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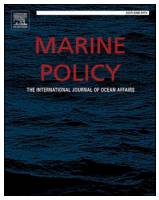

Full length article

Stakeholders' views on siting in-stream tidal energy projects in urban and remote communities in the United States

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ABSTRACT

Developers have proposed many in-stream tidal projects, but few commercial-scale devices have moved beyond the planning stages to construction and testing. To better understand social impediments to pilot project siting, this comparative case study was conducted in urban Puget Sound, Washington and remote Iguigig, Alaska. Stakeholder interviews were coded to identify themes about project development. Providing local renewable energy, advancing science and technology, and environmental awareness were perceived benefits, while negative environmental impacts, conflicts with other uses, and unintended consequences were perceived concerns of tidal energy. The major themes were: 1) organizations influence siting in urban areas while residents influence siting in rural areas; 2) stakeholder groups cited the wellbeing of their members to justify their stances on in-stream tidal energy projects; and 3) project siting was more successful where there was a simple and uniform assemblage of stakeholders and views. Stakeholders in the smaller, more uniform community were the most supportive of in-stream tidal energy because of a greater need for energy due to fewer energy options. Thus, siting in remote communities could allow tidal energy development to progress in mutually beneficial ways and help states like Washington and Alaska achieve their renewable energy portfolio goals.

1. Introduction

No single renewable energy technology can eliminate fossil fuel emissions from the energy sector. Instead, society needs a portfolio of renewable energy types, and many states, including Washington and Alaska, have set renewable energy portfolio goals [1,2]. In-stream tidal energy, which is a form of hydrokinetic energy, uses the natural ebb and flow of Earth's waters to generate clean, renewable energy and can be placed in any area with fast-moving water, such as ocean channels, narrows, inlets, rivers, or streams [3]. It can potentially provide clean energy with less environmental impact but is not widely used.

In-stream tidal energy offers several advantages. Scientists can forecast its energy generation over long periods given the consistency of tides and river flow [4], resulting in a predictable and reliable energy source. The ability to place devices in diverse environments and different parts of the water column maximizes the scope of potential sites while minimizing the visual and aesthetic impacts [3]. In-stream tidal energy projects produce significantly fewer emissions than energy produced by fossil fuels. Projects can also be located near energy demand, thus improving supply security and reducing transmission costs [5,6].

In-stream tidal energy can potentially contribute to the electric grid in a large-scale commercial capacity and small-scale remote settings [7–9]. The technology remains mainly at a pre-commercial capacity [10–12]. A project would need to be built at a commercial scale with multiple in-stream tidal turbines to harness enough energy to power urban areas. To achieve energy generation at that level, numerous turbines can be placed in high-current areas near one another, which reduces installation and operation costs [10,13]. At this production scale, turbines must be near a power facility that can receive and distribute the power to the electrical grid [13].

In addition to dense, urban areas, in-stream tidal energy can potentially serve more rural populations and support small energy distribution systems called microgrids [14–17]. Remote communities tend to have low population densities, limited conventional energy sources, lack of infrastructure, low economic activity, physical access constraints, and are typically located long distances from external markets [9,18]. For remote communities near a dynamic water source, a small-scale

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in-stream tidal energy project could address these challenges and meet their energy needs.

In-stream tidal energy is receiving global attention from scientists, industrialists, and politicians [19], which has translated to national governments funding research in the technology. Although developers have proposed many in-stream tidal projects, few commercial-scale devices have moved beyond the planning stages to construction and testing [20,21]. Scholars report social factors rather than technical limitations have impeded the implementation of marine renewable projects [22,23].

The societal challenges of tidal energy projects, such as the competing uses of the area, increased consumer electrical pricing, and fear of environmental impacts, have hindered in-stream tidal energy development [16, 24–26]. However, existing studies on tidal energy implementation often overlook social considerations [21,23,27]. A small but growing body of empirical studies examines social issues around tidal energy technology and how those issues can be mitigated [17, 23, 24, 26, 28–33]. Some authors have called for researchers to look beyond the logistical and environmental challenges and understand the social and economic impacts on the surrounding community [4,32,34, 35]. In the United States, there is also a need for improved and better-integrated governance structures.

Another challenge in-stream tidal energy projects face is stakeholders' perceptions [9,26,31]. Stakeholders include any person, group, or organization linked to developing a tidal energy project, such as turbine manufacturers, utility companies, environmentalists, government officials, and community members, including Tribal groups. Stakeholders can affect or be affected by the actions occurring before, during, or after project development. Stakeholders can also affect or be affected by objectives and policies associated with project development [35]. Stakeholders can also influence project delays or cancellations [36]. So, it is crucial to understand how stakeholders perceive in-stream tidal energy in different locations and scales to find places where developers can successfully site projects. Early and frequent stakeholder engagement is an essential aspect of any project to ensure the goals and ideas of these diverse groups are identified, discussed, and balanced to get broad community support for a project [9,31,35].

1.1. Research objectives

This study expands the small literature on the human dimensions of in-stream tidal energy by evaluating how remote and urban stakeholders view the technology in two case studies. It addresses three research questions:

1) How do stakeholders perceive a commercial in-stream tidal energy project in their location?
2) What are the benefits and concerns about a commercial in-stream tidal energy project?
3) How do stakeholders want their priority concerns about a commercial in-stream tidal energy project addressed?

This study also shows potential approaches and framing opportunities for stakeholder engagement around in-stream tidal energy. Finally, it shows how stakeholders would like their concerns addressed so that in-stream tidal energy projects and the overall in-stream tidal energy sector can move forward.

2. Case study overviews

Due to their history with in-stream tidal energy, two case study locations were chosen for this original qualitative research: Puget Sound, Washington and Igiugig, Alaska (Fig. 1). These cases allow a comparison between the potential tidal energy projects located in an urban and a rural area, which would yield diverse perspectives, a range of stakeholder characteristics, and differing circumstances. Both locations have the capacity for commercial-scale in-stream tidal energy that could provide a significant portion of the power needed by the surrounding community [37,38], and both locations are some of the few places in the United States that have a history with in-stream tidal energy pilot

Fig. 1. Research site locations.

projects. Their differences in waterbody type, population demographics and size, and stakeholder involvement in pilot projects provide an opportunity for comparison. Despite their differences, the projects exist within the same regulatory framework requiring Federal Energy Regulatory Commission (FERC) approval. The two projects had similar stakeholder groups, such as federal agencies and municipalities, engaged with project development. However, some stakeholder groups were different, such as non-governmental organizations (NGOs) only having a presence in Puget Sound. Finally, the two projects had different outcomes; one successfully implemented a pilot project while the other did not.

