An Analysis of the Leading Tidal Energy Projects in the United States since 2000.

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A thesis

submitted in partial fulfillment of the

requirements for the degree of

Master of Marine Affairs

University of Washington

2024

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Program Authorized to Offer Degree:

School of Marine and Environmental Affairs

University of Washington

Abstract

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Using both document review and interview data approach this study explores two of the leading pilot tidal energy projects completed in the United States: the Cobscook Bay Tidal Energy pilot project in Eastport, Maine and the Roosevelt Island Tidal Energy pilot project in the East River off of Manhattan, New York. The research draws upon project documentation and licensing to gain insight of these projects' progression through development stages. This study also utilizes in-depth, elite, semi-structured interviews of key pilot project developers, researchers, and permitting agency representatives to understand their experiences with tidal energy development. The study analyzes data from eleven interviews utilizing Atlas.ti software to identify major interview themes. The interviewees shared their views of the role of five major factors identified through literature review as having an impact on renewable energy project progression. These include: social acceptance, economic, political, legal, and ecological factors. Respondents shared how these factors appeared or were relevant to their experiences with the permitting or design stages, as well as how research and experimentation was developed. The themes that emerged from the review of project documentation and interviews were siting and design/deployment strategies, community engagement and social acceptance, U.S. economic and social structures, and permitting and the research cycle. The interviews also included respondents' assessments

of the pilot projects' progression, their identification of steps that were conducive to the development and elements that they would recommend changing. Lastly, the interviewees were able to share their opinions on what the future of tidal development in the U.S. might look like. These results provide lessons for future tidal energy development in the U.S. Interviewees point to future commercial scale tidal energy as either hybrid renewable portfolio solutions or as small-scale, community-based systems. Regardless of how commercial tidal energy will be developed in the U.S. economic, political, and legal challenges might continue along with the necessity for community engagement and ecological research. Understanding how these early U.S. tidal energy projects were developed is the key to possible future commercial scale tidal energy.

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Introduction

Background

Tidal energy provides a promising pathway for the future of renewable energy development in the ocean. Utilizing the ocean and other bodies of water, tidal energy is one option for greener electricity generation among a diverse portfolio of marine technologies. Researchers recognize the vast potential of the ocean to produce reliable, renewable energy for a variety of uses.[1] These technologies offer an opportunity to create more jobs and play a role in President Biden's larger environmental goals. After U.S. President Biden rejoined the Paris Agreement, the National Climate Task Force was established to reduce emissions, increase resiliency, advance environmental justice, and achieve true energy security.[2] President Biden secured large funding opportunities for development to achieve a net-zero emissions economy by 2050 and reach 100% carbon pollution-free electricity by 2035. Most notably, the Department of Energy's Water Power Technologies Office had set aside $45 million to fund pilot demonstration sites and community-led tidal and/or active energy projects in the U.S.[3] These support and funding opportunities are reflected in the tidal pilot projects analyzed in this study, as well as the increase in research surrounding renewable energy technologies.

There are three main types of marine renewable energy, which all seek to generate clean energy from the natural ocean and river sources. These three main types of technologies are wave, offshore wind, and tidal energy. The movement of waves, wind, currents, and tidal changes offer these energy extraction methods. Wave energy harnesses the power of moving ocean waves. There are numerous wave energy numerical models being piloted by developers (*Weber, 2018*). Offshore wind energy harnesses the same wind patterns and power as onshore wind turbines, but on floating platforms. Tidal energy harnesses the power of water in areas with high tidal ranges and strong currents.[1] Bays and rivers can constrict the water flow and tidal stream, creating faster currents for electricity generation. High tidal ranges occur when sites experience drastic differences between high and low tides. The tidal turbines function similarly to wind

[1] https://www.pnnl.gov/explainer-articles/tidal-energy#:~:text=Tidal%20energy%20is%20a%20form,the%20water%20to%20move%20faster. Accessed 1 June 2024
[2] https://www.whitehouse.gov/briefing-room/statements-releases/2024/04/25/fact-sheet-biden-harris-administration-announces-key-actions-to-strengthen-americas-electric-grid-boost-clean-energy-deployment-and-manufacturing-jobs-and-cut-dangerous-pollution-from-the/ Accessed 1 June 2024
[3] https://www.energy.gov/articles/biden-harris-administration-invests-nearly-16-million-advance-marine-energy-us-1 Accessed 1 June 2024

turbines, but placed underwater to generate power as the blades turn due to moving currents. Other popular tidal energy designs explored more globally include tidal lagoons, kites, and barrages.[1]

Tidal energy poses an attractive renewable energy option of these technologies because tidal ranges offer predictability and stability (*Khare & Ahmed, 2022)*. Within the United States there are currently no commercial tidal energy plants, however, there are various sites of high potential for tidal energy development. Some coastal bays in the U.S. have large tidal ranges that hold the potential for tidal energy electricity generation for up to 16 hours a day. Developers and scientists on both coasts of the U.S. have identified sites of higher tidal energy generation potential *(Kirchherr & Charles, 2022).* Various renewable energy companies have started to take notice of the sites with tidal potential in the United States and pilot projects have been in development.

Another positive aspect of this technology may be that in comparison to offshore wind, tidal energy could have lower operational costs (*Denny, 2009*). Though these possible benefits have been seen in some cases internationally, the true benefits of a commercial tidal energy project in the U.S. are unknown. Once benefits of tidal are more understood, tidal energy technology offers the potential for the United States to harness river and ocean tidal and current power.

Challenge and Opportunity

While tidal energy offers a number of benefits, developers will have to overcome many challenges. Tidal energy, globally, has seen slow progression in development compared to other renewable energy sources, most notably wind and solar (*Strielkowski, et al., 2021*). There has been no successfully tidal energy projects at the commercial scale in the United States. While feasibility studies, research, and pilot projects have been completed, the true benefits and negative impacts are not entirely known.

Three of the main challenges that tidal energy development has faced are financing, designing, and permitting development. Financial support is necessary to assist tidal energy developers in growing and developing the industry. While federal funding opportunities have been presented by President Biden and the DOE, developers have still struggled to find investors to support the research necessary to develop the industry. Funding and financing are important because developing tidal arrays and connecting them to the power grid requires extensive and costly engineering and manufacturing work.[4] The costs for tidal energy development include the project development, grid connection, moorings and foundations, installations, the device and materials, and operating expenditures. Early pilot projects and successful tidal energy projects abroad have led to a basis for developing research and methods of current financial feasibility.[5] These existing test and demonstration technologies are recognized to be high in cost, and in order to attain commercial competitiveness significant cost reduction must be achieved.[5] Other challenges tidal development continues to face are within the design and permitting stages of these projects.

Many of the design challenges are due to the complexities of tidal sites, unknowns of the engineering designs, and complications of the supporting infrastructure. Many tidally forced regions are far more complicated than ‘a single channel connecting two basins.’ Instead, these regions are often an interconnected web of channels connecting many basins (*Kilcher et al., 2021*). The complexity of these tidal systems creates challenges for the design and deployment logistics of the turbines and their supporting infrastructure. Construction challenges involve the shipping and availability of construction materials. The most common materials for the structure, such as steel, glass, and carbon composites are expensive. Steel is also heavy and causes additional environmental impacts. In comparison, if developers choose other materials, such as glass or carbon fiber, they may produce more greenhouse gases and ecosystem risks (*Walker, 2022*). Through storm events and strong currents, the tidal devices must be strong and heavy (*Parker, 2021*). These material challenges have led to high development costs. The energy generated within the generator must be transferred through underwater cables to an onshore station. In heavily trafficked coastal areas, these design requirements pose many challenges because of user conflict in these shared environments. Ocean and river tidal energy sites are usually collocated with ports which support coastal or inland sea shipping. The existence of undersea networking cables add to the concerns of user conflict. The design process of tidal technology has thus faced challenges because of

[4] https://www.pnnl.gov/explainer-articles/tidal-energy#:~:text=Tidal%20energy%20as%20an%20industry,costly%20engineering%20and%20manufacturing%20work. Accessed 1 June 2024
[5] International Energy Agency Technology Collaboration Program for Ocean Energy Systems. 2015. International Levelized Cost of Energy (LCOE) for Ocean Energy Technologies. https://www.oceanenergysystems.org/publications/oes-documents/market-policy-/document/international-levelised-cost-of-energy-forocean-energy-technologies-2015-/. Accessed 17 June 2024

these various complexities at their sites and expensive development costs. In addition to the design process, other stages and aspects of the developmental process are impacted by the environmental uncertainties.

Permitting has been an obstacle for most renewable technologies in the United States including tidal energy. Tidal projects face problems within the permitting stages because impacts to the marine environment are unknown (*Polagye, 2011*). Leasing permits for ocean use impact fishing and shipping industries since the turbines are deployed in water offshore close to coastal communities. Areas on the coast have important fisheries systems and many rely on tourism and reap recreational benefits from their proximity to the ocean. The U.S. has established many agencies that protect our coastal and river resources. Through the complexities of protecting the existing industries and site resources, any tidal project will have to obtain numerous siting leases and permits. Some proposed tidal energy pilot projects in the U.S. have obtained the Federal Energy Regulatory Commission (FERC) Preliminary Permit. Other sites have been performing feasibility studies or researching environmental impacts. These pilot projects and studies have been successful in obtaining some other short-term leases or signoffs with the ability to reapply every few years. These successes aid in building an understanding of the permitting entities involved and what some aspects of the permitting process may look like for a future commercial scale project. Permitting will likely face challenges for commercial scale projects. There is a question of how scalable the results of these pilot projects' demonstrations are and the continued scientific uncertainty surrounding potential environmental effects.

To help navigate these challenging permitting processes, this study analyzed leading tidal energy pilot projects. As development continues to be encouraged by President Biden and the DOE, many stakeholders continue to engage with the emerging marine renewable technologies. These stakeholders offer a unique perspective through their experiences with emerging technologies.

Multiple factors may contribute to the flow of the project's development. To build a broad analysis of the permitting and design stages of progression, specific factors were identified and examined. The main factors identified through previous studies that impact renewable energy development were social acceptance, economic, political and legal, and the adverse impacts of renewable energy projects on the ecological environment (*Strielkowski et al., 2021*). Stakeholder experiences shed light on how some of these factors were exposed and how stakeholders solved, or failed to solve, challenges to the project's flow in the face of these factors. This analysis examined stakeholders' reflections of how these factors impacted the pilot projects. An understanding of these impacts may assist future commercial scale tidal development.

Past research

This study has been built on past research examining international successes, environmental impacts, U.S. tidal energy pilot projects, and broader renewable energy literature. Impact studies have been conducted regarding marine mammals (*Copping et al., 2017*). The early analyses of economic opportunity sought to draw an understanding of the potential economic risks and trade-offs involved with future developments (*Delany, 2009*).

Preliminary tidal research has also focused on stakeholder management. Existing studies have sought to build the understanding of public trust and perceptions and attempted to build frameworks for more adaptive and inclusive stakeholder management (*Devine-Wright, 2011; Johnson, et al., 2015).* When conducting interviews at the location of a U.S. tidal pilot project, Johnson and colleagues (2015) identified fishers and NGOs as the stakeholders most likely be impacted by tidal development. Importantly, of the fishers interviewed in this paper, more than 70% claim they would like to know more about renewable energy (*Johnson, et al., 2015*). My analysis is based on these research papers suggesting that community engagement and action may be vital for tidal energy development. My analysis has been influenced by these studies as they suggest that tidal development has been influenced by ecological, economic, and social acceptance factors.

While this analysis focused on future development of tidal energy within the United States, there has been considerable successes abroad. Past research has sought to understand what learning occurred during each stage of development, which involved stakeholder interviews from both the Puget Sound and Scotland tidal energy projects (*McMillin, et al., 2016; Copping, et al., 2021; McTiernan et al., 2017*). Findings in these research papers suggest that many of the identified factors have been present in studies both in the U.S. and abroad. McMillin found that learning in tidal projects was from technical, economic, environmental, policy, and social perspectives. As this study focused on U.S. tidal projects, the international studies were used for building a broader understanding of the technology, rather than the specific processes or permits.

