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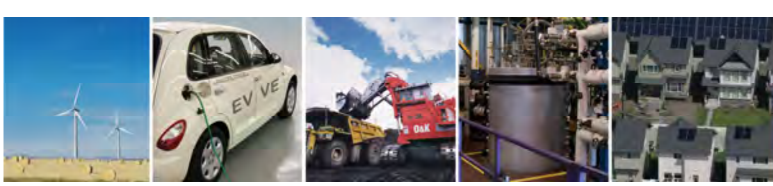
Sector Profile
An Assessment of the Marine Renewable Energy Sector in Canada – Now and in the Future



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Executive Summary

Today, most Canadian provinces encourage the development of new power production facilities to be independently owned (rather than government-owned), especially for renewables. Independent power producers own the facilities to generate electrical power and sell it either to provincial utilities or to end users.

As a result of current and longer-term market trends, many provinces have included renewable energy policy directives in their energy plans, energy efficiency mandates and renewable portfolio standards (RPS). For example, provincial utilities have been mandated to reduce fossil fuel usage and are seeking to diversify their renewable energy resource mix. As 18 percent of Canada's GHG emissions come from the electricity generating sector [1], renewables can contribute directly to their reduction, meeting electricity needs with clean, non-emitting energy sources and replacing traditional fossil-based forms of electricity generation. Renewable energy supports provincially legislated RPS policies and energy targets and diversifies the energy supply, contributing to its security.

Canada is exceptionally rich in wave, in-stream tidal and river current energy resources. Modeling studies estimate that ocean energy could provide 20 percent of Canada's potential renewable energy supply over the next 40 years. And marine renewables also present an emerging global market for early adopters and technology leaders. Canada can maintain a strong, out-in-front position if early initiatives are followed through.

Marine energy technology development today

The energy potential of waves, in-stream tidal and river currents have attracted the attention of more than a dozen technology developers across Canada. With so many technologies still under development, there is no clear indication which will prove to be the most efficient or cost-effective. Many of the marine energy converter devices are still at the concept, prototype or pre-commercial stages; some are approaching full-scale deployment for grid-connected electricity. Technology developers are trying to establish their leadership by developing partnerships with utilities, system integrators, manufacturers and independent power producers.

At the same time, the Canadian research and academic communities are helping accelerate the commercial deployment of these technologies by working to answer questions to help ensure technology adoption. Canada's academic community has significant expertise and R&D facilities in the field of marine renewable energy; by partnering with the academic community early in the process, technology developers can benefit from the training of highly qualified personnel that will be able to enter the workforce with knowledge directly applicable to the sector.

Supporting the development, demonstration and commercialization of marine renewable energy technologies are numerous programs such as Natural Resources Canada's Clean Energy Fund and Sustainable Development Technology Canada (SDTC).

Emerging trends

The creation of partnerships between technology developers and larger multi-national integration and manufacturing companies has also been identified as a growing trend. Partnerships have also developed between utilities or independent power producers and technology developers for specific demonstration projects internationally and within Canada. They support the sector by clearly indicating that there is a interest from the utilities and power producers for the technologies and commercial opportunities for the development of the resource.

Industry associations have also been created to support the development of the marine sector on an international and national level.

Powerful potential

The ability to build confidence in marine renewable energy requires technologies to be proven in operational environments as well as a clear understanding of the extractable resource and the potential for job creation and other economic benefits. For these reasons, a short-term priority has been placed on technology demonstrations. Enabling collaboration, avoiding the repetition of known mistakes, and providing sector-wide solutions to common problems is also necessary to assist the sector in being successful. Pursuing realistic and efficient approaches to skills and technology transfer is equally critical.

With the right momentum, resources and strategies, Canada could become a marine renewable energy leader. On the east coast, where provinces such as Nova Scotia are pushing to reduce fossil fuel reliance, this leadership opportunity is especially strong. More broadly, the country's hydropower expertise can be leveraged to support and accelerate the development of in-stream tidal and river current applications.

Learning from the experiences of the Canadian wind sector, a roadmap for marine renewable energy is needed sooner rather than later. This roadmap should provide the necessary guidance on how to move forward and where to focus efforts and resources, inventorying Canadian strengths, capabilities and gaps so that companies can capitalize on what exists and prepare and position for future areas of growth.

Introduction

Canada's marine renewable energy sector has more than a dozen technology developers working on devices to extract energy from waves, tidal currents and river currents. Many of these devices are still at the concept, prototype or pre-commercial stages, while others are approaching full-scale deployment for grid-connected electricity.

In this emergent sector, the path from prototype testing to commercialization is faced with barriers that need to be addressed to ensure the realization of the industry. Strategic guidance for sector and for public and private stakeholders is clearly required. A window of opportunity is open now to develop a technology roadmap that will provide the necessary perspective and direction.

Before setting the technology roadmap process in motion, it is necessary to have a complete understanding of the sector as it stands—its current status and the potential market opportunity for renewable energy technologies.

This sector profile report is a collaborative effort between CanmetENERGY, Natural Resources Canada (NRCan) and Natural Power. Funding for this report was provided by NRCan and Industry Canada. The report provides background information on the Canadian electricity market structure as well as a view of energy market trends and renewable energy integration. It also includes an overview of activities in the marine renewable sector, explores the role of marine energy in the future energy market, and concludes with a summary of opportunities and potential risks to the development of the emerging sector.

Government’s role in the electricity sector

Federal responsibilities

The federal government’s responsibility in the electricity sector is related primarily to the constitutional authority over international and interprovincial trade and commerce (e.g., construction and operation of international transmission lines, regulation of electricity exports to the United States). These responsibilities are within the authority of the National Energy Board (NEB), a federal regulatory tribunal [2]. The federal government also leads in areas such as energy science, technology and research, as well policy related to natural resource development for energy generation. The environmental assessment of proposed project developments, such as electricity generation, is an additional area of joint responsibility shared between the federal and provincial governments; with balanced involvement of each level determined by various environmental, regulatory and funding considerations [3].