2.1. Puget Sound, WA

Local history with tidal energy projects and the large population overlapping with suitable locations made this an excellent case study. Puget Sound, WA is an approximately 240 km fjord estuary that connects with the Pacific Ocean in the Northwestern United States [37]. With 4000 kilometers of shoreline, Puget Sound supports nearly 4.5 million people, including 118 incorporated cities, one of which is Seattle, and 15 American Indian Tribes.

In northern Puget Sound in 2006, the Snohomish County Public Utility pursued installing an in-stream hydrokinetic pilot project that was a preliminary step towards a potential larger-scale development [39]. The project called for deploying, operating, and monitoring two 6-meter open-center turbines in Admiralty Inlet. During peak tidal currents, the project could have generated as much as 300 kilowatts of energy, supplying grid-scale electricity. Developers planned to place the two turbines in 58 m of water and 1 kilometer from shore. Underwater transmission cables would bring power from the turbines to a power substation. Engineers designed a removable, gravity-based foundation so that all equipment was removable for maintenance or after the pilot project. Municipalities, federal and state agencies, NGOs, Indian Tribes, and industry voiced their opinions about the project. Despite extensive outreach and many public meetings, Snohomish Public Utility abandoned the long development process due to escalating costs in 2014.

2.2. Igiugig, AK

In Igiugig, AK, the local history of tidal energy projects and its rural location provide an excellent comparison to Puget Sound. Igiugig is a small village of fewer than 70 people, mostly Yup'ik Eskimos, Aleuts, and Athabascan Indians. It sits on the peninsula of southwestern Alaska on Lake Iliamna at the mouth of the Kvichak River. The Kvichak River has one of the largest sockeye salmon runs in the world [40]. There are no roads to the village. The only way to access Igiugig is by boat or plane; the closest nearby villages are about 50 miles away [41].

Due to its location, sending electricity from a commercial-scale power-generating facility to the village is nearly impossible. Instead, Igiugig primarily relies on diesel to fuel the village's generators. A barge delivers diesel when the weather is good and the lake is not frozen. When the lake is frozen, a plane delivers diesel. A commercial in-stream tidal energy project could supply cheaper energy while being predictable and producing less emissions than burning diesel.

ORPC, a marine renewable energy company, installed their RivGen Power System as a pilot project in the summer of 2014 to show the feasibility of their technology. In the Kvichak River next to Igiugig, they installed a cross-axial turbine and removed it before the coming winter due to concerns about ice flow down the river. In 2015, they modified and deployed the turbines in the deepest location in the area, situating them to allow vessel traffic. The turbines sent power to the village. During peak operation, the modified system could provide 25 kW, one-third of the village's electrical load [42]. The Igiugig Village Council supported the project with local resources, and the council, villagers, industry, federal agencies, and state agencies were all involved in the pilot project.

Following the pilot project in 2014 and 2015, Igiugig received a FERC10-year permit in 2019 to install and operate a modified RivGen Power System. The modified in-stream turbine successfully delivered power to the village. There were talks of adding a second in-stream turbine in 2021 [43], and as of 2022, the modified RivGen Power System was still in operation[44].

3. Methods

A descriptive, multiple-case, holistic case study [45] was conducted to compare diverse tidal energy development in real-world contexts. Stakeholder groups (e.g., federal government, Indian Tribes, industry) were the unit of analysis. Puget Sound's stakeholder groups included municipalities, Indian Tribes, industry, federal agencies, NGOs, and state agencies. In Igiugig, stakeholder groups included federal agencies, state agencies, industry, the municipal government, the village council, and village residents.

A purposive sample of interviewees consisted of stakeholders who played a significant role in the respective projects. The purposive sample drew on individuals named in public comments, interventions, and correspondence about the pilot tidal energy projects submitted to or by the FERC. Snowball sampling [46] was used to identify additional interviewees.

A preliminary assessment was conducted with in-stream tidal energy researchers from diverse fields of study (e.g., applied physics, engineering, fisheries, oceanography, and marine affairs) to identify potential benefits and concerns about tidal energy. Researchers were asked to name potential societal concerns and benefits of in-stream tidal energy technology based on their expertise and experience. The ten most common potential benefits and concerns (Table 1) were used to craft the interview guide.

Twenty-two semi-structured interviews (10 in Puget Sound and 11 in Iguigig) were conducted between July and October 2015 (Table 2). Most interviews were in-person except for five phone interviews when in-person was not possible. A representative from FERC was interviewed; however, because the agency is a regulatory gatekeeper, it was not considered a unique stakeholder group. The interview was used to generate themes during the grounded theory analysis but was not included in the ranking exercise. The interviewee from FERC was not preferential to either project or any of the benefits and concerns and said that FERC takes the same approach regardless of the project location.

Example questions from the interview guide are in Table 3. The interviews, which lasted approximately 35 minutes, were recorded and transcribed. A grounded theory [45,47] approach was applied to analyze the transcribed interviews using the qualitative data analysis

Table 1
Ten potential concerns and benefits of in-stream tidal energy.

Potential Concerns	Potential Benefits
Conflict with other uses of the water	Provides local renewable energy
Negative environmental impacts	Provides jobs
Relative high cost compared to other energy options	Provides a sense of pioneering for the community (e.g., the community would be the first or renowned for a project/technology)
Informing the public accurately about projects	Relative low cost compared to other energy options
Public perception of the project	Culturally appropriate (i.e., the project supports the ideals of the community)
Difficulty with project permitting	Advancement of science and technology
Variability of power production levels	Predictability (i.e., tides/currents are consistent)
Unintended consequences	Boost the local economy
Impact on other industries	Energy independence
Loss of access to space	Environmental awareness (e.g., the project would lead to environmental research that otherwise would not take place)

Table 2
Count of Interviews by Stakeholder Group.

