Photo Credit: Leigh Melanson

EXECUTIVE SUMMARY

MODULE 1 - OVERVIEW OF TIDAL ENERGY

Author: Dr. Graham Daborn

Tidal power is an old technology. The tidal movements of the oceans represent huge amounts of predictable, renewable energy derived from the gravitational effects of the Moon and the Sun, and have been used by human beings for centuries. Tidal mills, which convert the power of moving water into mechanical energy for grinding grain or sawing wood, existed in Roman times in Europe, and were widespread in eastern North America until the end of the 19th century. Since the beginning of the 20th century, however, interest has been in the generation of electricity from the tides, especially in the Bay of Fundy (Nova Scotia). This module provides a brief introduction to tidal power, its potential in Canada, the alternative approaches by which it can be captured, and the principal environmental and socio-economic issues involved.

Canada has tidal energy opportunities on all three coasts: the Atlantic, Pacific and Arctic. The greatest potential is in the Bay of Fundy, not only because it has the world's highest tides (up to 16m), but also because the region's electricity demand is currently being met primarily by fossil fuels. Tidal energy is renewable, and has the advantage, unlike wind, of being predictable, because the tides are predictable and well known; however, the power output varies over time because of slack water periods, variations in tidal range, and daily changes in the times of high and low tide. For one hundred years, there have been plans for generating electricity from the Fundy tides. Most of the schemes considered building barrages (dams) across the entrances to bays or between islands, storing the tidal waters at high tide, and then allowing the stored water to exit through turbines that would rotate to produce electricity. Conversion of the *potential energy* of the stored water is similar to that in hydroelectric power stations, with which Canada has a great deal of experience.

Research over many decades has shown that barrages have significant implications for water flows, regional ecology, and other coastal resources such as fishing and transportation. The Annapolis Tidal Generating Station, opened in 1985, has demonstrated that the more severe environmental effects are associated with the dam, rather than the turbines used to generate the power, although the latter may pose important risks to fish and mammal populations in the area. As a result, present approaches to tidal power development are based mainly upon electricity generators that are driven by the force of flowing water, rather than by the water stored behind a dam or barrage. These so-called *tidal in-stream energy converters* (TISECs) are analogous to windmills, in that they take the *kinetic* energy from flowing water, without requiring a barrage. Consequently, many of the negative effects of barrages can be avoided, although there remain concerns, particularly with regard to fish and marine mammals. There are numerous designs for TISECs currently being developed around the world, some of which are of commercial scale, able to generate 1 to 2 MW of power. A test site, the Fundy Ocean Research Centre for Energy (FORCE), is being established at the entrance to Minas Basin, Bay of Fundy, to test commercial-scale TISECs.

In 2008, Nova Scotia conducted a Strategic Environmental Assessment of tidal power development in the Bay of Fundy, the outcome of which was a commitment to a systematic, cautious programme of evaluation of tidal power potential in Nova Scotia. As the FORCE test facility is being completed, a broad programme of research and monitoring is under way to assess the environmental and socio-economic implications of large scale electricity generation from the Fundy tides. Principal environmental concerns include: the potential effects on fish, bird, mammal and other aquatic life associated with turbines, electrical cables, construction activities, etc.; the effects on sediment distribution and movement; and the overall effects on tides of removing some of the energy from the water. Socio-economic concerns include: the effects on other resource uses, such as fisheries, mining and transportation; the developmental opportunities for local communities, e.g. through job creation, tourism, etc.; and financial feasibility. These implications are examined in this toolkit.

MODULE 2 - MEASURING AND ASSESSING THE TIDAL RESOURCE

Author: Dr. Richard Karsten

With the world record tides of the Bay of Fundy, Nova Scotia has one of the world's best tidal power resources. Accurately measuring the size of this resource and assessing the portion of the resource that could be exploited is an important step in developing a tidal power industry.

HOW LARGE IS THE NOVA SCOTIA TIDAL RESOURCE?

The combined extractable power from the largest tidal flows in Nova Scotia is nearly 7500 MW. The vast majority of this power is located in Minas Channel (7200 MW). The passages of the Digby Neck region have another 230 MW, while Cape Breton has 5-10 MW.

HOW MUCH OF THE TIDAL RESOURCE CAN BE CONVERTED INTO ELECTRICITY?