The development of offshore wind energy has also led to a larger body of literature and research. While the research conducted to better understand and develop wind energy may not directly impact this study, there are large amounts of literature on this renewable energy, the energy management, and successful trials of these other technologies that are worthy of noting (*Zhang, et al., 2020*; *Musiel, 2008).* Zhang et al., researched the current status of offshore wind and tidal life cycle impact assessments, among other key project methodologies. The findings suggested that interested stakeholders are not following strict standards and therefore may be less confident in the results of impact assessments. This research, while for both offshore wind and tidal, suggests that stakeholders are able to elaborate on conditions for the future of commercial scale marine renewable energy in the U.S. Some environmental impacts, management practices, permitting or funding opportunities, permits, and stakeholder engagement practices may be applicable to tidal energy development.

Major Questions of this Study

I analyzed two pilot tidal energy projects within the United States. I examined the available literature for these projects, interviewed project developers, researchers, and permitting agency employees, and identified recommendations and strategies for future projects.

I sought to answer two main questions:

(1) What are the key design and permitting stages of tidal energy projects in the U.S.?

(2) What factors influence the developmental progression of tidal energy projects in the U.S.?

To address the first question, I compared the current stages of development within proposed U.S. tidal pilot projects and feasibility studies to identify the stage each progressed to. I defined the "stages" that are the key steps of a project's flow of development. I analyzed the permitting and design aspects of the leading pilot projects to determine key successes and some of the necessary stages of pilot tidal development in the United States. This analysis provides insights for future developers of tidal energy, environmental scientists, policy makers, researchers, local community members, or energy advocates. I carried out an in-depth document review to inform the analysis of each stage and aid in identifying possible factors that influence how a project evolves. I also used these documents to understand what information is publicly available about the projects and to develop interview questions.

To answer the second question, I interviewed stakeholders to better understand the multiple perspectives involved in these projects and how various factors identified in the literature gained importance in these projects. By interviewing the project developers, researchers, and agency employees involved in issuing permits, I was able to build an understanding of how these factors impacted the design and permitting stages. I was also able to understand, both from the interviews and documentation review, how important it was for those involved to consider and/or address various factors. Some of the components of project development cannot be generalized to other regions or states, but still shed light on what was addressed during the project. Interviewees shared their experiences on the projects and their opinions of aspects that went well or that they may have done differently. These reflections, as well as the roles of the factors, may aid in future development of other pilot projects or projects at the commercial scale of development.

Methodology

Case Study Selection and Analysis

To inform future commercial tidal energy development in the U.S., I sought to analyze two existing pilot tidal energy projects in the United States. While only a few tidal energy pilot projects have been conducted, I first set out to understand some of the considerations, key players, and the possible stages expected for a pilot to reach completion. The progression of these considerations and stages in these pilot projects present an idealized timeline and process for which a commercial scale project may follow in the future. Table 1 below identifies the completed tidal pilot projects in the U.S. I considered.

Table 1: United States Commercial Tidal Projects. [sources below]

Project Title	State Location	Water Body	Partners*	Design Type	Current Stage
Cobscook Bay Tidal Energy Project[6]	Maine (remote)	Cobscook Bay (Ocean)	Ocean Renewable Energy Company (ORPC), UMAINE	Array, 4 turbines	Demonstration (completed)
Roosevelt Island Tidal Energy (RITE)[7]	New York (urban)	East River (River)	Verdant, NYSERDA	Array, 3 turbines	Demonstration (completed)
Alaska River Project[8,9,10]	Alaska (remote)	Kvichak River (River)	Igiugig Village Council (lead), National Renewable Energy Lab (NREL), ORPC	Array, 4 turbines (2 sets of this device developed)	Demonstration (completed)

*Not an extensive list of all involved parties and entities.

[6]"Cobscook Bay Tidal Energy Project." *Tethys*, tethys.pnnl.gov/project-sites/cobscook-bay-tidal-energy-project. Accessed May 4 2024.
[7]"Roosevelt Island Tidal Energy (RITE) Project Pilot." *Tethys*, tethys.pnnl.gov/project-sites/roosevelt-island-tidal-energy-rite-project-pilot. Accessed 4 May 2024.
[8]*Cook Inlet Tidal Energy Resource Characterization Effort - NREL*, www.nrel.gov/docs/fy21osti/79933.pdf Accessed 3 May 2024.
[9] https://orpc.co/ Accessed 4 May 2024.
[10] https://www.energy.gov/eere/water/articles/north-future-wpto-helps-alaskan-partners-pursue-clean-energy-future-water-power Accessed 1 June 2024.

From the pilot projects, the projects I selected for further analysis were Cobscook Bay Tidal Energy Project and the Roosevelt Island Tidal Energy Project (RITE). The Cobscook Bay Tidal Energy Project and the RITE project were initiated by a developer and through the U.S. leasing process. The Alaska river project, while also having completed a successful demonstration, was originally proposed by members of the Igiugig village community. While both approaches were successful, my analysis was conducted on two developer proposed projects. Along with the initiation process, the RITE project and Cobscook Bay Tidal Energy project were both completed years before the Alaska River project was developed. These projects' success in obtaining numerous permits, initially the FERC pilot license, and conducting a demonstration provide a learning opportunity for future tidal energy projects. The two pilot projects chosen for my analysis were examined through their progression through stages and the factors identified and experienced throughout development.

From Table 1, other aspects of these pilot projects were built into my analysis and provided context for my research. The components for these pilot projects included the developing entity and project partners, tidal potential, possible design types, and the design and permitting processes. These pilot project contexts were developed from the understanding that state location and water body type, river or ocean, influenced aspects of the process. The below considerations built the foundation for my analysis of the pilot projects.

i. Tidal Energy Company and Project Partners

For the purposes of this study, a project included and identified as a pilot project had to have an entity that has offered a power purchasing agreement (PPA). With an agreement in place, the tidal project can then continue through other stages since this tidal energy developer and involved partners would conduct the design and permitting processes. Involved partners for these projects varied depending on the location, logistics of drawn agreements, regulatory requirements, and the preferences of the developers. Partners could include supply chain companies, subcontracted surveying companies, or funding entities. Other agencies and companies involved throughout the project's development could include state agencies, research institutions (both public and private), university researchers (either state or private), tidal institutions, and community-based groups and marine energy advocates. The tidal energy company's signed agreement terms dictate whether the presence of other partners were involved and possibly other entities they plan on collaborating with or subcontracting. The developers and some of the project researchers confirmed for each pilot project are listed in Table 1.

ii. Tidal Potential

Tidal potential is defined as the capacity within a coastal area of the continental United States for a tidal turbine to produce, given the physical characteristics of the site such as bathymetry, tidal range, average water depth, and other technical factors *(Karsten, 2012)*. The potential for the pilot projects in Table 1, as the "potential" changes through steps and the redesign process, was the reported resource potential from the developers at the beginning of the project.

Throughout these pilot projects, the potential was measured as theoretical, technical, or practical, and could decrease between these measurements. Theoretical resource potential refers to the energy available at the source. The technical resource potential is the proportion of the theoretical resource that could be captured through the technology options available. The practical resource is the potential of the technical resource that would be available after the considerations of external constraints. These external constraints would include socioeconomic, environmental, regulatory, or other user conflict at the site (*Kilcher, 2021*).

The potential to be produced by the turbine(s) is most commonly measured in kilowatts (kW) (*Kilcher, 2021*; *Ericsson, 2018; Moreton, 2017*). Some developers may choose to represent this in TWh (terawatt hours) or MWh (megawatt hours). This potential defined by the pilot projects was produced within a range of time and may have been up to 18 to 22 hours daily, depending on the site and turbine *(Moreton, 2017).* The practical potential at the selected site is an important component to consider for possible commercial scale tidal development. Therefore, this study examined the potential external conflicts that could decrease the potential resource.

iii. Design and Deployment Type

The "design type" defines the type of tidal turbine design proposed and developed for the demonstration. These design types for all the pilot projects were all technically stream tidal turbines. In this design the turbine(s) are placed directly into a tidal stream. These tidal streams can be any fast-flowing body of water created by tides *(Rutledge, 2022).* Depending on various limitations at a project site, the design of the turbine was either singular or an array. A singular turbine is one turbine, whether it was floating or bottom mounted, and had generators, rotors, and a set of blades. An array includes multiple turbine(s) that are connected together, whether the array be floating or bottom mounted, and also has multiple generators and sets of propellors.

In these pilot projects, the U.S. regulations ultimately determined the size and number of turbine(s) allowed for the demonstrations. The designs of these demonstration devices have been influenced by various considerations, many of which were site dependent. The considerations for user conflict and the industry competition at these sites further influenced the size and deployment strategies for the demonstrations.

These design decisions included materials used and where they were outsourced from, and the style (array or singular). The deployment strategies included the installation methods, mooring configurations, and the exact location of the turbine at the demonstration site. To deploy the turbines, large vessels were needed to move the turbine(s) and supporting platform out to the demonstration site. Along with the deployment strategy, the retrieval of the device and mooring systems was necessary for foresight planning.

The final demonstration design type and locations are listed in Table 1. Through these pilot projects' progression, the results of research or monitoring also impacted the development of the deployment and retrieval strategies. The materials and installation methods used for the project, both in the design and construction of the prototypes and eventually for the final design, are influenced by material availability and the current standards. The permits that were obtained through the process, as well as existing research and learning from other renewable energy projects provided a basis for these design and deployment decisions to be made.

iv. Stages

The pilot projects listed in Table 1 have all completed the goals set at their beginning. All of these pilot projects have completed a successful demonstration. To reach the demonstration stage, these pilot projects were developed through various stages. For the purposes of this research and my analysis, the steps taken by these pilot projects were defined by their initiation, design, permitting, and demonstration.

a. Project Identification and Initiation

As stated above, these pilot projects were initiated in various ways. Past feasibility studies and resource characterization occurred and were used to identify site locations. In some cases, the developers were able to apply for funding opportunities to develop at predetermined sites. In other cases, the state or local utilities were able to determine possible site locations and conduct feasibility research. The river tidal project in Alaska was first initiated by members of the community. In this initial stage, the developers started to identify research partners, the project title, and started building the foundation for the design and research methodologies. This stage varies among the pilot projects. Due to the current regulatory structure and the variations of state or local level support for tidal energy development, a future commercial scale project may follow any of these paths or be initiated in a different way.

b. Design and Deployment

The "design and deployment" stage in these pilot projects referred to the steps taken to develop the demonstration device, mounting platforms, and the supporting infrastructure. The deployment strategies for the demonstration device and its' retrieval were developed in this stage and tested prior to the demonstration. Designs for the demonstration turbines were chosen based on the research and feasibility studies performed prior to the deployment of these devices. Aspects of the design and deployment stage included proposals of materials and model type (after technology assessments) and the site/location for the turbine(s). This stage also included the materials and infrastructure necessary for the deployment and retrieval of the device and mounting platform. The team of engineers, developers, consultants, and designers that were selected were also announced. Even though these teams of engineers acknowledged that redesigning was likely to occur, they proposed design specifications or options to obtain permits. Engineering drawings and maps were created in the pilot projects to aid in the research processes whose efforts supported environmental impact statements. Stakeholders identified at the sites were also interested in learning more about the design and development. The deployment and retrieval designs were also a main point of this stage and were heavily influenced by user conflicts, timing constraints, and leasing requirements. On the commercial scale, design would most likely be considered one of the main stages. For early commercial scale projects, the design stage would also likely be iterative, as these pilot projects' development suggests.

c. Permitting

These pilot projects all interacted with various permits and licenses during their development. The FERC preliminary license allowed the developers to acquire the rights to investigate the sites for a 5-year period. Other licenses and permits acquired by these pilot projects were federal or state specific for the temporary rights to test, research, and deploy a short-term demonstration project. As the current regulatory system specifies, developers interested in a more long-term project would have to reapply for these permits or licenses. Reapplications for permits or licenses may also follow a larger redesign or if monitoring and research results yield new concerns or considerations. Some federal permits require that other permits have already been obtained, or in some instances, are obtained at the same time. Therefore, timing was an important consideration in these pilot projects' development.

d. Demonstration

Completion of a demonstration is the final goal for pilot projects. However, the demonstrations in the 3 cases were conducted with various learning and monitoring goals. The demonstration stage of the pilots included design reflections, data collection, and the ordering and purchasing of building materials. Developers also needed to consider and develop the assembly of the demonstration devices' supporting infrastructure. This included the cabling, grid connectors, control systems, and developing the framing and foundation (*MacDougall, 2015).* The developers of these pilot projects were able to deploy and retrieve the demonstration devices, conduct monitoring and various research studies, and produced reflections and reports of those research findings. The pilot demonstrations also offered stakeholders and community members an opportunity to observe how tidal turbines operate and may impact their usage of the site. Community members at the locations of these pilot projects were involved in the demonstration process and were able to offer input. Only the pilot projects outlined in Table 1 have reached a successful demonstration at the time this study was completed.

