2018 STATE OF THE SECTOR REPORT

marine renewables canada

MARINE RENEWABLE ENERGY IN CANADA

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JUNE 2018

Contents

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Contents

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Executive Summary

Marine renewable energy (MRE) from waves, tides and river currents has been harnessed for centuries – powering mills, transporting nutrient-rich sediment, moving vessels, supporting marine life migration – but only over the past few decades has it become more of a focus for its vast untapped reserve of power. Seventy-one per cent of the Earth's surface is composed of moving water, all containing energy that can be converted to electricity.

Theoretical estimates for global MRE potential indicate resources exceeding 100,000 terawatt hours (TWh) of electricity, equal to the power needs of over 8 billion Canadian households[1] – more than the current power demands of the entire planet.

Canada continues to deepen its exploration of MRE as a potential solution to clean energy, greenhouse gas emission (GHG) reduction, and economic growth targets.

Given the country's natural resource assets as well as existing expertise in the marine sector, ocean waves, wind, tides, salinity, temperature differences and river currents can all contribute to Canada's clean energy bottom line. Canada has an estimated 35,700 megawatts (MW) of tidal energy potential, enough clean power to displace over 113 million tonnes of CO2 (equal to removing over 24 million cars off the road). Adding wave and river, the potential climbs to 340 gigawatts, enough energy to power every home in Canada five times over. The country's offshore wind energy potential is still being mapped, but projected to be larger still.

The opportunity includes both large-scale transmission projects and small, distributed community generation. Over 300 companies have already found work in the Bay of Fundy's emerging tidal stream sector. A total of 251 remote Canadian communities rely on their own fossil fuel plants; 176 of them are fueled by imported diesel. Canada is now demonstrating river current technologies that offer remote communities a solution that can be cost competitive, avoid emissions, and create jobs.

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[1]Electricity Measurement and Conversion: Electrical capacity is denoted in watts (W), kilowatts (kW), megawatts (MW), and terawatts (TW), and electricity usage is most often measured in kilowatt hours (kWh), megawatt hours (MWh), and terawatt hours (TWh). The watt (W) is a measure of electric power. Power is the rate of doing work or producing or expending energy. A thousand watts of power produced or used for one hour equals one kilowatt hour (kWh). On average, a typical household in Canada uses about 1,000 kWh per month resulting in annual household consumption of 12,000 kWh of electricity per year. (1 kWh = 0.001 MWh; 1,000,000 MWh = 1 TWh)

Activity

MRE projects in Canada range in technology and scope, including:

- **The Fundy Ocean Research Center for Energy (FORCE)**, which has built onshore and offshore electrical facilities and subsea sensor platforms to support technology demonstration and research. FORCE is host to five tidal stream developers (including domestic and international partners), totaling 22MW of capacity under Nova Scotia's feed-in tariff (FIT) system:
    - Cape Sharp Tidal, a joint venture between Emera Inc. and OpenHydro
    - Atlantis Operations Canada Limited (joint partnership between Atlantis Resources Ltd. And Rio Fundo Ltd. (a DP Energy affiliate)
    - Black Rock Tidal Power (BRTP) (parent company SCHOTTEL)
    - Halagonia Tidal Energy, an affiliate of Ireland-based developer, DP Energy
    - Minas Tidal Limited Partnership (partnership between Minas Energy, Tribute Resources, and Tocardo)

  In 2016, Cape Sharp Tidal deployed its first turbine at FORCE, which was the first grid-connected tidal stream turbine in Canada, marking a huge milestone in the industry. Cape Sharp is now planning for a second deployment in summer 2018; subsequent deployments by other developers at the FORCE site are expected in 2019 and 2020.

- **Small-scale and off-grid, remote community projects** are being developed in Manitoba and British Columbia. A number of Canadian developers including Mavi Innovations, New Energy Corporation, Instream Energy Systems, Jupiter Hydro, Yourbrook Energy Systems, and Waterwall Turbine have carried out successful demonstration and deployments.

- **The Canadian Hydrokinetic Turbine Test Centre (CHTTC)**, a collaboration between Manitoba Hydro and the University of Manitoba and located on the Winnipeg River, has become the global hub for river current energy technology testing. CHTTC provides instruments to perform studies on the impacts of flows on turbines and the impact of turbines on the environment and has completed critical studies on winter operations, array optimization, and integration of river current energy in remote communities to displace diesel generation. Since 2013, CHTTC has carried out over fifteen deployments with device developers.

- **The West Coast Wave Initiative (WCWI)**, based out of the Institute of Integrated Energy Systems (IESViC) at the University of Victoria, has completed high resolution wave resource assessments, detailed wave energy converter technology simulations and both short-term and long-term electrical system integration studies. Through WCWI's work, there is now enough detailed information on the height, frequency and direction of its coastal waves to start developing and testing energy converters in the ocean.

- **In Newfoundland, the College of the North Atlantic's (CNA) Wave Environment Research Centre (WERC)** has six fully permitted mooring sites available and has been working with wave energy developers to demonstrate various technologies.

Policy

Nationally, MRE growth is supported through an increasing policy focus on clean energy adoption. The federal, provincial, and territorial governments established the *Pan-Canadian Framework for Clean Growth and Climate Change in 2016*, which addresses key areas for meeting emission reduction targets, driving innovation, and advance climate change adaptation. The Framework is an umbrella to many of the programs and policies that support renewable energy development in Canada, and therefore, it plays a key role in the MRE sector. Stemming from the Framework, the federal government has launched three key programs totaling $575 million - all of which are relevant to MRE projects. Additionally, the federal government recently tabled legislation to create a framework for offshore renewable energy development.

Provincial MRE policy initiatives have advanced on both the east and west coast. The Government of Nova Scotia continues to implement its *Marine Renewable Energy Strategy*, focused on industrial development. In early 2018, *Nova Scotia's Marine Renewable-energy Act* was proclaimed, creating a licensing system for MRE projects and as well as a permitting program for the demonstration of tidal stream energy technology in additional areas of the Bay of Fundy. In spring 2018, the Province granted Big Moon Power two permits totaling 5 MW; by 2020, the permitting program is expected to create up to 10 MW of new tidal energy development in Nova Scotia.

British Columbia is spearheading an effort to establish a roadmap for MRE development. The Ministry of Energy & Mines and Petroleum Resources has worked with the University of Victoria's WCWI to develop a roadmap that would support a vision for a scientific and technology hub dedicated to advance the level of understanding, innovation, and business of marine-to-wire renewable energy. Release of the roadmap is forthcoming and will assist in growing the sector in western Canada.

Growth

The MRE sector hovers at the edge of commercialization. While the market doubled from 2016 to 2017 – thanks in part to the successful deployment the first multiple device arrays – technology designs have not yet converged, and developers and investors face vastly differing market and policy conditions depending on where projects are sited. Steps to secure Canada's competitive advantage in MRE sector development include:

- Creating a market path to commercialization (including mechanisms like FITs and PPAs)
- Approaching innovation strategically (including funding, policy support, and other means for collaboration and risk sharing via federal and provincial programs specific to MRE)
- Increasing knowledge and building confidence (including technology demonstration and ongoing monitoring)
- Ensuring responsible and sustainable development (including meaningful engagement with Indigenous communities and other traditional resource users)
- Identifying and supporting competitive advantages for supply chain growth (including detailed analysis of sector strengths, export value and potential revenue)

Countries across the world – including Canada, Chile, China, Denmark, France, Indonesia, Ireland, Norway, Portugal, Spain, Sweden, the Republic of Korea, the UK, the US and others – have begun to foster activity in the MRE sector. Developers will follow the most inviting conditions; while some regions will await a more certain commercial market, other regions will create it.


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1.0 Introduction

Marine renewable energy (MRE) is largely an untapped resource, with the potential to provide new energy, economic, and environmental benefits for Canada. Harnessing the power of the tides, waves, offshore wind and rivers can provide a clean, sustainable electricity source, contribute to action on climate change, spur industrial growth by capitalizing on skills and assets already present in other sectors, and create a game-changing opportunity for remote communities – many of which continue to rely on imported diesel to generate electricity.

The MRE sector continues to show promise as a contributor to our low-carbon economy, with the global installed capacity doubling from 2016 to 2017. And through this period of growth, Canada has emerged as a global leader. Over the past decade, the Canadian MRE sector has established supportive policy, made key investments in technology demonstration infrastructure and technical and environmental research, and spurred activity by connecting a steadily growing supply chain of Canadian businesses. As a result, Canada is often recognized for its strategic approach, building the experience, knowledge, and innovation necessary to advance the Canadian sector.

Challenges remain: the sector has not yet converged on a single design solution for energy capture or mooring, and working with new technologies in marine environments is still pioneering work. Canada's MRE sector faces many of the same challenges the global sector faces: lack of market, challenges attracting finance, knowledge and technology gaps, and depending on location, insufficient infrastructure. Tackling these challenges requires sustained effort in key areas, including:

- establishing policies to support long-term activity
- accelerating innovation
- sustaining and growing a supply chain, and
- growing the technical and environmental knowledge base

The purpose of this document is to provide an overview of the current state of Canada's MRE sector, identifying successes and milestones to date, as well as the enabling policies, research organizations, and initiatives that have and will continue to support sector progress. It will also provide information on the global context in order to understand Canada's place in the bigger picture. Ultimately, this document aims to identify, in broad and specific terms, the strengths and challenges that can be addressed to ensure Canada enjoys the greatest environmental and economic benefits that derive from a strong, domestic MRE sector.

To encompass the current state of the Canadian MRE sector, this document will primarily cover tidal, wave, and river current energy resources. Although river current energy is not an offshore renewable resource, river current employs similar technologies to tidal stream; as such, river current energy has been recognized by national organizations[2] as an MRE resource. This document also addresses offshore wind, given its overlapping supply chain, regulatory issues, and environmental considerations – and Canada's growing interest.

[2] *Natural Resources Canada, CanmetENERGY. "What is marine renewable energy?"* *http://canmetenergy.nrcan.gc.ca/renewables/marine-energy/2475*

2.0 Benefits of marine renewable energy

MRE presents a number of potential benefits and advantages of interest to Canada; these vary depending on location, scale of development, and current provincial or territorial electricity mixes and policy environments.

Climate change and clean energy

Action on climate change requires a reduction in greenhouse gas (GHG) emissions. Renewable electricity is recognized as a leading solution to decreasing GHGs. Increasing the use of renewable energy sources for electricity is being driven by international, federal, provincial and territorial initiatives including the Paris Agreement and Pan-Canadian Framework for Clean Growth and Climate Change. Many provinces have also established policies to decrease GHG emissions from electricity production which include energy efficiency programs, caps on GHG-producing activities (electricity production, transportation, etc.), as well as commitments to increase renewable electricity generation *(see Section 5.0 for more on policy drivers).*

Like other renewable resources, waves, offshore wind, tidal currents, and river currents are clean and sustainable sources of energy. The addition of MRE resources to the electricity mix can assist in reducing the use of fossil fuels and GHGs. For example, utility-scale MRE projects could be used to displace carbon-emitting energy supplies, while smaller projects could supply electricity to remote communities currently using diesel fuel for generation.

The amount of carbon savings experienced through MRE development will be dependent on future deployment. The International Energy Agency (IEA) has calculated that MRE, alongside geothermal and "other renewables," could deliver 2% of the GHG emissions reductions necessary to limit global temperature rise to 2 degrees Celsius[3].

Reliability and energy diversification

Like other renewable resources, MRE is variable in nature. However, wave, tidal and river current resources have unique attributes that set them apart. They are generally more energy dense, more predictable, and more reliable than wind and solar energy – key benefits that can assist with electricity system planning and further diversification of the electricity mix.

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[3] International Energy Agency (IEA). Energy Technology Perspectives 2015. Mobilising Innovation to Accelerate Climate Action, Paris.
https://www.iea.org/publications/freepublications/publication/EnergyTechnologyPerspectives2015ExecutiveSummaryEnglishversion.pdf

Water is over 800 times denser than air: that means the energy potential in a slow moving tidal current can be similar to the energy potential in a gale force wind. This difference in density and power also means that MRE devices can be significantly smaller than wind turbines, and be placed closer together.

Tidal energy, driven by the gravitational pull of the moon and sun, is predictable days, weeks, and centuries in advance. The inherent predictability of tidal energy is highly attractive for grid management, potentially removing the need for back-up plants powered by fossil fuels. The use of tidal stream (rather than tidal range) technologies provides an option for small, community projects and incremental development.

River current energy is similar to tidal stream energy, however rivers flow in one direction, and often continuously. Canada's enormous river current resource – estimated at nearly three times our national energy demand – is particularly attractive for isolated communities; river systems are abundant, and can potentially provide services such as water pumping for storage, livestock, human consumption, small industry, and irrigation, and in many cases, replace the use of diesel fuel.

Offshore wind is an enormous opportunity for Canada: a well-known technology, a stronger and more predictable resource than onshore wind, and the longest coastlines in the world. Offshore wind speeds tend to be faster, which means exponentially more energy: a turbine in a 20km/h wind generates twice as much energy as the same turbine in a 15km/h wind. While offshore wind levels vary, they are more easily forecast – up to several days in advance. It's also relatively easy to transport large components by sea, making it easier to build bigger turbines, and capture more energy.

Wave energy is produced by winds blowing across the surface of the ocean. Since wave energy essentially is formed by wind energy being collected over large areas, while levels may fluctuate, its presence is relatively constant. Research conducted by the West Coast Wave Initiative in British Columbia has found that wave energy can be forecasted fairly accurately over the short time frames of interest to power system managers. On average, a four-hour wave forecast features just a 15 percent margin of error, while wind and solar in the Pacific North West are closer to 77 percent and 86 percent respectively. Due to this impressive forecastability, the requirements for back-up power source are significantly lower, allowing for more efficient use of the entire electrical system, less redundancy in capacity, and overall lower costs to integrate the same quantities of renewable energy.[4]

Further research through the PICS 2060 Integrated Energy Pathways project found that the integration of a 500 MW wave energy farm has the potential to reduce Vancouver Island's dependency on annual electrical transmission from the Lower Mainland by up to 11 percent, and reduce peak winter demand by up to 15 percent[5].

MRE can support more efficient grid use and management, supporting the integration and uptake of more intermittent renewable energy resources like wind and solar. The predictability

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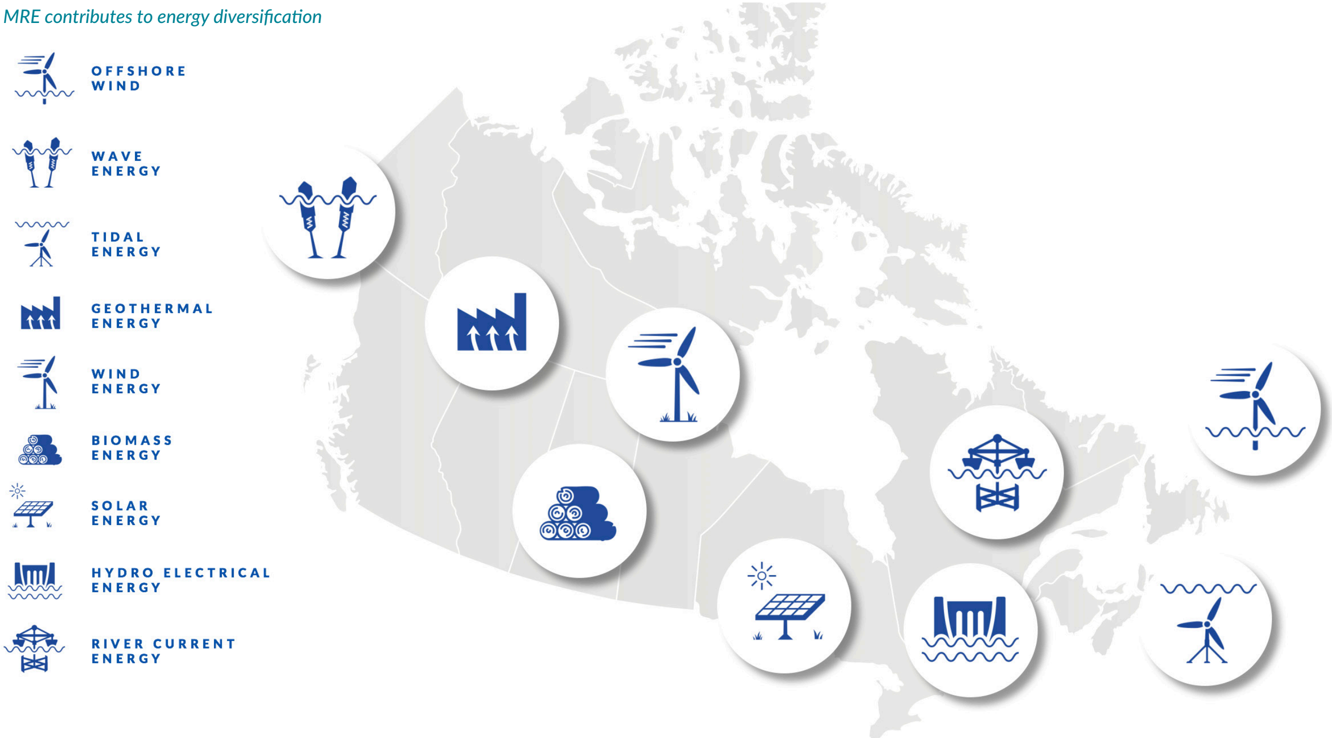
[4]*Robertson, B., Bailey, H., Buckham, B. Wave Energy: A Primer for British Columbia, 2017.*
http://pics.uvic.ca/sites/default/files/uploads/publications/Wave%20Energy%20Primer%20WEB%2003_31_2017a_0.pdf
[5]*Robertson, B. and et al., 2017.*

CANADA'S RENEWABLE ENERGY ADVANTAGE

MRE contributes to energy diversification



and reliability of MRE resources offers a complementary form of renewable energy, as it is able to ‘flatten out’ the load on the grid, and therefore improve the synchronicity of electricity supply and demand. MRE also partially avoids one of the central challenges with the intermittency of wind and solar: the ongoing need for a "double electrical infrastructure.”

During periods of high consumer demand when wind and solar resources are low or unavailable, there remains a need to provide electricity. The predictability of MRE creates a potential for big cost-savings: it cuts down on need for generation assets, grid infrastructure, and battery/smart grid storage.

Rural, remote and Indigenous community opportunities

There are currently 292 remote communities in Canada – nearly 60 per cent of which are Indigenous. Energy supply to remote communities is almost always imported from elsewhere, and in Canada, it typically is diesel fuel, contributing to GHG emissions. A total of 251 communities have their own fossil fuel plants, with 176 of these being diesel fuelled[6].

Many remote and Indigenous communities have significant access to renewable energy resources, including wind, solar, geothermal, river and tidal current, and wave energy. The

[6]Government of Canada. Status of Off-grid/Remote Communities, 2011.
https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/canmetenergy/files/pubs/2013-118_en.pdf

"avoided cost" of new electricity supply is very high, making MRE, even at higher costs, attractive. Those cost savings – combined with a local energy resource – can translate into benefits like job creation, local skill development and increased community self-reliance.

There is also increasing activity within Indigenous communities related to renewable energy development. A recent study found that there are 152 clean energy projects in Canada with Indigenous involvement, resulting in an estimated $842 in Indigenous employment income. While those findings represent larger hydro, wind, and solar projects, the study also found that an additional 1,200 smaller scale projects have also included Indigenous involvement[7].

Aside from diesel-dependence, some coastal communities have other electricity challenges, particularly in British Columbia. Many of them are at the end of long and frequently compromised transmission lines resulting in recurring black-outs and electricity loss. MRE could provide electricity generation at the point of use, mitigating the risk of black-outs and reducing requirements for transmission expansion[8].

Development of MRE in Canada's remote communities also presents new opportunities to develop systems and experience that could be applied in other regions of the world. Many island nations and communities in Asia and the Caribbean have MRE resources and similar challenges with reliance on diesel and unreliable electricity.

Economic opportunities

A recent market research report forecasts that the value of the global tidal and wave energy market will reach $11.3 billion in 2024[9]. That valuation creates significant potential for new industrial and economic growth in Canada – supporting both domestic and export opportunities.