Provincial responsibilities

The provinces have exclusive jurisdiction over the development and management of electricity generation—and therefore energy policy and regulation—within their respective boundaries. Any regulatory initiatives to increase electricity production or set renewable energy generation targets originate within the provinces. Marine renewable energy generation, however, is unique in that there is potential to develop projects outside of the boundaries of any one province and into offshore areas of federal jurisdiction. When projects are developed outside of provincial boundaries, the federal government has jurisdiction over the development and management of these projects.

Canada’s electrical energy structure
The Constitution of Canada assigns jurisdiction over electricity and natural resources to the provinces; as a result, this has led to independently designed and operated electricity systems according to each province’s bureaucratic structures and energy resources.

Each province has established regulators, licensing authorities and Crown corporations to administer electricity generation, distribution and sales. Most electric utilities are provincial Crown Corporations owned in total or in part by the provinces, with a growing mix of public and private ownership of assets. For example, in Quebec, Saskatchewan and Manitoba, a single Crown utility is responsible for electricity generation and distribution; Alberta has established a fully-structured electricity system, separating generation, distribution and sales to create a competitive wholesale and retail electricity market; Ontario has open access transmission, wholesale and retail markets, but remains heavily regulated; and British Columbia and New Brunswick have each completed the separation of their generation and transmission components in a move towards a competitive model while still retaining a Crown utility.

Across Canada, most of the provinces encourage the development of independently-owned power production plants, especially for renewables. Independent power producers own facilities to generate electrical power to sell to provincial utilities, directly to the end user or to supplement their own electricity usage.

As provinces have moved towards competitive models or have privatized, the role of independent, quasi-judicial regulators has increased. The following is a list of the energy regulatory bodies with responsibility in each province:

- ***British Columbia:*** British Columbia Utilities Commission
- ***Alberta:*** Alberta Utilities Commission
- ***Saskatchewan:*** Provincial Cabinet, upon recommendation from Saskatchewan Rate Review Panel
- ***Manitoba:*** Manitoba Public Utilities Board
- ***Ontario:*** Ontario Energy Board

- ***Québec:*** Régie de l'énergie
- ***New Brunswick:*** New Brunswick Energy and Utilities Board
- ***Nova Scotia:*** Nova Scotia Utility and Review Board
- ***Prince Edward Island:*** Island Regulatory and Appeals Commission
- ***Newfoundland and Labrador:*** Board of Commissioners of Public Utilities
- ***Yukon:*** Yukon Utilities Board
- ***Northwest Territories:*** NWT Public Utilities Board
- ***Nunavut:*** Government of Nunavut

Energy market trends

What's happening today

The encouragement of independent power producers to develop, own and operate electricity generation facilities is a result of several key market trends, including: greenhouse gas (GHG) emissions reductions; the development of carbon markets; grid reliability and security; strategic infrastructure replacement; demand side management; local economic development; energy diversification; and voluntary markets.

GHG reductions

The Government of Canada has committed to reducing total GHG emissions by 17 percent from 2005 levels by 2020 [4]. All of the provinces have commitments or objectives in place to reduce GHG emissions through a variety of strategies that will be discussed in detail in this section in accordance to provincial mandates summarized in Appendix A.

Development of carbon markets

Green energy export opportunities and state-/province-imposed renewable energy portfolio standards related to GHG emissions management are having a significant influence on Canada's electricity market. Four Canadian provinces and seven U.S. states have partnered in the Western Climate Initiative[1], which is developing a regional carbon market cap-and-trade program [5]. The Regional Greenhouse Gas Initiative (RGGI) includes ten U.S. states (with three provinces acting as observers) working collaboratively to reduce CO2 emissions [6]. Once these cap-and-trade markets are implemented, it is expected that they will drive growth in the renewable energy sector. Quebec and New Brunswick are overtly discussing the export market as a driver for clean energy and the BC Green Energy Task Force considers it to be a priority item on its agenda.

Grid reliability and security

As the demand for electricity increases, grid reliability and security continues to be a topic of concern. Provinces want to ensure that there is sufficient electricity to meet demand while mitigating risks that may cause disruptions to power supplies. Reducing external reliance on energy and creating a more dependable supply with more predictable costs is a top priority [7]. Self-sufficiency (i.e.: generating energy from within the province, to meet their needs) is now a strategic goal of several provinces, including British Columbia and New Brunswick (which have set self-sufficiency goals of 2016 and 2026, respectively).Grid planning and development is another emerging priority that is being looked at seriously across jurisdictions.

Strategic infrastructure replacement

Strategic planning and financial investments into Canada's aging transmission infrastructure will be needed to transport power from new sources, such as renewables, to demand centres, and to improve the efficiency of supply systems. The increase in renewable power plants has major implications on the design of the transmission grid because distribution of renewable resources is often geographically dependent, unlike traditional fossil-fuel based generation.

[1] Members include British Columbia, Manitoba, Ontario, Quebec, Arizona, California, Montana, New Mexico, Oregon, Utah and Washington.

Along with increasing energy demands, Canada's aging electricity generation facilities adds an additional level of complexity to long-term infrastructure planning. Foresight and planning is required to determine which sources of power generation (i.e. traditional fossil-fuel, nuclear or renewables) will be used to meet these growing demands and replace existing facilities that are approaching the end of their lifecycle. .

Demand side management
Demand side management is an approach that looks to change the habits of end users to reduce electricity demands during peak periods. In doing so, overall grid system efficiency can be improved and power producers can eliminate or delay investment in power plants or supply infrastructure. It is generally the responsibility of the provincial utilities to develop and manage demand side management programs.

Local economic development
The addition of domestic content requirements to renewable energy development regulations represents an effort to maximize the local economic opportunities associated with electricity generation in Canada. The encouragement of community and Aboriginal engagement in the development of renewable energy projects is another trend across Canada aiming to further encourage local economic development.

Energy diversification
Diversity in the resources used to generate electricity contributes to reliability and can be used to minimize the costs, losses and security issues typically associated with a centralized electricity generation model. Increasing the percentage of electricity from geographically distributed, scalable and renewable sources adds a new dimension to provincial energy mixes and can help reduce the generation variability and storage requirements.