It is important to note that the stages are not completed linearly in all projects. Some stages may be repeated, some omitted. Data collection and the involvement of stakeholder engagement and public meetings were conducted differently and varied depending on the developers' and project partners' approaches. Research was ongoing while these pilot projects were being developed. This research included stakeholder interviews, impact and risk assessments, and environmental monitoring. For some of the permits obtained, there was also a need to conduct post-demonstration analysis or research for the purposes of understanding possible long-term impacts.

I defined these stages to provide context for my examination of the factors that influence the progression of the leading tidal projects in the U.S. Differentiating between the design or permitting stage when assessing the existence and experiences related to each factor built a more expansive analysis of these pilot projects' progression. The ecological, political, legal, economic, and social acceptance factors were experienced differently within stages. Stakeholder interviews provided more insight into how these factors presented differently, both between the two selected pilot projects and within the design or permitting stages of both.

Case Study Contexts

Both of the selected cases have completed a demonstration of a pilot tidal turbine design. Along with obtaining the FERC pilot tidal license and working with FERC through the process, many other federal agencies were involved in these projects. Some of these agencies included the USCG, USFWS, NOAA-NMFS, USACOE, USEPA, and USDOE. The below sections outline information about the project locations, community populations, specific agencies and stakeholder groups, and the ecological landscape and considerations.

i. *Cobscook Tidal Energy Project (Maine)*

Cobscook Bay has a long history of supporting tourism, shipping, and fishing industries. Cobscook, the Maliseet Passamaquoddy tribal word for "boiling tides," aptly describes the tidal range averaging 24 feet and reaching 28 feet.[11] As described in Table 1, the Cobscook Bay Tidal Energy Project is located in Cobscook Bay off the coast of the city of Eastport, Maine. A small and remote community, Eastport is Maine's easternmost city with a population of around 1,299 people. A large portion of the population relies on the fishing industry supported by the biodiversity offered in the Bay. Marine species include scallops, striped bass, mackerel, herring, Atlantic Bluefin tuna, Atlantic salmon, mussels, periwinkles, and soft-shell clams.[11] Over 200 species of birds can be seen throughout the Bay, attracting high volumes of birding tourists. Cobscook Bay also has the highest density of nesting bald eagles in the northeastern United States, playing a key role in their repopulation.[11] The vast wildlife in the area is protected by state and federal regulations.

Eastport is home to part of the larger Cobscook Bay State Park. The park covers 888 acres and has long hosted tourists interested in camping, hiking, skiing, birding, and biking. Cobscook Bay State Park is also part of Moosehorn National Wildlife Refuge. Moosehorn (which now totals 24,400 acres) is one of the nation's oldest refuges. Cobscook Bay has an average water depth of 10 meters with the deepest point being measured at 45 meters.[11] The Eastport Port is the deepest natural seaport in the continental U.S. It is

[11] https://www.maine.gov/dacf/parks/trail_activities/cobscook_trail_conditions.shtml Accessed 1 June 2024

able to support cargo and naval ships and the commercial and recreational fishing industries. The Port also welcomes in cruise ships that boost tourism for the park.[12]

ORPC has shown interest in tidal development and research in the state of Maine since 2007. Research included representatives from the University of Maine and its partners at SeaGrant. Multiple Maine state agencies played a role in permitting or research for the area such as the MDEP, MDIFW, MDMR, MDOC, MSHPO, and MSPO. The agencies and key stakeholders engaged were found in the final Environmental Impact Assessment.[13]

ii. RITE (New York)

As depicted in Table 1, the RITE pilot project is located in the East River, a saltwater tidal estuary system, off of Roosevelt Island. As part of the Manhattan borough of New York City, the population surrounding the site location is around 1.646 million (2022). The pilot project and research was carried out by developer Verdant Power LLC and the New York State Energy Research and Development Authority (NYSERDA). Since the pilot testing site was located in the New York City urban environment, there were many stakeholder agencies involved. Some of the state agencies and authorities involved throughout this pilot project were the NYSDEC, NYSDOS, Port Authorities of NY, CT, and NJ, NYSDOT, NYPA, and NYSOPRHP (*Verdant, 2011*). In this highly populated urban area, city planners and other city level agencies were also involved. This included NYCEDC, NYCDOP, NYCDEP, RIOC, and the Community Boards of Queens and New York County. The pilot project engaged with non-governmental organizations like NYSCC, NAS, NHA, RIRA, and ACORE, as well as members of the Delaware Nation (*Verdant, 2011*).

The East River supports a vast amount of shipping and manufacturing, tourism, and fishing. The Port Authority of New York and New Jersey manages one of the largest containerports in the U.S. The Port offers areas for bulks and break bulks, auto services, chassis depots, and many other features to support the cargo shipping industry. The East River also hosts the Port's rail lift capacities, the largest on the U.S.

[12]https://www.portofeastport.org/ Accessed 1 June 2024
[13]https://www.energy.gov/sites/default/files/EA-1916-FEA-2012.pdf Accessed 1 June 2024
[14]https://experience.arcgis.com/experience/8a636da066824d77a47874fd2b6a3352/page/More-Information/?views=Chassis-Depots Accessed 1 June 2024

East Coast.[14] The extensive coastal and inland shipping are also boosted by the high population and tourism sector. It is estimated that around 50.6 million people visited Manhattan and the greater New York City area in 2023 and was ranked the most visited U.S. city for the year. The tourism industry in NYC continues to support much of the economic sector for the state and is an important consideration when developing electrical and technological advancements.[15] Roosevelt Island and the East River system support a large variety of species. Sport and recreational fishing looks for striped bass, American eel, flounder, perch, and blackfish. Bird species such as Northern Flicker, Eastern Kingbird, Cedar Waxwing, Yellow Warbler, Red-winged Blackbird, and Baltimore Oriole are observed in the summer months. The more common American Black Ducks, Mallards, and Canada Geese are found through the longer winter season.[16]

Both of these studies offered unique considerations and contexts that allowed for a more comprehensive analysis. The industries, species, populations and local community members, and ecological landscape of these pilot project sites all became considerations necessary for the developers and researchers to develop.

Data Collection

i. Document Review

To triangulate my data collection, first a document review was performed to develop a baseline understanding of the communities and project context. A review of the documentation and media available through publicly accessible sites aided in understanding the industries and wildlife present at these sites, as well as in narrowing down interviewee selection. Information pertaining to both projects was gathered to understand the details, rough timeline, community contexts, and project logistics. The documents selected for review included, but were not limited to, environmental reviews, engineering reports, relevant research papers, state legislature information, permitting procedural reviews, and any other information regarding key stages toward completion of the project. The document review was

[15] https://corporate.nyctourism.com/annual-report/2024 Accessed 1 June 2024
[16] https://www.nycaudubon.org/our-work/conservation/birds-of-ny-harbor Accessed 1 June 2024

conducted for the purposes of providing site specific context information, informing questions and situations that need to be addressed through the use of stakeholder interviews, and to provide supplementary data and additional knowledge to the research *(Bowen, 2009).*

I accessed the engineering reports and environmental reviews through either the state department or energy company website. Other documents that aided in a deeper understanding of project specifics included research papers and presentations done by a University partner, such as UMAINE or other state university. The state department, Department of Environmental Protection (or other state equivalent), had the information necessary to assess the policies and tasks forces created for tidal development. Documents point to the design elements and some of the permits obtained by the project as milestones. Further, newspaper articles and radio segments were able to offer some insight into the local opinions and developments of these projects.

ii. Interviews

a. Interviewee Selection

The literature and documentation review provided the ability to more effectively engage with specific stakeholders that were involved in each project. The groups of stakeholders I identified were the project developers, contracted researchers, and employees from the permitting agencies. From the environmental impact statements and project documents I was able to identify many of these developers and individuals monitoring permit applications. The permitting agency employees I selected all played an advisory role to regulators at their agencies. Many of these employees are senior staff that had knowledge and experience with the permitting processes within their agencies and act as advisors to the staff who write the permits. Through news and other social media platforms, the researchers that played more of an "external role" in their respective project were also identified.

The snowball method was used following the first round of interviews. The snowball sampling method involves identifying the "kernel of the snowball," as a first round of interviewees, also called a sampling “frame.” After these interviews, other potential interviewees or more broad stakeholder groups may be brought forward by the first round of participants, considered “experts.” Snowball sampling can also be referred to as “chain referral” sampling and is simply a way for experts to inform the interviewer of other experts, either their own coworkers or other individuals they interacted with during their experience. Utilizing this method allowed me to interview more individuals that were not easily sourced through the documentation review and the information that was available to me online. I have conducted the interviews following the methodologies frequently used and suggested in the literature (*Kirchherr et al, 2018; Cohen, 2011*).

The developer informants represented individuals from both power companies, Verdant Power and ORPC. The research respondents included individuals from Universities, graduate students, private research entities, and contracted research agencies. The permitting respondents included employees from NOAA, state agencies, and Sea Grant. Lastly, some identified respondents from federal agencies were selected to offer a broader insight.

b. Interview Procedure

The University of Washington’s IRB (Institutional Review Board) received and approved my study design and interview guide.[17] The interviews took place on zoom and interview transcripts were provided back to the interviewee through email correspondence for additional information or changes. Recording the interviews allowed for a cross check of the transcripts produced by the audio recordings. After receiving feedback from the interviewees, the interview transcripts, the recording of these interviews were destroyed. The interviewees’ identities were protected and withheld from any results or quotations used within my analysis.

The interview questions were provided to the interviewees ahead of the interview and the consent form was emailed as well. The methodologies used in my interviewing procedure are influenced by past studies of interviewing in social science(*Brady, 1976; Dexter, 1970; Boynton, 2005*). These semi-structured

[17] STUDY00019055: Exempt_STUDY19055_Leighton_Initial Application.pdf(0.01)

interviews were conducted with the respondents between December of 2023 and February of 2024. In total 11 interviews were conducted between the two projects (average time = 53 minutes).

The focus of the interviews, regardless of the informant being engaged with, was to understand how the factors identified in the literature impacted the permitting and design stages of these pilot projects. The focus factors were social acceptance, economic, political, legal, and ecological impacts. Interviewees were also asked about their role and to reflect on aspects of the project that went well or that respondents' may have changed. Through the questions, other possible interviewees were also noted. Broader questions at the end of the interviews sought to understand the respondents current views of tidal energy development in the future and suggestions of other experts. The interview questions asked are located in Appendix B.

Qualitative Data Analysis

The interview transcripts were coded through an iterative and detailed process. The codes used for the interview transcripts and their descriptions are provided in Appendix C. Common codes and relationships emerged through the coding process. These relationships pointed toward themes and cooccurrences that led to an expansive analysis of reflections provided by the respondents. Quotations and text from these coded transcripts was also used to illustrate my research findings.

ATLAS.ti is a research tool used to assist in qualitative analysis. Performing content analysis is a form of qualitative research that utilizes mixed methods of data collection and is based on procedures that have originated in social science. The discipline and positions I have taken as a researcher through the content analysis are based upon those methodologies (*Creswell, 2018; Locke et al., 2013; Corbin et al., 1991*).

Results

This section provides the findings and major themes from the interviews and project documents. These themes are siting and design/deployment strategies, community engagement and social acceptance, permitting and research, economic and social factors, and importance. The themes are followed by an assessment of respondents' experiences with what went well during their involvement with the project, what respondents' would have done differently with the project, and their views about the future of tidal energy.

Themes

a. Siting and Design/Deployment Strategies

Throughout the interviews every respondent was able to share aspects of the design and deployment processes. Emerging topics of these processes included the site selection and specifics, monitoring and testing, and lessons learned about developing this technology. Respondents highlighted that the design process for tidal energy specifically has made considerable steps forward.

