SUMMARY

Value Proposition for Tidal Energy Development in Nova Scotia, Atlantic Canada and Canada

April 2015

Prepared for: Offshore Energy Research Association (OERA)
Halifax, Nova Scotia

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The Value Proposition project was commissioned by the Offshore Energy Research Association (OERA) through funding support from the Province of Nova Scotia and co-funded by the Atlantic Canada Opportunities Agency (ACOA).

The OERA would like to thank ACOA for their funding support of this project. Additionally, the OERA gratefully acknowledges the time and effort of the Project Management Committee (PMC) - a volunteer advisory group from the Government of Canada and Province of Nova Scotia, industry and academia with expertise in marine renewable energy from across Canada, whom provided valuable input and feedback throughout the project.

Errors of fact or interpretation remain the responsibility of the report authors.

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This report is supported in part by the Atlantic Canada Opportunities Agency (ACOA) under the Atlantic Policy Research Initiative, which provides a vehicle for the analysis of key socio-economic policy issues in Atlantic Canada. The views expressed in this study do not necessarily reflect the views of ACOA or of the Government of Canada. The author is responsible for the accuracy, reliability and currency of the information.

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Summary

1. Background

The world's oceans contain vast amounts of hydrokinetic energy. If harnessed, this resource has the potential to greatly reduce dependence on fossil fuels to meet increasing levels of electricity demand. In so doing, it also has the potential to create an entirely new industry, offering technical solutions to an emerging global industry and resulting in substantial socio-economic benefits for those nations with resource potential and a desire to support industrial and tidal project development.

The tidal energy industry is at an early stage of development. It relies heavily on various forms of public support for its research and development activities, and also on private investors. The industry benefits from feed-in tariffs in some jurisdictions (including Nova Scotia), as it moves to a commercial stage of development. Governments and industry recognize that support is needed for a period of years while costs are brought down to competitive levels with alternative renewable energy sources. Onshore and offshore wind energy serve as examples of how public support can contribute to both environmental and industrial objectives.

The value proposition for tidal energy over the long term rests on two key factors: its cost competitiveness with other energy sources, and the benefits it generates for the local economy through supply chain development. The two are connected. In the short term, support is needed to encourage industry to invest in the research, development, innovation and demonstration (RDI&D) needed to commercialize the technology. In the longer term, as the goal of commercialization is achieved, industry pays the economic dividend in the form of a national supply capability to develop and operate tidal energy facilities. For the early adopter, this capability could be exportable, offering the potential to add greatly to economic impacts.

2. Objectives

This report was produced on behalf of the Offshore Energy Research Association of Nova Scotia (OERA) to provide government and industry with a clear understanding of the value proposition for tidal energy in Canada, including the opportunities and challenges of creating a supply chain for a future tidal energy industry.

The main objective of the report is to produce a comprehensive assessment of the value proposition for tidal energy that provides an estimate of the potential value, broader benefits and potential economic impacts of tidal power development to Nova Scotia, the Atlantic Region and Canada. Meeting this objective requires casting the net widely for relevant information and lessons learned. The main elements are:

- An exploration of tidal resource potential and development in other jurisdictions: the key factors affecting the pace of development, forms and levels of public support, and the value propositions put forward by industry and government to justify these levels of support.
- Three tidal development scenarios in Canada that form the basis for assessing the value proposition and are contrasted with the Nova Scotia Marine Renewable Energy Strategic plan (Early adoption). The various factors affecting the scale of development are examined over a 25-year study period: 2015-2040. The competitiveness of tidal energy against other energy sources is assessed using a levelized cost of energy (LCOE) approach.

- A close examination of supply chain opportunities arising from tidal development in Canada. Demonstration/pre-commercial and commercial development phases are explored, with a description of how a supply chain would develop over time. Supply chain opportunities are described, with associated cost estimates.
- Quantification of the value proposition, beginning with an assessment of industry participation and leading to estimates of economic impact under each scenario. The benefits of avoided greenhouse gas (GHG) emissions and other pollutants form an important part of the value proposition.
- An assessment of areas of uncertainty, examining the impact of risk on the value proposition and offering options for risk mitigation. The report concludes with suggested steps governments and industry could take on a range of issues that would enhance the value proposition.

3. Findings

General

The world's oceans contain an immense renewable energy resource. Hundreds of millions of dollars globally have been spent to date on research and development of tidal and wave devices to harness this potential. Much of this activity has occurred in the European Union (EU), driven by the prospects for creating a supply chain to meet the needs of an emerging regional and global marine energy industry, while simultaneously reducing dependence on fossil fuels and increasing energy supply security. These prospective achievements form the essence of the value proposition.

Canada also possesses substantial sources of marine energy, including the tides of the Bay of Fundy, one of the world's largest and most accessible resources. The total potential market value to a tidal energy supply chain is a function of the market demand for tidal devices to meet electrical energy needs. In the absence of firm projections, a scenario approach is used to establish market demand. The scenarios incorporate changes in capital and operating costs over time, reflecting 'industry learning' – improvements in turbine efficiency, manufacturing processes, economies of scale and marine logistics.

The major challenge currently facing tidal device manufacturers is to prove the reliability of the technology, and also that tidal energy can become competitive with alternative renewable energy sources, particularly offshore wind. Prototype testing and demonstration are on-going in the EU and in the Bay of Fundy (the first deployment was in 2009, with the next expected as early as 2015). The first crucial steps on the 'path to market' – becoming competitive with alternatives to create a demand for tidal energy – have been implemented in the U.K., France and Nova Scotia. These take the form of various support programs, including feed-in tariffs (FIT). But as currently structured, these will provide long-term support for capacity installed before 2020; policy and support beyond 2020 remains to be established.

The nature and level of policy support for tidal after 2020 is not clear in any jurisdiction. What seems clear is that an indication of further support is going to be needed to ensure the global rate of installations is high enough to achieve the industry learning essential to reducing costs and improving competitiveness. In other words, device manufacturers need to see a role for tidal in the energy mix – an eventual market characterized by strong and consistent demand in order to sustain their commitment of resources to continue developing the technology. This kind of policy support played an important role in the development of wind (onshore and offshore) and solar energy technology. For their part, governments need to see that the industry is taking the steps needed to put tidal energy on a path leading to cost competitiveness.