The exact proportion of the tidal resource that can or should be converted into electricity is an open question that depends on the efficiency of the turbine technology and acceptability of the environmental impacts of extracting the tidal power. Estimates are based on today's technology and on limiting the impact of power extraction to small reductions in the flow (5-10%). These estimates suggest the Nova Scotia tidal passages can support turbine arrays with an installed capacity of nearly 1500 MW. Once again, the vast majority of this capacity (1400 MW) would be located in Minas Channel. Currently, Nova Scotia has a generation capacity of about 2500 MW. So, tidal power could play a significant role in Nova Scotia's energy future.

HOW DOES THE TIDAL RESOURCE VARY ACROSS NOVA SCOTIA?

The tidal resource is not the same for all tidal passages. Tidal passages that connect tidal basins to the Bay of Fundy, like Minas Channel and Digby Neck, have a large extractable power. But, extracting power from these passages will have a direct impact on the tides in the tidal basin. Other passages that lie between two large bodies of water, like Petit Passage and Grand Passage, may have a smaller extractable power but a greater portion of this power can be exploited with little impact on the surrounding tides.

The speed of the tidal currents in each passage also affects how the power will be generated. Petit Passage and Digby Gut appear to be similar passages, but the speed of the currents in Petit Passage is almost twice that in Digby Gut. This means the same turbine will produce roughly eight times more power if placed in Petit Passage than if it was placed in Digby Gut. It will also experience four times as strong forces. Clearly, these passages require different technologies to efficiently exploit the resource.

The resource and deployment sites in each passage must be assessed individually to determine the technology to be used and the power that should be produced.

HOW ARE POTENTIAL TURBINE ARRAY SITES ASSESSED?

There are many aspects to determining a suitable site for an array of tidal turbines. In terms of the characteristics of the tidal flow, sites are assessed using a combination of observations of the tidal currents (using acoustic profilers) and numerical simulations. These assessment techniques can produce an accurate prediction of how the tidal currents will vary over years and decades. However, it is still difficult to predict high frequency, turbulent variations of the flow that will have important affects on power production.

Determining how large an array could be deployed at a given site is difficult. Turbine arrays can have odd cumulative effects; that is, 100 turbines may not generate 100 times the power of one turbine. An array of turbines can be more efficient than individual turbines if they increase the blockage ratio – the portion of the channel they occupy. An array can also decrease the efficiency if the turbines lie in each other's wake. The impact turbines have on the environment generally increases as the number of turbines increases; that is, 100 turbines have more than 100 times the impact of a single turbine. Once again, an assessment of how large an array can be deployed at each site is required.

MODULE 3 - TIDAL POWER EXTRACTION DEVICES

Authors: Dr. Sue Molloy and James Taylor, P.Eng.

TIDAL ENERGY CONVERTERS

The overall theme in tidal energy convertors (TEC) is that designs are changing constantly but that the fundamental science of operation does not. There is currently no single TEC model that can be applied to all tidal resource settings. However, there are two primary categories of tidal turbines, horizontal axis and vertical axis.

- Horizontal Axis: When a turbine has a horizontal axis, the axis of rotation is designed to be parallel or slightly off-parallel to the flow of the water. These types of turbines tend to resemble underwater windmills.
  - Cross flow: Cross flow turbines are a variant of horizontal axis. This model of turbine has the axis of rotation across the flow of water, parallel to the water surface. These turbines can resemble push-style lawnmowers.
  - Open centre: Open centre turbines are a variant of horizontal axis. These types of turbines are shaftless and have the blades connected to an outer rotating rim to allow current flow through a large centre hole.
- Vertical Axis: Vertical axis turbines have an axis of rotation that is perpendicular to the flow of water. This means the axle around which the blades rotate is vertical at 90° to the water flow direction. These devices can resemble egg beaters.

Turbines rotate in tidal currents of typically 2m/s - 4m/s (metres/sec) (4-8 knots). This rotational energy turns an axle that creates electrical energy through a generator. That electrical energy is then used to provide power for a specific use/user or is added to the central power grid. The high current speeds of the Bay of Fundy (more than 5m/s) offer developers both a unique opportunity and a formidable challenge.