As the global MRE industry grows, new innovations and technologies are needed everywhere. At this early stage, a global supply chain does not exist: there are no standard components, manufacturers, or performance metrics. This is an opportunity for Canada to establish a supply chain that can export innovation, technologies, and expertise to a global market estimated to reach up to $900 billion by 2050[10]. If Canadian suppliers participated in just 10% of this market and secured a 5% market share, it would be worth $4-5 billion over that timeframe.[11] Many of these projects require capabilities that already exist in Canadian companies working with the marine fabrication, shipbuilding, shipping, offshore oil, and ocean technology sectors. MRE presents a new market for these companies to tap into as well as new jobs and careers domestically.

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[7]Lumos Clean Energy Advisors. Powering Reconciliation: A Survey of Indigenous Participation in Canada's Growing Clean Energy Economy, 2017. http://indigenouscleanenergy.com/wp-content/uploads/2017/10/Powering-Reconciliation-A-Survey-of-Indigenous-Participation-in-Canadas-Growing-Clean-Energy-Economy.pdf

[8]Robertson and et al. Wave Energy: A Primer for British Columbia, 2017.

[9] Transparency Market Research. Wave and Tidal Energy Market - Global Industry Analysis, Size, Share, Growth, Trends and Forecast 2016 – 2024, 2018. https://www.transparencymarketresearch.com/wave-tidal-energy-market.html

[10]Carbon Trust. Accelerating Marine Energy: The potential for cost reduction – insights from the Carbon Trust Marine Energy Accelerator, 2011. https://www.carbontrust.com/media/5675/ctc797.pdf

[11]Gardner Pinfold Consultants Inc. & Acadia Tidal Energy Institute. Value Proposition for Tidal Energy Development in Nova Scotia, Atlantic Canada, and Canada, 2015. http://www.oera.ca/wp-content/uploads/2015/04/Value-Proposition-FINAL-REPORT_April-21-2015.pdf

A GROWING MARKET

$900 Bn

Estimated global market potential for wave and tidal energy by 2050

$73.7 Bn

Estimated Offshore wind market by 2022

$1.7 Bn

Estimated GDP Tidal energy in Nova Scotia could contribute by 2040.

Focusing only on tidal stream technology in Nova Scotia, a study entitled "Value Proposition for Tidal Energy Development in Nova Scotia, Atlantic Canada and Canada" (commissioned by the Offshore Energy Research Association (OERA) of Nova Scotia) examined the sector's economic potential up to 2040. Findings indicated the tidal stream industry could contribute up to $1.7 billion to Nova Scotia's gross domestic product (GDP), create up to 22,000 full time positions and generate as much as $815 million in labour income. The opportunity spills over significantly into supply chain activity throughout the Atlantic region and elsewhere in Canada.

That level of activity has not yet happened: to date, MRE project activity globally and in Canada remains in very early stages, with the world's first multi-device arrays deployed only recently. But these early projects have already yielded significant economic benefits. Activity around the Bay of Fundy has engaged over 330 businesses. The development of Cape Sharp Tidal's 4 MW project in the Minas Passage of the Bay of Fundy resulted in $33 million in local contracts and over 300 people working on the project.

In the United Kingdom (UK), where wave and tidal energy activity has been more concentrated, a 2015 report cited that about 1,700 people have been working in the sector with nearly CAD$782 million spent to date in the UK supply chain. It is estimated this number will grow to over 20,000 skilled jobs in the next decade[12].

[12] *RenewableUK. Wave and Tidal Energy in the UK: Capitalising on Capability A report for the Marine Energy Programme Board 2015.* *http://www.marineenergywales.co.uk/wp-content/uploads/2016/01/Capitalising-on-Capability-2015.pdf*

BUILDING THE

FUTURE

marine renewables canada

INTERVIEW

Dr. Brad Buckham, Director

West Coast Wave Initiative (WCWI), British Columbia

There are three stages to wave power delivery: first, resource characterization; second, energy extraction; last, integration into our electricity system. We specialize in the first and last – to give a fully integrated cost of wave energy. The big tool we use is simulation software – built working with DSA – to project wave energy outputs before a device is built and deployed.

It's all about reducing uncertainty. That's how investment and devices will advance.

We work with any remote coastal community seeking to get off of diesel based energy generation. In British Columbia, the greatest degree of motivation and active leadership in green community energy systems has been in First Nations communities, with over 1.5 GW of installed green power capacity. That's significant. For coastal First Nations, tides and waves and offshore winds are the predominant renewable option, so these communities will like be leaders in marine renewable energy as well.

Mitigating the reliance on diesel in coastal communities not only directly benefits the communities, it reduces risks of catastrophic fuel spills all along our coast: a broad benefit.

There is also a synergy between renewable integration and economic development: if we create a large industrial load – for example a new ice plant to service fishing vessels along the coast – it's easier to integrate a renewable energy supply.

Our resource assessment work is well underway; we've now launched a new centre called the Pacific Regional Institute for Marine Energy Discovery (PRIMED) to work with wave energy developers help assess technology performance, and build partnerships between developers and communities to help projects that are ready to commercialize.

3.0 Global market

The global resource potential for MRE is significant: water covers approximately 71% of the earth's surface. Theoretical estimates for tidal energy show that there could be up to 1,200 terawatt hours (TWh) of electricity potential, while wave resources present up to 29,500 TWh of potential[13]. Energy from river currents is also substantial, especially in Canada – but worldwide estimates of the resource have yet to be produced. On an annual mean basis, the offshore wind resource available in the North Atlantic alone is estimated to be sufficient to power the world[14].

Over the years, a number of estimates have been made by various organizations to quantify the MRE market potential and trajectory. A 2011 report by Carbon Trust estimated that a high scenario for wave and tidal energy deployment could be up to 55 GW by 2050, resulting in $900-$1000 billion. More recently, the International Energy Agency's Ocean Energy Systems estimated that there is potential to develop 300 GW of MRE (not including offshore wind) by 2050, resulting in 680,000 direct jobs by and 500 million tonnes of CO2 emissions saved[15].

Reaching this potential is dependent on market supports and policies being implemented that will support advancement of the sector. Therefore, Canada and many other countries such as UK, France, Ireland, the United States (US), and various countries in Asia and South America have been establishing supportive policies and investing in the sector for both clean energy and economic reasons.

Government policy and investment

A concerted focus on MRE development in Europe began about a decade earlier than in Canada. Currently, France and Scotland are recognized as leading in sector development, having established strategies and associated funding mechanisms to not only develop the core technologies, but to establish a new industry. In both countries, full-scale devices are being deployed and small arrays demonstrated, supported largely through a combination of demonstration grants, price supports through feed-in tariffs (FITs) or renewables credits, and investment in test and demonstration facilities. Some countries have also invested in infrastructure that would assist not only with MRE, but other similar marine sectors.

Some jurisdictions have focused on developing funding mechanisms and innovation programs that target not only the development of MRE devices, but enabling technologies to support the deployment, operations, and recovery of a device. For example, both the UK's Offshore Renewable Energy Catapult[16] and Energy Technologies Institute's Marine Energy Program[17]

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[13] Ocean Energy Systems (OES). An International Vision for Ocean Energy, 2017. https://www.ocean-energy-systems.org/publications/vision-and-strategy/document/oes-vision-for-international-deployment-of-ocean-energy-2017-/

[14] Possner, A., Caldeira, K. "Geophysical potential for wind energy over the open oceans." Proceedings of the National Academy of Sciences of North America 114 (43), 2017. http://www.pnas.org/content/114/43/11338

[15] OES. An International Vision for Ocean Energy, 2017.

[16] Offshore Renewable Energy Catapult. Research and Innovation Reports. https://ore.catapult.org.uk/research-innovation/resources/research-and-innovation-reports/

have included a focus on project components such as grid and cable connection and environmental monitoring technologies. Support for enabling technologies is critical to support cost reductions and the overall future competitiveness of the MRE sector.

The US, France, Scotland and a number of other countries in the EU have established funding programs to support MRE development. A recent study[18] noted a number of these jurisdictions have created funding mechanisms that appear effective in meeting technology and industry growth objectives, including Wave Energy Scotland, ADEME (France), the UK Green Investment Bank, and the European Union Fast Track to Innovation Fund, and the Sustainable Energy Authority of Ireland (SEAI) Early Commercialization Fund (proposed). Overall, the European Union (EU) has awarded almost approximately CAD $587 million through various programs since 2008. Individual countries have also targeted towards MRE, with Ireland's estimated investment of approximately CAD $72 million and the US having allocated CAD $450 million to MRE through its programs since 2006.[19] While MRE investment by Canada's federal and provincial governments is estimated at over $75 million[20] , Canada has no funding program that specifically targets MRE.

Industry growth and technology development

Growth of the MRE sector over the last 15 years has been slower than predicted: this is still an emerging market, and the financial market collapse in 2008 had a dramatic impact on MRE investment. However, recent modeling suggests that the rates of growth seen in the offshore wind sector in the last 20 years will be reproduced in the MRE sector between 2030 and 2050[21]. Growth in the sector is evidenced by recent analysis showing that cumulative MRE capacity has doubled worldwide from less than 12 MW in 2016 to over 25 MW in 2017.[22]

As there have been multiple deployments of single devices worldwide, there is a growing evolution to focus on multiple-device deployments that will build scale and help achieve cost reductions.

The tables below provide more detailed information on individual demonstration projects and installed capacity and details on Canadian technology and projects can be found in Section 6.0.

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[17]Energy Technologies Institute (ETI). Marine Energy Programme. http://www.eti.co.uk/programmes/marine

[18]MacDougall, S. Funding and Financial Supports for Tidal Energy Development in Nova Scotia, 2016. http://www.oera.ca/wp-content/uploads/2016/12/2016-09-09-TE-Funding-Financial-Supports_FINAL.pdf

[19]U.S. Department of Energy. U.S. Department of Energy Wind and Water Power Technologies Office Funding in the United States: Marine and hydrokinetic energy projects, 2016. https://www.energy.gov/sites/prod/files/2016/05/f31/MHK-Projects-Report-5-12-16.pdf

[20]Estimated for marine renewable energy in Canada includes: $7.1M ecoEII program, $27M Clean Energy Fund, $25M SDTC (not all was allocated), $15M Government of Nova Scotia, and an estimate of $3-5 million from various other agencies and departments (ACOA, Western Economic Diversification, etc.)

[21]OES. An International Vision for Ocean Energy, 2017.

[22]OES. 2017 Annual Report https://www.ocean-energy-systems.org/news/press-release-annual-report-2017-published/

INTERNATIONAL TIDAL ENERGY PROJECTS

Country	Project + Developer	Capacity	Technology	Status
Canada	See Section 6.0 for details	30.95 MW (multiple projects)	Various	Various stages
China	Xiushan Island Zhoushan, Zhejiang	1 MW	N/A	Modular device to be expanded to 3.4 MW
China	Guo Dian United Power Co., Zhairuoshan Island	300 kW		Deployment planned for 2018
China	Hangzhou Jianghe Hydro-Electric Science & Technology Co., Zhairuoshan Island	300 kW		Deployment planned for 2018
France	OpenHydro Paimpol-Bréhat	1 MW (2 x 0.5 MW)	Horizontal axis	Installed
France	Sabella - Passage du Fromveur Ouessant, Brittany	1 MW	Horizontal axis	Retrieved July 2016 Reinstalled Nov 2016
France	OpenHydro - EDF Energies Nouvelles , Raz Blanchard	14 MW (7 x 2 MW)	Closed turbine	Deployment planned for 2018
France	Guinard Energies, Brest & Ria d'Etel	3.5 kW – tested 250 kW - planned	Funnelled turbine	3.5 kW tested 2017; 250 kW demonstration planned for 2018
Italy	Ponte di Archimede – Kobold I Strait of Messina	0.055 MW	Vertical Axis	Installed 2006; Operational
Netherlands	Tocardo, Oosterschelde	1.2 MW (5 x 0.24 MW)	Horizontal Axis	Installed 2016; Operational
Netherlands	Tocardo – Afsluitdijk, Den Oever	0.3 MW (3 x 0.1 MW)	Horizontal Axis	Operational
Netherlands	Tocardo – BlueTEC Texel	0.24 MW (1 x 0.24 MW)	Horizontal Axis	Floating structure
South Korea	Uldolmok Tidal Power Station (1), Jindo Island	1 MW	Vertical Axis	Installed 2009; Operational
South Korea	Uldolmok Tidal Power Station (2), Jindo Island	0.5 MW	Horizontal Axis	Installed 2011; Operational
United Kingdom	Schottel - Plat-O Yarmouth	0.1 MW (2 x 50 kW)	Horizontal Axis	Installed 2015; Operational
United Kingdom	Nova Innovation, Yell	0 30 kW	Horizontal Axis	Installed 2014; Operational
United Kingdom	Nova Innovation Shetland	0.2 MW (2x 100 kW)	Horizontal Axis	Installed 2015; Operational
United Kingdom	Andritz/Atlantis - MeyGen Phase 1A, Pentland Firth	6 MW (4 x 1.5 MW)	Horizontal Axis	Installed 2016; Operational
United Kingdom	Scotsrenewables - SR2000 at EMEC, Orkney Scotland	2 MW	Horizontal Axis	Installed 2016; Operational
United Kingdom	Tocardo – EMEC, Orkney, Scotland	2 MW	Horizontal Axis	Planned for 2018

United Kingdom	Schottel – Plat-I EMEC Orkney, Scotland	1 MW (16 x 62 kW)	Horizontal Axis	Installed 2017
United Kingdom	Andritz/Alstom Sound of Islay	10 MW	Horizontal Axis	Planned for 2018
United Kingdom	Minesto - Holyhead Deep Anglesey	10 MW	Tidal Kite	Planned for 2018
United Kingdom	Marine Current Turbines (MCT) – SeaGen Near Portaferry, Northern Ireland	1.2 MW	Horizontal Axis	Installed 2008
United States of America	Ocean Renewable Power Company - Cobscook Bay, Maine	0.15 MW	Horizontal Axis	Installed 2012; Operational
United States of America	Verdant Power – East River, New York		Horizontal axis	Testing planned

Adapted from : European Commission JRC Ocean Energy Status Report 2016 Edition
http://publications.jrc.ec.europa.eu/repository/bitstream/JRC104799/kj1a28407enn.pdf

INTERNATIONAL WAVE ENERGY PROJECTS

Country	Project + Developer	Capacity	Technology	Status
Australia	Carnegie – Perth	0.72 MW	Point Absorber	Installed
Australia	Carnegie - CETO6 Garden Island	4 MW	Point Absorber	1 MW Installed; 3 MW planned
Canada	See Section 6.0 for details	200 - 300 kW (multiple projects)	Various	Various stages
China	Wave Pendulum Daguan island, Shandong Province	30 KW	Oscillating	Installed 1999; Operational
China	Sharp Eagle Wave Energy Demonstration Project	100 kW	Point absorber	Installed 2017
Ireland	Seapower, Galway Bay	N/A	Attenuator	1:4 scale tested 2017
Ireland	Westwave, Killard	5 MW	TBD	Planned for 2018
Italy	40Southenergy, Marina di Pisa	100 kW	Oscillating	Installed 2015
Japan	Mitsui Engineering & Shipbuilding and Ocean Power Technologies, Kozu Island		Point Absorber	Planned
Korea	Floating Pendulum Wave Energy Converter, Jeju Island	300 kW		Planned testing
Korea	Yongsoo	500 kW	Oscillating	Installed 2016
Norway	WavEel – Wave4Power, Runde	N/A	Point Absorber	Installed 2016
Portugal	WaveRoller – Swell, Peniche	5.6 MW	Oscillating	Planned for 2018
Spain	Wello – Baby Pengiun, Canary Island	N/A	Rotating Mass	Reliability testing

Spain	Wedge Global, Canary Island	N/A	Point Absorber	Reliability testing
Spain	Oceantec, Bimep	30 KW	Oscillating	Installed 2016
Spain	Mutriku	0.3 MW	Oscillating	Installed 2011
Sweden	Seabased – Sotenäs, Västra Götaland	10 MW	Point Absorber	1 MW installed
United Kingdom	Albatern, Isle of Muck	22 kW	Attenuator	Installed
United Kingdom	Eco Wave Power Gibraltar	100 kW	Point Absorber	Installed 2016; Operational
United Kingdom	Wello – CEFOW EMEC	3 MW	Rotating Mass	Planned for 2019
United Kingdom	Corpower EMEC	25 kW	Point Absorber	Planned
United States of America	Fred Olsen Navy Test Centre, Hawaii	23 kW	Point Absorber	Demonstration planned
United States of America	Northwest Energy Innovations - Azura Wave Navy Test Centre, Hawaii	20 kW	Point Absorber	Prototype installed/tested 2015

Adapted from : European Commission JRC Ocean Energy Status Report 2016 Edition
http://publications.jrc.ec.europa.eu/repository/bitstream/JRC104799/kj1a28407enn.pdf

INTERNATIONAL RIVER CURRENT ENERGY PROJECTS

Country	Project + Developer	Capacity	Technology	Status
Canada	See Section 6.0 for details	212 kW (multiple projects)	Various	Various
Chile	Idenergie	<1 kW	Cross flow horizontal axis	Installed 2017-18 – irrigation canal
Colombia	Smart Hydro Power – Neiva		Horizontal axis	Installed – irrigation canal
France	Hydroquest – SEENOH test site	80 kW	Vertical axis	Installed 2017
France	GKinetic and DesignPro – SEENOH test site	25 kW	Horizontal axis	Planned deployment 2018
Germany	Smart Hydro Power - Rosenheim	5 kW	Horizontal axis	Installed 2013
Germany	Smart Hydro Power – Munich	5 kW	Horizontal axis	Installed 2011
India	New Energy Corporation – Chilla Canal	50 kW	Vertical axis	Installed 2011
India	Smart Hydro Power, Gram Oorja, and Sanjeevani Seva Trust – Karnataka, India	5 kW	Horizontal axis	Installed
Indonesia	PT BIMA Green Energi, Telkomsel, & Smart Hydro Power	5 kW	Horizontal axis	Installed
Myanmar	New Energy Corporation – Ringmo	20 kW	Vertical axis	Installed 2014

Nepal	New Energy Corporation	5 kW	Vertical axis	Installed 2015
Nigeria	Smart Hydro Power - Akwanga	5 kW	Horizontal axis	Installed
Peru	Smart Hydro Power & ECI – Bellavista	5 kW x 2	Horizontal axis	Installed
Peru	Government of San Martin, Comite de Electrificacion Marisol, GIZ, and Smart Hydro Power	5 kW	Horizontal axis	Installed
United States	Ocean Renewable Power Company	25 kW	Cross flow horizontal axis	Installed 2014 Re-installed 2015

Adapted from : European Commission JRC Ocean Energy Status Report 2016 Edition
http://publications.jrc.ec.europa.eu/repository/bitstream/JRC104799/kj1a28407enn.pdf

The development of MRE technologies has been progressing steadily, with tidal stream technologies moving close to commercialization. Through 2016 and 2017, several commercial milestones were reached, including: Nova Innovation's installation of the first tidal energy array in Scotland's Shetland Islands, Atlantis Resource's deployment of four 1.5 MW turbines as part of the Meygen project in Scotland's Pentland Firth, and Cape Sharp Tidal's deployment of the first of two turbines in Minas Passage, Bay of Fundy. A number of smaller tidal energy projects also reached the deployment and installation phase in the EU and Canada. This increasing deployment activity signals tidal stream energy's advancing technological maturity: horizontal axis turbines have reached a technology readiness level (TRL)[23] of 8, with leading technologies on the verge of completing the TRL path[24].

Lessons learned from large-scale tidal stream activity have also led to a growing interest in small-scale technologies in Canada, the US (Alaska in particular), and many islandic or energy-challenged nations in Asia. Smaller technologies – both bottom-mounted and floating – may be ideal for remote communities as an off-grid solution.

Community-scale project development has also been the primary focus for river current energy technologies, with Canada and the US both conducting resource assessments, technology demonstration, and R&D to support development. France, Ireland, and Norway also have technology developers actively working to develop devices to harness river current energy. While the global market for river current energy is significant, few strategies or data exist to assess the global resource opportunity, technology progress, or growth.