The lack of an established global supply chain represents an opportunity for prospective suppliers, whether in Canada, the EU or elsewhere. Across a wide range of goods and services, it means there exist no barriers to entry from entrenched competition. The manufacture of tidal device components and supply of marine cable represent two notable exceptions, with the market for these items controlled by a few large industrial companies based mainly in the EU. But these items account for only 30-40% of capital costs, leaving the other 60-70% of the value of development open to an emerging supply chain. Most of this 60-70% consists of goods and services that would or could be supplied at or near the tidal development site. These include a range of environmental assessment and planning services, facilities and vessel construction, device assembly and installation, and cable installation. Local operation and maintenance expenditures would exceed 80% of total annual operations and maintenance (O&M) costs.

Suppliers in Nova Scotia, the Atlantic Region and Canada are in an excellent position to meet 60-70% of the goods and services required for tidal development in the Bay of Fundy. Decisions about whether to enter the market will depend on an assessment of the level of demand against supply-side factors including investment requirements and competitive conditions. Participation by domestic suppliers is assumed to be strong, resulting in positive economic impacts (gross domestic product (GDP), employment and income) varying more or less proportionately to assumed installed capacity under each scenario. The impacts are most intense during the development phase when tidal devices are installed, though on-going O&M also generates considerable on-site activity. That development in the tidal scenarios occurs in a largely rural area adds to the significance of the employment and income impacts because of the general scarcity of job opportunities and relatively low incomes.

Tidal developments outside Canada also provide opportunities for Canadian suppliers. Some estimates suggest this market could have a value in the $900-1,000 billion range by 2050. Even if Canadian suppliers were to compete in 10% of this market and secure just a 5% market share, it would be worth $4-5 billion over the period. Success in the export market would be enhanced if tidal development were to occur earlier, or at least no later, in Canada than in other jurisdictions. This would be the case under the Early Adoption Scenario, with 500MW installed in Nova Scotia by 2032.

In a world where addressing climate change is becoming increasingly urgent, investing in clean technologies that displace fossil fuels and contribute to the avoidance of GHG emissions (and other harmful pollutants) adds greatly to the tidal value proposition. Using conservative estimates of environmental costs per tonne, the value of avoided emissions ranges from about $200 million under the Demonstration Scenario to $1.0 billion under the Early Adoption Scenario.

Set against the benefits side of the value proposition – creating an industry, reducing GHGs and other emissions, improving energy security – are the costs embedded in the policy support needed to encourage tidal energy development. In Nova Scotia, primary support takes the form of a feed-in tariff for both distribution- and transmission-scale projects for up to about 20MW of installed capacity. The analysis indicates tidal cost parity with alternative renewable energy sources is expected to occur soon after 2040. Accordingly, implicit in each scenario is some form of public support needed to bridge the gap between the levelized cost of tidal energy and these alternatives.

The rate of tidal capacity installations globally forms a key determinant of the rate at which tidal costs are expected to decline. This in turn affects when cost parity would be reached and the level of support needed to bridge the energy cost gap. The assumption made about the global installation rate, then, becomes a major factor in the analysis. Considerable uncertainty surrounds this factor. This analysis adopts what seems to be a realistic assumption given available information. But if a higher rate were achieved, then costs would drop faster, parity with alternatives would be achieved sooner, and the level of public support would be less.

Specific

- **The value proposition (justification for public support) for tidal energy among EU member states hinges on its capacity to further policy in three key areas: economics, climate change and energy security.** Harnessing tidal energy is of interest to several nations with resource potential. Outside Canada, the EU – and the U.K. in particular – are the most advanced with respect to quantifying the resource potential and supporting technology RDI&D. The level of financial support directed by national governments and the European Commission (EC) towards tidal energy in the EU over the past several years amounts to several hundred million dollars. Support takes many forms including direct funding to device developers, to researchers at universities and institutes, and to fund test and demonstration facilities (e.g., the European Marine Energy Centre). Several countries have also introduced feed-in tariffs to subsidize energy producers (in anticipation of commercial production). Such support is the norm with technologies that hold promise to further key policy objectives – this is the essence of the value proposition. Wind energy serves as a good example of how public support has been used to good effect in bridging the gap between early development and commercialization, and in the process, creating dynamic industries in countries that were early adopters (e.g., Denmark, the U.S., Spain and Germany).

  In various industry (and some government) documents, considerable emphasis is placed on the opportunity for creating a new industry to supply the unique goods and services needed to develop the tidal resource. Impacts are quantified in terms of the value of industry output (potentially billions of dollars), jobs created, income earned, contribution to GDP, and export potential. The merits of the tides as a renewable energy source contribute to climate change commitments with respect to reducing GHG emissions and the related environmental/ economic costs associated with global warming. Last, but not least, tidal energy is also put forward as an important means of improving energy security and making a valuable contribution to price stability. The specific value proposition factors and measures used to quantify indicators are shown in Table S.1.

Table S.1: Value proposition in EU for tidal energy

Criteria	Value Proposition Motivators	Potential Measures
Economic growth	Supply chain development	National share of development expenditures
	Employment & income	GDP, employment and income created
	Regional disparities	Industry locating in rural areas of tidal potential
	First mover advantage & export potential	Inward investment & export capability
	Industrial location	Cost of electricity (relative)
Energy Security	Reducing fossil fuel dependence	Stable electricity price
	Depletion of conventional resources	TWh displaced/cost vs alternatives
	Age of existing generating capacity	Timescale for delivery
	Geopolitics	Uncertain supply/risk
	Increasing energy demand	Secure domestic source
Climate Change	Climate change commitments	% contribution to renewable energy supply (TWh)
	Renewable energy source	Tonnes CO_2e avoided
		Cost of carbon avoided (compared to alternative clean tech.)

- **Global tidal potential is substantial and developing it could require expenditures in the $1,000 billion range.** The theoretical global resource potential for tidal energy (in-stream and tidal range) is estimated to be approximately 1,200 million MWh per year, enough energy to supply the annual needs of 100 million households (slightly fewer than the number of households in the U.S.). The practical potential is considerably less, though nonetheless substantial. In 2013, the International Energy Association (IEA) indicated installed capacity could reach 23,000MW by 2035, while the UK's Carbon Trust projected 55,000MW by 2050. Reaching the latter capacity is expected to require cumulative expenditures in the CA$900-1,000 billion range. Though the timing of these projections may seem overly optimistic in light of the challenges the industry is facing in securing on-going support for developing the technology, they do provide a sense of the value of the global industry that would supply the goods and services.

