ISLAND INSTITUTE

Electrifying Maine's Working Waterfront

A STUDY OF SHORESIDE CHARGING INFRASTRUCTURE

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with Haley Ward, Inc.

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

BACKGROUND AND PURPOSE

Working waterfronts are economic engines and cultural touchstones—and increasingly, important players in climate solutions. Ports and working waterfronts worldwide are moving toward electrification, with growing interest in electric and hybrid marine propulsion.

On Maine's coast, Island Institute has been leading the marine electrification movement since 2020 as part of our efforts to ensure an enduring and prosperous marine economy. To date, the organization has helped transition more than twenty workboats from gas to electric propulsion, deployed demonstration boats to build confidence in electric systems, and conducted foundational greenhouse gas assessments across the seafood sector that identified fuel use as a top contributor of emissions. Every step of the way, Island Institute has grounded its marine electrification work in real data and on-the-water testing, actively building the ecosystem and buy-in needed to make this ground-breaking transformation possible.

To guide this transition, Island Institute led the first statewide analysis of shoreside electric vessel charging potential, conducted by Homarus Strategies LLC in partnership with Haley Ward, Inc. This report provides a broad perspective on the existing conditions, feasibility, planning and implementation considerations, and technical solutions to expand electrification of the marine sector along the coast of Maine. There are several working definitions of the term *working waterfront*. For the purposes of this report and analysis working waterfront means "a physical place that facilitates or provides access to the water in order to enable economic activity."

The audience for this report is policy makers, working waterfront owners, operators and users, municipal leaders, and all other community stakeholders interested in shoreside electrification.

Establishing reliable shoreside charging infrastructure will require careful planning, capital investment, and coordination with utilities. This report provides recommendations for planning the siting of shoreside charging infrastructure, in alignment with statewide initiatives like *Maine Won't Wait*. It includes potential infrastructure locations, educational resources, and a geospatial tool to guide future investment and development.

OPPORTUNITY

At a time when Maine's natural resource-dependent businesses like fishing, aquaculture, and marine tourism face mounting pressures of aging infrastructure, climate impacts, and rising costs for fuel, materials, and services, a great opportunity exists.

Maine's working waterfronts are at the start of a once-in-a-century energy transition, with opportunities to decarbonize through electrification, hybrid systems, and efficiency technologies.

The scale of Maine's marine electrification potential is significant: research from similar regions, such as the Nova Scotia Lobster Fleet Electrification Assessment, suggests over 2,300 vessels could be prime candidates, offering greenhouse gas reduction potential equivalent to roughly 35,000 cars annually. The potential for impact is enormous if we can bring solutions to scale.

A history of sustainable practices, the innovative and entrepreneurial nature of our fishermen and sea farmers, the backing of state level recommendations, and most notably, the size and makeup of our commercial fleet make Maine the right place for this work.

METHODOLOGY

To assess the suitability of Maine's working waterfronts for electric vessel charging, a comprehensive geospatial analysis and Multiple Criteria Evaluation (MCE) was conducted across all 1,605 waterfront areas.

The study focused on four vessel types: commercial fishing day boats, aquaculture craft, small recreational outboards, and larger recreational yachts. These "use cases" helped frame the analysis, as each was evaluated based on fuel type, vessel operation, and available land use and infrastructure—factors that shape how shoreside charging can meet operational demands.

The analysis incorporated data on power grid infrastructure from Central Maine Power and Versant Power, vessel registrations, marine traffic patterns, and existing waterfront facilities to assess each site's potential for electrification. Each was then scored from 0 (least suitable) to 3 (most suitable) across four criteria: power supply conditions, current local demand, market potential for future development, and overall site viability.

Extensive stakeholder engagement complemented the geospatial work, including semi-structured interviews with 35 fishermen, shoreside business owners, municipal officials, electrical engineers, and grid operators, as well as four community roundtable discussions in Ellsworth, Machias, Portland, and Rockland.

THREE TYPES OF CHARGING INFRASTRUCTURE

Understanding the three different types of chargers, their energy needs, and charging times is key to addressing Maine's charging infrastructure challenges.

LEVEL 1 – This type of infrastructure requires a typical 120-volt outlet (like outlets found in homes or commercial spaces) and is the simplest and most readily available electrical infrastructure. Typically, users use this to charge basic batteries or small utility vessels/vehicles.

LEVEL 2 – This type of infrastructure requires a 220/240-volt outlet (like outlets for electric dryers or stoves) and provides more power resulting in shorter charging times. Typically, users will use this to run high-power appliances, tools, and machinery, but can also use this for charging larger vessels or vehicles. Many at-home chargers for electric vehicles use this type of infrastructure as well.

LEVEL 3 – This type of infrastructure, commonly referred to as Direct Current Fast Charging (DCFC) or simply Fast Charging, can be designed to deliver varying degrees of high power. As indicated in the name, this uses direct current energy (versus Alternating Current (AC) conventional to level 1 and level 2 charging) to charge a battery. This requires 480 volt/3-phase power. In most cases, the current grid is not set up for this type of power and likely requires additional infrastructure such as transformers, updated electrical lines, or other technology solutions.

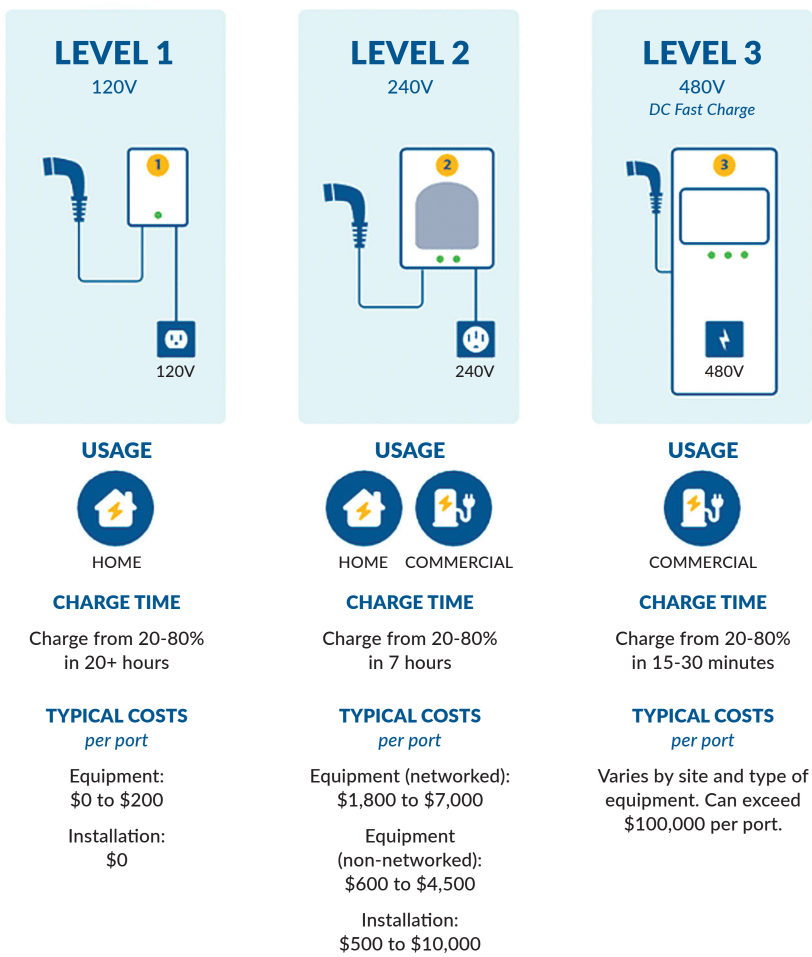

Figure 1.
Shows the differences between the three charging infrastructure types for typical electric cars, including current charging times and typical costs. Information is based on 2024 dollars and metrics.

WHAT IS 3-PHASE POWER?

Most homes use single-phase power, where voltage follows a single sine wave. Three-phase power uses three waves, each 120° apart, providing smoother, more efficient electricity with relatively smaller wires and equipment. It is ideal for large buildings, factories, ships, and heavy-duty electric motors.

SITING CHARGING INFRASTRUCTURE

The successful development of shoreside charging infrastructure across a variety of working waterfronts and use case types requires three basic features:

1. Space for chargers and charging pedestals
2. Space for vessels to connect and charge
3. Delivery of power to support charging demand

Other considerations may include community planning and zoning regulations, future land use planning, economic development trends and activity, existing business and user engagement, utility engagement, infrastructure needs (outside of electrical grid), and other resiliency measures. These criteria help municipal leaders, owners, operators, and users of the working waterfront, and other stakeholders assess the availability and suitability of shoreside charging infrastructure.

PLANNING EFFORTS TO SUPPORT MAINE'S WORKING WATERFRONT USERS

Maine's working waterfront areas vary from larger commercial wharves to simple boat launches with both privately and publicly owned infrastructure. Though the decision-making factors may differ between ownership types (private entities may prioritize the return on investment or capital incentives, while public entities may prioritize future infrastructure demand or other environmental factors such as emissions reduction), the planning, design, and implementation strategies require the same considerations:

- Assess and identify the specific needs of community stakeholders (residents, tenants, business owners, customers etc.)
- Evaluate the opportunities and limitations of the current grid power capacity and infrastructure
- Identify and develop overall community goals and financial options for electrification

These considerations and practical guidance for developing shoreside infrastructure are included in Section IV. Next Steps Planning Guide of this report.

KEY FINDINGS AND RECOMMENDATIONS

1. Marine electrification will support Maine's climate goals.
This analysis demonstrates how marine electrification can support *Maine Won't Wait: A Four-Year Climate Action Plan* (2024 update) by providing a foundation for strategic clean energy investments that strengthen business resilience and economic competitiveness.

2. There is strong potential along the coast for single- and multi-use case charging.
233 working waterfront locations are highly suitable for charging a single vessel type—whether commercial fishing day-boats, aquaculture craft, small recreational boats, or larger yachts. 140 additional sites can accommodate multiple vessel types, offering flexible charging solutions.

3. There are clear regional advantages.
Different coastal regions match different vessel types:
- Southern Maine (Kittery through Casco Bay): Best for recreational vessels
- Midcoast (Sheepscot to Penobscot Rivers): Best for aquaculture vessels
- High-value commercial harbors (Stonington, Bass Harbor, Jonesport/Beals): Best for commercial fishing fleet electrification

5. Fast charging power access is a limiting factor.
Only 25% of Maine's working waterfront facilities have access to the 3-phase power needed for Level 3 fast charging within 250 feet. Most sites would need major electrical infrastructure upgrades, which will require careful planning, capital investments, and coordination with the electrical utilities.

6. Mooring systems complicate charging.
Many commercial fishing harbors use moorings instead of docks, making it harder to connect boats to shore-based chargers. This affects how and where charging infrastructure can be deployed.

7. **There is no universal charging solution.**

   Different boats need different approaches. Large battery systems may require fast charging at the dock, overnight charging, or even recharging while vessels are underway. A combination of charging strategies may be needed for larger commercial vessels.

8. **Coordinated, strategic planning and infrastructure development will expedite results.**

   For Maine to meet its climate goals and capture the economic benefits of marine electrification, we must provide pathways for all parts of the state's maritime economy to participate. This requires:

   - Integrated Planning: Coordinate efforts between state, regional, and municipal governments alongside marine-related businesses
   - Strategic Investment: Target investments that prioritize flexibility and broad distribution across industry segments and Maine's diverse geography
   - Infrastructure Development: Focus on high-value opportunities while addressing grid capacity constraints in rural areas
   - Stakeholder Engagement: Continue collaboration with working waterfront owners, operators, and users to ensure strategies meet real-world needs

CONCLUSION

This first-of-its-kind statewide assessment provides the foundational data previously lacking to realize Maine's marine electrification potential. The comprehensive geospatial analysis, stakeholder engagement, and identification of 373 highly suitable sites across multiple vessel types demonstrate significant opportunity while highlighting critical infrastructure needs.

This report directly supports the 2024 update to *Maine Won't Wait: A Four-Year Climate Action Plan*, providing the evidence base for strategic investments that protect against climate impacts through clean energy installations that make businesses more resilient and economically competitive in the emerging clean energy economy.

Infrastructure is always costly, but with careful planning, community engagement, and thoughtful investment, integrating charging infrastructure and other electrification strategies will allow communities and working waterfront owners, operators, and users to realize economic and environmental benefits.

By supporting the development of shoreside charging infrastructure informed by this assessment, Maine can position itself as a leader in sustainable maritime electrification practices, strengthen the resilience of working waterfront communities, and preserve the working character of the state's waterfronts while transitioning to clean energy technologies.

ACKNOWLEDGEMENTS

This report reflects the voices and opinions of dozens of individuals who gave their valuable time and effort to this enterprise through participation in interviews and in-person workshops. **Central Maine Power** and **Versant Power** staff contributed valuable resources to supporting the authors' data requests and for engaging with the project team to support this analysis. **Catherine Segada,** a graduate student at the University of Maine, provided invaluable support for the project in performing stakeholder interviews. The authors also wish to acknowledge and commend the resilience of **Maine's working waterfront stakeholders** who devoted significant time to this enterprise during and after the December and January 2023/24 winter storms, which decimated our coastline and transformed the shape of Maine's working waterfronts forever. The authors thank each of them for their expertise, energy, and perspective.

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DISCLAIMER

The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions or policies of the Island Institute, Central Maine Power, or Versant Power. Mention of trade names or commercial products does not constitute endorsement.

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ABOUT

This report was commissioned by Island Institute and produced by Homarus Strategies LLC in collaboration with Haley Ward, Inc.

INTRODUCTION

Ports, harbors, and working waterfronts across the world are electrifying, and many are prioritizing the transition to electric marine propulsion (see Appendix 3 - What Are Other Locales Doing?). There are a few early adopters in Maine, but most vessels are still utilizing gas or diesel for propulsion. There has recently been a push to investigate the potential for hybrid systems, with some initial research kicking off in the near future. Though more common on land-based vehicles, marine electric propulsion will continue to grow as people become more familiar with the technologies, and reliable charging infrastructure becomes available. For vessel owners, operators, and users to confidently participate in the energy transition, integrated planning, targeted investments, and a focus on safety and cost effectiveness are paramount.

Similar to land-based electric vehicles, there is perceived risk and hesitancy to invest in electrified boat technology without adequate, reliable charging infrastructure. Our interviews with Maine marine stakeholders confirmed that reliable charging infrastructure would be necessary to support market development and broad adoption of electrified marine propulsion. Delivering power from shore to vessel is well-established in working waterfronts of all sizes but scaling to support demand from multiple users and use cases, as well as delivering enough energy to charge large batteries, is uncommon for Maine's working waterfront areas.

There are several working definitions of the term *working waterfront*. For the purposes of this report and analysis working waterfront means "a physical place that facilitates or provides access to the water in order to enable economic activity."

This report was developed to help working waterfront owners, operators, and users, municipal leaders, and any other stakeholders interested in shoreside electrification. The consulting team used a combination of traditional research, geospatial analysis, and direct engagement with experts and stakeholders (fishermen, shoreside business owners, municipal government staff, electrical engineers and grid operators, etc.) to develop a guide for planning the development of shoreside charging infrastructure at multiple scales and in multiple use cases. The recommendations in this report include considerations for planning, land use applications, community planning, existing conditions, and state-wide frameworks such as the state's climate action plan, *Maine Won't Wait*.

Anticipated outcomes of this report include the identification of potential charging infrastructure locations, education materials for a variety of different stakeholders, and a high-level geospatial tool to help inform future planning and implementation strategies. While acknowledging the different charging infrastructure opportunities and levels (see Section III. Geospatial Analysis—Results), this report and analysis focus on the suitability of siting Level 3 infrastructure (also referred to as Direct Current Fast Charging (DCFC or DC for short).

In many cases, hybrid and fully electric propulsion provide significant operational advantages and cost savings. As with diesel and gasoline powered vessels, shoreside infrastructure supporting refueling systems are necessary parts of electrified marine propulsion. This report includes a presentation of the factors that lead to or detract from the suitability of siting shoreside charging infrastructure and that could enable it at other sites, and a discussion of the steps stakeholders and policymakers can take to plan for and facilitate shoreside charging development in Maine's working waterfronts.

