Thinking big and starting small: Identifying considerations for small-scale tidal energy in Southwest Nova Scotia

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Abstract - **Nova Scotia's marine renewable energy (MRE) sector can contribute to provincial goals for carbon neutrality. Within Nova Scotia, tidal energy has been an interest to industry stakeholders for over two decades, yet general momentum for the industry has shifted. Previous tidal energy projects and recent studies suggest a broader consideration for the role that scalable tidal energy (i.e., small-scale) development can play in the province. This research explores considerations of developing tidal energy in Southwest Nova Scotia with an emphasis on small-scale tidal devices. Using a literature review and semi-structured interviews with stakeholders from different sectors of Nova Scotia's MRE energy industry, key issues and challenges were explored. Results underline four main themes that affect industry growth potential, which include cost and financing, technology, policy, and energy distribution. The discussion highlights key insights regarding the value of small-scale technology, regulatory pathways and collaboration, and using global best practices to accelerate tidal energy industry goals in Nova Scotia.**

Keywords—**Marine renewable energy, small-scale, tiday energy.**

I. Introduction

COUNTRIES are committing to the race to net zero as the impacts of climate change are experienced worldwide. To achieve carbon neutrality by 2050, renewable electricity will play an essential role in meeting energy demands. Marine renewable energy (MRE) among other renewables like solar and wind energy are pathways toward cleaner electricity generation. Nova Scotia, Canada, is one of several regions exploring MRE and specifically tidal stream energy, given its notable tidal range in the Bay of Fundy. While significant investment in utility-scale testing has occurred in Nova Scotia, more recent testing has focused on small-scale tidal energy in Southwest Nova Scotia. While both utility-scale and small-scale tidal energy have a role in supporting Nova Scotia's energy mix, this exploratory study focused on opportunities for small-scale tidal ventures in the province. This study assessed the landscape of Nova Scotia's current tidal energy sector to understand the factors influencing the viability of small-scale tidal energy ventures in Southwest Nova Scotia. A particular emphasis was placed on exploring the barriers to industry growth of small-scale tidal energy development.

The specific interest in small-scale tidal energy stems from the technology's adaptable and scalable qualities that can support residential communities based on their required energy needs [1]. Particularly rural, or remote coastal communities have a significant incentive because of the potential to achieve energy security, even if off-grid [2]. Identifying methods for off-grid communities to eliminate reliance on diesel and other fossil-fuel-reliant energy is a critical step towards net zero. Meanwhile, for on-grid communities, a diverse energy mix supports local resilience which is important for environmentally vulnerable coastal locations. Additionally, small-scale tidal energy provides the opportunity to exploit more tidal locations because the required offshore environment for these ventures is more forgiving [3]. For example, small-scale developments can be placed in tidal zones with smaller depth ranges or slower currents that are easier to access for installation and maintenance, increasing overall efficiency [4]. Currently, literature that defines the capacity of small-scale tidal energy is disputed but suggests that small-scale technologies range from projects with 5 Kilowatt (kW) capacities to 500kW [1] [5]. The challenge with defining the capacity of a small-scale or community-scale project is that they are largely dependent on the size

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of the grid that the project is connected to, meaning the scale definition of a venture is often contingent on the grid size. This paper explores opportunities and barriers to implementing small-scale tidal stream energy projects in Southwest Nova Scotia.

Fig. 1. Current FORCE tidal energy test site and small-scale tidal test sites for consideration in southwest Nova Scotia (made in Google Maps).

Nova Scotia currently trends towards utility-scale projects, supported by the 2009 establishment of Fundy Ocean Research Centre for Energy (FORCE) in the Minas Passage of the Bay of Fundy. This Canadian non-profit uses its offshore facility west of Parrsboro, Nova Scotia to provide developers and researchers a location to test and demonstrate tidal stream development [6]. While FORCE has earned a global reputation for its robust testing site in the Minas Passage with current speeds up to 5 m/s and depths of 40-50 metres – best suited for utility-scale projects - a report by Nova Scotia's Offshore Energy Research Association (OERA) suggested a global absence of testing sites for small-scale MRE developments [7]. A small-scale test centre would have intermediate depths (10-30 m) and intermediate current speeds (2-4 m/s) [7] [8]. The report suggests that the conditions in tidal areas of Southwest Nova Scotia including Grand Passage and Petit Passage (Figure 1) meet the environmental requirements to fulfill a small-scale testing centre [7].