Voluntary markets
More prevalent in the United States than in Canada, voluntary markets are energy markets that allow consumers to voluntarily select whether their electricity is supplied by renewable or non-renewable sources [8]. Voluntary markets create investment directed at green energy resource development.

Projections for the longer term
Beyond the trends listed above, there are also many drivers that, while not influencing decisions today, are expected to affect planning decisions in the near future. These include:

Smart grid
Involving a broad range of utility applications, the smart grid aims to enhance and automate the monitoring and control of electrical distribution to reduce overall energy use, manage peak use and improve reliability [9]. Because of the two-way communication between the demand and the production of electricity, the smart grid may be able to optimize the load and distribution in real time, allowing for a greater integration of the variability of renewables into the grid.

Electrification
Traditional fuels are increasingly being replaced by electricity to meet the demand of new technologies like electric transportation or the use of electric drives in industry. The conversion to electricity will significantly alter the energy mix in Canada. Although forecasts of energy needs have not been able to assess the impact of switching to electricity by consumers and industry, the available resources to generate clean electricity may make electrification an area of interest to Canada.

Energy Storage

Energy storage technologies are being developed with the intent of smoothing the intermittent and variable (i.e.: non-firm) characteristics of renewable resources and facilitating grid integration. Energy storage provides an opportunity to increase the ability of renewables (based on variable resources) to meet supply demands. Energy storage may also be used to manage peak supply, improve reliability and decrease overall system capacity and would compliment a system that includes smart grid and / or electrification.

Off-grid and remote communities
Many communities in Canada still rely on diesel-powered generators. In order to reduce fuel costs as well as GHG and noxious emissions in these communities, governments, utilities and local groups are placing a priority on finding better electricity sources. Renewable energy technologies may provide a good opportunity to meet the off-grid, distributed and scalable generation needs of these remote communities. In addition, renewable energy technologies may lead to the creation of jobs and other potential local economic benefits to these communities.

Renewable energy in relation to market trends

As a result of current and longer-term market trends, many provinces have included renewable energy policy directives in their energy plans, energy efficiency mandates and renewable portfolio standards (RPS) [10]. For example, provincial utilities have been mandated to reduce fossil fuel usage and are seeking to diversify their renewable energy resource mix. For more insight into the current and future demand for renewable energy in Canada, see Appendix A for a review of each province's mandates and strategies.

What is renewable energy?

Renewable energy is energy obtained from resources that can be naturally replenished or renewed within a human lifespan—that is, a sustainable source of energy. Some natural resources, such as moving water, wind and sunshine, are not at risk of depletion from their use for energy production. Energy production from these sources is also considered non-emitting because combustion is not used in order to generate electricity.

With its large landmass and diversified geography, Canada has an abundance of renewable resources that can be used to produce energy [11].

The increase of renewable energy in our electricity mix provides important opportunities that fit directly with the trends in the electricity market. Eighteen percent of Canada's GHG emissions come from the electricity generating sector [2]. Renewables directly support the Government of Canada's goal of reducing GHG emissions and meeting most electricity needs through the use of clean, non-emitting energy sources. Renewable energy supports provincially legislated RPS, policies and energy targets. Renewables also contribute to diversification objectives to enable greater security through the provision of a geographically distributed electricity supply.

The varieties of renewable energy

Hydroelectricity is by far the most significant contributor of renewable energy produced in Canada, with hydro sources providing approximately 59% of Canada's electricity. Other forms of non-emitting renewable energy experiencing high growth rates in Canada include run-of-river, wind and solar energy.

Due to their high energy density and reliability, Canada's oceans and rivers have the potential to become major contributors of renewable energy—whether it's the conversion of energy from ocean waves, tidal flows or river currents.

Wave energy can actually be considered a concentrated form of solar energy, as the sun heats the surface of the ocean creating wind, which in turn creates waves. In-stream river current technology uses the flow of the river to turn turbines. Modern in-stream tidal technology developments are focused on harnessing tidal currents and are most useful in regions with high tidal ranges and natural constrictions such as straits, narrows or fjords. Tidal current resources are more dependable and predictable than any other renewable resource, including hydropower.

Efforts to collect energy from tides, currents and waves are now being explored on Canada’s east and west coasts and in rivers across Canada [12]. The Ocean Renewable Energy Group (OREG) believes that renewable energy from our oceans has the potential to contribute a significant portion of Canada's current and future energy demand—perhaps 20 percent of the new capacity to be developed by 2050 [13]. While renewable energy currently supplies only a small amount of Canada's total energy needs, there is great potential for expansion.

Renewable energy challenges

Utilities face three key challenges when it comes to increasing the usage of non-emitting renewables: variability, costs and infrastructure:

Variability

First, there are the issues associated with the intermittency and variability (i.e., the non-firm characteristics) of renewable energy sources. Although this varies by the type of renewable energy, it is a challenge utilities and electricity suppliers must address (as this is not an issue with traditional methods of electricity generation). While energy storage provides an opportunity to address these issues, it is not currently being employed on a commercial scale.

Cost

The second key issue relates to the short- to medium-term cost of renewables. The costs of more mature renewable electricity supplies (such as wind or solar) have declined significantly over the past two decades and are expected to continue to drop with experience and economies of scale. Similar cost reductions are also expected of less mature renewable energy technologies.

That said, the availability of abundant conventional energy resources and amortized heritage assets in Canada (e.g., large hydro electric, natural gas and coal facilities) contribute to continued low production prices for electricity, which make it difficult for renewable electricity to be selected on a direct and current cost basis. The emergence of environmental and social costing mechanisms in the years ahead may provide some certainty and incentives for the renewable energy electricity market, but without explicit price corrections to reflect the true marginal costs of new energy development, this challenging situation will not change. As one sector representative said: “electricity in Canada is undervalued and renewable electricity is really undervalued.”[13]

Marine renewable energy costs are still largely unknown; predictions of the potential costs in the decades to come are very difficult to estimate accurately. However, marine renewable energy is expected to achieve a highly competitive cost position as it matures and as non-renewables become more expensive due to fuel and carbon costs.