Community and stakeholder engagement was critical to the development of this report. The consultant team performed semi-structured interviews and hosted roundtable discussions with a variety of different types of stakeholders. A total of 35 Mainers from different areas along the coast were interviewed and shared insight around experience and perspectives of the current working waterfront infrastructure planning and operations. Four community roundtable discussions were held in Ellsworth, Machias, Portland, and Rockland to discuss local and regional issues and opportunities of shoreside charging infrastructure use, planning, and development (see Appendix 5 - Interview Guide). These interviews and discussions informed the geospatial analysis and next steps planning guide, enabling this report to present a shoreside charging suitability baseline that could serve as a foundation for further local and regional planning efforts, market development, and incentives programs for electric marine propulsion in Maine.

The bulk of the report presents the results from a geospatial analysis that used a Multiple Criteria Evaluation (MCE) framework in a Geographic Information Systems (GIS) environment to establish relative scores for suitability of working waterfront areas for siting charging infrastructure. Suitability was scored based on a set of four assessments—existing supply conditions, potential current local demand, market indicators for future development, and a general score for viability based on the current site conditions. A discussion of the methods and rationale for these assessments is available in the geospatial analysis section of this report, with an overview of the analysis below.

GEOSPATIAL ANALYSIS—OVERVIEW

Maine's coastline hosts over 1,600 working waterfront areas with variations in size, ownership structures, populations, economies, and local infrastructure. The GIS analysis aimed to capture and synthesize these unique aspects into attributes that could provide a uniform approach to scoring and analysis. The resulting effort consists of four marine vessel use cases:

1) Commercial Fishing ("FISH")
2) Aquaculture ("AQUA")
3) Small-Engine Recreation ("OUTB")
4) Larger Vessel/Yacht Recreation ("YCHT")

with four criteria:

1) Supply/current grid accessibility
2) Demand/current users nearby
3) Market/future users likely
4) Viability/site conditions likely favorable

Each criterion is scored as it compares to standardized metrics across the entire region—sites are scored from "0" (least optimal) to "3" (most optimal).

Each location was analyzed and scored, receiving a score ranging from 0 to 12 for each of the four use cases.

The analysis indicates that there are hundreds of Maine working waterfront sites highly suitable for shoreside charging infrastructure (see Table 1 below). Sites that are highly suitable for a single use case totaled 233 areas and outnumbered sites suitable for combinations of two uses (91 areas), three uses (43 areas), and four uses (6 areas). Distribution of highly suitable sites also varied across the use cases and regions of the state (see Section III. Geospatial Analysis—Results for Priority Sites Map).

Table 1. Number of Working Waterfront Sites and Their Suitability for Shoreside Infrastructure. This table shows the number of total working waterfront areas per county and how the scoring suitability was distributed among the areas.

Working Waterfront Sites		Highly suitable sites by use case			
County	**Total working waterfront sites**	**FISH**	**AQUA**	**OUTB**	**YCHT**
Cumberland	440	31	88	88	66
Hancock	253	38	10	5	3
Kennebec	12	0	0	1	0
Knox	188	35	27	14	3
Lincoln	163	15	18	9	6
Penobscot	31	0	0	4	0
Sagadahoc	100	0	9	13	2
Waldo	67	0	0	4	0
Washington	145	13	7	0	0
York	206	1	6	33	19
	1605	**133**	**165**	**171**	**99**

The suitability scores should be used to aid in prioritizing discovery and planning efforts for shoreside infrastructure development. These scores do not indicate which sites are “developable” or “not developable” (see Section IV. Next Steps Planning Guide). The scores support prioritization opportunities given the current infrastructure, economic, and environmental status and should be used as a foundation to build upon for any given project discovery or planning. Note that this analysis utilized large datasets over a large timeframe. Current conditions may vary from datasets due to external concerns such as storm damage, economic and land use changes, and other community factors. Additional dataset considerations are detailed in Appendix 2 - Geospatial Analysis: Scoring Criteria.

Finally, the maps and geographic analysis presented are intended to allow the reader to determine which vessel electrification use cases are more likely to be viable across the working waterfront areas of Maine. The report presents three shoreside electrification planning and development strategies that could be pursued by local, regional, and state governments to establish electrified working waterfront development programs: “low-power widespread demonstration,” “high-power public investment,” and “early adoption incentivization” (see Section IV. Next Steps Planning Guide). Each strategy includes a set of approaches to understand reasonable expectations for investigating applicability and implementation of shoreside charging infrastructure. The consulting team recommends considering sites with high suitability among three more use cases and/or high scoring single-use areas where additional external factors are considered (ex. Infrastructure condition, economic development strategies, funding availability etc.)

I. WHY MAINE, WHY NOW?

Maine's working waterfronts are economic engines and cultural touchstones central to the state's viability, identity, and resilience. Maine fishing, boating, and maritime industries face significant pressures including aging infrastructure, climate impacts, and increasing fixed costs like fuel, materials, and services. As Maine navigates the shift towards sustainable energy, examining opportunities for electrification in its maritime sector could reduce carbon emissions, and bolster economic resilience.

The *Maine Won't Wait Climate Action Plan,*[1] updated in November 2024, sets clear goals for reducing emissions across key sectors. Two of the seven strategies of the plan are directly relevant to this report. Strategy A.2 – Accelerate Maine's Adoption of zero-emission medium and heavy-duty vehicles, says specifically:

> *Some sectors of Maine's marine economy have electrification and emission reduction opportunities, while others require more innovation and clean-fuel options... Maine and key stakeholders should continue to support innovation and efforts to help commercial marine and small harbor craft adopt electrified propulsion and other low- and zero-emission vessel technologies.*

And Strategy D.2 says, "Help Maine businesses and natural resource industries succeed in the global climate and clean energy economy." This strategy is focused on increasing the resilience of Maine's heritage industries to climate threats and includes the recommendation to "help Maine businesses and other entities take advantage of electrification, efficiency, electric vehicle, and clean-manufacturing business incentives and recognize exceptional efforts."

Additionally, the SEA Maine *Roadmap for the Marine Living Seafood Economy* includes three specific recommendations for integrating clean energy initiatives, technology and planning in Maine's marine economy.

Specifically, the report calls for "Support [of] decarbonization as fuel costs continue to rise. Early innovations in electric boat engines are in process and will continue to scale up towards possibly meeting the needs of workboats in the marine living resource economy", as well as broader recommendations like, "Support [for] sector-wide clean energy initiatives undertaken by the Island Institute and GMRI, among others, to implement solar energy, e-boats, and greenhouse gas measurement".

The SEA Maine report also calls for integrating marine related work into broader community level energy conversations and projects, "Incorporate marine living resources businesses in community clean energy projects (e.g. community solar) to ensure they have access to clean reliable energy".

These recommendations clearly point to the importance of exploring the opportunities and challenges presented in this report.

Members of Maine's aquaculture and fishing industries have already begun adopting electric outboard motors, demonstrating a willingness to trial the technology while clarifying the economic benefits—lower fuel costs, reduced maintenance, and improved reliability. This early experience provides a foundation for engaging with larger-scale electrification as the economic case becomes clear for vessels and operations.

EXISTING CONDITIONS IN MAINE

Maine's Working Waterfronts

As stated earlier in this report, the consulting team used the following definition for the working waterfront, "a physical place that facilitates or provides access to the water in order to enable economic activity." Maine's working waterfronts are the backbone of the state's coastal economy. These areas provide ocean access points for fisheries, aquaculture, recreation, and other maritime industries, and define a large part of the coast's cultural heritage. The working waterfronts face mounting challenges, from sea level rise and shifting economic conditions to aging infrastructure and diminishing public access. Integrating new technologies, such as shoreside electrification infrastructure, provides an opportunity for these areas to modernize the infrastructure which improves reliability and future energy demands, while safeguarding the unique character and utility of these waterfronts for current and future prosperity and resiliency. Leaning on the local expertise and experiences of critical stakeholders was vital to the development of the recommendations set forth in this report and informed the consulting team around what data and attributes to use when evaluating suitability for shoreside infrastructure locations.

The length of Maine's coast—including all islands and shorelines to each head of tide—is estimated at over 5,000 miles. Maine's coastal landscape is intricate, tidal, and subject to constant change. To establish a domain for analysis, the consultant team used the Island Institute's "Last 20 Miles" dataset, which is an inventory of the existing conditions of shoreline access across Maine's entire coast. The consultant team acknowledges that this dataset was published in 2007 and has not been updated in totality since. Therefore, it is likely that this dataset includes information that is not up to date or has changed in some way from external factors such as the 2023/2024 storms. That being said, this dataset provided useful definitions and descriptions for analysis in this report.

Maine's Power Grid

The delivery of electricity to Maine residents and businesses is primarily the responsibility of two major utilities: Central Maine Power (CMP) and Versant Power. These companies each manage large service territories covering most of the state, dividing the coast roughly in two. Several smaller territories and island communities are served by electrical cooperatives that generate or purchase power from the utilities and distribute it along their own grid networks. For the purposes of this analysis, the consultant team used spatial information characterizing the power distribution networks from data provided by CMP and Versant. The electrical cooperatives and independent utilities serving Maine island communities may also be able to supply power sufficient to support shoreside charging infrastructure but were not included in this analysis.

The distribution of electricity occurs through a network of power lines owned by the utilities, using both single-phase and three-phase power systems. Three-phase power provides greater power capacity and improved distribution efficiency compared to single-phase systems, particularly when serving larger loads. Three-phase power infrastructure can be costly to install and maintain but is required when considering high-power demands.

Power capacity and availability are important considerations of future electrification uses and should be included and evaluated when planning for and implementing shoreside charging infrastructure. Both level 1 and level 2 charging infrastructure can use single-phase power, whereas DCFC infrastructure requires three-phase power and, in many cases, infrastructure modernization and upgrades. It is important to note that electrical system upgrades may still be required to support level 2 charging infrastructure.

The power distribution system is designed to accommodate regional demand and is interconnected to the broader transmission system. Therefore, it is important to work closely with utility companies to understand current demand and condition of the infrastructure and transmission capacity and include the utilities in future infrastructure planning and installation. DCFC charging, for example, often requires additional infrastructure, and may even include installing additional substations to accommodate power distribution. Understandably, this type of infrastructure requires capital, planning, and engineering for development. Furthermore, the demand and seasonality of that demand is important to consider when planning for future electrification needs. There are many factors that currently exist in Maine's dynamic power grid including the advancement in clean energy solutions, the seasonal weather variations, and industrial business uses. Communities need to understand current, seasonal, and future demand scenarios to properly plan and implement infrastructure to support shoreside electrification. Coupling other energy solutions during this planning and data gathering process is encouraged to achieve economies of scale and cohesive energy balancing. There are other innovative technologies that can be considered during electrification exploration, including adding clean energy solutions, including battery storage, or other micro-grid technologies.

Maine municipalities can work with their utilities to commission a load flow study and analysis to characterize their power distribution system and support planning for additional demand. Several towns in Maine have commissioned such studies and used the results to support planning and grid modernization efforts. Any interested municipal officials are encouraged to reach out to their utility's public or government relations contacts to initiate the process. Individual and business customers can also reach out to their utility to discuss grid upgrades that may be necessary to support additional loads for shoreside charging.

II. ELECTRIC VESSEL CHARGING AND SAFETY STANDARDS

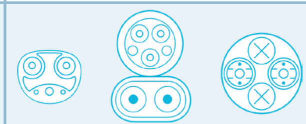
Sending energy from the electrical grid to ships at berth to power systems without the need for onboard power generation is decades-old established practice in nearly every harbor and port in the country. **Systems and charging standards that support high-energy/high-speed battery charging require dedicated hardware, including charging stations (sometimes called "pedestals") and upgraded grounding and fault detection safety equipment.** Power demand from these systems can be high, and when capacity for charging multiple vessels simultaneously is desirable, demand can quickly surpass the local circuit's capacity to deliver.

Shore power to marine vessels can be provided in high and low voltages. Higher voltage systems, e.g. shore power for idling, or "cold ironing", cruise ships at berth, can provide power in the thousands of volts. Significant electrical grid upgrades and specialized equipment costing hundreds of thousands to millions of dollars are often required for these systems. In Maine, the container and cruise ship port facilities that may adopt this technology are isolated to just a few areas including Portland, Bar Harbor, and other communities that may prioritize industrial port development or increased berthing in the future.

Batteries used for marine propulsion that are suitable for the vast majority of Maine working waterfront use cases are charged at more "conventional" levels (240V for Level 2 charging, or 480V for Level 3/DC Fast Charging (DCFC)). Alternating Current (AC) charging with Level 1 or Level 2 systems requires little to no grid modifications and minimal upfront investment, from the hundreds to low thousands of dollars for the installation of weatherproof systems to support a 120V outlet to power a Level 1 charger, to tens to the low hundreds of thousands of dollars for a 240V circuit powering a Level 2 charger. Level 3 DCFC significantly increases charging capacity and speed by providing DC power directly to batteries, bypassing any onboard AC-DC converters and increasing charging rates significantly. Level 3 charging systems typically require 3-phase power delivery, although some manufacturers have developed a Level 2/Level 3 hybrid system that charges a battery located on the pedestal that can discharge at high voltages and charge vehicles/vessels rapidly. Level 1, 2, and 3 charging systems could be sited along wharves and piers or in parking lots (supporting, for example, boats on trailers) that serve working waterfronts, depending on vessel use case and local circumstances.

The battery systems used to power electric vessels determine what charging infrastructure will be needed. These vessels can have a wide variety of configurations, and various battery chemistries provide advantages and disadvantages including longevity, cost, safety and durability, and sourcing/place of manufacture. Most fully electric or diesel-electric hybrid vessels are equipped with integrated batteries that can serve as ballast or are otherwise integrated into the vessel architecture to maximize space, balance, and the integrity of sensitive electrical components. With an approximate weight of 1,200 lbs for a 100-kWh lithium battery pack, weight and space constraints quickly emerge as design considerations for any battery system. Many battery systems are "stackable", meaning that multiple standardized battery packs can be added in a modular format to suit the power needs of each vessel and its duty cycles.

Vessels serving regular routes with predictable service schedules (ferries, tugs, municipal harbor craft, aquaculture yard boats, etc.) may be well suited to fully electric propulsion as charging can be integrated into berthing and propulsion systems can be designed with certainty around power demand and charging location. Vessels in service on unpredictable routes or schedules, recreational vessels put to a variety of uses or in ports without reliable charging infrastructure, or commercial vessels that require system redundancy to ensure safety and reliability may be more suitable for hybrid systems that allow either an internal combustion engine or electric motors to drive a propeller shaft. In either case, typical battery sizes for electrified vessels range from 100 kWh to 400 kWh depending on the use case.

CHARGING TYPE	Level 1	Level 2	Level 3 (DCFC)
Voltage	120V	240V	480V
Power delivery	Single-phase	Single-phase	3-phase
Typical power required	1-2.4 kW	9.6-19.2 kW	50-400 kW
Approximate cost	$100s-$1,000s	$1,000s - low $100,000s	$100,000s+
Time to charge a 100 kWh battery	40-72 hours	5-11 hours	40-60 minutes
Charging standard	 J1772	 J1772 / J3400 (NACS)	 J3400 / CCS / CHAdeMO

Working waterfront owners/operators seeking to support larger fleets of electrified vessels with charging infrastructure can expect their local power delivery requirements to increase significantly as they design charging systems to include additional chargers. Demand scales linearly with use, and systems that are designed around maximum demand may require significantly more robust power delivery infrastructure than what is typically used at any one time, increasing costs and complicating power grid design. Siting projects like shoreside charging infrastructure that could significantly increase local demand could require major improvements of older or lower capacity infrastructure, installed and upgraded along more rapid timelines than originally planned. For this reason, private and public working waterfront operators contemplating the integration of shoreside charging should engage with their electrical utility very early in the planning process to determine the local grid's load hosting capacity and integrate the design and buildout of any Level 3 charging systems into municipal and regional planning discussions (see Section IV. Next Steps Planning Guide).

SAFETY

Safety is a primary concern for all maritime users, and safe installation and operation of shoreside charging infrastructure and battery systems are no exception. Adherence to relevant safety standards is essential, as is working with licensed electricians and other professionals, appropriate permitting. It is highly advisable to coordinate with harbormasters and representatives of local emergency response systems prior to and during the planning and installation of shoreside charging infrastructure.