> *"Tidal is probably the most advanced of the three major types of energy from the ocean because it has started to consolidate on a couple of designs" (Respondent 11).*

> *"Then the project itself, because it was the first project of its kind, you necessarily were only able to learn things because you were in the actual operating environment and because of that experience we progressed to a different way of deployment, anchoring design, and design of how the turbine would be in the water column, which was a huge, huge step forward" (Respondent 1).*

Respondents shared that the design process allowed for the developers and researchers to better understand the materials and functions of the proposed designs. Issues posed for the design and deployment strategies were the materials used and the supporting infrastructure development.

i. Cobscook Bay Tidal Energy Project (Maine)

The site selected for the Cobscook Bay pilot project was off the coast of the city of Eastport. The remote site was chosen for numerous reasons including the tidal potential of the area and the types of fishing activity in the area.

> *"It's [the site] kind of a blind spot… more of just an area of opportunity for this type of thing because I think throughout much of Maine you have a lot of folks who care a lot about the traditional grounds and rights of extractive fishery gears. So, you're talking about trawling, long lining, netting, and all those different activities. It's pretty prevalent thing that's going on outside and in most of that region. But, inside Cobscook Bay, none of it. The only thing you get there is lobster traps and that's way different because it's fixed gear" (Respondent 8).*

The design chosen for the pilot project was a TidGen® Power System consisting of 4 turbines on a fixed bottom mounted frame. More information regarding the design specifications, materials used, and technical implications are available in the design report (*ORPC, 2013*).

ORPC released their EIS and study results each year from 2012 to 2016. These reports outlined some of the major studies done for the area. This included passive acoustic monitoring using a hydrophone for fish pass, fisheries and marine mammal monitoring, benthic and biofouling studies.[13] Some of this research was required through ORPC's obtaining of the FERC pilot license. The results from the fish behavior studies was generally positive but left many questions unanswered about a future scaled up project.

> *"What we learned was, yes, the unit goes pretty slow, and the fish or the animals tend to go around the unit. We learned a lot more than we thought. We thought it would be more harmful than animals than it was, so that was really helpful. Still don't know what it would do to whales and whether a large array would do different things because we're really only testing a single unit" (Respondent 6).*

ORPC, with the help of the many involved stakeholders, were able to develop preliminary findings about the environmental impacts of their turbine design. These findings may be particularly useful for future projects in rural, ocean environment tidal energy projects.

ii. RITE (New York)

The siting and deployment processes of the tidal turbine(s) were an important consideration during both pilot projects. In the New York RITE pilot, the site location for the demonstration and environmental monitoring was in the East River.

> *"We were paying for the development of some tech because the location of the project was in the East River of New York, which is a very heavy current tidal producer, tidal space, which is why it makes it great for this sort of work. On the other side, it is also heavily trafficked by marine transportation. It is definitely in a dense urban setting, basically in a river between Manhattan and in Queens, and it is extremely turbid" (Respondent 10).*

Here the theme of social acceptance emerges. Social acceptance and the site were closely related because the location of the turbines have direct impact of the surrounding communities.

The exisitance of various user conflicts through the river and the densly populated community Verdent had to be very selective of the site location. The respondents involved in RITE pointed out the historical presence of industry in the area.

> *"In the Roosevelt project, people were very supportive of the project. Across the river and up a little bit was a major power plant that you know was the cause of asthma alley as they called you could see the yellow plume coming out of it. The community was all on board like make that smog go away. I don't have to look at the energy system and I'm good, right? So, they were pretty supportive of that one" (Respondent 10).*

The RITE project EIA outlines some of the major studies done for the area. Many of these studies were similar to those conducted in Cobscook that were required for the FERC license. At the state level, New York and New York City agencies were concerned with the fish and user conflict in the East River. The researchers involved reflected on the monitoring done and some of the issues that arose.

> *“They [regulators] wanted us to do trawl net surveys while the turbines were operating and a number of things. There's no way you could drag a troll net in the East River with the current running, like even tugboats had a hard time holding station” (Respondent 9).*

The siting and design/deployment strategies of these pilot tidal energy projects were mentioned frequently by respondents when discussing factors. The location of the project, the design of the turbines, and the deployment strategies lead to differences in some monitoring or studies done, materials or design specifications selected, and played a role in acheiveing these projects’ goals.

b. *Community Engagement and Social Acceptance*

As with siting and design, both pilot projects were able to develop practices for community engagement in the hopes of gaining social acceptance. Respondents shared their experiences with the engagement process and reflected on how gaining social acceptance played a role within their work.

i. *Cobscook Bay Tidal Energy Project (Maine)*

ORPC set out in the city of Eastport with the goal of gaining social acceptance through mutual partnership. ORPC had a history of research in the city, collaborating with the community and gained their trust.

> *“The project needs to be the local communities project, so when you first are engaging with the community, whether it be elected officials or general supporters or the local utility, we're always*

looking for who that local trusted partner that we begin to work with and how do we begin to make this a community lead project" (Respondent 1)?

ORPC and the researchers were able to integrate into the community. These integration techniques included employement opportunities, holding an active presence in the community, and seeking historical knowledge from stakeholders.

> *"I think that employing local people to assist was definitely something that helped the developer, but not just to gain local knowledge, but also build that, those relationships within the community because you're not just building a relationship with that person but also with their family with their friends. In a small area that makes a big difference if people will speak on your behalf. It goes a long ways" (Respondent 2).*

> *"I mean, it's Mainers at their best and that means they're really a part of what is ingrained in the daily life. There is a lot of outside activity. It's sort of a tough group to crack. That's kind of my point. And so going into it, I thought, man, this is not the place you want to try to do something like this. But after they [ORPC] got started doing some surveys and their initial outreach efforts, they were pretty well received. I think it was because the dialogue was positive and the interactions with the community members were positive. They [ORPC] had an office down there so they had a presence and people could come in and talk to them if they had some questions. I think that was really important" (Respondent 6).*

The employment and use of resources from within the company aided in gaining economic support and added to the community perceptions of energy independence.

> *"I think an important feature of community acceptance in these small scale, locally focused energy production projects, you necessarily involve multiple local contractors. Then it becomes an economic part of the business model and that it becomes an economic opportunity beyond the environmental attributes of green electrons going to shore. You become an additional customer to*

sell to an existing business. In some cases, somebody is able entrepreneurially to create a service. There are multiple ways of involving the community in the project so that it becomes their project" (Respondent 1).

Other community engagement strategies ORPC used included volunteer research programs for the whale and bird observation studies, essay contests at the local schools to christen the project and involving UMAINE graduate students in the monitoring and data collection.

Respondents reflected on their experiences with some of the legal or political conflicts that appeared. This includes the political will of stakeholders. One of the main stakeholder groups they were engaged with during the Cobscook Tidal Energy project were fishers. Respondents reflected on the political will and weight these commerical fishers had.

That's one of the conflicts [with wind] at the moment with commercial fishers in particular, you're simply swapping one industry for another, you're saying that we don't matter. We are currently an economic development engine and you're trying to push us side and tell us to compromise. We'd rather fight about it. Now when you compete there are conflicts. When they're conflicts it gets into some folks fight with words and others fight with fists, and what I learned over time, it still comes down to often who yells the loudest that wins" (Respondent 2).

Political and legal conflicts brought forward by stakeholder groups in the community were intertwined with social acceptance and community engagement strategies. The timing of engagement practices and public perception throughout the projects' progression was a consideration mentioned by each respondent group.

ii. RITE (New York)

In the heavily urbanized environment surrounding the location of the RITE pilot demonstrations, Verdant and NYSERDA had to be creative in their community engagement strategies. While the siting played a role in gaining some general social acceptance due to the other heavy industry presence in the river, there are still strong voices within the community.

The developers and researchers chose to focus on building a product that would benefit the community, and then focus on how to communicate those benefits.

> *"But we [the developers] still have some work to do to really make our product compelling and sell itself in that market, right? It's still some pretty tough lifting. Is that like, how you're selling it? And what are the real benefits to the community and then also how does it fit into their day-to-day life, how is it going to really help them" (Respondent 9)?*

While many of the community members voiced less concern about the RITE project because it has no viewshed, the issues of cabling infrastructure and user conflict persist.

> *"We [NYSERDA] deal with issues with coastal communities having to host infrastructure, which is the cables that come onshore, run through a community, interconnected a substation maybe substations had to get built bigger or converter stations have to be built which are 5 acres of sort of an industrial looking building. So, we work with a lot of communities on, you know, what are those issues and how do we get past them? How do we avoid the avoid minimizing and mitigate whatever we can" (Respondent 10)?*

Verdant was able to gain support from some of the local NGOs, including the Roosevelt Island Operating Corporation (RIOC), that voiced their support. Due to the urban nature of New York City and the presence of many industry user conflicts, the developers reflected on their shift toward community collaboration. Competition for space in the East River and the dense population created a need for early coalition building to gain social acceptance.

> *"Some of that is regulated and some of that is just community building…there is an organization there called RIOC that bought into the story. I think there was a sense of wanting the turbines to be there because of the sustainability aspect and there was a conscious outreach to the*

community to explain what was going on. I don't think that wasn't sort of, strictly speaking, a legal requirement, but it is a social requirements. As we think about, for example, other projects in New York [offshore wind projects]. That's really where we're starting our efforts is on the community building, coalition building efforts rather than pure engineering. We have to investigate the engineering to really sort of draw the outlines of our proposal and what can be done. The first sort of public step is more coalition building among all of the constituencies in a highly densely populated, very active metropolitan region so that's what we're engaged on now. Everyone from whale watchers to you know just local residents, there will be outreach. So yeah, that's absolutely, an important part of our planning" (Respondent 9).

Respondents from both projects' highlighted that once stakeholders were identified, success was in how they were engaged with, when, and where.

"We [the researchers] wanted to be visible and flexible for the community. We were very keen on making sure that we were communicating in appropriate ways to the diverse audience and stakeholders that we had, that we were tailoring our communication and engagement strategies to those that we were engaged with. So, knowing the different people need to engage differently, that was really important to our work. It was just sort of a commitment right from the outset and it was something that was always on our mind" (Respondent 7).

"I've learned over my time in doing public engagement, is that where you meet matters. So, for instance, if you want to engage with nation tribal members, holding a meeting in Eastport might not be the best place, because that's not their home anymore, part of their travel homelands, but there you know they currently reside at…you are more likely to be successful if you move around go to where folks are most comfortable, setting also matters. Some folks are just more comfortable in some settings than others. Engaging fishers, some really didn't like being in high school. Some didn't finish high school. They went straight into the workforce. So, holding a public meeting in a classroom where they have to squeeze themselves into desks, it's not a place to

engage some folks that don't want to be there in the first place. The meeting would actually happen in the parking lot afterwards or during a smoke break and that's what the best dialogue would happen. It's not just about outreach. It's not a one-way street" (Respondent 8).

All of the respondents shared that community engagement played a role through their work and that the various strategies used were aimed at gaining social acceptance. These engagement strategies may be different depending on the community, stakeholders identified, and the developers or researchers' own prior knowledge.

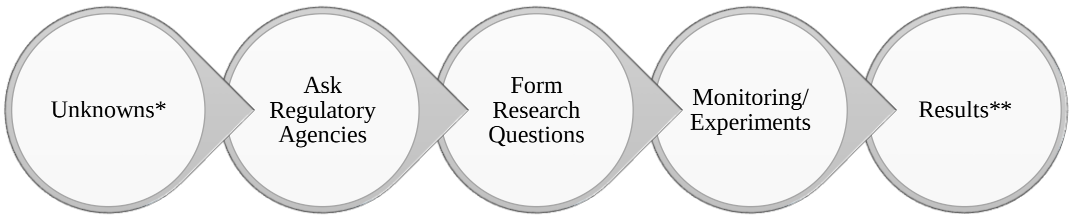
c. Permitting and the Research Cycle

FERC developed a pilot license for developing tidal energy projects, as well as preliminary projects and specific guidelines for testing. The RITE project received the first FERC Pilot License for Tidal Power in January of 2012. The Cobscook Bay project followed soon after in Febrary of 2012.[18] The FERC license, along with some of the first permits obtained for testing, had requirements that were mentioned by many of the respondents.

"Under the pilot program, you have to demonstrate and provide some baseline information, but you can put things in the water that have some unassigned risk. You have to be willing to be able to shut them [the turbine(s)] off at any time. This is different from conventional hydro… this requirement that you had to demonstrate that you could stop the blades and you could remove it on a moment's notice was new" (Respondent 11).