- **Canadian tidal potential is likely to be developed initially where the value proposition is strongest: in the Bay of Fundy**. The theoretical potential of in-stream tidal energy in Canada is estimated to be 42,000MW at some 190 sites on the Atlantic, Pacific and Arctic coasts. The estimates of extractable power using today's technology vary, and considerably more analysis is needed to determine practical potential. Some high potential sites are favourably located, while others are remote, located some distance from transmission grids. Some accessible sites in Canada offer potential, but without FITs or other forms of support, the opportunity is likely to be limited to small-scale tidal technology to serve remote, off-grid communities now relying on expensive diesel generators.

  On the assumption that tidal development would occur first at those sites where the value proposition would appear to be strongest, the analysis is focused on the potential in Nova Scotia and specifically, the Bay of Fundy. This area meets three key criteria: excellent resource potential, relatively low cost for grid access, and a legislated requirement to meet carbon emissions and renewable energy targets (linked to energy diversity and security). Realizing this potential would require major investment in infrastructure, tidal arrays and a wide range of support services.

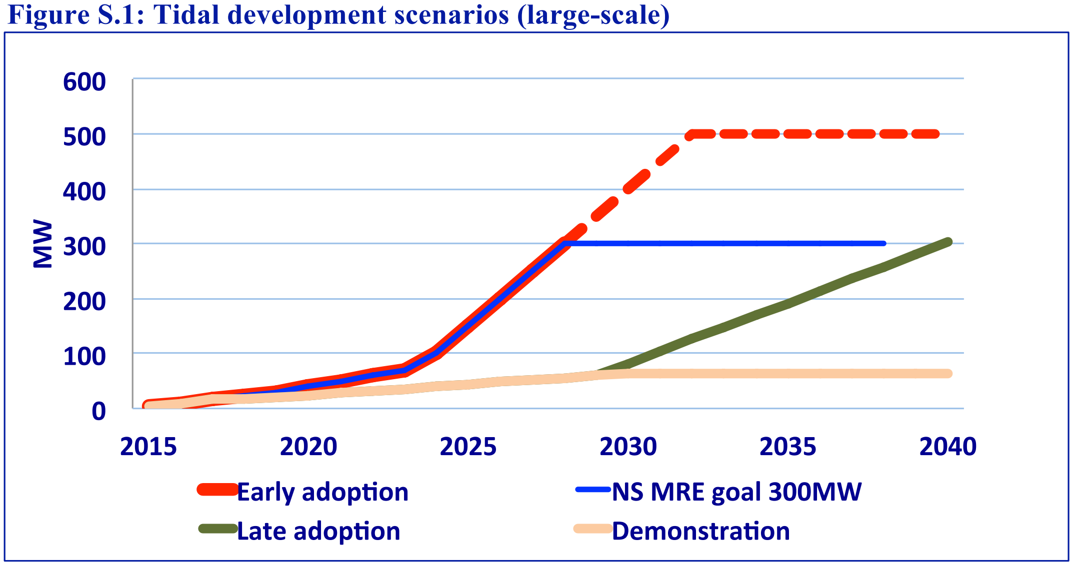
- **The scale of any potential tidal development in Nova Scotia depends on resource, environmental, market, economic and policy factors**. Preliminary research indicates that resource potential at the most attractive site, the Minas Passage in the Bay of Fundy, could yield 2,500MW of extractable power with minimal impact on tidal flow. Further study is needed to establish the full range of impacts turbines would have on the marine environment, and conversely, the impact that the marine environment would have on turbine performance. Tidal power has attractive marketability characteristics: like wind, it is renewable; though it has the great advantage over wind of being predictable. Nonetheless, there would be load-balancing challenges in absorbing large amounts of tidal energy, given current and future levels of wind capacity in the Nova Scotia electrical system. Certainly, 2,500MW would exceed the absorptive capacity of the Nova Scotia market, so access to electricity markets beyond the Province would be needed to realize this potential. This would require strengthening the transmission system between Nova Scotia and New Brunswick (likely to occur as the Maritime Link is built), and also between New Brunswick and New England. Accessing markets beyond Nova Scotia would be premised also on the competitiveness of tidal energy with alternative sources of electricity. Against the backdrop of these factors, Nova Scotia's Marine Renewable Energy Strategy sets out the elements for a 'phased and progressive' approach to achieving a long-term goal of producing 300MW of tidal power.

- **The value proposition analysis relies on three scenarios for large-scale grid-connected tidal development and two scenarios for small-scale distribution system development implemented over the 2015-2040 period**. These alternative paths (illustrated in Fig. S.1) provide contrasting conditions against which to assess potential supply chain development, energy costs and economic impacts. Development in all scenarios benefits from Nova Scotia rate support under the FIT and community feed-in tariff programs (COMFIT).

  Large-scale

  - **Demonstration scenario – 64MW**. Developers take full advantage of the infrastructure at Fundy Ocean Research Centre for Energy (FORCE) under various government or research initiatives, with installed capacity levelling off at 64 MW by 2030. A key assumption is that the tidal industry has not managed to achieve sufficient cost reduction to become competitive with alternative renewable energy sources in Nova Scotia, and public support to make up the difference is not available after 2030.
  - **Early Adoption scenario – 300/500MW.** With indications that tidal energy costs are declining rapidly, the industry continues to receive support from governments until tidal energy is competitive with alternative renewable sources. Implicit in this scenario is that Nova Scotia and Canada accelerate the installation of tidal capacity, resulting in greater competitive opportunities for Canadian companies in the international supply chain, but with the higher costs associated with early development. Capacity expands rapidly after 2023 following regional transmission system investment, reaching the 2012 Nova Scotia Marine Renewable Energy Strategy (NS MRE Strategy) goal of 300MW by 2028. Capacity reaches 500MW in 2032, when the upper limit of regional market potential is reached.
  - **Late Adoption scenario – 300MW**. Capacity development follows the Demonstration Scenario until 2029 and then increases to 300MW by 2040 as tidal technology approaches cost competitiveness with alternatives. Cost competitiveness is driven by the growth of tidal capacity internationally, but late entry into the marketplace reduces the competitive advantage for Nova Scotian and Canadian suppliers in accessing international supply chain opportunities. A key assumption is that the investment needed to integrate several hundreds of MW of tidal energy are made during the expansion of the bulk power system in Nova Scotia and New Brunswick to incorporate the Maritime Link.