Battery systems in the marine environment are subject to unique operational stresses. While properly/professionally designed and installed battery systems have a very high

Microgrids: One potential solution

Local microgrids are systems designed to increase local energy resilience and are a promising strategy to support shoreside charging infrastructure. Microgrids integrate local power generation from local and often renewable energy sources and incorporate energy storage in batteries to supply power to customers when external connections to the transmission system fail or during periods of peak demand. A microgrid is a power distribution system that can be physically isolated and operated independently from the main power grid. Microgrid systems often incorporate locally distributed energy generation such as solar panels, and battery energy storage systems (BESS). In the event of a grid outage, microgrids can seamlessly transition to "island mode," providing continued electricity supply to users within the defined area. This enhances energy security, independence, and resilience, particularly in rural, remote, or otherwise vulnerable areas prone to power disruptions. Examples of such vulnerable communities include those along radial lines (like those that extend down peninsulas) that lack any redundancy, as is the case for islands that receive power from submarine cables or many of Maine's peninsulas. Furthermore, microgrids can facilitate the integration of renewable energy sources by enabling localized energy generation and consumption, reducing reliance on the central grid and promoting sustainable energy practices.

safety record, the risk of lithium battery fires still exists and must be fully evaluated by any working waterfront operator contemplating shoreside charging infrastructure development. Implementation of safety features such as battery management systems (BMS), fire suppression systems, and thermal management solutions contribute to the safe charging and operation of electrified propulsion systems on boats, but there are additional ways to ensure that shoreside charging is performed safely.

Several maritime safety organizations and regulatory bodies have developed standards and guidelines related to battery and charging system safety in marine applications. These include:

- **American Boat and Yacht Council (ABYC):** ABYC's E-13 standard specifically addresses the installation of lithium-ion batteries on boats. ABYC E-13 is considered the industry standard for lithium battery installations on marine vessels in the United States. It's important to note that ABYC standards are voluntary, but they are widely adopted by boat builders, installers, and surveyors, and are often referenced by the USCG and insurance companies. It covers a wide range of safety issues associated with battery electric propulsion and charging, including:

  Battery installation: Ensuring secure mounting, proper ventilation, and protection from the marine environment.

  Charging systems: Requirements for chargers compatible with lithium batteries, including voltage regulation and charging profiles.

  Overcurrent protection: Mandating proper fusing and circuit protection to prevent electrical hazards.

  Temperature management: Guidelines for thermal management to keep batteries within safe operating temperatures.

  Battery Management Systems (BMS): Requirements for BMS functionality to monitor and control battery performance and safety.

- **Society of Naval Architects and Marine Engineers (SNAME):** SNAME has published technical papers and guidelines related to electric and hybrid propulsion systems, including considerations for battery safety and charging infrastructure on board vessels.[2]

- **American Bureau of Shipping (ABS):** ABS has published guidance notes on battery systems for marine and offshore applications, addressing design, installation, and testing requirements.[3]

- **Det Norske Veritas (DNV):** DNV, a quality assurance and risk management company operating internationally, has developed reports and standards for battery systems in maritime applications, covering safety, performance, and testing.[4]

- **US Coast Guard (USCG):** While the USCG hasn't issued comprehensive regulations specifically for electric vessel charging and battery propulsion systems in the same way they have for traditional fuel systems, they have released some important guidance and policy that address key safety aspects. The most relevant standards and documents include:

  Policy Letter 20-03: Carriage of Lithium-ion Batteries on Small Passenger Vessels :[5] This policy letter provides guidance on the safe carriage, storage, and charging of lithium-ion batteries on small passenger vessels. It addresses issues including:

    - Charging locations and monitoring
    - Battery inspection and maintenance
    - Use of appropriate charging equipment
    - Handling of damaged batteries

- **Marine Safety Center (MSC) Guidelines for Electrical Plans – Small Passenger Vessels:**[6] While this document primarily focuses on general electrical system requirements, it does include some provisions relevant to battery systems and shore power connections, including requirements for battery installation and accessibility, and guidelines for shore power connections, including circuit breaker requirements and grounding considerations.

- **46 CFR Part 183 — Electrical Installations:** This section of the Code of Federal Regulations provides general requirements for electrical installations on vessels, including batteries and shore power connections. Many Maine working waterfront facilities operators may be familiar with the updated regulatory requirements for ground fault circuit interrupters in shore power systems, which often require significant electrical system upgrades on board vessels receiving power. While not specific to shoreside charging or lithium-ion battery safety, the regulation provides a foundational framework for electrical safety in the marine environment.

Adherence to these and other relevant standards is essential for the safe design, installation, and operation of shoreside charging infrastructure and battery systems for electric vessels; it is recommended that any working waterfront operator interested in installing charging infrastructure do so through a licensed and reputable installer. While the US Coast Guard has not yet issued guidance directives for shoreside charging specifically, harbormasters and other emergency responders must have adequate training and equipment/planning capable of responding to lithium battery fires on the working waterfront. Although no specific guidance on this type of planning yet exists, the Maine Commercial Fishing Safety Council has begun to discuss and contemplate the requirements and capacity needs of maritime first responders in working waterfront areas that host battery propelled vessels and associated charging infrastructure.

Conversations between businesses, municipal and state officials, and safety experts should focus on ensuring a safe and reliable transition to electric propulsion, and safety should be a core element of shoreside charging system design. Electrified vessels and charging systems should be designed by reliable and reputable engineers and installed by certified technicians in accordance with the latest ABYC, USCG, and other standards and requirements as they are developed and evolve.

III. GEOSPATIAL ANALYSIS—RESULTS

The theoretical framework for our coastwide data analysis is based on regional planning and geospatial analysis. The main implications brought to this study from these disciplines are the following:

Regional planning means that while many results will have specific scores relevant at the local level—these may pertain directly to parcels, local businesses, wharves, or access points—the study makes no actual site-level recommendations. We suggest that the results be taken as evidence for further investigation, not authoritative representations. Some error is to be expected from data interpretation.

Geospatial analysis means that our methods, parameters, data interpretation, and the inferences assume a basic understanding of Geographic Information Systems (GIS). We use but make little reference to some standard concepts: cost distance vs. Euclidean distance, spatial autocorrelation, statistical breaks for data classification, etc.

VESSEL TYPES AND USE CASES

We focused our analysis on use cases for electric power in marine propulsion that are likely to be adopted early and effectively in the coming years. This analysis is informed by a strategy that advances electrification by supporting early adopters through three pathways:

Economic: Incentivize markets in which electrification provides practical economic benefits and alternatives to users, lowering capital and practical barriers to investment.

Environmental: Convert the greatest number of horsepower-hours to kilowatt-hours, minimizing carbon emissions.

Cultural: Prioritize high-visibility opportunities and work with community leaders to reach the greatest number of early adoption users.

The four use cases that we established to best capture these tenets are the following:

Day-boat fishery (a.k.a. "FISH")

Description. The representative example of this use case is the Maine lobster boat. These are typically 24'-45' in length, dory-bowed with semi-displacement hulls, owned by an individual or co-op member, and used to tend a "gang" of traps on single day trips.

Context. Fixed lobster traps are reachable via coastwise navigation during the effort of one workday, returning to the home port by day's end. While other species are commonly targeted, the lobster fishery accounts for around 75% of annual landings by value. These crafts are also occasionally used on multi-day trips for distant water fishing, but this is not the dominant use.

Use case. The "use-case" here attempts to capture the idea that most boats in this class exert a high level of propulsion power intermittently throughout the workday and regularly return to the same locale (usually a wharf or co-op) for refueling and overnight berthing. This berthing location is typically the principal place of work for this use and is in close driving range to users' residences.

Aquaculture craft (a.k.a. "AQUA")

Description. A representative example of this use case would be the working skiff. These are typically under 24' in length, flat-bottomed (e.g. Carolina skiff), owned by an individual or more likely an aquaculture company, and used to tend the aquaculture farm and to transport harvested product from a leased marine area to a processing facility.

Context. The harvest is performed on a leased and delineated area of shallow marine water, proximate to the berthing location of the craft, which is also generally proximate to the processing facility. The craft is usually not used for coastwise and/or offshore transportation. While there are many forms of aquaculture, the oystering industry is likely the most dynamic market in this industry as of this writing.

Use case. The "use-case" here attempts to capture the idea that most boats in this class exert a low level of propulsion power in a limited capacity throughout the workday and always return to the same berthing location. Refueling may be done at the aquaculture facility, or incidentally at a neighboring fishing co-op or town wharf. This aquaculture facility is typically the principal place of work for multiple users of the same vessel and is in close driving range to users' residences.

Outboards and small-craft recreation (a.k.a. "OUTB")

Description. A representative example of this use case would be the recreational powerboat. These are typically under 21' in length, having a planning or semi-displacement hull (e.g. Boston Whaler), normally powered by outboard auxiliary power, owned by an individual for private use, and typically used seasonally for pleasure.

Context. This type of boat is typically used for recreational fishing and coastal touring. While some owners may trailer their boats and store them at their own residences, most users utilize harborside amenities for day-use activities—including convenience stores, restaurants, and lodging. Excursions are typically for less than one day, returning to the point of departure by evening.

Use case. The "use-case" here attempts to capture the idea that the vast majority of boats in this class exert a medium level of propulsion power consistently throughout the recreational outing, and although a variety of amenities areas may commonly be visited, these craft normally return to the same point of departure.

Yachts and leisure-boat recreation (a.k.a. "YCHT")

Description. A representative example of this use case would be the pleasure yacht. These are typically over 21' in length, having a displacement hull, normally powered by inboard auxiliary power, owned by an individual or company for private use or chartering, and typically used seasonally for pleasure.

Context. This boat is typically used for coastal cruising. While some owners may elect to keep their boats proximate to vacation or personal residences, most frequently these boats are stored in harbors and waterfronts in which a high level of other boat traffic is present, and therefore supporting marine amenities are likely to be present as well. These areas often support seasonal population and areas of tourism. Excursions are typically one or more days, and outings are normally planned to coincide with vacation or other extended leisure time.

Use case. The "use-case" here attempts to capture the idea that boats in this class exert a high level of propulsion power during very intermittent recreational outings, and although commonly berthed in a preferred port of call, these craft frequently engage in overnight trips or stays in other locations along the coast. While each berthing place is generally understood to be a preferred place to store the boat, owners may drive further distances from their residence so that they can store their yacht in advantageous locations.

It is important to note that there are other marine craft not considered in this analysis. Descriptions and rationale for omission are found below:

Municipal harbor craft: These include water-taxis, pilot boats, tow boats, pump-out boats, and other working craft that support the marine economy. While these may indeed be meaningful targets for early adoption of electrification, they represent a small proportion of boat ownership coastwide. Due to the small numbers, this use case was not considered in this analysis.

Ferries: These craft represent the highest level of frequency and most regularity of use. Charging electrified ferries requires technologies and capital that are not quite market realities as of the writing of this report. Additional studies are needed in this area and were not included in this analysis.

Commercial shipping: Like ferries, there are infrastructure and technology constraints for this use case. Additional studies are needed in this area and were not included in this analysis.

SCORE SUMMARIZATION

In order to create a cohesive method for assessing a wide array of disparate elements, this report uses a simple, communicable classification system—each set of independent use cases is independently evaluated against four "scoring criteria" (power supply, consumer demand, likely market, and site conditions) to describe the feasibility of each site for each of the four use cases. See Appendix 1 - Geospatial Analysis: Scoring Criteria for detailed explanations of the scoring criteria.

Power supply (S)

This assesses proximity to the existing grid based on a minimum set of requirements: Euclidean distances to single-phase or three-phase depending on the use case.

Consumer demand (D)

This assesses proximity to existing boat-owners based on a set of driving distance requirements, depending on the use case.

Likely market (M)

This assesses indicators of activity associated with each use case that may indicate that the area is of high interest to electrified vessel owners/operators.

Viable site conditions (V)
This assesses beneficial site condition attributes that are likely to promote development efforts, namely: existing shoreside infrastructure, public access, and road access.

Each of these subject areas is assessed and assigned one of the following scores:

Score = 0 Likely not workable
These sites do not meet the minimum threshold for further investigation. Pursuing development in this area is not recommended.

Score = 1 Possibly workable
These sites meet the minimum threshold for further investigation. Pursuing development in this area is not recommended, but should not be completely discounted.

Score = 2 Likely workable
These sites meet the established threshold for further investigation. Pursuing development in this area is recommended.

Score = 3 Optimal
These sites exceed the established criteria for further investigation. Pursuing development in this area is highly recommended.

In general, the scoring methodology attempts to create meaningful differentiation for ordinal classification in the data set. These ordinal data scores are then compared with each other for each criterion. Ordinal classification schemes are generally based on the mean, standard deviations, and/or meaningful/manual class breaks in the case of heavily skewed data distributions.

Each of Maine's 1,605 working waterfront sites was assigned a unique score based on each of four scoring criteria as it relates to each vessel use case. For assessing each waterfront location's "overall score" for each use case, the team suggested simple addition. This sets a coastwide scoring system with "0" as the least optimal and with "12" as the most optimal. See the Score Guide in Appendix 1 in conjunction with the legend to assist with map reading; see Appendix 2 - Geospatial Analysis: Scoring Criteria for a detailed explanation.

DEFINING "PRIORITY SITES"

Based on this analysis and consultant team's recommendations, sites that score 9-12 are considered "high scoring" and should be evaluated first. Note that if a single criterion scores "0" points, the remaining criteria must all score "3" or "optimal" points to be considered. For the purposes of summarization, sites that meet this threshold are considered "priority sites." It is also important to note here that priority sites in this context mean sites that appear favorable based on the data analysis; each will require additional vetting and analysis for shoreside infrastructure considerations.

RESULTS

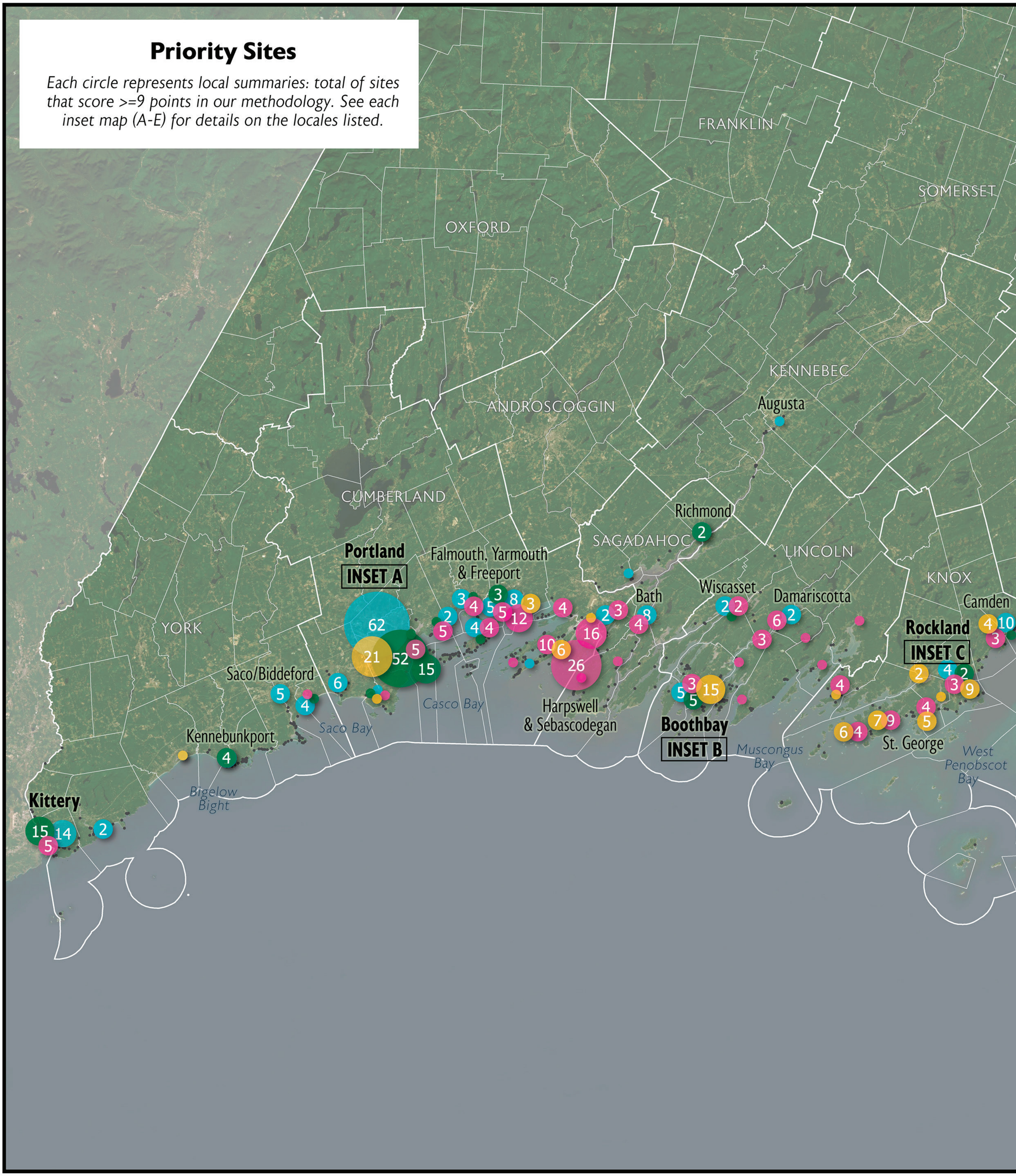
The following maps represent several scales of summarization for the scores developed in the analysis described in this report. For more detail, please see the online data dashboard and interactive map at: islandinstitute.org/shoreside-charging-report

The first map, showing "coastwide" priority sites, summarizes total numbers of priority sites by use case, where a "priority site" must have a score greater than or equal to "9". This threshold ensures that if any component of the score is equal to "0," then all three remaining must be highly optimal for the site to be considered a priority.