Southwest Nova Scotia, in particular Grand Passage and Petit Passage, were until very recently the focus of extensive small-scale tidal energy exploration and testing. Since 2019, Sustainable Marine Energy's (SME) inshore 280 kilowatts four-turbine floating tidal system called Plat-I underwent testing in Grand Passage [9]. Federal and other government funding of up to $28.5 million supported this small-scale tidal research and testing [10]. Nova Scotia is well suited for tidal energy development given the emergence of FORCE in the Minas Passage, Sustainable Marine Energy's successful testing of the Plat-I in Grand Passage, and extensive research and environmental assessment at both locations. SME, however, withdrew its application for further testing in Nova Scotia at the FORCE site and Grand Passage sites after investing $30 million over several years. In its departure, SME highlighted key challenges inhibiting development especially the regulatory regime from the Department of Fisheries and Oceans (DFO) [11]. The company's Canadian subsidiary has since been placed into voluntary bankruptcy [12]. As tidal energy producers experience major barriers and setbacks to providing Nova Scotia with clean tidal stream energy, a deeper assessment of small-scale tidal energy's current state will help provide clarity on future opportunities and expectations for this industry.

II. Methods

Twelve MRE industry stakeholders were consulted in semi-structured interviews. Each participant was identified from one of five stakeholder categories: Developer (3), Government Figure (2), Energy/Utility Provider (1), Academic Expert (3), and MRE Industry (3). Those categorized under Tidal Developer were actively involved with developing small-scale tidal energy projects in Southwest Nova Scotia or elsewhere in the world. The sample size is relatively small, due in part, to the size and scale of the MRE industry in Nova Scotia.

In this research, participants categorized under Government Figure represented either municipal or provincial representatives who engage with tidal energy projects and marine renewable energy development. Participants categorized as Utility Provider were involved in provincial energy distribution and the utility grid system. Those categorized as Academic Expert studied and published research regarding tidal energy. Finally, participants labelled as MRE Industry Member work for and represent marine renewable energy organizations. This involves both non-profit and for-profit organizations. It is important to note the scope and limitations of this study. While efforts were made to gather diverse perspectives, certain stakeholders such as federal government representatives and Indigenous stakeholders were not included in the interview process. Future research may explore these perspectives for a more comprehensive understanding. The research highlights key thematic areas that emerged from interviews with the existing study sample.

III. Considerations for Industry Commercialization

Discussions with stakeholders and a review of key literature highlights four thematic areas that impact tidal energy development in Nova Scotia. While the thematic areas were not informed by discussions with the DFO and Indigenous rights holders, insight into tidal energy development and in particular challenges in establishing small-scale tidal energy in Nova Scotia emerged for discussion.

A. Policy

Policymakers can influence the success of a renewable industry by allocating resources, establishing policies, and regulating industries. The province of Nova Scotia established renewable energy goals in 2009 including

critical pieces of legislation such as the Renewable Energy Strategy in 2010 [13] and the Marine Renewable Energy Act in 2015 [14]. Effective MRE policy and a roadmap are critical for growing an industry. A roadmap for industry growth, for example, can articulate the scope and size of an emergent industry like MRE.

Several stakeholders believed tidal energy development in Nova Scotia was meant to serve rural, coastal, and somewhat isolated communities supporting electrification of local grids while others interviewed believed Nova Scotia should become a flagship and export products and industrial expertise to the rest of the world.