Infrastructure

The third major challenge relates to the planning of transmission infrastructure upgrading at a time when many of the prime sources of potential new renewable energy developments are not close to existing generation or demand areas. Long-term grid planning is required to consider the full range of potential renewable energy options that may come online during the system’s operational life.

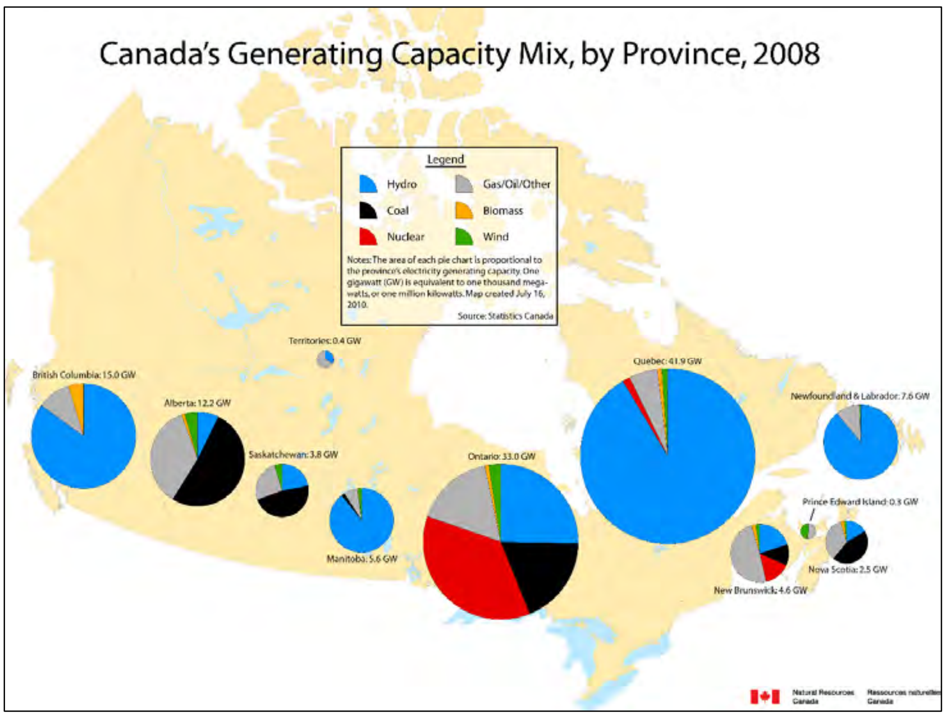
Energy supply and demand

It is estimated that Canada's total end-use energy demand will increase at 0.7 percent per year from 2007 to 2020, primarily due to slower economic growth assumptions as well as energy demand management and environmental programs [10]. In the electricity supply outlook proposed by the NEB, the generation capacity of electricity is expected to increase 20.7 percent between 2008 and 2020 [10].

Demand for renewable energy in Canada's electricity market

The figures below provide a breakdown of electricity generation by province and fuel type for 2008—clearly illustrating the need for renewable energy (other than traditional hydro) to play a larger role in Canada's electricity market mix in order to achieve national/provincial emissions or renewable energy generation targets. By 2020, the NEB expects wind energy to experience a more than 592 percent increase (from 2008 levels) in installed capacity to 16,400 MW; other generation technologies such as biomass, waste heat, solar and tidal are expected to increase by 139 percent (from 2008 levels) to 3,750 MW [10].

Figure 1: Map of Canada's Generating Capacity Mix, by Province, 2008



To reduce GHG emissions and air pollution, the provinces have shown interest in increasing renewable energy generation into their electricity mix. In addition, provincial governments are increasingly active in promoting the deployment of emerging renewable energy, including marine renewables. An in-depth overview of provincial climate change, energy and electricity plans is provided in Appendix A; highlights on mandates and timelines are listed below [7].

Province	Target
British Columbia	Energy self-sufficiency by 2016; reduce GHG emissions to 33 percent below 2007 levels by 2020.

Province	Target
Alberta	Reduce GHG emissions to 50 percent below 2005 levels by 2050.
Saskatchewan	Reduce GHG emissions to 20 percent below 2006 levels by 2020.
Manitoba	Reduce GHG emissions to 6 percent below 1990 levels by 2012.
Ontario	Reduce GHG emissions to 6 percent below 1990 levels by 2014, 15 percent by 2020 and 80 percent by 2050.
Quebec	Reduce GHG emissions to 6 percent below 1990 levels and include 3,500 MW of renewable energy by 2035.
New Brunswick	Legislated RPS of 10 percent of electricity sales by 2016; reduce GHG emissions up to 2 Mt below 2003 levels by 2020.
Nova Scotia	Legislated RPS of 15 percent by 2010,and 25 percent by 2015; stated intent to increase RPS to 40 percent of total electricity supply by 2020. Reduce GHG emissions to 10 percent below 1990 levels by 2020.
Prince Edward Island	Legislated RPS of 15 percent by 2010; stated intent to increase RPS to 30 percent of total electricity supply by 2013. Reduce GHG emissions to 10 percent below 1990 levels by 2020.
Newfoundland and Labrador	Eliminate 1 million tonnes of GHG emissions per year by 2015; reduce GHG emission to 10 percent below 1990 levels by 2020.
Yukon	Increase renewable energy supply by 20 percent by 2010.
Northwest Territories	Reduce GHG emissions to 10 percent below 2001 levels by 2011.
Nunavut	No specified energy targets.

Canada’s marine energy sector at a glance

All over the world, researchers are looking at different ways of extracting energy from marine environments: ocean and tidal currents, tidal rise and fall, wave motion, salinity and thermal gradients, submarine geothermal, marine biomass and river currents, to name a few. Given the make-up of Canada’s marine resources, our renewable energy sector is focusing most of its attention on waves, tidal currents and river currents.

