distributed Wind Finance Case Study: 10 kW for 40+ Years. https://www.cooperative.com/programs-services/bts/radwind/Documents/RADWIND-Finance-Case-Study-Long-Term-Savings-Oct-2022.pdf

[54] NRECA. 2021. Distributed Wind Case Study: Rural Electric Convenience Cooperative. https://www.cooperative.com/programs-services/bts/radwind/Documents/RADWIND-Case-Study-RECC-May-2021.pdf

[55] McCabe et al. 2022. Distributed Wind Energy Futures Study. https://www.nrel.gov/docs/fy22osti/82519.pdf

that could be invested for a distributed wind project while still maintaining profitability. Threshold CapEx calculations consider wind resource potential, the technical performance of distributed wind energy systems, the value of distributed generation, and the operational lifetime of distributed wind systems. Higher values of threshold CapEx mean higher favorability for distributed wind energy. For Kitsap County, the threshold CapEx for front-of-the-meter and behind-the-meter distributed wind systems is $450-530/kW and $7,000-8,400/kW, respectively.

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 11). Second, once areas of wind interest are identified, onsite wind measurements are recommended at or near the anticipated turbine hub height in order to refine energy generation estimates. These onsite wind measurements are generated by installing a meteorological tower with anemometers or by deploying a lidar, and it is recommended that one year of wind observations are gathered to accurately capture the seasonal cycle of wind resource.

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.Thus, 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).

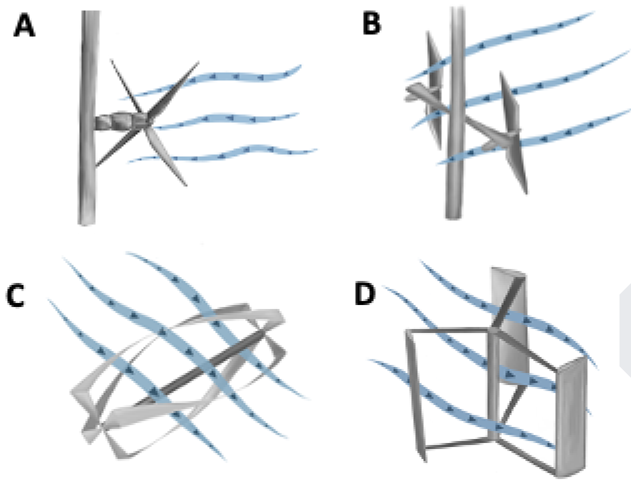

Figure 15. Axial-flow turbines (a, b) rotating on the axis of the incoming water flow, while cross-flow turbines (c, d) rotate across the flow.

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 30kW/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 inline with speeds observed in Puget Sound. We used NREL's Marine Energy Atlas[56] 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 Pass.