An academic expert describes that the location of FORCE provides insight into intentions for Nova Scotia's tidal energy industry, "this is not about generating electricity for Nova Scotia. This is about building an industry that will export their expertise to the world and export their manufacturing to the world... [policymakers] didn't think 'let's generate an efficient turbine that can generate electricity at a reasonable cost for Brier Island'. They thought about a global scale… and that meant the turbines had to be big. They had to go into the fastest flow, and they had to generate the most electricity".

Meanwhile, municipal stakeholders believed that tidal energy could play a role, in part, in electrifying their community and look to the provincial government to enable a net zero economy that includes tidal energy in its energy portfolio. A government official explains, "We need more support on the infrastructure side." This representative described his municipality's need for financial support to convert existing infrastructure towards a "net zero economy". While it is important to be flexible to industry progress and changes, it is equally important for stakeholders to have a clear understanding of where tidal energy will add value to the economy. This way if the industry goal is to become a flagship and export products, manufacturing services, and expertise, municipal and provincial stakeholders can allocate resources towards the broader supply chain or alternative renewables to provide local energy. Alternatively, if the desired objective is to subsidize Nova Scotia electricity using tidal energy, more infrastructural resources and collaboration with energy providers can be established to support this outcome. Regardless, as an acting authority and broker between stakeholders, policymakers have an opportunity to establish the direction of the market and implement resources that will efficiently support the industry's strategic priorities. An MRE Industry stakeholder explains the need for "a regulatory pathway. That is completely missing and that's really a barrier to investment and a challenge for stakeholders to wrap their minds around how this is all going to work."

To provide policies that clarify the industry's future and incentivize collaboration, regulatory reform is required. Nova Scotia is currently experiencing significant industry innovation without the concurrent policy innovation to support net zero benchmarks. According to interviewees, it's one of the biggest missing pieces to support industry growth. According to an MRE Industry member, one of the foremost needs to jumpstart tidal energy in Nova Scotia is updated regulation and support. They explain, "There is no national or even provincial strategy anymore for tidal. There was a strategy that came out in 2012, but we're 10 years out from that. I really think having some kind of refresh with a vision for the sector with some goals and objectives would be immensely helpful... the challenge that the industry is having right now is the regulatory pathway and predictability." More recently, a federal task force has been created to address this ongoing challenge [15].

Addressing the regulatory environment is critical especially aligning provincial and federal policy that supports the growth of the blue economy including MRE. Currently, MRE developers in Nova Scotia experience policy fragmentation and challenges especially in addressing the regulatory issues associated with the Fisheries Act. This is a challenge for provincial representatives who often mediate challenges between federal regulators and local developers. As a government figure explains, "How do we create a regulatory environment where we get [developers] a line of sight, but if something happens, we can pull them back'?" Policy must innovate alongside Nova Scotia's tidal energy sector for it to become feasible in the long term. This requires clarified market priorities, widespread collaboration, and comprehensive legislation. Legislation can also clarify the mechanisms for validating and financing innovative renewable energy development.

B. Cost and financing

Strategies for financing renewable energy projects range between private investments, community trusts, and government subsidies. With goals for net zero by 2050, investors are identifying ways to profit from the renewable energy transition. Established renewables such as wind and solar have benefitted from a Levelized Cost of Energy (LCOE) but unfortunately, the start-up cost of tidal energy technology in Nova Scotia is exorbitant due to the numerous production steps required to achieve a market-ready product [16]. To finance tidal energy, acquiring upfront capital from investors is necessary [16]. Industry representatives highlight the challenges of financing tidal energy projects due to the high-risk nature of novel renewable technology and external factors that affect the stability of the industry. De-risking investments can be accomplished by creating affordable and reliable technology, or through government interventions by creating regulation that supports a stable and long-term market [17].