As of 2008, Canada was home to more than a dozen wave and tidal energy companies with renewable energy technologies under development [14]. While activity in this field has significantly increased over the last few years, many of the devices are still in the early stages of .development. A 2008 survey showed that approximately 52 percent of wave and tidal current technologies were within the concept phase and 46 percent were in various stages of testing/demonstration [14].

Research development and demonstration

With so many technologies still under development, there is no clear indication as to which ones will prove to be the most efficient or cost-effective. As such, many technology developers are trying to establish themselves as sector leaders by developing partnerships with system integrators, manufacturers and utilities. At the same time, the Canadian research and academic communities are helping to accelerate the commercial deployment of these technologies by working to answer the questions that many technology developers simply do not have the capacity—for example, due to a lack of time, money, staff, facilities or modelling expertise—to answer on their own.

Academic and research working groups

Canada's academic community has significant expertise and R&D facilities in the field of marine renewable energy; by partnering with the academic community early in the process, technology developers can benefit from the training of highly qualified personnel that will be able to enter the workforce with knowledge directly applicable to the sector.

Examples of international academic working groups include:

- **SuperGen Marine:** A partnership of research staff from academic institutions in the United Kingdom. Its second phase, which began in 2007, defined 12 workstreams to understand the device-sea interaction of energy converters from prototype to commercial-scale.
- **International Network of Offshore Renewable Energy (INORE):** Encourages collaboration and discussion between young researchers working on offshore wind, wave or tidal energy. INORE has created several arenas, including an annual symposium and an online discussion forum, in order to provide opportunities for early-stage researchers to discuss their work and learn from the experiences of others.
- **Wavetrain RTN (Research Training Network):** A three-year project initiated by Portugal's Wave Energy Centre in 2004, it focused on training researchers in the technical aspects related to wave energy. Wavetrain2 is currently operating with a larger focus on both the technical and non-technical barriers associated with the commercialization of wave energy.

To remain at the forefront of technology innovation, intensive research efforts are needed to reduce development costs and commercial uncertainty. Within Canada, the research community, which includes experts from a variety of related disciplines, are working to alleviate the load on technology developers to address technology-specific issues.

Examples of Canadian research working groups include:

- **Fundy Ocean Research Centre for Energy (FORCE):** A cooperative of researchers, scientists, developers and regulators that owns and operates the first North American tidal demonstration facility in the Bay of Fundy. FORCE also includes an Environmental Monitoring Advisory Committee (EMAC) that provides independent and expert ecological knowledge and advice on the environmental effects of FORCE's monitoring programs.
- **Fundy Energy Research Network (FERN):** Launched by Acadia University in 2008, it helps communicate, coordinate and collaborate marine-related environmental research activities in the Bay of Fundy.
- **Offshore Energy Environmental Research (OEER)** and **Offshore Energy Technology Research (OETR):** Not-for-profit corporations that encourage and fund research work.
- **West Coast Wave Collaboration Project (WCWCP):** A network of researchers, engineers and industry partners that collects and analyzes wave data to validate the development of industry-standard modelling tools.

National research activities

There exist several federal research facilities with expertise and infrastructure to support the development of this sector. Examples of research organizations that are involved in various research and development activities include:

- **Natural Resources Canada**: NRCan's CanmetENERGY is the nation's largest centre for clean energy research and technology development. Its marine energy group is currently the only federal program dedicated to marine energy R&D initiatives, helping to further develop wave, tidal and river current technologies by providing expert technical advice, delivering federal R&D projects and programs and forging national and international networks that facilitate the sharing of knowledge, expertise and best practices..
- **National Research Council (NRC)**:The NRC has two world-class research centres with facilities and expertise that are applicable to marine renewable energy research and testing: the Institute for Ocean Technology (IOT) and the Canadian Hydraulics Centre (CHC).
- **Fisheries and Oceans Canada (DFO):** DFO's Bedford Institute of Oceanography is a leader in assessing oceanographic impacts of offshore exploration and development and has long history in ocean and ecosystem science.

International research and development initiatives

Recognizing that marine energy is an important new area of research, development and deployment, several collaborative organizations have been created to help address the R&D challenges facing the deployment of these technologies.

Canada plays an important role in many of these international organizations, including:

- **International Energy Agency (IEA):** Established to implement an international energy programme, the IEA acts as policy advisor to countries on energy-related issues, including renewable energy. The IEA's Ocean Energy Systems Implementing Agreement (OES-IA) facilitates and coordinates ocean energy research, development and demonstration through international cooperation and information exchange—ultimately leading to the deployment and commercialization of ocean energy technologies. Canada currently holds a position on the IEA Executive Committee.
- **International Electrotechnical Commission (IEC):** The leading organization in the creation of international standards for all electrical and electronic technologies. With the expected growth of the marine energy sector, the codes and standards developed through the IEC are critical in moving technologies forward by providing concise guidelines for device designers, manufacturers, regulators and operators. In 2007, the IEC established Technical Committee 114 (TC 114) to address the need for standards related to marine energy converters.

  Canada currently holds the position of Chairman of TC 114 and Project Leader for two of its working groups. A Canadian subcommittee of TC 114 was also established to ensure that Canada's views and requirements are well represented at the international level.

Public sector investment

As renewable marine energy technologies advance toward commercialization, public sector investments to the marine energy sector have been increasing. Significant initiatives have been taking place around the world in recent years, including the United Kingdom, the United States, Spain, Portugal, New Zealand, Korea and Norway.

For example, in 2007, the U.S. Department of Energy established a research program in marine and hydrokinetic energy, including wave, current (tidal, in-stream and ocean) and ocean thermal energy conversion. In 2008, approximately $10M USD was invested in advanced water power research, mostly related to ocean energy activities [15]; by 2010, the DOE that investment had increased to more than $37M USD for marine and hydrokinetic energy technology development [16].

In Canada, the public sector is becoming more aware of the opportunities associated with marine renewable energy and has been engaging in efforts to better understand the full potential of Canada's rivers and oceans. Natural Resources Canada's Clean Energy Fund has awarded $146 million (over the next five years) to support renewable, clean energy and smart grid demonstrations across the country; among the projects supported through the Clean Energy Fund is FORCE, which will use the funding to support the purchase and installation of the electrical cables required to deliver tidal-generated electricity to shore. Another funding mechanism available to developers of renewable energy technologies is Sustainable Development Technology Canada (SDTC), which aims to help develop and demonstrate innovative clean technologies. To date, seven marine energy technologies have received SDTC funding, totalling close to $20M.