Tidal turbines can be moored in a variety of ways. Turbines can be floated on the surface of the water, usually on a floating platform or set of pontoons, with the blades of the turbine underwater. Vertical axis turbines typically use this style of mooring to take advantage of the highest-speed currents approximately 1m below the surface. Typically, in a floating structure, there will be some form of cable mooring to keep the turbine in relatively the same place. Some turbines can be anchored to a permanent structure like a pier and extended out into the water. Currently, most horizontal axis designs are being deployed on the sea bottom. They are connected to a pile that is driven into the ocean floor or connected to a concrete surface that has been installed on the sea floor, known as a gravity base.

In Nova Scotia, each model of tidal turbine has, or is expected be, tested. In 2009, the first turbine, an open center model developed by Open Hydro, was installed and removed from the Bay of Fundy.

A general attitude in the tidal industry right now is that turbine designs need to be kept simple. Fewer parts in the design mean less maintenance will be required over the life of a turbine and a simple design enhances the ability of the device to work in the marine environment.

Some questions currently facing designers include:

- What is the marine environment like at the installation site?
- How will the turbine be installed?
- How accessible will the turbine be for maintenance?
- How long will the turbine last before maintenance is required?
- What kind of maintenance can be expected?
- How much time will there be to access the turbine at slack tide?
- Should the turbine be installed on the sea floor or floated at the surface?
- How will the geological marine environment affect the turbine and vice versa?

As projects progress, these questions get asked over and over again, and each new marine environment requires a new set of answers. At present, turbines need to be customized for an environment as there are no "one size fits all" turbines at the moment. Some solutions to these types of questions have been successful in one location and found to be completely inappropriate in others. For example, the Bay of Fundy has approximately 20 minutes of slack tide and very high current speeds, which makes drilling to install concrete piles unattractive. However, piles have been used successfully to support many turbines in the ocean around the European Marine Energy Centre Test Centre in the Orkney Islands in Scotland, where the currents are somewhat slower.

MODULE 4 – THE REGULATORY REGIME FOR TIDAL ENERGY

Author: Elisa Obermann

Tidal energy is a public resource, and like many natural resources, tidal energy is governed by several pieces of legislation, regulations, and overarching policies. Laws and policies are designed to ensure that the development of this resource is carried out in the best interest of the public and the environment. As the marine ecosystem supports multiple users and uses, legislation strives to provide suitable licensing processes, environmental protection, worker/public safety, resource conservation, recognition of other users, community benefits, and economic benefits.

POLICY AND PROGRAMS FOR TIDAL ENERGY

The development of tidal energy in Nova Scotia has been supported through enabling policies, strategies, plans, programs, and regulatory development. Several provincial policies, programs, and legislation addressing tidal energy development have been established in recent years, with many of them informing the current regulatory requirements and processes for tidal energy, including:

- **Strategic Environmental Assessment (SEA):** SEAs are an important planning tool and provide an assessment of the social, economic, and environmental effects and factors associated with potential development of renewable energy sources. A SEA was completed for the Bay of Fundy in 2007-2008 and the Cape Breton region in 2012-2013. An update to the Bay of Fundy SEA will be completed in 2013.

- **Renewable Electricity Plan:** The Government of Nova Scotia's Renewable Electricity Plan, established in April 2010, sets out a detailed path for achieving the target of 25% renewable electricity supply by 2015 and establishes an ambitious goal for 2020 to have 40% of Nova Scotia's electricity supply (sales) produced from renewable resources. The 2020 goal is now legislated in Nova Scotia's Electricity Act. It also includes direction to establish a feed-in tariff (FIT) for tidal energy.

- **Renewable Electricity Regulations:** The Renewable Electricity Regulations established under Nova Scotia's Electricity Act in October 2010 provide a legal basis for many of the actions put forward in the Renewable Electricity Plan. The regulations outline many of the legal criteria and requirements for the Community Based Feed-In Tariff (COMFIT) program as well as establish a One Window Process to review COMFIT applications and details on the developmental tidal FIT.

- **Enhanced Net-Metering Program:** Net-metering is a utility-led program by Nova Scotia Power that allows a consumer to meet their annual electricity needs with a low impact renewable electricity generation facility of up to 1 MW capacity. Tidal energy is considered a low impact renewable resource that qualifies for this program.

