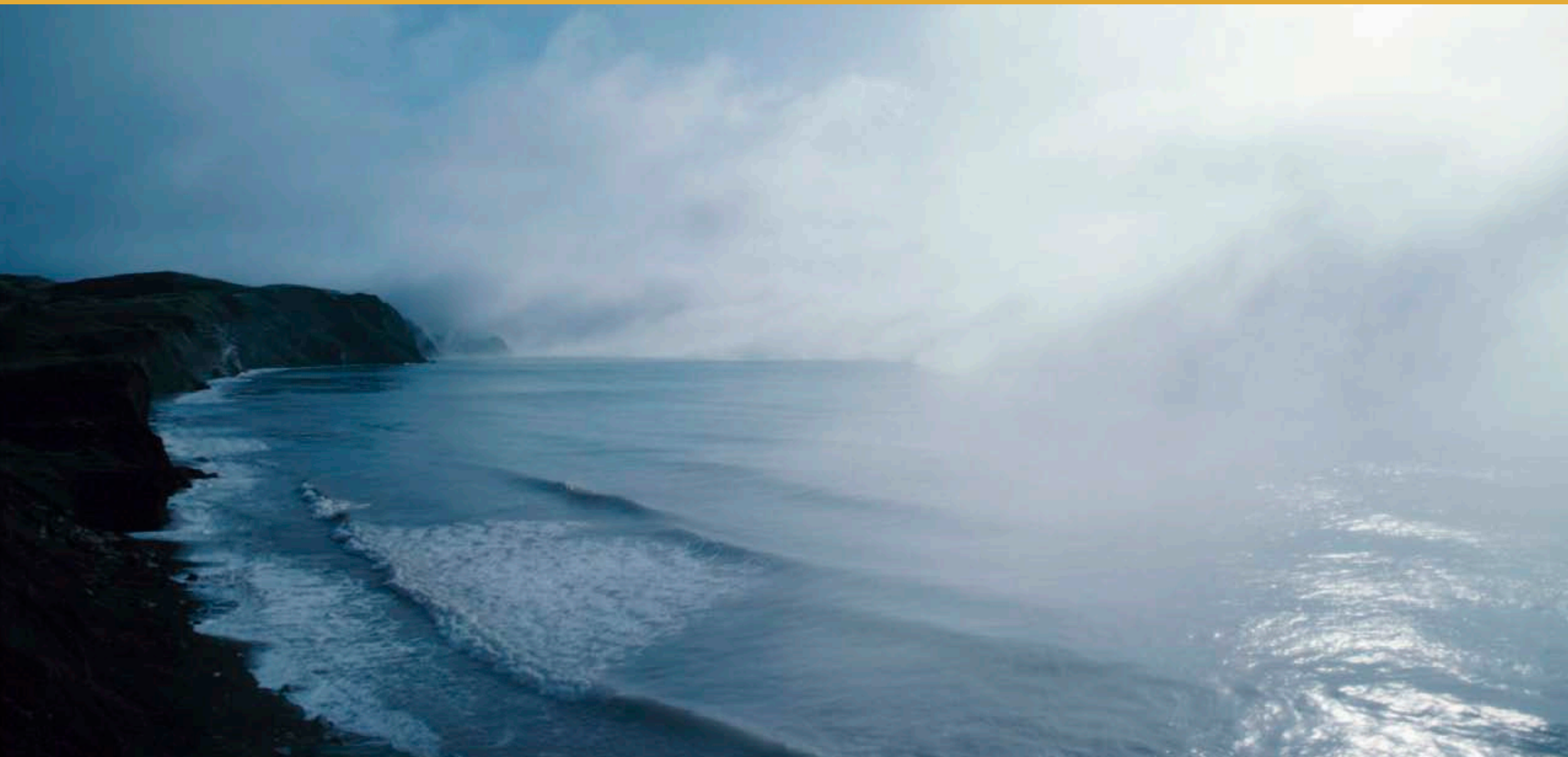
Charting the Course

Canada's Marine Renewable Energy Technology Roadmap



DEDICATED TO THE MEMORY OF RICHARD PENNY
NOVA SCOTIA DEPARTMENT OF ENERGY

Background documents are available in the Marine Energy TRM section of the Ocean Renewable Energy Group (OREG) website:
www.oreg.ca/index.php?p=1_58_Marine-Energy -TRM

ISBN M154-56/2011E - 978-1-100-19522-3

This document was prepared under the direction of the Marine Renewable Energy Technology Roadmap Steering Committee using input obtained from key marine renewable energy industry and academic participants at three workshops held across the country between February and June 2011. The document attempts to represent the views of the workshop participants and the Steering Committee members; it does not necessarily reflect the views of the Government of Canada or of individual organizations represented, nor does it constitute an endorsement of any commercial product or person.

The financial support of the Government of Canada, as represented by Natural Resources Canada, is acknowledged.

All dollar figures are in Canadian dollars, unless otherwise stated

Charting the Course

Canada's Marine Renewable Energy Technology Roadmap

Acknowledgements

Special acknowledgement goes to the members of Steering Committee for their dedication, time and leadership throughout the roadmapping process. The Steering Committee met or teleconferenced on numerous occasions between the workshops, carrying out much of the background work and providing input on the direction and approach to the workshops.

Appendix A contains a list of the workshop participants; their involvement and advice provided the bulk of the content of this report.

Industry Chair:

James Taylor, General Manager, Carbon Management, Nova Scotia Power

Federal Secretariat:

Tracey Kutney, Sr. Research Engineer, Natural Resources Canada
Monika Knowles, Marine Energy Officer, Natural Resources Canada

Facilitation/Project Team:

Stantec Consulting
Natural Power Consultants
J. McIlroy Consulting

Marine Renewable Energy Technology Roadmap Steering Committee:

Chris Campbell, Executive Director, Ocean Renewable Energy Group

Joe Fitzharris, Vice President and GM, Marener Group of Companies; Chair, Maritime Energy Association

Jean-Francois Ally, Project Manager, Alstom Power

Clayton Bear, President and Founder, New Energy Corporation

Carl Carson, Chief Engineer, Rolls Royce

Imad Hamad, Executive Vice President and GM, Renewable Energy Research

Melanie Nadeau, Sr. Manager, Sustainability, Emera

Brad Buckham, A. Professor, Mechanical Engineering, University of Victoria

Richard Karsten, A. Professor, Mathematics and Statistics, Acadia University

Alex Tu, Sr. Strategic Technology Specialist, BC Hydro

Peter Underwood, Government of Nova Scotia, Executive Council Office

Geoff Turner, Sr. Policy Advisor, Renewable Energy, BC Ministry of Energy and Mines

Ted Currie, Sr. Environmental Analyst, Fisheries and Oceans Canada

Tony Kosteltz, Head, Climate Change Technology Integration, Environment Canada

Tim Karlsson, Director, Environment and Clean Energy Industries, Industry Canada

Additional Report Reviewers:

Henry Jeffrey, Sr. Research Fellow, University of Edinburgh
Jennifer Matthews, Research Manager, FORCE; OEER
Russell Stothers, COO, Clean Current; Chair, IEC TC114 Canadian Subcommittee
Anna Redden, A. Professor, Biology, Acadia University

Foreword

Canada's marine renewable energy sector has the potential to become highly competitive in the global marketplace - serving domestic and global power needs. The plan developed by industry, through this roadmapping process, defines the approach that will see projects around the world use Canadian technologies and expertise. To date, the Canadian sector has focused on gaining experience with marine renewable energy solutions and technologies, and on finding ways to accelerate the formation of a supply chain for commercial-scale activity. The development of this roadmap maintains this industrial development focus, rather than adopting a strict R&D or technology demonstration-driven strategy.

There are no 'small projects' when operating in the challenging marine environment: development, installation, operation and retrieval involve high costs and high risks. Mitigating these challenges will be critically important to the long-term success of Canada's marine renewable energy sector. Doing so requires one thing above all else: collaboration.

Data, resources, technical approaches and experiences must be shared if the sector is to advance. A prime example of such collaboration is Nova Scotia's commercial-scale, shared infrastructure 'incubator' initiative in the Bay of Fundy—the Fundy Ocean Research Centre for Energy (FORCE). FORCE has created a world-leading, grid-connected, shared-infrastructure demonstration centre with the capacity to aggregate individual trials into a 5 MW power plant, with the goal of scaling up to arrays totalling 65 MW. Reducing costs and risk while accelerating the achievement of operational scale, the FORCE approach is clearly working.

The Ocean Renewable Energy Group (OREG) estimates that Canada has committed more than $75 million in federal and provincial support to marine renewable energy development projects in the last five years. $100 million will be invested in phase 1 of FORCE alone—two thirds from private investments. The installations of technology arrays could see upwards of $500 million invested in the coming five years.

Although the marine renewable energy sector is at an emerging stage of development, the *Renewable Electricity Regulations* in Nova Scotia, the *Clean Energy Act* in British Columbia, and Quebec's *Plan Nord* are all helping to move Canada's marine renewable energy sector towards a scale that will interest the financial world.

In July 2011, the Government of Nova Scotia announced the province's plan to create the 'winning conditions' for development of an in-stream tidal energy sector that will serve Nova Scotians for generations to come. The province's suggestion that an imminent industrial strategy will focus on 65 MW by 2015 with another 300 MW over the next 5 to 10 years provides another essential signal required by project developers, the supply chain, and the financial community.

In this context, the sector's leadership has developed a national vision and strategy for Canada's marine renewable energy sector through this roadmap. Canada's focus on where its sector needs to go has placed our marine renewable energy sector on a course towards fulfilling its significant potential. Internationally, Canada must aim to be no less than a leading market player. Within our own borders, we should strive to build significant domestic capacity and provide substantial economic returns.

More than 100 experts contributed their ideas through a series of three workshops to produce this comprehensive technology roadmap. This process engaged a variety of players, including new supply chain members who are ready to implement the plan. It has demonstrated the growing convictions that marine renewable energy is an inevitable and sustainable addition to the world's clean energy future.

Join us as we move forward and act decisively to build and maintain 'Advantage Canada'.

Sincerely,

James Taylor
Chair, Marine Renewable Energy Technology Roadmap

October 2011

Table of Contents

List of Tables

Executive Summary

Canada's marine renewable energy sector has taken an industrial approach to the development of technologies and expertise. Internationally, Canada is recognized for its abundant wave, tidal and river-current resources; the sector's goals are to realize the economic opportunities inherent in these resources, to add diversity to Canada's electricity portfolio, and to become a leading player in marine renewable energy on the global stage.

Marine renewable energy: *The conversion of kinetic energy from waves, in-stream tidal currents, and river-currents into mechanical energy; used primarily to generate electricity, but can also be used to pump water or for other consumer needs*

Canada is rated third in the world for the number of in-stream tidal and wave energy conversion device developers [Khan, 2009] and is considered to be well along the path to the demonstration of grid-connected marine energy converters. Emerging policy and regulatory initiatives are developing the permitting approaches and supportive markets required by pioneer projects. Canada's shared infrastructure is also well advanced: the world's highest capacity, grid-connected, technology-demonstration centre is located in the Bay of Fundy; strategic research collaboratives exist on both coasts; and world-leading Canadian technology is on track for commercial-scale testing.

