Obstacles in the Path to New Clean Technologies: An Examination of Challenges for In-stream Tidal Energy Development in Canada's Bay of Fundy

Craig Chandler[1]

1. Mersey Consulting Ltd., Halifax, Canada

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I. Introduction

THE Bay of Fundy, located between the Canadian Provinces of Nova Scotia and New Brunswick, is home to the highest tides in the world. This predictable motion of billions of tonnes of water on each tidal cycle creates fast-flowing tidal currents at many locations in the Bay of Fundy, presenting at these locations the potential to generate significant amounts of clean, renewable energy from the natural flow of the open water [1].

In-stream tidal energy technologies, also referred to as tidal in-stream energy converters, are intended to generate electricity from tidal currents. While successful projects have taken place in Europe and Canada, the technology remains pre-commercial and has yet to be widely adopted [2].

In-stream tidal energy has a unique place in the global clean technology toolbox. While it has the potential to provide utility scale energy to electrical grids around the world, its potential application is limited to those areas with high tidal current flows and sufficiently deep water. Globally, such a resource is often located away from populated areas and therefore from a source of demand for the generated electricity [3].

However, the predictability of tides translates into a predictability for tidal energy, giving it a unique advantage over conventional renewables such as wind and solar that are only predictable over short timeframes. Similarly, the ability to convert tidal current energy to electricity provides an advantage for coastal and island communities that have tidal current resources, and where the deployment of other renewable energy sources is not practical [3].

Over the past two decades there has been a renewed interest in developing technology capable of extracting energy from tidal currents, with a number of jurisdictions around the world creating policies designed to encourage development. These policies often have motivations such as the stimulation of local economic activity, the creation of export opportunities and the generation of renewable energy within the jurisdiction [1][4].

This research paper examines the case of Nova Scotia, Canada, with a focus on project timelines and accomplishments in the context of policy development and implementation. In particular, the paper examines the progress and outcomes of the companies and projects that the policies have attracted and attempts to make meaningful observations regarding proponent attributes.

II. Methods

The investigations draw on published materials including legislation, corporate information, and academic papers relevant to the Nova Scotia situation, as well as the author's experience working in the in-stream tidal energy industry. Information derived from the author's involvement in the industry excludes confidential information, but rather consists of general observations related to the practical implementation of policy and legislation, and the general issues facing the development of in-stream tidal energy projects in the Bay of Fundy.

From the above sources, relevant regulations and policies established since 2009 are examined, challenges and opportunities associated with tidal energy development in Nova Scotia are discussed, specific obstacles are identified, and observations regarding success or failure of projects are made.

Attention is given to the issue of potential environmental effects caused by in-stream tidal energy devices in the context of regulatory frameworks and related requirements. Public investment in research is discussed in relation to the knowledge gained through these activities and resulting changes in relevant regulatory frameworks through the same timeframe.

III. Results

The primary motivations for Nova Scotia to create a conducive environment for development of an in-stream tidal energy sector were to generate renewable electricity that could be used to reduce the province's reliance on fossil fuels, and to build an industry around that resource that could export its products and expertise globally. Concurrent with the early stages of Nova Scotia's initiative, efforts were underway in the United Kingdom to stimulate technology development and export growth through the wave and tidal energy sector [4].

The development and testing of novel marine renewable energy (MRE) devices encompasses many challenges, including those technical, financial, environmental, and regulatory [5]. To ease these challenges, the Nova Scotia government enabled the formation of the Fundy Ocean Research Center for Energy (FORCE) in 2009 following a Strategic Environmental Assessment (SEA). This non-profit organization was tasked with the creation of an in-stream tidal energy demonstration site in the Minas Passage of the Bay of Fundy, complete with subsea transmission cables for grid connection. FORCE was funded by the governments of Canada and Nova Scotia, industrial benefits funds from the oil and gas industry, and fees and contributions from FORCE's membership, which is comprised of tidal energy project developers [4].

FORCE was originally envisioned to be a location where project developers could demonstrate that their pre-commercial device could generate electricity in the extreme tidal flows of the Minas Passage before going on to develop commercial projects elsewhere in the Bay of Fundy or around the world [1].

Between 2008 and 2020, 8 companies have at different times held test sites ("berths") at the FORCE demonstration site. In 2008, Minas Pulp & Power (with technology partner Marine Current Turbines), Alstom (with technology partner Clean Current) and Nova Scotia Power (with technology partner OpenHydro) were the original 3 berth holders. In 2011, Atlantis Resources was selected for a fourth berth [6]. Fig. 1 shows a timeline of key events from the early years of Nova Scotia's tidal industry development initiatives.