Technology and sector trends

With only a few technologies with demonstrations in the open sea, technology development and activities are beginning to show clear technology trends. One example is the similarity between in-stream river and tidal current technologies. Tidal turbines, which are designed for bidirectional flow, only need some modifications to be applicable to uni-directional flow for in-stream river applications. Technologies which are suitable for both in-stream river and tidal current applications have increased market opportunity.

The UK is currently considered to be a leader in this sector as they have many wave and tidal technologies under development and had the first multi-berth tidal and wave testing center off the coast of Orkney at the European Marine Energy Centre (EMEC). However, there is still the recognition for the need for large scale commercial testing facilities. Countries such as Portugal, Spain, Ireland and the U.S. are forging ahead on building multi-unit testing facilities. While the FORCE demonstration facility, in Canada, currently only tests individual tidal turbines, FORCE is intending to be the first test centre in the world to test small arrays.

The creation of partnerships between technology developers and larger multi-national integration and manufacturing companies has also been identified as a growing trend. These partnerships have developed between utilities or independent power producers and technology developers for specific demonstration projects internationally and within Canada. Such partnerships support the sector by clearly indicating that there is an interest from the utilities and power producers' for the technologies and commercial opportunities for the development of the resource. Some examples of utilities and independent power producers who have shown early stage interest in the marine renewable sector include: EDF, E.ON, Scottish Power, SSE Renewables, Nova Scotia Power, Alstom, Voith-Seimens, and Rolls-Royce. These partnerships help validate the market opportunity for the sector.

Industry associations

Industry associations have been created to support the development of the marine sector on an international and national level. The European Ocean Energy Association "represents the interests of the sector through its regular contact with European institutions" [17] . RenewableUK (formerly the British Wind Energy Association) represents renewable energy industry interests in the UK. The Ocean Renewable Energy Coalition (OREC) and the Ocean Energy Council (OEC) to support activities in the U.S., the Marine Renewables Industry Association (MRIA) to support Ireland's activities, and Aotearoa Wave and Tidal Energy Association (AWATEA) supports marine activities in New Zealand. The Ocean Renewable Energy Group (OREG) supports activities in Canada, and currently has the largest membership in a dedicated marine renewable energy association in the world.

Marine energy's role in the future energy market

Forecasts of the role marine energy will play in future energy markets vary widely. The National Round Table on the Environment and Economy has suggested a contribution of 14,000 MW of wave and tidal energy is needed to attain 2050 GHG reduction targets [18]. OREG supports this target and has incorporated it into its vision of "A Canadian ocean energy sector deploying 15,000 MW by 2050; creating sustainable benefits for Canadians and exporting technology and expertise in the global market" [13] A Pollution Probe report on Canada's Potential Green Power (2025) projected a broad mix of renewables with 500 MW each from wave and tidal sources by 2025, as shown in the table below [19].

Table 1: Potential Green Power Portfolio for 2025 as reported by the Pollution Probe

GREEN POWER
VISION & STRATEGY

Potential Green Power Portfolio for 2025

TECHNOLOGY	CAPACITY (MW)	CAPACITY FACTOR (PER CENT)	ELECTRICITY GENERATION (TWh)
Wind – onshore	21,000	30	55
Wind – offshore	3,400	40	12
Small hydro	10,000	50	44
Biomass	4,500	80	32
Geothermal	500	95	4
Solar	1,000	14	1
Wave	500	30	1
Tidal	500	30	1
TOTAL	41,400		150

A paper titled 'A Path to Sustainable Energy by 2030' published in the November 2009 edition of *Scientific American* suggests that the transition to a carbon-free energy system is achievable by 2030 [20], describing a global scenario that includes 500,000 tidal generators and 750,000 wave energy converters by 2030. This would be huge growth for the sector and, while welcome, requires an enabling environment to be realized.

The often-referenced Forum for Renewable Energy Development in Scotland, Marine Energy Roadmap sets out high-, medium- and low-penetration scenarios [21]. The low scenario is set at 500 MW; medium at 1000 MW and high at 2000 MW of installed capacity by 2020.

The broader UK Energy Research Centre, Marine Renewable Technology Roadmap has put forward a vision for installed capacity of 2 GW by 2020 in UK waters [22], whereas the UK Crown Estate has a targeted goal of 700 MW by 2020 in just the Pentland Firth region of the Orkneys in northern Scotland [23].

Opportunities for marine renewable energy

It is understood that marine renewables will be considered alongside other renewable energy sources for investment and policy support. The following drivers have been identified as the rational to justify and encourage investments in marine energy in Canada.

Environmental benefits

Marine renewable energy provides a clean and sustainable energy source. When included in a provincial electricity portfolio, marine renewables will help provinces meet their renewable mandates and GHG emissions reduction targets in addition to supporting the federal government's climate change commitments. Marine renewables provide diversification and can be developed where other renewable resources may be non-existent or are limited. Similar to other renewables, marine renewable technologies are scalable and can be deployed in remote locations (to reduce the dependence on diesel) as long as the resource exists.

Resource potential and energy characteristics

Canada is exceptionally rich in tidal current, wave energy and in-stream energy resources. Modeling studies estimate that ocean energy could provide 20% of Canada's potential renewable energy supply over the next 40 years [24]. This significant, untapped resource has an energy density up to 50 times that of wind and 100 times solar PV, and is more predictable than wind and solar power.

Economic prospects

Marine renewables present an emerging global market for the early adopters and leaders in the technology, engineering, shipbuilding, marine fabrication, marine operations experience, project development, finance and services industries. Canada can maintain a leadership position if early initiatives are followed through.

Access to the growing U.S. clean electricity market is an especially important economic opportunity. Marine energy offers the Canadian power export and trading sector additional clean energy export options, particularly in the northeastern and western states.