With the conviction that policy, regulatory and industrial interest will continue to increase, the Marine Renewable Energy Technology Roadmap Steering Committee asked more than 100 sector participants to provide their insights on how to chart Canada's marine renewable energy technology-development strategy.

The vision

The vision is for Canada to become a global leader in the delivery of clean wave, in-stream tidal, and river-current energy-production systems and technologies.

To make this vision a reality, Canada must leverage its strengths to build significant domestic capacity and provide substantial economic returns, including:

- A generating capacity, installed by Canadian industry, of 75 MW by 2016, 250 MW by 2020 and 2,000 MW by 2030—bringing in $2 billion in annual economic value
- Demonstrating leadership in technical solutions and services such as assessment, design, installation and operation to provide value-added goods or services to 30 percent of all global marine renewable energy projects by 2020 and to 50 percent of all projects by 2030
- Becoming a world leading developer of integrated, water-to-wire river-current systems by 2020

Deployment must be rapid and aggressive to reach the installed capacity goals and to secure Canada's leadership position in this developing sector.

The transformation of marine renewable energy development into a competitive component of Canada's energy portfolio requires a strategic focus on reducing costs and risks as well as demonstrating the reliability of marine renewable energy power plants in operation. Canada has already started down a path that demonstrates the value in creating shared infrastructure initiatives that can eliminate barriers, facilitate collaboration, accelerate technology development, and approach a scale of operation that justifies innovative regulatory, research, supply chain, and financing efforts. This approach is emerging as Canada's strategic advantage.

***Advantage Canada:** Potential development areas, based on existing resources, technologies and expertise, which represent sustainable market leadership opportunities for Canada*

Canada's marine renewable energy sector must continue to develop in this direction to accelerate innovation and collaboration, and drive the development of commercial-scale wave, in-stream tidal, and river-current demonstrations. This initiative must make Canada the most attractive place for technology and operational experience development. This initiative will form the foundation of six pathways leading to 'Advantage Canada', by accelerating cost and risk reduction, increasing reliability, and boosting Canada's experience and reputation as a leader in marine renewable energy.

Pathways to the vision

- *Leveraging Canada's shared infrastructure:* Build initiatives to accelerate the development of technologies and Canadian experience
- *Defining marine solutions to meet utility needs:* Continue the early engagement of Canadian utilities to define electricity solutions
- *Ensuring Canada's advantage in river-current technologies:* Exploit early experience to secure the existing leadership in this world market
- *Developing critical technology components:* Find Canadian opportunities (e.g. energy-conversion technologies and all supporting technologies in the water-to-wire system) that will have sector-wide applications
- *Leveraging skills and experience from other sectors:* Create new business opportunities and incorporate existing strengths and experience
- *Developing and setting project design guidelines:* Extend Canadian leadership in standards development to the standard operating procedures and best practice guidelines of an operating marine renewable energy sector

Critical enablers of the vision

The development of technology incubators to share experience and accelerate innovation is fundamental to the progress along these pathways. Aggregating early activity will create the scale and momentum needed to incent the development of technologies and the transfer of skills from other sectors (such as oil and gas, fisheries, and salvage operations). The early achievement of full-scale demonstration is expected to showcase Canada's engineering, procurement, and construction capabilities as a demonstration of expertise, leading to international exports.

The activities that will enable progress along the pathways and define Canada's marine renewable energy strategy are:

- *Developing technology incubators*
- *Accelerating innovation*
- *Enhancing cross-sector technology and skills transfer*
- *Enhancing engineering, procurement, and construction capabilities*
- *Developing Canada's market position*

Building experience through action

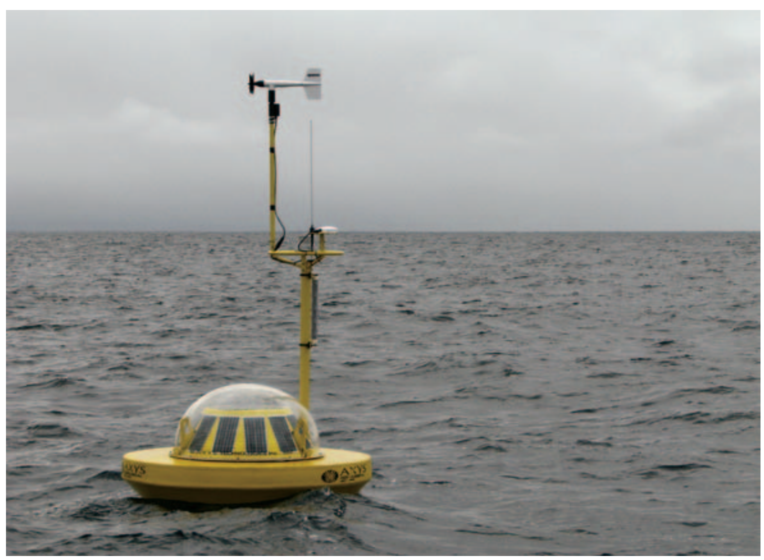
For marine renewable energy to become competitive with other energy generation systems, technical advances must reduce the risks and lifecycle costs associated with capital expenditures (CAPEX) and operational expenditures (OPEX). By working with marine renewable energy systems operating in the water, the development of industrial infrastructure and technological solutions will be stimulated. Canada must use this initial deployment experience to develop effective operational expertise as quickly as possible.

Capitalizing on Canada's strengths

Canada's most prominent advantages are its abundant wave, tidal, and river-current resources; its capacity in technology-based research and development; and its developing fiscal and policy environment.

A community of industry, government, and academic players has come together to build on these Canadian advantages and plot the course of development described in this roadmap. Although focused on technology requirements, this sector-based community has also proposed the development of clusters of activity to drive implementation with an industrial approach and scale.

It is clear that Canada must act immediately and decisively to grow and retain a leadership position in the developing marine renewable energy sector. In following the six pathways, the marine renewable energy sector must first build strong domestic capability—which will, in turn, enhance Canada's global reputation and foster the export of technologies, systems, and expertise. This international build-out will then allow for the use of standard approaches, expediting the reduction of unit costs as this sector grows and allowing Canada to further expand within the domestic markets.



1 Clustering for Success

Canada's waves, tides, and rivers are vast energy resources that can be used to generate sustainable, emission-free electricity and deliver both short- and long-term economic benefits. The challenge for marine renewable energy technology developers in Canada and around the world is to produce solutions that will reliably deliver utility-grade electricity at a cost competitive with other alternatives.

Canada has taken a leadership position in tackling that challenge—most recently by engaging a number of private- and public-sector players to produce this technology roadmap. This roadmapping effort facilitated collaboration between industry, academia and government to chart a course for the development of technologies, technical skills and experience to ensure that Canada's marine renewable energy sector derives the most benefit from its existing potential in the domestic and international markets.

This roadmap promotes methods to accelerate the development of industrial approaches to achieve marine power generation. In producing this document, the workshops concentrated on four main areas:

- Development targets and identifying technological opportunities
- Technical means of achieving faster cost reductions and advancing operational approaches
- Critical technical issues that either create advantages for Canada or put its progress at risk
- Strategic priorities to focus research, design, and development

One of the main considerations during the development of this roadmap is the unique opportunity presented by the abundance of Canada's marine renewable energy resources, which provides context for the significant impact that this sector could have in the country's future energy mix.

Table 1. Canada's estimated marine renewable energy resources versus electricity demand

	In-stream Tidal	River-Current	Wave
Extractable mean potential power	~ 6,300 MW[1] NS, NB, QC, BC, Arctic	Estimated to be > 2,000 MW[2] QC, ON, MB, BC, Arctic	~ 27,500 MW[1] BC, NS, NL
Total extractable mean potential power		~ 35,700 MW	
Canadian electricity demand (rated capacity, 2010)		134,000 MW[3]	

[1] Resources indicated are based on the mean power potential defined in Cornett [2006], assuming an extraction of 15% [Bedard, 2007].

[2] Based on the U.S. estimate of the U.S. river-current resource. A Canadian study is underway, with the Canadian resource expected to be greater than 2,000 MW. The U.S. resource estimate is based on energy potential defined in Miller [1986], assuming an extraction of 15% [Bedard, 2007].

[3] Data from NEB [2011].

1.1 The Engagement Process

The *Marine Renewable Energy Technology Roadmap* was launched with a meeting of the Steering Committee and the development of a draft vision in December 2010.

More than 100 experts—including representatives from research centres, technology developers, independent power producers (IPPs), utilities, service providers, and governments—took part in a series of three workshops and related follow-up activities as described in Table 2. Through this process the vision was upheld, Canada's strengths and weaknesses assessed, six technology pathways were defined, and mechanisms to accelerate cost and risk reduction were identified.

The workshops provided much of the substantive input into the roadmap. They also served to engage a variety of players who are ready to implement its plans.

Table 2. Overview of the technology roadmap workshops

Halifax (February 8, 2011)	Montreal (March 30, 2011)	Vancouver (June 9, 2011)
• Confirmation of the vision • Current state of the marine renewable energy sector • Canada's technological strengths and weaknesses • Gaps in Canadian capabilities • Priority technology opportuni-ties	• Carry-forward messages from Halifax • The cost-reduction challenge • From deployment experience to effective operations • Marine renewable energy project lifecycle; identification of critical activities for success • 'Heat map' process to determine technology pathways • Priority issues and pathways	• Carry-forward messages from Montreal and Halifax • Input into the six technology pathways • Commonalities found in the pathways; determination of the enablers • How the enablers and pathways might be implemented • Implementation: who, how (plans) and when (timelines)

1.2 The Vision

The vision upheld for the Canadian marine renewable energy sector conveys a sense of urgency, focuses on leadership within the supply chain, and emphasizes value-creation for Canada:

> *Canada's marine renewable energy sector is a leader in the global market; delivering clean wave, in-stream tidal, and river-current energy-production solutions, systems, and services.*
>
> *Leveraging Canada's strengths and building on a national foundation of competitive energy production and installed capacity, our success will be based on:*
>
> - *Greater than 75 MW installed by Canadian industry by 2016*
> - *More than 50 percent of projects globally use Canadian technologies or expertise*
> - *2,000 MW installed by Canadian industry by 2030*
> - *$2 billion annual economic value to Canada by 2030*

Deployment must be rapid and aggressive to reach the installed-capacity goals of 75 MW by 2016, 250 MW by 2020 and 2,000 MW by 2030.

The vision sees Canada becoming a global leader in the development of integrated water-to-wire solutions for river-current energy systems by 2020. Canada will become the leader in defining standard operating procedures and best practices that support an integrated approach to marine renewable energy system development.

The vision also has Canada leading the development and demonstration of integrated resource assessment, site assessment, installation, operations and maintenance of marine renewable energy systems. By leveraging this expertise, Canada will be able to provide value-added supply chain goods or services to 30 percent of all global projects by 2020 and to 50 percent of all projects by 2030. Niche technology and technical services (such as moorings, foundations, deployment systems, connectors, monitoring equipment, communications systems, and other supporting technologies) will also be identified and developed for the world market by 2020.