From a technology perspective, investors look for a higher Technology Readiness Level (TRL) which indicates how close the product is to market readiness signaling a lower investment risk profile. An academic expert explains a higher TRL demonstrates that technology is "close to

being commercially viable and it gives more credibility not only to the developer and the manufacturer but the investors. They start to identify the financial risks and start to lower their own risk profile" Unfortunately, to achieve a higher TRL, more research, development, and prototyping is needed, requiring significant upfront capital. Small-scale tidal energy could be identified as one opportunity to de-risk investments because its smaller size naturally accrues less upfront cost and risk. An academic MRE researcher discussed the value of using a smaller, scalable approach rather than creating utility-size turbines to capture peak energy levels. They suggest that developers are "better off designing something smaller, which is capturing 80% of the energy available than having to put a lot of extra money to just capture that extra bit of energy". This implies that small-scale ventures would have the opportunity to develop into utility-scale projects once technological de-risking has been validated through early testing.

The other way to finance development and de-risk investments is by creating regulatory interventions to reduce market uncertainties [18]. Governments have some control over the long-term stability of renewable investments. For example, the province of Nova Scotia created aggressive Feed-in Tariff (FIT) and Community Feed-In Tariff (COMFIT) programs to incentivize small-scale renewable development by providing a rate of $0.652/kWh for tidal energy [19]. Much of this funding went towards tidal-specific projects, some of which are still actively developing in Southwest Nova Scotia, although COMFIT has since been cancelled [20]. With this program, some industry-wide experts felt that the subsidy created an award for energy generation once the technology was actively operating, rather than supporting the upfront development needs of tidal energy production. A tidal energy developer explains, "this program was set up like a carrot at the end of the stick that we're chasing, trying to get to 65.2 [cents per kilowatt hour]. But to get that rate, it had to remain 51% community controlled, [meaning] that that amount of money has to be raised within the community which is really hard". To improve the effectiveness of government incentives, the province could implement regulatory structures that support the early TRL development of projects instead of back-end investments once projects are generating electricity. Unfortunately, costs associated with MRE development are significant and Nova Scotia like other provinces, must consider these costs among other investment priorities.

C. Technology

Technological innovation is the driving force behind the tidal energy sector. The province of Nova Scotia, with the support of Natural Resources Canada, invested in technological development through the creation of FORCE. Private tidal energy companies like Nova Innovation -and until recently, Sustainable Marine Energy- operate in Southwest Nova Scotia to test and prove their tidal devices and arrays. Between funding, test centres, and research institutions, Nova Scotia is well-positioned to become a globally recognized flagship for tidal energy.

The province's prioritization of utility-scale development with the creation of FORCE is viewed by some MRE stakeholders as limiting and instead advocate for investment in small-scale tidal energy. An academic expert explains, "The principle behind FORCE was a good idea, but it's the wrong location. It's the wrong conditions. It's way too high energy and environment to test things… there are a lot more places on Earth, where the average flow speed is 1.5 meters per second and 2.5 meters per second… There's enough energy in the world's tides to meet all the OECD [Organization for Economic Co-operation and Development] energy requirements if we could harness all of them. The portion of that energy that is within High Flow sites, is less than 10%. So, focusing on the Minas Passage, the Mull of Kintyre in Scotland, and the bays around South Korea, makes sense on a mega-scale project, but that's not going to be financially viable, not for [approx.] 30 years. Small-scale needs to happen first". A small-scale testing site in a location that mimics common tidal conditions around the globe would support successful scalable production where environmental and technical thresholds can be more easily identified. Additionally, a small-scale teste centre might support and catalyze information sharing among developers that might accelerate tidal energy development in Nova Scotia.

The goal of tidal energy is to eventually generate energy efficiently, which requires research and development along with multiple iterations of a device's blueprint. Individual developers are limited by the amount of testing they are permitted to do which some experts suggest could be enhanced through collaborative testing. By providing tidal energy developers with an opportunity to lower research and development costs through common testing equipment, facilities, and monitoring with the expectation to share testing data publicly, the industry becomes simultaneously more collaborative and competitive. In this way, developers can learn from each other and apply these findings to expedite development and troubleshoot technological issues quicker, with the expectation that individual developers and the industry will benefit from more efficient and effective turbines. Local developers acknowledge the mutual benefits of having nearby competitors to precipitate a stronger and more credible market for tidal energy. One tidal developer describes the need for credible competition to create a strong tidal energy market. With a novel technology that must be proven to investors and publicly accepted to integrate into the market, collaboration provides more visibility and credibility for individual projects while simultaneously accelerating them. As representatives of public interests, policymakers have an opportunity to facilitate and promote collaboration that allows for increased data and testing.