To access these opportunities, it is possible for the marine energy sector to adapt technologies and infrastructure from other industries (rather than inventing them afresh), and to capitalize on extensive skills available in other sectors, including those where Canada is a recognized expert.

Successful initiatives in countries like Scotland, which include the country's high support tariff, strength of commitment to the sector and, critically, visible and consistent support message from government to local communities and sector—are being explored by provinces in Canada such as Nova Scotia.

Canadian innovation and expertise

Technology and expertise transfer are viewed as key strengths for the east coast of Canada due to the experience in the offshore oil and gas sector. Not only may marine renewable energy become a new business opportunity, but the experience of developing a manufacturing, supply, services and support sector alongside the oil and gas sector development also provides a strategic advantage. The east coast of Canada may become a global leader in marine development as a result of the urgency some provinces are placing on efforts to reduce fossil fuel reliance, with Nova Scotia as a key example. There is also an opportunity to leverage Canada's hydropower expertise to support and accelerate the development of both tidal current and in-stream river applications.

Focus within the provinces, linked to a technology roadmap based on the significant tidal and wave resources, could result in a dramatic acceleration of development efforts within the marine renewable sector.

Leadership and strategy

Canada is routinely identified as a global leader in marine renewable energy, following the UK and closely tied with the United States. A key opportunity exists, as there are not yet any dominant marine energy technologies or dominant supporting technologies: the market remains wide open.

The FREDS report provides the marine sector in Scotland a clear vision of the potential and future in its vision "To create the world's leading marine energy industry, one that will provide a substantial contribution to the sustainable economy and environment of Scotland.” [21] This vision appears to be getting traction both within the sector and in the public domain, both of which are critical making the vision a reality.

OREG has consistently pointed to the need to focus on the development of a marine energy sector in Canada. Based on discussions with industry, associations and political leaders in Europe, OREG has attempted to advance a vision for the sector in this country. To maximize its natural resource advantage, Canada, in partnership with OREG and industry, is well equipped to develop a clear vision that will secure opportunities and meet anticipated challenges.

Risks to Canada’s marine renewable energy sector

Without a relevant strategy and a commitment to support Canada’s emerging sector, marine energy may repeat the wind sector’s experience of becoming a technology and expertise importer. Uncertainty of scale, scope and timing will delay investment and capacity building until much has developed in other countries. A reliance on external expertise, experience and technology causes investment to flow to foreign suppliers, in which case Canada will miss out on the current opportunity to export its own technology, services and expertise.

Waiting on foreign demonstrations and deployments would cause Canada to become a late adopter, failing to use its excellent marine energy resources for domestic use in the near term, and in the longer term not meeting its GHG emission reductions or opportunities to export technologies and green power.

Developing a strategy

The lack of a national strategy or roadmap is one of the most critical barriers to the sector’s development [25]. The need for a comprehensive strategy at the national, provincial and regional level will provide a clear pathway for large-scale technology development and deployment.

Learning from the experiences of the Canadian wind sector, a roadmap for marine renewable energy is now under development. This roadmap should provide the necessary guidance on how to move forward and where to focus efforts and resources, inventorying Canadian strengths, capabilities and gaps so that companies can capitalize on what exists and prepare and position for future areas of growth. This should provide direction for sector, public and private stakeholders to advance the R&D, technology, services and the capacity to support commercialization. This guidance has the potential to accelerate the country’s competitiveness in the international marine renewable energy market.

At the same time, a strategy should identify critical development milestones leading towards commercialization of a technology, and to determine areas of strategic opportunity/advantage.

Cost

Cost to the consumer is a significant consideration when utilities consider the prospect of renewable energy inputs onto the grid. Reducing this cost is critical for marine renewable energy to be a commercially viable option. While in the medium to long term marine energy is expected to be competitive, it is currently a challenge to gain support from utilities, regulators and the public.

With no apparent short-term market for marine renewable electricity, the sector is strained to find the capital needed to develop and test devices. Critical federal funding programs include the Clean Energy Fund, STDC and the Industrial Research Assistance Program (IRAP), as well as the provincial Innovative Clean Energy (ICE) Fund in British Columbia. These programs, their funds and the support they provide are essential to early deployments of technologies. Even so, there remains a funding shortfall for the stage after single-device demonstrations moving to multi-device arrays.

Operational experience

The ability to build confidence in marine renewable energy requires technologies to be proven in operational environments as well as a clear understanding of the extractable resource and the potential for job creation and other economic benefits. For these reasons, a short-term priority has been placed by industry on technology demonstrations.

Finding ways to enable collaboration to avoid repeating known mistakes and providing industry-wide solutions to common problems is necessary to assist the sector in being successful. Pursuing realistic and efficient approaches to skill and technology transfer is equally critical.

The marine renewable energy supply chain

With the sector currently considered to be pre-commercial, the development of a supply chain does not seem to be high on the priority list. Yet it is wise to develop this infrastructure early on—to ensure it is in place once technologies are commercially ready.

Defining requirements for suppliers, skills transfer and human resources is needed to respond to growth projections. The detrimental effect of time delays and external supply chain reliance experienced in the wind sector need to be taken seriously. The wind sector imports technologies, services and expertise that could have been developed in Canada. A marine energy sector strategy addressing supply chain considerations should be undertaken earlier rather than later to proactively avoid similar consequences.