Figure S.1: Tidal development scenarios (large-scale)



Small-scale

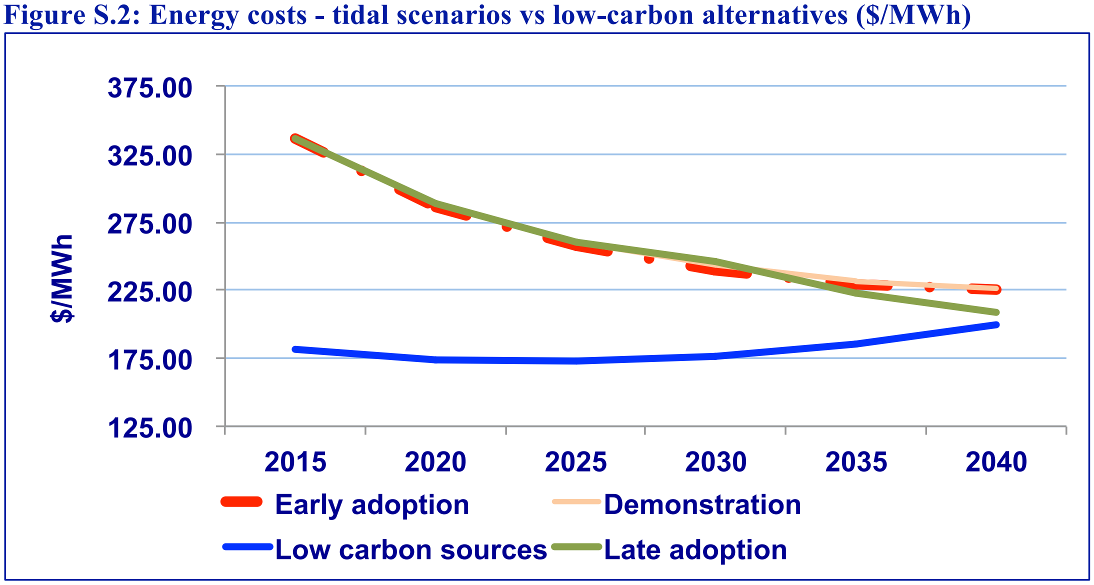
- **Low scenario – 3.5MW**. Approved developments range from 500kW to 1.95MW in Digby County (Digby Gut, Grand Passage and Petit Passage) and from 100 to 500kW in Cape Breton (Bras d'Or Lakes). The devices will be installed by 2017.
- **High scenario – 10MW**. Several sites in Canada offer tidal energy potential, but moving beyond the level of capacity supported by COMFIT requires sites that meet three key criteria: they are economic in their own right (because no other jurisdiction in Canada yet offers rate support); capacity can be absorbed by distribution systems; and they meet all regulatory and environmental assessments and are accepted following any First Nations consultations. In the absence of information on these considerations, no specific sites beyond those in the Low Scenario are identified for the High Scenario.

- **Assuming on-going public support, tidal energy costs will decline over the study period, becoming competitive with alternative renewables by the early-2040s.** Having reliable capital and operating cost estimates for tidal energy is important because it enables an analysis of competitiveness with alternative energy sources and also provides a basis for evaluating the prospective tidal energy supply chain and the economic impacts flowing from tidal development. Tidal costs now are relatively high because the technology is at an early stage of development. Costs will decline as manufacturing and installation processes are industrialized. The rate of decline depends on the rate at which tidal devices are installed.

  Industry learns from experience, technological innovation occurs, and scale economies are achieved. *The cost analysis in this report assumes installations are occurring globally to help drive costs down*. The rate of global growth is a critical assumption; a higher growth rate would cause costs to decline more rapidly and parity to be reached sooner.

  A conventional LCOE approach is used to determine how costs are expected to change over the 2015-2040 study period. A comparison of costs for each scenario with the average for a mix of low carbon alternatives indicates that grid-parity would be reached soon after 2040 (Fig. S.2).

Figure S.2: Energy costs - tidal scenarios vs low-carbon alternatives ($/MWh)



The rate at which costs decline has a direct bearing on the level of support the tidal industry would need before the technology is competitive with relevant alternatives. This level of support (illustrated by the wedge between tidal and the low-carbon alternatives) may be characterized as the tidal 'learning investment' governments make to meet economic and energy policy objectives.

- **The emergence of a tidal energy supply chain is contingent on the industry moving successfully through RDI&D into commercial development**. From the perspective of market pull and push, the industry path would appear to be set for the next 4-5 years. Locations where the resource is most promising (U.K., France and Nova Scotia) have mechanisms in place to support prototype and developmental grid-connected installations. Industry observers suggest that a minimum of two years continuous performance would be needed to meet the reliability and operability criteria established by Independent Power Producers (IPPs), insurers, lenders, investors and utilities. This suggests 2018-2019 at the earliest for the first pre-commercial arrays (reliable technology, but not yet cost-competitive).

  The FITs in the various jurisdictions are essential to industry development to this stage. There is uncertainty about the industry development path after 2019, because policy everywhere is unclear about future levels of public support for technology development. The basis for the uncertainty lies in tidal energy costs that will still be too high in 2020 to be competitive with alternative renewable sources. This threshold may not be reached until 2030 at the earliest, in large part because it has taken the device developers much longer than anticipated to conduct the RDI&D. In the meantime, device developers are urging governments to continue the support they say is essential to maintaining industry interest – support to encourage the deployment of the additional arrays that are essential to achieving the industry scale, supply chain specialization and efficiencies that will bring costs down.

  The nascent tidal industry, then, finds itself at a critical juncture. Costs must come down to be competitive, but costs can only come down if the rate of capacity installation increases. And while industry looks to government for support, government is looking to industry to do more to resolve some of the outstanding challenges. Assuming the combination of factors needed to break the logjam emerges over the next few years, the tidal industry could enter a commercial phase of development by about 2020. *Implicit in this assumption is the global installation of some 150MW of tidal capacity in small arrays between 2015 and 2020.* This rate of installations is essential to force a reduction of tidal costs to about $290/MWh by 2020. Limited supply chain development is likely to occur up to this point.

  Assuming delivered tidal energy can enter electrical grids at a cost competitive with alternative renewables (including public support), the global industry would be characterized by a rapid build-out of capacity in locations worldwide. This could exceed 500MW by 2030. This expansion could only occur as a result of important changes in the structure and operation of key aspects of the tidal industry as we know it today.