Wave energy technologies are in an advanced development phase, requiring more refinement and demonstration to reach maturity alongside tidal stream. Globally, there are a number of initiatives underway to support the de-risking and commercialization of wave energy led by Wave Energy Scotland, the Sustainable Energy Authority of Ireland, Ocean Energy Systems, US Department of Energy, and West Coast Wave Initiative.

[23]By definition, a TRL indicates the commercial ability of a technology. There are nine TRLs. See Glossary for more information.
[24]European Commission. JRC Ocean Energy Status Report 2016 Edition.
http://publications.jrc.ec.europa.eu/repository/bitstream/JRC104799/kj1a28407enn.pdf

marine renewables canada

INTERVIEW

Alisdair McLean, Director

Cape Sharp Tidal, Nova Scotia

Cape Sharp Tidal is a joint venture between Emera Inc. and OpenHydro, a Naval Energies company. OpenHydro and Emera have a shared interest in exploring the tidal energy potential of Nova Scotia's Bay of Fundy. Our long-term goal is to create a sustainable tidal energy industry for Nova Scotia. OpenHydro brings more than 10 years of experience in developing and deploying in-stream tidal energy technology. Emera brings significant energy industry expertise, combined with regional knowledge.

We are proud of our role in pioneering a new renewable energy industry and we're committed to doing things the right way. Cape Sharp Tidal's biggest achievement in marine renewable energy to date is its successful deployment and grid connection of Canada's first in-stream tidal turbine at the FORCE berth site in the Bay of Fundy's Minas Passage. The 2-MW turbine was deployed and grid-connected in November 2016 and recovered in June 2017. We're the first and still only developer to successfully deploy an in-stream tidal turbine in the Bay of Fundy and connect it to the Nova Scotia power grid.

We are preparing the next phase of the Cape Sharp Tidal demonstration project and will deploy our tidal stream turbine in mid-2018 at the FORCE test site. We are building on our success in every part of this demonstration project, and we have been working to apply what we learned from the previously deployed turbine and environmental monitoring devices that were recovered in June 2017. We're also continuing to improve our technology and are increasing the turbine's operating efficiency.

We're excited about what the future holds, and we believe that tidal energy can co-exist with existing ocean-based industries to the benefit of all Nova Scotians. Over time, we need to demonstrate that tidal energy does not cause environmental harm and that it can be generated economically. As we plan for our next deployment, we'll continue to engage with stakeholders and Indigenous communities regarding our plans.

4.0 Key factors to growth

As a new industry, the MRE sector must overcome several risks and challenges in order to advance. While there may be challenges unique to particular regions, many of them span the globe.

4.1 Cost reduction and innovation

MRE projects are often sited in harsh, high-flow environments where deployment and operating costs are high; these costs are challenging to offset during this early stage while technology designs and development approaches are still evolving. To date, the levelized cost of energy (LCOE) for MRE projects shoes a wide range as these have been installed in different types of sites, using different devices at different stages of technology development.[25]

Fortunately, over the past five years, increased MRE technology demonstration and refinement has brought cost reductions as well as clearer cost estimates. This is largely due to achievements in building economies of scale by producing and deploying multiple devices, learning by doing, process optimization, engineering validation, and improved commercial terms[26].

Recent analysis led by the UK's Offshore Renewable Energy Catapult illustrated that cost reduction for in-stream tidal energy will be realized through increased deployment as suppliers and developers overcome early design and operational challenges as well as incremental innovation and continuous learning. It is projected that cost reductions can be achieved over a relatively modest volume of deployment – LCOE of £150 per MWh by 100MW installed, £130 by 200MW and £90 by 1GW[27] (approximately CAD $260 per MWh by 100 MW installed, $225 per MWh by 200 MW, and $155 by 1 GW).

As river current energy is in earlier stage of market development, analysis and estimates for cost and LCOE are difficult to find. However, there is an expectation that the costs of river current energy may be lower than tidal energy due to the following factors (dependent on site location):

- continuous operation of the generator because of steady flowing currents
- lower velocity flows, and/or
- closer proximity to a base load[28],

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[25] *Offshore Renewable Energy Catapult. , 2018. https://s3-eu-west-1.amazonaws.com/media.newore.catapult/app/uploads/2018/05/04120736/Tidal-Stream-and-Wave-Energy-Cost-Reduction-and-Ind-Benefit-FINAL-v03.02.pdf*

[26] *Offshore Renewable Energy Catapult, 2018.*

[27] *Ibid.*

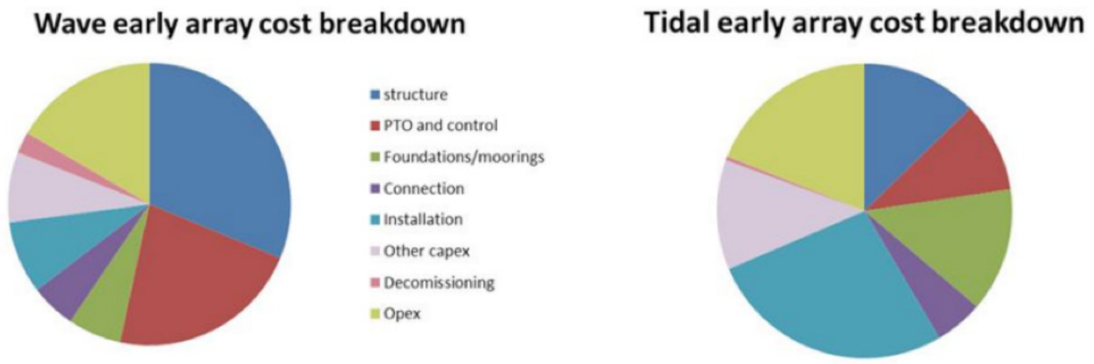
[28] *Base load is the minimum amount of power that a utility or distribution company must make available to its customers, or the amount of power required to meet minimum demands based on customer requirements.*

While costs for MRE will come down, it will take considerable innovation and commercialization efforts for it to be competitive with more mature renewable energy resources like onshore wind and solar. For example, analysis by Bloomberg New Energy Finance has illustrated MRE is not yet competitive with other forms of generation with estimates of the LCOE of tidal stream at approximately CAD$589/MWh and wave at approximately CAD$666/MWh. In contrast, the estimates for other renewables are lower with onshore wind at CAD$91/MWh and offshore wind at CAD$168/MWh.[29] Although it will take time to drive costs down, the UK's Energy Technologies Institute concluded that tidal stream energy has the potential to compete with other low carbon sources, after a decade of running its marine energy programme which targeted innovation projects to realize cost reductions[30]. Of note, community-based wind projects in Canada with feed-in tariff incentives secured prices as high as CAD$495/MWh as little as five years ago; these prices have since fallen dramatically.

To date, government supported R&D and incentives have been necessary to support technology and project development and have also been one of the key motivations for private sector investment. Commercial markets are not yet driving MRE development because the costs, on a project basis, are still too high.

The demonstration of multiple MRE devices in arrays is critical to driving costs down. Further, the strategy for reducing costs must focus on the entire project and lifecycle inputs, as an MRE device itself only represents about one-third of overall costs (wave energy devices and their power take-off components are somewhat higher, representing just over half of the costs). The remaining costs exist in the services, techniques, and equipment needed to deploy, operate, and maintain arrays of devices (estimates for 10 MW arrays) as illustrated below. A focus on cost reductions in both capital and operating expenditures, targeting the inputs throughout the lifecycle of a project, will not only lower the cost of electricity produced but also engage the broader range of skills, equipment, and materials that foster supply chain growth and its subsequent economic benefits.

BREAKDOWN OF SIGNIFICANT COST ITEMS FOR MRE PROJECTS[31]



[29]Bloomberg New Energy Finance. Levilized cost of electricity for the first half of 2017.
[30]Energy Technologies Institute. "Tidal stream energy has the potential to compete on cost with other low carbon sources, but wave energy needs radical innovation - ETI report,"2015. http://www.eti.co.uk/news/tidal-stream-energy-has-the-potential-to-compete-on-cost-with-other-low-carbon-sources-but-wave-energy-needs-radical-innovation-eti-report
[31]SI Ocean. Ocean Energy: Cost of Energy and Cost Reduction, 2013. http://si-ocean.eu/en/upload/docs/WP3/CoE%20report%203_2%20final.pdf

Reductions in capital and operating costs are necessary if MRE-produced electricity is to be competitive with other sources. These reductions can be achieved through scale and volume, experience, and innovation. Cost reduction activities and solutions also present opportunities that can be applied to the global industry – with multiple companies in multiple jurisdictions continually partnering on solutions. Innovation, in particular, is a key area where new methods and tools can translate to economic opportunities.

The good news: experience with early commercial projects is already illustrating how improved technologies, materials, processes, and economies of scale can drive costs down dramatically. The first phase of Scotland's MeyGen tidal energy project, consisting of 6 MW, is estimated at $15 million per MW of nameplate capacity. During the 100-MW phase two of MeyGen, costs are estimated to drop to $7.8 million per MW.[32]

4.2 Infrastructure

Infrastructure plays a key role in MRE development, including grid infrastructure, marine facilities and ports, and test centres. With so many different technology designs and concepts under demonstration, sometimes each with unique infrastructure requirements, it can be difficult for industry, governments and communities to make investment decisions – the challenge of early adopters.

Access to the grid

In some coastal and remote regions, electricity transmission infrastructure may not be adequate – or even available. MRE may require upgrades to the grid, cabling, and smart grid infrastructure as well as investments in energy storage. In some regions with great potential for tidal energy such as the UK and other parts of Europe, the need for grid infrastructure has been identified as a challenge, with some of the best MRE resources often being a significant distance from the existing grid. While different areas of Canada also have grid challenges, some of the best tidal sites like the Bay of Fundy benefit from their close proximity to the existing transmission system. Building new grid connections or upgrades can be challenging from a regulatory and investment perspective: there is still uncertainty around how soon projects will connect to – and fully exploit connection to – the grid.

Marine facilities and ports

Marine and port infrastructure for device deployments, operations, and maintenance in many prime MRE locations may not have all of the assets or capabilities required as the sector advances. Analyses of port needs have been conducted in a number of countries including

[32] MacDougall, S., 2016. This estimate is based on the published cost estimates of early projects in the UK and France and the input costs used for the Nova Scotia demonstration feed-in tariff.

Canada (specifically, Nova Scotia). France and regions of the UK have both conducted analyses of marine infrastructure needs and subsequently invested in port upgrades. For example, the region of Bretagne invested CAD $335 million in the port of Brest to attract industry in the tidal stream and offshore wind energy sectors[33]. In the UK, Cornwall invested CAD $42 million to establish a marine renewables business park, providing workspace and industrial units.

While some of the recent investments in ports have been driven through other marine and offshore sectors' interests and potential, the economic potential from industrial development of MRE (including offshore wind in some cases) has been a key driver. At the same time, the slower pace of sector development creates challenges in determining when the "tipping point" will occur, meriting infrastructure upgrades or development to service a growing industry.

In Europe, the issue of port infrastructure and grid challenges also effects the advancement of offshore wind. In some areas with significant MRE potential, including offshore wind, work has been done to determine how co-locating the various forms of generation could offset some of the high infrastructure costs[34]. While offshore wind development has yet to take hold in Canada, interest is growing and long-ranging planning for the MRE sector as a whole may optimize any future investment in infrastructure.

Test Centres

As the MRE sector emerges, test centres have played a critical role in providing infrastructure. Many countries with interests in MRE development have established demonstration centres to facilitate commercialization.

Centres around the world offer opportunities to test technologies at different stages of development; these opportunities may be enhanced with additional assets, including:

- site approvals and permitting
- assistance with supporting technologies and methods
- grid connection
- targeted technical and environmental research
- baseline studies and environmental monitoring
- stakeholder engagement

There are currently over 40 test and demonstration centres for MRE globally, with three in Canada. Further details about Canada's demonstration centres are discussed in section 6.0.

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[33] MarineEnergy.biz."Port of Brest steps up for marine renewables," 2017. https://tidalenergytoday.com/2017/10/05/port-of-brest-steps-up-for-marine-renewables/

[34] Aalborg University, Marintek and SINTEF. The Capitalisation Potential for Ports During the Development of Marine Renewable Energy, 2015. https://www.sintef.no/globalassets/project/beppo/beppo_wp3_report_capitalisation_potential_for_ports_in_mre.pdf

GLOBAL DEMONSTRATION AND DEVELOPMENT CENTRES FOR MARINE RENEWABLE ENERGY

Country	Centre	Type	Depth	Speed/ Avg. power density (wave)	Grid connected	Other details
Belgium Harbour of Ostend	Ostend wave energy test site	Wave	n/a	n/a	No	Wave pool and a towing tank for testing wave, tidal, floating wind turbines, and other offshore structures.
Canada Nova Scotia	Fundy Ocean Research Center for Energy (FORCE)	Tidal	45 m	5+ m/s	64 MW subsea cables; Substation and transmission line at 138kV	5 berths, permitted site, environmental monitoring, ongoing R&D.
Canada Manitoba	Canadian Hydrokinetic Turbine Testing Centre (CHTTC)	River	11 m	1.5-2.5 m/s	Bi-directional meter to allow for connection	Provides performance measurement, flow analysis, mooring system, underwater monitoring, modelling, environmental assessment, and cold climate testing services.
Canada Newfoundland & Labrador	Wave Environment Research Centre	Wave	6-30 m	10.7 kW/m	No	Provides 6 mooring sites, weather station, wave data collection and houses Multi-Trophic pilot aquaculture farm, a lab and workshop space.
Chile	Marine Energy Research and Innovation Centre (MERIC)	Wave Tidal				
China[35] Shandong Province	National small scale test site	Tidal Wave	50-70 m	1.2 m/s		Includes monitoring centre and ocean observation system.
China Zhejiang Province	Zhoushan tidal energy full scale test site	Tidal	20-60 m	1.5kW/ m2		3 test berths and 1 demonstration berth will be built in the site.
China Guangdong Province	Wanshan wave energy full scale test site	Wave	30 m	4 kw/m		3 berths for 100 kW each.
Denmark Hanstholm & Nissum Bredning	Danish Wave Energy Centre (DanWEC)	Wave	n/k	n/k	n/k	Established in 2009
France Brehat	Paimpol Brehat	Tidal	30-45m	2.6 m/s (spring tide)	Export cable: 8MVA-10kVDC Hub connection: 1MVA-690VAC	2 berths Test performance reliability of tidal devices; develop and test new sub-systems (instrumentation, connectors, etc.); conduct research on environmental impact
France Le Croisic	Sem-Rev	Wave, floating offshore wind	35-40m	12 kW/m	Export cable: 8MVA-20kv	Test performance and reliability of wave energy devices
France Bordeaux	Seeneoh	Tidal	8m+	3.5 m/s	Export cable: 690 VAC-100 kW	3 berths; tidal estuarine test site; test performance and reliability; analyze environmental impacts

Ireland Galway Bay	Galway Bay Marine and Renewable Energy Test Site	Wave	23m	2.5kW/m2	In planning	2 berths; ¼ scale prototype test site; permitted. Hosts SmartBay which supports innovation in the field of marine sensing, data management and communications.
Ireland Belmullet, Co Mayo	AMETS	Wave	50-100m	45-50 kW/m2	10 MW export capability	Full scale grid connected wave energy test site.
Japan Goto islands, Nagasaki	Japan Marine Energy Centre	Tidal				
Republic of Korea Jeju	K-WETEC	Wave	40 m		Yes	5 berths, offshore substation, 5 MW total capacity
Republic of Korea TBD	Tidal Energy Open Sea Test Centre	Tidal			Yes	5 berths, 4.5 MW total capacity
Mexico Baja California	Port El Sauzal	Wave				Under development
Netherlands Den Oever	Tidal Test Centre	Tidal	4.2m	1.4-4.5 m/s	160 kVa	Performance testing for intermediate scale devices; grid connected
Norway Runde Island	Runde Environmental Centre (REC)	Wave			Yes, 0.5 MW subsea cable	Offers facilitates preparations, licensing, deployment and monitoring
Spain Canary Islands	Oceanic Platform of the Canary Islands (PLOCAN)				Proposed – 15 MW	Offshore multipurpose platform providing workshops, laboratories, classrooms, training rooms and open working areas around a test tank to facilitate sea trials and launching vehicle to the sea; proposal for electrical system to be installed.
Sweden Lysekil	Lysekil wave energy research test site	Wave				Permit allows for arrays of maximum 20 wave power devices, 2 substations and land cables, plus related equipment; total capacity of 30 kW – 1 MW.
United Kingdom	European Marine Energy Centre	Tidal Wave	25-50 m	1.3-3.4 m/s	11 kV control & switching stations	14 full-scale test berths; 2 scale test sites and 2 nursery sites; Supervisory, control and data acquisition (SCADA) system; Weather stations (MET) that feed into SCADA CCTV monitoring
United Kingdom	WaveHub	Wave Offshore wind	60-100 m	Wind speed of 10 m/s	25 km of 11/33kv subsea cable for up to 20 MW of wave energy generation	4 berths up to 5 MW each; fully monitored and permitted site; Upgradable to 50 MW once 33 kV has been developed
United States Hawaii	US Navy Wave Energy Test Site	Wave	30-80 m	n/k	Yes	2 test sites for 100 kW-1 MW devices; 1 site for up to 250 kW at shallow depth; moorings and power cable connections available.

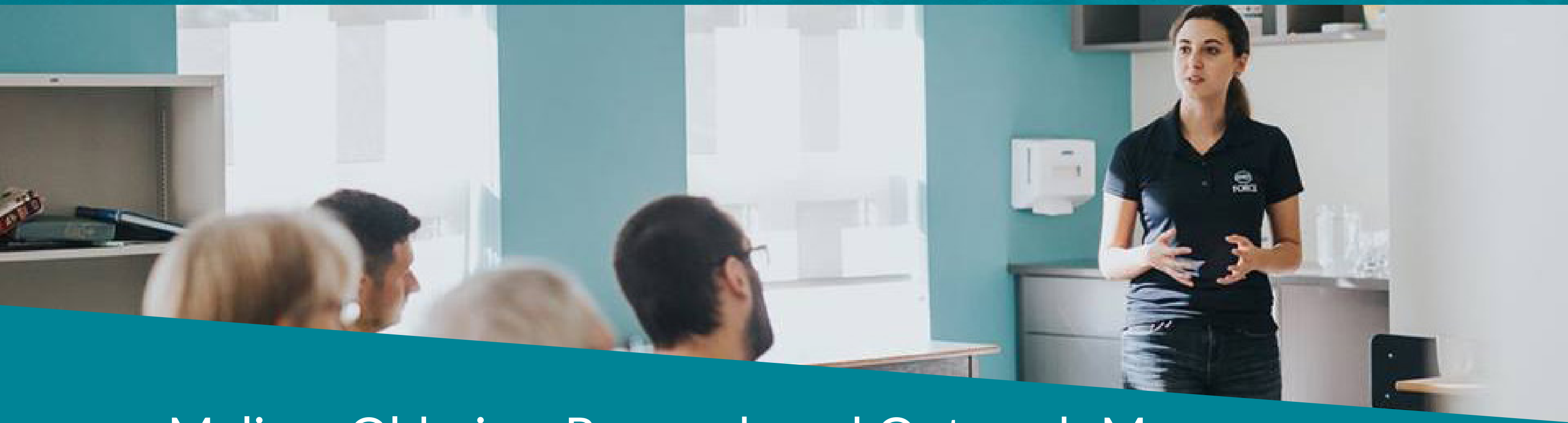
United States Oregon	Pacific Marine Energy Center South	Wave	65-78m		Proposed	4 berths; Facility for evaluating full-scale WEC device performance, environmental interactions, and survivability; planning to be operational by 2021.
United States Oregon	Pacific Marine Energy Center North	Wave	16m	-	-	2 berths up to 100 kW each; uses the Ocean Sentinel test buoy for site and device monitoring and as an artificial electrical load for devices.
United States Washington	Pacific Marine Energy Center Lake Washington	Wave	51m	-	No	Off-grid wave energy test site suitable for prototype testing
United States Alaska	Pacific Marine Energy Center Tanana River	River current		3 m/s	No	Site can support a single floating platform located in mid-channel with an anchored mooring system rated to 50,000 pounds holding force.
United States North Carolina	Jennette's Pier Wave Energy Test Facility	Wave	6-11m		No	Includes 2 shallow water test berths.
United States North Carolina	US Army Corps of Engineers Field Research Facility	Wave	7 m		No	Offers a wide range of technical and testing infrastructure support services for wave developers.
United States New Hampshire	Center for Ocean Renewable Energy	Tidal Wave	8-52 m	2 m/s	No	Full-scale tidal test site; floating test platform available for use. Wave energy test site has a subsurface mooring system and a large feed buoy is available as a platform.
United States Maine	UMaine Deepwater Offshore Wind Test Site	Offshor e wind Wave			Yes	Focused on the testing of offshore wind turbines, but also allows for wave energy; site is limited to two wave energy converters and a single subsea utility line with a maximum capacity of 25 megawatts.
United States Massachusetts	Marine Renewable Energy Collaborative (MRECo) Bourne Tidal Test Site (BTTS)	Tidal	7 knots			Can accommodate turbines up to 3 m in diameter with maximum power outputs of 100 kW.