[56] https://maps.nrel.gov/marine-energy-atlas/

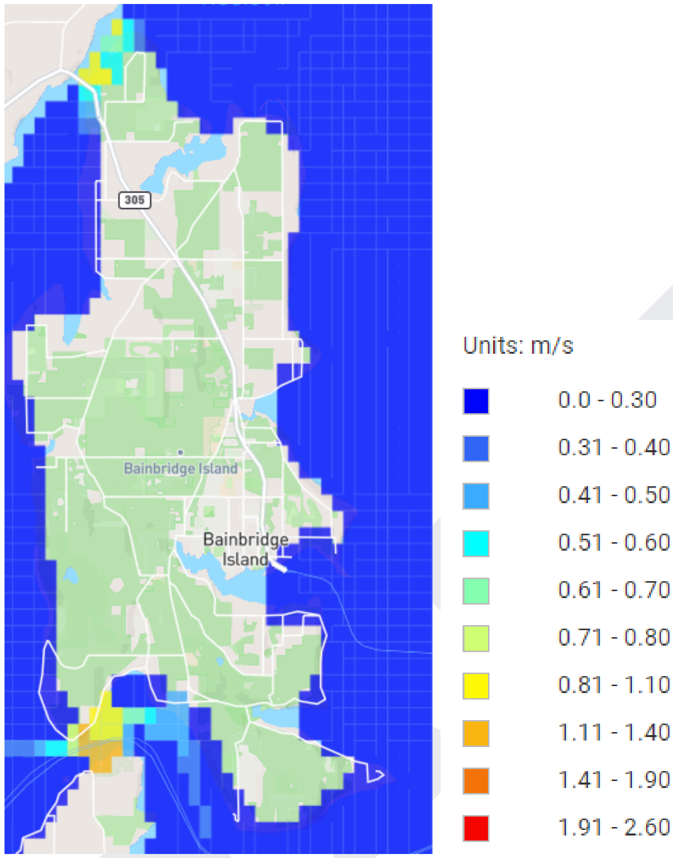

Figure 16. Annual depth-average tidal current speed (m/s). From NREL's Marine Energy Atlas, data from Haas et al. 2011[57].

Locations of Interest

To assess the potential for marine energy at Agate Pass 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 or RM2[58]. This reference model was created by the Department of Energy 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 Agate Pass over a two month period from July 27-September 9 in 2015 with an acoustic doppler current profiler. These measurements are used by NOAA to predict tidal currents around the Puget Sound. Since tidal currents vary with the position of the moon and sun, two months of data is enough to understand how the shape of the bottom of the ocean influences the tidal currents. Using these types of measurements, tidal currents can be predicted indefinitely into the future. These predictions are posted on the NOAA website[59] for recreational or

[57] Haas et al. 2011. Assessment of Energy Production Potential from Tidal Streams in the United States. https://doi.org/10.2172/1219367
[58] https://tethys-engineering.pnnl.gov/signature-projects/reference-model
[59] https://tidesandcurrents.noaa.gov/

commercial use. We used the reference model turbine and the velocity measurements to estimate marine energy generation for both a shallow water and deep water deployment, at 8.7 ft and 21.9 ft. 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.

The Reference Model 2 provides a power curve which describes the power output of this turbine at different current speeds. The power curve was applied to each time in the ADCP 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, respectively). There may be areas of Agate Pass 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 are unlikely to meet significant amounts of Bainbridge's generation in the near future at Agate Pass.

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 for meeting the demand of a particular load and is likely worth revisiting as the technology improves. At this stage, if Bainbridge Island were interested in exploring tidal energy, the most viable option would be to pursue federal funding for a research project in collaboration with the Department of Energy'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 analyze, design, and test particular devices in the water to help advance the knowledge and technology around tidal energy for community-based applications. 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, which recently announced the first of five phases totalling $35 million in investment in tidal demonstration projects[60]. One of the projects chosen is led by Orcas Power and Light Cooperative, which 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

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 in order to achieve the possibilities described in Pathway #2. Additional off-island purchases are likely needed to meet the goal, at least in the near-term.

[60] https://www.energy.gov/articles/biden-harris-administration-invests-nearly-16-million-advance-marine-energy-us-1