  - IPPs would emerge to take responsibility for project design, implementation and operation, much as they do in the mature onshore and offshore wind energy industry.
  - Technology developers would transition to their typical role as technology suppliers.
  - IPPs would have access to conventional sources of finance and insurance based on devices meeting accepted reliability criteria and manufacturer's warranties.
  - A convergence of technologies would be expected, given the need to achieve production and installation efficiencies. Purpose-built vessels would enter service to deploy and retrieve tidal energy conversion devices.

- The projected pace of development, coupled with the size of the devices, would require investment in facilities close to tidal sites for assembly, fabrication and installation.
- With a strong and consistent level of demand for tidal energy, an industry supply chain would develop leading to the production of 'off the shelf' goods and services typical of mature technologies (such as wind energy).

- **Supply chain development in Nova Scotia and elsewhere in Canada is contingent on expectations for strong and consistent demand for tidal energy and the goods and services tidal development projects require.** Common to each large-scale Scenario is a test phase, 2015-2017, when the berth holders at FORCE deploy their devices. Small-scale projects are implemented over the same period. At FORCE, one or more of the developers deploy small arrays, bringing total capacity to 20MW by about 2018. To this point, with deployments spread across several developers and some uncertainty about support beyond the current FIT, it is likely that assembly of the large-scale devices and any structural fabrication would take place in existing facilities in Halifax, with devices towed to the Bay of Fundy for deployment. In other words, before 2018, there is still likely to be insufficient clarity around tidal competitiveness (including reliability and financing) and the prospect of a rapid build-out to warrant investment in assembly/fabrication facilities.

  For large-scale tidal, the nature and extent of supply chain development would depend greatly on what happens after 2018. This is when the scenarios begin to diverge.

  - **Demonstration Scenario:** the market pull for tidal capacity beyond the level of FORCE capacity does not arise. Tidal development is assumed to benefit from a reduced FIT available during the 2020s, but tidal energy does not reach the level of competitiveness needed to expand beyond 64MW. There is insufficient justification for dedicated assembly/ fabrication facilities in the Bay of Fundy; this work is staged from Halifax.
  - **Early Adoption Scenario:** through a combination of declining costs and public support, there is sufficient market pull for up to 500MW of tidal capacity to be installed by 2032. The first phase consists of 300MW, meeting the NS MRE Strategy goal. With sufficient regional demand for renewable energy, development is assumed to continue to 500WM. Nova Scotia Power Inc., (NSPI) would signal its intent to issue RFPs for specified blocks of power. This level of certainty provides the basis for the market entry of IPPs and investment in a Bay of Fundy facility for device assembly and fabrication. The expectation of strong and consistent demand over a decade also provides a strong incentive for domestic supply chain development.
  - **Late Adoption Scenario:** the market pull in Nova Scotia for tidal capacity beyond 64MW does not arise until 2030, after on-going tidal development in other jurisdictions has caused costs to decline to levels approaching competitiveness with low-carbon alternatives. Industry has converged on one or two designs. There is justification for a dedicated assembly/fabrication facility in the Bay of Fundy, though the facility is not constructed until the late 2020s. A domestic supply chain would begin to emerge in the 2030s.

  Small-scale tidal projects differ in number, size, complexity and duration, and as a consequence, most requirements are likely to be served by suppliers who adapt their goods and services, rather than the emergence of a dedicated supply chain. The small scale of projects favours use of local assembly, fabrication and installation facilities. Turbines are an exception; supply chains for the efficient manufacture of standard components and parts would be expected to emerge as demand increases.

- **Tidal energy development would create opportunities for suppliers covering a wide range of goods and services, with the nature and scale of opportunities dependent on the level of demand.** Many of the activities comprising a tidal project would be familiar to those companies with experience planning and building for, and operating in, the marine environment. For some suppliers, meeting the domestic tidal energy goods and services requirements would be fairly straightforward because they currently have the direct capability and capacity. For others, it would be a matter of adapting their offering and expanding their capacity in anticipation of, or in response to, demand. Interviews conducted with prospective suppliers indicate that many would be taking a 'wait and see' approach, holding off decisions on investing in adaptation or expansion until it becomes clear a strong and consistent demand exists or can be safely anticipated.

  Nova Scotian, regional and other Canadian suppliers have the capability and experience to supply 60-70% of the goods and services required for large-scale development. This content estimate is tied to site-specific inputs or activities and is fairly consistent across scenarios. A breakdown of requirements, costs and an estimate of local content is shown in Table S.2.

  Supply capability is expected to be high for most inputs, with the exception of turbines, ancillary equipment and marine cables. These components are likely to have high import content. Device developers are most likely to rely on existing manufacturing facilities (mainly in Europe), allowing them to refine operations and extend production runs to minimize costs. Nonetheless, as confidence in the continued prospects for tidal development grows, domestic industry could adapt and compete effectively in the supply of some of the goods and services that initially are likely to be imported (e.g., certain device components, turbine blades). In the case of small-scale development, tidal devices are manufactured in Canada. Supply content would approach 100% if domestically manufactured devices were used.

  Tidal development outside Canada provides an export opportunity for domestic suppliers. The capability and capacity developed by Canadian suppliers in tidal projects in the Bay of Fundy would provide an excellent foundation for participating in this global market. Among the promising areas of global opportunity for Canadian suppliers are:

  - Resource modelling and site characterization (directly applicable);
  - Constructing purpose-built vessels and work boats (directly applicable);
  - Fabricating support structures (directly applicable);
  - Sensors, acoustics, instrumentation and monitoring (some adaptation required);
  - Manufacturing composite turbine blades (innovation and adaptation required); and
  - Marine cable installation, interconnection and electrical systems (innovation required).