Policymakers can play an essential role in this process by supporting and supervising a small-scale test centre to ensure that information sharing is executed in a fair and well-regulated manner. Another essential area of collaboration is between tidal energy stakeholders and utility providers.

D. Energy distribution

Energy distribution is a critical stage in the energy lifecycle, bringing converted electricity to customers. For the clean energy transition, utilities are challenged to accommodate new forms of energy such as tidal into their renewable energy mix. Nova Scotia's grid is controlled by the utility company Nova Scotia Power. Once a provincially owned public company, Nova Scotia Power was privatized in 1992 [21]. It is currently wholly owned by the parent company Emera and regulated by the Nova Scotia Utility and Review Board (UARB). According to several industry stakeholders, the loss of Nova Scotia Power as a crown corporation impacted the province's ability to create an effective and diverse renewable energy sector. For example, as a for-profit company with shareholders, Nova Scotia Power is required to pay dividends which are ultimately fronted by provincial customers. An academic expert explains, "Nova Scotia Power is mandated by law to provide a 7%-year return to shareholders. Do you know what stock returns normally are? About 1% to 2%. It's a 7% annual return to shareholders for the essential system that all of Nova Scotia relies on and this is in the legislation mandated by law. So, when Nova Scotia Power is protecting their interests, they're protecting shareholder profits". While providing a competitive rate of return is a common practice among North American utilities, from a renewable energy developer perspective, this rate of return eliminates the amount of capital that can be invested into renewable energy. To maintain fiscal health, Nova Scotia Power like other for-profit corporations, must weigh the benefits and risks when investing in small-scale renewable energy projects like tidal energy. Consequently, large-scale renewable projects are a much higher priority for the utility. A utility provider explains, "As a public utility Nova Scotia Power is obligated to provide its customers with the best and lowest cost energy option available (unless otherwise mandated by public policy). Investing in small-scale tidal energy projects that are expensive and higher risk is unlikely unless it is incentivized and encouraged through federal and provincial channels." This model requires a wrap-around policy approach, where legislation is required to incentivize the utility to invest in renewables and ensure approval from the UARB. Political intervention, however, might deter future and ongoing private investment in renewables like tidal energy.

Energy market specifications including the number of customers, consumption rates, and purchasing power, affect the supply and demand of electricity in Nova Scotia. Demand for energy and the procedure for supplying electricity to customers affects the feasibility of tidal energy in the province. With no competing utility companies, energy developers must sell to Nova Scotia Power permitting the utility to buy electricity at wholesale rates to integrate it into the entire grid. While a centralized system has benefits, this model prevents electricity from going directly into the communities that generate it and presents challenges in local initiatives that seek to lower the cost of power [22]. Additionally, because power is an essential service, it has inelastic demand, which gives Nova Scotia Power the ability to control prices with minimal consequences to its market size. Currently, Nova Scotia has some of the highest rates of energy poverty in the country [23], forcing hesitancy within the provincial government to add more costs to the local ratepayer from high-risk renewable investments such as tidal energy [24]. Despite that, energy poverty causes more reactive public spending in the social welfare and public health sector [23], which are resources that could alternatively be spent in the clean energy sector, if Nova Scotians had access to more affordable energy rates. Renewables are a necessary next step toward carbon neutrality, so how can Nova Scotia make that transition without jeopardizing the average Nova Scotian's livelihood? Many industry experts interviewed believe the answer to this important issue is small-scale.