Stakeholder Group	Puget Sound (Count)	Igiugig (Count)
Federal Agency	3	1
Industry	2	3
Municipal government	1	2
NGO	1	0
State government	1	0
Tribes	2	0
Village Council	0	1
Village Resident	0	4
Total	***10***	***11***

software MAXQDA 12. Constant comparison was used during open, axial, and selective coding to iteratively examine codes to allow concepts and themes to emerge inductively [48]. More than 900 unique coded segments were analyzed to find common themes across stakeholder groups and locations. These resulting cross-cutting themes are discussed in 4.3. This analysis also yielded insights into the synergies and tensions between how stakeholder groups would like their concerns to be addressed (4.2).

Rankings were calculated to compare concerns and benefits. Interviewees were provided with the list of potential concerns and benefits (Table 1). They were asked to rank their perceived benefits and concerns of a commercial in-stream tidal energy project from greatest to least. Interviewees could add any benefits and concerns that had not been listed. The greatest benefit or concern received a 1; the second greatest received a 2, etc (Table 4). Values were assigned for each ranking on the original list to allow for comparing results by stakeholder and location. The value used for analysis was set by taking the ranking (e.g., 1, 2, 10, etc.) and subtracting it from the greatest number of responses by any interviewee (i.e., 10) plus one (i.e., 11) so that a ranking of 10 (i.e., lowest possible rank) would be assigned a 1 and not a 0. For example, if an interviewee said that their second top perceived benefit was "Predictability" (i.e., "Predictability" had a rank of 2), the value would be 9 (i.e., 11 minus 2). Because of the number of interviewees in each stakeholder group, the rankings were normalized by combining the values assigned for each benefit or concern within a stakeholder group and dividing by the number of interviewees in the stakeholder group. Sometimes, interviewees added benefits or concerns to the ten benefits and concerns listed, but all additions were idiosyncratic, so they were not included in this analysis. However, these added concerns and benefits are discussed in 4.1.3.

4. Results and discussion

4.1. Ranking results

The ten perceptions of tidal energy presented to interviewees captured most of their concerns and benefits. Figs. 2- 5 display the ranking of concerns and benefits in the two locations.

4.1.1. Ranked benefits

Providing local renewable energy stood out as the greatest benefit in both locations, substantially more so than other benefits in Igiugig. Providing local renewable energy, energy independence, advancement of science and technology, and jobs were also highly ranked benefits in both locations. Environmental awareness and being culturally appropriate were greater benefits in Puget Sound than in Igiugig. Low cost and predictability were two of the lower benefits in both locations.

4.1.2. Ranked concerns

The greatest concern in both locations was the potential for negative environmental impacts from an in-stream tidal energy project. Challenges created by conflicting uses of the project area and potential unknown or unidentified consequences of project installation were the other primary concerns in both locations. Public perception of a project was a significantly greater concern in Puget Sound. Concern for the variability of power production was low in both places but particularly low in Puget Sound. This could be due to the reliance on tides instead of river currents, which can be more variable than tidal forces.

4.1.3. Added concerns and benefits

Interviewees could add concerns and benefits that they considered important and not included in the provided lists (Table 5). One important concern not included in the list was an in-stream tidal energy project interfering with treaty rights. This concern could fall under other concerns, such as loss of access to space, environmental impact, or conflict with other uses. However, one Tribal stakeholder group representative felt that, in their view, it was intense and distinct enough of a concern to have it listed separately.

4.2. Addressing concerns

Of the ten concerns provided to interviewees and additional concerns they mentioned, five were consistently among the greatest concerns in both Puget Sound and Igiugig. This section looks at how great a concern was in each location and how various stakeholder groups proposed that their concerns be addressed satisfactorily.

4.2.1. Negative environmental impacts

After combining all the rankings for all stakeholders by concern, negative environmental impacts was the greatest combined concern in Puget Sound and Igiugig. Several stakeholders mentioned fish and

Table 4
Example ranking calculations.

	Example 1	Example 2
Step 1. Original	4th greatest benefit was "Relative Low Cost"	9th greatest concern was "Public Perception"
Step 2. Number assigned	4	9
Step 3. Number of provided concerns/benefits	10	10
Step 4. Number of provided concerns/benefits + 1	11	11
Step 5. (Number of provided concerns/benefits + 1) - (Number assigned)	7	2
Final assigned ranking	7	2

Table 3
Example interview questions.

Example Questions
If a commercial tidal project were to be developed in [Puget Sound/Igiugig], would it affect [stakeholder group] interests?
Please rank the mentioned concerns from that of greatest concern to that of least concern.
You mentioned that ____ was a concern of yours. How could your concern be addressed to your satisfaction if a commercial-scale tidal energy project were to be developed in the [Puget Sound/Igiugig]?
If your top three concerns were addressed to your satisfaction, would you be supportive of a tidal energy project?
How could the project be structured to ensure the top identified benefits?
What about [Puget Sound/Igiugig] makes it a good or bad location for a tidal energy project?