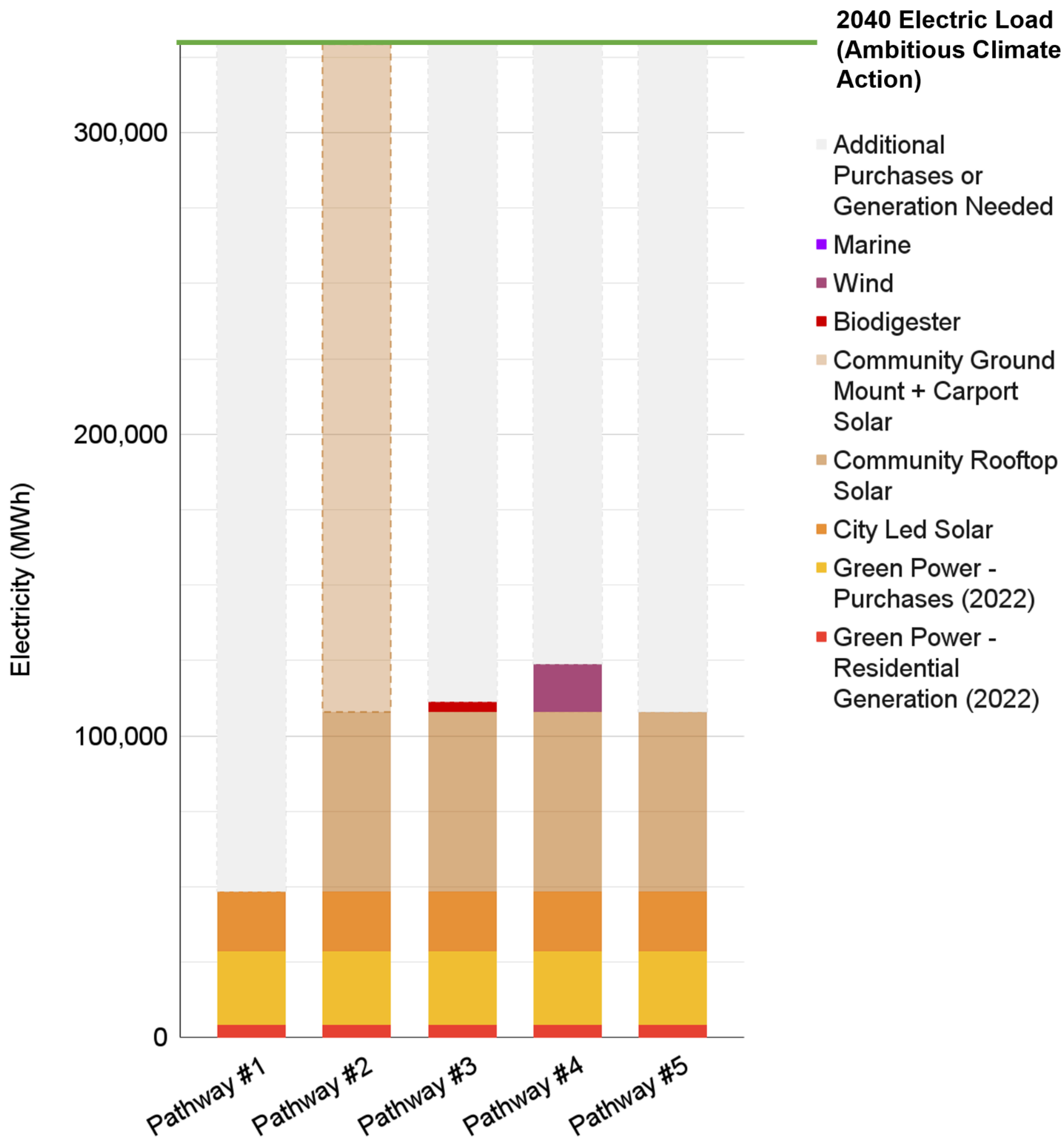

Figure 17. Contributions of each pathway to 2040 energy consumption on Bainbridge Island.

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)	83,602 (Pathway #1 and #2)	7,143 (Pathway #1)	3,175 (Pathway #1)	3,485 (Impact Bioenergy estimate)	15,969 (one 2MW turbine at 3 sites)	132 (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%
Cost (2023 USD)	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 H2 2023 US Solar PV system pricing	$61,600 - $93,800 per ton of waste Source: Xiao et al. 2022	Small distributed: $7,850/kW Midsize distributed: $3,333/kW Utility scale: $1,370/kW Source: Distributed Wind Market Report: 2023 Edition	~$6,500 - $26,000/kW Few commercial technologies, but significant government funding likely available Source: OES Report 2015

In addition to generating renewable energy on island, there are several options for purchasing off-island credits or offsets in order to meet the goal of 100% renewable energy by 2040, listed below. The City already participates in several purchase programs, and purchased 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 have been discussed and some initial assessments have been completed by PSE.

In deciding how much to purchase, individuals, businesses, or the City 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 towards meeting the 100% renewable energy goal.

In addition to PSE's purchase programs, the overall mix of energy provided by the utility is expected to become more renewable by 2045 in alignment with the requirements of Washington's Clean Energy Transformation Act[61]. Bainbridge will need to decide if this cleaner mix contributes towards meeting the goal.