[35] *Chenua, Ni. "National Ocean Technology Center, Tianjin, China Development of Ocean Energy Test Field in China," Journal of Shipping and Ocean Engineering 5 (2015): 44-49.* http://www.davidpublisher.org/Public/uploads/Contribute/557bc8f74390e.pdf

BUILDING THE

FUTURE

marine renewables canada



INTERVIEW

Melissa Oldreive, Research and Outreach Manager

Fundy Ocean Research Center for Energy (FORCE), Nova Scotia

We spent the last year focused on four key priorities. That includes site operations: we've upgraded our substation to 30 MW capacity, and continue to assist the five technology developers with a berth at FORCE. Over the last year and a half, we've had a single, grid-connected device deliver energy to the grid. It's a big milestone—one of many accomplished in the Bay over the last few years.

A key activity for us continues to be environmental monitoring – understanding turbine interactions with marine life and the marine environment. In the last year alone, we completed approximately 130 hours of hydro-acoustic fish surveys, 11 days of lobster surveys using 48 traps, 334 days of C-POD data collection bringing the total to more than 1,300 'C-POD days', bi-weekly shoreline surveys, 16 seabird surveys, and 4 marine noise surveys.

We also remain focused on research innovation. Working in high flow sites is new not only for renewable energy technology, but also subsea sensing. We have built and deployed three Fundy Advanced Sensor Technology (FAST) instrument platforms to improve our ability to characterize the site, conduct environmental monitoring, and improve marine operations.

Finally, engagement. FORCE has held more than 50 meetings with groups around Nova Scotia, with a focus on fishing and First Nations communities. Ultimately, in-stream technology must demonstrate its ability to co-exist with other users of the Bay in the long term. While there are still important research questions to answer, there is a consensus that this technology has the potential to play an important role in helping respond to the impacts of climate change. As well, with over 300 companies involved in tidal stream activity in the Bay of Fundy to date, it can be an important economic driver for ocean-based jobs.

We've seen this realized in one of our biggest achievements to date -- the installation of four underwater power cables. With a combined length of 11 kilometres, the four cables have a total capacity of 64 megawatts, equivalent to the power needs of 20,000 homes at peak tidal flows. Over 25 personnel were directly involved in planning, mobilizing, surveying, and installing the cables, with support from teams across Atlantic Canada.

Moving forward, companies need to show leadership and sensitivity around historical ownership, access, management, and benefit – when they are developing their project, making partnerships, and hiring their teams. Finally, the project will benefit from a long-term deployment in the Minas Passage. If a device can be operating in the water continuously for a couple of years, that will allow us to refine our monitoring efforts and really get a sense of what's happening in terms of energy generation and cost.

4.3 Environmental considerations

MRE devices hold the potential for lower potential ecological impacts than conventional technologies. In particular, *kinetic energy* devices – such as tidal stream, river current, wave energy devices – reduce or avoid many of the known impacts of potential energy devices like hydro dams because they: 1) do not force marine life and migrating fish to pass through them, and 2) have smaller effects on water flow and sedimentation (which can lead to problems with erosion and land drainage).

During the early stages of MRE device deployment, any impacts are likely to be small. But more data is required: many devices are in the testing phase; only a few have been in continuous operation for multiple years. While research to date is positive, it is not extensive – uncertainty remains. This is largely an industry-wide challenge that continues to be assessed by researchers, regulators, and industry. In particular the Annex IV report, *State of the Science: Environmental Effects of Marine Renewable Energy Development Around the World*[36] indicates:

> "Most of the perceived risk to animals from MRE devices is due to uncertainty about the interactions because of the lack of definitive data, and continue to present challenges to permitting/consenting of commercial-scale development."[37]

The report summarizes the potential environmental impacts and knowledge from experience to date. Potential impacts fall into a number of categories:

- *Interaction of marine mammals and fish with devices:* MRE devices may interact with marine life in a number of ways including possible collisions, avoidance, evasion, and attraction. The potential for marine animals to collide with devices is a primary concern; while no collisions have been observed around single devices or small arrays to date, that finding requires additional data and improved methods for data acquisition[38].
- *Underwater noise and disturbance:* Noise from MRE devices could induce behavioural changes or physical impacts such as hearing loss. To date, there have been no observations of operational noise from MRE devices affecting marine animals[39].
- *Changes to habitats:* The use of gravity foundations, piles, anchors, mooring lines, and/or cables to mount MRE devices may alter benthic (bottom) habitats. The presence of devices may attract fish and benthic organisms, allowing them to reef around the device[40]. To date, most evidence of changes in benthic habits is from offshore wind installations. The effects MRE devices have on reefing are not known, but it is expected that it would be very similar to those of other marine industries where structures are placed on the seabed[41] .

[36] *Copping, Sather, Hanna, Whiting, Zydlewski, Staines, Gill, Hutchison, O'Hagan, Simas, Bald, Sparling, Wood, and Masden. Annex IV 2016 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World, 2016.* https://tethys.pnnl.gov/sites/default/files/publications/Annex-IV-2016-State-of-the-Science-Report_LR.pdf

[37] *Copping et al. 2016*

[38] *Ibid.*

[39] *Ibid.*

[40] *Ibid.*

[41] *Ibid.*

- *Effects of electrical cables:* MRE devices require cables to carry electricity generated to a land-based substation, as well as cables to connect multiple devices. While electromagnetic fields (EMFs) occur naturally in the marine environment, marine cables may be another source of EMF. Laboratory and field studies have been conducted to determine the potential effects on marine animals from EMF emissions produced by MRE cables. To date, there has been no evidence to show that EMFs from MRE devices will cause a negative or positive effect on marine animals[42].

- *Energy removal and changes in flow:* MRE development could affect the physical environment by changing natural flow patterns around devices and the operations of a water body as a whole[43]. A small number of devices will not have measurable changes, but large commercial arrays have the potential to alter a system over time. Given the low deployment levels of MRE devices, there are few field studies of energy removal and changes. Many models have been developed to assess the potential risks, including one showing that 2,500 MW could be extracted from the Bay of Fundy without significant effects to flow (1% change)[44]. However, most models have focused on optimizing power, rather than environmental concerns like sediment transport, water quality and marine ecology[45].

Assessing impacts can be challenging when working in high-flow environments. Turbidity, current speed, and sedimentation can make it difficult to conduct research, collect data, and monitor effects as some sensing technologies may be available, but not originally designed to work in high-flow environments like the Bay of Fundy. Central to retiring outstanding questions around environmental effects will be monitoring and data gathering innovation must be a continued focus to retire outstanding questions around environmental effects.

A critical aspect of assessing and mitigating any potential environmental impacts is through the demonstration of devices in open water operating environments. Deployment of devices and devices in arrays are critical to building knowledge as direct observation and experience is needed to inform evaluations of risk and impacts[46].

4.4 Public acceptance

As the MRE sector grows, acceptance and support from the public and stakeholders will be critical to sustainable development. To date, acceptance of the sector has been relatively positive, with an increase in concerns or opposition sometimes occurring as a scheduled deployment has approached. Studies of MRE public acceptability reveal a strong degree of support for the technologies. In the EU, a survey carried out in 25 EU member-states shows that 60% of respondents favour MRE use, while 24% have a neutral attitude[47]. In the UK, a

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[42]Ibid.
[43] Ibid.
[44]Karsten, Richard H., McMillan, J.M., Lickley M.J. and Haynes, R., "Assessment of tidal current energy in the Minas Passage, Bay of Fundy," Proceedings of the Institution of Mechanical Engineers, 222, Part A: Power and Energy, (2008), 293-507.
[45]Copping et al. 2016
[46]Ibid. [47]European Commission. Energy Technologies: Knowledge-Perception Measures, 2006. http://ec.europa.eu/research/

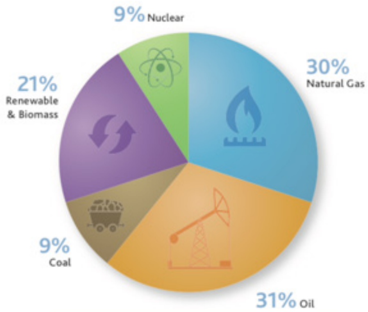
survey issued by the Department of Energy and Climate Change illustrated similar results, with 73% of respondents supportive for wave and tidal energy development[48]. In Nova Scotia, a 2016 public opinion survey of 500 people (with oversampling among residents in communities near potential future MRE development) indicated over 80% of respondents completely or mostly supported tidal energy demonstration[49]. Factors raised that could impact support included environmental impact, generation of renewable energy, and respect for local fisheries and Indigenous communities.

As MRE advances and installed capacity grows, public awareness will also increase which may affect acceptance levels. Increases in installed capacity may also be perceived as a threat or potential impact to other users and uses of the marine space such as fishing, oil and gas, recreational activities, aquaculture, navigation, and ecotourism.

Early engagement, relationship-building, and ongoing communication are integral to understanding and addressing the concerns of the public, Indigenous communities, and stakeholders. Many countries involved in MRE development have adapted or developed processes to ensure proper engagement takes place. These processes may exist under legislation, policies, guidance, or developed by industry, sometimes through associations to establish industry best practices[50].

[48]Department of Energy and Climate Change (DECC). DECC Public Attitudes Tracker – Wave 15, 2015. www.gov.uk/government/uploads/system/uploads/attachment_data/file/254725/summary_wa ve_7_findings_decc_public_attitudes_tracker.pdf
[49]Corporate Research Associates. Tidal Energy Public Perception Study. Summary Report, 2016.
[50]Acadia Tidal Energy Institute (ATEI) developed a Community and Business Toolkit for Tidal Energy Development which includes a chapter on Stakeholder and Community Engagement, containing information on public acceptance and resources on engagement. For more information visit: http://tidalenergy.acadiau.ca/tl_files/sites/atei/Content/Reports/Module_6_Stakeholder_and%20_Community_Engagement.pdf

5.0 Policy drivers in Canada



Primary Energy in Canada (2010)
(Source: Canadian Council on Renewable Electricity)

While more than 65 per cent of Canada's electricity is provided by renewable sources (principally hydro), the energy system as a whole (including electricity, heat, and transport), is still heavily reliant on fossil fuels[51]. In 2010, fossil fuels delivered about 70 percent of the primary energy used in Canada[52].

Canada has committed to acting on climate change and cut its emissions by 30 percent from 2005 levels by 2030. At the international level, these commitments have been formalized through the signing of the Paris Agreement[53] which pledges that signatory countries will work to keep global temperature from increasing by 2 degrees Celsius and pursue efforts to limit the increase to 1.5 degrees Celsius. At the national level, a number of policies, legislation, and initiatives have been established or are underway to achieve climate goals. Many policies are also focused on "clean growth" with initiatives not tackling just a cleaner environment, but one that will also lead to economic growth and a future low-carbon economy.

Increased renewable energy use can go a long way in meeting Canada's climate goals. Replacing fossil fuels with renewable resources in the electricity, transportation, and heating sectors would virtually eliminate Canada's energy-based GHG emissions; reaching this target requires doubling renewable sector output[54]. While Canada has abundant untapped renewable resources, supportive policies are required to bring them to bear. A number of policies and initiatives have been established or are under development that will drive their development:

- Canadian Energy Strategy: The strategy, established in 2015, is a cooperative initiative between provinces and territories towards sustainable energy development. Actions in the strategy include energy conservation and efficiency, clean energy technology and innovation, and deployment of energy to people and global markets. In relation to renewable energy, a key effort of the strategy is to "accelerate the development and deployment of energy research and technologies that advance more efficient production, transmission, and use of clean and conventional energy sources."

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[51]*Natural Resources Canada. 10 Key Facts on Canada's Energy Sector.* https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/10-Key-Facts-on-Canada%27s-Energy-Sector2017-en.pdf
[52]*Natural Resources Canada. Additional Statistics on Energy.* http://www.nrcan.gc.ca/publications/statistics-facts/1239
[53]*United Nations. The Paris Agreement.* https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
[54]*Canadian Council on Renewable Electricity (CanCORE). Powering Climate Prosperity, Canada's Renewable Electricity Advantage, 2015.* http://renewableelectricity.ca/wp-content/uploads/2016/11/CanCORE_Report_ENG_Final.pdf

- *Pan Canadian Framework for Clean Growth and Climate Change:* The Framework addresses key areas for meeting emission reduction targets, driving innovation, and advance climate change adaptation. As an umbrella to many of the programs and policies that support renewable energy development in Canada, it plays a key role in the MRE sector. Under the Framework, the Government of Canada commits to work with the provinces on a number of clean electricity actions, including:
    - A phase-out of traditional coal-fired electricity by 2030, including through equivalency agreements
    - Setting performance standards for natural gas-fired electricity generation
    - Investments in clean energy, transmission lines between and within provinces and territories, energy storage and smart grid technologies to build a modern electricity system, and
    - Work in partnership with northern, remote and Indigenous communities to reduce their reliance on diesel
- Coal phase-out and *GHG regulations*: Canada has committed to phasing out of traditional coal-fired generators by 2030. In February 2018, amendments to Canada's coal-fired electricity regulations were introducing, requiring generators to meet a stringent performance standard by December 2029[55]. Canada also co-founded the Powering Past Coal Alliance with the UK in 2017 to help achieve rapid phase-out of traditional coal power.
- *Price on carbon:* In 2016, the federal government announced its plan for carbon pricing. Provinces have the ability to implement either a direct pricing system or a cap-and-trade system by 2018.

Aside from federal and national efforts, individual provinces have established a number of climate and economic policies that will drive and support the uptake of renewables:

- *Renewable energy procurement:* All of provinces in Canada have been supporting increased renewable development energy in various ways – including legislated renewable energy portfolio standards (RPS), targeted requests for proposals (RFP), FIT, and standing offer programs (SOP). For example, British Columbia's *Clean Energy Act* includes a commitment that 93% of the province's electricity supply come from clean or renewable sources[56] and Nova Scotia established targets for 25% renewable electricity use by 2015 and 40% by 2020 *(see Section 8.1 for more information on individual provinces and territories' renewable energy plans as related to MRE).*

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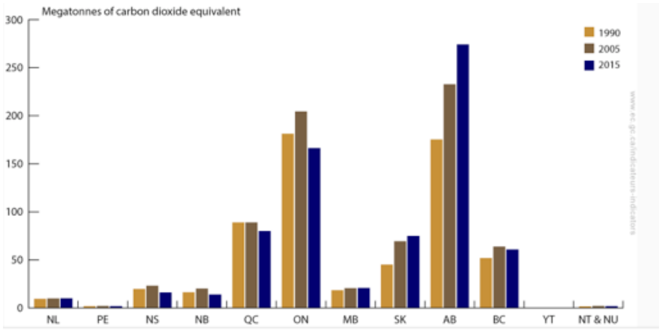
[55]*Government of Canada. Proposed amendments to coal-fired electricity regulations and proposed natural-gas-fired electricity regulations.* https://www.canada.ca/en/environment-climate-change/news/2018/02/proposed_amendmentstocoal-firedelectricityregulationsandproposed.html

[56]*Office of the Premier of British Columbia. "New Act Powers B.C. Forward With Clean Energy And Jobs," Press Release, 2010.* www2.news.gov.bc.ca/news_releases_2009-2013/2010PREM0090-000483.htm

- GHG emissions[57]: Each province has differing amounts of GHG emissions due to factors such as population, energy mix, and economic base. Some provinces like Nova Scotia have been heavily reliant on fossil fuels for electricity, while others, like British Columbia, have an electricity system comprised of 90% renewable energy, mostly from hydro. Nova Scotia was the first province in Canada to impose regulated caps on GHG and air pollutant emissions from power generation plants with the 2009 *Greenhouses Gas Emissions Regulations under the Environment Act*. These regulations were designed to reduce current GHG from electricity by about 25% from the base year (2007). Since that time, many other provinces have implemented GHG or carbon reduction legislation[58].



GHG Emissions by province and territory (Source: Government of Canada)

[57]*Government of Canada. Greenhouse Gas Emissions by Province and Territory.* ***https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/greenhouse-gas-emissions/province-territory.html***
[58]*Osler. Carbon and Greenhouse Gas Legislation Across Canada, 2018.* ***https://www.osler.com/en/resources/regulations/2015/carbon-ghg/carbon-and-greenhouse-gas-legislation-across-canada***

6.0 Marine renewable energy development in Canada

In recent years, the level of technology and project development has increased in Canada and among Canadian developers. The sector includes a mix of Canadian technology developers working on small-scale and remote community technologies and projects, as well as international developers focused on utility-scale development where large resources are present. Although the sector is still early stage, activity by industry, the research community, government and communities has increased. The intensity of this activity positively correlates with provincial government policy (and therefore varies depending on region).

Canada is home to several tidal, wave, and river current energy device developers, many of whom are focusing on small and community-scale technologies. The table below identifies Canadian technology developers that are currently active in the sector. Some have built experience through tank testing in flume or wave tanks, tow testing in open water, and/or the deployment of devices. For some technology developers, the next step will be the demonstration of devices connected to the utility grid and generating electricity. Moving to grid-connection is dependent on a number of factors, including:

- site identification, characterization, and preparation
- regulatory approvals and permits
- project financing
- supply chain partnership
- technology readiness

The table below includes the growing list of Canadian-made MRE technologies.

CANADIAN MARINE RENEWABLE ENERGY TECHNOLOGIES

Device Developer	Description	Status
Accumulated Ocean Energy (AOE) www.aoecanada.ca British Columbia	Wave	Work underway with the University of Victoria and the West Coast Wave Initiative on computer simulation of the AOE Accumulated Ocean Energy Point Absorber System. Now preparing to build the physical model for tank testing based on the current data from two years of computer modeling and research.
Blu-tility British Columbia	Wave	Planning for technology design and development underway.
Grey Island Energy www.greyislandenergy.com Newfoundland and Labrador	Wave Point absorber	Wave tank testing at NRC (1.5kW)
Idenergie www.idenergie.ca Quebec	River	Idénergie is a micro-scale river turbine developer also specialized power electronic converters. Multiple demonstration projects have been performed. Turbine model in redesign to meet the market requirements.
Jupiter Hydro Inc. www.jupiterhydro.com Alberta	Tidal, River Helical	Scale model tests in open water; Independent confirmation of tests by the University of Calgary; 2012 Test with two prototypes done by CHTTC; has established recent partnership with Hatch Engineering and is seeking approval for a 4.7 MW demonstration in the Bay of Fundy, Nova Scotia.
Mavi Innovations www.mavi-innovations.ca British Columbia	Tidal, River Ducted cross-flow turbine 20-50 kW	Completed testing of scaled turbine prototype at NRC-IOT in 2008. Built a 20 kW turbine for deployment at the CHTTC in Manitoba in fall 2013. This turbine is designed for both tidal and river applications. Turbine deployed in 2017 in British Columbia.
NeptuneWAVE (formerly Mermaid Power Corporation) www.neptunewavepower.com British Columbia	Wave	Demonstration deployments in 2016 and 2017; pursuing further approvals; Obtained investigative use license for the testing of its 200 kW Neptune 5 wave energy device in Georgia Strait, British Columbia in early 2018.
New Energy Corporation www.newenergycorp.ca Alberta	Tidal, River Vertical axis turbine 5W to 250 kW	Commercial products; deployments and operational (see next table)
Seawood Designs Surf Power www.surfpower.ca British Columbia	Wave Point absorber	1:10 model tested at NRC in 2010
Water Wall www.wwturbine.com British Columbia	Tidal, River Horizontal axis	1 MW WWT device deployed and tested with micro-grid system in 2016; Energy extraction of WWT devices can range between 0.5-2 MW for remote or on-grid applications.
Yourbrook Energy Systems	Tidal	80 kW prototype tested in 2016 in Haida Gwaii, British Columbia; Plans for scaled demonstration aimed at commercialization underway.