[18]https://www.ferc.gov/licensing/hydrokinetic-projects Accessed June 9, 2024

Both pilot projects set out to receive the FERC license, as well various other permits and funding opportunities. To fufill the various requirements of these opportunities, environmental research was vital



in the development of these projects. A clear relationship between the permitting processes and the research process is described through the timeline in Figure 1.

*Permits and licenses appear throughout this research cycle. The FERC pilot license for example was obtained at the beginning, prior to identifying unknowns. Permits that were necessary to obtain prior to the monitoring and experiments, in the pilot case demonstrations, may have been unknown to developers and researchers prior to communicating with regulatory agencies. In an ideal commerical tidal energy project, the results of monitoring or experiments would also lead to obtaining proper permits.

**Results may have been intermediate and fed back into the "form research questions stage" to become iterative. Some results also informed further questions that were analyzed. The results of the monitoring and experimentation informed permitting and fulfilled requirements for licenses. These results were presented through reports that are accessible to all regulatory agencies and to the general public.

Figure 1: The Research Cycle for Tidal Energy Pilot Projects [own data]

Respondents were asked to reflect on the research process through their role. As expected with pilot projects, the amount of unknowns was the starting point for many respondents.

> *"Everything was uncertain like environmental impacts was uncertain, the permitting process was uncertain, what information parameters the regulators need to know was unknown, they weren't even sure. We didn't know positive or negative how the community would view the project or how*

they would want to be engaged with it, we had to figure that out. So, there was definitely some gaps, but I think just like all science and development, there are places to start (Maine, Researcher)."

The interviewees selected for this analysis have been experts in their roles for many years. While their interactions with tidal energy may have began with their experiences on one of these projects, many had already interacted with renewable energy technologies. Some respondents acknowledge drawing from their own past research experiences. This meant developing methodolgies for either the social, ecological, or technological research based on their areas of expertise. Developers and researchers pointed their questions to the permitting agency representatives. This was to asesss what questions must be answered for the project to progress through permitting.

"In an advisory role we said, 'what do you think might happen?' We ended up actually in some conversations with the regulatory agencies about what kinds of questions we should be asking as researchers so that they had answers when they had to make decisions" (Respondent 6).

From these beginning questions, research teams or adaptive management steering committees were formed to develop their research approaches. The trust in the research and adaptive management teams allowed for major progression in the research process. Many respondents reflected kindly on their experiences developing the research alongside the other stakeholders involved.

"During the project there was a large time period of developing studies to monitor the impacts of the turbines. There were informal consultations and meetings between the working groups. The process was collaborative. We were conducting site visits and working with each other at the site. There was a lot of care and attention given, and an overall understanding that the research was a part of the progress, with what little was known about the technology at the time, so there was room to learn" (Respondent 3).

"So, there were all kinds of things that worked really well as our team, that sort of level of trust and respect amongst our group was critical to its success. We met a lot. We spent a lot of time learning from each other with a lot of conversations and open dialogue and being able to ask each other questions, feeling comfortable enough to ask each other questions that works really well. That commitment to this team made that process successful" (Respondent 5).

The findings of the environmental impact studies such as the bird observations or acoustic monitoring periods were made publicly available. This accessiblitity reflects the trust built within the management teams and the goals set out for the research.

"I came at it from the question of like what information did people need, in particular ORPC was never going to get anything in the water if the regulators weren't on board. So, we were sharing data all along and that was something different, normally many scientists and researchers, we'll wait until whole thing is published before they'll share the data and maybe that was risky for us, but it gave everybody some sense of what was happening. And we made mistakes, we made some big mistakes in how we analyzed data and we had to readjust, and we had to go back to everybody and say, we made this mistake like it's really this way not that way, and that helped build trust with people because we put ourselves out there. And they were okay if we came back and gave them corrections along the way. So, I think that that approach made things work for the whole project" (Respondent 5).

The research process was driven by the collaborative nature of those involved and the action items required through various permits. As such, regulators were able to share the starting questions that guided the research forward. Data sharing, adaptive management, and the required environmental studies were able to reveal lessons learned and establish recommended practices for future projects. While trust within these interviewee groups was built and identified as a strong point of value for project progression, certain frustrations have arisen. The greater conflict identified for both of these projects is the continued concerns for the impacts to the environment and future permitting barriers.

From the permitting perspective, many feel that as these demonstrations are not considered full scale, many unknowns still remain. The environmental concerns of these projects and the level of certainty needed for permits to be granted is reflected through the aprehensions of permitting agency representatives.

> *"It's a very difficult thing to be able to interpret what an animal is going to do, especially as an animal the size of a whale. That's why the most difficult thing in my job is to try moving forward with uncertainties and trying to put those uncertainties into categories of risk. Where we think that it's low or high. Or it could be a low risk of occurrence, but then it could be a high risk to the animal if it does occur… We're never going to know everything when you're dealing with wild animals in the open ocean"* (Respondent 4).

Other researchers and developers reflected on this permitting conflict with contension. Through President Biden's energy goals and climate change, these other respondents felt frustrated by the lenghty permitting process, citing it hinders innovation.

> *"But that's one of the challenges…so, if you're permitting a power plant, that should be harder than permitting a clean renewable energy source. I find it so frustrating"* (Respondent 10).

> *[with turbines] "The habitats will change. It just is, right? And people say, well, it's great environmentally, we're gonna have this, we're gonna have that, which is true, right? The question that everybody struggles with is, well, what do you want? Right? It's change. Is it good or bad? Do you want the system that you have today? Do we think this is the best and highest functioning [ecological] system, or do we want a different system"* (Respondent 10).

Through these challenges, at the broader scale there was an understanding that developing the licensing for these early pilot projects would be difficult.

> *"…part of it [license reuirements] was to be a little bit less harsh on a sustainable industry because we're used to regulating power companies that have had established projects for a good*

while and they have a good cash flow. Then these guys are relying on venture capital and trying to get through the valley of death as they call it…it's harder for them to get with all the uncertainties about their technologies though, I can understand why they'd be frustrated at times, although I don't think the regulations or the regulatory environment is to be blamed for the failures, or the fact that the industry hasn't taken off" (Respondent 11).

Permitting faced challenges and was influenced by the research process and development that occurred throughout both pilot projects. Respondents were able to reflect on the regulatory structure and needs which pose opportunity for future commercial tidal energy projects to better understand the permitting process.

d. U.S. Economic and Social Structures

Repondents were asked to reflect on any economic factors that they experienced during their interactions with the pilot project. Through these reflections, the funding support needed and role for the local economy were mentioned most frequently.

When respondents were asked to reflect on political or legal factors, many reflected on the federal support. The funding process was therefore heavily influenced by these social factors. Political or legal conflicts within the pilot project had a direct impact on political support, which impacted funding opportunities and grants.

"In the given early nature of tidal projects, we are going to rely on some of these [state and federal] agencies for funding. Not only permitting, but funding, because, first of a kind projects are always expensive and we can't compete purely on price as of yet, so we're going to require some funding. And so that's true in Alaska, that's going to be true in New York, and it's true off the coast of West. We're looking for sources of grant funding to help make those projects happen. The rationale being that if you want clean energy, you have to lean into it" (Respondent 9).

Both projects obtained funding support to conduct monitoring and experiments from federal sponsers such as the DOE. The Cobscook Project gained funding from a state source that had requirements laid out for the projects duration.

> *"Whoever is selected would commit to job creation, the development of a supply chain, R&D partnerships with the university, and continued close relationships in collaboration with the host community. We should also look for export opportunity as well, so that's a huge responsibility"* (Respondent 1).

Political support, through the context of apply for and receiving grants and funding awards was mentioned by many respondents. Through these repondents reflected on the importance of funding opportunities to support the pilot projects, political factors and motivations were not widely understood.

> *"That is we're going to get into the political side of things. Because those are the drivers that we have little control over and usually make the least amount of sense… We have to make progress and some political decisions set us back. It is obviously a controversial situation, and we are going to have a lot of people that are unhappy"* (Respondent 3).

When political decisions are made at the federal or state level that are not in agreement with tidal energy development, it could cause timing conflicts and tension between those working on the projects and the agencies and investors supporting the project finacially.

Legal factors were the least reflected on by respondents. Multiple respondents stated that the legal factors were not as present within the context of their role or their interactions with the pilot projects. This was observed through the lack of elaboration on these factors or that there was acknowledgment of their existance in the project, but without much elaboration as to how.

Some respondents clearly stated legal factors were present in the pilot project. These legal factors were influenced by social acceptance and economic factors.

"Everything is legal in society" (Respondent 2).

"So legal factors come down to 2 things in my opinion. One is regulatory. This is what the current set of rules are and that can have effects in terms of whether development can be permitted based on those rules. The second is what is socially acceptable? And oftentimes that comes down to individuals, groups of individuals. While you have life choices and what I often see are there's push back, both on the regulatory system as well as the judicial system. It comes down to folks with the economic means to play in the judicial system. So, by that I mean oftentimes lawsuits are brought by wealthier families and groups, against a development that they just don't want to see happen" (Respondent 6).

This countered other respondents who were unable to identify legal factors existed or that they had any interaction with the legal factors through the pilot project.

"*Politcal [factors] yes, legal no"* (Respondent 1).

"Political and legal factors. I certainly didn't deal with the legal factors. That all plays into it [the project], but I was largely unaffected. I think that's fair to say" (Respondent 2).

Through the responses, economic and social factors appeared to impact the pilot projects' progression through development. Funding opportunities, political will and support, and legal implications for the future of tidal were discussed by the repondents through these reflections.

e. Importance

Respondents were asked about each of the factors and how they impacted the peritting or design elements of the project. During reflection, respondents were asked to elaborate on the level of importance held by the factors, as they interacted with them. Not all respondents provided elaboration on the factors' importance. Most of the responses of importance were from researchers or permitting agency employees, while none are from the pilot project developers.

Below in Table 2, the importance value is the amount of times respondents mentioned that specific factor as important. As such the numbers represent a cooccurance of each factor code and the importance code. Economic and social acceptance were highlighted by respondents the most frequently amoung the factors analyzed.

Table 2: Factors and Importance [own data]

Factor	Importance
Ecological	8
Economic	17
Legal	5
Political	6
Research	10
Social Acceptance	17

Across both projects the two main factors that are important to the permitting or design components of the project were social acceptance and economic. Social acceptance was mentioned by multiple respondents as an important, if not the most important, piece to guiding the permitting or design elements of the projects.

> *"If you don't have social acceptance, you're not going to be able to do much. I know that that was always like right at the top of our concerns, our engagement with stakeholders as part of the research"* (Respondent 6).

> *"I mean, they [the developers] wouldn't get very far if the community didn't want them to be there. They needed to be put in the effort right away, engaging, communicating, and being as transparent as possible. I don't think they would have been successful at all had they not done all of those things and to their credit they did a great job"* (Respondent 5).

In the economic theme, the importance of funding support, research grants, and contributions to the local economy were considered important to permitting or design contributions.

“The economic factor that was critical for even if advancing this technology and embracing the recommendations of the resource agencies, that was the money available to support this emerging technology. And that was largely public federal funds from the Department of Energy. I know there's investors behind it as well” (Respondent 7).

“That was very important, obviously, that we were able to secure some large grants to do the research. It was important work and we needed it. We wouldn't have been able to do that without funding…you’re not going to get anywhere without investments and here investing in an uncertain new technology is risky. Another aspect of the economic side is the benefits to the community. They were hiring local folks to be involved in the project and I think that contributes to some levels of social acceptance. That said, hey they’re invested in the community, they’re hiring folks here not just having people coming from far away. Those benefits are also very important. I’m sure you heard that this is a very economically challenged region [Cobscook Bay] that they are working in and it has one of the most high levels of unemployment so job creation was an important piece” (Respondent 6).

Other responses pointed to the risk adverse approach taken, collaborative nature of the projects, federal support, ecological impact consideration, historical contexts of the site location, and the existing known benefits of tidal energy development as other “important,” contributors.

The research approach and the importance of the research that was conducted during the pilot projects was reflected of the structure of the research teams and the ecological factors being monitored.

“The ability to work together to address risk, perhaps I didn't stress that one enough. But as we started with a risk averse approach and obtained data relative to specific designs, we were able to then modify our risk assessment. So, that itself, evaluating risk based on new data. That was a big factor in the progress of the permitting and future actions of deployment within deployment” (Respondent 3).

"That [ecological] was a driving factor. In context, this is very important. Ecological factors were very important" (Respondent 4).