Appendix A: Provincial climate change commitments and renewable energy plans [7]

Province	Ministry	Plan/Date	Objectives	Timeline
British Columbia	Ministry of Energy	Clean Energy Act (June 3, 2010)	Achieve electricity self-sufficiency at low rates; new investment in clean, renewable power and energy security; create jobs in every region.	**2012:** Reduce GHG emissions to at least 6% below 2007 levels **2016:** Electricity self-sufficiency Reduce GHG emissions to at least 18% below 2007 levels **2020:** Electricity self-sufficiency plus 3,000 GWh Reduce GHG emissions to at least 33% below 2007 levels **2050:** Clean and renewable energy target of 93% Reduce GHG emissions to at least 80% below 2007 levels.
Alberta	Department of Energy	Launching Alberta's Energy Future (December 2008)	Clean energy production; wise energy use; sustained economic prosperity	**2015** Three to five projects expected to store about 5 million tonnes of CO2 a year **2020** Reduce emissions by 50 Mt **2050** Reduce emissions by 200 Mt 50% reduction in GHG emissions relative to 2005 levels.
Saskatchewan	Ministry of Energy and Resources	Climate legislation (December 1, 2009)	This legislation was designed to create: - a "Saskatchewan Technology Fund," which would collect payments from large emitters to invest in low-emission and emission-reducing technologies, - a Climate Change Foundation, intended to promote public awareness of and research into low-carbon technologies.	**2020** Reduce GHG emission by 20% from 2006 levels

Province	Ministry	Plan/Date	Objectives	Timeline
Manitoba	Innovation, Energy and Mines	Beyond Kyoto, Manitoba's Green Future, Next Steps: 2008 (April 2008) The Climate Change and Emissions Reductions Act (Bill 15) was Assented to June 12, 2008	Address climate change, to encourage and assist Manitobans in reducing emissions, to set targets for reducing emissions and to promote sustainable economic development and energy security	**2012** 6% below 1990 levels (legislated) Reduce emissions by approximately 3Mt (from 20 Mt to 14 Mt) **2016** 1000 MW of wind generated electricity
Ontario	Ministry of Energy and Infrastructure	Ontario's Green Energy Act (GEA), received Royal Assent on May 14, 2009	Increased development of renewable power with a focus on both these actions' economic and environmental benefits. Conservation, renewable energy and Smart Grid technology are all priority areas	**2014** Reduce GHG emissions to 6% below 1990 levels; Phase out Ontario's coal-fired generating plants. **2015** A 50% increase in clean renewable electricity capacity **2020** Reduce GHG emissions to 15% below 1990 levels (reduction of 99 Mt); Reduce the carbon content of transportation fuels by 10% by 2020 (using a low-carbon fuel standard) **2025** Save 6,300 megawatts of electricity through conservation by 2025 **2050** Reduce GHG emissions to 80% below 1990 levels
Quebec	Ministère des Ressources naturelles et de la Faune	Using Energy to Build the Quebec of Tomorrow, released in 2006,	Energy supply security, economic development, empowerment of local and First Nations communities, energy efficiency, sustainable development.	**2012** Reduce emissions to 6% below 1990 levels **2015** New electricity projects totalling 4,500 MW Reducing petroleum product consumption by 2 million TOE 4,000 MW of wind-generated electricity **2035** 3,500 MW of renewable energy (part of which would come from wind power and emerging sources) added to the capacity already called for in the energy strategy.

Province	Ministry	Plan/Date	Objectives	Timeline
New Brunswick	Department of Energy	Climate Change Action Plan: 2007 – 2012, released June 2009	Invest in tidal and wind power research and commercialization. Foster development of renewable energy opportunities	**2012** GHG emission reductions of 5.5 Mt annually Reduce GHG emission from public operations by 25%, as measured from 2001 levels **2016** 10% of electricity sales must come from new renewable sources according to Legislated Renewable Portfolio Standard **2020** Reduction of up to 2 Mt below 2003 GHG levels **2026** Position New Brunswick for self-sufficiency.
Nova Scotia	Department of Energy	Renewable Electricity Plan, released in April 2010	Grow the economy while protecting the environment, Invest in tidal and wind power research and commercialization.	**2013** Deadline for Renewable Energy Standard: 18.5% of NSPI electricity (post-2001 supplies) must come from new clean renewable sources **2015** 25% of total electricity supply must come from renewable sources according to Legislated Renewable Portfolio Standard **2020** Deadline for GHG reductions to 10% below 1990 levels; Deadline for 20% increase in energy efficiency; Renewable energy target of at least 40% total electricity supply
Prince Edward Island	Department of Environment, Energy and Forestry	The Prince Edward Island Energy Strategy and Prince Edward Island and Climate Change: A Strategy for Reducing the Impact of Global Warming, both released in 2008	Energy Security, environmental sustainability, economic development Invest in wind power research and commercialization.	**2013** Target to double (the province's) legislated renewable energy portfolio standard from 15% to 30% **2020** 10% for GHG emissions below 1990 levels **2025** Reduce the amount of CO2 emitted per megawatt hour of electricity use by 20% of current emissions

Province	Ministry	Plan/Date	Objectives	Timeline
Newfoundland and Labrador	Department of Natural Resources	Focusing Our Energy, released in 2007,	The energy strategy outlines four key focus areas — oil and natural gas, electricity, environment and economy	**2015** Elimination of 1. million tonnes of GHG emissions per year **2020** Reduce emissions to 10% below 1990 levels
Yukon	Department of Energy, Mines and Resources	Energy Strategy for Yukon, published in January 2009 Yukon Government Climate Change Action Plan, which was released in February, 2009.,	Improving energy efficiency and conservation, producing more renewable energy, meeting electricity needs, responsibly developing oil and gas and making good energy choices.	**2015** Reduce Yukon government's internal operations' GHG emission by 20% **2020** Increase renewable energy supply in Yukon by 20% Yukon government's internal operations become carbon neutral Increase energy efficiency in Yukon by 20%
Nunavut	Energy Secretariat	Ikummatitt: The government of Nunavut Energy Strategy, released in 2007	Improve the security of the energy system by reducing reliance on imported fossil fuels, diversifying energy supply to include clean, alternative energy and domestic energy sources. Reduce the impact on the environment by reducing energy-related emissions which contribute to pollution and climate change	No specific GHG reduction targets. Aim to monitor, document and adapt impacts of climate change.
Northwest Territories	Department of Environment and Natural Resources	- Energy for the Future: An Energy Plan for the Northwest Territories (2007), - Draft NWT Hydro Strategy (2008) - Energy Priorities Framework (2008)	Reduce reliance on diesel fuel, development and use of energy resources and provide the tools required to implement energy conservation and efficiency initiatives	**2011** 10% reduction in GHG emissions below 2001 levels

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