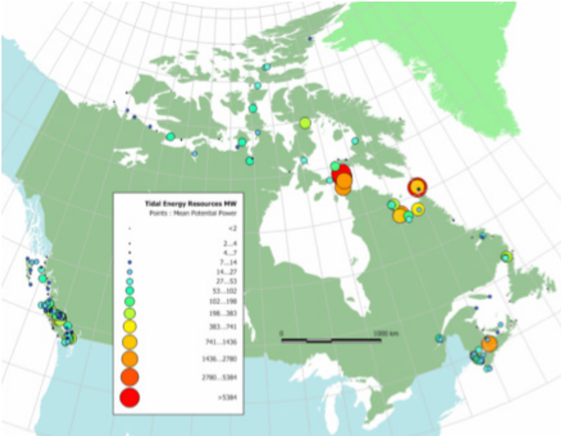
Canada has significant MRE resource potential in every province; growing development interest is not surprising. A world-class resource, legislated renewable targets, tidal feed-in tariffs and funding for infrastructure and research have spurred enormous activity in Nova Scotia, attracting Canadian and international developers, private sector investment, and local suppliers and researchers. Other jurisdictions have also seen progress, with development interest focused on small-scale tidal, wave, and river current energy technologies and projects. The table below provides details on MRE projects that have been proposed or are underway in Canada.

CANADIAN MARINE RENEWABLE ENERGY PROJECTS PLANNED & INSTALLED

Type	Project (developers/ partners)	Capacity	Location	Status
Tidal	Atlantis Operations Limited (AOCL)	4.5 MW	FORCE, Nova Scotia	Approvals and PPA received; Upcoming deployment
Tidal	Black Rock Tidal Power	4.5 MW	FORCE, Nova Scotia	Approvals and PPA received; Upcoming deployment
Tidal	Big Moon Power	5 MW	Minas Basin, Nova Scotia	Application submitted to Nova Scotia Department of Energy; awaiting decision/approval.
Tidal	Cape Sharp Tidal	4 MW	FORCE, Nova Scotia	Approvals and PPA received; 2 MW deployed 2016; Recovered 2017; Next deployment mid-2018.
Tidal	Halagonia Tidal Energy	4.5 MW	FORCE, Nova Scotia	Approvals and PPA received; Upcoming deployment
Tidal	Minas Tidal Limited Partnership	4 MW	FORCE, Nova Scotia	Approvals and PPA received; Upcoming deployment
Tidal	Fundy Tidal Inc.	500 kW	Grand Passage, Nova Scotia	COMFIT approval; PPA; planning
Tidal	Fundy Tidal Inc.	500 kW	Petit Passage, Nova Scotia	COMFIT approval; PPA; planning
Tidal	Fundy Tidal Inc	1.95 MW	Digby Gut, Nova Scotia	COMFIT approval; PPA; planning
Tidal	Canoe Pass Tidal/ New Energy Corporation	500 kW	Campbell, River, British Columbia	Approvals received; planning
Tidal	Water Wall Turbine	1 MW	Dent Island, British Columbia	Approvals received; deployed 2016
River	Idénergie	<1 kW	Laurentides region, Quebec	Multiple R&D, test and demonstration performed 2013-2016
River	Idénergie	<1 kW	Parks Canada locations	6 turbines deployed in 2016
River	Mavi Innovations	22 kW	Blind Channel, British Columbia	Turbine deployed; full commissioning planned for 2018
River	New Energy Corporation	25 kW	Sagkeeng First Nation, Manitoba	Approvals received; Upcoming deployment 2018
River	New Energy Corporation	30 kW	Pointe du Bois, Manitoba	Deployed and operating
River	New Energy Corporation	5 kW	Coffee Creek-Yukon River, Yukon Territories	Planning, unit sold
River	New Energy Corporation	25 kW	Mackenzie River, Fort Simpson, Northwest Territories	Commercial demonstration completed

River	New Energy Corporation	5 kW	Mackenzie River, N'Dulee Ferry Crossing, Northwest Territories	Approvals pending
River	New Energy Corporation	100 kW	Duncan Dam, BC	Units sold and test program completed
River	Verdant Power	5 MW	Cornwall River, Ontario	Planning first stage of commercial project by 2021 or earlier. Designing river mounting systems to lower costs for deployment and retrieval for testing and demonstration in Ontario.
Wave	NeptuneWAVE	200 kW	Georgia Strait, British Columbia	Deployment and demonstration in early 2018.

6.1 Tidal Energy



Tidal energy resources - Inventory of Canada's Marine Renewable Energy Resources, 2006.

Canada has some of the world's best sites for tidal stream energy development, with 42,000 MW of mean potential[59]. Many of them have energetic tidal resources and are close to either grid infrastructure or remote communities that could benefit from clean electricity. An assessment of Canada's MRE resources identified 191 sites having potential mean power estimated to be greater than 1 MW. Of these, Nunavut, British Columbia, and Nova Scotia have the greatest number of sites[60]; unsurprisingly, these regions have witnessed accelerated interest and focus in tidal stream. While there is interest in the North, it remains challenging to integrate early stage tidal stream in harsh, remote environments.

Nova Scotia

Tidal stream development in Canada is most concentrated in Nova Scotia, where activities around the Bay of Fundy's tidal energy resource are often described as an incubator for the Canadian industry. Given the size of the resource, there is potential for both community and utility-scale projects, both of which have been spurred by government policy, community interest, and private sector investment.

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[59]*Cornett, Andrew. Canadian Hydraulics Centre. Inventory of Canada's Marine Renewable Energy Resources, 2006.*
https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/canmetenergy/files/pubs/CHC-TR-041.pdf
[60]*Cornett, Andrew, 2006.*

Fundy Ocean Research Center for Energy (FORCE)

The Fundy Ocean Research Center for Energy (FORCE) is Canada's leading research centre for tidal stream energy, located in the Bay of Fundy, Nova Scotia. Since its establishment in 2009, FORCE has acted as a catalyst for industry development. It works with developers, regulators, and researchers to study the potential for tidal turbines to operate effectively and safely. FORCE provides shared onshore and offshore electrical infrastructure, with 64 MW of subsea cable capacity, environmental monitoring, research, and stewardship of the site. Currently, FORCE provides five berths for the demonstration of tidal stream energy; each berth is held by individual developers (or "berth holders"), who have collectively received approval for 22 MW under Nova Scotia's FIT program for developmental tidal arrays.

As part of its mandate, FORCE conducts ongoing environmental studies, environmental effects monitoring, and applied research. Its monitoring program is designed to better understand the natural environment of the Minas Passage and the potential effects of turbines related to fish, seabirds, marine mammals, lobsters, marine noise and other variables.

FORCE has also created the Fundy Advanced Sensor Technology (FAST) program to advance the science of site measurement in high flows, providing industry, scientists and regulators with the ability to evaluate – and operate in – extreme sites like the Bay of Fundy. The FAST program includes a series of onshore and offshore research assets; a primary focus is the development of underwater monitoring platforms. These platforms use a variety of onboard sensing equipment to capture data from the Minas Passage and are designed to:

- Advance capabilities of site characterization
- Establish environmental monitoring standards and technologies
- Support turbine-related research

Fundy Advanced Sensor Technology (FAST) Platform at FORCE

Project development

Project developers operating at FORCE under Nova Scotia's FIT program *(see Section 8.2 for more about the FIT)* include:

- **Cape Sharp Tidal**, a joint venture between Emera Inc. and OpenHydro. Cape Sharp was awarded a FIT in for 4 MW, and deployed its first 2 MW turbine at FORCE in November 2016. It was the first grid-connected tidal stream turbine in Canada, marking a huge milestone in the industry. The 2-MW turbine is part of Cape Sharp's project plans for a 4 MW tidal array (2 x 2MW). In developing the project, Cape Sharp has used 70% local content, totaling $33 million in contract awards to the local supply chain. Over 300 people worked full-time on the first phase of the project.

  Cape Sharp Tidal's turbine was retrieved in June 2017 to allow for upgrades to its turbine control centre (TCC). This was the first time OpenHydro's pioneering TCC technology had been used anywhere in the world, an important step in advancing the ability to generate electricity from multiple turbines at sea and export to shore via a single export cable. Plans are underway for Cape Sharp Tidal's next deployment in mid-2018 and work continues toward a demonstration array of two interconnected 2 MW turbines.

Cape Sharp Tidal 2 MW turbine after retrieval.

Since the 2016 deployment, Cape Sharp Tidal and FORCE have both issued quarterly environmental monitoring reports based on their environmental effects monitoring programs (EEMP). The monitoring reports will help further knowledge about the environmental effects of tidal stream energy in the Bay of Fundy, advancing the scientific understanding at the FORCE site, and assisting industry, government, and stakeholders in future planning regulatory and planning decisions.

- **Atlantis Operations Canada Limited** (a joint partnership between Atlantis Resources Ltd. And Rio Fundo Ltd. (a DP Energy affiliate) was awarded a FIT for 4.5 MW in December 2014. Atlantis Resources has been leading the world's largest commercial tidal stream energy (400 MW) project in Scotland – MeyGen—and has gained valuable experience working in high-flow tidal energy conditions that can be transferred to its project at FORCE.

- **Black Rock Tidal Power (BRTP) (parent company SCHOTTEL)** has a FIT for 5 MW and has recently evolved its project plan to focus on floating tidal stream technology. BRTP will use small floating platforms, such as Sustainable Marine Energy Ltd.'s PLAT-I platform to deploy SCHOTTEL Hydro turbines.

- **Halagonia Tidal Energy,** an affiliate of Ireland-based developer, DP Energy, received approval for a fifth berth at FORCE in 2015. Halagonia will develop the site, working closely with Andritz Hydro Hammerfest. Approvals have been received as a well as a FIT to install three 1.5 MW turbines at the site.

- **Minas Tidal Limited Partnership** (a partnership between Minas Energy, International Marine Energy Inc., and Tribute Resources) has received approvals and a FIT for 4 MW and has been progressing plans to demonstrate tidal turbines at FORCE. As Minas Tidal's project advances, the development team has also been working on providing education and engagement across Nova Scotia, particularly in coastal community schools.

Outside of the FORCE site, there a number of projects in the planning stage in Nova Scotia. Most of these are focused on community-scale projects, connected at the distribution grid rather than transmission system. Nova Scotia's Community-Based FIT (COMFIT) stimulated interest in small-scale project development and community ownership of projects. In 2012, Fundy Tidal Inc. received COMFIT approval for five community-scale projects. After more baseline studies and feasibility assessment, three of the projects are being developed in Grand Passage, Petit Passage and Digby Gut. These projects will range from 500 kW to 2 MW. In late 2014, Fundy Tidal Inc. partnered with Tribute Resources to develop the COMFIT projects. Fundy Tidal Inc. has been engaged in Nova Scotia Power's interconnection process for the Digby Gut project and is working towards financial close for all projects.

In 2018, *Nova Scotia's Marine Renewable-energy Act* was proclaimed, establishing an additional 10 MW opportunity for development *(see Section 8.1 for more details on the Act and 10 MW program)*. As a result, there has been increasing interest in Bay of Fundy tidal energy development from domestic and international industry. Recently, Big Moon Power Canada Corporation (BMP) submitted another project proposal for technology development in the Bay of Fundy; the province awarded the project development permits totaling 5 MW in April 2018 under a FIT of 35 cents/kWh. In working towards its project plans, BMP conducted sea trials and testing of its technology using a 200 kW prototype and a 1/10th scale model 2016 and 2017. BMP is aiming to deploy its technology in Nova Scotia with a 1 MW commercial scale demonstration project mid-way through 2018.

BUILDING THE

FUTURE

marine renewables canada

INTERVIEW

Voytek Klaptocz, Managing Director and Co-Founder

Mavi Innovations, British Columbia

Mavi was created back in 2008 to commercialize turbines; we saw a big potential for hydrokinetics to become part of the solution for reducing GHG emissions.

Our turbine installation at Blind Channel, deployed in June 2017, demonstrated many firsts for community-scale power generation in British Columbia, including turbine, mooring and cable deployment, hybrid power systems, diesel network integration, the use of local suppliers, vessels and divers. The turbine has only seen limited operation as more project level development work is required. But it has remained successfully moored without damage by logs for 8 month and going. And nothing can replace obtaining field experience with a real end user – Blind Channel Resort.

The integration of all the power sources (diesel, batteries, tidal) is complex for a real application. There were lots of details and nuances to work through that could not have been solved without actually doing the project.

Right now we're focused on Blind Channel and evaluating a possible additional grid connected hydrokinetic project on the Ottawa River.

Our work on developing methods of modelling turbine farms with University of Victoria and Laval University – primarily sponsored by NRCan – can contribute significantly to future projects. Fast and accurate turbine modelling means bankable power estimates for any project.

The lifecycle costs are still very high, making it very difficult to make a business case for marine renewables without significant subsidies. The expectation is that, through economies of scale, the price will come down to make marine renewables cost competitive with other technologies. The biggest challenge, however, is demonstrating a large enough market that will enable this cost reduction – as was the case with wind and solar. At this point, market size estimates are too optimistic; more realistic numbers may be sobering, but would allow the industry to focus in on the real opportunities, and streamline efforts through a focused approach.

British Columbia/Western Canada

To date, over 30 investigative permit applications for tidal energy have been made in British Columbia[61], but few projects are under development – largely due to the lack of policy and funding supports. The resource is there, but sector development has been limited with regards to grid-connected projects. Despite this reality, Western Canada is home to most of the country's device developers, with many of them pursuing off-grid and remote community projects. While these are sometimes viewed as niche projects and technologies, Canada's market for remote community projects is large, and global demand makes an even more compelling case for involvement in this type of market. Active developers and projects in/from British Columbia and Western Canada include:

- **Canoe Pass Tidal project**, led by New Energy Corporation – an Alberta-based tidal and river current energy device developer. The project is located in a narrow passage between Quadra and Maude Islands off the east coast of Vancouver Island, just north of Campbell River, British Columbia. The 500 kW project involves the installation of two 250 kW New Energy EnCurrent turbines that will be connected to a local 25 kV distribution line. New Energy has received environmental approvals for the project and has completed various civil works.
- **Instream Energy Systems** focuses on both tidal stream and river current energy technology development. Over the past several years, Instream has been successful in obtaining and advancing a number of its international project efforts and collaborations. Instream secured a berth at the Morlais Demonstration Zone in Anglesey, Wales for a multi-turbine pre-commercial trial. The company is also working to deploy a second-generation device in US demonstrations on both coasts; its Marine Floating Platform Design Project, in collaboration with UK based IT Power Consulting, is near completion.

Mavi Innovations Mi1 floating turbine deployed at Blind Channel, British Columbia.

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[61] Government of British Columbia. Applications and Reasons for Decisions (ARFD). http://www.arfd.gov.bc.ca/ApplicationPosting/index jsp?FileNumber=&SubPurpose=&Client=&PrimaryStatus=any&keyword=&Purpose=OCEAN+ENERGY&Submit=Submit&Region=&cp=1

- **Mavi Innovations** has been working towards the development of a small-scale tidal project in Blind Channel, British Columbia aimed at offsetting a remote eco-lodge's use of diesel fuel. In 2017, the project reached some major milestones, approaching full commissioning of Mavi's Mi1 floating tidal turbine. The turbine has been integrated into the existing diesel network, along with an additional smart diesel gen-set and battery storage. Mavi has also installed its mooring system, laid the cable, and began work to commission the hybrid power system.

- **Waterwall Turbine (WWT)** successfully deployed and conducted a short-term testing of its 1 MW device at its Dent Island Lodge site in British Columbia in 2016 . WWT's tidal energy system combined three major sub-systems—a floating tidal turbine, a proprietary microgird management system, and an energy storage system. The project included significant local content with a shipyard and manufacturing spending a year to fabricate the device resulting in more than 30,000 person-hours of labour .

Waterwall Turbine deployment at Dent Island, British Columbia

- **Yourbrook Energy Systems** led an initial pilot project with an 80kW prototype of its small-scale technology in Haida Gwaii, British Columbia. The data collected over a three-month period supports the technology methodology and the prototype is now going to upgraded for use in a scaled demonstration project, aimed at supporting future commercialization.

[62] *Natural Resources Canada. Water Wall Turbine Dent Island Tidal Power Generation Project.* *http://www.nrcan.gc.ca/energy/science/programs-funding/16690*

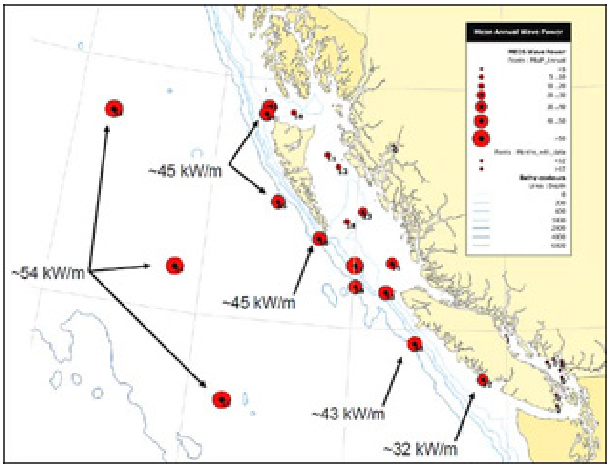
Northern Canada

Assessments and studies indicate Nunavut may have some of the best tidal energy resources in Canada, with 30,000 MW of estimated mean potential and 34 sites identified[63]. The Northwest Territories (NWT) also has potential for tidal energy, with 35 MW of estimated mean potential from four identified sites[64].

Frobisher Bay has some of the highest tides in Canada and could potentially supply electricity to Iqaluit, where population size and electricity demand may be high enough to support tidal energy development[65]. However, significant technical challenges exist in installing MRE projects in the North, including harsh ice conditions and the remote location. In order to assess the feasibility of tidal energy development, the Government of Nunavut has recommended modeling tidal currents in Frobisher Bay as a first, investigative step.

Despite the challenges in developing tidal energy in Canada's North, the high cost of using diesel for electricity generation – combined with a drive for community sustainability and climate change – has motivated companies and communities to explore the possibility of tidal energy development in Nunavut. Nunavut-based independent power producer Apqak Renewable Energy Inc. has expressed interest in bringing the most advanced tidal energy turbines to Nunavut to establish an initial 10 MW project.[66]

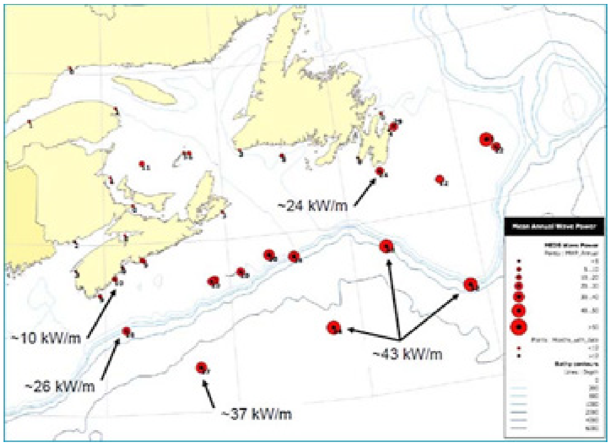
6.2 Wave Energy



West coast wave energy resources - Inventory of Canada's Marine Renewable Energy Resources, 2006.

Like tidal stream, Canada has significant wave energy resources on the Atlantic and Pacific coasts, with an estimated extractable potential of 10,100 to 16,100 MW . Due to obstacles such as harsh maritime conditions, conversion losses, environmental and social factors, and significant seasonal variations, the usable power from waves represents only a small fraction of the potential. There is significant wave energy potential on both the east and west coasts of Canada (as noted in Table 2), but the near shore wave potential on the west coast may represent the most near-term opportunity for development.

