Marine Renewable Energy in Canada: A Century of Consideration and Challenges

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I must go down to the seas again, for the call of the running tide
Is a wild call and a clear call that may not be denied
JOHN MAASEFIELD, Sea Fever

Introduction

There should be little doubt that the world needs to diminish its dependence upon fossil fuels for electricity generation. Marine renewable energy (MRE), in the forms of offshore wind, tidal, wave, or ocean thermal energy, remains the largest under-exploited energy source, with the potential to supply more than the total electricity demand in the world. It is estimated that the global wave energy resource alone is about 32,000 terawatt hours (TWh) per year, compared with the global electricity supply of ~24,000 TWh per year in 2014.¹ Global potential for tidal power could be up to 1,000 TWh per year.² The various MRE technologies differ significantly in their readiness for large-scale exploitation. The most mature technology is that of offshore wind generation, which has evolved from extensive experience on land. The least mature is wave energy generation, numerous devices for which are still in early developmental stages. Mechanical energy from tides is a centuries-old technology based upon impoundment of tidal waters, and barrage-based installations (the tidal range approach) for electricity generation has been considered in Canada (the Bay of Fundy) and Europe for more than 100 years. One turbine installed in a dam at

¹ World Energy Council, World Energy Resources, Marine Energy (London: World Energy Council, 2016). 1 terawatt hour (TWh) = 1,000 megawatt hours (MWh).
² M. Hoogwijk and W. Crijns-Graus, Global Potential of Renewable Energy Resources: A Literature Assessment (Renewable Energy Policy Network, 2008).
Annapolis Royal, Nova Scotia, has been in operation since 1985. New technologies designed to convert the energy of flowing water (i.e., tidal stream), rather than impounded water, are rapidly developing and offer significantly fewer environmental effects than those based on barrages or tidal lagoons.

In Canada, significant opportunities exist for MRE on all three coasts. Of the options, tidal stream energy is particularly attractive because its timing and scale are eminently predictable, and its development can be incremental, which is an important consideration when the environmental effects are uncertain. Large-scale tidal stream devices generating one to two megawatts of electricity offer considerable potential, especially for isolated communities on all three coasts where tidal flows exceed one to two meters per second. In addition, arrays of such large-scale devices could make valuable contributions to established electricity grids, especially where, as in the Bay of Fundy, a large tidal resource exists in a region of strong energy demand.

Issues Affecting Progress

Technological Issues

During the past decade, tidal stream energy conversion technologies have advanced from conceptual designs to the testing of full-scale devices. While this progress in engineering is encouraging, challenges remain. Unlike wind power, the industry is nascent and has yet to converge on a single design type. The most mature designs tend to utilize lift-based axial- or cross-flow turbines, with a wide variety of installation configurations (e.g., bottom-mounted or surface-piercing, gravity-based or pile-driven). To date, tidal stream device deployments worldwide have been short-term (mostly less than one year), and have generally consisted of only one device, the largest thus far consisting of four. Deploying and operating large-scale arrays is therefore some time away.

Field testing to date has indicated that a major technological challenge to reaching commercial-scale arrays is in designing devices that can survive the extremely harsh environment in which they must operate. The fast currents that characterize tidal energy sites generate huge forces on any stationary structure. Furthermore, tidal energy sites tend to be extremely turbulent as water is pushed at high speeds through complex channels and around headlands. Turbines built to operate in bi-directional flow are subjected to forces from many directions, leading to more rapid turbine failure. In areas

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3 “Failed tidal turbine explained at symposium,” CBC News, 8 July 2011, http://www.cbc.ca/news/canada/nova-scotia/failed-tidal-turbine-explained-at-symposium-1.1075510.
with sediment-laden water, devices may be ‘sand-blasted’ on each tide, which hastens corrosion of essential components. Failures of seals and connectors are a common problem in any marine undertaking, and the lifespan of undersea components can be shortened by constant motion due to currents and by fluctuating environmental conditions. In addition, device access is generally limited to periods of low flow between each tide, and calm weather conditions. Depending on device design, regular maintenance may require costly retrieval of the entire device.

Other technological obstacles are related to the supporting infrastructure rather than the devices themselves. Many of the areas identified for instream tidal energy development are remote, and manufacturing facilities or vessels large enough to transport and deploy full-scale turbines may not be available locally. Furthermore, electrical grids in remote areas generally must be redesigned and strengthened to deliver tidal energy to where it is needed. Continued development and testing is expected to overcome many of these challenges in the near future.

**Environmental Issues**

Development of any marine industry poses potential risk to the environment, and tidal energy is no exception. Previous environmental studies at established tidal power stations, particularly the Annapolis Tidal Generating Station in Nova Scotia, identified numerous environmental issues, many of which are attributable to the dam rather than the turbine. Consequently, stand-alone tidal stream technologies are now being demonstrated in Nova Scotia and elsewhere.

To address environmental effects in Nova Scotia’s high flow passages, numerical models describing the energy resource, flows of water, mixing, etc., on both large and small scales have been developed, allowing more precise prediction of the physical effects of extracting energy from the tides. Video and sonar technologies have been used to examine benthic life in the passages, and field investigations have looked at changes in sediments and salt marshes that might arise from changes to tidal flows. Priority environmental issues relate to the behavior of fish, birds, and marine mammals in the vicinity of working turbines, the possible mortality and deterrent effects that an array of turbines might have on the normal migratory behavior of these animals, and the population level consequences of these.