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 emission-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.

Conclusions and Implications for City Priorities

Based on technical analysis and discussions with the Bainbridge Island community at 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 due to tree cover sites are limited, 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 Pass, but do not generate significant amounts of power and the available 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 the City of Bainbridge Island include any efforts to advance on the solar pathways. This could include beginning to install solar on the remaining suitable City facilities, development of educational materials or

[61] https://www.cleanenergyplan.pse.com/

outreach to residents 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 the goal of 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

Table A1. Full list of 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	Pavillion/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

The spatial data sources for the marine energy and wind energy are available as individual map PDFs here and are included in the Resilience GIS Map Package from Google Drive - https://tinyurl.com/56txyutd.

BI CAP Dashboard (2/15/24)

Goal: Foster public transparency by developing clear, concise, and easy to use information that enables the City Council, City Staff, and Community to evaluate the progress in meeting the goals of the BI Climate Action Plan.

Audience: There are multiple audiences for the dashboard (e.g., City Council, public, CCAC members, and City Staff).

Proposed Process for Developing Dashboard

1. CCAC members areas of interest for developing goals for the Dashboard.

Name	GHG	Energy	Building	Transportation	Waste	Natural Environment	Engagement	Implement
Steve	X	X		X				
Julie					X	X	X	
Sanjay		X		X			X	
Ray	X	X				X		
Mike C.	X		X	X				
Michael K.		X	X			X		
Kevin			X				X	X
Jens								
Derik								

2. Form three subgroups. Each subgroup selects 1-3 goals using the criteria agreed upon above (develop goals by March 11th for discussion at the March 20th CCAC meeting)

- GHG/Energy/Buildings (Steve, Ray, Michael K., Jens)
- Transportation/Waste/Natural Environment (Derik, Sanjay, Mike C.)
- Engagement/Implementation (Julie, Kevin)

3. Develop criteria for evaluating which goals to consider for each area (review and approve at the February 21st CCAC meeting).

- Decision Making/Relevance: Would it assist in decision making for the City Council and City Staff and help to evaluate and explain progress in meeting the CAP goals? Would it help the CCAC provide advice to the Council?

- Understandable/Relatable: Is it easy to understand and relatable for the public?

- Data Availability/Quality/Cost: Is the data available and easily accessible? Is the data of high quality (e.g., QA/QC has been conducted)? Is there a cost for obtaining the data and what is the cost?

- Staff Effort: What is the level of effort for staff to track and update the goal?

4. CCAC reviews and approves the goals at the April 17th CCAC meeting.

5. Subgroups meet and have discussions at subsequent CCAC meetings. Draft Dashboard by July 17th CCAC meeting.

Questions for CCAC

1. What platform do we use (it will depend on the data but a few examples of platforms)?

- Tableau: Headwaters Economics has created an interactive tool in Tableau that helps city planners and leaders prioritize adaptation strategies through the lens of equity. Tableau was widely used during COVID-19 to present and track the state of the pandemic.

- Power BI, Microsoft's product, is likely a lower cost option for dashboards and is also widely used by governments to visualize their data. It lacks some of the elegance of Tableau but it may be easier for City staff to administer. The WA DOH is using it for reporting on respiratory illness statewide. It also may be included in the City's subscription to Office 365 (depending on plan level).

- Infogram is a low-cost data visualization service that is used widely and is optimized for mobile devices. It does not require any training to use quickly, unlike Tableau and Power BI.

2. Who is responsible for creating the dashboard and collecting, managing, and maintaining database?
- City staff or a contractor could be responsible for collecting, managing, and maintaining the database.
- The CCAC could help develop the database or could be more involved in data collection and management.

3. Do we engage the public in selecting the goals and providing advice on the Dashboard?
- Mixed.
- Some say yes and others say no that the dashboard will be reviewed by the City Council and City Staff so could ask for public input during that process but not necessarily separately.

4. How often should the dashboard be updated?
- Need to how often to evaluate the costs/staff work/etc. for the dashboard.