The vision, originally developed by the Steering Committee and confirmed by the sector through the workshops, suggests that Canada can quickly become a global leader in marine renewable energy. It is supported by a strategy comprising pathways, goals and enablers to help facilitate measurable progress.

1.3 The Strategy: A Time to Lead

Canada's marine renewable energy sector has focused on taking an industrial approach to the development of the sector in order to ensure a competitive, economical advantage to Canada. This approach earned Canada a third-place ranking worldwide for the number of marine renewable energy technology developers [Khan, 2009]—and Canada is now considered to be well along the path to the demonstration of grid-connected marine energy converters.

Industrial approach: *A focus on moving from trials and development to providing utility-grade power systems, working at commercial scale, and mobilizing a supply chain that can transition to a mature, self-sustaining sector*

Enabling fiscal, policy, and regulatory environments are beginning to take shape to meet the needs of the sector, and will create the permitting pathways and supporting markets required by pioneer projects in Canada. The country's approach to shared infrastructure is well advanced: strategic research collaboratives are at work on both coasts; world-leading technology is on track to be tested as power plants; and the world's highest capacity, cabled, technology-demonstration centre—the Fundy Ocean Research Centre for Energy (FORCE)—will be fully in place by 2012. By working with commercial-scale power-production systems operating in the water, the development of appropriate industrial infrastructure will be stimulated—putting Canada in a strong position to advance international efforts in marine renewable energy technology and operational refinement.

For marine renewable energy to become competitive with other energy sources, technological advances are required to reduce the risks and costs currently associated with marine renewable energy systems. To offer effective operational solutions as quickly as possible, Canada must implement a strategy that leverages not only its vast resources, research capacity, and deployment experience, but also a number of other inherent strengths, including:

- **An engaged community:** Since the mid 2000s, players in the Canadian marine renewable energy sector have been collaborating to advance the sector, forming the Ocean Renewable Energy Group (OREG), FORCE, the Fundy Energy Research Network (FERN), the West Coast Wave Collaborative (WCWC), and the Offshore Energy Environmental Research Association (OEER). Provincial governments (including British Columbia, Ontario, Quebec and Nova Scotia) are also helping to grow Canada's marine renewable energy sector as are funding agencies and programs such as Sustainable Development Technology Canada (SDTC); the Atlantic Canada Opportunities Agency (ACOA); Natural Resources Canada's Program for Energy R&D (PERD), Clean Energy Fund (CEF) and ecoEnergy Innovation Initiative (ecoEII); the National Research Council's Industrial Research Assistance Program (IRAP);

and the Scientific Research and Experimental Development (SRED) tax credits.

- **Supply chain capacity:** For decades, Canadian scientists, engineers, developers and entrepreneurs have been building the hydro, maritime, and offshore oil and gas capacities that can also provide the skills and technology required to successfully harness marine renewable energy resources.
- **International engagement:** Canada's marine renewable energy sector is providing leadership to collaborative international activities and research through the International Energy Agency's Implementing Agreement on Ocean Energy Systems (IEA OES-IA), the development of international codes and standards through the International Electrotechnical Commission Technical Committee for Marine Energy (IEC TC114), and other joint projects and activities with the United Kingdom, United States, and others.

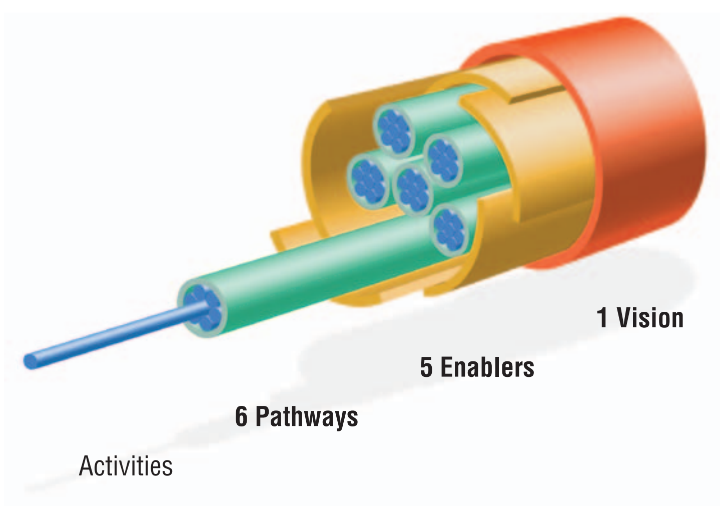
The actions outlined in this roadmap are intended to combine the strengths of the Canadian marine renewable energy sector while identifying opportunities for leadership, economic development, and clean energy development. The overall strategy is to encourage collaboration and accelerate deployments through the sharing of knowledge and infrastructure—acknowledging that when it comes to marine renewable energy in Canada, the whole is greater than the sum of its parts.

While the marine renewable energy vision speaks to installed generation capacities, the sector is focusing on more than just megawatts. The vision will be achieved through the development of a robust and resilient supply chain and by taking advantage of opportunities to lead in an emerging global sector. Success will also be measured through the development of regional energy supply and export opportunities. The vision recognizes that marine renewable energy represents a unique opportunity—both as a new energy resource and as a new international market opportunity—to contribute to Canada's claim as an energy superpower.

Six pathways, five enablers, one vision

A key enabler of the strategy detailed in this roadmap is a focus on technology incubation—aggregating and accelerating early industrial-scale project demonstrations and technology innovation to support the pursuit of six interrelated **pathways**, leading to actions that will achieve critical goals and, cumulatively, the overall vision. Each pathway contains priority technical development activities and timelines that will grow Canada's marine renewable energy sector. The country's technology incubator initiative—which aims to make Canada the world's most attractive place for technology and industrial development—is the foundation for five **enablers** that will lead to successful international market penetration.

Pathway: *Core development direction comprising coordinated activities that build upon each other over time to achieve defined goals*



The vision for Canada's marine renewable energy sector looks as far ahead as 2030; however, the Steering Committee and workshop participants have stressed the importance of achieving significant progress in the short and medium terms (by 2016 and 2020, respectively). Acting now is critical if Canada is to secure a leading place as global developments in the marine renewable energy sector progress. Table 3 offers the two scenarios Canada faces, highlighting the advantages of early action in the sector.

***Enabler:** Sector activities and tactics that create the foundation for progress*

Table 3. Two scenarios for Canada's marine renewable energy sector in 2030

Results of Early Action	Results of Late Action
Pioneer the market, conduct strategic research, create technology incubators	No investment (or just R&D alone)
Demonstrated industrial capacity and expertise	Some local support work
International partnerships and market access	Expertise and technology must be bought
Expanded Canadian marine renewable energy production makes up a part of the Canadian renewable energy mix	Just initiating Canadian marine renewable energy production
Marine energy is generating significant economic benefits	Marine energy development is an economic cost

2 The Action Agenda: Technology Pathways

The six technology development pathways defined through this roadmapping project reflect Canada's strengths as well as the value of opportunities at both the domestic and international levels. Each pathway speaks to a critical aspect of technical skills, technology, and operational development with priority actions that allow Canada to achieve its short, medium- and long-term goals.

The six pathways are, in most cases, complementary and should be pursued simultaneously to have the greatest impact on the development of the Canadian marine renewable energy sector.

Table 4. Technology pathways and associated priority actions

Technology Pathway	Priority Actions
Leveraging Canada's shared infrastructure	• Support testing activities for river-current and wave energy, continue supporting in-stream tidal • Develop supporting technologies and engage service companies • Foster the development of global standards
Defining marine solutions to meet utility needs	• Meet the needs of the electricity system • Develop reliable forecasting models • Facilitate communication between utilities and developers
Ensuring Canada's advantage in river-current technologies	• Support and refine river-current power-system solutions • Develop and demonstrate experience in river-current power system operations and management • Continued development of river-current site-assessment expertise
Developing critical technology components	• Promote the development of Canadian technology • Identify what should be made in Canada and what should be bought • Establish an information-sharing environment for the Canadian marine renewable energy sector
Leveraging skills and experience from other sectors	• Engage related sectors in the marine renewable energy sector • Create opportunities for technology and experience adaptation • Conduct strategic regional environmental assessments while engaging other sectors • Promote regional centres of expertise for the development of marine renewable energy personnel
Developing and setting project design guidelines	• Sector engagement to encourage development of standard operating procedures • Develop Canadian monitoring systems • Develop an understanding of lessons learned through demonstration projects

In the following sections, the six technology pathways are presented in more detail along with key actions and goals across three distinct time periods: near term (2011–2016), medium term (2016–2020) and long term (2020–2030).

2.1 Pathway 1: Leveraging Canada's Shared Infrastructure

2011 - 2016

Demonstration of commercial-scale projects, approaches, and expertise

2016 - 2020

Canada's test centres and deployments are central to the development of standards, best practices, and SOPs

2020 - 2030

Testing and development facilities develop into long-term commercial project sites

A shared-infrastructure approach for marine renewable energy is being explored around the world, with the European Marine Energy Centre (EMEC) in northern Scotland being the first established facility for technology testing. The benefits of this type of centre were quickly realized and, as a result, plans for development zones, multiple-device facilities, and other testing areas are now being developed globally.

The FORCE shared-infrastructure model allows for:

- *Demonstration of in-stream tidal energy technologies*
- *Trials up to 5 MW*
- *Cables sized to facilitate first arrays*
- *Testing of leading technologies, all in the same area*
- *Engagement of IPPs and OEMs*
- *Strategic research*
- *Community liaison*
- *Environmental monitoring advisory*

In Canada, the Fundy Ocean Research Centre for Energy (FORCE) was created to test grid-connected, full-scale in-stream tidal technologies and to assess the environmental sustainability of in-stream tidal energy developments. With the decision to install cabling infrastructure sized to allow for the interconnection of arrays at each of its four berths, it is expected that FORCE will play a critical role in facilitating the development of sustainable, commercial-scale in-stream tidal energy plants in Nova Scotia and throughout the rest of Canada.

The evolution of FORCE mirrors the advancements in the sector towards demonstrations of arrays, which is more reflective of the power plants of a commercial sector. This type of forward thinking, combined with a focused research program and committees for environmental monitoring advisory, technical advisory, and community liaison, has allowed FORCE to become a model facilitator to the global sector.

The experience that is gained through shared-infrastructure initiatives such as FORCE is critical to the success of the development of the Canadian marine renewable energy sector. Appropriately designing these initiatives will make Canada the most attractive country to develop technologies and test devices, thereby attracting national and foreign investments to Canada.

While this opportunity is being realized for in-stream tidal energy in the Bay of Fundy, there are opportunities to develop similar initiatives to advance the development of river-current and wave energy technologies. By aggregating river-current activities in Quebec, Manitoba and Ontario; and by evolving the West Coast Wave Collaboration (WCWC) in British Columbia for wave energy, Canada has the potential to become the preferred destination to test and demonstrate the reliability and commercial readiness of wave, in-stream tidal, and river-current energy technologies. These initiatives would then foster the development of an internationally recognized marine renewable energy supply chain and inform the development of global standards.