Penetrating the export market would present a challenge because the same logic that drives the relatively high potential local content reflected in Table S.2 also applies to other jurisdictions, especially the EU with its industrial strength and long history of offshore oil & gas development and marine capabilities. *Export opportunities would be strengthened to the extent the timing, pace and scale of tidal development here places Canada in the position of an early adopter. This would be the case under the Early Adoption Scenario only.*

Table S.2: Tidal development costs by scenario and domestic content estimate, 2015-2040

		Total Expenditures: 2015-2040					% spent in Canada (2)	NS MRE Case (3)
			Early adoption					
Cost centre (1)	**Supplier**	**Demo**	**NS MRE**	**Maximum**	**Late adoption**	**% of total**	**%**	**$000 (2012)**
MW		67	300	500	300			
1. Pre-project planning								
Site screening								
Resource assessment	Consultant	320	1,305	2,025	1,153	0.1%	100%	1,305
Constraints analysis	Consultant	128	522	810	461	0.0%	100%	522
Health & safety analysis	Consultant	256	1,044	1,620	922	0.1%	100%	1,044
Grid connection assessment	Consultant	192	783	1,215	692	0.1%	100%	783
Logistical analysis	Consultant	320	1,305	2,025	1,153	0.1%	100%	1,305
Technology assessment	Consultant	256	1,044	1,620	922	0.1%	100%	1,044
Preliminary feasibility analysis	Consultant	128	522	810	461	0.0%	100%	522
Environmental & technical assessment								
Environmental scoping	Consultant	639	2,610	4,049	2,305	0.2%	100%	2,610
Physical surveying	Consultant	1,278	5,219	8,099	4,610	0.3%	100%	5,219
Meteorological & resource assessment	Consultant	959	3,914	6,074	3,458	0.3%	100%	3,914
Grid infrastructure assessment	Consultant	639	2,610	4,049	2,305	0.2%	100%	2,610
Marine infrastructure assessment	Consultant	1,278	5,219	8,099	4,610	0.3%	100%	5,219
Sub-total		6,392	26,095	40,494	23,052	1.7%		26,095
2. Project implementation								
Planning								
Public consultation	Consultant	1,203	4,912	7,622	4,339	0.3%	100%	4,912
Mi'kmaq ecological knowledge	MEKS services	1,203	4,912	7,622	4,339	0.3%	100%	4,912
Environmental assessment	Consultant	3,610	14,736	22,867	13,018	1.0%	100%	14,736
Permitting and regulatory approval	Legal	6,016	24,560	38,112	21,696	1.6%	100%	24,560
Sub-total		12,032	49,120	76,224	43,392	3.2%		49,120
Design								
Front-end engineering design	IPP/Engineer*	4,512	18,420	28,584	16,272	1.2%	75%	13,815
Procurement	IPP*	1,504	6,140	9,528	5,424	0.4%	75%	4,605
Detailed design	IPP/Engineer*	9,024	36,840	57,168	32,544	2.4%	90%	33,156
Sub-total		15,040	61,400	95,280	54,240	4.0%		51,576
Procurement & assembly								
Construct operations facilities	IPP/Contractor	1,000	1,500	2,000	1,500		100%	1,500
Develop site for device assembly/maint.	IPP/Contractor		75,000	100,000	75,000		100%	75,000
Mechanical (turbine & power take-off)	OEM*	38,822	158,489	245,942	140,007	10.3%	0%	0
Electrical (generator & transformer)	OEM*	66,552	271,695	421,614	240,012	17.7%	0%	0
Subsea cabling	OEM*	30,832	125,870	195,324	111,192	8.2%	0%	0
Control system	OEM*	8,648	35,305	54,786	31,188	2.3%	0%	0
Grid connector	IPP/Contractor	7,896	32,235	50,022	28,476	2.1%	100%	32,235
Device framing & foundation	IPP/Contractor	89,112	363,795	564,534	321,372	23.7%	100%	363,795
Final assembly	IPP/Contractor	29,704	121,265	188,178	107,124	7.9%	75%	90,949
Transportation services	IPP/Contractor	5,546	22,641	35,135	20,001	1.5%	100%	22,641
Sub-total		277,112	1,131,295	1,755,534	999,372	73.7%		586,120
Installation & commissioning								
Mobilize logistical equipment	IPP/Contractor	6,542	26,709	41,447	23,594	1.7%	50%	13,355
Install foundation/moorings	IPP/Contractor	26,170	106,836	165,787	94,378	7.0%	90%	96,152
Load-out and install devices	IPP/Contractor	9,814	40,064	62,170	35,392	2.6%	90%	36,057
Install marine electrical systems	IPP/Contractor	16,356	66,773	103,617	58,986	4.4%	50%	33,386
Commission facilities	IPP/Contractor	6,542	26,709	41,447	23,594	1.7%	50%	13,355
Sub-total		65,424	267,090	414,468	235,944	17.4%		192,305
Total		376,000	1,535,000	2,382,000	1,356,000	100.0%		905,216
Average cost per MW		5,432	5,117	4,612	4,375			
3. Operation & maintenance (4)								
Management	IPP	125,341	450,879	621,807	243,080	29.6%	90%	405,791
Maintenance	IPP/Facility	293,027	1,054,082	1,453,684	568,281	69.2%	75%	790,562
Decommissioning	IPP/Contractor	5,081	18,279	25,208	9,855	1.2%	100%	18,279
Total		423,450	1,523,240	2,100,700	821,215	100.0%		1,214,632

1. Cost breakdown based on Synapse 2013. Cost for operations facilities and device assembly/maintenance estimated by consultant. All costs in 2012 dollars.
2. Indicates initial share of expenditures by input assumed to be procured in Canada (mainly Nova Scotia). Share is assumed constant across scenarios and over time.
3. The percentage share of expenditures is applied to the Early Adoption Scenario (MRE 300MW) spending to illustrate the dollar content
4. O&M and decomissioning costs expressed as percentage of total annual costs (2015-2040).

* Indicates requirements that need not be produced or conducted locally

4. Value proposition

In-stream tidal energy is an emerging technology with the potential to form the basis for a new industry in Canada and other jurisdictions. The three tidal development scenarios examined produce widely differing economic impacts across the selected indicators. This is because the scenarios are based on different assumptions regarding the scale and timing of development – two of the main factors determining the economic impact.

Tidal development can be expected to have a substantial impact on the economy of Nova Scotia, and also the economies of the Atlantic Region and Canada. Because most of the in-stream tidal development in each of the large- and small-scale scenarios occurs in Nova Scotia waters, the direct impacts are concentrated in Nova Scotia, with spill over effects in the Atlantic Region and elsewhere in Canada. The economic impacts summarized in Table S.3 present cumulative (2015-2040) and average annual values for each Scenario (including the NS MRE Strategy 300MW phase of the Early Adoption Scenario). The economic impact values are based on Nova Scotia tidal development only, and exclude the potentially substantial impacts arising from export market opportunities.