For the purposes of this paper, a "project" is defined by the issuance of a regulatory tool granting permissions for a project to proceed under specific terms and conditions. At various times and under various conditions these have been referred to as Project Agreements, Licences or Permits, but for simplicity all are referred to herein as a "permit".

Following the withdrawal of Nova Scotia Power/OpenHydro and Alstom between 2010 and 2014, the two vacated berths were awarded to Black Rock Tidal Power and OpenHydro in March 2014 through a Request for Proposal (RFP) process. A Feed-in Tarriff (FIT) was established in 2014, and a fifth berth was created for DP Energy in 2015 [7]. Atlantis subsequently conveyed its berth to DP Energy, giving DP Energy a second berth.

In 2018, OpenHydro's insolvency led to the relinquishment of its berth. In 2020, Big Moon Power was awarded this berth through a competitive process [8].

In 2018 the government of Nova Scotia introduced a permit program under the Marine Renewable-electricity Act that allowed companies to apply to develop and operate projects anywhere in the Bay of Fundy. The program had a total capacity cap of 10 MW and between 2018 and 2020, five companies were approved for projects under the program [9].

Fig. 2 shows the approximate timelines for all 14 permits that have been issued since the beginning of the provinces tidal industry development program in 2008.

It is noted that in some cases, permits were transferred to other entities, and in other cases different technologies were substituted by the proponent. These conditions do not affect the analyses because in the cases where either of these conditions occurred, no technology deployments have taken place to date.

A. Regulatory Requirements for Projects

Projects also require additional regulatory consents that can vary depending on the project size, technology and location. In general, the following regulatory approvals are required:

- Project permit from Government of Nova Scotia (as described above)
- Approval from Transport Canada
- Fisheries Act authorization from Fisheries and Oceans Canada (DFO).

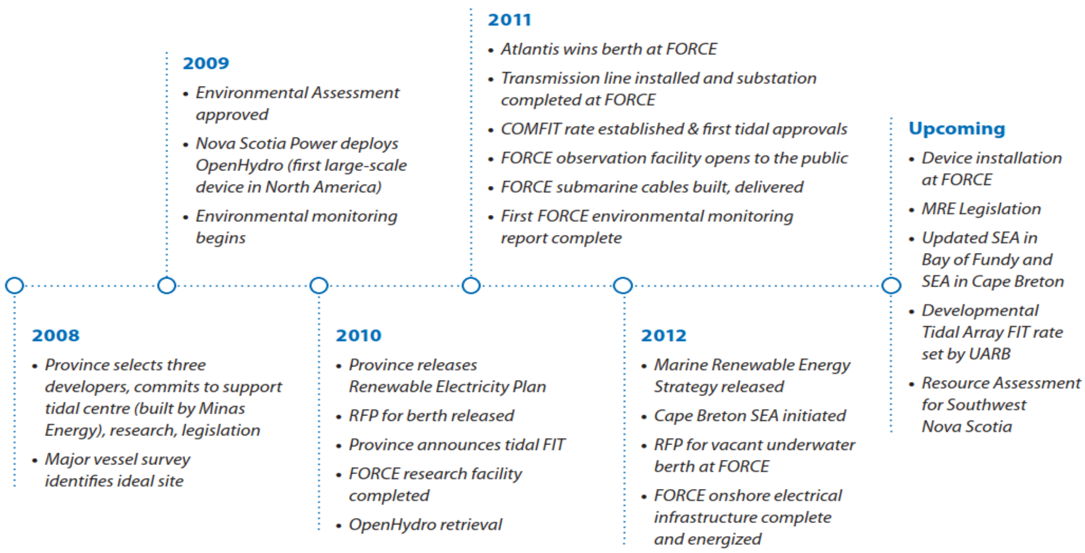

Fig. 1. Timeline of activity in early years of Nova Scotia's tidal energy sector [6].