Table 5. Pathway 1: Key actions and related goals

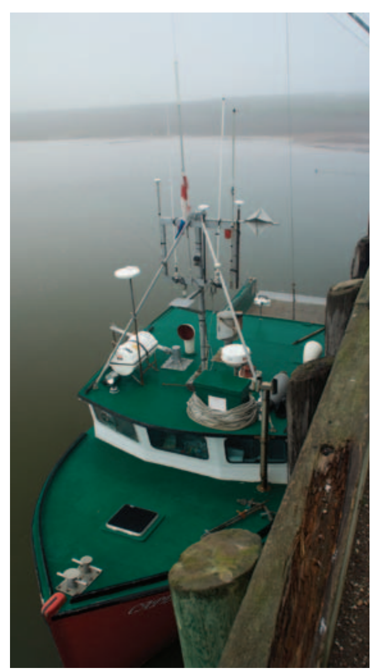
	Key Actions	Goals
2011 - 2016	*Conduct resource and site investigations for wave energy, strategic environmental assessments, permitting, and interconnection planning*	*Active development consortium, permitted wave development site(s) and interconnection*
	Identify existing river-current technology-development efforts	*Demonstrating commercial-scale approaches*
	OREG and other associations work to attract expertise from other sectors to these strategic developments	*Supply chain emerging around in-stream tidal, wave and river-current initiatives*
	Continued evolution of collaboration models; securing knowledge and experience	*SOPs for commercial-scale projects*
	Development of common standards, infrastructure, and tools that can be shared	
2016 - 2020	*Establishment of world-class shared-infrastructure for river-current activities*	*Significant export activity of technologies and expertise*
	Focus on demonstrations that bring together strong Canadian teams and develop water-to-wire systems	*Canada's development centres are central to standards, SOPs, and best practice development*
	Shift focus of infrastructure facilities to information databases, outreach, and best practices	*Migration of shared infrastructure into commercial development*
	Development of test centre for full-scale wave energy demonstrations	*Contracts for the first wave arrays to be deployed*
	Development of common standards, infrastructure, and tools that can be shared	
2020 - 2030	*Deployment of grid-connected wave energy converter arrays*	*World-leading wave technologies deployed in BC*
	Maturing sector focus on technology refinement and further cost reduction	*Need for testing and development facilities may be met in commercial sites*
	Expand number of technology options tested to increase supply chain opportunities	*Clusters of global-leading companies exist around shared infrastructure*
	Define and act on any need to maintain dedicated development infrastructure	*FORCE and equivalent have fulfilled purpose*

2.2 Pathway 2: Defining Marine Solutions to Meet Utility Needs

2011 - 2016	2016 - 2020	2020 - 2030
Grid-integrated marine renewable energy projects	Marine renewable energy is viewed by utilities as viable and reliable Utilities integrate marine renewable energy into long-term planning	Canada exports expertise for marine renewable energy project integration with utilities and system operators

In developing Canada's marine renewable energy sector, it is important to ensure that marine energy converters are designed to meet the requirements of utilities. The interconnection of new resources requires a detailed understanding of real-world performance to ensure smooth grid integration and reduce issues related to power quality, supply reliability, safety, and cost. As utilities are governed by strict standards related to the transmission and supply of electricity, real-world operational experience must be used to systematically address and evaluate the technical risks in marine renewable energy projects—and then, in turn, to educate and engage independent power producers (IPPs), regulators, and the utility market. Power-technology companies and engineers must also be engaged to ensure the sector meets common integration and project design requirements.

How projects will connect to an aging electricity infrastructure and how the power supply will fit into the overall system will emerge as critical factors in determining where marine renewable energy projects can become economically viable. Leadership opportunities exist in finding solutions for transmission, distribution, and community-scale system integration. Canada has an advantage in these areas due to the fact that it has a number of integrated utilities—and most of those utilities are already engaged in the development of the marine renewable energy sector.

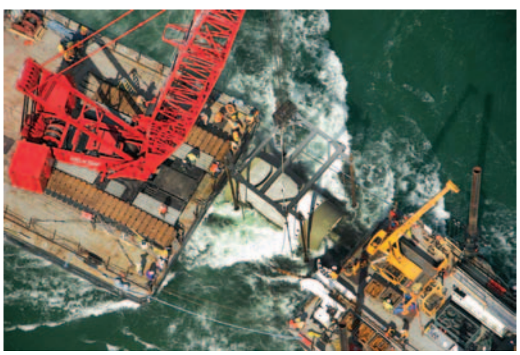


Priority 2-A: Meet the needs of the electricity system

The vision identifies an early goal of 75 MW in installed capacity by 2016. Not only will the technology need to be developed, commercially viable, and deployed, but the infrastructure to distribute the electricity will also need to be in place. This requires the identification of longer-term marine renewable energy extraction opportunities so that the appropriate transmission networks can be planned and extended to these locations—a process that can take many years.

Table 6. Priority 2-A: Key actions and related goals

	Key Actions	Goals
2011 - 2016	*Identify the locations of likely marine renewable energy projects*	*Grid-expansion requirements defined for marine renewable energy*
	Identify grid-expansion requirements	*Grid-integrated marine renewable energy projects*
2016 - 2020	*Ensure marine renewable energy projects meet all safety and best practice standards*	*Technology is safe and is perceived to be safe, with robust standards in place*
		Marine renewable energy projects factored into long-term utility planning
2020 - 2030	*IPPs, financiers, and utilities promote Canadian grid-integration approaches worldwide*	*Canadian marine renewable energy projects worldwide perform as expected and integrate smoothly into the grid*



Priority 2-B: Develop reliable forecasting models

Although Europe has been identified as a leading player in the development of wave energy converters, Canada is considered an active sector player with an abundant resource. The best way to ensure Canada's advantage in wave energy—whether in techniques, system components or technology development—is to ensure that Canada develops some of the best tools in resource evaluation and forecasting.

Table 7. Priority 2-B: Key actions and related goals

	Key Actions	Goals
2011 - 2016	*Develop a network of offshore wave and monitoring buoys; build satellite links to yield flexibility in deployment site* *Build near-shore hindcasting model to allow simulation of wave energy device performance* *Explore ability of wave energy control systems to optimize the energy capture from the wave resource*	*International recognition for wave energy system controls*
2016 - 2020	*Adjust the hindcasting model to include a forecasting component* *Build the near-shore model out towards the day-ahead scheduling tool needed by the utility*	*Development of 12–24 hour forecasting*
2020 - 2030	*Increase level of Canadian involvement in international monitoring*	*Exporting wave energy system forecasting models*

Priority 2-C: Facilitate communication between utilities and developers

The key to this pathway's success is the continued communications between utilities and developers. Early engagement with utilities allows developers to ensure their energy converters and projects will meet utility requirements, and to assure utilities that their power-delivery requirements can be met by the developer. This partnership approach will foster the needed working relationships to minimize barriers when delivering the marine renewable power to the grid.

Table 8. Priority 2-C: Key actions and related goals

	Key Actions	Goals
2011 - 2016	*Identify requirements to meet utility needs*	*Open communication between utilities and marine renewable energy sector*
2016 - 2020	*Leverage Canadian power technology expertise*	*Utilities are comfortable contracting power from marine renewable energy projects*
2020 - 2030	*Package standard electrical requirements for marine renewable energy interconnection and provide to the international market*	*Canada exports expertise for marine renewable energy project integration with Utilities and system operators*

2.3 Pathway 3: Ensuring Canada's Advantage in River-Current Technologies

2011 - 2016	2016 - 2020	2020 - 2030
Canada has proven solutions for deployment, operations and maintenance, and retrieval	Canada is globally recognized as leader in river-current technologies	50 percent of global projects use Canadian technologies or expertise

Canada has a unique opportunity for global leadership in the development of river-current energy systems. Canadian companies are currently testing technology prototypes and completing international sales, while major utilities (including those in Quebec, Ontario, Manitoba and British Columbia) have expressed strong development interests and are participating in project trials. In addition, Canada can exploit its extensive and recognized experience in river-based power production and technology design, conventional hydropower leadership, and experience in device modelling to further secure its advantage in river-current technology development.

The key to the success of this pathway is to focus on the entire system—from water to wire—while continuing to refine the necessary river-current technology expertise. This involves the entire marine renewable energy community, including technology developers, research centres, utilities, academic institutions, and government departments. Collaboration between these groups will accelerate demonstration of reliable of river-current power systems in Canada and facilitate their export into the global market.

Priority 3-A: Support and refine river-current power-system solutions

A development or testing site proposed by one of the provinces could serve as the shared-infrastructure initiative needed to accelerate the development of Canadian river-current power systems. Equipment and techniques established for this site will play an essential part in proving that deployment, operation, maintenance, and retrieval systems can offer cost reductions and increase power-system reliability. At the same time, utility engagement will grow the sector's experience, and the resulting projects will be able to sell technology and power at a competitive price. These types of projects will provide the knowledge to support the streamlining of the permitting process and provide insight into the development of monitoring best practices, offering Canada the opportunity to export water-to-wire development expertise.

Table 9. Priority 3-A: Key actions and related goals

	Key Actions	Goals
2011 - 2016	*Support and refine river-current power system solutions*	*Proven, commercial-ready systems and solutions for installation, deployment and retrieval*
2016 - 2020	*Engineer for cost and reliability*	*Broader site applicability creates larger market*
2020 - 2030	*Grow market penetration by providing reliable electricity solutions*	*Canadian supply of 50 percent of water-to-wire river-current power systems to the International market*

Priority 3-B: Develop and demonstrate experience in river-current power system operations and management

Early-stage deployments of river-current power systems have required technology providers to support project-development teams. This experience has and will inform the client-service approach to support future sales. Resource assessment and environmental assessment management experience will be exportable expertise. This early experience can be packaged into training for clients and project developers, which may allow Canadian project developers to become a critical part of international project initiatives.

Table 10. Priority 3-B: Key actions and related goals

	Key Actions	Goals
2011 - 2016	*Demonstrate experience in river-current power plant operations and management*	*Demonstration of commercial-ready power solutions in multiple environments*
2016 - 2020	*Pioneer training and/or demonstration of engineering, procurement, construction, and asset management internationally*	*Globally recognized as leader in river-current technology systems*
2020 - 2030	*Promote expertise to users in the international markets*	*Canadian project developers active in asset management internationally*

Priority 3-C: Continued development of river-current site-assessment expertise

Early projects have shown that site-assessment needs are much broader than simply measuring the available resource. The academic/industry research partnerships that have grown around in-stream tidal and wave energy studies must be encouraged for the river-current sector. Expertise in site characterization must be applied to properly assess the currents, turbulence, and seasonal variability. It must also include site bathymetric and geological surveying, and address issues of in-water debris, ice, other uses, and access to transmission. A supply chain-building effort around pioneer projects will embed lessons learned and demonstrate a Canadian sector ready to market its ability to match technology to opportunity.