The interpretation of the values in Table S.3 follows the NS MRE Strategy 300MW phase of the Early Adoption Scenario (use the corresponding values to interpret the Scenarios):

- **Tidal Expenditures:** Total capital expenditures (CAPEX) of $1,535.0 million plus operating expenditures (OPEX) of $1,523.2 million refer to total cumulative spending over 25 years. Nova Scotia content (where direct expenditures occur) is 60% of CAPEX ($921.0 million) and 80% of OPEX ($1,218.6 million) for a total of $2.139.6 million. All values are expressed in 2013 dollars (excluding inflation).
- **Gross Domestic Product:** The NS MRE Strategy 300MW installation generates an overall GDP impact of $1.7 billion, including a direct impact of $1.1 billion. The average annual direct GDP impact is $42.9 million.
- **Employment:** Almost 22,000 full-time equivalent (FTE) jobs would be created, 15,000 of these engaged in direct activities at the assembly facility and in marine logistics, initially in planning and device assembly, construction and deployment, and within 4-5 years in maintenance activities as well. Average direct employment per year would reach about 600 FTEs, with an average of about 880 FTEs when indirect and induced effects are included.
- **Income:** Tidal development and operations would generate about $815 million in direct labour income, with an overall impact of $1.1 billion including spinoff impacts. The average annual direct income impact would be $32.6 million.
- **Tax revenues:** though difficult to quantify, the construction and operation of the tidal energy facilities would generate millions to tens of millions of dollars annually (depending on scale) through corporate and personal income, sales, excise, and municipal property taxes.

It is important to note that these impacts would *primarily affect the rural economy bordering the Bay of Fundy*. Because of limited economic opportunities, the rural economy tends to be characterized by relatively high unemployment rates and generally lower income levels than more urban areas. An industry offering the employment and income levels indicated in Table S.3 would provide a much-needed economic infusion.

Table S.3: Tidal development value proposition – benefits and costs (2015-2040) (1)

	Demonstration (67MW)		Early adoption NS MRE (300MW)		Early adoption Maximum (500MW)		Late adoption (300MW)	
	Cumulative	Average/yr	Cumulative	Average/yr	Cumulative	Average/yr	Cumulative	Average/yr
Total spending in NS ($000s) (2)	**568,425**	**22,737**	**2,139,592**	**85,584**	**3,133,580**	**125,343**	**1,484,132**	**59,365**
Economic impacts								
GDP ($000s)								
Direct	283,245	11,330	1,073,263	42,931	1,559,919	62,397	737,669	29,507
Indirect	77,602	3,104	294,045	11,762	427,376	17,095	202,102	8,084
Induced	86,649	3,466	328,327	13,133	477,202	19,088	225,664	9,027
Total	**447,495**	**17,900**	**1,695,635**	**67,825**	**2,464,497**	**98,580**	**1,165,434**	**46,617**
Jobs (FTE)								
Direct	3,948	158	14,958	598	21,740	870	10,281	411
Indirect	949	38	3,594	144	5,224	209	2,470	99
Induced	892	36	3,381	135	4,914	197	2,324	93
Total	**5,788**	**232**	**21,933**	**877**	**31,879**	**1,275**	**15,075**	**603**
Labour income ($000s)								
Direct	215,027	8,601	814,774	32,591	1,184,222	47,369	560,006	22,400
Indirect	45,981	1,839	174,228	6,969	253,230	10,129	119,750	4,790
Induced	36,325	1,453	137,641	5,506	200,052	8,002	94,603	3,784
Total	**297,333**	**11,893**	**1,126,643**	**45,066**	**1,637,504**	**65,500**	**774,358**	**30,974**
Emissions avoided								
Tonnes: 000s	4,795.5	191.8	9,738.2	389.5	24,158.0	966.3	9,738.2	389.5
$millions	198.4	7.9	402.9	16.1	999.6	40.0	402.9	16.1
Present value: $millions	92.7	3.7	161.6	6.5	415.7	16.6	161.6	6.5
Learning investment								
Energy price gap: PV$000s	255,500		813,000		1,030,000		305,250	

Source: Statistics Canada Inter-Provincial Input-Output Model (2010)

1. These are the expected economic impacts in Canada. They will be concentrated in Nova Scotia with spillover effects in the Atlantic Region and elsewhere in Canada. See Table 5.1 and Annex 4.

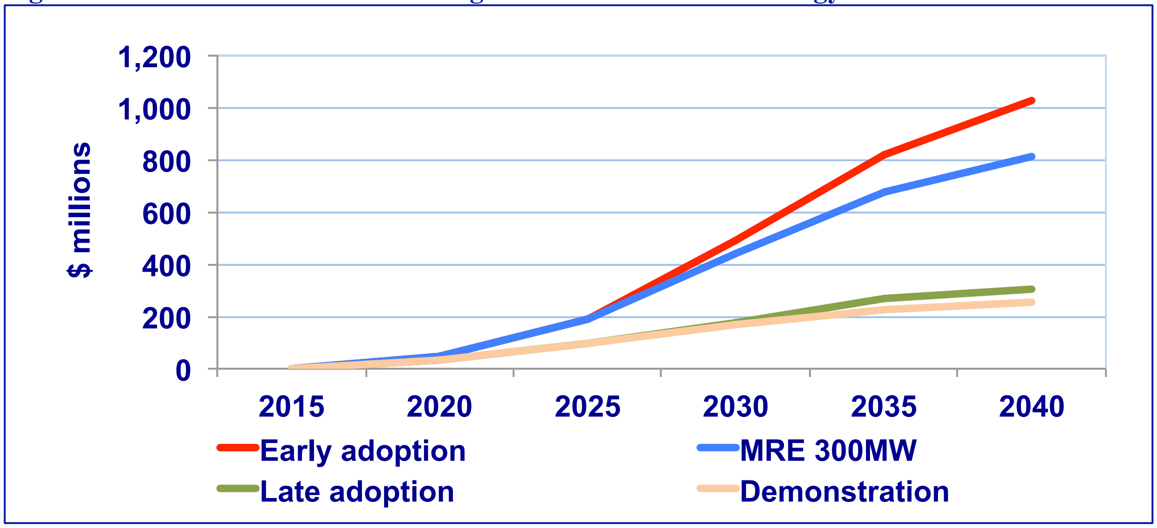
2. See Tables 3.7 and 5.2

Export potential adds to the value proposition. Even a market share of 5% in the supply of inputs accounting for just 10% of the estimated CA$1,000 billion global market could amount to an export value in the CA$5 billion range by 2050. The latter exceeds cumulative tidal development spending in Canada, even under the Early Adoption Scenario. As noted, because of timing and scale, export potential for Canadian suppliers would be greatest under the Early Adoption Scenario. Under the high market share assumptions, the economic impacts flowing from this level of participation could exceed the cumulative economic impacts arising from domestic tidal development by a factor of two to three (based on the not unreasonable assumption that impacts would be roughly proportional to levels of spending shown under the Early Adoption Scenario in Table S.3).