The permitting was seen as an important consideration. Respondents reflected on learning about the permitting process through their research and experience on these pilot projects. Building an understanding of the permitting process was important to progressing through it.

"I think the importance of understanding the permitting was really something that came into focus throughout the entirety of the project. The challenge that I saw when they were working on permitting was basically that because this was such a novel activity deployment technology, the permitting was not in place to be efficient. So, largely what I mean is they've developed this technology, they have a staff of engineers and from the initial idea out toward test deployment, there were a lot of years. A lot of that has to do with all of the different levels of permitting that they needed, right? They needed permits to connect the device to the grid. They needed permits for the Endangered Species Act, they needed permits for the Marine Mammal Protection Act, and they needed permits from the Coast Guard for how to put this thing onto the maps and how they were supposed to signal it to vessels and such. All of those different dynamics just took so much time. On an in an easier system, it might have been quicker. But, when you're talking about trying to figure out what's going on down there, 30 feet down and 5 knot currents it's challenging" (Respondent 7).

"It was important to understand who is giving our licenses and permits. There was some confusion over BOEM's role, or who was licensing within state waters" (Respondent 2).

Another reflection was the importance of understanding the historical context of the site and communities present at the location of the pilot projects.

[Another factor was] "maybe history, the importance of history as being sort of a place to start. Again, in the beginning we [the researchers] really didn't start from nowhere. They had proposed

> *huge dams in the region [Cobscook Bay], years before that had fallen apart. There is the history of the fisheries and how they have fluctuated. This area used to be a large industrial fishery and so there were conversations about energy development in the past that were important to build on. There had been the big dream of Roosevelt, where they wanted to harness all the tidal power in the region. That image was still in people's minds of those huge turbines which impacted public perception"* (Respondent 5).

Overall, the respondents that were able to elaborate on the importance of specific factors as the project developed were able to bring forward reflections of the values apparent in their role.

Assessments

Respondents were asked to reflect on their experiences working on these tidal projects and reflect on aspects of the project's approach that went well or that they may have done differently. These responses were coded and are represented below through word clouds. These word clouds display the frequency of various terms that respondents used or highlighted through their responses.

The size of the word reflects the frequency it appears in the responses for each question. A note that some adverbs and conjunctions have been removed from the word cloud for clarity (*Bowen, 2009*). Further, words that appear in the word clouds may have multiple meanings depending on the respondents' use or could be used as synonyms. These appear in the word cloud as separate words; however, it is important for the analysis to understand that similar ideas are being presented, just through different terminology.

The word "power," was used in the context of political or legal power, used when elaborating on the agencies or stakeholders' holding power over project specifics. Power was also used when discussing tidal energy power, used to elaborate on design specifics and energy production. The word "term," is used interchangeably with "time," and "year," as presented in the word clouds, all signifying respondents discussing timing, or the section of development being discussed. The words, "area," and "site," were both used to describe the location of the project, either the site located in Cobscook Bay, or the site in the East River. Lastly, the word, "place," is used in the context of the location, used with "area" or "site," or when discussing the history and context of the community that lives in the location of the project.

a. Went Well

Figure 2 represents words that frequently appear in their responses and reflections to what respondents felt went well. The key words, "community" and "people appear most frequently. Following closely are, "process," "ORPC," and "information." Respondents were asked to elaborate on these positive experiences and how they evolved as the project continued.

Figure 2: What respondents reflected well word cloud. [own data]

The research process was highlighted as a success for both pilot projects. The detail of studies conducted, and public accessibility of the data captured aided in supporting the community engagement strategies. By sharing and reporting the data collected during the pilot project research and demonstrations, some of the concerns communities had about research biases were eased.

Both projects' highlighted that the developers and researchers played a role in this community engagement and that it went well. In Maine, ORPC operated out of an office location within the community and utilized local contractors to support the research. In New York, the developers and researchers worked closely with non-profits operating in the East River and on Roosevelt Island to gain local support. Involving the community was viewed by the respondents as essential for these projects' success.

> *"I think something that I would identify as going well would be the community engagement and kind of working with the subcontractors and that continues to occur today. It helped our company create a core value way of working wherever we go…The project needs to be the local communities project, so when you first are engaging with the community, whether it be elected officials, general supporters, or the local utility, we're always looking for who that local trusted partner that we begin to work with and how do we begin to make this a community project" (Respondent 1)?*

> *"They [ORPC] had an office down there so they had a presence and people could come in and talk to them if they had some questions. I think that was really important. And their approach, I think maybe because of the university, it had that local feel instead of an outsider coming in. I think the university played a key role in doing a really good job with outreach and I always refer to other projects I'm involved with to look at how they did it because they did a good job. To do it in the area they did, I think that that really shows that what they did worked" (Respondent 3).*

> *As with any infrastructure, you're putting or making changes to a locality. So, with something like a tidal turbine, you first have to prove that it's safe and that it's not going to harm any aspect of the community. Some of that is regulated and some of that is just community building….But there were residents there that bought into the story. It was a welcome thing in the community but there was a conscious outreach to the community to explain what was going on. Those are the first*

steps. Everyone from whale watchers to you know just local residents, there is outreach. So yeah, that's absolutely, an important part of our planning" (Respondent 9).

Across both projects there was a resounding feeling of collaboration and excitement to work with others on the new technology. The collaboration and sharing of ideas was viewed as a positive point for both projects' and as a component of success. As much remained unknown about tidal energy, the projects both brought forward many experts in the renewable space, creating an interdisciplinary approach.

"The process was collaborative… working alongside ORCP and the Army Corps of Eng. was really fun. We were conducting site visits and working with each other at the site. There was a lot of care and attention given, and an overall understanding that the research was a part of the progress, with what little was known about the technology at the time, so there was room to learn" (Respondent 6).

"Working through this group, I think was a good way to kind of tease out where information needs were because there was different expertise sitting there and the different expertise had different concerns. The structure of the meeting and the people that were in the meeting and the expertise that were brought together in the meetings was really helpful to discussions and kind of flushing out a lot of the information gaps that we might have. Then, really how we can address them" (Respondent 4).

Overall, the respondents' reflected on aspects of the project that they perceived as successes or appraoches that contributed to the learning involved in the research process. This included community engagement strategies, collaboration between researchers, permitting agencies, and developers, and keeping the research open and unbiased.

b. Done Differently

Figure 3 represents words that frequently appear in their responses and reflections to what respondents felt they may have changed or done differently. The key words, "site" and "challenge" appear most frequently. Following closely are the key words, "grid," "funding," and "people." Respondents also elaborated on setbacks that were resolved during the project.

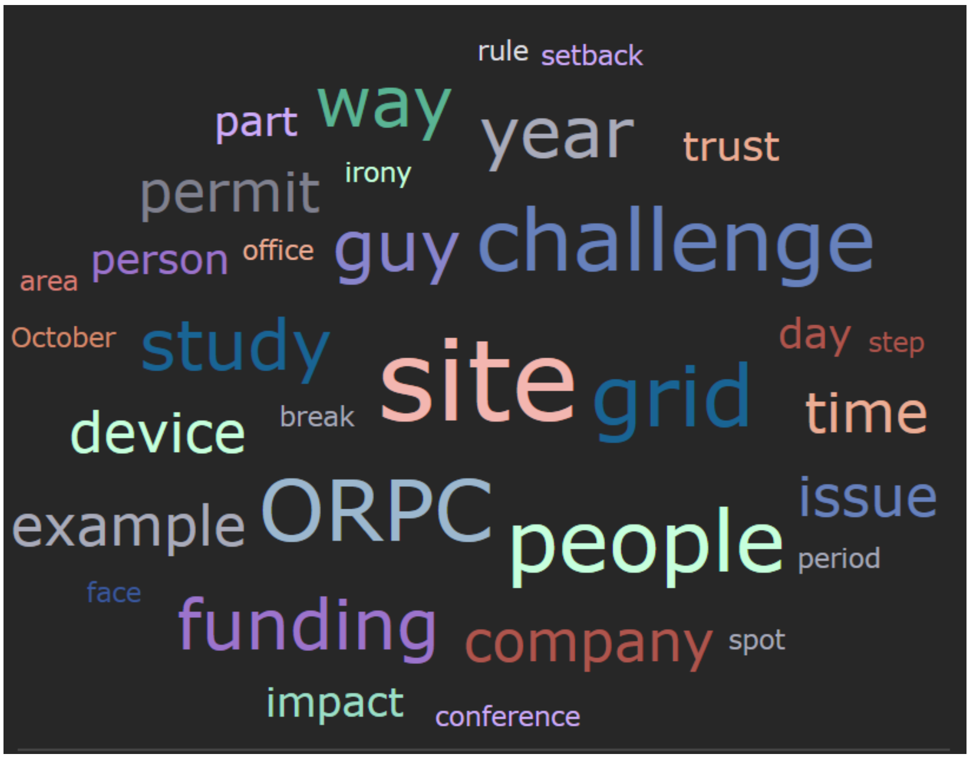


Figure 3: What respondents would have done differently word cloud. [own data]

While siting, permit time, and confusion regarding which agencies held authority over permitting, trust and research were the main key points of contention.

Many of the researcher's felt it was difficult at times to appear unbiased and neutral in their research for the project. Gaining and maintaining trust with the community was important.

> *"Our [researchers] goal was to be kind of neutral and have that kind of unbiased ability to deliver science. I'm not saying that went badly, it just was difficult for us to seem impartial*

sometimes. And it took, it was a lot of work, to rewrite that and get people's trust from a really broad perspective" (Respondent 5).

Through the extensive monitoring and experimentation periods of the research as these projects started, technology issues and timing were mentioned as project setbacks. Many of the permits called for technical monitoring over specified trial times, and many reflect on the issues with these early technologies.

"Ultimately, we went through a number of trials and the big the big challenge was that the tech never seemed to work long enough for us to get the needed data and videos….We would prepare for sampling at the time the machines got deployed for operation. They would go in the water; they would run for anywhere from 5 min to 2 days and break and then they'd get pulled again and we wouldn't know…So, we went through this for I think it was probably 10 years of trial and error trying to get the systems to work" (Respondent 10).

"…the device came out of the water earlier than expected. We had a vendor who provided us with a generator that didn't work properly, and we were unable to get satisfaction from the vendor. They just didn't have the right equipment; they went out of business. So, we didn't have a lot of recourse and we were sort of in a tough spot….Which led us to design the buoyant tension mooring system that DOE has provided funding for and what's not well known is, the year after that project came out of the water, we actually went back in the water with this revised deployment technique and new design for how a turbine would be in the water column. And that has been the basis of our designs ever since. So, you know, the generator issue was excruciatingly frustrating, but it led to other things occurring that would be beneficial" (Respondent 1).

As mentioned in the importance theme, the permitting process and the agencies responsible for providing licenses and permits was part of the learning process for these pilot projects. Permitting caused timing issues and in many cases impacted the communities' trust and perseption of the project developers. For exampple, in the Cobscook project, when developers applied for permits or were completing monitoring and experiemental studies, communities members wanted to be aware ahead of the permits. When issues with the permitting time frames arose, the relationship between the developers and the fishers was at risk.

> *"The project research was definitely trial and error when looking at the methodologies for deployment. We started broadly and hoped to streamline as we carried on. You have to think that consultation studies can take a long time. The informal being around 3-4 months and formal being closer to 6 months"* (Respondent 2).

> *"They [ORPC] said if you [fishers] can help us choose those sites, we'll go with what you say as long as they meet our or environmental parameters. Really it was this 2-way street with the Cobscook Fishers Association and a study site and a control site were formed. The sites were chosen, and they applied for it with FERC with the one caveat that the commercial fishers said, you need to be out of the control site by October 1st. They had harvesting after that time and said we don't fish there but need it cleared out. They said done, they shook on it, and they went through the permitting. Then later there was a public event in Eastport and ORPC was essentially unveiling the technology that they were testing, and the timeframe was going to go from June through December…the person representing ORPC said, you got to work with us guys, we're behind permitting schedule, you know, we just had unforeseen setbacks and they're like, we're dragging that area you said you would be out. Come October 1st, one of the permitting guys said no we have to pull it [the demonstration] early"* (Respondent 8).

While community engagement streategies for both pilot projets were developed and thought out, some respondents reflected on the importance of continued communication. Some of the respondents were able to share how some of the issues that arose were addressed. In Figure 3, the "people" encompassed fishers and other community members. Respondents highlighted that communication and flexibility was necessary to keep people engaged.