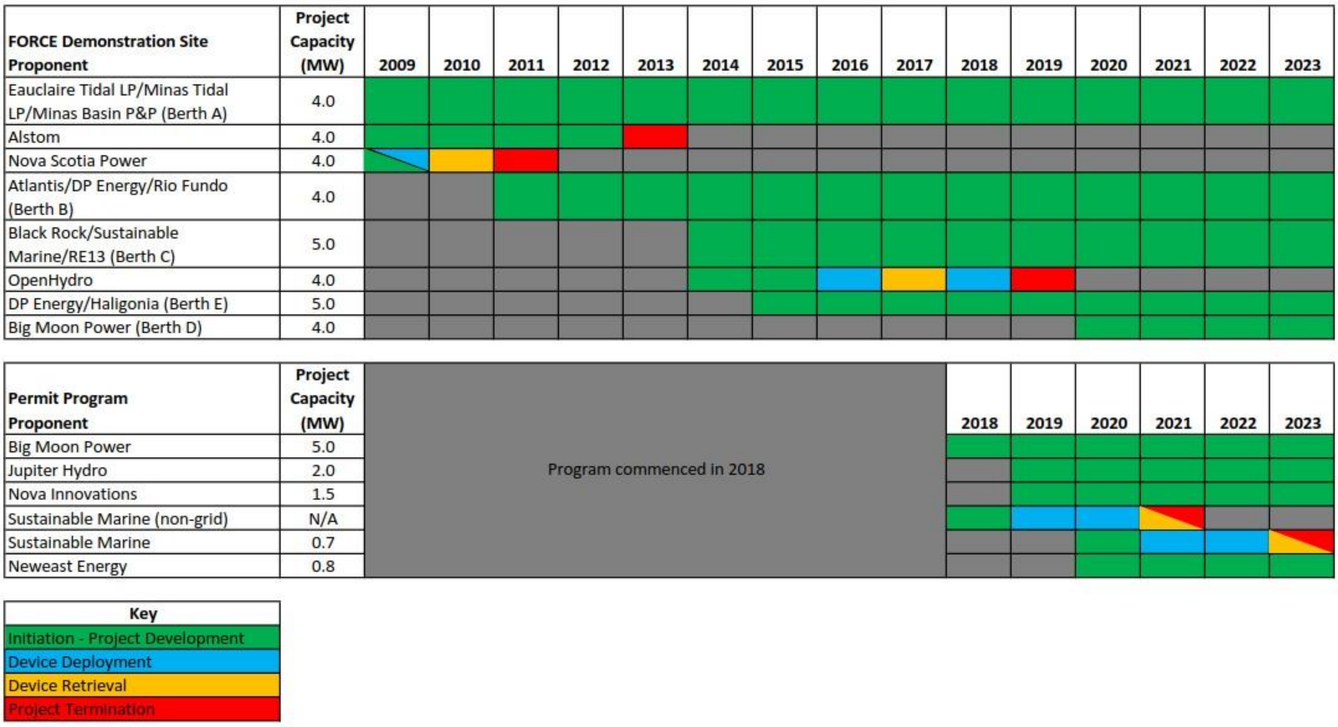

Fig. 2. Approximate project timelines [1][4][5][6][7][8][9][10][11]

The FORCE Demonstration site, with a combined permitted capacity of 22 MW, has an additional environmental permit from the Government of Nova Scotia relating to a Nova Scotia regulatory requirement for an environmental assessment to be conducted for tidal energy projects with a capacity of over 2 MW [12]. None of the individual projects discussed in this paper required a separate environmental assessment: those at the FORCE site operate under FORCE's environmental assessment approval, and projects outside of the FORCE site do not exceed a capacity of 2 MW [7][9].

The navigation permit from the federal transportation regulator, Transport Canada, tends to be a straightforward process and to the author's knowledge has not caused regulatory challenges for any of the projects discussed in this paper.

The Fisheries Act authorization requirement is essentially the environmental permit for an in-stream tidal energy project in the Bay of Fundy. Projects are regulated under the general provisions of the act which are oriented towards traditional marine construction projects. Some proponents feel that the lack of specific policy for in-stream tidal energy projects has led to an overly conservative interpretation of the act, inconsistent application of the act, and an elevated regulatory risk for in-stream tidal energy projects [11]. Whatever the case, meeting Fisheries Act requirements has proven to be a major project challenge for some projects (typically axial flow turbines) while others were not required to obtain permits (typically cross-flow turbines) [11][13].

B. *Public Funding*

Public funding for in-stream tidal energy projects in the Bay of Fundy has taken 3 forms. The first is subsidized infrastructure, such as that associated with the partially pre-permitted FORCE site that is equipped with subsea cables connected to the Nova Scotia electrical grid [1][4][7]. The second is research conducted by academic institutions and private companies, which has primarily focused on increasing understanding of marine life in the Minas Passage where the FORCE site is located, and understanding potential interactions between marine life and tidal energy devices [14]. While the environmental research programs have for the most part been successful in their general goals, there is no clear evidence that the knowledge gained through these activities has had a significant impact on DFO's approach to regulating the sector.

The third a source of public funding for in-stream tidal energy projects has been direct funding to project proponents by Natural Resources Canada (NRCan) through various programs that support the development of new renewable energy technologies. These have included CAD$4M to Nova Innovation, CAD$28.5M to Sustainable Marine Energy (Canada) Ltd., and CAD$29.75M to DP Energy affiliates. Funds are distributed on a reimbursement basis, therefore proponents can also only access the funds once work has been completed. In applying for these funds, proponents were required to meet various requirements that included demonstration of sufficient technical, financial, and organizational capabilities [14][15][16].