Creating smaller distribution storage networks where communities are in proximity to the source of energy conversion could support autonomous community renewable energy goals [22]. If smaller, remote communities had the opportunity to generate electricity in their community and use it locally rather than sending it to centralized network, rural Nova Scotian communities would experience energy resilience. A tidal energy developer explains how this would look different for each unique community, "Community-Scale; That's another way to define it. It does mean that 'small-scale' will be bigger in areas that have more people. That's a beautiful solution. So, it essentially means that the power will be used locally primarily." With more autonomy over their power, communities would be incentivized to capitalize on their unique natural resources for energy, which would encourage many coastal communities to identify opportunities to incorporate tidal energy or other clean sources that are unique to their geographic location.

Current infrastructure in Nova Scotia has been mainly developed around fossil fuels. Unfortunately, a singular type of renewable (i.e., solar or wind) will not be able to replace fossil fuel energy alone. This means the grid must evolve to accommodate a diverse energy mix. An MRE figure explains this industry concern, "electricity infrastructure will be a challenge, particularly when we're bringing on all these variable resources and then the need to combine with energy storage". Finding affordable methods to store the power tidal energy creates is necessary for it to be an effective renewable.

Additionally, Nova Scotia's current infrastructure applies limits to how much energy can be integrated into the grid, because of minimum annual load. A tidal energy developer explains, "Right now, with Nova Scotia Power, you're not allowed to exceed what's called the minimum annual load, which is the minimum amount of power that the community uses. So, the smallest amount of power that the community uses on an annual basis becomes the maximum amount of power that your project is allowed to generate".

The current infrastructure does not allow for communities to be independently powered by variable sources of energy at the risk of damaging the grid by overloading substations. To accommodate tidal energy, storage systems that are easily dispatchable and controlled need to be integrated into the grid infrastructure. This is an enormous expense, especially once more types of variable energies are brought into the mix and the energy load increases. Infrastructure in the Nova Scotian communities where tidal energy would best fit are often minimally equipped to accommodate new renewable energy. An academic in Nova Scotia explains how the current grid infrastructure in optimal tidal locations in Southwest Nova Scotia could not accommodate a large tidal industry, "they basically have a single line going down Digby Neck and it's not a lot of power. It's built to supply the people who are there. If you wanted to put in a new industry… you could not do that right now, it couldn't handle the [electricity] load". For tidal energy to become an effective renewable in Nova Scotia, infrastructural development must happen concurrently. Because of this challenge, industry experts believe that small-scale tidal energy could play an immediate role in helping scale-up the industry despite the current infrastructural deficits. If the province pursued community-scale electrification, the localized energy source would alleviate transmission burdens and line loss from the extreme distance electricity travels to Southwest Nova Scotia. A government figure explains, "We have a 69-kilovolt line in the valley which is the most inferior line in the province and so what that means is when they generate electricity from Point Aconi or Point Tupper, it's got to travel a long way to get to the further east end of Digby County. And so [small-scale] it's an opportunity to ease the burden on the transmission grid. Even though it's small in nature, it's only like 420 or 720 kilowatts, the SME project would still ease some of the burden on transmission for Nova Scotia Power."

This type of integration could benefit Nova Scotia Power by introducing local energy and reducing the distance electrons need to travel through transmission lines. It would also demonstrate the feasibility of a local market for small-scale tidal energy in Nova Scotia. Despite that, the current grid would need to undergo major improvements, according to a tidal energy developer, "we need smarter distributed grids….or grids that can be an island. So, what you would do in that circumstance is you would say 'We won't supply to the transmission, but we will supply to the community, to the islands.' And so that gives them better security supply more reliability and their energy independence". By using an energy mix that includes community-scale tidal energy along with localized smart grid infrastructure and storage, communities can procure clean and reliable energy.

IV. Discussion

Interviews with select MRE stakeholders coupled with a review of key MRE literature highlight current barriers that hinder tidal energy industry growth. In this assessment of barriers to small-scale tidal energy development, three strategic insights emerged.