The biggest challenges faced in sensing both fish and marine mammals at the Fundy Ocean Research Center for Energy (FORCE) turbine test site in Minas Passage in the Bay of Fundy have been high flow-induced effects on noise and sensor mooring stability. These and other challenges experienced
in conducting effects monitoring have created much uncertainty for regulators concerned with the potential effects of tidal turbine installations on critical habitat and endangered and commercial species. Assessing the likelihood of marine animals encountering tidal devices and colliding with their moving parts has been attempted through acoustic detection of tagged fish (four species of concern), passive acoustic detection of marine mammals, and various sonar technologies to monitor the seasonal presence, distribution, and movements of fish. Coupling of sensor technologies has recently aided understanding of the avoidance or evasive behavior of marine animals in close proximity to turbines, but the collection of sufficient data to address regulator concerns, even at the turbine demonstration stage (single device or small array), is expensive and the data sets are enormous. Automated detection software for many acoustic sensing technologies are in need of further development and will require validation via field sampling programs.

Research on environmental effects of tidal energy development will be incomplete for some time yet. Ongoing efforts are required to enable assessment of risk and, where identified, development of risk mitigation strategies. Priority activities need to include advancements in sensing technologies and software, high performance sensor moorings, field validation, and environmental monitoring guidelines for tidal energy developers and regulators.

**Socio-economic Issues**

Even if the current testing programs confirm that tidal stream technologies are technologically feasible and environmentally acceptable, there remain significant challenges toward their widespread development and application. First and foremost of these is financing. MRE electricity is initially more expensive than that from fossil fuels, and, given the uncertainty in the performance and maintenance costs of tidal stream devices, private sector funds have not been very forthcoming. In fact, at the present time, risk assessments tend to encourage companies to delay investment, leaving the costs of research and demonstration to be met primarily from public funds. The more rapid development of MRE in Europe than in Canada is reflective of the willingness and capacity of European countries to address the challenges of climate change, and greater public investments have been made. Potential conflicts with existing uses and users of tidal coastal waters remains a challenge. In 2008 and 2014, Nova Scotia

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4 S. MacDougall, “The value of delay in tidal energy development,” *Energy Policy* 87 (2015): 438–446.
conducted two strategic environmental assessments⁵ and a policy review⁶ in relation to tidal power development in the Bay of Fundy that included extensive public and interest group consultations. These concluded that the public was cautiously optimistic that tidal stream energy could materially assist the province to reduce its use of coal and bring economic and social benefits to coastal communities. Subsequently, however, some coastal resource user groups have resisted even the testing of large tidal stream devices, arguing that turbines will significantly affect their use of space, kill marine life, and place endangered species at risk. In spite of the considerable research carried out since 2009 to assess the real risk to marine organisms, misinformation is rife, and the reluctance of developers to release information promptly allows such misinformation to prevail regardless of its lack of basis in fact.

An additional cause of declining public confidence lies in the slow progress of testing. After eight years, two turbines only have been installed at the Minas Passage test site: one in 2009 that failed after three weeks, and a second in 2016 that was removed after six months of operation. These short deployments result from the extremely harsh conditions encountered within the Minas Passage; an important consequence, however, is that answers to some of the critical environmental questions cannot be obtained without prolonged monitoring with turbines operating on site.

In contrast to some negative views repeated in the media, there remains optimism in government and the scientific sector that environmentally acceptable, cost-effective means of capturing energy from Canada’s tidal waters can be found. If so, its predictability and potential use to support remote coastal communities that are currently dependent upon diesel fuel (e.g., in the Arctic) could benefit these communities and contribute to Canada’s national plan to deal with greenhouse gas emissions. In addition, the expertise developed in environmental assessment, monitoring, and deployment is a marketable asset as other countries around the globe attempt to capture their tidal energy resources. Already, the challenging environmental conditions of high flow tidal waters has stimulated major innovations and improvements in monitoring technologies by Canadian companies that have substantial markets worldwide.

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⁵ Offshore Energy Environmental Research Association (OEER), Fundy Tidal Energy Strategic Environmental Assessment Final Report (Halifax: OEER, April 2008); Jacques Whitford, Background Report for the Fundy Tidal Energy Strategic Environmental Assessment (Halifax: Jacques Whitford, January 2008); AECOM Canada Ltd., Tidal Energy: Strategic Environmental Assessment, Update for the Bay of Fundy (Halifax: AECOM Canada Ltd., 2014).

⁶ R.O. Fournier, Marine Renewable Energy Legislation: A Consultative Process, Report to the Nova Scotia Government (Halifax, 2011).
The Role of Governance

The faltering progress of device development, combined with continuing questions of feasibility, true operating costs and benefits, and environmental effects, leave tidal power electricity generation in an uncertain position in Canada. In some ways, this is a repetition of past experience: electricity from the tides of Fundy has been considered numerous times over the last 106 years. Part of the cause lies in the extremely dynamic conditions at the site(s) chosen for testing. A second factor is the limited development of marine spatial planning in Nova Scotia’s coastal waters, where important fisheries, aquaculture, transportation, recreational, and tourism-related activities already exist. Addition of renewable energy developments inevitably raises issues of conflict, particularly with fisheries in the Bay of Fundy.

Two things are clearly required: 1) an effective marine spatial plan for each location suitable for marine renewable energy development; and 2) a long-term vision for marine renewable energy at all levels of government. This vision needs to encourage systematic and achievable developments in science and engineering that will assist coastal communities and the nation to minimize dependence on fossil fuels.