C. *Project Failure Modes*

The intent of this paper is to use publicly available information and the author's general experience with marine technology development projects to perform an analysis of in-stream tidal energy projects that have been proposed for construction in the Bay of Fundy over the past 15 years. Given that none of those projects are currently operating (July 2023), a high-level examination of the apparent reasons for the lack of success is worthwhile, even if that analysis is partially based on subjective criteria.

For many people, the projects that come to mind are those that either ended in device failure or with the failure of the proponent company. In a different context these projects are the successes from the 14 different permits/projects that have been proposed over the past 15 years. The original and ongoing intent of Nova Scotia's policy is to foster both a Nova Scotia tidal industry and the development of new clean energy technologies. The testing of new technologies in their intended deployment environment is essential to the development of those technologies. Inherent in such testing, particularly in a violent marine environment, is the high probability of the failure of some component of that technology. Through such testing comes learning and progress.

D. Failure Mode Analysis

The reasons for a lack of deployment or "failure to launch", aside from those projects where the proponent acquired a permit within the past few years, can be complex and a detailed external assessment of root causes, even with input from those directly involved with projects, is unlikely to accurately reflect the situation. To accomplish a meaningful, if subjective, analysis of the relative success of the 14 in-stream tidal energy projects that have received permits over the past 15 years, the following criteria were evaluated:

1. **Number of years that the proponent has held the permit.** This objective criterion establishes the length of time that the proponent has had to progress their projects.
2. **Whether the project failed to launch.** This objective criterion provides a basis for a subjective assessment of whether the proponent had the capacity and motivation to progress the project. In the current evaluation, a project was deemed to have failed to launch if the following subjective but indicative sub-criteria, devised by the author applying general industry experience, were met: a) the proponent held the permit for 5 years or more, or the project permit was terminated, and b) the proponent did not deploy the approved technology at the project site.
3. **Whether the proponent was at any time actively fabricating a full-scale version of the approved device for the project, installing an approved technology at the project site or operating an approved technology at the project site.** This objective criterion provides a basis for assessing whether the proponent advanced their project design, project financing and other aspects of the project sufficiently to take on the higher levels of commitment required for the construction phase of the project. Alternatively, this criterion could indicate the degree to which the proponent was motivated to progress the project.
4. **Whether the proponent successfully operated the approved technology at the project site**, including the demonstrable operation of the device in accordance with approved parameters. This objective criterion provides a basis for assessing, in the case of proponents that constructed their projects, whether the proponent successfully completed the construction phase and had the sufficient technical and financial resources to successfully enter the operational phase.
5. **Whether the proponent is currently operating an approved technology at the project site.** This objective criterion provides a basis for assessing a proponent's technical, financial, and organizational ability to maintain project operation.
6. **Year of deployment** (if deployment occurred). This objective criterion provides a basis for a subjective assessment of the proponents' engagement in the industry, both with respect to their chronological entry into the Nova Scotia industry and elapsed time between permit acquisition and device deployment.

Additional information was compiled for each project to allow correlation of characteristics of each project and project proponent with that project's ranking through the analyses described above. These criteria included:

- whether company was pre-commercial
- whether company was a technology developer
- generating capacity per device
- parent company size
- parent company head office location
- previous deployment experience of the company

Sources included [1][6][7][8][9][10][11][13][17][18][19][20].

E. Summary of Preliminary Findings

A preliminary analysis of results yielded the following:

- Five full-scale devices have been deployed in the Bay of Fundy to date.
- None of the five devices deployed were Canadian technologies.
- No devices are currently operating in the Bay of Fundy.
- Only two projects are currently active, with some or all fabrication work completed.
- Only one of the top five most successful projects involved a Canadian proponent.
- Four of the five most successful projects were led by proponents whose parent company or major investor was a medium or large company.

- Four of the five most successful projects were led by pre-commercial entities that were also developers of the project technology.
- The four least successful projects were led by proponents that were not pre-commercial entities or technology developers.
- Four of the five most successful projects involve devices with a rated capacity of 1 MW or less.
- Four of the five most successful projects involve technologies with significant previous deployment experience.
- The technologies associated with the five least successful projects tended to have a relatively low amount of deployment experience. The exceptions are technologies proposed by proponents that are not technology developers (i.e., the proponents have proposed to purchase existing technology that has been deployed elsewhere).

The preceding observations are based on the subjective analysis of available information. Conclusions or projections concerning the relative likelihood of success of a given project, proponent or technology cannot be drawn from this information as there are many factors that contribute to success, failure, or a lack of progress for any given project.

Additionally, in-stream tidal energy projects in the Bay of Fundy have not seen enough success to provide an adequate basis for broad conclusions regarding the factors that contribute to success.

Ongoing research will augment this study by examining the specific factors affecting the exit or lack of progress of specific proponents. These results will be presented in the final paper.

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