Spatial data sources include:

Island Institute — Last 20 Miles
Central Maine Power — 1-phase and 3-phase utility lines.
Marine Cadastre — Vessel Traffic Counts
MEDHS — Health Inspections (Restaurants & Lodging)
MEGIS — NG911, Towns, Counties, Transmission Lines, Aquaculture Sites
MDEP — Underground Tanks (Fueling Stations)
MDIFW — Maine Boating Registration
TIGER — Zip Codes
USGS — National Hydrography Dataset
USCG — Federally Documented Vessels
Versant Power — 1-phase and 3-phase utility lines.

All maps projected in Universal Transverse Mercator 19 North (UTM 19N), North American Datum 1983 (NAD 83). EPSG: 26919

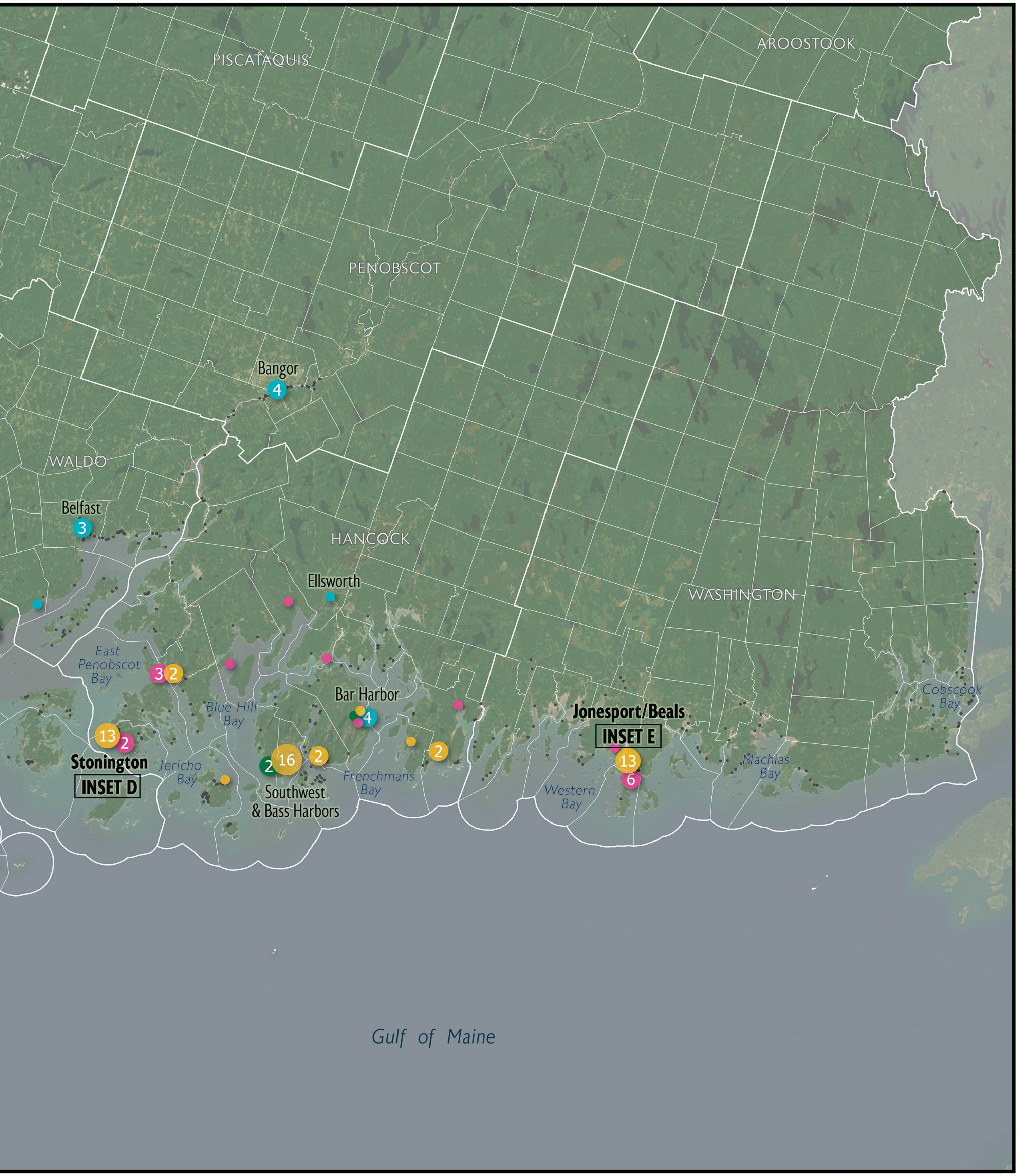


Optimal Sites by Use Case for Future Electrification | Kittery to Lubec, ME

Map Data Notes: *Sums for each locale generalized. Inset maps may include or exclude specific sites depending on restrictions/publication requirements.*
Scale: *1 : 900,000 or 1 inch = 14.2 miles*

More Information:

Online Data Portal: *Please follow th*
where more detail and information ca
URL: *<https://www.islandinstitute.org*



Priority Sites: (Local sums >= 9pts)

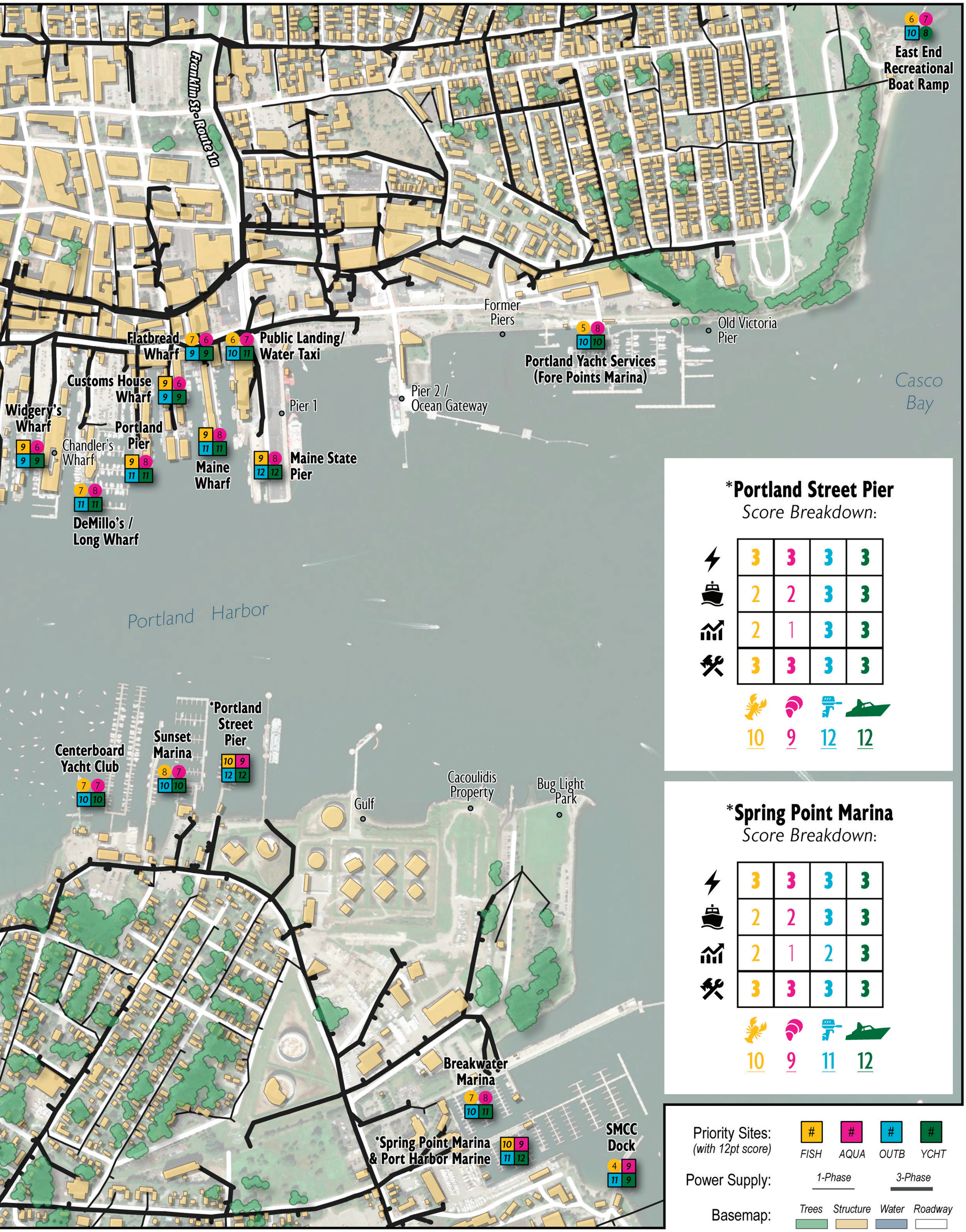
#	#	#	#
FISH	AQUA	OUTB	YCHT

Features: Working Waterfront Site (Last 20 Miles) •

ne link below to a data portal and interactive map
n be found on the results of this study.
g/priorities/marine-economy/electrifying-maines-working-waterfront/>

Waterfront and Priority Sites | Portland Harbor, ME

Standout Site: *Spring Point Marina & Port Harbor Marine*
Primary Use Cases: *Open market; recreation opportunities dominant.*
Scale: *1 : 9,600 or 1 inch = 800 feet*

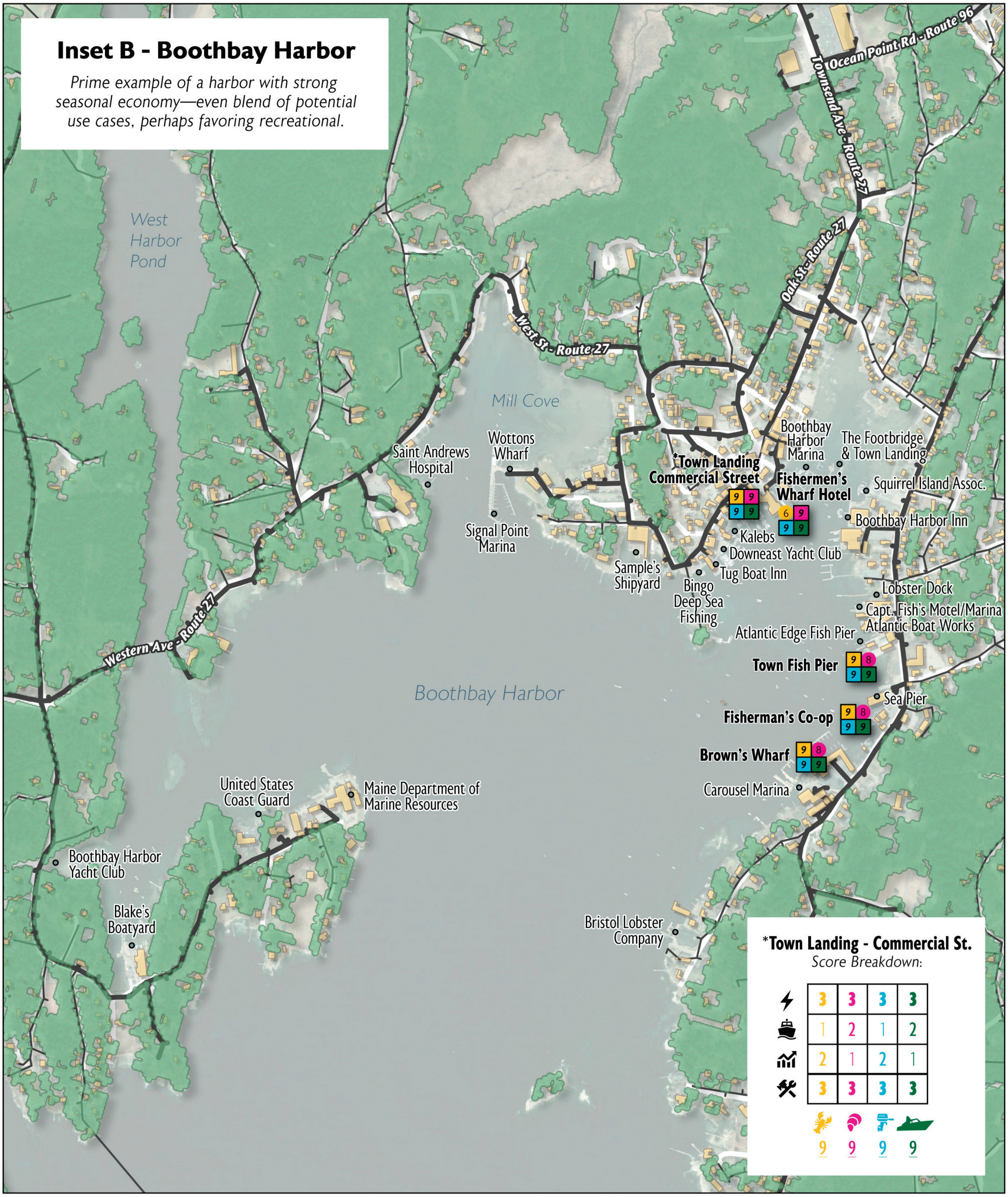


*Portland Street Pier Score Breakdown:

	FISH	AQUA	OUTB	YCHT
⚡	3	3	3	3
🚢	2	2	3	3
📈	2	1	3	3
🛠	3	3	3	3
Total	10	9	12	12

*Spring Point Marina Score Breakdown:

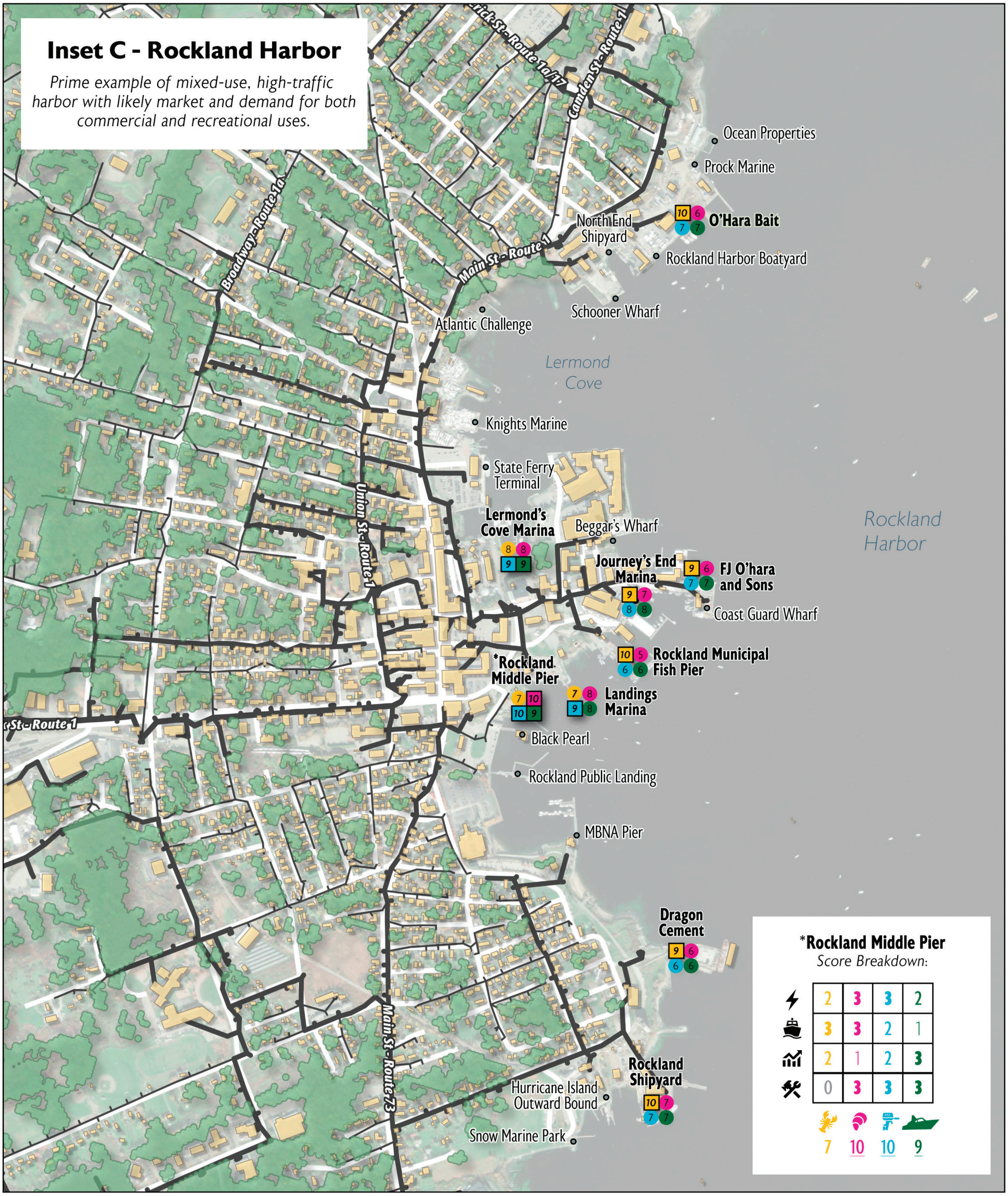
	FISH	AQUA	OUTB	YCHT
⚡	3	3	3	3
🚢	2	2	3	3
📈	2	1	2	3
🛠	3	3	3	3
Total	10	9	11	12