"I can give a specific example, just some of the work we were doing had things in the water and a fisherman thought, oh, that's ORPC's fault or something that we had done and so it kind of like sets you back when you have to bring the person back along and get them to not be concerned about something that you may have done. You have to kind of keep looping back with people and I think they had picked a site, and the fishermen weren't happy with it, but then ORPC was flexible, and they moved the site. So, I think that having that flexibility enables you to overcome those issues. So, I feel like sticking with it and being really open and transparent and working with people through those issues, enabled things to keep moving along in that project" (Respondent 6).

Depending on the respondents' roles and responsibilities within these projects, the aspects of the project that were considered setbacks were resolved outside of their interactions. The respondents mainly remained opptomistic about the project and asknoweldge that since the technology and process are new, issues with the prototype technology was expected.

c. Future Development

While tidal energy is still considered a new and emerging technology, the funding, research, and design improvements may point to an optimistic future. Respondents were asked to reflect on their experiences working on these tidal projects and provide their opinions of tidal energy and what they believe its role will be within the larger renewable energy development in the United States.

Figure 4 displays the four main ideas respondents shared in their reflections on the future of tidal energy. A "no" was provided meaning respondents believed tidal energy will not find success the commercial scale in the U.S. A "yes" was provided by respondents that believe tidal energy will find commercial success in the U.S. The other two main ideas were "small and remote" or "grid support," which were elaborations from a yes or no, which respondents provided conditions for which tidal energy may see future commercial scale success in the U.S. Some overlap between each are observed from the progression of respondents answers, or when the topic was revisited further along in the interview. The respondents roles and interactions may vary based on the time in which they were involved with the project.

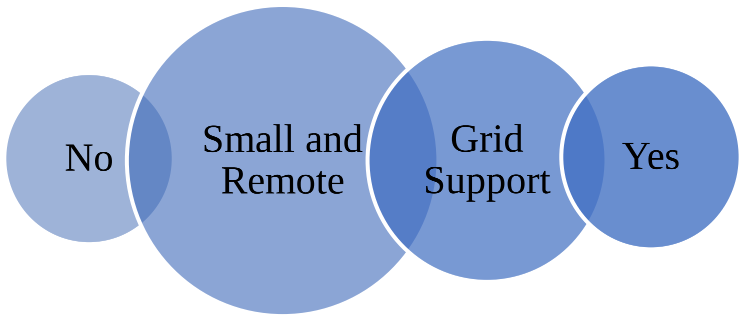


Figure 4: Future of tidal energy per respondents. [own data]

Many respondent's provided a mixture of optimism but made note of conditions or possible hurdles commercial tidal energy development may face. One standing no was provided.

> *"Not this type, not the type of tidal that they were looking at. I don't think the hydrokinetic tidal seems like a viable option to me. I think that I was always a little suspicious of it working or not. When the thing broke after about 30 days, we all kind of knew"* (Respondent 7).

Other concerns or conditions for tidal development may be impacted by the site selection and availability of those spaces may be limited.

> *"I think there it will always be a niche market necessarily because the only place you can put these is where the water is deep enough and fast enough. Which, you know, is not everywhere and is, it is only a small subset even of the coastal region. But I think within sort of the best coastal sites, I think it is going to make sense for tidal energy to be a part of the country's renewable portfolio and at this point, every piece counts"* (Respondent 11).

"The challenge is that hydro kinetic systems, hydraulic generation is that it is sited in biodiverse and ecologically rich locations. To be most effective, they need to be co-located with load servers and load pockets…If you're truly tidal, that means you're probably in a closed system or you're damning something up and letting it run out, which is again a huge habitat impact. And so you're gonna have massive ecological impacts for relatively small energy gains compared to offshore wind systems and your costs just won't compete. And so, I would see no reason why anyone who has an opportunity for offshore wind would choose a hydrokinetic project instead" (Respondent 10).

Many respondents expand on site selection but felt that tidal development may have success within small and remote communities. Though there are few of these sites or coastal communities, tidal would likely have a largely positive impact for these areas.

"I think it [tidal energy] could play a bigger role. Community to community, in a small, you know, it might seem small in terms of the larger renewable portfolio, but it's important to those local communities. So it could be, you know, super important and that in that way, where it's not the biggest for energy, but it's important at local-to-local scale" (Respondent 5).

"Some of those local benefits will be really important. So, I think it'll be part of a portfolio, or a piece of the puzzle, but in terms of massive energy contribution, I'm not convinced yet. But I think it offers a lot of opportunities at the small scale which is really neat and even like remote rural areas, if they're able to provide some stability and power to some of these places in a way that's less costly and stable. I think that will be really important local impact. In addition to jobs, energy independence is really important" (Respondent 6).

The other common condition for tidal development in the future considered it's role within the larger context of marine renewable energy. Respondents reflected on other marine renewable energy technolgogies that may be further developed.

“In those areas, it provides a benefit actually to transmission and distribution so that it's more than the electrons, you're actually part of the grid infrastructure because of the predictability and the storage can be designed at a proper size. It makes wind and solar more efficient because the utility can manage it because of the predictability of the tidal” (Respondent 1).

“It would be part of the portfolio solution…so this is fertile ground for people of your generation to create a matrix of various biomass, geothermal solar, wind, hydro, whether it's impoundment or by river, so you've got all these sort of inputs and they've got all their strength and weaknesses. Then battery storage obviously would need to be in there too if you're if you're powering a grid for a remote community, but somebody is going to get smart enough to just plug and play all these things together and go look at a site and say here's what you need. You need these 3 and here's why, and here's your hybrid system that powers your community and let's get diesel out of here. Somebody's going to do that. That has to happen really, it's emerging now. I don't think anybody's got it dialed in yet, but I can see that happening” (Respondent 3).

Through both these reflections, respondents also elaborated that tidal energy would play a role in these contexts because of what it has to offer. Respondents pointed to predicitibility and viewshed as important selling points for the technology in the future.

“I sure hope so. Tidal energy is interesting in that it has some advantages over wind and solar, most notably predictability. And also, one quality that has shown itself to be quite valuable and just asked the wind guys is no visual footprint. Right, it's not in anybody's view. And you wouldn't, I think have called that. You know, one of the most important things is that, look at the headaches it costs for the wind guys, right? Those are a couple of strong advantages of tidal power that are going to need to count for something” (Respondent 9).

“There isn't a compelling reason for hydrokinetic over lower cost alternatives. There's the predictability of the energy, but right now, that's not valued to that larger degree. Now maybe it

will be in the future. We understand that the offshore wind blows at a certain time. The solar runs at a certain time and these guys [tidal energy developers] can make up the delta in between in which case there's a of value in the market for resource that works at a certain time" (Respondent 10).

While many of the respondents provided those responses that elaborated on a possible yes, depending on the site location or tidal's possibility to pair with other renewable technologies, there was one respondent fully supportive of tidal as it has been developed in the pilot demonstration.

"I do. I think for Maine there is also the possibility for restorations of the tidal levees or damn impoundments" (Respondent 2).

The most frequent response for tidal energy's future was its' possible role in small and remote communities, and the abilities tidal energy poses to help these locations transition from diesel energy or gain more energy independence. In summary, the selected interview excerpts show how these respondent's view the future developmental success of tidal energy in the United States.

Discussion

The development of pilot tidal energy projects served as the basis for this research. The stages of progression demonstrated by the selected pilot projects were the initiation, design and deployment strategies, permitting, and the demonstration. These stages aided in expanding my analysis for the interviews. When interviewing, the stages of design and deployment strategies and permitting were used to further distinguish the factors' presence in the development. Through interviews and the review of project documentation, the themes that emerged were design and deployment strategies and siting, community engagement and social acceptance, economic and social factors, permitting and the research cycle, and the importance of the factors. Both selected pilot projects showcase these themes differently and the factors were observed to have different impacts based on the role of the interviewee. The interviews conducted also allowed me to identify major assessments of the pilot projects' progression through the experiences of the respondents. The assessments included what respondents felt went well during their experiences with the project and things the respondents would have done differently. Lastly, the interviewees were able to share their opinions on what the future of tidal development in the U.S. might look like. These themes and assessments presented through my research aim to provide suggestions and recommendations for future pilot or commercial scale projects.

For the future tidal development, respondents provide the conditions for which they see tidal will have a role to play. The interviews indicate that the researchers appear the most apprehensive about the future commercial success of tidal energy at the large scale in the U.S. The developers remain the most optimistic, often providing details of their companies' next steps and hopes for tidal development to continue. The permitting agency employees fall in the middle of the scale or shift between the small and remote to a full yes based more on their time of interactions with the project and the agencies they represent. For example, one permitting agency representative shared their optimism for tidal energy playing a role for small and remote communities as a "backyard" type system. The same respondent had cited earlier that permitting would be the biggest barrier to tidal and pointed to the amount of unknowns that remain in the ecological space. Other respondents, mainly developers, were more hopeful that tidal energy could play a role within the larger marine renewable energy industry. Many cite that tidal energy is predictable and would offer support to a hybrid grid system, alongside offshore wind, or solar capabilities. This idea of a future marine renewable hybrid system is supported in more recent literature (*Guillou, 2017*) and by other developers and research agencies internationally.[19,20] The respondents roles, time interactions with the projects, and their roles as community members and representatives in these spaces had an impact on how they continue to view tidal energy and the development of tidal at the commercial scale.

The interviewees' experiences reflect their dedication to their roles and their experiences with these pilot projects. The roles held by the interviewees during their experiences with these pilot projects also had an

[19]https://www.utmconsultants.com/news/can-tidal-power-be-the-solution-to-intermittent-wind/42181/. Accessed 9 June 2024
[20]https://hydrosphere.co.uk/wind-and-tidal-power-an-answer-to-increasing-energy-demand/#:~:text=Because%20they%20naturally%20peak%20at,to%20tidal%20turbines%20operating%20alone. Accessed 9 June 2024

influence on how they perceived each of the identified factors and their experiences with the design or permitting stages. Within these interviewee groups, respondents were mainly senior level staff, many with years of experience in the renewable energy space and served advisory roles. While many respondents have worked within these spaces, many had not interacted with tidal energy development with an actual demonstration until these pilot projects were developed. When respondents were reflecting on these pilot projects and the factors presented, their responses reflect that time constraints, trust building, and the opportunity to learn were present throughout their experiences. Respondents also reflected that these projects, and future developments, would not succeed without the consideration of each factor. When respondents were presented with factors, they may not have experienced as thoroughly in their role, there was still acknowledgement of those factor's importance or value to the project overall. One respondent mentioned that while they did not interact with any legal factors during their time working on the Cobscook project, they suspected that if a tidal project were to be developed at a commercial scale more legal pushback would appear using judicial power. Since not all factors are equally experienced between different interview groups, respondents indicated that the adaptive management practices and involvement of research institutions and partnerships went well. One research respondent reported that it was the best collaboration effort on which they have worked during their three decades of conducting research. By inviting collaboration and different expertise to the table, innovation and data sharing came more naturally. These collaborations built trust and contributed to improved interactions with other factors. The importance of selecting and utilizing proper adaptive management practices and understanding the community needs was also supported by the literature (*Johnson & Jansujiwicz, 2015; Devine-Wright, 2011).*

The site location and greater state context influenced many of the decisions and community characteristics. As supported by the engineering reports, the designs chosen for the turbines, supporting infrastructure, and mounting were influenced by the geography present at the site location. The designs and the environmental monitoring methodologies for the RITE project were influenced by the river ecology and species of concern in the area. For example, the water in the East River is said to be extremely turbid, one respondent claiming to be able to see less than 6 feet in. The researchers had to be creative in setting up fisheries behavior monitoring with newer camera technologies and reviewed countless hours of footage because of this physical characteristic. In the Cobscook Bay pilot project, the site selected for the demonstration was described by a researcher as a fishers “blind spot,” meaning the site wasn’t used as much by trawlers. In this site, the developers and researchers were conducting similar experiments and monitoring projects as the RITE project but had a lot more biological concerns in the greater context of the Gulf of Maine. Birding and growing concern for Lobsters, various species of Tuna, and the possible presence of other Endangered Species led to apprehension in the Cobscook project for what permitting agencies would deem as “scalable” research findings.