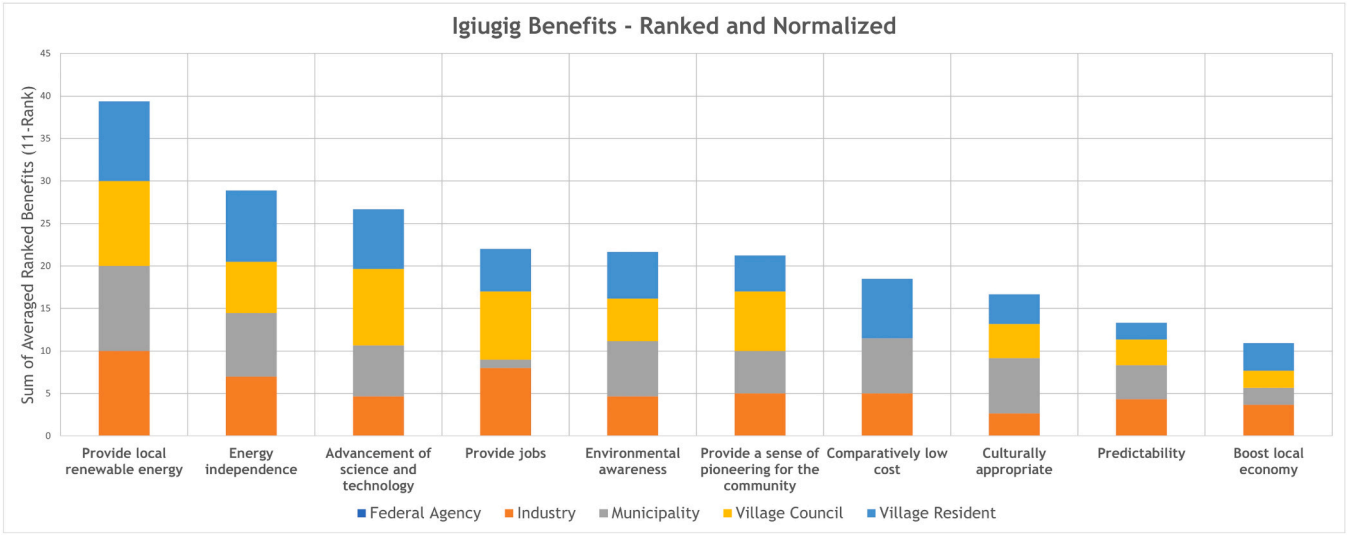

Fig. 2. Igiugig benefits.

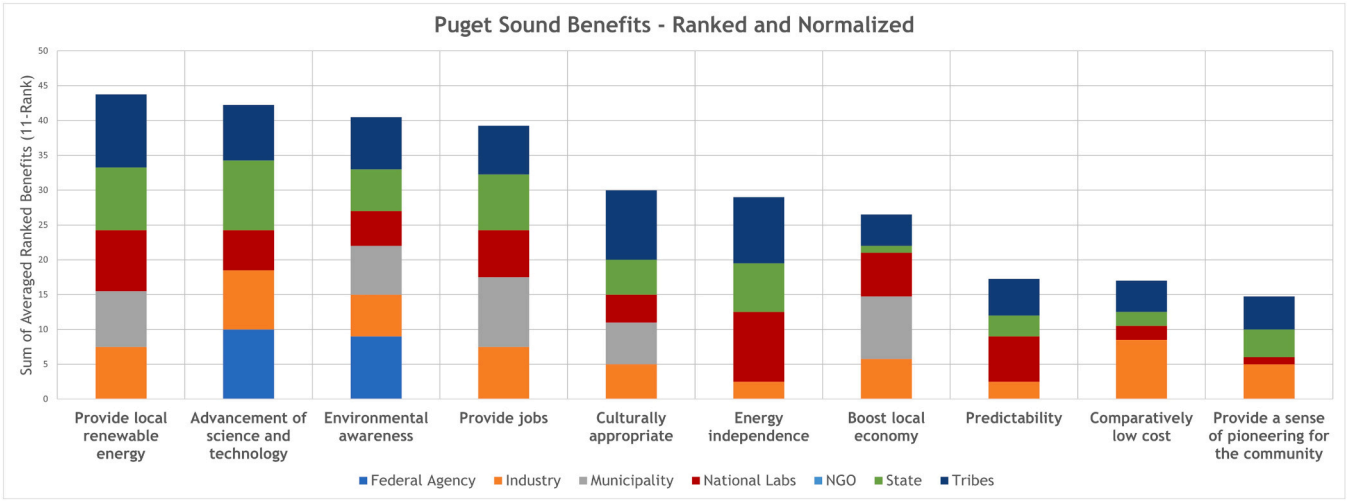

Fig. 3. Puget Sound benefits.

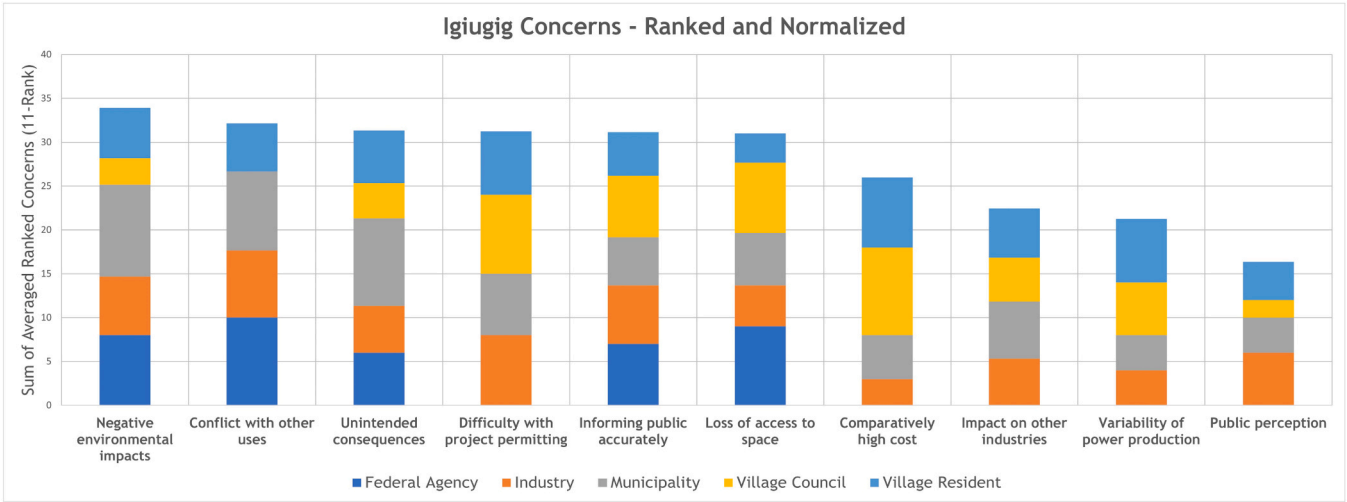

Fig. 4. Igiugig concerns.