Waterfront and Priority Sites | Boothbay Harbor, ME

Standout Site: *Town Landing at Commercial Street*
Primary Use Cases: *Small-scale recreation, fishing, and aquaculture.*
Scale: *1 : 12,000 or 1 inch = 1,000 feet*

Priority Sites: (with 12pt score) — # FISH, # AQUA, # OUTB, # YCHT
Power Supply: 1-Phase, 3-Phase
Basemap: Trees, Structure, Water, Roadway



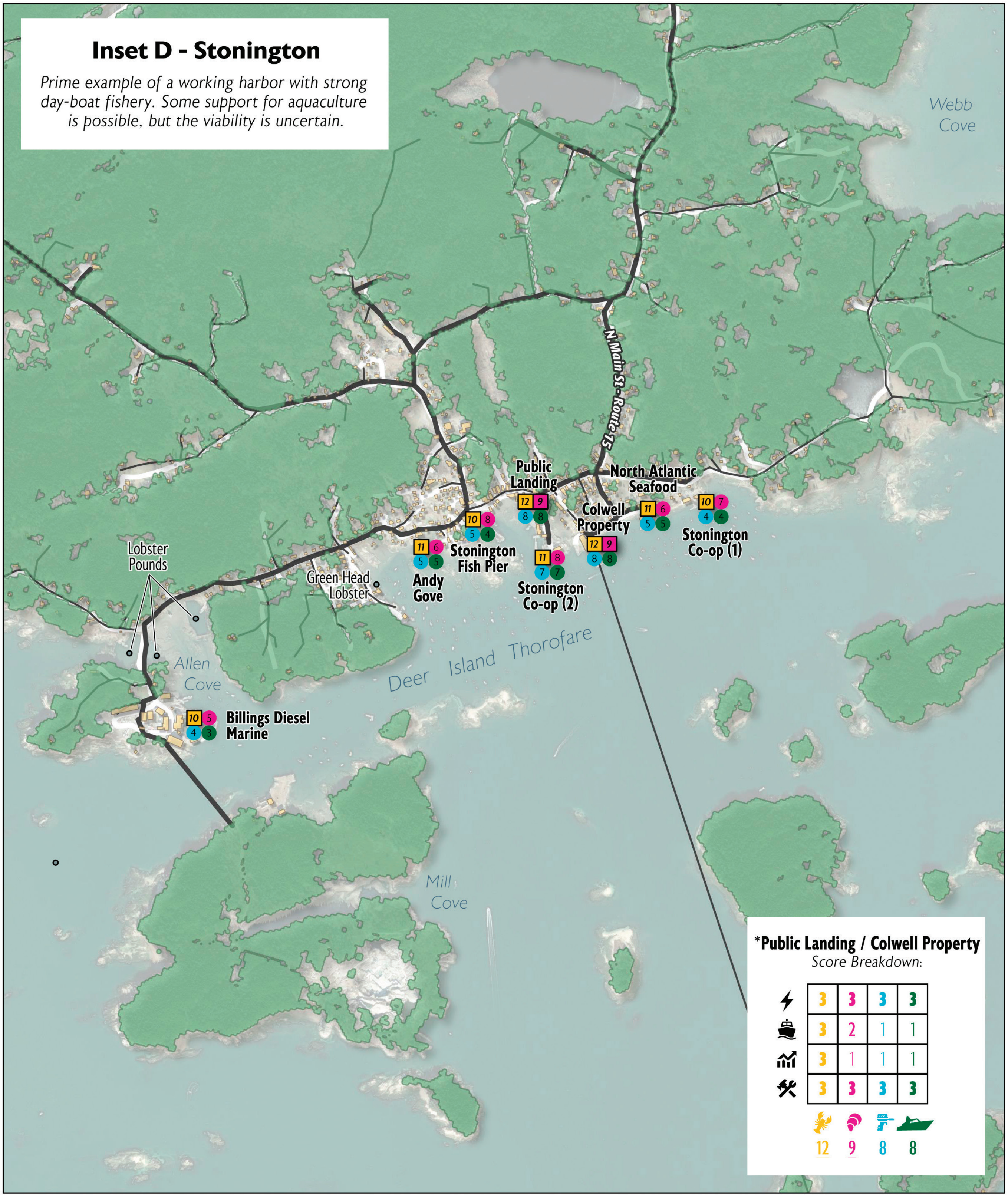
Waterfront and Priority Sites | Rockland, ME

Standout Site: *Rockland Middle Pier*
Primary Use Cases: *Recreational outboard and commercial fishing.*
Scale: *1 : 12,000 or 1 inch = 1,000 feet*

Priority Sites: *(with 12pt score)* # FISH, # AQUA, # OUTB, # YCHT

Power Supply: *1-Phase*, *3-Phase*

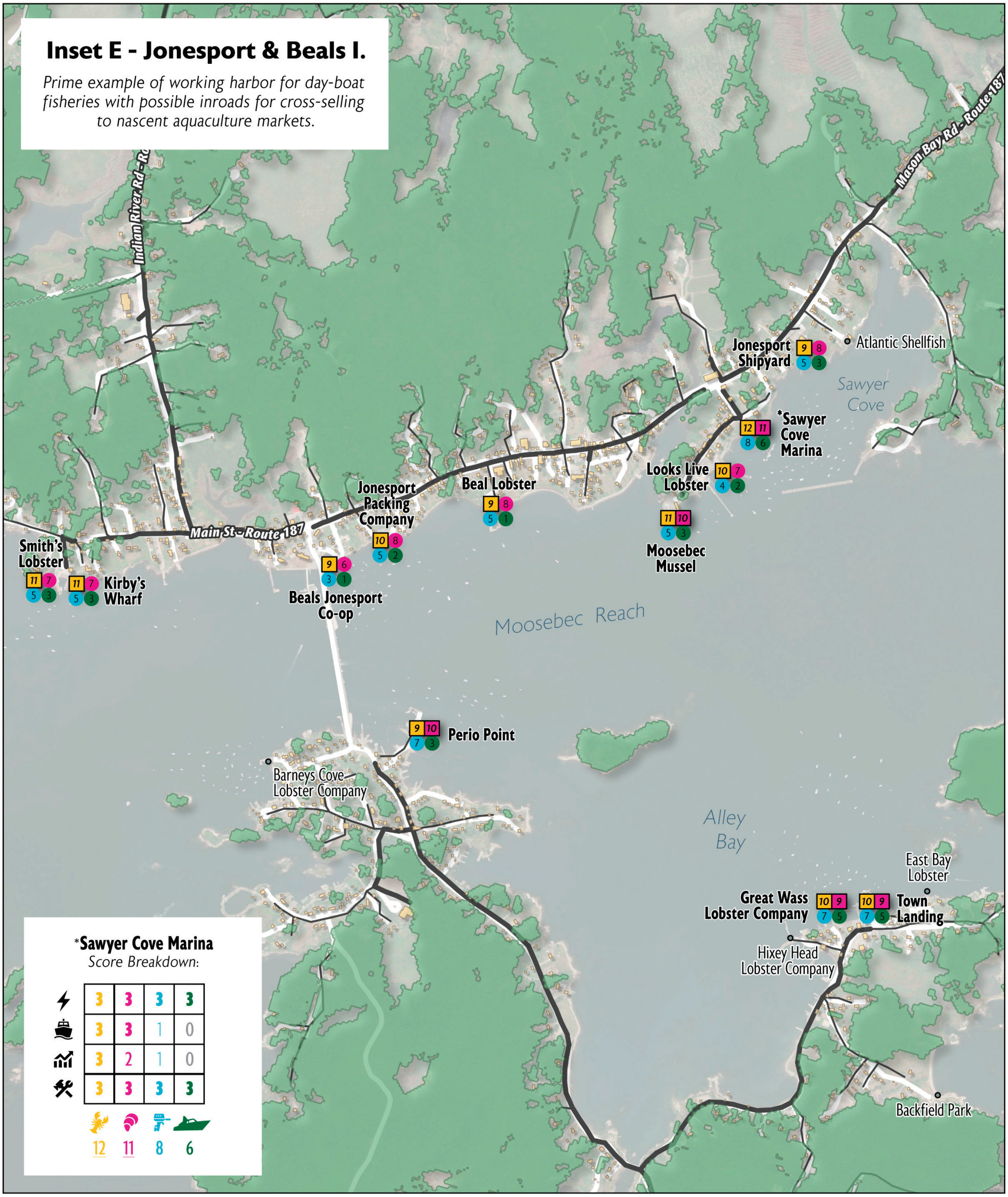
Basemap: *Trees*, *Structure*, *Water*, *Roadway*



Waterfront and Priority Sites | Stonington, ME

Standout Sites: *Town Landing and Colwell Property*
Primary Use Cases: *Day-boat fishery.*
Scale: *1 : 18,000 or 1 inch = 1,500 feet*

Priority Sites: (with 12pt score) — FISH, AQUA, OUTB, YCHT
Power Supply: 1-Phase, 3-Phase
Basemap: Trees, Structure, Water, Roadway



Waterfront and Priority Sites | Jonesport & Beals Island, ME

Standout Site: *Sawyer Cove Marina*
Primary Use Cases: *Commercial fishing and aquaculture.*
Scale: *1 : 18,000 or 1 inch = 1,500 feet*

Priority Sites: *(with 12pt score)* # FISH, # AQUA, # OUTB, # YCHT

Power Supply: 1-Phase, 3-Phase

Basemap: Trees, Structure, Water, Roadway

Generally, the evidence suggests that the southern Maine coast, from Kittery through Casco Bay, appears favorable for shoreside charging infrastructure investments supporting the recreational market, including both small outboards and larger yachts. The Midcoast region, from the Sheepscot River to the Penobscot River, appears most favorable for exploring charging infrastructure investments to support the aquaculture market. A handful of locales along the Midcoast region present the most viable opportunities for combining strategies—or rather exploring development for multiple recreational and non-industrial use cases in the same waterfront facilities. For commercial fishing users and working waterfront owners/operators, the most viable opportunities for substantive shoreside charging infrastructure investment are in high value commercial harbors, such as Stonington, Bass Harbor and surrounding areas of Mount Desert Island, and Jonesport/Beals. For these more rural communities, grid capacity and the distribution of 3-phase power present immediate constraints and should be evaluated in all shoreside charging infrastructure planning processes.

Portland is Maine's largest and most industrialized port by a significant margin and, as such, does not represent the majority of Maine's coast. It has, by its nature as the state's largest city, a level of infrastructure investments that are outsized when compared to other communities and therefore possesses more sites suitable for beneficial electrification projects than other, more rural and remote harbors. However, the power grid along the eastern end of the Portland waterfront is nearly oversubscribed, and additional capacity will be necessary in order to support significant additional demand associated with vessel charging infrastructure east of Custom House Wharf.

Using the "Priority Sites" threshold for each contributing criterion, the consulting team have created the following descriptive typologies for discussing and classifying the various locales for regional consideration ("Priority Locales.") See regional map for more detail. In general, Jonesport, Southern MDI (Bass Harbor and Southwest Harbor), and Stonington cast similar evidence for a **Working Harbor** typology. Camden, Rockland, and Boothbay might be typified as **Seasonal/Mixed Use** waterfronts. Sebascodegan Island presents numerous waterfront opportunities for **Demonstration Aquaculture,** and the Portland region is a singular **Maritime Hub.**

Locales by typology:

Working Harbor: This type of priority locale is remote, sparsely populated, normally has some 3-phase power infrastructure, and is dominated by the FISH use case. While other use cases may or may not be active in this locale, they do not likely support a viable option for development.

Seasonal/Mixed Use: This type of priority locale represents an even blend of recreational and commercial use cases. Although generally lower density, these locations either act as vacation destinations or have a high level of maritime-adjacent activity with a good supply of local amenities. These are the only rural cases that are likely viable for attempting mixed or multiple electrification strategies in tandem.

Maritime Hub: This is Portland, Maine. The density of Portland is unrivalled in all other locales along the Maine coast. This means that there is an altogether different scale of boat use, traffic, amenity options, power supply, human activity, etc. Portland is therefore a locale with diverse and complex site conditions that are both highly likely to be viable, but also likely to require a more thorough subsequent examination.

Demonstration Aquaculture: This type of priority locale can be found throughout the midcoast and perhaps in several areas downeast. These areas are very rural, directly proximate to a high level of aquaculture activity, close to single phase power supplies, and normally have good access and use privileges. Although this classification may seem niche, it represents a solid intersection between the suggested values: cultural, economic, and environmental efforts are highly achievable with small amounts of investment.

DEVELOPING PARALLEL SITING STRATEGIES FOR SUCCESS

There may be opportunities for fulfilling multiple objectives or serving multiple use cases with integrated shoreside charging investments or initiatives. Our analysis of Maine's working waterfront areas and engagement with stakeholders shows that integration of multiple electric vessel use cases in shoreside charging infrastructure planning is possible, but specialization in a single use case may be a viable starting approach for most working waterfront owners/operators.

It is recommended that state, regional, and municipal shoreside charging infrastructure planning and development efforts integrate the opportunity to support multiple vessel use cases. This can be achieved while implementing more standardized siting and capital investment priorities based on specific, targeted criteria like emissions reduction, air quality, rural development, or decarbonized food systems integration. Additionally, planning efforts can and should prioritize value-added opportunities to electrify other working waterfront systems (e.g. forklifts or other yard vehicles) or to charge electric vehicles on site. Grid investments that support projects facilitating multiple additional use cases for vessel and vehicle electrification may be more attractive for public investment than projects that support just one facility or one vessel-use-case. It is always important to consider other energy technologies and upgrades when conducting this work/study, such as grid infrastructure or renewable energy generation systems

Use cases where local commercial and economic dependence is at stake (i.e. dayboat fishery), for instance, will require unique and devoted resources for each type—demonstration projects, substantive outreach efforts, strategic partnerships, and rapid functional, technical, and economic parity with fossil fuel counterparts. The substantial financial and social scaffolding required to achieve measurable success in the commercial fishery space will no doubt compete for resources (volunteer hours, social capital, grant support, etc.) that might be spent in areas with more rapid and visible results. Possible strategies include:

Low-Power Widespread Demonstration: This strategy attempts to effect immediate change through a campaign supporting widespread implementation of low-cost charging applications. These are likely to be charging stations that only require single-phase power (Level 2 charging) and are likely to be immediately economically viable alternatives to current propulsion norms for many users. Examples of applications may include: municipal harbor craft, aquaculture vessels traveling short distances, small outboard recreation, etc.

High-Power Public Investments: Maine's higher-power propulsion use cases (day-boat fisheries, small ferries, etc...) requiring 3-phase connections in rural areas are likely key components of coastwide electrification. However, they should be looked at as long-term investments rather than a near-term opportunity for widespread implementation. The benefits of supporting early adopters and demonstrating the viability of integrated propulsion/charging systems in Maine's working waterfronts could exceed the initial costs of investment.