In addition to the GDP, jobs and income impacts, tidal development would also produce benefits in the form of reduced costs arising from avoided GHG and pollutant emissions. These benefits range from about CA$200 million under the Late Adoption Scenario to almost CA$1.0 billion under the Early Adoption Scenario.

Set against these benefits are the costs of generating them. The analysis indicates that the tidal LCOE is not expected to achieve parity with low-carbon alternatives in Nova Scotia until after 2040. The gap in each Scenario, referred to in Table S.3 as the 'learning investment', would be covered through some form of public support as illustrated in Fig. S.3.

Figure S.3: The Cumulative 'Learning Investment' for tidal energy



The level of support varies widely by Scenario. It is lower in the Late Adoption Scenario than in the equivalent capacity NS MRE Strategy (a present value of about CA$305 million versus CA$800 million) because most of the capacity in the former is installed after 2030. This allows the system to benefit from greatly reduced capital and operating costs. The investment is greatest under the Early Adoption Scenario (a present value of about CA$1,028 million) because most of the capacity is installed before 2030, resulting in limited benefit from cost reductions due to industry learning. It is worth repeating that implicit in these scenarios is the trade-off between energy costs and industrial opportunity: the lower costs associated with the Late Adoption Scenario come at the expense of lost first mover advantages and related supply opportunities both domestically and in export markets. These advantages and supply opportunities are greater under the Early Adoption Scenario, but at a higher learning investment.

5. Future considerations

Through various policies, programs and initiatives, the Governments of Nova Scotia and Canada have laid the groundwork for early tidal industry development. Governments in other jurisdictions have provided and continue to provide similar forms of support. Technology developers find themselves at a critical juncture; they have invested heavily in RDI&D, and must continue to do so in order to reduce costs and prove commercial viability. Continued development and demonstration are important steps in the commercialization process, and to help offset risk at this stage, governments have introduced defined levels of revenue support in the form of feed-in tariffs. The latter are critical to achieving the high rate of global installations that would bring costs down.

But risk in various forms remains: the large upfront investment required; uncertainty about costs and performance of the technology; uncertain or shifting government policies; permitting delays; access to the transmission grid; availability and cost of financing; power purchase agreements; weather; market and foreign exchange fluctuations; social acceptance and environmental effects. All these factors contribute to uncertainty with respect to industry development timetables, the rate of installations (globally), and therefore establishing the confidence needed for the emergence of industry supply chains.

The Governments of Nova Scotia and Canada are able to influence some of these risk factors as they apply to tidal industry development within Canada. Government support could be channelled to reduce uncertainty in several areas, and in so doing, make a valuable contribution to realizing the tidal value proposition.

Among the key steps for consideration:

- **Continue the commitment to tidal R&D**

  Through various initiatives over the past several years, the Government of Canada and the Government of Nova Scotia have supported tidal energy R&D. Successful demonstration projects in the UK provide encouragement that the technology holds commercial potential. But considerably more investment is needed to prove the technology and bring costs down to levels where they begin to become competitive with alternative sources of renewable energy. This requires a continued commitment to R&D by governments over the next 5-10 years, plus continued support for investment in tidal capacity by industry and utilities. Both are essential to finding ways to reduce costs and enhance competitiveness, and also to reduce GHG emissions.

- **A further round of feed-in tariffs to support capacity installation beyond 23MW**

  Renewable energy standards (RES), such as those in place in Nova Scotia, are a good market-pull policy, but without targeted support, they favour the least expensive renewable energy technology, in particular, more mature technologies such as onshore wind. Feed-in tariffs are effective in supporting the development of a new technology until it can become competitive, thereby diversifying the electricity supply and stabilizing long-term prices. The current FIT and COMFIT support about 23MW of tidal capacity. A further round of FIT/COMFIT would increase the likelihood of achieving the value proposition associated with higher development scenarios.

- **Implement the regulatory elements outlined in the Marine Renewable Energy Strategy**

  A long-term view of a stable regulatory regime will provide developers a clearer line of sight to commercial development. Completion of work currently under way to formulate and implement the regulatory elements outlined in the Marine Renewable Energy Strategy is vital to defining this clear line of sight.

- **Advance industry-enabling infrastructure development to encourage supply chain interest/participation in tidal opportunities**

  The infrastructure needed to support the industry must be designed, planned, funded and built. This could occur incrementally as the industry develops. Planning should be undertaken in consultation with current and prospective industry stakeholders (FORCE berth holders, Fundy Tidal Inc., and other potential developers) to identify critical requirements.

- **Develop a strategic, collaborative tidal energy research and innovation initiative**

  Considerable amounts of data have been collected to date in studies funded by OERA, the province and the federal government. Effective, public dissemination and continued data gathering will not only assist developers by reducing upfront costs and risks, it will help Nova Scotia know its own resource and the surrounding ecosystem.

- **Create a federal-provincial innovation fund for marine renewables RDI&D, with a focus on challenging issues and where export potential is greatest**

  Several recent reports have broken down estimated learning rates by cost centre. The learning rates by cost centre, when weighted by the proportion of total costs of TEC development, show areas where proportionately greater cost reductions may be found. These indicate areas where focused R&D support could have greater impact on tidal energy. Much of the work in these particular cost centres would be sourced locally if the demand were to arise (e.g. structure, installation, operations and maintenance). This suggests fertile ground for both cost reductions in Nova Scotia/Atlantic Canada/Canada and innovations that could benefit the global tidal energy industry. For example, solutions for underwater (wet) electrical connections and substations have not yet been developed.

  Targeted research, development and innovation grants for marine electrical technology can give Canadian companies a lead in this niche of the global tidal energy supply chain. Models for specialized innovation funds include the UK's Carbon Trust and Offshore Renewable Energy Catapult.