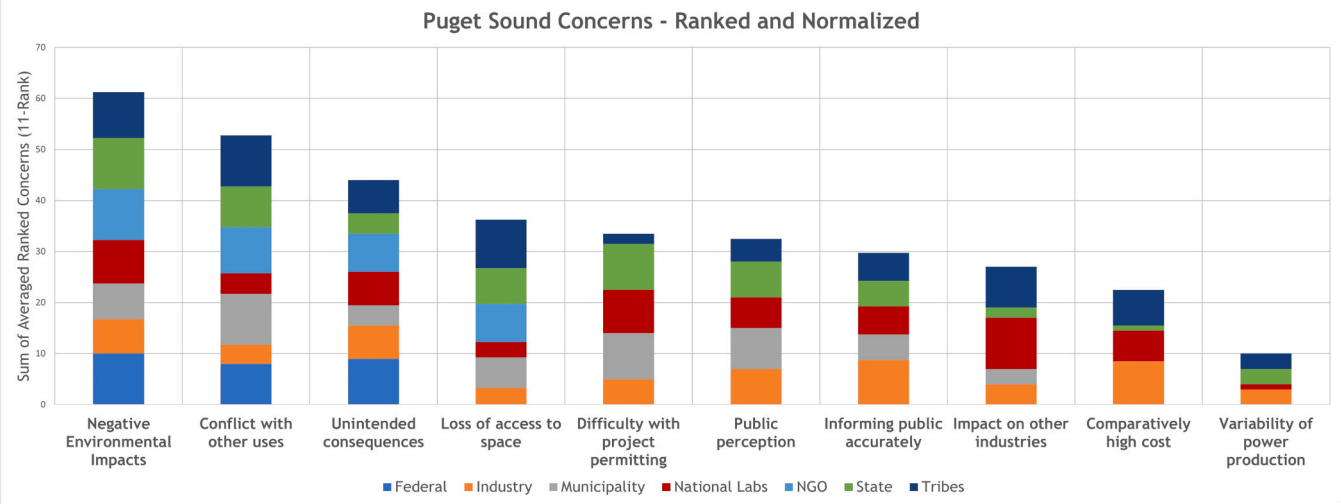

Fig. 5. Puget Sound concerns.

Table 5
Concerns and benefits added by interviewee.

Location	Concern or Benefit	Stakeholder Group	Description
Puget Sound	Benefit	Industry	Perceived benefit of contributing to a diversified energy portfolio
		Federal Agency	Being low carbon emitting
		State Agency	Finding ways to reduce environmental impacts
	Concern	Tribes	Interfering with treaty rights
		Federal Agency	Scientific uncertainty
		Industry	Ability to obtain environmental data
			Durability of the technology
Igiugig	Benefit	Village Resident	Providing professional development opportunities
			Educate the community
	Concern	Federal Agency	Insufficient study scoping
		Industry	Changing the character of the community
		Village Resident	Grid integration

mammal strikes by turbine blades as a primary concern. In particular, federal and state agencies, municipalities, NGOs, and Indian Tribes were especially concerned about negative environmental impacts. The Indian Tribes and NGOs of Puget Sound stated that they would remain opposed to in-stream tidal energy development based on negative environmental concerns even if they were addressed.

However, other stakeholders offered several ways to resolve their concerns about negative environmental impacts. Nearly all stakeholders referenced some device monitoring. Starting with a small project and slowly scaling up while monitoring the devices was seen as one path forward toward addressing this concern. Others built upon using monitoring by suggesting creating mitigation plans and adaptive management to improve the project as it is implemented. As a representative of the FERC mentioned:

> *"Well, there's a number of tools for dealing with potential environmental impacts, including - well, first of all, if you start early with moving the project slate to avoid these potential impacts. If there's a way to mitigate for them that would prevent them on-site, you mitigate for them. And then, if there's uncertainty, you can get into the adaptive management and schemes. You know, we write all sorts of conditions into the licenses that are there to protect the environment."*

While negative environmental impacts were the greatest cause of concern for all stakeholders, it is also the concern with the most research. Researchers have completed significant work evaluating various environmental concerns, including collision risks for animals, sound impact on animals, changes caused by energy removal, electromagnetic field impacts, and changes in habitats [49]. Tools such as providing adequate resources, adaptive management, and extensive stakeholder engagement have been used and suggested to address these conflicts [31,50].

4.2.2. *Conflict with other uses*

Conflict with other water uses was the second greatest concern in Puget Sound and the fourth greatest concern in Igiugig. Municipalities, NGOs, Indian Tribes, industry, and federal agencies saw this conflict as particularly concerning. Interviewees identified broad site scoping, adaptive management, and extensive, early, and often stakeholder engagement as ways to prevent and address conflicts with other area uses. Some of these approaches may cause greater conflict. For example, broad site scoping combined with early stakeholder engagement could bring additional powerful stakeholders into negotiations. Moreover, stakeholder engagement processes might not include involving stakeholders in decision-making or granting them decision-making authority. Nevertheless, each one of these approaches or a combination of these approaches could help address conflicting uses of a project area and should be considered within the specific regulatory, economic, and political climate [30, 31, 50–52].

4.2.3. *Unintended consequences*

Unintended consequences were the second greatest concern for stakeholder groups in Puget Sound and the third greatest concern among stakeholder groups in Igiugig. Federal agencies, municipalities, NGOs, and national laboratories were especially concerned about unintended consequences. For some interviewees, unintended consequences pertained to environmental consequences; for others, unintended consequences included social factors.

To address this concern, most stakeholder groups mentioned monitoring and a way to respond quickly to problems that arise with the device. One stakeholder wanted to ensure the habitat was returned to its original condition should any potentially harmful unintended consequences occur. Some stakeholders suggested doing exhaustive background research on any potential conflict that could come with installing in-stream tidal energy devices. Increased effort in predicting and preemptively mitigating adverse outcomes has long been called for but poorly implemented [53–55].

4.2.4. Loss of access to space

Loss of access to space was the fourth greatest concern in Puget Sound and the fifth greatest concern in Igiugig among stakeholder groups. Federal agencies, Indian Tribes, and NGOs were concerned about losing access to space. One Indian Tribe representative suggested making sure that devices were placed in areas that were not usual and accustomed fishing areas. In contrast, another Indian Tribe representative stated that was not possible. A federal agency representative suggested ensuring a reasonable relationship with any people who previously used the area to explain why the project is taking place, to acknowledge their concerns, and to attempt to resolve concerns to the best of the project lead's ability. Project-centric development approaches like this have raised issues of when stakeholder engagement should occur and how stakeholder issues can be resolved to their satisfaction [56].

4.2.5. Accurately informing the public

Accurately informing the public about the project was the third greatest concern in Igiugig and the fifth greatest concern in Puget Sound among stakeholder groups. Industry, federal agencies, and national labs were concerned about approaches for informing the public about projects. One industry representative suggested that the project developer be proactive in supplying prompt and correct information about the development and status of the project. Other industry representatives suggested engaging early and often with the public while acknowledging that they may not have all the answers. Another industry representative successfully held public meetings at various times and locations to give as much accurate information as possible. They stated, "I think fear about a project development like this comes from a lack of understanding."