Early Adopter Incentives: This strategy looks to specialized and attractive technologies targeted at innovative and early adopter markets. Early adopters can do much to push the normalization of beneficial electrification efforts. This approach is like how innovators and early adopters helped to propel the electric vehicle market toward more widespread and affordable product development once technical barriers were lowered.

Promoting the adoption of electric propulsion in the lobster fishery may require a high level of investment and resources due to:

- High power demands requiring 3-phase power supply for many vessels
- Negotiating cooperatively owned site infrastructure
- More rural and remote site locations

The results of this work will be beneficial—many horsepower-hours could be converted to kilowatt-hours (30-40%) by retrofitting a very modest number of vessels, resulting in potential cost savings for businesses. However, conversion is not without its challenges. Charging larger batteries aboard working lobster fishing vessels could require the integration of DC fast charging into loading/unloading operations. Alternatively, vessels would need to be provided with Level 2 or Level 3 charging capability where they are berthed or moored overnight. Many of Maine's commercial fishing harbors are not currently configured to provide berths to numerous commercial fishing vessels; instead, they are primarily moored when not in use. Statewide initiatives supporting the development of shoreside charging infrastructure will be most successful if flexibility is a core principle and any developed program benefits are broadly appropriate for and distributed across industry segments and the geographies of Maine.

IV. NEXT STEPS PLANNING GUIDE

Taking the early steps to facilitate the transition to electrified marine propulsion is an exciting and challenging time for municipalities and private businesses. Once working waterfront owners and operators begin to devote resources to exploring the feasibility or planning the siting of shoreside charging infrastructure, a structured approach with integrated decision-making is key to achieving a successful outcome. Maine's working waterfronts are unique, and decision-making processes developed for any scale (individual wharves/docks, municipal harbor complexes, coordinated regional planning) must be flexible and integrate the unique characteristics of each working waterfront. This section is intended to support Maine's working waterfront owners/operators, users, officials, and the public as they begin to think and plan for integrating the marine space into energy planning conversations..

The recommended planning process for shoreside charging infrastructure involves four phases:

1. Pre-planning
2. Planning and Engineering
3. Construction
4. Evaluation and Maintenance

1. PRE-PLANNING

The pre-planning phase allows decision makers to determine their unique electric marine propulsion baseline requirements, evaluate power delivery options and infrastructure needs, estimate costs and explore financing options, coordinate with stakeholders and the public, discover opportunities to lower costs and join with other similar projects, and integrate planning with local/regional safety and emergency management agencies. Although each working waterfront facility's circumstances are unique, most types and ownership structures will benefit from following these steps in the pre-planning process.

1a. Establish initial contact with external parties. Depending on your business or organization, these could include:

- Your local government, including planning officials, harbormaster, shellfish warden, etc.
- Your electric utility
- The regional council (e.g. Regional Planning Commission or Council of Government) serving your town[7]
- Nonprofit organizations supporting this work in businesses and communities (e.g. Island Institute)
- Trade associations serving maritime businesses and municipalities (e.g. Maine Marine Trades Association, Maine Harbor Masters Association, etc.)
- Community leaders in the fishing/aquaculture/marine trades sectors, whose support and perspective will be critical for smooth planning and build-out

1b. Assess your working waterfront or harbor's baseline energy use and the power requirements of your vessels, tenants, or customers. Knowledge is power, and having access to the right information is critical for planning and implementation of any electrification project. There are many places to start, including resources we have compiled to help get started. To keep updated on the latest electrified boat technology resources visit our website and toolkit. Additionally, you can contact your energy provider to start the conversation.

1c. Assess the status of power distribution to your harbor/site. Consult the resources in this report or other authoritative sources of information to determine power distribution, capacity, and other factors that could determine the feasibility of installing shoreside charging infrastructure. Municipalities can work with their electric utility to perform a load flow study and analysis to determine specific opportunities and impediments to power delivery for shoreside charging infrastructure.

1d. Identify opportunities to integrate shoreside charging infrastructure siting into existing planning and redevelopment efforts. Does your business require additional energy efficiency or shoreland zone resilience upgrades? Does your town have ongoing working waterfront economic climate or climate planning efforts? Is the utility planning upgrades in the area? Are colleagues at other organizations (whether private or public sector) planning similar efforts that could align with yours? Creating conversations across broader areas can help reduce costs and increase learning opportunities.

1e. Investigate siting and permitting policies, charging system suppliers, and up-to-date conversations about electrified propulsion. Understanding these factors will allow you to make informed decisions about siting and the suitability of including shoreside charging into your operations.

1f. Identify sources of capital and incentives. Grants from federal sources available to municipalities and some types of non-public ventures (co-ops, land trusts, etc.) may be available and may cover significant costs. State and federal tax incentives may be available as well. Consult a CPA or other financial expert to learn more.

2. PLANNING AND ENGINEERING

The planning phase allows decision makers to design and begin the process of capitalizing shoreside charging infrastructure projects once general feasibility, market opportunity, and local planning studies indicate that they are appropriate for a working waterfront area. During this phase, a harbor or business works with partners, suppliers, and the utility to establish a timeline and specific steps for a project, which can vary significantly.

2a. Determine your system characteristics and budget. Based on the pre-planning steps you've undertaken, establish a complete list of charging system components, electrical system upgrades, and physical infrastructure needs for your project. Develop a budget and identify sources of external capital. Apply for any grants you've identified as a good fit for your project. Choosing who supplies your charging system is a complex task that should be undertaken by each facility operator based on their own unique needs and protocols. While only a few vendors are currently marketing marine-specific Level 3 chargers, depending on the circumstances many existing Level 2 charging systems may be appropriate if energy demand is low.

2b. Contact your electric utility to discuss your system design and power needs. The utility will determine your designed charging system's load requirements, whether upgrades are needed at your site and the associated costs, if any. They may be able to offer a timeline for upgrades that may be a prerequisite for installation.

2c. Identify a contractor(s) for infrastructure upgrades. Most shoreside charging infrastructure projects will require a licensed electrician to install equipment, and many will require additional surface infrastructure upgrades like a concrete slab. Use the appropriate process to identify these contractors and work with them to pull permits for your project.

2d. Engage directly with community members. Electric marine propulsion and shoreside charging is a significant change for many Maine working waterfronts. Ensuring that marine stakeholders, community members and leaders, and interested non-residents understand your vision for your working waterfront and the economic benefits that will accrue to the area will ensure a smoother integration and prevent any unnecessary conflict with other working waterfront users and community members. Take the opportunity to create appropriate conversation with individuals and organizations you contacted during pre-planning at this crucial time in the process.

2e. Plan for the future. Based on experience with installing your system(s) and building a charging market, plan for any additional opportunities or anticipated demand early and prepare your site for the future. Consider any sophisticated system upgrades like bidirectional charging that may have been left out from the project initially. Integrate your project into broader working waterfront economic development and resilience planning to maximize compatibility, reduce redundancy and other inefficiencies, and support further adoption of electrified marine propulsion.

3. CONSTRUCTION

The construction phase is a dynamic time when smart planning and effective partnership development can make or break a project. Specific elements of project capitalization and build phases will vary widely; ensure that you are working with organizations that are adaptable and experienced, support the integration of your project into the power distribution system, and tell your story as the process unfolds.

4. EVALUATION AND MAINTENANCE

The evaluation and learning phase is an important part of ensuring that a shoreside charging project is successful, integrated into local and regional economic development planning work, and able to provide lessons learned for your business/community and others seeking to electrify their working waterfronts.

4a. Continue to coordinate with your electric utility. Engagement with your contact(s) at your utility as projects come online can ensure that the system is stabilized and ensure that delivery to your site is smooth and predictable, while any unanticipated challenges can be addressed.

4b. Assess performance with customers/tenants. Work with electric vessel operators to support their confident use of your facilities and build your market. Document vessel use where possible and work with partners to determine cost savings across your customer base or their accounts.

4c. Share your highlights, challenges, and experiences. Early adoption of new technologies and the development of new markets in Maine's working waterfronts is tough no matter the focus. Honest and transparent discussion of shoreside charging will ensure that stakeholders and the public understand and trust the technology and even consider adoption themselves.

Appendix 1
GEOSPATIAL ANALYSIS: SCORE GUIDE

Power supply (S):		**How close to the grid?**
<250 ft from grid	3	**next to the right type of power supply,** likely requiring minimal investment to establish connection
<500 ft from grid	2	**near the right type of power supply**, likely requiring some modest amount of investment to establish a connection
<1,000 ft from grid	1	**not far from the right type of power supply,** a connection may be feasible but will likely require substantial investment
>1,000 ft from grid	0	**far from the right type of power supply,** a connection at this location is not likely to be feasible unless all other conditions are optimal
Consumer demand (D):		**How many suitable boat owners are within driving distance?**
$(+1\sigma, max)$ of $\sum$ users	3	**accessible to a very large share of suitable boat owners,** likely meaning the location would have a high amount of demand
$(\bar{x}, +1\sigma)$ of $\sum$ users	2	**accesible to an above-average share of suitable boat owners,** likely meaning the location would have a reasonable amount of demand
$(-1\sigma, \bar{x})$ of $\sum$ users	1	**accessible to a below-average share of suitable boat owners,** likely meaning the location would have a low amount of demand
$(min, -1\sigma)$ of $\sum$ users	0	**accessible to a very small share of suitable boat owners,** likely meaning the location would have little or no demand
Likely market (M):		**How much nearby activity suggests future growth potential?**
$(+1\sigma, max)$ of activity ratio	3	**amid very dense levels of suitable activity,** suggesting the location will likely expect dependable growth for similar use cases
$(\bar{x}, +1\sigma)$ of activity ratio	2	**amid above-average levels of suitable activity,** suggesting the location might expect moderate growth for similar use cases
$(-1\sigma, \bar{x})$ of activity ratio	1	**amid below-average levels of suitable activity,** suggesting the location may or may not expect growth for similar use cases
$(min, -1\sigma)$ of activity ratio	0	**amid very sparse levels of suitable activity,** suggesting the location should not expect to see growth for similar use cases
Site conditions viable (V):		**Is the site favorable—road access, public privilege, and shoreside infrastructure?**
3 of 3 criteria	3	**highly suitable with all three basic criteria met**, likely meaning the location would present fewer issues when moving toward development
2 of 3 criteria	2	**suitable with two basic criteria met,** likely meaning the location could present at least one issue when moving toward development
1 of 3 criteria	1	**likely not suitable with only one basic criteria met,** likely meaning the location will present several issues when moving toward development
0 of 3 criteria	0	**not suitable with no basic criteria met,** likely meaning the location would present a large number of issues when moving toward development

Appendix 2
GEOSPATIAL ANALYSIS: SCORING CRITERIA

The following provide detailed explanations of the methods we used to develop scores for each of the four scoring criteria.

POWER SUPPLY: PROXIMITY TO EXISTING GRID

For general planning purposes, we used the “grid proximity” of potential sites. This assumes that the most significant impediment to developing a site would be the cost of building new infrastructure to establish a connection where one did not previously exist. This approach enables us to apply one consistent ordinal scoring treatment to all waterfront sites coastwide, across both service providers’ data attributes and coverage areas.

We restricted our analysis to working waterfront areas within the service areas of Central Maine Power and Versant Power, which account for a significant percentage of working waterfront areas.

To create our scoring system, we focused on just one factor: how close a potential site is to the existing power grid. We believe this is the most important factor when deciding if a site can be developed, because connecting to the power grid gets much more expensive the farther away you are.

We used the spacing between utility poles to help us estimate distances. In cities, utility poles are typically about 125 feet apart, while in rural areas they can be up to 300 feet apart. The farther a site is from existing power lines, the more it costs to build new infrastructure to connect it to the electrical grid.

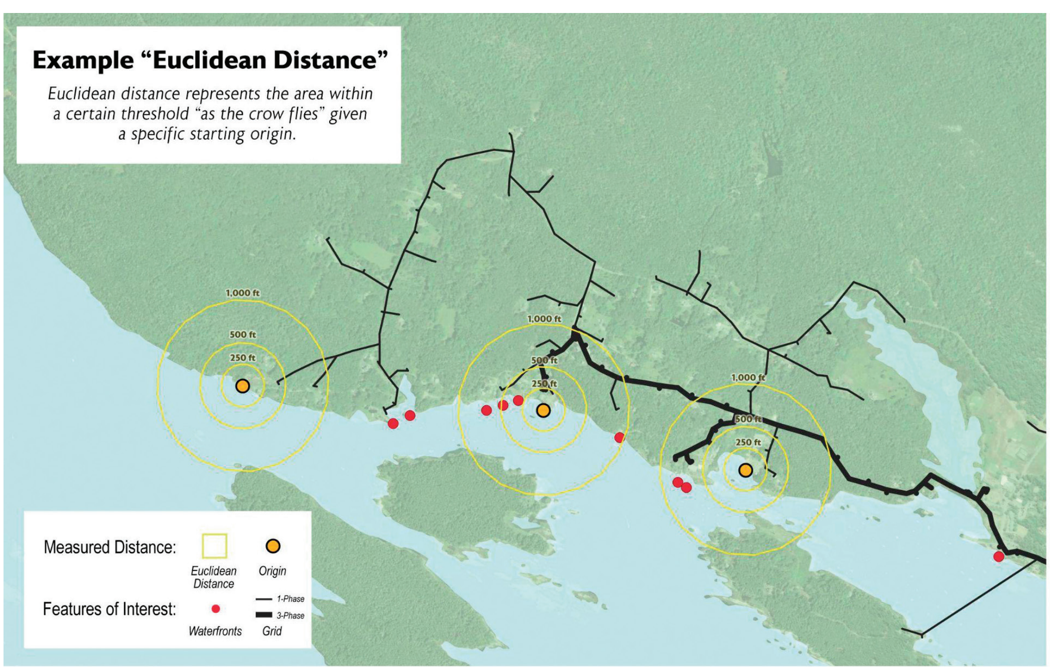
We’ve set the ordinal scores for these distances to be:

Score = 0
>1,000 feet (300 meters)
These sites are too distant to be worthy of immediate investigation. Pursuing development in this area is not recommended.

Score = 1
500-1,000 feet (150-300 meters)
These sites are likely too distant for further investigation. Pursuing development in this area is not recommended, but should not be discounted.

Score = 2
250-500 feet (75-150 meters)
These sites are likely sufficiently proximal for further investigation. Pursuing development in this area is recommended.

Score = 3
<250 feet (<75 meters)
These sites are sufficiently proximal for further investigation. Pursuing development in this area is highly recommended.



Sites are only assessed for proximity if they also meet the minimum phase-level requirements for the appropriate charging station type. This means that higher-power use cases—FISH and YCHT—are compared against distance to 3-phase connection opportunities; whereas lower-power use cases—OUTB and AQUA—are compared against distance to both 3-phase and 1-phase connection opportunities.