[63]*Cornett, Andrew, 2006.*
[64]*Ibid.*
[65]*Climate Change Secretariat. Department of Environment, Government of Nunavut. Ocean Resources. https://nunavutenergy.ca/en/node/122*
[66]*Varga, Peter. Nunatsiaq News. "Start-up company pitches tidal power for Nunavut," Noovembeer 19, 2014. http://www.nunatsiaqonline.ca/stories/article/65674start-up_company_pitches_tidal_power_for_nunavut/*
[67]*National Roundtable on the Environment and Economy. Advice on a Long-term Strategy on Energy and Climate Change, 2006. http://collectionscanada.gc.ca/webarchives2/20130322143450/http://nrtee-trnee.ca/publications-2*

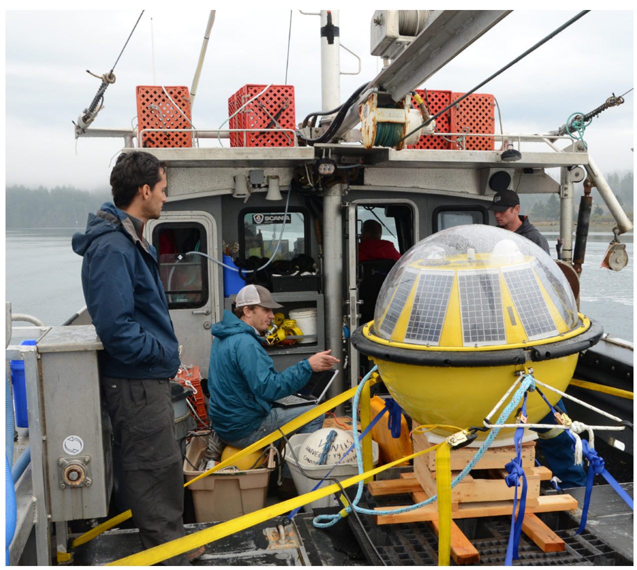


West coast wave energy resources - Inventory of Canada's Marine Renewable Energy Resources, 2006.

There are more than 200 wave energy devices in various stages of testing and demonstration globally, and the sector is often cited as being behind tidal energy in terms of technology convergence and commercialization. With Canada's immense wave energy resource potential, both coasts have a number of R&D activities underway to support future development; as well, several Canadian wave energy developers are engaged in various stages of technology development.

West Coast Wave Initiative

In British Columbia, the West Coast Wave Initiative (WCWI), based out of the Institute of Integrated Energy Systems (IESViC) at the University of Victoria, has been spearheading much of the wave energy development activities in Canada. WCWI's main focus is on determining the feasibility, impacts, and possible structure of future wave energy conversion opportunities in the province and Canada overall[68].



Working with industry, WCWI has completed high-resolution wave resource assessments, detailed wave energy converter technology simulations, and both short-term and long-term electrical system integration studies. WCWI has also developed and validated a high-resolution wave model of the pacific coast that is utilized as both on 12-year hindcast and a 48-hour forecast. Through WCWI's work, there is now enough detailed information on the height, frequency and direction of its coastal waves to start developing and testing energy converters in the ocean. *For more information about WCWI's key research findings, see its co-authored report with the Pacific Institute for Climate Solutions, "[Wave Energy: A Primer for British Columbia]".*

[68]Robertson, B. and et al., 2017.

Recently, WCWI expanded its efforts to support wave research and development across the globe by establishing the Pacific Regional Institute for Marine Energy Discovery (PRIMED). PRIMED will lead work to eliminate uncertainty and risk for "first-of-a-kind" community-based MRE projects. The institute will make use of extensive wind, wave and tide data and consolidate it with new data gathered by sensors on the new Canadian Pacific Robotic Ocean Observing Facility (C-PROOF). Using simulations, PRIMED will provide detailed predictions of energy supply prior to the deployment of devices.

Wave Environment Research Centre

On the east coast of Canada, the College of the North Atlantic (CNA) hosts and operates the Wave Environment Research Centre (WERC), located in Lord's Cove on the south coast of the island of Newfoundland. The centre was established to conduct research in the development of a wave-powered water pump coupled to a novel shore-based aquaculture system. Currently, there are six fully permitted mooring sites (at depths of 6 to 30 m) available within 1.5 km from shore. The site has collected more than three years of weather and wave environment data. With a dedicated wharf and slipway, the site is ideal for the testing and demonstration of wave energy converters and other surface and sub-surface structures in an energetic near-shore environment, as well as the development of associated instrumentation and sensor systems.

In 2017, WERC conducted sea trials of its wave pump, a device intended to provide a flow of sea water to an onshore aquaculture farm. Over the last 6 years of developing the project, it has engaged over 200 college and university students and over 20 scientists, technicians and faculty. WERC recently upgraded its wave measurement capability with a second Nortec AWAC and telemetry system, while Rutter Inc. has deployed extensive radar-based wave measurements at the site. Atmocean, a US-based wave energy developer, has tested its wave powered pump at WERC and NRG Systems is currently evaluating the marine durability of several of its meteorological sensors.

Atmocean wave powered pump deployed at WERC.

INTERVIEW

Clayton Hiles, Director of Engineering

Cascadia Coast Research, British Columbia

Scott Beatty and I studied wave energy together as graduate researchers at the University of Victoria, where we developed our skills and passion for marine renewables through that time. We now work together as partners in Cascadia Coast Research. Cascadia supports the marine renewable industry by providing science and engineering services in the areas of resource assessment, device modelling, laboratory testing and power performance assessment. As a partner in the West Coast Wave Initiative, we generated a detailed hind-cast of wave conditions and wave climatology of the British Columbia's Coast that has been fundamental to much of the subsequent wave energy research here on the west coast.

Marine renewables, particularly wave energy, requires a market where experience can be gained, trust can be generated and modest profits can be realized. Similar to what we are seeing in tidal energy, this market may be small and rely on stable government assistance, but we need commercial projects, successfully spending time in the water and generating electricity, to gain further traction.

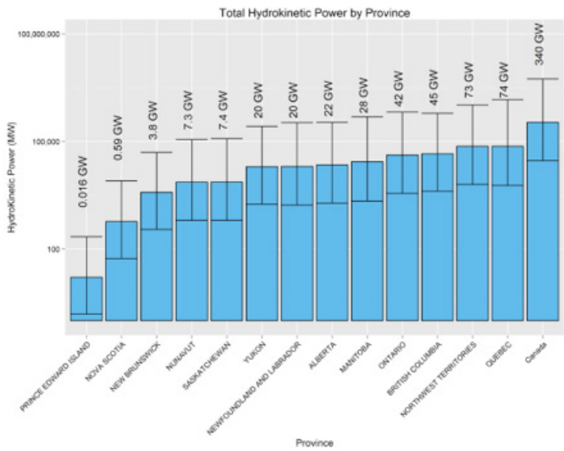
We continue to work in marine renewables because we are passionate about the work and feel we have the skills to advance the industry.

We continue to work in marine renewables because we are passionate about the work and feel we have skills to offer the industry.

Wave technology and project development

Canada has several wave energy technology developers who are various stages of testing and commercializing their technology; many of them are challenged by a lack of policy supports, market supports, and infrastructure. In spite of these challenges, there continues to be domestic and international interest in Canada's wave energy potential. In British Columbia, Global Energy Horizons, a Victoria and Australia-based Carnegie Wave Energy, have actively maintained an Investigative Use Permit for a region just off Ucluelet, British Columbia, since 2008[69]. This type of permit covers activities at the early stage of a major project, offering access to Crown land sites to determine how suitable the area is for the proposed development. Canadian company, NeptuneWAVE has also received an Investigative Use Permit for the testing of its 200 kW Neptune 5 device in Georgia Strait, British Columbia, and deployed its device in early 2018. *See table 6.0 for a list of Canadian wave energy device developers.*

6.3 River Current



Ocean, Coastal and River Engineering National Research Council of Canada, 2017. Assessment of Canada's Hydrokinetic Power Potential Phase III Report Resource Estimation.

Canada's best kept secret may be its huge potential in river current energy. Initial assessments have indicated that the theoretical energy potential of the country's rivers for in-stream (hydrokinetic) technologies could be up to 340 GW[70] - three times Canada's total installed electricity generating capacity. The greatest potential is in British Columbia, Quebec, and the Northwest Territories . Further work is underway to determine optimal locations for device deployment and project development. River current energy technology is very similar to tidal stream, however rivers only flow in one direction and often continuously, making it a reliable and predictable energy resource that may be used for base load generation.

While Canada has a significant river current energy potential, uptake and development of the sector has been slow. In commercializing the technology, several challenges exist – winter operations can be problematic due to ice, power efficiency strongly depends on the location of the turbine, and in many locations, stream size will fluctuate seasonally.

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[69] *Robertson, B. and et al., 2017.*
[70] *Natural Resources Canada. River hydrokinetic energy.* http://www.nrcan.gc.ca/energy/renewable-electricity/marine-energy/7371

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However, as efforts increase to assist remote communities in moving away from the use of diesel electricity generation, river current energy presents an attractive option. Many river current resources are near rural and remote communities; in addition to providing clean electricity, river current projects may also create opportunities for capacity-building and economic development. Beyond Canada, there are also many opportunities globally in remote communities and island nations for river current. River current devices are also a good match for constructed waterways, such as irrigation canals and aqueducts, providing an opportunity to use existing infrastructure for power generation.

Canada's Marine Renewable Energy Technology Roadmap recognized river current energy as a major advantage for Canada and outlined an action plan to support development . To date, Canadian companies, researchers and government have been working to develop the sector and a number of key actions have been realized.

Canadian Hydrokinetic Turbine Test Centre

The Canadian Hydrokinetic Turbine Test Centre (CHTTC) has been leading the majority of testing and research for river current energy. A collaboration between Manitoba Hydro and the University of Manitoba, the CHTTC is located on the Winnipeg River and provides a permitted site for the testing of river hydrokinetic technologies. It assists companies in accelerating the commercialization process, increasing technology readiness levels (TRL) and reducing development cost through access to a shared facility. The CHTTC has also been leading a number of critical studies on winter operations, array optimization, and integration of river current energy in remote communities to displace diesel generation.

Since 2013, CHTTC has carried out over fifteen deployments with several device developers including Mavi Innovations, New Energy Corporation, Jupiter Hydro, Clean Current Power Systems, and GEM Holdings. It has also collaborated with SMEs to provide services and innovation to the river current industry. To support the future development of river current projects, CHTTC has successfully finalized an instrumentation platform, started developing a low-cost velocity device for long-term marine resource assessment, and performed fieldwork on the Winnipeg River to validate its satellite resources assessment for river current sites. Researchers working at the site have also developed procedures for flow characterization. These allow customers and developers to have full knowledge of a potential site for development and make the most informed decision about the type of river current device to use.

[71] *Canada's Marine Renewable Energy Technology Roadmap, 2011.* http://www.marinerenewables.ca/wp-content/uploads/2012/09/MRE_Roadmap_e.pdf

CanmetENERGY

Natural Resources Canada's (NRCan) CanmetENERGY Marine Energy Technology Group has initiated a collaborative research project in advancing river current energy with the National Research Council (NRC), academia, and industry. This project aims to develop new methodologies for identifying river locations for river current energy projects using satellite images, to evaluate and improve river current energy systems performance, and to design technical guidelines for deployment of multiple turbines for large/utility scale projects.

River current energy technology and project development

In addition to activity at CHTTC, Canadian river current energy developers are gaining experience – particularly in remote communities – through demonstration in Canada and internationally. This includes Idénergie, which has partnered with Parks Canada to demonstrate six river current devices in Jasper National Park (AB). New Energy Corporation has been actively in developing river current energy in remote Canadian and international communities. In 2014 New Energy installed a 5 kW in Ringmo, Nepal, an isloated village in the Himalayas. In 2015, New Energy installed a hydrokinetic platform in Myanmar to power a school. The system includes battery storage and the ability to provide peak power of up to 20 kW. More recently, New Energy partnered with Sagkeeng First Nation in Manitoba to install a 25 kW hydrokinetic turbine in the Winnipeg River: work commenced to test the turbine in 2017; installation will begin in 2018. In partnership with CHTTC and NRCan/CanmetENERGY, the Winnipeg River project is fully equipped to monitor the turbine performance.

6.4 Offshore Wind

Although this report is primarily focused on tidal, wave, and river current energy, Canada also has excellent offshore wind energy resources. With the longest coastlines in the world, Canada has a major opportunity to advance offshore wind energy: a resource that is stronger (by up to 70 per cent) and more predictable than onshore wind.

Beyond domestic offshore wind opportunities, Canadian companies can also participate in a rapidly expanding international market. Globally, there are over 80 offshore wind projects operating in 15 countries in Europe, Asia, and, more recently, the US. At the end of 2016, there were 12,193 MW of offshore wind installed and an additional 6,300 MW under construction[72]. Based on projects in the pipeline, its estimated that growth between 2017-2022 will result in a cumulative installed capacity of 51,769 MW.[73] Toronto-based Northland Power Inc. owns 100% of the 252 MW DeBu offshore wind project and 60% ownership of a 600 MW Dutch

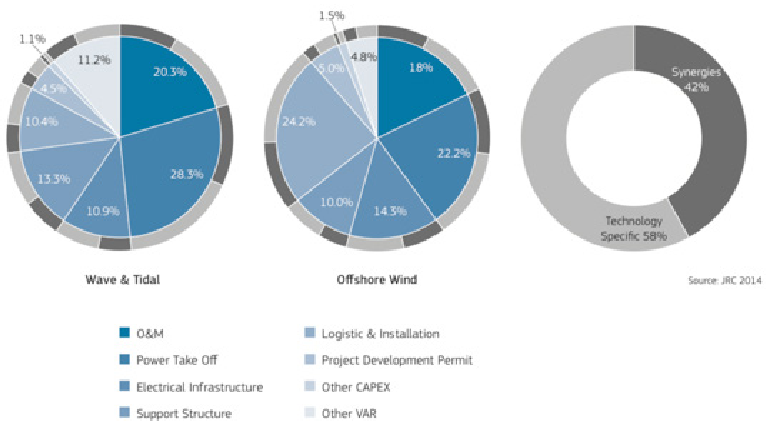
[72]National Renewable Energy Lab (NREL). 2016 Offshore Wind Energy Market Report, 2017. https://www.energy.gov/sites/prod/files/2017/08/f35/2016%20Offshore%20Wind%20Technologies%20Market%20Report.pdf
[73]NREL, 2017.

project totaling $4.2 billion. In 2015, Enbridge invested $750 million to take 25% ownership of a $3 billion, 400 MW project in the UK. Canadian financial institutions are also participating in the sector, with banks such as CIBC, BMO, and National investing in European offshore wind projects.

In response to growing market activity and supportive policy, Canadian developers are signalling interest. In 2017, British Columbia-based, NaiKun Wind Energy, executed a Letter of Intent with Orsted of Denmark to further advance its 400 MW offshore wind project proposed for Hectate Strait between Haida Gwaii and Prince Rupert[74]. On the east coast, Beothuk Energy has proposed several offshore wind projects including Prince Edward Island (200 MW), New Brunswick (500+ MW), St. Ann's Bay (500 MW), Yarmouth (1000+ MW), and Burgeo Banks (1000 MW).

By most measures, including project scale and investment level, offshore wind is more mature than other MRE technologies. This maturity has also propelled the rest of the sector. Offshore wind, wave, and tidal energy projects often operate in harsh environments and have similar supply chain and regulatory issues. From a project development and supply chain perspective, a study developed by the European Union's Joint Research Council (JRC) identified that about 42% of wave, tidal, and offshore wind energy projects have significant synergies[75].

SYNERGIES BETWEEN WAVE & TIDAL ENERGY AND OFFSHORE WIND



European Commission. Ocean Energy.
https://setis.ec.europa.eu/system/files/Technology_Information_Sheet_Ocean_Energy.pdf

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[74]*NaiKun Wind Energy. "NaiKun Wind Energy Group Forms Strategic Partnership with DONG Energy." September 12, 2017.* http://naikun.ca/naikun-wind-energy-group-forms-strategic-partnership-with-dong-energy/

[75]*Magagna D, & Uihlein A . 2014 JRC Ocean Energy Status Report: Technology, market and economic aspects of ocean energy in Europe, 2015.* https://www.eip-water.eu/sites/default/files/2015-JRC%20ocean%20energy%20report_v2.pdf

6.5 Supply chain development

The MRE sector's nascent state presents an opportunity. In Canada, at the local level, many studies indicate that 60-70% of goods and services could be supplied near a development site.[77] A broad range of skills, services, equipment, and materials are required at each development stage—from research and development through to environmental assessment and planning, engineering, manufacturing, cable installation, and ongoing operation and maintenance (O&M). Studies have also found that local operation and maintenance expenditures could exceed 80% of total annual O&M costs.[78]

This opportunity extends to the international market: a global supply chain is not yet established. Jurisdictions everywhere are faced with the same technical challenges and require new innovation to harness the resource(s) and produce competitive electricity. The market will grow even further as the sector matures and expands, opening more export opportunities for businesses that have experience, services, and supplies on offer.

Building a competitive supply chain is a key factor in realizing the benefits and long-term opportunities of MRE development. Already, a major focus for active MRE countries like France, the UK, Canada, and Ireland is the development of a supply chain that can service both local and global projects as the market grows. The competition is on.

Canadian suppliers are well positioned, with capabilities and experience from ocean technology sectors like offshore oil and gas, defense, and marine operations that directly translate to MRE sector activity – and many are gaining early experience. As mentioned earlier, even at this early stage, hundreds of businesses have been involved in the MRE sector across Canada. In addition to design and fabrication work, there has also been businesses and researchers assisting in R&D, environmental assessment, and modeling exercises.

The challenge for local suppliers has been the erratic pace of new technology development: hurry and wait. Despite the challenge of working in a not-quite commercial sector, suppliers across Canada have been finding regional, national, and international opportunities. Several suppliers have developed international partnerships that have led to critical enabling technologies, technical standards, research, and financial gain.

TURBINES MEAN BUSINESS:

Cape Sharp Tidal contracted local suppliers Aecon, Lengkeek Vessel Engineering, and Hawboldt Industries for the welding, testing, painting and assembling components for one of two open-centre tidal turbines and a large barge for deployment. Cape Sharp also contracted Atlantic Towing Limited to provide marine tug and barge services, as well as numerous other suppliers in the province.

[77]Gardner Pinfold Consultants Inc. & Acadia Tidal Energy Institute, 2015.
[78]Ibid.

THE COMPLETION OF THE FAST-3 SENSOR PLATFORM IN 2017, NOW GATHERING DATA IN THE BAY OF FUNDY, INVOLVED MANY SMALL TO MEDIUM-SIZED CANADIAN OCEAN TECHNOLOGY COMPANIES. A PARTIAL LIST INCLUDES:

- ASL Environmental Sciences (Saanichton, BC) – equipment supply and technical support
- CulOcean Consulting Ltd. (Halifax, NS) – site characterization and selection
- Earle MacAloney Excavation Ltd. (Parrsboro, NS) – on-land platform management
- Huntley's Sub-Aqua Marine (Kentville, NS) – vessel supply and marine deployment
- Kongsberg Maritime Canada Ltd. (Dartmouth, NS) – equipment supply and technical support
- OceanMoor Technical Services (Falmouth, NS) – marine technical management
- Open Seas Instrumentation (Musquodoboit Harbour, NS) – platform design and construction
- Seaforth Geosurveys Inc. (Dartmouth, NS) – platform deployment location evaluation and selection
- Velocity Machining & Welding (Dartmouth, NS) – high precision components for FAST-3 platform fabrication
- WPV Designs (Fall River, NS) – instrument mount fixtures design and fabrication

INNOVATIVE INTERNATIONAL PARTNERSHIPS:

- Rockland Scientific, Dalhousie University, Black Rock Tidal + FloWave TT, European Marine Energy Centre (EMEC), and Ocean Array Systems partner to develop a new sensor system to measure the impact of turbulence on tidal devices. Project results will be used to improve turbine designs and operation performance, as well as assessment of installation sites.
- Cascadia Coast Research, a research and engineering services company, focused on resource assessment, device modelling, laboratory testing and power performance assessment has supported the development of a hind-cast model for wave conditions off the BC coast, and has provided expert advice to both the US Department of Energy's Wave Energy Prize and Wave Energy Scotland's funding calls.
- Dynamic Systems Analysis (DSA), with offices in British Columbia and Nova Scotia, has played an important risk reduction role for the sector by providing modeling software that allows clients to understand how equipment will react under various weather and ocean conditions. DSA has been involved with tidal energy development in the Bay of Fundy, wave energy R&D in British Columbia, and new developments in UK and Asia

While Canadian suppliers have experienced early success in early research and demonstration activities, a stable, long-term supply chain ultimately depends on market growth. Predictable, long-term policy signals and a growing market – with progress towards more commercial projects – will ensure that suppliers commit long term business resources and investment.