The community population at the site, urban or rural, also impacted aspects of the project development. The more isolated nature of the Cobscook Bay communities means they have experienced more economic challenges, have not had consistent economic development, and had a longer history of reliance on diesel for energy. In the urban environment of the RITE project, the tourism, manufacturing, and shipping industry support the city’s large economy. This created more user conflict and economic competition not as relevant in Cobscook Bay. Future work may develop this difference to identify where commercial tidal energy projects would be more economically successful. For example, the tourism industry in Maine is supported by the greater national preserve where people like to hike, camp, and enjoy the natural environment. In contrast, the urban tourism industry in New York City hosts many large entertainment events and spectacles include landmarks like the Empire State Building or Statue of Liberty. These differences in the urban or rural environments may shape how economic decisions are made.

This research exhibits some limitations related to interviewing. These interviews took place online during a 3-month period which limited the number of respondents available to participate. The number of respondents was further restricted due to legal Non-Disclosure Agreements signed by several identified respondents. As the field of renewable technology and tidal energy is still young it was important to keep respondents anonymous. Still, there is the existence of hesitancy to answer certain questions or elaborate on information, as well as a hesitation of some possible interviewees to participate at all.

Through the process of interviewing the respondents were provided with the questions ahead of the interview. We do not know whether respondents reviewed the material prior to their interview or not. In either case the order of the questions and the presentation of each factor remained in the same order. This may have led to bias as some respondents may have attributed higher importance to factors listed earlier in the interview. See questions in Appendix B for the ordering of these questions. If the study or questions were conducted at a larger scale, it would be recommended to randomize the order of the questions to reduce this risk of exposure bias.

For my analysis, I interviewed project developers, contracted researchers, and employees at permitting agencies that play an advisory role. In the future, researchers may want to include community members, representatives from state or local governments, tribal members, members of the fishing industry, port authorities, or NGO representatives. In future research, it may benefit to include questions about the capacity for tidal to work in remote areas or what the permitting structure for these projects will look like at the commercial scale. If the future for tidal development would find success in remote areas, as predicted by the respondents, the permitting and regulatory structure would need to adapt to the needs of these communities. The factors of social acceptance, economic, political, legal, and ecological were all present and experienced by the respondents. Through the interviewees experiences on the two selected pilot projects, the themes showcase how these factors were present through the design and deployment and permitting stages of development. These lessons serve as a catalyst for possible future commercial scale tidal energy projects in the United States.

Appendix A

Common Abbreviations

BACI	before and after controlled impact
BOEM	Bureau of Ocean Energy Management
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
EPC	Engineering, Procurement, and Construction
FERC	Federal Energy Regulatory Commission
MHK	Marine Hydrokinetic (Industry)
MRE	marine renewable energy
MMPA	Marine Mammal Protection Act
MAIC	Maine Aquaculture Innovation Center
MDEP	Maine Department of Environmental Protection
MDIFW	Maine Department of Inland Fisheries and Wildlife
MDMR	Maine Department of Marine Resources
MDOC	Maine Department of Conservation
MSPO	Maine State Planning Office
NIMBY	not in my backyard
NREL	National Renewable Energy Laboratory
NOAA	National Oceanic and Atmospheric Administration
NMFS	(NOAA) National Marine Fisheries Service
NYSDEC	New York State Department of Environmental Conservation
NYSDOS	New York State Department of State
NYSERDA	New York State Energy Research and Development Authority
ORPC	Ocean Renewable Power Company
PNNL	Pacific Northwest National Laboratory
SMEA	(UW) School of Marine and Environmental Affairs
SSM	Snowball Sampling Method

UMAINE	University of Maine
USACOE	United States Army Corp of Engineers
USCG	United States Coast Guard
USDOE	United States Department of Energy
USEPA	United States Environmental Protection Agency
UW	University of Washington

Appendix B

Interview Questions

1. What role(s) did you play in (x project's development)?

2. Did your role change in any way as the project evolved?

3. How long/ when were you engaged with the project?

4. In your opinion, what went well during the project's (entire) development that you engaged with? What do you think explains that?

5. In your opinion, what did not go well during the project's (entire) development that you engaged with? What do you think explains that?

6. Was there any intervention or correction to address some of those factors (issues)?

Renewable energy literature has defined various factors impacting the design and permitting steps of renewable energy project development that are included in the following subsequent questions. Please use this opportunity to reflect on your own experiences.

7. One such factor is social acceptance. Did social acceptance play a role in the design stage of the project, if so, how? If you could quantify it's importance to the design stage on a scale of (not important, somewhat important, or very important) what would you say?

8. How about its role in the permitting stage? If you could quantify it's importance to the design stage on a scale of (not important, somewhat important, or very important) what would you say?

9. Economic factors were also mentioned in the literature. Did economic factors play a role in the design stage of the project, if so, how? How important was this factor? (same scale)

10. How about its role in the permitting stage? (same scale)

11. How did political and legal factors play a role in the design stage of the project? How important was this factor? (same scale)

12. How about in the permitting stage? (same scale)

13. How did ecological factors play a role in the design stage of the project? How important was this factor? (same scale)

14. How about in the permitting stage? How important was this factor? (same scale)

15. Where there any research gaps that played a role in the design stage of the project, if so, how?

16. How about in the permitting stage? (same scale)

17. Are there any relevant factors that impacted the design or permitting stages of this project that we have not discussed yet?

18. From your experience, could you see tidal energy playing a bigger role in the future of US renewable energy development and if so, how might we get there?

19. Are there any individuals you recommend I should talk with?

Appendix C

Code Descriptions

Code	Description
Done Differently	ideas of project aspects or approaches that would have been done differently, reflective, opinions on project methods and outcomes, project difficulties, mistakes
Community Engagement	
Community Engagement: Community providing knowledge	sharing or learning from the community to the developers, collaborators, or researchers, pertaining to siting or of local resources
Community Engagement: Engagement Strategies	methodologies used by developers and/or other outside institutions to engage or communicate with the local community members, how the stakeholder groups were distinguished/communicated to/and addressed, public meetings, involvement in research, understanding time and place to engage, reflections of strategies that work/don't work
Design	
Design: Engineering (Design)	components or ideas about the development of the tidal devices' design (from developers or others), mentions of design challenges, design iterations/changes, engineering process and decision making
Design: Siting (Site selection)	the site itself chosen for the project, the process of selecting the site for a tidal project, site complications, site specifics, other users of the space considered when selecting site
Ecological	
Ecological: Environmental Impacts	broad mention of any unknown/known impacts to the environment, positive or negative implications of the tidal device operation to the environment
Ecological: Fish/ Small Species	any fish or small marine species mentioned, how these species are impacted, studies done involving these species, behavior changes, under ESA, fishing rights
Ecological: Marine Mammals/ Large Species	whales, seals, sharks, etc., larger marine mammals, protected by the MMPA, under ESA, how these species are impacted, studies done involving these species, behavior changes
Ecological: Oceanography	mentions tides, sediment shifts, impacts to ocean floor, bathymetry, coastline, coastal erosion, interactions with waves and tidal patterns
Ecological: Seabirds	seabirds, birding, noise pollution impacts to seabirds, studies done involving these species, behavior changes
Economic	

Economic: Competition/Market	economic market competition with other technologies or industries, competition with other stakeholders at site, other developers/researchers conflict, purchase agreement challenges, cost competitiveness, purchaser agreements, tidal energy market, purchasing power
Economic: Design/Technology Cost	costs relating to the development of the technology equipment or research required to obtain permits, cost gaps due to knowledge gaps
Economic: Funding	mention of funding received/ existing/given, sources of funding, amount, resources for funding, impacts to research based on funding, where the funding money is being spent, agencies and/or partners involved in funding process
Economic: Local Economy	economic capacity and state of the local communities that reside and/or work near the site(s) selected for the project, benefits to local economy, job creation, involvement of residents with compensation, support the local economy by employment/bring in money to the community
Future	
Future: No	a strict no, mostly no, negative or uncertain opinions toward future development of tidal
Future: Small/Remote	a no or yes but with the further explanation of tidal energy development being geared for small and/or remote communities, elaborate from a no or a yes to only include specific communities where tidal could have a future
Future: Yes but...	a yes, a yes but with an elaboration that is not strictly small and/or remote communities, implied yes, hopeful and/or positive opinions toward future development of tidal
Importance	directly state an idea or factor is important, level of importance, ranking or comparing factors, vital, necessary, implying or stating tidal development will not occur without it
Legal	
Legal: Legal (broad)	any mention of legal/legality/non-political social components that do not fall under the other sub-codes of the code legal
Legal: Litigations	legal litigations mentioned, lawsuits, lawyers, mentions any part of the process of taking legal action
Legal: NDA	mentions signing or being aware of the presence of Non-Disclosure Agreements
Legal: Permits	permits, permit requirements, discussion of permitting process or steps

Legal: Regulatory	individuals or institutions in charge of regulating/ or not regulating a component of the site/ project, mention of a regulatory agency
NNYNM (State Context and Relevant Examples)	tidal projects or examples mentioned that are not specifically about either the RITE project (developed by Verdant Power) or the Cobscook Tidal Energy project (developed by ORPC)
ORPC: Adaptive Management Committee	mention of ORPC's adaptive management committee, their meetings, or other members of such group
Other Factors	any other important factors identified not encapsulated by the other factors, other components/ideas mentioned that have not been addressed by other questions
Political	
Political: Conflicts	conflicts between stakeholders, conflict creating political will, political weight, conflict leading to stakeholder mobilization
Political: Federal	any mention of federal a federal entity/entities, federal role, political motivations at the federal level (higher than local/state), presidential, BOEM, funding support from federal level
Political: Politics (broad)	any mention of politics/political will/political support or motivation that does not fall under the other sub-codes of the code political
Political: State	mention of state entities, state support or lack thereof, governor, state laws/funding, state senator/senate, state involvement in permitting, state laws enacted over tidal energy
Renewables	wind/wave/solar/offshore wind or any other type of renewable energy technology, mentions renewable in the context of competing with diesel, mentions other renewables as competition or to pair with tidal, future of renewables, broadens tidal to be renewable
Research	
Research: All of it	everything, no starting place, all was brand new, fully developed research without context of other methodologies
Research: Developing research	aspects of the research process post- start, how the research progressed, what questions/lessons learned pushed forward, research methodologies that developed through the process
Research: Future (unknowns)	what is still unknown at the time of interview about impacts, permits, animal behavior, etc., unsure
Research: Trust (internal)	trust building or relationship between researchers/developers/collaborators, internal trust, respect, or positive collaboration between project developers/researchers/collaborators/regulatory

Research: Starting Points	claims existence of knowledge gap but had starting points, used methodologies or own research experience to start to form questions, used other studies to inform approach, what these starting points were, what questions were asked at the very beginning based on project stakeholders' previous research experience
Role (Job)	
Role (Job): Collaborator	any individual not in a role specified in the other sub-codes under the code job, either more broad than these individuals or any person not directly involved with permitting/designing/or researching (as a contracted researcher)
Role (Job): Developer	engineers, project managers, VP, any individual spoken to from the developer (either employed by ORPC or Verdant)
Role (Job): Permitting	any individual involved in the development of research for the purpose of issuing (or assisting in the issuing) of a permit necessary for the tidal project, NOAA, state agencies employees, individual's questions/research needed to give out permit or advise agency to give out permit
Role (Job): Researcher	a researcher/ scientist (biologist, social scientist, oceanographer, etc.) that was contracted by the developers to assist with either specific research goals or for the entire researching process, may have worked on tidal/tidal research not entirely for the project but contributed to a portion of research done for permitting/design reasons on the project
Social Acceptance	broad mention of social acceptance from the community and/or other stakeholders involved, different from engagement/engagement strategies as this pertains to the acceptance or "permission" for the tidal project to continue, community support, community acceptance and involvement,
Stakeholders	any mention of key players both within the community and the other individuals/groups involved with the project, community members, fishermen, college/high school/K-8 students
Trust (external)	trust and bias/unbiased, building trust with the community, trust within stakeholder groups and with outsiders, gaining acceptance through trust building/ establishing relationships, remaining unbiased in research, funding conflicts reflect trust
Timing	any mention of years, time passed, time in role, time for aspects of the development/ permitting to take

	place, comparisons of timing project components, (can be days, months, years, decades, etc.)
Went Well	components or ideas about the development of the project that went well, reflective positive, components of the project that advanced development forward, recommendations for other projects (to do), particular steps were successful, essential to project's success

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