With early and frequent engagement through public meetings, newspaper announcements, open houses, newsletters, and other actions, the public and stakeholders are provided an opportunity to gather information and comment. Nevertheless, not all stakeholders will have the same idea of what a proper level of engagement is and who should be involved. Furthermore, some stakeholders may want to be more engaged than just in public comment periods. Excluding important or powerful stakeholders can impact project development [30]. Tools and frameworks, such as Strategic Environmental Assessment (SEA), can foster appropriate levels of engagement. A SEA considers environmental, economic, and social policy consequences and allows them to be addressed at the earliest decision-making stage [57]. A SEA used in the Bay of Fundy for in-stream tidal energy development successfully engaged stakeholders from geographically isolated areas and increased stakeholder involvement. It is also vital that stakeholder engagement be formally integrated with policy implementation and regulation for tidal energy [52].

4.3. Cross-cutting themes

The text analysis identified three cross-cutting themes. The themes covered how the variance in stakeholders between the two locations drove siting outcomes, how stakeholders used well-being to support or oppose a project, and how fewer organized stakeholder groups and more uniform perspectives correlated to more successful project siting.

4.3.1. Theme 1: in an urban area, organizations had more influence over tidal project siting, while in a rural area, individual residents had more influence

Stakeholder groups in each location differed in the types of groups and the degree of support for an in-stream tidal energy project. In Puget Sound, the snowball sample included organized groups but not individual residents. In other words, when asked who else should be interviewed about this issue, prominent actors in this case study did not mention any individuals. This suggests that they did not recognize the views of individual residents as being highly important for consideration. However, in Igiugig, the snowball sample included residents because prominent actors recognized the importance of individuals and because there were fewer organized groups and, notably, no NGOs.

The prominence of stakeholder groups in the sample also appeared to align with their level of influence. In Puget Sound, the most influential groups were organized groups. For example, the NGO stakeholder groups saw no benefit in a tidal project and gave organized and influential opposition to the project. There was no organized opposition in Igiugig, and prominent village residents were most influential here.

The successful siting of an in-stream tidal energy project may hinge on the views of influential stakeholder groups. In Igiugig, all interviewees, including prominent village residents, were either supportive of a project or conditionally supportive, assuming their concerns were resolved. In Puget Sound, all but two interviewees either supported a project or could be supportive, depending on the project details. The two exceptions were from the Indian Tribes and NGO stakeholder groups. When asked hypothetically how their views on the project might change if their top concerns were addressed satisfactorily, Tribal and NGO representatives stated they would remain opposed to a commercial in-stream tidal energy project in Puget Sound.

4.3.2. Theme 2: stakeholder groups cited the well-being of their members to justify their stances on in-stream tidal energy projects

The second theme is that stakeholder groups justified their stance on in-stream tidal energy projects, whether supported or opposed, based on what strengthened members' well-being. One atypical example is an organization that views non-human species as constituents whose welfare must be protected. In this example, the opposition of NGO representatives in Puget Sound was driven by a belief that there are perpetual environmental concerns and the NGO needs to represent and steward the well-being of the voiceless (i.e., non-human species). One NGO representative stated,

> *"I have concerns about the spinning aspect and whether or not that can be physically damaging to underwater species. And then I always have the concern that whenever we humans do something in an environment, we tend to disrupt habitats and often displace critters. And so those are always going to be concerns… as far as trying to weigh the benefits of human use versus non-human use and the differences—we kind of hold the power in the voice, and they don't. So, somebody has to keep that in mind as we go forward on these projects."*

The Indian Tribes in both cases offer an interesting example of commonalities and contrasts in using well-being as a justification. Igiugig and Puget Sound both had stakeholder groups that represented the interests of indigenous people. In Puget Sound, this was composed of several Tribes across the region. In Igiugig, it was the Village (i.e., Tribal) Council. In both cases, these stakeholder groups strive to promote Tribal members' well-being and continued existence [41]. Both stakeholder groups expressed opinions about tidal energy projects near their communities grounded in the well-being of their Tribe members.

Both groups had similar values and recognized similar general benefits that tidal energy technology could offer. Both indigenous groups need to ensure that their members have access to energy, a clean environment, and employment opportunities and recognize that in-stream tidal energy can potentially supply these things. The Indian Tribes of Puget Sound and the Village Council of Igiugig both value natural resources in the area where a tidal energy project could be placed. Despite having similar interests, the Village Council in Igiugig supported a commercial in-stream tidal energy project if their concerns could be addressed. In contrast, the Indian Tribe representatives in Puget Sound were not supportive.

The Village Council in Igiugig saw a potential commercial tidal energy project as an opportunity to displace the use of diesel, provide economic opportunity, bring employment possibilities to villagers, and instill a sense of pride in the community. With fewer employment

opportunities in a remote community like Igiugig than in a more populated region like Puget Sound, it is logical that village members would more greatly value potential employment. Also, as pointed out by an interviewee, a community leader can increase community well-being by having a commercial in-stream tidal energy project that allows them to fly in less diesel for power generation and decrease fuel spillage, emissions, and noise. The Igiugig Village Council believed the benefits of a tidal energy project outweighed any perceived environmental impact risk, such as to the world's largest sockeye salmon run that passes by the village [40]. They perceived little to no environmental risk associated with the project and applied for grants to fund it. The situation in Igiugig is consistent with other studies of small, remote municipalities and their perspectives on tidal energy projects [9,33]. Interviews with community representatives from Sitka, Alaska and the San Juan Islands in Washington State reveal their support of local tidal energy projects hinged on whether the project aligned with their community values and supported better energy resource availability and benefits [33]. These findings are consistent with this paper's description of community well-being.