BUILDING THE

FUTURE

marine renewables canada

INTERVIEW

Tim Brownlow, Director Industrial Relations
Peter Huttges, Coastal Business Manager

Irving/Atlantic Towing, Nova Scotia

The main catalyst for us to get involved was the opportunity to work with global companies to deploy tidal turbines in our own back yard. We have been working every day for the past 50 years plus in the Bay of Fundy, and no one knows the tides and or workings of the Bay more better than us.

We are the only marine company in Atlantic Canada to deploy and recover tidal turbines in the Bay of Fundy. That service is based on our exceptionally experienced crews and our equipment – designed for our Atlantic Canadian waters. It's also a better business case to use existing assets here, in the Maritimes, rather than bringing in much more expensive assets from overseas.

During our 50 years plus in service we've been involved with the oil and gas, defence, and marine transportation sectors. for over 50 years. That This pedigree enables us to transfer to marine renewables seamlessly: our client track record speaks for itself, especially in terms of our values and safe working practices. We know the Bay of Fundy, and we can transfer that knowledge to turbine deployment and recovery. And We didn't do this overnight – we had to prove our existing assets and knowledge would be successful, working very hard to earn the respect and trust of this new industry. And That's also the fun part: meeting with individual tidal companies, reviewing their unique technologies, and helping them to try to achieve their goals.

7.0 Research, innovation, and collaboration

Research and innovation are key ingredients to commercializing any new technology; in the MRE sector, they are critical to reducing costs, risks, and regulatory uncertainty. This section identifies key issues and research areas, including organizations involved in Canadian MRE sector research, as well as international collaborations and partnerships.

7.1 Innovation challenges and research needs

There are still many technical, environmental, and social challenges to be tackled in the emerging MRE sector. These challenges[79] often define the research: they are critical to industry advance, and thereby pose an opportunity for innovation and its associated rewards. Many key research areas are the focus of specific organizations, and drive their program funding:

Resource characterization – Solutions to offer a more detailed and accurate picture of existing and future the ocean energy resource conditions, such as wind speed, atmospheric temperature, wave height, tidal flow etc.

Environmental monitoring – Remote sensory solutions to better assess the condition and performance of ocean energy devices as a result device-environment interaction, e.g. biofouling, mammal and marine life interactions, turbulence.

Sensors and instrumentation - Sensors, equipment and platform for site assessment and monitoring tidal energy systems, as well as data collection. Challenges related to this area include: survivability and measurement validity in the high current, design to facilitate easy deployment and recovery, easy maintenance.

Advanced materials – Materials other than steel for the structure and prime mover, such as steel reinforced concrete, rubber or fibre reinforced polymer to provide advantages such as weight savings. Challenges include corrosion, protection from water absorption, and cavitation in the marine environment.

Control systems - Control systems and software that increase yield are needed to improve the way a device interacts with the marine resource e.g. adjusting pitch, yaw, height etc.

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[79] The list of challenges are compiled from the following reports: SLR Consulting. Marine Renewable Energy Supply Chain Development Ocean Technology Sector, 2013. https://energy.novascotia.ca/sites/default/files/mre_supplier_report_final_16may2013.pdf; SI Ocean. Ocean Energy: State of the Art, Strategic Initiative for Ocean Energy, 2013. http://si-ocean.eu/en/upload/docs/WP3/Technology Status Report_FV.pdf ; Carbon Trust. Technology Innovation Needs Assessment, 2012. https://www.carbontrust.com/media/168547/tina-marine-energy-summary-report.pdf

Electricity infrastructure and cabling - Electrical/electronic equipment, cabling and connectors associated with individual cables or subsea electricity conditioning equipment. Challenges include design survivability and durability in the high current environment, deployment, accessing for repair and maintenance and packaging of components for subsea use, and connection methods to turbines.

Foundations and moorings – Method and structural components used to anchor a device – can be moored, a floating structure (with flexible moorings), or a sea-based structure (e.g. gravity-based or foundations). Challenges include need for design optimization to improve durability and robustness, particularly for deep water installations and very high flow sites, and station-keeping technologies.

Deployment and recovery - Methodology and equipment to launch and deploy all aspects of MRE systems: cabling, subsea grid, turbines, mooring systems, monitoring instrumentation. Includes initial deployment and recovery for repairs and regular maintenance.

Array design optimization – Development of innovative design software tools and models to optimise performance of multiple device projects.

Operation and Maintenance – Operation & maintenance of a device over its lifetime. This will be influenced by the location of the device and its foundation. Challenges include the need to reduce time and cost of retrieval of devices and infrastructure solutions such as ROVs, site sensors, and appropriately equipped onshore facilities.

7.2 Engagement of universities and research organizations

The growth of the MRE sector depends on innovating in all areas of project development and building a body of knowledge that stretches across the globe. There are many Canadian and international organizations involved; while MRE sites may have varying characteristics and study objectives may also vary, research from international projects can play a critical role in supporting and informing Canadian activity.

International

In addition to demonstration and test sites *(see Section 4.2 for more information about international sites)*, there are several international organizations focused on applied research and technical innovation with the potential to speed the pace of development, reduce costs and risks, and build exportable expertise and technologies. The table below highlights a number of active initiatives. *(Note: there are numerous academic institutions involved in MRE; this list is specifically aimed at identifying organizations and consortiums intent on tackling technical and environmental challenges relevant to the Canadian MRE sector).*

Country	Organization/ Initiative	Overview
International	International Energy Agency's Ocean Energy Systems (OES) www.ocean-energy-systems.org	OES is an intergovernmental collaboration, which operates under framework established by the International Energy Agency in Paris. It currently has 25 members including Canada and focuses on key areas of research and collaboration such as: Cost reductions, environmental issues, grid integration, technology development, consenting processes, and wave energy modelling.
International/ United States	OES Annex IV www.tethys.pnnl.gov/about-annex-iv	Annex IV was established by OES to examine environmental effects of MRE development and is led by the United States. Annex IV coordinates research that can progress the industry in an environmentally responsible manner.
Chile	Marine Energy Research and Innovation Centre (MERIC) www.meric.cl	MERIC is a centre for marine energy R&D focusing on resource assessment, site characterization, bio-fouling, bio-corrosion, environmental and social impact and technology adaptation to extreme ocean conditions.
Europe	Oceanera-NET www.oceaneranet.eu	OCEANERA-NET is a network of 15 national and and regional funders and managers of research and innovation programmes, from 8 European countries.
France	France Energies Marines www.en.france-energies-marines.org	Resource assessment, simulation tools, foundations & moorings, reliability, electrical interconnection, offshore operations, energy storage
Ireland	Marine Renewable Energy Ireland www.marei.ie	A marine and energy-based research, development and innovation hub focused on scientific, technical and socio-economic challenges across the marine and energy spaces.
Scotland	Wave Energy Scotland www.waveenergyscotland.co.uk	Programs focused on power take-off, control systems, wave energy converters, structural materials and manufacturing processes.
United Kingdom	Energy Technologies Institute (ETI) Marine Energy & Offshore Wind Programs www.eti.co.uk	Supported 14 technical projects targeted at innovation in MRE and offshore wind.
United Kingdom	SuperGen Centre for Marine Energy Research www.supergen-marine.org.uk	Consortium of academic and industrial partners successfully led multiple phases of research on key challenges facing the sector including: Array planning, turbulence, power take off development, reliability, conversion and power conditioning, mooring and foundations, environmental and economic impact.
United Kingdom	Offshore Renewable Energy Catapult www.ore.catapult.org.uk	Leading technology and innovation centre for MRE (wave, tidal, offshore wind), focused on commercialization of new technologies.

Canada

The MRE sector benefits from significant research capacity in Canadian universities, associations, and networks. Academic institutions also serve a critical role in training – the skills required by future MRE personnel can be provided through new programs and course instruction. The following is a list of organizations currently involved in the sector *(Note: this list is only partial, intended to illustrate some of Canada's existing capacity and expertise.)*

Organization	Type	Location	Focus/Involvement
Acadia University/ Acadia Tidal Energy Institute www.acadiau.ca	University	Nova Scotia	Oceanography, resource modeling, marine ecology, sustainable environments and communities, economics and finance.
Cape Breton University www.cbu.ca	University	Nova Scotia	Marine ecology, sustainable environments, community sustainability
College of the North Atlantic www.cna.nl.ca	University	Newfoundland & Labrador	Investigating options for an emerging wave energy test site.
Dalhousie University www.dal.ca	University	Nova Scotia	Engineering, oceanography, policy; access to tank testing at Aquatron Laboratory
Fundy Energy Research Network (FERN) www.fern.acadiau.ca	Network	Nova Scotia	Coordinates efforts to address the environmental and technological challenges of tidal energy developments in the Bay of Fundy. Includes 4 sub-committees: Hydrodynamics & Geophysics, Biological & Ecological Effects, Engineering Challenges, Socio-Economics
Laval University	University	Quebec	Engineering, numerical modeling
Marine Technology Group – CanmetENERGY	Government	Ontario	Supports the development of MRE technologies, working with industry, other government departments and academia to address cross-cutting marine energy issues and guide technologies toward market success.
National Research Council www.nrc-cnrc.gc.ca	Government	Ontario	Physical and numerical modeling and analysis services in hydraulics including off-shore wind energy, wave or tidal energy generation and hydro power. (Ottawa) Testing facility for model validations and tow tank work. (Newfoundland)
Nova Scotia Community College (NSCC) www.nscc.ca	College	Nova Scotia	Energy Sustainability Engineering Technology (ESET) program, ocean technology program, various trade programs
Offshore Energy Research Association www.offshorenergyresearch.ca	Not-for-profit research funding	Nova Scotia	Supports research to enable the sustainable development of Nova Scotia's MRE resources through strategic partnerships with industry, government, and academia.

Organization	Type	Location	Focus/Involvement
Saint Mary's University www.smu.ca	University	Nova Scotia	Behaviour of sediments, effects on marine environment
University of Manitoba www.umanitoba.ca	University	Manitoba	Faculty of Engineering involved in the establishment of the Canadian Hydrokinetic Turbine Testing Centre (CHTC) and will be involved in development and research at CHTTC once activity commences
University of Victoria – Institute for Integrated Energy Systems (IESVic) www.iesvic.uvic.ca	University	British Columbia	Supports collaboration between science and engineers, economists, and environmental scientists to examine entire energy systems; supports research activities of the West Coast Wave Initiative (see Section xxx for more on WCWI)

Over the last decade, a strong network for research expertise and R&D facilities has emerged to support Canadian activity; the largest cluster located in Nova Scotia. Provincial universities, FORCE, the Offshore Energy Research Association (OERA) and others have contributed to a growing body of knowledge focused on environmental interactions, technical issues, and cost reductions. To date, Nova Scotia has seen over 95 research studies conducted – many focused on understanding interactions between tidal energy and marine life. OERA has funded many of these studies; in 2016, OERA commissioned the "Nova Scotia Tidal Research Summary Report"[80] summarizing the tidal-energy related research undertaken in the Bay of Fundy since 2007.

Since its establishment in 2012, the Acadia Tidal Energy Institute (ATEI) has been leading research, outreach, and engagement activities on tidal energy resource assessment, environmental and socioeconomic impacts, investment and financing, and sustainable community development. Among other research and tools and research, ATEI has developed a community and business toolkit for tidal energy development, a tidal energy atlas, and a community engagement handbook. Another initiative of Acadia University, the Fundy Energy Research Network (FERN), has been fostering collaboration around tidal energy research and established sub-committees that advise on key research priority areas across a number of disciplines.

In addition to many individual research studies, Dalhousie University has also been using its Aquatron Laboratory to develop the Vectron (the world's first instrument to accurately measure turbulence throughout the water column) and to study marine life in a controlled marine lab environment. The Aquatron is the largest university aquatic research facility in Canada with six large tanks, a variety of smaller tanks, and research spaces. It has been used by

[80] *Daborn, Graham. Nova Scotia Tidal Research Summary Report. Researching Tidal Energy – Marine Life: the Nova Scotia Experience, 2016.* http://www.oera.ca/wp-content/uploads/2016/05/Researching-Tidal-Energy-FINAL-May-2016.pdf

MRE developers and researchers to study the impact of hydrokinetic turbines on fish[81]. In early 2018, the Government of Nova Scotia and OERA came together to create the Aquatron Tidal Energy Research Program, targeted at supporting a reliable test environment for de-risking tidal related development activities[82].

In addition to activities and infrastructure in Nova Scotia, Canada has a number of other research initiatives and facilities to support MRE development.

In Newfoundland and Labrador and Ontario, the National Research Council's Ocean, Coastal and River Engineering Research Centre operates facilities that support technology development and research; this includes a 200-metre towing tank, an offshore engineering basin, wave flumes, a coastal wave basin, and an ice tank. Several MRE technology developers have used these facilities to assist with prototype development. Also in Newfoundland, the Marine Institute has a number of facilities for applied research related to ocean technology and marine operations, including a flume tank and acoustics tank.

In Manitoba, as mentioned earlier, CHTTC offers a commercial, real-world setting, with regulatory approval for hydrokinetic turbine deployment, retrieval, connection to the electrical grid using Canadian Standards Association (CSA) standards for testing devices, and measurement instruments to perform studies on the impacts of flows on turbines and the impact of turbines on the environment *(see Section 6.3 for more information on CHTTC).*

British Columbia is home to various MRE and ocean technology research and innovation activity, including wave energy research at University of Victoria's WCWI; the WCWI provides services to wave energy developers by using a network of wave measurement buoys and various modelling techniques *(see Section 6.2 for more information on WCWI).*

The Government of Canada has also been initiating research activities to support MRE development. CanmetENERGY and NRC have been working collaboratively to develop a MRE resources atlas, initially focused on British Columbia: the aim is a comprehensive assessment of tidal, wave and river hydrokinetic energy resources throughout the province. The atlas will provide a specialized geo-spatial analysis, mapping and decision support system to assist and inform industry, communities, and other stakeholders in identifying and evaluating sites for prospective development; the project will also provide an estimate unit cost of energy for wave, tidal and river hydrokinetic resources and estimate the potential future market penetration for MRE in the province.

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[81] Macneill, A., Mahon-Hodgins, L., Eddington, J., Batt, J., Bibeau, E., Kregting, L. and Molloy, S. Tidal Turbine-Fish Interaction Pilot Study in the Aquatron Controlled Lab Space, 2017. https://www.researchgate.net/publication/319644440_Tidal_Turbine-Fish_Interaction_Pilot_Study_in_the_Aquatron_Controlled_Lab_Space

[82] Charlton, Michael. "Dal's Cutting-edge Aquatic research facility to test tidal energy projects," January 26, 2018. https://www.dal.ca/news/2018/01/26/dal-s-cutting-edge-aquatic-research-facility-to-test-tidal-energ.html

7.3 Standards development

A thriving MRE industry is not possible without standards – standards that address the safe, reliable, and economical deployment of MRE devices. Standards are now being developed in Canada and internationally to reduce the technology risks (e.g. power performance, design, moorings) and other uncertainties. In 2007, the International Electrotechnical Commission (IEC) created the TC114 committee to prepare international standards for marine energy conversion systems (i.e. MRE devices). The committee's primary focus is on the conversion of wave, tidal, and other water current energy into electrical energy (although other conversion methods, systems, and products are included).

Shortly after the creation of TC114, a mirror committee was established in Canada through support from NRCan's ecoENERGY Innovation Initiative program. The Canadian sub-committee is comprised over thirty technical experts from industry, academia, and federal and provincial governments. These experts participate with the international community through IEC to develop consensus-based standards based on their experience, expertise, and knowledge of other similar standards. Canadian participation helps ensure the needs of Canada are addressed by the consensus-based standards development process. In collaboration with external partners, the Canadian sub-committee has completed eleven research projects investigating key questions to support standard development. The IEC TC114 has to date published eight standards[83] and expect to publish at least two additional standards in 2018.[83]

The creation of standards for the MRE industry has created many benefits. These include:

- a reduction in the cost of the resulting technologies
- an improvement in the knowledge to support the development of regulations, and
- a reduction in trade barriers which provides improved access to international markets for Canadian companies.

The standards have also been directly utilized in third party verification of marine renewable technologies and projects, which have a direct impact on reducing risk. Third party verification to these standards is in infancy, but is expected to also produce benefits through more competitive financing and insurance premiums for projects through demonstration of the reduced risk.

[83] *International Electrotechnical Commission. TC114 Marine energy – Wave, tidal, and other water current converters.* http://www.iec.ch/dyn/www/f?p=103:22:1962984316495::::FSP_ORG_ID,FSP_LANG_ID:1316,25

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FUTURE

marine renewables canada

INTERVIEW

Acadia Tidal Energy Institute (ATEI), Nova Scotia

(Left to right) Dr. John Colton, Dr. Shelley MacDougall, Dr. Richard Karsten, Dr. Anna Redden, and Dr. Graham Daborn.

Most of our understanding of the Bay of Fundy system gained in the last 100 years is a result of research attempting to answer tidal power-related questions.

Acadia's history with tidal power research is long - the first connection was with Professor Ralph Clarkson's 1915 proposal to use the force of the tide to pump water to the top of North Mountain in Kings County, Nova Scotia.

We hosted the first ever conference of scientists and engineers to discuss the environmental implications of barrage tidal power in the Bay of Fundy - and as the Annapolis Tidal Generating Station project took shape, Acadia played a prominent role in the Fundy Environmental Studies Committee (FESC) as well as spearheading research to understand its environmental footprint through the Acadia Centre for Estuarine Research (ACER).

In 2008, with tidal stream technology emerging, Acadia spearheaded the formation of the Fundy Energy Research Network (FERN) comprised of individuals and institutions involved in tidal energy-related research. In 2011, five Acadia faculty formed the Acadia Tidal Energy Institute (ATEI) and have been leading research, education, and outreach activities in this new wave of tidal energy development even since.

Those efforts have created critical knowledge and tools to support everyone with a stake in activity related to tidal energy. Specifically, Acadia research has provided accurate and detailed resource and site assessment, led understanding into potential environmental impacts, led numerous large collaborative research projects, led academic involvement in the industry through FERN and other activities, and informed policy development related to resource measurement, site assessment, environmental and social impacts, economic benefits, and financial support in Nova Scotia.

And that work continues. Acadia's research is broad, multidisciplinary, and continues to evolve – alongside Nova Scotia's century old exploration of tidal power. It's an adventure.

7.4 International collaboration

Canada has established itself as a leader in the global MRE market; along the way, Canada has developed strong international partnerships. These collaborations have been important for information-sharing, identifying research and business opportunities, and partnering to address critical challenges facing the global industry.

Over the past several years, Canadian universities, businesses, and organizations have established formal collaborations with groups from the UK, France, Chile, and Wales.

OERA has led a number of international collaborations including a memorandum of understanding (MOU) between Nova Scotia, OERA, and the United Kingdom's InnovateUK (formerly Technology Strategy Board (TSB)) was signed in 2014 to encourage joint research to develop new and innovative technology for high-flow tidal environments. The agreement was significant, as it led to a joint call for R&D projects focused on advancing environmental monitoring, sensing, and instrumentation. The call resulted in two projects[84] led by Canadian and UK businesses and researchers being awarded, totaling $1.4 million. OERA also established a formal MOU with France Energies Marine in 2016 to collaborate on research projects that will improve technologies and applications for tidal energy in the Bay of Fundy and off the coast of France.

Marine Renewables Canada has recently established MOUs with Marine Energy Wales[85] and ADEMAR (Chile) in an effort to share knowledge and identify areas for future collaboration.