1) Small-scale technology

A reoccurring consideration emerging from the research was the importance of advancing a tidal energy industry test centre in Southwest Nova Scotia through small-scale and scalable technology. Participants noted that historically Nova Scotia has developed MRE policy and infrastructure to support a utility-scale industry, leading to higher-risk investment profiles for potential funders, lower technology readiness levels due to the provincial test site's vigorous tidal conditions, and overly narrowed target markets. Communities that would most benefit from tidal –like the municipalities of Southwest Nova Scotia– exist in very close proximity to high-flow tidal sites where tidal stream energy device operations have the potential for high economic impact and relatively low impact on the environment. Alternatively, if the goal for tidal energy in Nova Scotia is to become an export industry, most of the global markets have environments that reflect small-scale tidal conditions (2-4 m/s currents) [7].

By taking an adaptive approach as suggested in the Tidal Energy: Strategic Environmental Assessment (SEA) Update for the Bay of Fundy [25], scaling technology using incremental developments, the tidal sector can streamline technology upgrades while meeting environmental monitoring assessment requirements. If developers start with utility-scale developments in extreme tidal environments and experience technological failures or assess environmental harm, it is more challenging to identify technical capacity and threshold for environmental impact. Moreover, there is increased data available globally for projects that fall under the small-scale parameters which can be used to support Nova Scotia's small-scale tidal sector as it grows. This can be accomplished using publicly available data for environmental monitoring or through data sharing programs for environmental monitoring between jurisdictions to avoid compromising intellectual property. Once small-scale tidal and its associated infrastructure has been rigorously tested and validated in the province, utility-scale tidal then becomes more achievable.

2) Regulatory roadmap

For small-scale technology to become a priority within the industry, an updated regulatory roadmap for tidal energy is required. In this context, a regulatory roadmap would outline a proposal for updated tidal energy strategies and amend or develop new legislation. A regulatory pathway would also identify intentional markets for tidal energy and leverage small-scale technology benefits. According to industry experts, policymakers need to adjust the regulatory supports in place for the tidal industry to develop. Notably, rather than leveraging policies such as feed-in tariffs, Nova Scotia might focus on financial incentives that support scalable testing and development of projects. Current utility constraints create challenges for developers to feed into the grid, so by funding upfront development that helps de-risk investment and raise TRLs to prompt alternative financial opportunities, more progress can occur. Industry stakeholders underscored the need for updated and comprehensive acts that support tidal energy. In particular, the Marine Renewable Energy Act [14] could be amended with an updated vision for the tidal sector. Additionally, relevant legislation such as the Fisheries Act [26] could be adjusted to include considerations for alternative blue economy industries like marine renewable energy. This would allow developers to overcome policy constraints that stall business and device development. The Tidal Task Force on Sustainable Tidal Energy Development addressed these concerns, in part, by suggesting in their final report that the Fisheries Act authorization process may become more flexible. This includes recommendations of a *staged approach* for deployments with requirements for environmental monitoring. Addressing additional recommendations by the Tidal Task Force on Sustainable Tidal Energy, the Government of Canada released (June, 2024) a report *Blue Economy: Targeted Regulatory Review* that specifically addresses marine energy and environmental protection.

Nova Scotia might also consider more regulation to incentivize small-scale development in tidal energy. In the province, energy poverty and rate hikes are disincentivizing a rapid renewable transition. In 2022, the Public Utilities Act was amended to cap rate hikes at 1.8 percent over two years under Bill 212 [27]. Yet, in February 2023, the Nova Scotia Utility and Review Board ratified a rate hike of 14% by 2025 with average increase in rates for 2023 and 2024 of 6.9% [28][29]. This rate increase exacerbates current energy poverty levels in the province and likely impact ongoing and new investment in MRE and other renewables.

Increased MRE stakeholder and rightsholder collaboration would accelerate the development of a regulatory roadmap. MRE industry collaboration would support small-scale tidal energy in Southwest Nova Scotia by mapping key regulatory policies and processes that would include, for example, environmental monitoring and ways and means of addressing grid capacity and infrastructure restrictions.