Table 11. Priority 3-C: Key actions and related goals

	Key Actions	Goals
2011 - 2016	*Continued development of river-current site-assessment and characterization expertise*	*Proven Canadian solutions for resource and site characterization* *Standards and best practices development underway*
2016 - 2020	*Standards developed and adopted internationally*	*Exporting system support and project development expertise*
2020 - 2030	*Promote deployments in regions where energy prices are high (e.g. to offset remote diesel generation)*	*Canadian project developers active internationally*

2.4 Pathway 4: Developing Critical Technology Components

2011 - 2016	2016 - 2020	2020 - 2030
A working group sharing lessons learned Canadian energy converters are being reliably demonstrated	External stakeholders are invested in marine renewable energy projects 'Made in Canada' components are being used	50 percent of commercial marine projects contain Canadian technologies or expertise

Technology and project developers are racing to be the first to successfully demonstrate reliable electricity production from wave, in-stream tidal, and river-current energy projects. This competitive climate has led them to work in silos, sometimes outside their areas of core expertise. Yet finding the winning solutions for Canada—those that will accelerate the development of the marine renewable energy sector as a whole—requires open working environments to address the spectrum of project-development needs. This allows technology developers to focus on refining their energy converters while others address cross-cutting technological challenges. This collaborative approach is expected to lead to new intellectual property and proprietary techniques that the Canadian sector will then be able to take to world markets.

This pathway develops mechanisms to identify needs and opportunities associated with planning and implementing pioneer power projects. Exposure to industry-leading technologies while the sector is at an early stage of development will create Canadian business opportunities through shared leanings and technological convergences, thereby defining the next-generation approaches.

Priority 4-A: Promote the development of Canadian technology

This priority is focused on creating opportunities at testbeds to research, develop, and demonstrate Canadian energy-conversion technologies and to refine the components in their systems. This would allow the sector to identify technical approaches and supporting technologies that can be developed in Canada to serve the global marine renewable energy sector. Canada also has a significant opportunity with developing and manufacturing these technologies—which, in turn, could provide opportunities to launch some of the world's first commercial-scale marine power projects. This would allow the sector to experience the full lifecycle of these projects.

Table 12. Priority 4-A: Key actions and related goals

	Key Actions	Goals
2011 - 2016	*Create opportunities for development in Canada:* • *Testbeds, support programs, and early projects identify technical and technology needs* • *Large-scale testbeds demonstrate technologies* *Design appropriate incentives to attract Canadian technology development*	*Canada is considered an attractive place for international investment in marine renewable energy* *Canadian energy-converter technology is being reliably demonstrated* *Canadian technologies and techniques are being developed, adapted, and proven*
2016 - 2020	*Look to external stakeholders for large-scale investments* *Expand testbeds for more deployment opportunities* *Strengthen relationships between academia, industry and external stakeholders through the innovation centres* *Focus on cost-reduction while improving reliability* *Promote Canadian products*	*30 percent of commercial marine developments worldwide contain Canadian technologies or techniques (i.e. energy converters, components, or expertise)*
2020 - 2030	*Continue to develop and promote Canadian products* *Offer warranties on Canadian technologies* *Increase interest in Canadian products by consider-ing additional cost-reduction techniques (e.g. mass production)*	*50 percent of commercial marine projects contain Canadian technologies*

Priority 4-B: Identify what should be made in Canada and what should be bought

Canada does not currently have an identified supply chain in place to fully support marine renewable energy technologies and sector development. Increasing the contribution of critical components that are designed, tested, and manufactured in Canada will provide a significant advantage to the country in the global marine renewable energy sector. A strategic make/buy analysis has been proposed to understand where Canada has the best opportunity for manufacturing specific components and whether those components represent a long-term market opportunities. This strategic analysis ensures Canada's skills are appropriately used to meet the demands of the worldwide market. In the long term, this will lead to Canadian technologies being used in projects worldwide.

Table 13. Priority 4-B: Key actions and related goals

	Key Actions	Goals
2011 - 2016	*Identify the criteria to carry out the make/buy analysis* *Establish with project developers and original equipment manufacturers (OEMs) an inventory of what marine renewable energy projects will generally need (e.g. gearboxes, monitoring equipment, foundations, vessels, connectors)* *Carry out make/buy analysis with OEMs and suppliers* *Engage aerospace, offshore oil and gas, and power-generation sectors* *Establish a central database for the results of the make/buy analysis*	*National make/buy strategy*
2016 - 2020	*Identify and implement strategies to convert strategic 'buy' components into 'made in Canada' components* *Increase Canadian manufacturing capability*	*30 percent of components in Canadian projects are made in Canada*
2020 - 2030	*Improve productivity of Canadian manufacturing*	*50 percent of components in Canadian projects are made in Canada*

Priority 4-C: Establish an information-sharing environment for the Canadian marine renewable energy sector

Many developers are currently working in isolation without sharing lessons learned—regardless of whether those lessons are core to their intellectual property or part of the general project experience. This has resulted in many of the sector's demonstrations experiencing challenges or component failures—some of which may have already been experienced in other projects. FORCE is currently working to bring leading technologies into a collaborative and common environment. The intent of this priority activity is to establish forums where technology developers can share information in a safe, contributors-only environment without concern of revealing sensitive information.

Table 14. Priority 4-C: Key actions and related goals

	Key Actions	Goals
2011 - 2016	*Ensure that knowledge is shared among an appropriate community without revealing core intellectual property when a project is demonstrated in Canadian waters (e.g. through a berth/test agreement)*	*Sharing of information is available through the members of the agreement (i.e. a closed working group)* *Canadian installations have accelerated learning curves, demonstrate superior reliability and have lower costs*
2016 - 2020	*Develop a international workgroup for sharing the general common issues, information, and techniques*	*Sharing platform is available for project and technology developers in Canada* *Canadian technologies and support continues to be critical in reducing risks and costs and in improving reliability of the world's marine renewable energy developments*
2020 - 2030	*Ensure that the Canadian workgroup is tapping into the detailed knowledge and experience from the global sector*	*Canadian technologies and components are an essential part of the emergence of competitive marine renewable energy in the international market*

2.5 Pathway 5: Leveraging Skills and Experience from Other Sectors

2011 - 2016	2016 - 2020	2020 - 2030
Technology adaptations and innovations are being demonstrated Community college and university programs exist	Global best practices in environmental assessment are Canadian-based Demonstrated leadership in areas such as technology adaptation from other sectors	Canadian oil and gas companies are among the key developers and funders of marine renewable energy projects

Canada has an extensive history in marine and hydro operations as well as more recent experience in the industrial development of offshore oil and gas. Canada is also acknowledged internationally for its hydropower projects and the manufacturing of clean energy technologies. Many of the technologies, components, and techniques currently being developed by the marine renewable energy sector may already exist in these related sectors. As such, this pathway is focused on engaging related sectors (e.g. offshore oil and gas, electrical utilities, naval, fisheries, salvage operations, aerospace) and leveraging their skills and experience to provide critical support to the marine renewable energy sector. These sectors are composed of close-knit communities with strong industrial associations and clustering mechanisms; the ability to engage these groups will be a key Canadian marine renewable energy advantage.

Within this pathway, there is also the opportunity to leverage skills and experience from the international marine renewable energy community. Canada's marine renewable energy association, OREG, works collaboratively with sector leadership in key global market regions. The FORCE initiative has formed a strategic relationship with the European Marine Energy Centre (EMEC) and is drawing on that organization's experience in early infrastructure deployment. Canada also plays leadership roles in the International Energy Agency's Implementing Agreement on Ocean Energy Systems (IEA OES-IA) and the development of marine renewable energy standards through the International Electrotechnical Commission Technical Committee for Marine Energy (IEC TC114). These types of collaborative engagements will remain critical in determining Canada's position in the international market.

The activities of this pathway focus on identifying specific areas within the marine renewable energy sector that will benefit from input from other sectors. By finding integration and demonstration opportunities that will facilitate technology transfer and adaptation within Canada and around the world, this pathway aims to establish a successful, competitive, high-value supply chain for Canada's marine renewable energy sector.

Priority 5-A: Engage related sectors in the marine renewable energy sector

Much of the ocean science and technology advancement in recent years has focused on supporting the oil and gas exploration and development industry on Canada's east coast. The offshore oil and gas sector's vast experience working in harsh marine environments and dealing with the need for environmental data gathering, equipment handling, communications, and subsea operations and power supply could translate into a significant opportunity to adapt technical solutions and applications that meet the needs of the marine renewable energy sector. Engagement and related experience will create new economic opportunities for Canadian companies in the offshore oil and gas sector as well as in other sectors.

Table 15. Priority 5-A: Key actions and related goals

	Key Actions	Goals
2011 - 2016	*Foster engagement of related sectors in the marine renewable energy sectors*	*Other sectors are aware of marine renewable energy sector activities*
2016 - 2020	*Related sectors work at developing marine renewable energy as a new business opportunity*	*Experience, knowledge, and financial support from other sectors is contributing to marine renewable energy projects*
2020 - 2030	*Companies from related sectors lead the projects, deploying commercial marine renewable energy technologies*	*Canadian oil and gas companies are among the key developers and funders of marine renewable energy projects*

Priority 5-B: Create opportunities for technology and experience adaptation

OREG, as a representative of the marine renewable energy sector, will need to collaborate with analogous offshore, hydro, electrical, and other associations to bring relevant sector experience into consideration when describing the needs of early marine renewable energy projects. Technology developers will need to consider technology transfer and adaptation approaches and collaborative R&D initiatives to ensure that technology adaptation opportunities are acted on. These activities focus on shortening the time needed to identify, modify, and demonstrate the adapted technology components from other sectors.

Table 16. Priority 5-B: Key actions and related goals

	Key Actions	Goals
2011 - 2016	*Formation of workgroups to dissect and define project need/opportunities with the expertise of mature sectors*	*Adapted technologies are being demonstrated in pioneer projects*
2016 - 2020	*Demonstration of successful adapted technology solutions of interest to international developments*	*Demonstrated supply chain links and leadership in specific areas such as monitoring equipment*
2020 - 2030	*Emergence of a marine renewable energy integrated supply chain*	*Canadian marine renewable energy supply chain continues to be source of integrated innovative solutions for world markets*

Priority 5-C: Conduct strategic regional environmental assessments while engaging other sectors

The provincial strategic environmental assessment (SEA) developed for the Bay of Fundy in 2008 helped Nova Scotia establish Canada's first large-scale tidal facility. Insight provided by an integrated review of Canadian projects could be used to streamline future marine renewable energy environmental assessments. With Natural Resources Canada and Fisheries and Oceans Canada looking at key permitting questions, and by drawing on the permitting experience of established sectors, Canada is in a strong position to pioneer best practices and reduce costs associated with the assessment and permitting of marine renewable energy projects.