CONSUMER DEMAND: PROXIMITY TO EXISTING BOAT OWNER TYPES

This score describes the proximity between existing boat owners (potential existing **users**) and their relative access to working waterfront locations (potential **sites**). This particular part of the assessment attempts to answer the following question:

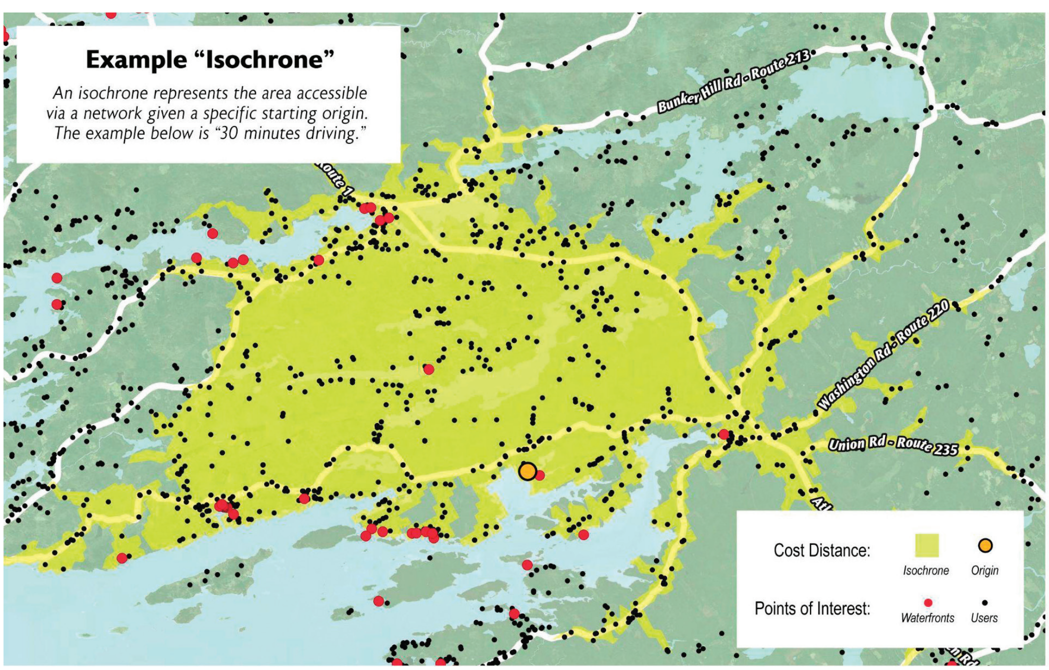
> *How many existing users live within a reasonable driving distance from the waterfront location in question, and is that quantity above or below average?*

To do this, we set several givens and assumptions. Instead of trying to identify exactly where all existing boats are currently used, moored, or located (frankly not possible with the data available), we look to identify the proximity of the boats’ owners and their residences. These are likely more durable locations—we assume that a boat owner may more readily change their place of shore access than their place of residence. Not only does this method enable us to merge disparate datasets (Maine Boat Registrations and USCG Federally Documented Vessels), but our rationale is also that a subset of boat ownership—namely those with residences in Maine—will be a more direct and consequential population to target for long-term electrification.

So, to achieve our sample population, we took two datasets that capture the vast majority of vessels under auxiliary power: the State of Maine’s Boat Registration Dataset and the U.S. Coast Guard’s Federally Documented Vessel Dataset. Boats used in coastal Maine follow a mandate that they should register in **one but not both** of these agencies, which means that duplicates for the same calendar year are non-existent or extremely rare.

From these merged datasets we were able to extract the following congruent attributes: boat length, boat use type, and approximate residence location. Using each waterfront location, an “isochrone” shape was created, demonstrating the distance of linear travel possible along the transportation network. These isochrones were then used to summarize the number of potential existing users that fell within the boundary of each. Each geometry’s summary conceptually represents a specific “share” or “ratio” of potential customers (existing boat owner residences) that may or may not wish to access the waterfront at that location.

Each waterfront “demand” score is only assessed for the total sum of the type of boat-owner population that most likely captures the probable use-case. These filtered owner resident counts are used for summary in the “isochrones.”



For example:

FISH
Boat length: > 24 feet in length.
Use type: commercial.
Driving distance: < 30 minutes by car.

AQUA
Boat length: < 24 feet in length.
Use type: commercial.
Driving distance: < 30 minutes by car.

OUTB
Boat length: < 21 feet in length.
Use type: recreation.
Driving distance: < 30 minutes by car.

YCHT
Boat length: > 21 feet in length.
Use type: recreation.
Driving distance: < 60 minutes by car

We've set the ordinal scores for these quantities to be:

SCORE = 0
(min,-1σ) of ∑ users (well below average)
These sites have a relatively low number of users within driving distance and are not worth further investigation. Pursuing development in this area is not recommended.

SCORE = 1
(-1σ,x̄) of ∑ users (below average)
These sites have a below average number of users within driving distance and are likely not worthy of further investigation. Pursuing development in this area is not recommended, but should not be discounted.

SCORE = 2
(x̄,+1σ) of ∑ users (above average)
These sites have an above average number of users within driving distance and are likely to be worthy of further investigation. Pursuing development in this area is recommended.

SCORE = 3
(+1σ,max) of ∑ users (well above average)
These sites have a high number of users within driving distance and are worthy of further investigation. Pursuing development in this area is highly recommended.

LIKELY MARKET: PROXIMITY TO INDICATORS OF RELEVANT ACTIVITY

We differentiate between two economic concepts:

1) where are the actual **existing consumers** of this new service likely to be (treated above as the score for "consumer demand"), and
2) where are the **emergent or future possible consumers** of this new service likely to be (treated here as "likely market")?

To address this second category we do not look specifically at existing boat owners or users, but instead the types of activities and indicators that are typical of each use case, namely: lobstering statistics (FISH), places of aquaculture activity (AQUA), availability of local amenities (OUTB), and frequency of larger vessel traffic (YCHT). These derive from disparate datasets, but are compared in a similar matter, using a geographic density function. This density function serves as an estimate (similar to a "heat map") for how common or uncommon an activity is in a particular area based on a search radius, imposed upon the source data. Once the "density indicator" is created, these are sampled for values at each waterfront location. Although the process is subjective and meant to illustrate differentiation, the resulting categories are derived from data that have little or no geographic gaps; they represent a full treatment of that theme across the entire study area.

Each waterfront "market" score is assessed for its relative density indicator using separate data inputs and parameters for each use-case. For example:

FISH
Source data: Active harvesters by port of call.
Density function: Kernel density within 6 nautical miles.

AQUA
Source data: Active aquaculture: sites, leases, permit applications, and LPAs.
Density function: Uniform density within 3 nautical miles.

OUTB
Source data: Active amenities: fuel, food, lodging, other access points.
Density function: Uniform density within 1 nautical mile.

YCHT
Source data: Active vessel traffic, according to AIS.
Density function: Maximum annual average count within 1 nautical mile.

We've set the ordinal scores for these relative densities/ frequencies to be:

SCORE = 0
(min,-1σ) of density indicator (well below average
These sites have a relatively low level of local activity and are not worth further investigation. Pursuing development in this area is not recommended.

SCORE = 1
(-1σ,x̄) of density indicator (below average)
These sites have a below average level of local activity and are likely not worthy of further investigation. Pursuing development in this area is not recommended, but should not be discounted.

SCORE = 2
(x̄,+1σ) of density indicator (above average)
These sites have an above average level of local activity and are likely to be worthy of further investigation. Pursuing development in this area is recommended.

SCORE = 3
(+1σ,max) of density indicator (well above average)
These sites have a high level of local activity and are worthy of further investigation. Pursuing development in this area is highly recommended.

SITE CONDITIONS: VIABLE AND/OR FAVORABLE TO IMPLEMENT

While each site will undoubtedly have a vast level of construction and permitting considerations that are outside the scope of this assessment, we wished to assess general attributes for each site and provide a coastwide score for "favorable" versus "not favorable" attributes. The Last 20 Miles data provide a host of helpful and illuminating fields and values regarding the nature of each site. These are used broadly and generally to provide an additional scoring metric for differentiation.

For this analysis, favorable sites are generally described as having: 1) public access permission and/or privileges, 2) presence of a wharf or year-round floating dock, and 3) decent road access. Each one of these criteria are given a point if and when they are fulfilled, and a point is not given if and when they are not fulfilled: e.g. if all are fulfilled, a score of "3" is given, if none are fulfilled, then a score of "0" is given.

Appendix 3
WHAT ARE OTHER LOCALES DOING?

The maritime sector can be classified as a "hard-to-abate" segment of the economy: it is energy intensive to move vessels through the water; technical applications for emissions reductions are often broadly dispersed and require unique innovations or infrastructure; low-carbon alternatives are immature, represent a small market share of available options, or are expensive; and fiscal or regulatory incentives are not yet fully in place if planned at all.

In the case of Maine's oceangoing vessels, each of these challenges exist. However, recent technical innovations and projects centered around the development of complete integrated electrification systems in the Canadian Maritimes, the United Kingdom, Washington, and Alaska are demonstrating that electric marine propulsion can be a viable, safe, and cost-effective option for businesses and communities. These energy systems are being developed and implemented now, and Maine is well positioned to establish and implement versions that support our unique working waterfront requirements, grid configuration, and climate exposure.

NOVA SCOTIA

In Nova Scotia, a recent study found that the majority of lobster vessels operating within 20 kilometers (12 miles) of shore are prime candidates for battery-electric propulsion systems. The proximity of their fishing grounds and "day boat" duty cycle reduces the need for large onboard energy storage solutions and supports the transition to electrification without compromising operational capacity of this type of fishery. Further, the study found that these vessels could save significant amounts of money. For Maine, with its similarly configured fleet of smaller fishing vessels and working boats, this model presents an opportunity to reduce reliance on diesel fuel, which accounts for a significant portion of operational costs.

The Nova Scotia Lobster Fleet Electrification Assessment, conducted by the nonprofit organization Oceans North, paints a promising picture for a cleaner future for the province's vital fishery. The study reveals that a significant portion of the lobster fleet, over 2,300 vessels, could be prime candidates for electrification due to their operational range and energy consumption patterns. This offers a substantial opportunity to reduce greenhouse gas emissions (GHG) from the industry, estimated at 82 million kg of CO2 annually – equivalent to roughly 35,000 cars.

Nova Scotia's marine vessel electrification strategy is largely driven by federal government investment funding to subsidize the costs of purchasing hybrid systems and support for local government integration of charging infrastructure and associated costs. The Province's "Smart Grid Nova Scotia" initiative offers a framework for planning shoreside charging and vessel electrification buildout, but as with Maine, further investments in power transmission and distribution infrastructure modernization are likely to be necessary to support the increased demand from users supported by the vessel electrification program.

While Maine's political and regulatory environments differ from Nova Scotia's, both regions are subject to increasing and similar pressures, including: 1) rising sea levels, 2) extreme weather events, 3) shifting habitat for key fisheries species including lobsters and groundfish, and 4) volatile economic incentives and risks exacerbated by climate change. Maine, like Nova Scotia, would need to greatly invest in shoreside infrastructure to support such a transformation. This includes upgrading the electrical grid to accommodate increased demand for charging systems and establishing charging stations at key harbors along the coast. Government incentives, grants, and policy support would also be essential in bridging the gap between the initial costs of electrification and the long-term benefits, similar to the incentives explored in the Nova Scotia report. Differing from the narrower focus presented in the Nova Scotia report, however, Maine should also make use of its much more extensive and vibrant recreation and vacation economies to explore other suitable use-cases to catalyze this effort.

PLYMOUTH & THE SOUTH COAST OF ENGLAND

A consortium of local government officials, researchers at the University of Plymouth, and working waterfront operators is implementing a pair of regional projects along the South Coast of England to electrify harbors and build electric vessels for suitability demonstrations. First, the Electric Seaway Project is focusing on infrastructure development for small and mid-sized recreational and commercial vessels with a £3.2 million UK government grant. The project will support the buildout of charging infrastructure for electric boats at 10 locations along the South Coast catering to leisure and commercial vessels. The project aims to significantly reduce carbon emissions and contribute to the UK's "Maritime 2050" decarbonization goals. Second, the Zero Emissions Network of Workboats (ZENOW) Project is aimed at profiling the use cases and duty cycles of commercial electric vessels in the UK while simultaneously supporting the region's nascent electric boat construction industry. Under a £5.4 million grant from public sources (UK SHORE and Innovate UK), ZENOW will deploy a network of 20 electric workboats across 10 UK locations by March 2025, corresponding to the home ports of the Electric Seaway Project. The project will involve a three-year demonstration period, collecting data on the performance, efficiency, and environmental impact of electric workboats. Similar to efforts underway in the US, the ZENOW Project will gather data to characterize electric boat operations and support the design of electrified propulsion systems for a variety of marine vessel use cases.

The projects are sited in rural areas similar to Maine's coastal communities and working waterfronts, although the UK's harbors are mostly operated by large private companies and siting considerations are more streamlined than in Maine. Additionally, the UK's power grid is managed by National Grid, a large regulated monopoly. This centralized model allows for coordinated planning and investment in grid infrastructure and more rapid deployment of funding from UK Government sources (the equivalent of federal grants in the US). Nonetheless, project data could prove valuable and informative for establishing best practices and informing future infrastructure development in Maine.

FRIDAY HARBOR, WASHINGTON

The Port of Friday Harbor, Washington, a hub for maritime activity in the San Juan Islands, recently secured a $7 million grant to develop an electrified boat technology project including electric vessel procurement and charging system installation. The initiative aims to significantly reduce carbon emissions and enhance the sustainability of the port's operations. The grant will support implementation of several elements of the port's electrification initiative including:

- **Charging Infrastructure:** The port will install state-of-the-art charging stations to accommodate both large cruise ships and smaller vessels. This infrastructure will be designed to handle the varying energy demands of different vessel types and sizes, ensuring efficient and reliable charging.

- **Solar Canopy and Microgrid:** A solar canopy will be constructed over the port's parking area to generate renewable energy. This energy, combined with local energy storage systems, will form a microgrid that can provide backup power to port operations during power outages or periods of high demand.

- **Electric Workboats:** The port will acquire a fleet of electric workboats to replace its diesel-powered vessels. These harbor craft will be used for various tasks including maintenance, towing, and transporting personnel and cargo.

The State of Washington has established a decarbonization planning effort similar to Maine's own Climate Council-led process, although Washington's efforts are more comprehensive, market driven, and integrated into local and regional planning and financing mechanisms. The San Juan Islands, like Maine's coastal and island communities, are known for their natural beauty and serve as seasonal hubs for recreational boaters and tourism, and are also particularly vulnerable to climate change-driven storms and sea level rise. Friday Harbor's setting on a rural island community is worth monitoring for Maine communities to evaluate opportunities and lessons learned.

The Port of Friday Harbor serves a diverse range of maritime users, including commercial fishing vessels, passenger ferries, recreational boats, and cruise ships. The success of the Port's electrification project will depend on the reliability of the local power grid. OPALCO, the electric utility serving San Juan County, is currently undertaking a major upgrade to its Friday Harbor substation to accommodate increased demand. This upgrade will ensure that the port has the necessary power supply to support its electrification efforts. As with those of many of Maine's smaller ports and harbors, Friday Harbor's planning efforts integrating shoreside charging infrastructure development alongside more traditional grid upgrades are a major catalyst for their success.

SITKA, ALASKA

The Alaska Longline Fishermen's Association (ALFA), based in Sitka, has placed the first hybrid commercial fishing vessel in the US into service under a $700,000 award from the US Department of Energy's Vehicle Technology Office (VTO). ALFA's project focuses on hybrid electric propulsion retrofit systems as a proof of concept for reducing fuel consumption and CO2 emissions in the fishing industry, resulting in significant cost savings for fishing businesses and economic development opportunities for maritime support service providers, alongside regional goals to modernize cargo and merchant shipping propulsion to use alternative gaseous and liquid fuels for propulsion.

The project involved converting one of ALFA's member vessels to a hybrid system, combining a traditional diesel engine with an electric motor and battery pack. The hybrid approach allows for efficient use of diesel power for long transits and enables silent operations during low-power fishing activities. Throughout the project, real-world data on fuel consumption, operating conditions, and energy use are being collected to optimize hybrid systems for fishing vessels and inform the future of fleet electrification in fleets of vessels similarly sized to those in Maine.

Appendix 4
STAKEHOLDER INTERVIEWS

We conducted 29 semi-structured interviews with 35 participants from Maine's coastal communities to capture current perspectives of the opportunities and challenges associated with shoreside charging infrastructure and marine vessel electrification and to inform the development of this report. The interviewees represented a diverse range of perspectives, including fishermen, aquaculture operators, harbormasters, port managers, shoreside business owners, and sustainability experts. Our interviews aimed to capture the lived experiences and expert opinions of individuals directly involved with working waterfront infrastructure development and resilience.

We used a semi-structured interview protocol allowing for both pre-defined questions and organic follow-up discussions, enabling a deeper exploration of the nuances and complexities surrounding shoreside electrification. The interviews were not limited to specific topics, allowing for the interviewees to provide their opinions on any relevant topic. The intention behind the interview questions was to gather detailed information on the technical, regulatory, and socioeconomic issues of shoreside electrification.

The following section synthesizes findings from interviews with various stakeholders, offering a detailed look at the perspectives and technical insights relevant to shoreside electrification. This section aims to provide a nuanced understanding of the diverse challenges and opportunities identified across different user groups contacted for this report.

SUMMARY OF INTERVIEWS BY STAKEHOLDER TYPE

1. Harbor Masters and Port Managers

Current Shore Power Status: Harbor masters and port managers consistently report limited shore power access at their facilities. Most existing infrastructure provides 120V AC power, primarily catering to recreational vessels with minimal power requirements. Some facilities offer 50-amp outlets, but lack the infrastructure necessary for high-demand electric vessel charging. A common deficiency is the absence of three-phase power, which is essential for Level 3 charging. Many locations only have single-phase power and some only have power available for specific equipment like pumps and hoists, but not vessel charging.