3) Using global best practices

While Nova Scotia has unique social, economic, and environmental attributes that could leverage the province and country as a flagship for tidal energy, it is important for industry actors to engage in global best practices for small-scale tidal energy development. Interview participants suggest that Scotland has developed critical practices to consider integrating. The European Marine Energy Centre (EMEC) scale testing and demonstration facilities have allowed for a wider range of scalable arrays to be tested, promoting a supply chain that caters to multiple stages of development and grid integration [30]. Scotland has also seen community trusts create monetary opportunities from local developers, promoting more energy resilience in their home community [31]. Meanwhile, research participants point out how grid operators in New Zealand [32] have developed a network that allows small-scale developers to sell onto and buy off the grid, promoting more industry competition and energy diversity. Places like the United States are also looking at how tidal applications can power other blue economy industries, incentivising industry collaboration [33].

The literature review identified global best practices that support scalable tidal energy development. For example, the Netherlands uses advanced water management practices [34] to study the effects of scalable tidal energy development to determine the environmental threshold for the number of turbines that can be installed. Meanwhile, Korea has invested in a small-scale test centre through the Korea Institute of Ocean Science and Technology (KIOST) [35]. Considerations for the value of small-scale energy exist in literature and global initiatives, and Nova Scotia can capitalize on this international market through supportive scalable infrastructure and investments.

V. Propelling Tidal Forward: Recommendations for Small-Scale Tidal Industry Development

Key recommendations based on the literature and data from the interviews can support small-scale tidal energy development in Nova Scotia. Additionally, the creation of the Task Force on Sustainable Tidal Energy Development [15] is working to address regulatory and policy challenges addressed in the research.

1) Invest in a small-scale tidal test centre in Southwest Nova Scotia's Grand Passage or Petit Passage.

Prioritising scalable tidal energy is critical to mitigating current developmental barriers. To ensure this is an industry-wide priority, investing in infrastructure that supports scalable tidal projects is crucial. Multiple ways exist for the Province of Nova Scotia to encourage growth

in small-scale. Like EMEC's multi-site test centre, Nova Scotia can invest in a small-scale test centre in Southwest Nova Scotia, ideally in Grand Passage or Petit Passage. A test centre could be stand-alone or work in partnership with FORCE. Investment in a test centre can be de-risked and incentivized by a clear regulatory road map that addresses key challenges in Nova Scotia tidal energy development especially regarding environmental monitoring. The Task Force on Sustainable Tidal Energy Development will address the regulatory challenges that might support a small-scale test centre.

2) Identify political incentives for the utility to integrate small-scale renewable energy

Upgrades to and greater capacity of infrastructure to accommodate small-scale projects like tidal is critical to ensure provincial energy security and resilience. This requires incentives for utility companies like Nova Scotia Power to take on small-scale projects and invest in supportive infrastructure such as smart grids and storage units for variable energy sources. This type of incentivization must balance the integration of small-scale renewables without further financial exposure to ratepayers. The utility's priority is providing the lowest cost of energy to ratepayers, which emphasizes the development of large-scale renewables and the ongoing use of fossil fuels for dispatchable energy. Potential political incentives include requiring the UARB to evaluate the hidden social costs of using fossil fuels (i.e., measuring climate change related healthcare costs, costs of storms and power outages in communities, etc.) when making decisions on General Rate Applications (GRA). Alternatively, policy incentives through a GRA trigger could help encourage small-scale development. This would require the utility to make specific financial investments in energy storage developments to support small-scale renewable ventures when requesting an annual rate increase above 5%, ensuring a diversified renewable energy mix that will support local endeavours for community resilience. These are potential facets to politically incentivise small-scale development through utility governance, but there are boundless alternative policy options. Through industry collaboration and the use of other global best practices, finding the most fitting policy incentives for the province is possible.

VI. Conclusion

With such a unique natural resource in the province's backyard, tidal energy can become a significant industry in Nova Scotia. For the sector to become successful, current support mechanisms and expectations must also prioritize small-scale tidal energy development. To achieve this, the province should realign priorities to support scalable technology, revise regulatory pathways and potential applications, develop collaboration channels, and apply global best practices. This requires an extensive revision of current regulatory and policy practices in the Nova Scotia MRE sector to support the long-term prosperity of this relatively untapped energy source.

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