Table 17. Priority 5-C: Key actions and related goals

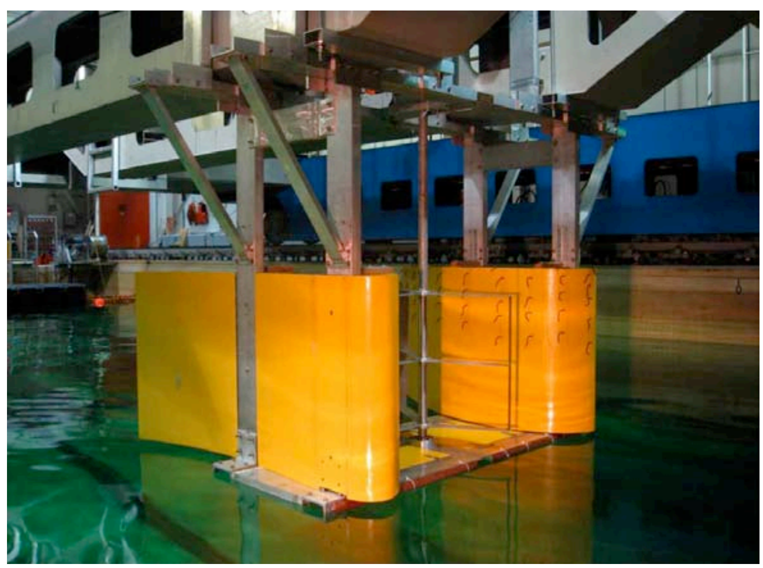
	Key Actions	Goals
2011 - 2016	*Build on Nova Scotia's SEA experience* *Use adaptive management principles for EAs* *Draw upon experiences from other sectors and the international community to inform the SEA and EA process*	*Completed SEAs and EAs inform permitting and strategic environmental research needs* *SEAs provide the opportunity for testing river-current and wave energy projects*
2016 - 2020	*Develop best practices and experiences from the SEA and EA processes* *Disseminate Canadian best practices to international markets*	*SEA and EA information sharing taking place internationally* *Experience success internationally (e.g. permits granted based on the Canadian approach)* *Canadian SEA process time and costs are reduced by 50 percent from 2011 levels.*
2020 - 2030	*Implement international experience to develop a refined and streamlined SEA and EA processes*	*Canada's SEA and permitting practices recognized as global best practices*

Priority 5-D: Promote regional centres of expertise for the development of marine renewable energy personnel

Canada's marine renewable energy sector is applying general electrical engineering, ocean engineering, and marine operations expertise from other sectors. As the sector grows, it is unclear whether future needs can be met through the training and expertise developed in other sectors alone. Building a marine renewable energy-specific knowledge base that addresses the specialized needs of the sector can focus efforts to establish a Canadian advantage.

Table 18. Priority 5-D: Key actions and related goals

	Key Actions	Goals
2011 - 2016	*Engage provincial community colleges to set up trades and technology programs in all aspects of marine renewable energy* *Develop university programs with input from other related sectors and academia*	*Community college programs exist (e.g. skilled workers for construction, deployment, maintenance, monitoring)*
2016 - 2020	*Preference to local (i.e. Canadian) graduates* *Expand apprenticeship programs*	*30 percent of skilled workers come from Canadian community college and university programs*
2020 - 2030	*Programs continue and expand*	*70 percent of skilled workers come from Canadian community college and university programs*



2.6 Pathway 6: Developing and Setting Project Design Guidelines

2011 - 2016	2016 - 2020	2020 - 2030
SOPs and best practices developed based on lessons learned	Technologies and equipment able to perform in the Bay of Fundy is sought after and recognized internationally as best-in-class	Global leader in design, deployment and retrieval (i.e. lifecycle operations and maintenance) for extreme environments

Developing and setting project design guidelines—from site characterization to the technologies and technical approaches required across all aspects of deployment, operations, maintenance, and retrieval—is a key area of project development that needs to be addressed. Fortunately for Canada, it is also an area where a significant opportunity for leadership exists.

Setting best practice guidelines will be done through the development of standard operating procedures (SOPs), which will be complementary to the work being undertaken by the IEC TC114—a committee Canada helped establish. These guidelines and SOPs will become part of all projects regardless of location or technology.

To help establish guidelines, technologies must be deployed in the commercial environment. This allows for a better understanding of the resource-device interaction and the operating conditions. As many devices as possible need to be deployed in Canadian waters, with the results of testing made available. Improvements to materials, equipment, and infrastructure will be made through lessons learned and continued R&D.

Priority 6-A: Sector engagement to encourage development of standard operating procedures

As described in Pathway 5, many of Canada's related sectors have technologies, expertise, and experience that can be adapted to the marine renewable energy sector. Working with the collaborative groups developed through that pathway, this pathway will focus on the specific activities required to develop SOPs for activities that will bring a competitive advantage to Canada.

Table 19. Priority 6-A: Key actions and related goals

	Key Actions	Goals
2011 - 2016	*Engage other sectors with related expertise (e.g. oil and gas, aquaculture, ship yards, ports)*	*Developed procedures for deployment, operation, maintenance, and retrieval based on lessons learned*
2016 - 2020	*Increase work on standards related to project development*	*Canada is considered the training centre for best practices*
2020 - 2030	*Continue development of SOPs and industry best practices*	*Global leader in design, deployment and retrieval (i.e. lifecycle operations and maintenance)* *Recognized globally as leader of SOPs, best practices and project expertise*

Priority 6-B: Develop Canadian monitoring systems

The high current velocities and extreme tidal range of the Bay of Fundy create challenges in collecting environmental and site resource data for in-stream tidal demonstrations. Canada can use these challenges to its advantage, however, by establishing improved SOPs and best practices for designing and deploying monitoring platforms and instruments in high-flow areas—the rationale being that if the monitoring technology can reliably collect continuous real-time data in the Bay of Fundy, it can collect data anywhere (the so-called 'Fundy Standard').

Table 20. Priority 6-B: Key actions and related goals

	Key Actions	Goals
2011 - 2016	*Identify Canadian expertise for monitoring approaches transferrable from other sectors* *Encourage academia/industry collaboration to develop suite of monitoring devices; support manufacturing of devices in Canada*	*Development of a Canadian monitoring systems and monitoring approaches*
2016 - 2020	*Develop, test, and prove monitoring devices*	*Proven devices that can withstand the most harsh environments* *Canadian monitoring equipment is sought after and recognized internationally as best-in-class*
2020 - 2030	*Develop second- and third-generation of monitoring equipment able to withstand extreme environments*	*Canada is recognized as a global leader in monitor-ing equipment; expertise, approaches and systems are exported worldwide*

Priority 6-C: Develop an understanding of lessons learned through demonstration projects

There have been a good number of lessons learned through demonstration projects, yet many of these are not shared throughout the marine renewable energy community. This can lead to the repetition of efforts—and errors. This priority aims to create SOPs and best practices through which the findings from marine renewable energy technology deployments are documented and used to advance the sector by promoting more efficient deployments, feeding into future activities such as arrays and cost-effective generation.

Table 21. Priority 6-C: Key actions and related goals

	Key Actions	Goals
2011 - 2016	*Initiate comprehensive reviews on demonstration projects* *Define ongoing monitoring needs*	*Experience from earlier projects informs deployment approaches*
2016 - 2020	*Develop and improve array configuration and monitoring approaches* *Start developing best practices to identify key considerations for array configurations*	*Array of devices feeding the grid* *Deployment of cost-effective, second-generation moorings and foundations* *Use of cost-effective deployment and retrieval systems, including marine renewable energy-specific vessels*
2020 - 2030	*Develop best practices for project lifecycle management* *Employ approaches developed in Nova Scotia throughout Canada*	*A global leader and exporter of site-characterization and project-development expertise.*

3 Building the Tactics for Success: Enablers

While each of the pathways is distinct, certain common themes cut across all six—types of activities that will help create the conditions for the pathways to succeed. These are the activities that ensure progress along all of the pathways. The fundamental 'enabler' is a focus on:

I. Developing technology incubators

This approach is expected to:

II. Accelerate innovation
III. Enhance cross-sector technology and skills transfer
IV. Enhance engineering, procurement and construction capabilities
V. Develop Canada's market position

3.1 Developing Technology Incubators

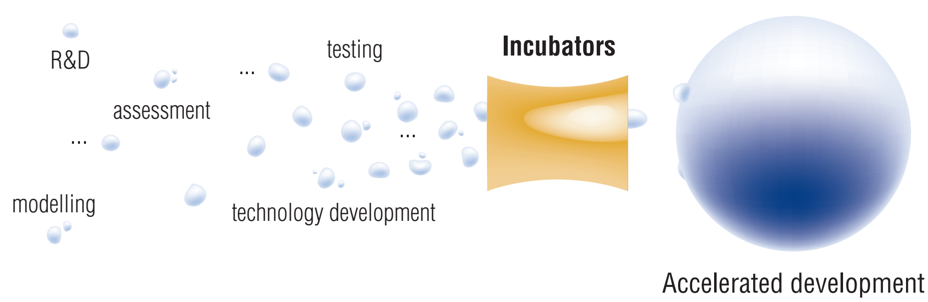
As described in Pathway 1, the Fundy Ocean Research Centre for Energy (FORCE) has evolved from a facility where single in-stream tidal energy converters are tested and the environmental sustainability of in-stream tidal energy developments is assessed to one that also facilitates the development of commercial-scale arrays.

***Incubator:** An entity (e.g. consortium, facility) to foster entrepreneurship, technology innovation, and development through the use of shared resources, expertise, and intellectual capital*

Supported by a common-user model, in 2012 FORCE will provide project developers the opportunity to test arrays of full-scale, grid-connected, in-stream tidal energy conversion systems—putting Canada at the forefront of the global marine energy sector. The development of FORCE has catalyzed collaborative initiatives to focus on gaining the necessary operational experience, technology testing, and focused research and development.

FORCE is one example of a technology incubator being implemented, as it allows for the shared infrastructure to aggregate technology testing activities. This aggregation of activities and collaborative approach to projects creates a scale and scope significantly beyond that of individual projects, facilitating technology development, supply chain development, and focused research while accelerating the development of operational experience for all members of FORCE.

The needed 'incubator' can be realized in the form of demonstrations, laboratories, sector consortia with specific technical expertise (e.g. resource or technology modellers), research networks (e.g. FERN, OEER), or development-scale testing centres. The key attributes of technology incubators are that they aggregate and foster technology development—they are venues where sector representatives can collaborate to efficiently



Key aspects of the technology incubator model include:

- *A place for the industry to work together*
- *Central knowledge base for common activities such as environmental monitoring and site characterization*
- *Sharing of operational experience and lessons learned*
- *Reduced development time, cost and risks*
- *Potential to share infrastructure and common equipment*
- *Potential for individual technical setbacks to be offset by successes with other technologies*
- *Greater visibility and impact than individual efforts*
- *Opportunity to progress from individual device trials to commercial-scale arrays*
- *Community outreach capacity*

solve common issues. Potential supply chain members are more likely to identify opportunities as consolidation of early individual and smaller projects will increase visibility of activities and sector advancements.

The essential concept is to accelerate learning by doing—to reduce risks and costs. Aggregating the needs of multiple projects can focus the scope of research and drive the installation, operational and servicing solutions more appropriate to commercial-scale projects. By aggregating and consolidating multiple individual activities, *the result of efforts will be greater than the sum of its parts*. Commercial-scale operations will be achieved much faster than by individuals working alone.