Demand and User Types: While current demand for high-power charging of electric vessels is low, there is a growing demand for standard shore power from larger recreational vessels (over 30 feet). These vessels require higher amperage and three-phase power to run onboard systems. As one harbormaster noted, "the demand for shoreside power is growing rapidly. The vessels demanding it are the ones over 30 feet and typically recreational". Recreational vessels are generally considered the most immediate users of shore power, but interviewees noted the transition to electric propulsion is also being discussed for commercial vessels and harbor craft. Ports that accommodate cruise ships and ferries also have unique power needs that differ from smaller recreational or commercial vessels.

Infrastructure Challenges: A primary concern of interviewees is the electrical grid's capacity to support increased charging loads, as the current infrastructure is not designed for the high power demands of electric vessels. Upgrades to the grid are essential, including the installation of new transformers, distribution lines, and substations. Many ports lack infrastructure for Level 2 or Level 3 charging, which would require higher voltages and amperages. Multiple aquaculture operators specifically highlighted a lack of three-phase power at their sites. Upgrading to a three-phase system is required for larger vessels. There is also a need for new trunking sized for larger cables when adding new shoreside infrastructure. Additionally, interviewees noted that the physical location of the infrastructure is a concern due to storm surge and sea level rise.

Partnerships and Collaboration: Most port managers are interested in collaborating with electric utilities, but there are concerns about the utility companies' willingness to partner and the perceived need for a stronger collaborative relationship with utilities. Some interviewees also believe that it is important to involve highway departments in conversations about electrification as they will be implementing the physical infrastructure. One coastal resource manager stated that a good municipal or regional partnership is built on "Collaboration and communication. I think it is critical when you're dealing with different partners. So, you know, being able to communicate effectively and collaborate on those ideas [are] I think the two most important parts [of this type of planning effort]..." Some interviewees also suggested that coordinating upgrades for multiple projects could provide a better path for implementation, such as by combining electrification upgrades with necessary repairs to existing infrastructure.

Financing and Municipal Planning: Many port managers noted the difficulty of securing funding for electrification upgrades. Interviewees expressed the belief that municipalities would not be able to secure public support for shoreside charging projects at public facilities unless dedicated grants were made available given the high priority of other projects and investments.

2. Fishermen and Aquaculture Operators

Initial Hesitation: Many fishermen and aquaculture operators express initial skepticism about electrification, often due to concerns about cost, reliability, and the practicality of transitioning from combustion engines. One aquaculture expert from Downeast mentioned that there is a "large distrust in anything new and that for electric to be adopted diesel would have to be illegal or electric would have to be free." This sentiment shows the level of skepticism and the need for a more compelling and well-supported case for adoption, with early-adopters demonstrating the value and benefits.

Specific Needs and Use Cases: Despite initial hesitation, most fishermen and aquaculturists see the value in electrification when considering certain use cases. One aquaculture operator stated that "the best location for electrification would be skiffs for oyster or scallop farming". There is some interest in hybrid vessels, as they provide a balance between range and sustainability, especially if there is some economic support for adoption.

Concerns about Infrastructure: Many operators are concerned about the availability of charging infrastructure in smaller ports and the lack of universal charging standards for marine applications. They also mention the high cost of implementation and the lack of incentives to offset these costs. Additionally, there is a preference to adopt low cost, easy solutions rather than high cost or complex solutions.

Benefits of Electric: Despite the barriers, some interviewees cited the potential benefits of electric vessels such as reduced noise, which is particularly important for those in the aquaculture and commercial fishing industries. One interviewee stated, "The same population that's very anti-electric vehicles actually is slightly more OK with the idea of electrification of boats because of the auditory aspect...you are taking that wear and tear off of your eardrums and you are taking that noise pollution away from you. And of course you could have a better financial bottom line, eventually at some point, because you're not using as much fuel...".

3. Recreational Boaters and Marina Owners

Interest in Electric Vessels: There is a growing interest in electric vessels among recreational boaters, driven by their quiet operation, low emissions, and lower running costs. However, many see electric vessels as a futuristic application of emerging technology in the electric vehicle industry, with limited current demand.

Shore Power for Recreational Vessels: Recreational vessels are the current large users of shore power for onboard electrical loads. The increased demand for shore power in this segment is due to the larger size and increased power demands of recreational vessels, which require more amperage to run onboard systems such as air conditioning. The current infrastructure in many marinas is insufficient for the demand from these larger vessels.

Logistical Challenges: There are logistical challenges that need to be addressed for shore power at marinas. For example, there can be a challenge in implementing car charging alongside boat charging due to the proximity of the water and the infrastructure needed for safe operations. Many marinas are on moorings rather than docks, which also limits the ability for vessels to be plugged in.

Financial Barriers: There are large financial barriers for marinas in adopting shore power for electric vessels, including the large upfront costs and the need to reconfigure the existing layout of marinas. Additionally, there are challenges in calculating pricing for electricity without dedicated charging stations. For example, an operations manager stated that she does not know what to charge users without a charging station.

4. Municipal and Regional Planners

Focus on Resilience and Climate Action: Municipal and regional planners prioritize resilience and climate action, emphasizing that electrification is an important element of sustainability. However, many municipalities are first addressing the physical damage caused by recent storms, which has diverted resources away from electrification projects.

Integration with Existing Plans: Planners are seeking opportunities to integrate electrification projects with existing climate action plans and working waterfront development projects. This ensures that investments in electrification are coordinated with other economic development and environmental efforts. The city of Portland has already conducted a load flow analysis to better understand grid requirements for implementing shoreside power for large vessels.

Need for Demonstration and Education: There is a need for demonstrations of electric vessels to show that they are a practical alternative to combustion powered vessels. Many municipal staff do not understand the current infrastructure or the requirements for implementing shoreside electrification. For example, Nichole Sawyer, a dean of workforce development, noted that "there should be more awareness about shoreside electrification".

Grid Constraints: A large concern for many municipalities is the constraint of the grid, and the limited available land to implement solar arrays or other forms of renewable generation. The planners note a preference for implementing microgrids with storage to help lessen the impact on the grid, which was noted as a limiting factor by multiple participants.

Use Case: Planners also noted that a strong use case is necessary before any large scale implementation of electric vessel technology, and that the aquaculture industry, with its consistent patterns and shorter routes, may be a good initial target for adoption.

5. Policy Experts and Non-Profit Organizations

Importance of Policy and Funding: Policy experts and non-profit organizations emphasize the need for clear policies and incentives to accelerate the adoption of electric vessels and shore power. They noted that current policies are insufficient to reach desired outcomes, and that there is a need for subsidies to encourage businesses and individuals to adopt this technology.

Focus on Working Waterfronts: There is a focus on the unique needs of the working waterfront and a strong belief that there needs to be specific incentives for this sector. However, there is also recognition that the recreational boating sector will have a much greater impact overall because of the sheer size of the sector, and that it should not be ignored.

Need for Community Engagement: These stakeholders noted the importance of engaging with local communities and involving them in the planning process. This is essential to overcome resistance and build a consensus for electrification projects. They also noted that a lack of transparency and perceived bias has led to negative sentiment about adopting these new technologies.

Standardization: Many policy experts noted the need for standardization in charging connectors, equipment, and processes. This would simplify the implementation of charging systems and allow different vessels to use the same infrastructure. The report Standards of shoreside charging for battery-powered vessels: Technical Report emphasized that "a higher level of standardization should facilitate technical choices and make it easier to specify new projects".

TECHNICAL DETAILS AND KEY THEMES

Charging Levels: The interviews and reports reference different levels of charging. Level 1 (120V) for small loads, Level 2 (240V) for some larger vessels and equipment, and Level 3 DC Fast Charging, which requires 3-phase power. Level 3 DC fast charging is most appropriate for quickly charging boats between 21 and 60 feet. There was an emphasis on not implementing fast chargers everywhere, as slower overnight chargers may be more appropriate in many aquaculture, municipal, and recreational applications.

Grid Capacity and Upgrades: A significant barrier is the lack of grid capacity to support high-demand charging. Upgrades are needed, including transformers, distribution lines, and substations. The interviews highlight the importance of performing site-specific investigations of grid capacity for each new charging project to ensure its feasibility.

Vessel Power Needs: Vessel power requirements vary significantly. Static gear vessels (e.g. potters, divers, netters) have lower power needs, while mobile gear vessels (e.g. trawlers, dredgers) require much more power. Vessels with predictable routes and schedules, such as ferries, are easier to plan for electrification.

Battery Technology: Current battery technology is not sufficient for full electrification of all vessel types, particularly larger vessels. Lithium-ion batteries are not practical for larger, ocean-going vessels due to weight and energy density limitations. There is ongoing research in alternative technologies like Sodium-Sulfur (Na-S) and Lithium-air (Li-air) batteries.

Alternative Fuels: There is growing interest in alternative fuels like hydrogen and methanol, particularly for larger vessels where batteries are impractical. However, these alternatives would also require new infrastructure to be developed.

Shore Power Connections: Standardization is required for shore power connections. Both AC and DC charging are used, depending on the vessel and shoreside infrastructure. Many systems today are custom-built to fit a specific use case, which limits interoperability.

Microgrids: The use of microgrids is a potentially valuable way to increase the resilience of ports and to allow for renewable generation, such as solar and wind. Microgrids can also integrate battery storage, which can help to manage power demand on the grid. Some interviewees also noted the potential use of tidal power to help offset the electrical needs of a port.

V2G (Vessel-to-Grid): There is a potential for vessels to provide power back to the grid using bidirectional charging, helping with grid stability and providing revenue for vessel owners.

CONCLUSION

The interviews conducted for this project reveal a diverse range of perspectives and challenges surrounding shoreside electrification in Maine. While many stakeholders recognize the potential benefits, there are also significant barriers related to infrastructure, funding, policy, and public perception. Moving forward, it will be crucial to address these challenges through strategic investments, clear policy guidance, smart planning, and collaborative partnerships among ports, utilities, and the community. Overall, interviewees suggest that the next steps for Maine's working waterfronts could be to focus on creating a framework for pilot projects, which will allow stakeholders to test different technologies and implementation strategies.

Appendix 5
INTERVIEW GUIDE

SHORESIDE CHARGING INFRASTRUCTURE

Interview guide - Maine port managers and stakeholders

Script

Thanks very much for taking the time to speak with me. This interview is part of a project whose purpose is to evaluate the opportunities and challenges of shoreside charging infrastructure in Maine. The primary goal of this project is to produce a report on the technical, regulatory, and socioeconomic issues of shoreside electrification. As an expert on key issues that are highly relevant to this topic, your insight is going to be incredibly helpful in informing our report.

During this interview, which I hope will feel more like a conversation, I'm going to ask you a series of open-ended questions. The interview will be recorded so that your responses can be part of our report. The report will not identify you by name or affiliation, just by your general profession, like '[fisherman] or [municipal government staff member]'. If there's anything you'd like to say that you want kept off the record just let me know and I will pause the recording. Please answer questions with as much detail as you can, no topic is off the table and every detail is relevant. My goal is for us to have an in-depth back and forth conversation that gets to the heart of the issues and your opinions on them.

Before we start do you have any questions about this project, the interview, or anything else?

I'm going to begin recording our conversation.

Ice breakers

1. For the record please state your name and position/affiliation.
2. *[Fishermen]* What species do you fish for, and where do you operate generally?

   [Aquaculture operators] What species do you grow, and where is your lease/farm?

   [Others] What are your day to day responsibilities working at [organization]?
3. Please describe your experience with coastal infrastructure or working waterfront issues over the course of your [choose: career/lifetime] (Probe if desired).
4. Can you characterize the vessels that use or operate in your port? Do you have docks (with shore power usage) or moorings? (Probe: what proportion of boats use moorings vs. berths?)
5. When I say 'shoreside electrification' what immediately comes to mind? (Optional probe: please elaborate on that a bit. Why do you think of [answer to 3]?
6. Please tell me what your own personal experience has been with shore power. That can include conversations, observations, hands-on experience, or anything else.

Site-specific questions

1. What is the current status of shore power access at [your port/your facility/the berths in your town]? How many boats use shore power, what sorts of loads are they running, etc.?
2. How many pedestals or outlets designated for shore power exist in your port? Do you know how many are 110v, 220v, 480v, etc?
   a. [If the subject is familiar with electrical engineering concepts] Are there any specific classes of power delivery, for example Level 2/220v or Level 3/480v+, that you believe will be most appropriate for your port?
3. *[Port managers]* Do you actively encourage maritime users to use shore power?

   [Fishermen/aquaculture operators] Does your port actively encourage you to use shore power for any applications?
4. Are you currently focusing on advancing electrification in your port, specifically?
   a. *[If yes]* Please tell me about that work. What is being planned?
   b. *[If no]* Why not? What would need to change in order for you to become more focused on shoreside electrification?

5. Where, specifically in your port, do you think shoreside electrification has the most promise?
   a. *[If already deployed]* Where is it getting the most use already, and why is that the case?
   b. *[If already deployed]* Do you know what costs were associated with installing these systems? Who bore those costs, and were there any complex funding arrangements, loans, grants, or joint ventures involved?
   c. *[If not yet deployed]* What might limit adoption or availability of shore power in your port?
6. What are the siting requirements for marine charging stations in your port, as you currently understand them?
7. Are there electric vehicle (car) charging stations in or around your port? Do you see any value or opportunities in using EV chargers for both vessels and cars/trucks?
8. What category of maritime users are most likely to use shore power in your port? How many of these users are there in your port specifically?
9. What shoreside businesses operate in your port?
   a. *[If this will require an extensive list]* Can you please characterize the types of shoreside businesses in your port that you believe can or could host shoreside charging infrastructure in the future?
10. Are there any municipal facilities in your port that currently host or could host charging infrastructure?
   a. *[If yes]* Has your port already incurred any expenses associated with building shoreside electrification infrastructure, and if so what were those costs?
11. Let's say you were planning a new shoreside electrification project in your port. Could you please walk me through the steps that you would take to move from an idea to a completed project?
   a. Who else in your port/city/town would be heavily involved in planning and implementing this shoreside power project?
12. What, if any, specific policy or physical barriers to shoreside electrification exist in your port?
   a. *[If specific barriers are identified]* How can those barriers be overcome?
13. Are there existing solar arrays in your port or nearby along the coast that would be a suitable location for charging infrastructure?
   a. How has your town handled solar power generation and grid interconnection?
   b. Do you see potential in solar generation and energy storage coupled with dockside charging or other large energy users in your port? Why/Why not?
14. Do you think sea level rise or other climate impacts will change how the placement of charging infrastructure is handled locally?

GENERAL QUESTIONS

1. What has your experience been with [CMP/Versant/local energy co-op] generally? Do you believe they are or will be a good partner in any current or future shoreside electrification efforts in your port?
   a. *[If the subject has significant experience]* Has your town ever asked for or discussed asking for a load flow analysis?
2. What is the current fiscal environment, as you see it, for businesses or port managers to pursue shoreside electrification? What could change to make it easier?
3. Are there any general permitting, transmission, or engineering issues that need to be addressed before shoreside electrification can be fully deployed in Maine?
4. What are your thoughts about the current and future state of demand for dockside power delivery?
5. What is the State of Maine doing to evaluate or encourage shoreside electrification? What about federal agencies? Is this enough, in your opinion, to achieve necessary or positive outcomes for shoreside power project development?
6. Who do you think is doing the most or the highest quality work in shoreside electrification in Maine? Who are the thought leaders that you look to in municipal planning and port infrastructure development?
7. Do you work closely with any other ports on planning efforts that require a similar amount of planning and resources as shoreside charging? Why do you work with them in particular? What makes a good municipal or regional partnership in your view?

8. What state, federal, or private funding opportunities are available for those looking to expand charging infrastructure that you're aware of? Have you used any of these?

9. Do you see opportunities to tie the expansion of shoreside electrification work to any other economic development projects at the state or federal levels?

   a. *[If yes]* What might determine the success or failure of this sort of coupled development effort?

   b . *[If not]* Why is this issue unique?

10. Do you think sea level rise or other climate impacts will change how the placement of charging infrastructure is handled regionally or statewide?

CONCLUSION

This concludes my questions for you. Are there any other issues you'd like to discuss, or any questions I should have asked?

Thank you very much for the opportunity to learn from you and bring your experience into our project. If you would like to follow up on anything we discussed, please don't hesitate to get in touch. Thanks so much for your time.

END NOTES

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