The Indian Tribes of Puget Sounds did not see the potential benefits of in-stream tidal energy as worth the potential risk to their fisheries and the well-being of their fisherfolk. Indian Tribes of Puget Sound saw potential conflict with their right to fish in usual and accustomed places. They were vocal protesters in Snohomish Public Utilities' attempt to install a pilot project. They sought to maintain the ability of their commercial and subsistence fisherfolk to fish without any impact from tidal energy devices. One Tribal representative extrapolated how use conflicts and well-being concerns about the pilot project would be magnified if the project led to a commercial-level tidal energy installation. The interviewee rationalized:

> *"For a utility-sized project, a couple of 500 kilowatt or 1-megawatt turbines is really meaningless to a utility. They're literally have to put hundreds of those out there to be of any real benefit to the utility. You just can't take up that much marine space without being an impact to the commercial fisherman that make their living off of it."*

With established renewable energy sources in Puget Sound, this is not an incentive for the Indian Tribes to introduce environmental impact questions into their fishery resources. One tribal representative raised the concern that there was too much uncertainty about the impact of tidal energy devices, saying:

> *"And the other problem is to just be able to monitor doesn't tell us what the impacts are, because they're working in such a harsh environment. Monitoring techniques they're using are as experimental as the project itself. Maybe even more experimental because it's just never been done before. And so, we're not even sure how good the data would be coming out of the monitoring. Somehow, we've got to be able to monitor the projects in a way that gives us good data to actually assess what the impacts are."*

The Tribal representatives believed their concerns could not be satisfactorily addressed to the extent that they would support the project. One Indian Tribe representative stated:

> *"There's really no way to mitigate that* [my concerns]. *You could potentially site it to an area that's not fished as heavily as others. But there's really no way to prevent the interference from happening."*

4.3.3. Theme 3: siting was more successful where there was a simple and uniform assemblage of stakeholders and views

The third theme is that Puget Sound had more and varying interests that made project development more complicated from a stakeholder perspective than Igiugig. Fewer and less diverse interests provided a more straightforward path for project development in Igiugig than in Puget Sound.

Puget Sound (7) had slightly more stakeholder groups than Igiugig (6), which increased the range and types of interests surrounding the tidal project. For instance, municipalities would be required by Washington's Shoreline Management Act law to become involved in permitting. Also, the tidal energy industry was interested in further studying the technology and developing local clean, renewable energy. Additionally, the resource-conscious NGOs and fishing-invested Indian Tribes bring unique interests and concerns, as previously discussed. One representative of a state agency reflected,

> *"There's a lot going on in the Sound as far as fishing and traveling and barges and, you know, you name it. So, putting something below that possibly could be hit by an anchor or what have you is a high concern. I know for us; specifically, you know [the] salmon migration corridor is very important. And that also affects orcas."*

Based on their past experiences, all the governmental organization stakeholder groups (municipalities, state agencies, and federal agencies) saw that it would be difficult to appease everyone due to the great number of interests in Puget Sound. One municipal interviewee described their framing of the complications with installing a commercial in-stream tidal energy project in Puget Sound:

> *"…the more links that you have in your chain, the more apt your chain is to fail. A strong chain is a short-chain, and when you start working in all these stakeholders, it's like herding cats. And it really only takes one to do something you didn't expect to derail your whole process. Puget Sound is a very obviously heavily utilized area, and there's a lot of stakeholders in there, and to do anything new in Puget Sound, you're going to have to get all of them in a row, or you're going to have to fight down the ones that don't agree. And there are people who are simply going to oppose because…not even because they necessarily object, or because they have certainty that this is going to damage them. They may be opposing just because you're introducing uncertainty into their business model."*

In contrast, Igiugig may be a more favorable place for project development due to widespread support and a relative lack of concerns among stakeholders. Igiugig had a less complex and more uniform constellation of stakeholders and opinions than Puget Sound. In Igiugig, all stakeholders would conditionally support a project if their concerns were addressed satisfactorily. While in Puget Sound, two stakeholder groups, including Indian Tribes, remained unsupportive even if their concerns were addressed satisfactorily. When speaking about the interests in Igiugig, one Village Council member noted that Igiugig was a "clean slate" given its lack of development. In Igiugig, physical infrastructure and long-established stakeholder interests and perspectives provided opportunities for in-stream tidal energy. With in-stream tidal energy in its early phases of development, the technology will inherently bring uncertainty along with project development. Locations with a simpler and more uniform complex of stakeholders and views make project development easier because it needs to address fewer interests [58]. Also, fewer layers between government, decision-makers, and the general public aid better stakeholder and civic engagement, allowing for collaborative approaches to tidal energy projects in remote locations [33]. So rural and remote locations, such as Igiugig, may be amenable for successfully siting commercial in-stream tidal energy projects.

5. Policy implications

The impetus for this project was, in part, a Washington State law passed in 2006 that requires large utilities to obtain 15 % of their electricity from renewable energies other than hydroelectricity, such as tidal energy, by 2020 [1]. Similarly, in 2010, Alaska set a non-binding goal to obtain 50 % of its electricity from renewable sources by 2025 [2]. In-stream tidal energy can potentially contribute to policy goals around decarbonization, especially in rural areas dependent upon diesel, like Igiugig, Alaska. Understanding how social factors influence the successful siting of tidal energy projects is relevant to helping Washington and Alaska achieve their renewable energy portfolio goals and other milestones. For example, Washington State's Energy

Independence Act and other provisions require 100 % greenhouse gas-neutral energy by 2030 and 100 % renewable or zero-emitting energy by 2045 (Wash. Rev. Code §19.285; Wash. Admin. Code §480–109; Wash. Admin. Code §194–37).

The findings of this study also pertain to national policies and recommendations. Identifying pathways for reaching large-scale commercial tidal energy implementation helps achieve the Federal Sustainability Plan (Executive Order 14057), which requires federal agencies to use 100 % carbon pollution-free electricity by 2030, among other policies. This study also helps fulfill a National Academies of Sciences, Engineering, and Medicine policy recommendation for increased research on the socio-economic aspects of clean energy [59].

6. Conclusions and generalizability

This research aimed to understand the human dimensions and social conditions that influence where pilot tidal energy projects can be successfully placed. Earlier work exploring the siting of in-stream tidal energy devices has overlooked stakeholders' perceptions [27] despite increasing concerns about the acceptance of renewable energy projects [28]. There is also a need to explore the role of the location of in-stream tidal energy projects and their relative levels of acceptance or support [29,60]. Repeated efforts to test tidal energy and other marine renewable technologies have failed due to a lack of acceptable and permitted sites, among other causes [61,62].