Incubators provide the benefit of aggregating independent projects in order to stimulate technology innovation, monitoring techniques, permitting and strategic research, which helps:

- Reduce individual project costs, risks, and time
- Accelerate deployment and early achievement of utility-scale technologies
- Provide accelerated learning opportunities for the sector, yielding insights into technical refinement, and generating credible intelligence on costs and performance
- Incent technology innovation and adaptation
- Create the opportunity for developing SOPs
- Enable extensive knowledge sharing on operational issues
- Raise sector profile with all stakeholders

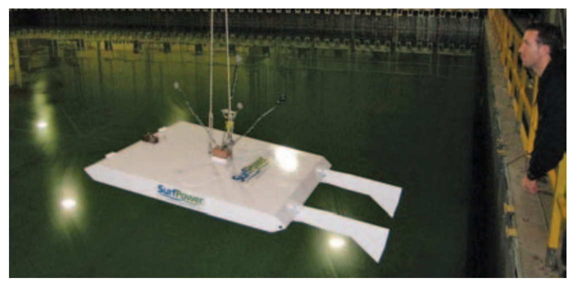


Table 22. Goals for developing technology incubators

Key Principles	Activities	Deliverables
• Canadian technology and expertise development • Accelerate identification of solutions to fundamental issues • Reduce costs through shared infrastructure • Protection of commercial intellectual property • Stimulation of new innovation	• Engage related sectors • Test and develop experience • Gather, process, analyze, and store data • Package, publish, and present findings • Market to the global community	• Accelerated project delivery and learnings • 'Made in Canada' intellectual property • Technology from world-tested systems • Refined standards, SOPs, and best practices • Enhanced Canadian reputation and profile, leading to export

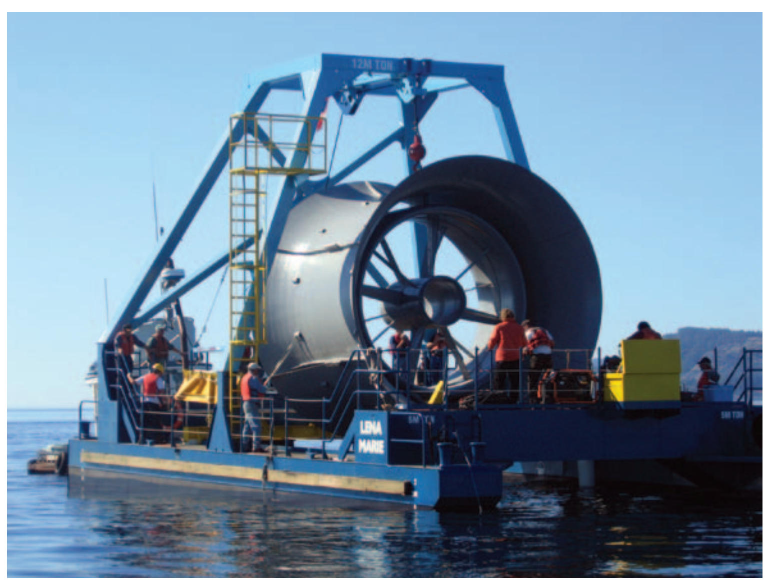
3.2 Accelerate Innovation

Shared infrastructure will draw together the best Canadian technologies and technical approaches and integrate them with leading international technologies and capabilities. It will provide opportunities to identify common challenges and prompt the development of critical technologies and techniques, which may include subsea connectors, subsea geological analyses, operation and maintenance platforms, foundations and moorings, monitoring equipment and devices, and permitting approaches.

Canada must expand its capacity to develop and advance these needed technical solutions. The resulting intellectual property will be demonstrated in the near-term Canadian projects. With that proven experience, Canadian niche solutions will have opportunities in world markets.

Table 23. Goals for accelerating innovation

Key Principles	Activities	Deliverables
• Industry, universities and researchers engaged together in strategic innovation • Sharing of enabling and new intellectual property for critical niches • Rapid delivery of 'inventions to market' • Adoption of 'industry has a need, inventors have a solution' mode of operation • Prioritization of advances that differentiate Canada	• Ensure early projects create opportunities to develop, test and demonstrate the best solutions • Encourage innovative intellectual property and sharing agreements	• Access to broad research skills • Canadian solutions recognized as 'winners' around the world • Proven model for collaborative R&D, problem solving, and identification of innovation opportunities



3.3 Enhance Cross-Sector Technology and Skills Transfer

The concentration of activity and the rapid scaling achieved through successful technology deployments at test centres will increase the attractiveness of the opportunity to adapt technology, techniques, knowledge, skills, and processes from other sectors such as offshore oil and gas, conventional hydropower, environmental monitoring, electrical integration, data gathering and storage, and engineering and project services. The accumulation of experience with commercial-scale projects will provide some of the world's first opportunities to grow supply chain capacity and mobilize knowledge and experience that will be sought by international clients.

Workgroups will be established to allow both formal and informal information exchanges to build strong, Canadian, cross-sector relationships.

Table 24. Goals for enhancing cross-sector technology and skills transfer

Key Principles	Activities	Deliverables
• Communication and demonstration opportunities • Inclusion of other Canadian industrial sectors into marine renewable energy activities • OREG acting with other associations to increase their sector's participation in marine energy	• Develop cross-sector networks • Establish online forum sharing within Canada • Establish cross-sector workgroups, conferences and closed sessions • Ensure cross-sector participation in project development, research, etc.	• Integration of experience and capacity from associated sectors • Rapid movement by Canada along the 'learning curve' • Engagement of established project developers and integrated manufacturers into the marine renewable energy sector

3.4 Enhance Engineering, Procurement, and Construction Capabilities

Successful early development of industrial-scale activity will require mobilization of project teams that can form engineering, procurement, and construction consortia—enabling more effective deployment of marine renewable energy domestically and in the growing international market. These consortia would fulfill the need for risk and safety studies, design verification, testing and inspection services, site condition analyses, engineering, deployment and retrieval, project lifecycle management, and the establishment of SOPs.

Table 25. Goals for enhancing engineering, procurement, and construction capabilities

Key Principles	Activities	Deliverables
• Leading expertise, working together • Demonstrating capabilities, sharing risks and rewards • Involvement of all geographical and industrial areas of Canada	• Demonstrate engineering, procurement, and construction capabilities with initial projects • Expand OREG's inventory of contractors, suppliers, and other needed members • Begin with modest demonstrations in Canada in the near term to build on for future growth	• Executed engineering, procurement, and construction projects/contracts • Working model for large, international undertaking

3.5 Develop Canada's Market Position

Canada's marine renewable energy sector will continue to target international market opportunities while demonstrating capabilities and delivering technological solutions within Canada. The sector will promote Canadian capabilities and pursue international sales and export opportunities.

This enabler will focus on ensuring that technical developments are relevant to emerging world markets and will engage international project and technology development leaders, identifying mid-term opportunities and creating marketing plans for each strategic area. In parallel, active international promotion and branding will be done across various platforms.

Table 26. Goals for developing Canada's market position

Key Principles	Activities	Deliverables
• Understanding potential international customers for Canadian marine renewable energy • Delivering system solutions • Earning a market reputation through demonstration at home	• Carry out market research on resources, price, alternatives, etc. • Perform analysis and product development/alignment • Monitor global competition • Promote and communicate Canadian marine renewable energy in various forums • Pursue strategic international partnering/collaboration	• Product development projections • Partnerships and consortia bidding internationally • International recognition for Canadian marine renewable energy technologies and expertise • Sales and exports

4 Moving Ahead

Five years ago, Canadian interests set out to capture a position among the world leaders in marine renewable energy, by forming the sector association. With a focus on creating a place for the industry to emerge—and a market to drive it—the foundation was set for a more overt and inclusive strategy: this roadmap.

In 2010–2011, Canada witnessed a dramatic increase in support for marine renewable energy: plans for focused feed-in tariffs in Nova Scotia and British Columbia, a resource-development strategy in Quebec, the inclusion of marine renewable energy in federal research and development funding programs, and fiscal supports for renewable energy. These have all helped make Canada one of the most-favoured places in the world for marine renewable energy development. With the largest financial contribution from the 2010 Clean Energy Fund and a clear fit between this roadmap's objectives and the current ecoEnergy Innovation Initiative, the environment for the early phase of implementation is promising.

A supportive environment to build confidence and attract investment

The emergence of a longer-term development strategy in Nova Scotia—which aims to deliver the first commercial-scale array developments and more than 300 MW installed capacity by 2025—is building further confidence in the development of the sector's supply chain. Joint plans between Hydro Quebec and the Government of Quebec to include river-current development in the 200 MW of installations under Plan Nord are further demonstrating the transparency, longevity and certainty required to attract engagement by the financial sector.

Criteria for attracting investors to Canada's marine renewable energy sector:

Transparency: *Is it clear where industrial development is today—as well as where it is going?*

Longevity: *Is the vision realistic enough, large enough and of long enough duration to stimulate engagement?*

Certainty: *Are the roles of society, government and industry clear? Are risks being reduced and do they allow appropriate rewards to all?*

This supportive environment must advance alongside the pathways outlined in this roadmap. Progress to date has given sector leadership the confidence to come forward with an integrated strategic vision and to put forth the plan, outlined in this roadmap, for accelerating innovation in the interest of producing commercially competitive solutions.

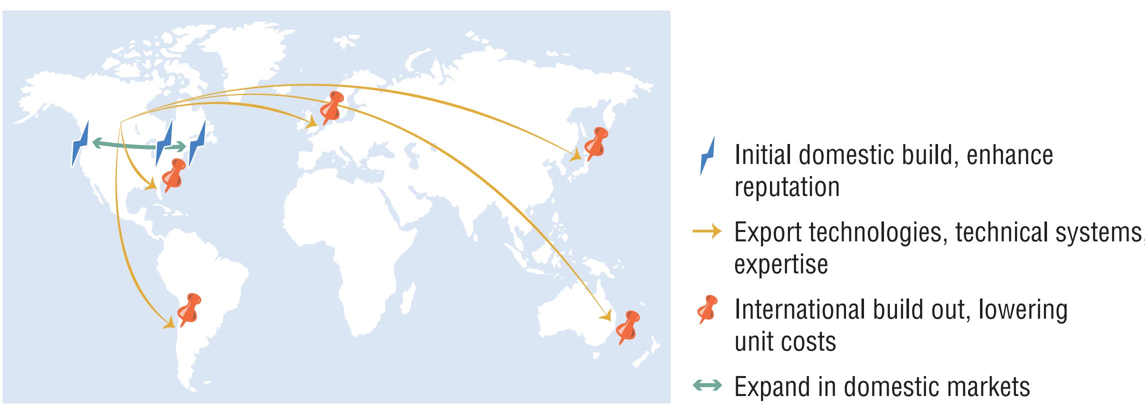
The marine renewable energy sector must move its technology innovation agenda forward under the assumption that a supportive policy environment will also evolve to facilitate the sustainable development of these marine resources.