[84]The two projects supported by the OERA-InnovateUK funding call included: 1) Emera, OpenHydro, Ocean Sonics, Acadia University + Tritech, Sea Mammal Research Unit (SMRU) and SMRU Canada: Project will deliver an innovative system using both passive and active acoustic sensor technologies to improve 'real-time' tracking of fish and mammals at tidal sites in the Bay of Fundy. 2) Rockland Scientific, Dalhousie University, Black Rock Tidal + FloWave TT, European Marine Energy Centre (EMEC), and Ocean Array Systems: Development of a new sensor system to measure the impact of turbulence on tidal devices. Project results will be used to improve turbine designs and operation performance, as well as assessment of installation sites.

[85]Marine Renewables Canada and Marine Energy Wales. "Wales and Canada strengthen marine energy ties," November 23, 2016. http://www.marinerenewables.ca/wales-and-canada-strengthen-marine-energy-ties/

8.0 Enabling policy, legislation, and programs

Although Canada is rich in MRE resources, development activity is tied to government support and policy drivers *(see Section 5.0 for more information on policy drivers)*. Energy policy differs from province to province, with each province having differences in its electricity mix, demand, and environmental and economic drivers. Consequently, MRE activity varies between jurisdictions. This section details the policy supports and programs that have been established at the federal and provincial levels that have a direct impact on Canadian MRE activity.

8.1 Policy and legislation

Government of Canada

At the federal level, recent initiatives to renew and establish existing legislation affecting resource development and environmental assessment directly impact the MRE sector and will likely support projects of greater scope and scale in the future.

Legislative framework

In 2011, the Government of Canada announced the establishment of a Marine Renewable Energy Enabling Measures program to work towards a framework for administering renewable energy activity in the federal offshore. In 2018, the Government of Canada introduced Bill C-69, which includes the proposed *Canadian Energy Regulator Act (CERA)*, legislation that would replace Canada's National Energy Board (NEB) with the Canadian Energy Regulator (CER). The Act gives the CER responsibility for regulating offshore renewable energy projects and associated offshore power lines and includes the ability to set future regulations as the offshore renewable energy industry matures.

Under CERA, a company planning any work or activity related to a future offshore renewable energy project and associated offshore power lines will need to apply for and receive an authorization from the CER before proceeding. Offshore renewable energy projects include research or assessment conducted for the potential development of renewable energy resources, the development of renewable resources to produce energy, and the storage of the renewable energy. The CERA is applicable to projects occurring in Canada's offshore, defining "offshore area" as Canada's internal waters or territorial sea that are not situated in a province, the Continental Shelf of Canada and the waters situated above it. Therefore, CERA will not apply to the Bay of Fundy, which has historically been part of Nova Scotia and New Brunswick.

Environmental Assessment

Over the course of 2016-17, the Government of Canada led an extensive review of environmental and regulatory processes to address concerns about the existing system. The outcome of the review were changes proposed in Bill C-69, including the Impact Assessment Act (IAA) and establishment of the Impact Assessment Agency of Canada (currently the Canadian Environmental Assessment Agency) to lead all federal reviews of major projects in cooperation with federal regulators (e.g. CER), provinces, territories, and Indigenous jurisdictions.

MRE falls under two categories under the IAA – projects will either require an impact assessment or a non-impact assessment:

- Impact Assessment: The new Impact Assessment will be required for projects listed under the "designated project" regulations (the Project List). Under the previous environmental legislation (Canadian Environmental Assessment Act 2012), the *Regulations Designating Physical Activities* established 50 MW as the threshold to trigger an assessment process for in-stream tidal. It is possible that this threshold may change depending on the current consultation process around the new designated projects list. It is also possible that offshore wind projects may be added to the Project List. If an offshore renewable energy project is a designated project on the Impact Assessment Project List it will be subject to an integrated review panel between the Impact Assessment Agency of Canada and the CER. The review panel would have a maximum timeline of 600 days, following the receipt of complete application, to review these projects.
- Non-impact Assessment: For offshore renewable energy projects that don't trigger an impact assessment (i.e. not on the Project List), the CER would have a maximum timeline of 300 days, following the receipt of complete application, to review these projects. The CER would consider numerous factors in this project review including: environmental effects, safety, health/social/economic effects, traditional knowledge of Indigenous peoples that have been provided, scientific information and data, interests of Indigenous peoples, and regional or strategic assessments.

British Columbia

The Government of British Columbia established a leasing policy for MRE projects in 2011: the Land Use Operational Policy for Ocean Energy Projects.[86] Under this policy, industry has sought investigative licenses to conduct some of the preliminary site work required to develop a project[87].

In 2015, the provinces of British Columbia and Nova Scotia renewed an MOU to encourage greater collaboration on tidal energy research and policy development[88]. The MOU outlined key priorities, including partnering on research and technology development, and sharing information best practices in regulation and permitting.

More recently, the Government of British Columbia released its 2018 Budget, which allocated $4 million over three years for the development of an "energy roadmap" aimed at supporting the transition from oil and gas to clean electricity. Roadmap development has yet to get started, but may have implications for the MRE sector.

New Brunswick

An administrative framework for the development of tidal energy on Crown lands – *Allocation of Crown Lands for Tidal In-Stream Energy Conversion Projects*[89] was established in 2011. The policy was developed to provide a controlled, incremental development approach for issuing leases.

Under New Brunswick's 2011 energy policy, *The New Brunswick Energy Blueprint*, government also committed to encourage research and development that would identify new cost effective and environmentally progressive methods of using tidal energy and other renewable resources.[90] New Brunswick's 2014-2020 Climate Change Action Plan reaffirms commitments to support the uptake of increased renewable electricity generation.

Nova Scotia

The Government of Nova Scotia has put a number of measures in place to support its 2012 Marine Renewable Energy Strategy, including the development of a Statement of Best Practices in collaboration with Marine Renewables Canada, updates to the Bay of Fundy Strategic Environmental Assessment (SEA) and the establishment of new legislation.

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[86]*Government of British Columbia. Land Use Operational Policy for Ocean Energy Projects, 2010.* http://www.for.gov.bc.ca/Land_Tenures/tenure_programs/programs/oceanenergy/index.html
[87]*Government of British Columbia. Applications and Reasons for Decisions (ARFD)* http://www.arfd.gov.bc.ca/ApplicationPosting/index.jsp?FileNumber=&SubPurpose=&Client=&PrimaryStatus=any&keyword=&Purpose=OCEAN+ENERGY&Submit=Submit&Region=&cp=1
[88]*Government of Nova Scotia. "Nova Scotia and British Columbia Collaborate on Tidal Energy," July 21, 2015.* https://novascotia.ca/news/release/?id=20150721003
[89]*Government of New Brunswick. Allocation of Crown Lands for Tidal In-Stream Energy Conversion Projects, 2011.* http://www2.gnb.ca/content/dam/gnb/Departments/nr-rn/pdf/en/Publications/CLM0222009.pdf
[90]*Government of New Brunswick. The New Brunswick Energy Blueprint, 2011.* http://www2.gnb.ca/content/dam/gnb/Departments/en/pdf/Publications/201110NBEnergyBlueprint.pdf

In 2015, Nova Scotia introduced its *Marine Renewable-energy Act* to provide a clear and efficient process to support the sustainable growth of the sector. In early 2018, the Act was proclaimed with amendments allowing for the demonstration of tidal stream energy technology in additional areas of the Bay of Fundy outside of the FORCE berths. The amendments provide a new development pathway, allowing for new entrants into Nova Scotia's tidal energy market, with the flexibility to propose a range of project sizes up to 5 MW. Under the amendments, a new permit system has been established for demonstration permits up to 5 MW, with no more than 10 MW of total power authorized under the Act. The permits can be for grid non-grid connected projects. As mentioned above, Nova Scotia's Minister of Energy awarded two permits under the new system in April 2018; additional permits may be awarded in the near future, with a number of Canadian and international MRE developers expressing interest.

8.2 Funding and support programs

Many governments around the world have invested in MRE development with grants, tax credits, or fixed price (feed-in tariff) contracts. Several countries, including the US, UK, New Zealand, and Spain, have developed funding programs specifically for MRE.

Aside from programs in Nova Scotia, there are few programs designed to specifically target MRE activity in Canada. However, there are numerous programs focused on clean energy, innovation, climate change, and ocean technology that can support MRE development.

Government of Canada

In 2015, a liberal government took federal office with a broad agenda to tackle climate change and advance innovation in Canada. *The Pan-Canadian Framework on Clean Growth and Climate Change* along with the federal government's 2017 Budget, included a number of programs that could support MRE development:

- $21.9 billion through the Green Infrastructure Fund (including millions for clean energy in remote communities and emerging renewable energy commercialization - more details below)
- $1.4 billion in increased financing support for clean technology available through the Business Development Bank (BDC) and Export Development Canada (EDC)
- $400 million over five years to recapitalize the SD Tech Fund led by Sustainable Development Technology Canada (SDTC)

- $200 million over four years to support clean technology research, and the development, demonstration and adoption of clean technology in Canada's natural resources sector to Natural Resources Canada, Agriculture and Agri-Food Canada, and Fisheries and Oceans Canada (more details below)
- $1.26 billion to a five-year Strategic Innovation Fund, and
- $21.4 million over four years starting in 2018-19 to Indigenous and Northern Affairs Canada to support the deployment of renewable energy projects in communities that rely on diesel

In 2017-18, NRCan developed and launched a number of new national programs targeted at emerging technologies, clean energy technology demonstration, and remote community energy sustainability, all having relevance to MRE, including:

- **Clean Growth in Natural Resources Program**: This program has a budget of $155M over four years to support clean technology research, development and demonstrations in Canada's natural resource sectors in the areas of energy, mining, and forestry. As part of this program, NRCan also established the Clean Growth Collaboration Community, an online platform tool that allows post-secondary institutions, utilities, the private sector, and the public sector to connect with Provincial/Territorial Departments, Federal Research Centres, and other stakeholders to discuss opportunities that could be supported by the Clean Growth program.
- **Emerging Renewable Power Program**: This program has a budget of $200 million over 5 years, under the Green Infrastructure Fund, with an objective to support the deployment of emerging renewable energy technologies not yet commercially established in Canada. The funding is aimed at supporting deployment of utility-scale renewable energy projects using technologies which have not yet been deployed commercially in Canada and expanding the portfolio of commercially-viable, investment-ready technologies available.
- **Clean Energy for Rural and Remote Communities Program**: With a budget of $220M over six years (starting in 2018/19) under the Green Infrastructure Fund, this program has an objective of reducing reliance on diesel in rural and remote communities and industrial sites by supporting the transition to more sustainable energy solutions.

To support and facilitate funding for clean energy and innovation, the Government of Canada has also established two new portals:

Clean Growth Hub: The Clean Growth Hub is a whole-of-government focal point for clean technology focused on supporting companies and project, coordinating programs, and tracking results. The Hub assists in identifying funding and other mechanisms that will support early stages of research, technology demonstration, export, and business growth. It is also equipped to provide information on policy, regulatory, and procurement issues.

Innovation Canada: Launched in 2018, Innovation Canada acts as a single point of contact for Canadian innovators and entrepreneurs looking to grow their businesses. The gateway service is aimed at connecting businesses with necessary resources such as funding, loans and capital, tax credits, wage subsidies, expert advice, and partnering tools that will support innovation efforts.

In addition to new programs and services, the Government of Canada has several existing programs that are relevant to MRE development. SDTC manages the SDTech Fund, aimed at. To date, it is estimated that SDTC has awarded approximately $25 million[91] to MRE technologies, however, some projects were not executed.

The federal government has also included MRE under its Scientific Research and Experimental Development (SR&ED) Program, a tax incentive program that provides claimants cash refunds and/or tax credits for expenditures on eligible R&D work done in Canada.

British Columbia

Under the *Pan-Canadian Framework on Clean Growth and Climate Change*, British Columbia and the Government of Canada have agreed to work together to spur the development and commercialization of new technologies that will reduce emissions and create jobs for Canadians. In April, the governments of British Columbia and Canada partnered to establish a $40 million joint fund with contributions from British Columbia's Innovative Clean Energy (ICE) Fund and SDTC. The funding available through this joint fund will leverage federal, provincial and private sector investments. The $20-million provincial contribution comes from the ICE Fund. The federal contribution will be provided through the SD Tech Fund, managed by SDTC.

The parties will conduct a joint call over a three-year continuous intake period to seek out clean-energy projects and technologies that will mitigate or avoid provincial greenhouse gas emissions, including prototype deployment, field testing and commercial-scale demonstration projects.

Nova Scotia

In order to create a market for tidal energy at this early stage in industry development, Nova Scotia established FIT for large-scale and community-scale (COMFIT) tidal energy projects ranging from .53 - .65 cents/kWh. To date, five developers at FORCE and three community-scale projects have been approved for the FIT program. Under Nova Scotia's *Marine Renewable-energy Act*, projects that receive a permit under the new 10 MW permitting program, can also receive a power purchase agreement (PPA) of up to 15 years at a price set by the Minister of Energy. Any utility in Nova Scotia will be required to procure all electricity under the PPA.

[91] *Sustainable Development Technology Canada (SDTC) funding contributions towards projects have been cited from the 2010 SDTC Annual Report Supplement: http://www.sdtc.ca/uploads/documents/2010_Annual%20Report%20Supplement_FINAL.pdf.*

In addition to market mechanisms, some organizations in Nova Scotia also have funding programs established specifically to support MRE and ocean technology. The OERA focuses on providing funding for research that will de-risk environmental and technical aspects of tidal energy and recently issued a number of collaborative and standalone calls for MRE research. In 2017, OERA and NRCan partnered to deliver a joint $1.25 million research call to address knowledge gaps and challenges associated with tidal energy development in Canada *(see Section 7.2 for more information about OERA).*

Innovacorp, a Nova Scotia organization with a mandate to identify, fund, and foster innovative start-ups, developed three ocean technology funding programs with applicability to MRE. Funding calls were launched in 2017 for: *1) Demo at Sea Program*, providing access to the Flume Tank at the Marine Institute in St. John's, Newfoundland and Labrador and FORCE's Fundy Advanced Sensor Technology (FAST) Platform; *2) Early Adopter Program*, providing Nova Scotia ocean technology companies with up to $20,000 each towards the first deployment and testing of a product with an early adopter customer; and *3) OceanTech Development Program*, providing up to $20,000 to address short-term milestones in their technology development plan.

Ontario

A FIT was established under *Ontario's Green Energy Act* in 2009 which includes a fixed price for waterpower projects, including river hydrokinetic. Projects must have an electricity generating capacity between 10 kilowatts (kW) and 5500 kW. The FIT offers a 40-year contract with a rate of 24.6 cents/kWh.

BUILDING THE

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INTERVIEW

Stephen Dempsey, Executive Director

Offshore Energy Research Association (OERA), Nova Scotia

From resource models to assessing near and far-field effects, OERA has been at the forefront of deepening our understanding of the potential tidal energy has for our future. Science closes critical knowledge gaps and benefits a wide range of stakeholders, including governments that regulate the sector and the private companies that invest in it.

Collaboration is critical to the effective growth of the emerging tidal sector. While tidal energy resources exist off the coasts of many countries, there are only a few that have chosen to support the early work necessary to initiate tidal energy developments. At the forefront of this effort are the UK, France and Canada. OERA has partnered with Innovate UK, that country's leading scientific research and development agency, to share the cost of research development projects in the area of 'sensors for high flow environments' – thus reducing costs for each partner, shortening project development cycles, and enabling effective international partnerships. OERA has also partnered with France Energies Marine, an organization that combines the research focus of OERA with the industry networks of MRC, to collaborate on research priority development and project selection.

OERA's legacy is completing the first tidal energy resource and strategic environmental assessments in Canada, supporting research, advising the province of NS on the conditions necessary for responsible deployment of tidal energy devices and working with regional, national and international partners to create the technologies and innovations necessary for success.

9.0 The Path Forward

Marine renewable energy is a new sector that poses challenges, but also many benefits. Over the last decade, Canada and other countries with significant MRE resources set aspirational targets for installed capacity, with the ambition to develop policies and programs to achieve those goals. The industry has been slower to develop than expected; because of that, some companies have failed, price competitiveness is still an issue, and investors are concerned about the financial risk. But the potential for a new global industry still exists and becomes more viable as the world increases its focus on finding climate change solutions. Activity to date has created a solid foundation to create and sustain an industry; infrastructure and technology investments can leverage further growth. But a multi-faceted, strategic approach to MRE development is still lacking; Canada is courting the opportunity, but has not yet fully committed. The following steps could help secure Canada's competitive advantage in MRE sector development.

Create the market path to commercialization

Achieving widespread deployment of MRE requires strategic, parallel action in technology development and market creation to close the cost gap. At this stage in development, securing private sector investment and financing requires a certain level of risk-sharing and market pull mechanisms like FITs and PPAs. Research and development (R&D) alone will not deliver the necessary performance improvements and cost reductions.

Approach innovation strategically

Reaching higher levels of installed capacity and achieving cost reductions is dependent upon innovating, gaining experience from early projects, and reducing costs through a "learn-by-doing" approach. Finance and funding, policy support, and a means by which technology developers, supply chain companies, industrial partners, utilities, researchers, and investors can collaborate and share risks is a key factor in achieving commercial viability of the resource.

Several countries have implemented programs specific to MRE to foster innovation. The adoption of a similar approach in Canada could build on its current foundation and consolidate activity to pursue common innovation and development needs.

Increase knowledge and building confidence

Demonstrating technologies and project methods is crucial to gathering data and monitoring environmental effects. This information is important for determining whether any adverse environmental impacts exist and developing safety and mitigation measures when deemed necessary– a key aspect of building public confidence and support. The ability to demonstrate technologies and project methods in the marine environment will require straightforward and effective permitting processes to allow installations (especially smaller applications) to proceed in a timely manner.

Ensure responsible and sustainable development

Working with Indigenous and local communities is imperative in the development of the MRE sector. Early engagement and relationship-building will not only build trust, but it will ensure that the benefits and risks of the project are well understood – assisting developers in learning how local communities may want to be involved. Introducing a new industrial activity to an environment that already has many users and uses can create concern and opposition, but co-existence can be achieved through open lines of communication, information-sharing, and ultimately, meaningful engagement.

Identify and support competitive advantages for supply chain growth

While Canada has an opportunity to take advantage of the emerging supply chain opportunities, there currently are gaps in determining which areas Canada has a competitive advantage versus areas for collaboration or importing. While it is well recognized that Canada has strengths in areas such as site characterization, ocean technology and sensing equipment, detailed analysis is required to identify the capacity of firms to work in these areas, assess capabilities of these companies, and assess the export value and potential revenue creation of these subsectors. Further work and analysis of these topics will also help to encourage engagement among firms and support the development of a true business case.

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Acronyms

CHTTC	Canadian Hydrokinetic Turbine Test Centre
FERN	Fundy Energy Research Network
FORCE	Fundy Ocean Research Center for Energy
IEA	International Energy Agency
NRCan	Natural Resources Canada
OERA	Offshore Energy Research Association
OES	Ocean Energy Systems
SDTC	Sustainable Development Technology Canada
WERC	Wave Environment Research Centre
WCWI	West Coast Wave Initiative

Glossary

Array
A set of multiple devices connected to a common electrical grid connection.

Berth
A berth is a defined area for testing and/or development of a MRE project using single or multiple devices.

Extractable potential
The actual value of the theoretical resource that can be exploited using existing technology options, taking account of current technology limitations. Constraints such as water depth, estimated spacing requirements, and device capture and conversion efficiency assumptions will need to be considered.

Gigawatt (GW)
A unit to measure the capacity of large power plants or of many plants. One gigawatt (GW) = 1,000 megawatts = 1 billion watts.

Grid-connected
Electrical generation devices connected to the utility grid and generating electricity.

Kilowatt (kW)
A unit used to measure electricity output, typically applied to measure output of households and large appliances.

Megawatt (MW)
A unit used to measure the output of a power plant or the amount of electricity required by an entire city. One megawatt (MW) = 1,000 kilowatts = 1,000,000 watts.

Strategic environmental assessment (SEA)
A systematic decision support process, aiming to ensure that environmental and possibly other sustainability aspects are considered effectively in policy, planning and program making.

Supply chain
A supply chain is a system of organizations, people, activities, information, and resources involved in moving a product or service from supplier to customer. Supply chain activities transform natural resources, raw materials, and components into a finished product that is delivered to the end customer.

Theoretical potential
Theoretical maximum energy contained within the overall resource.

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