This original research paper presented two case studies to understand better stakeholder groups' perceived benefits and concerns about developing an in-stream tidal energy project. Both locations used similar technology but varied vastly in population size and degree of isolation from traditional municipal power sources. This paper examined how to address stakeholders' concerns satisfactorily so that pilot tidal energy projects could be placed in the water, thus further developing tidal energy toward widespread commercial implementation. This comparative case study can help further stakeholder-supported in-stream tidal energy technology implementation. Results can also help policymakers achieve carbon reduction and decarbonization goals through a nuanced understanding of new site identification and development that places human dimensions at the forefront.

This study found that there was overall more support in a smaller community isolated from municipal power sources that had a demonstrated need for energy. Across both case studies, the top perceived benefits of tidal technology were providing local renewable energy, advancing science and technology, and environmental awareness. The priority concerns were negative environmental impacts, conflicts with other uses, and unintended consequences. These benefits and concerns are consistent with those found in other studies [29,63]. These concerns can be leveraged to oppose tidal energy projects. Similarly, when seeking to promote a project, these benefits can be a basis for discussion with stakeholders to illustrate the positive outcomes of tidal energy projects for a community and the planet. For example, concerns about environmental impacts could be reframed as an opportunity to raise environmental awareness through baseline studies and monitoring in the area where a pilot study might be located. Addressing concerns and amplifying benefits could be achieved through adaptive management, strategic environmental assessment, and marine spatial planning [30,31,64,65].

Themes derived from the grounded theory analysis may help identify fertile waters for installing in-stream tidal energy projects. These themes were having stakeholders with a favorable opinion of the project compared to other locations, a strong well-being justification, and a simple and uniform stakeholder assemblage. A project may more likely succeed if it fulfills some of these themes. Project development may progress further in places where multiple stakeholder needs can be met, and many stakeholders view the project as capable of improving their well-being. So, when organizing discussions around tidal energy projects, including all stakeholders impacted by or interested in a project is vital. Stakeholders should be presented with the specific benefits that meet their needs and improve their well-being rather than the general benefits of tidal energy. Stakeholders, whether in support or opposition of a project, may have more influence on the development process if they organize into a formal group, especially in highly-populated areas. So, it is also essential to keep in mind the varying organizational power of stakeholder groups and ensure that all stakeholders who want to be heard and engaged can do so.

Further research is needed into the views of indigenous peoples on tidal energy development. Research with indigenous communities outside the United States shows a mixed response to marine renewable energy projects [16, 66–68]. Kerr et al. (2015) found that in New Zealand, Māori communities took legal action against a tidal energy project because permitting the project would give de facto property rights in conflict with their claim of customary ownership. In contrast, an indigenous group in Australia had favorable views of a proposed tidal project, was collaborating with developers, and saw potential economic benefits for the community. One crucial factor differentiating these cases may be a history of legal conflict over the recognition of and impingement of indigenous rights to natural resources and marine spaces. The findings of Kerr et al. (2015) align with our study in that the Indian Tribes around Puget Sound have a history of needing to resort to legal action to protect their customary use rights. In contrast, Iguigig, comprised of a primarily indigenous population, does not have this history of conflict and instead sees the project as a way to meet the village's critical energy needs.

Indigenous communities in Canada provide perhaps the best non-U.S. case studies for comparison. One study found that remote, indigenous communities were reluctant to accept emergent renewable energy, such as tidal, and preferred energy efficiency measures over extraction of energy resources, in general [67]. Another study of largely indigenous, remote communities in British Columbia, Canada found that they were interested in tidal energy because it would provide self-sufficiency and community autonomy [16]. The self-sufficiency, community autonomy, and the aforementioned economic benefit for the community from Kerr et al. (2015) could all be coded as examples of community well-being and are consistent with the findings of this paper. However, even when there is interest and a community well-being justification, uncertainty, financial investment, and government support can stall tidal energy projects [68].

Place attachment is another theory applied to understanding acceptance of tidal energy projects [28,32]. Place attachment explores how emotional connections and symbolic meanings of a place affect how people react to changes in a place. A positive relationship between place attachment and acceptance suggests a good fit between the meanings associated with a place and a project. This is perhaps the case in Iguigig, with perceptions that a tidal energy project would improve the community's well-being. Notably, this perception was held uniformly across indigenous and non-indigenous residents [69]. However, meanings of place are also context-dependent, which could explain why Indian tribes in Puget Sound did not accept a tidal energy project because it would negatively impact community well-being. One key consideration in the applicability of this theory is that it looks mainly at emotional and symbolic connections. Indian Tribes, in addition to these types of connections, have tangible claims to traditional land and resources that may increase the type and weight of connection to place [70].

The findings of this study should be further explored in other case studies to understand their generalizability better. The findings of this and previously published studies indicate that the differences in response between remote and urban areas are not directly due to their remoteness but rather the other characteristics that tend to occur more or less frequently in remote or urban areas. Some points to probe include the factors (including place attachment) influencing the response of indigenous people to tidal projects, how different levels of formal organization in remote communities influence their views and reactions to tidal projects, and how the opinions of remote communities with large

indigenous populations and customary rights contrast with non-indigenous remote communities.

Marine renewable energy and in-stream tidal energy technology continue to evolve. They have a role in the blue economy, and policy efforts focused on decarbonization. Human dimensions must be placed at the forefront of any conversation about new project development and pathways toward decarbonization. Unique stakeholders will emerge for each new tidal energy project location, and consideration of their opinions is necessary. As the case studies in Puget Sound and Igiugig have shown, some sites may be more prone to project success. One example is places with fewer, more uniform stakeholder groups that more efficiently provide the opportunity for the concerns of all stakeholders to be addressed. Another example is places that can adequately justify a project as promoting a community's well-being. Small, remote communities with less infrastructure and energy resources may fit this profile. This and other studies [9,17] have shown that small, remote communities may provide locations for pilot projects that can yield needed data to determine if and how to develop tidal energy devices toward full commercial implementation. However, being a small, remote community is just a large-level indicator of suitable pilot project sites; a more nuanced assessment of community views (especially indigenous groups) and economic, environmental, and technical constraints and opportunities should be conducted during any siting process [17,67].

CRediT authorship contribution statement

Beaver Ezra: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Validation, Visualization, Writing – original draft, Writing – review & editing. **Jenkins Lekelia Danielle:** Conceptualization, Funding acquisition, Methodology, Resources, Supervision, Writing – original draft, Writing – review & editing.

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Declaration of Competing Interest

None.

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Data availability

Data will be made available on request.

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