Meeting the next milestone

Canada's marine renewable energy sector has set itself a challenging first milestone for 2016. However, as a result of earlier efforts and a clear focus on achieving industrial solutions, the leadership behind this roadmapping initiative believes a significant share of the global marine renewable energy opportunity is Canada's to lose. The six pathways described in this document outline specific near-term tactics and priority actions. A focused effort to aggregate early wave, in-stream tidal, and river-current development efforts into facilitated and concentrated efforts will accelerate actions and realize goals. Early emergence of an industrial capacity is the stimulus needed to attract the right skills and stimulate career development of a new generation of marine renewable energy leaders who will grow this international industry.

The ultimate goal of this strategic approach is to maximize the economic benefit of leadership in the marine renewable energy sector to Canada. This can only be done if marine renewable energy proves itself to be a commercially competitive energy resource while, at the same time, making Canadian expertise, technology and technical approaches indispensable to the global market. With engaged utilities, market-based targets, and provincial and federal policies and programs facilitating clean technology development, leading international equipment manufacturers are expected to join in the implementation of this roadmap. While the financial development of the sector remains a challenge, piloting commercial-scale market-driven projects is an essential step forward in expanding the sector domestically and around the world. The development of this technology roadmap has already recruited new partners for the sector; its publication will no doubt attract others.

Figure 1. Canada's marine renewable energy technology and expertise deployment plan



Preparing for 'when', not 'if'

In his opening remarks at the Vancouver workshop that helped create this document, Dr. John MacDonald (founder of MacDonald Detweiler & Associates and Day 4 Energy) emphasized that it was not a question of *if* the world will adopt renewables such as marine, but rather *when*. Throughout the workshop discussions, the underlying theme has always been that the sector is capable of working through the technical challenges to create industrially successful marine renewable energy solutions. Implicit is the belief that investing in being an early innovator—and in demonstrating marine renewable energy solutions to the world—is critical if Canada is to fully benefit when the international sector takes shape.

The *Marine Renewable Energy Technology Roadmap* provides guidance on activities and approaches to building 'Advantage Canada' within this global marine renewable energy opportunity. The time to act is now.

Appendix A: Workshop Participants

Acadia University
Anna Redden

ACOA
Andrew Parsons

AECOM
Russell Dmytriw

Alstom Power
Frank Kaye

Andritz Hydro Canada
Keith Pomeroy, Nicolas Devooght

Atlantic Marine Geological Consulting
Gordon Fader

BMT Fleet Technology
Graeme Comyn, Niall Dixon-Payne

Canadian Standards Association
Jeff Shikaze

CIDCO
Martin Lapointe

Clean Current
Russell Stothers

Daewoo Shipbuilding & Marine Engineering
Nam Ki Lee

Dalhousie University
Andrew Henry

Day4 Energy
John MacDonald

Emera
Katie Burgess

Environment Canada
Jennifer Wilson, Kelly Vandeligt

exp Global
Suki Gill

FORCE
Doug Keefe

Fundy Tidal
Dana Morin

GL Noble Denton
Michael Molek

Hatch
Michael Morgenroth

HDR | DTA
André Casavant

Hemmera
Jon Turner

Industry Canada
Eric Barker, Rosemary Swindells

Instream Energy Systems
Conor Walshe

Irving Equipment
Rod Malcolm

Lockheed Martin
Steve Marsden

Marine Current Turbines
David Ainsworth, Martin Wright

Marmen
Yannick Laroche

Mavi Innovations
Bill Rawlings

McGill University
Geza Joos

MDA Corporation
Russ Baker

Minas Basin Pulp and Power
John Woods, Aaron Long, Terry Gerhardt

Natural Resources Canada
John Marrone

Natural Resources Canada, Geological Survey of Canada
Phil Hill

NB Power
Mike Bourque

New Brunswick System Operator
George Porter

New Energy Corporation
Andrew Walls

Newfoundland and Labrador Department of Natural Resources
Paul J. Morris

Nortek
Eric Siegel

Nova Scotia Department of Energy
Richard Penny

Nova Scotia Power
Kelly Cantwell, Ken Meade, Erin MacNeil, Jamie MacNeil

Ocean Networks Canada
Scott McLean

Ocean Renewable Power Company
Monty Worthington, John Ferland

Offshore Energy Research / FORCE
Jennifer Matthews

OREG
Jessica McIlroy

Quebec Ministry of Economic Development
Will Dubitsky

Renewable Energy Research
Josephine Nicdao

Resolute Marine Energy
Bill Staby

Roper Resources
Chris Roper

Sabella / CHIQ
Marcel Boridy

Sea Mammal Research Unit
Dom Tollit

SeaBreeze Power
Paul Manson

Seawood Designs
Charles Wood

TM4
Désirée Tremblay

Transport Canada
Leslie James

Triton Consultants
Mike Tarbotton

Twig Energy
Kathrin Ohle

University of New Brunswick
Liuchen Chang

University of Victoria
Curran Crawford

Verdant Power Canada
Trey Taylor

Voith Hydro
Pierre Séguin

William Alexander & Associates
James R. O'Hagan

Appendix B: Acronyms and Definitions

Term	*Definition*
Advantage Canada	Potential development areas, based on existing resources, technologies and expertise, which represent sustainable market leadership opportunities for Canada
Array	Multiple energy-conversion devices that have been designed to work as an energy plant with individual devices positioned to optimize the energy output for the plant, taking into account fluid flow, wake and topographic effects
Berth	A project installation and operation location within a test centre
Capital expenditures (CAPEX)	Up-front expenditures to design, permit, purchase equipment (including energy converters, buildings and cabling), and install the project
Clean energy	Any source of energy, product, service, or process that reduces (or causes little to no) harm to the environment and/or power-production methods that are not associated with greenhouse gas (GHG) emissions
EMEC	European Marine Energy Centre
Enabler	Sector activities and tactics that create the foundation for progress
Environmental assessment (EA)	A process to assesses the potential environmental effects, positive or negative, of proposed initiatives before they are carried out
FERN	Fundy Energy Research Network
FORCE	Fundy Ocean Research Centre for Energy
Grid	A network of interconnected cables for transmitting and/or distributing electricity
Heat map	A graphical polling tool to gauge levels of support from an audience for diverse ideas
IEA	International Energy Agency
IEC	International Electrotechnical Commission
Incubator	An entity (e.g. consortium, facility) to foster entrepreneurship and technology innovation and development through the use of shared resources, expertise, and intellectual capital
Industrial approach	A focus on moving from trials and development to providing utility-grade power systems, working at commercial scale, and mobilizing a supply chain that can transition to a mature, self-sustaining sector
In-stream tidal energy	Capture and conversion of the kinetic energy of flowing water, due to tidal currents, without the use of a barrage or dam
IPP	Independent power producer
Marine renewable energy	The conversion of kinetic energy from waves, in-stream tidal currents, and river-currents into mechanical energy; used primarily to generate electricity, but can also be used to pump water or for other consumer needs
OEER	Offshore Energy Environmental Research Association

Term	*Definition*
OEM	Original equipment manufacturer
OES	Ocean Energy Systems
Operation and maintenance (O&M)	The combined activities for operating and maintaining a device, system or plant
Operational expenditures (OPEX)	Ongoing expenditures associated with the operation and maintenance of a device, system or plant
OREG	Ocean Renewable Energy Group
Pathway	Core development direction comprising coordinated activities that build upon each other over time to achieve defined goals
Power system	Includes all components in the energy generation device (or plant) from water-to-wire
R&D	Research and development
Renewable energy	Energy that comes from sources that are naturally replenished such as waves, tides, river-currents, sunlight, wind, and geothermal heat
River-current energy	Capture and conversion of the kinetic energy of flowing water in a river, without the use of flow diversion, a barrage or dam
SEA	Strategic environmental assessment
SOP	Standard operating procedure
Supporting technology	A component or technology that is a part of the power system but does not directly perform the energy conversion (e.g. cable connectors, deployment barges, foundations, moorings, design software)
Sustainable	Meets present needs so that the resource is not depleted or permanently damaged, and allows future generations to meet their needs as well
TC114	IEC Technical Committee 114 for Marine Energy
Technology component	Any individual or separable part or subsystem of the power system. In this document, the term is interchangeable with ‘supporting technology’
Wave energy	Capture and conversion of the kinetic and potential energy associated with the propagation of surface waves, integrated from the sea floor to the surface

Appendix C: References

Bedard, R., Previsic, M., Hagerman, G. (2007). North American Ocean Energy Status, March 2007. Electric Power Research Institute Tidal In-Stream Energy Conversion Report No. TP-008-NA.

Cornett, A. (2006). Inventory of Canada's Marine Renewable Energy Resources. National Research Council Canadian Hydraulics Centre Technical Report No. CHC-TR-041.

Khan, J., Bhuyan, G. (2009). Ocean Energy: Global Technology Development Status. Report prepared by Powertech Labs for the IEA-OES. Available: www.iea-oceans.org.

Miller, G. et al. (1986). Allocation of Kinetic Hydro Energy Conversion Systems in USA Drainage Basins. New York University, pages 86–151.

National Energy Board (2011). Canadian Energy Overview 2010. Energy Briefing Note. ISBN 1917-506X.

Appendix D: Photo Credits

Page i: James Taylor in front of the OpenHydro open-centre turbine in Halifax, NS. Courtesy of Nova Scotia Power Inc.

Page 3: AXYS WatchMate metocean buoy gathers wave energy data for the West Coast Wave Collaborative (WCWC), BC. Courtesy of AXYS Technologies Inc. (AXYS)

Page 5: The 25 kW EnCurrent power generation system. Courtesy of New Energy Corporation Inc.

Page 9: TREK turbine for deployment in the St. Laurence near Montreal, QC. Courtesy of Renewable Energy Research (RER)

Page 12: Subsea power cables for deployment at FORCE. Courtesy of FORCE

Page 14: Lobster fishing boat, for equipment deployment for Acadia University research activities, docked at the Parrsboro wharf, NS. Courtesy of Stephane Kirchhoff, Ocean Tracking Network

Page 15: Deploying the TREK turbine in the St. Laurence near Montreal, QC. Courtesy of Renewable Energy Research (RER)

Page 19: OpenHydro turbine lifting frame on the OpenHydro Installer. Courtesy of Dan Thompson, Nova Scotia Power Inc.

Page 22: Sabella turbine testing. Courtesy of Sabella Énergie Inc.

Page 23: Clean Current river-current turbine. Courtesy of Clean Current Power Systems Inc.

Page 26: Testing in the NRC-IOT tow tank, in support of University of British Columbia Graduate Thesis. Courtesy of Mavi Innovations Inc.

Page 27: Verdant Power turbine deployment at the RITE project. Courtesy of Verdant Power.

Page 29: SyncWave wave energy device – image from the Charlotte proof-of-concept tests. Courtesy of SyncWave Systems Inc.

Page 32: SurfPower prototype testing. Courtesy of Seawood Designs Inc.

Page 33: Clean Current tidal turbine testing at Race Rocks, BC. Courtesy of Clean Current Power Systems Inc.

Page 34: Tugs at dawn, Atlantic Towing tugboats in Minas Passage, 2010. Courtesy of Dan Thompson, Nova Scotia Power Inc.

Page 37: OpenHydro open-centre turbine. Courtesy of OpenHydro Group Ltd.

Back Cover: Cape Breton, Great Bras D'Or Channel. Courtesy of Greg Trowse.