- **Community-Based Feed-In Tariff (COMFIT):** The COMFIT is a program designed to support smaller-scale renewable energy projects developed and owned by communities. Tidal energy is supported through the COMFIT program and is eligible to receive an established price per kilowatt hour (kWh).

- **Developmental Tidal Array Feed-In Tariff (FIT):** A FIT specific to large-scale devices and tidal arrays is being developed by the Nova Scotia Utility and Review Board. It will cover projects connected at the transmission level using devices greater than 0.5 MW.

- **Marine Renewable Energy Legislation:** Unlike other resources, legislation specific to tidal energy does not exist. The Bay of Fundy SEA recommended that legislation for marine renewable energy be developed. The Government of Nova Scotia has been working to develop new legislation that would provide clear, predictable, and efficient processes to support the sustainable advancement of the sector.

- **Marine Renewable Energy Strategy:** In May 2012, the Government of Nova Scotia released its Marine Renewable Energy Strategy. It includes enabling mechanisms and activities to help advance tidal energy in Nova Scotia, including a feed-in tariff scheme coupled with a licensing process that will be established in legislation to provide a pathway for projects to proceed from the testing stage to demonstration and, finally, to commercial development.

• **Statement of Best Practices:** The Government of Nova Scotia is currently developing a statement of best practices that embeds standard requirements and practices for risk assessment as well as options for precautionary and adaptive environmental assessment, licensing and management, site assessment and environmental monitoring requirements, modeling and monitoring energy production, deployment of devices, stakeholder consultation and engagement, and transparency in environmental data collection and dissemination.

RELEVANT LEGISLATION, REGULATION, AND THE PERMITTING PROCESS

There are multiple federal, provincial, and potentially, municipal authorities involved in the regulation of tidal energy. Nova Scotia's current regulatory framework and policies reflect the varied and complex public interests associated with tidal energy. These public interests include: multiple uses of the marine environment; potential conflicts among these uses; granting rights to produce energy from a shared, public resource (oceans); and the sale and distribution of electricity through a regulated, integrated utility (Nova Scotia Power Inc.).

PROVINCIAL LEGISLATION	FEDERAL LEGISLATION
• Nova Scotia Environment Act	• Fisheries Act
• Environmental Goals and Sustainable Prosperity Act	• Canadian Environmental Assessment Act
• Fisheries and Coastal Resources Act	• Species at Risk Act
• Endangered Species Act	• Migratory Birds Convention Act
• Energy Resources Conservation Act	• Navigable Waters Protection Act
• Crown Lands Act	• National Energy Board Act
• Beaches Act	• Oceans Act
• Special Places Protection Act	• Canada Environmental Protection Act
• Electricity Act	• Shipping Act
• Public Utilities Act	• Canada Labour Code
• Social Legislation	
• Assessment Act	
• Municipal Government Act	

THE FUTURE OF TIDAL ENERGY REGULATION

Nova Scotia's Marine Renewable Energy Strategy includes a plan to establish a licensing process in legislation for tidal energy projects. The licensing process will include two licensing streams—one for technology development and the other for commercial power development. This system will focus on a staged, progressive, and adaptive approach to development and deployment of in-stream tidal devices.

MODULE 5 – ENVIRONMENTAL RISK ASSESSMENT

Authors: Lisa Isaacman and Graham Daborn (Executive Summary written with assistance from Monica Reed.)

Understanding the potential environmental implications of Tidal Energy Convertors (TEC) development is crucial for the technology's success in providing clean, renewable energy. With little evidence on the environmental effects of TEC development, careful assessment and mitigation of environmental risk is required. Independent scientific experts have collaborated to produce "A Framework for Environmental Risk Assessment and Decision-Making for Tidal Energy Development in Canada," which was prepared for the Department of Fisheries and Oceans and the Nova Scotia Department of Energy. This framework provides guidance for project planners and reviewers in the assessment and mitigation of environmental risks for TEC development proposals and projects. Module 5 highlights the Framework's key considerations and procedures and is intended to inform project planners and reviewers, as well as the general public.

Ecological components, including wildlife, physical habitats (sediment, water, vegetation, geology) and ecosystem processes (e.g., biophysical dynamics, food-web interactions), are often referred to as *receptors* because they receive the pressures induced by development. When examining the potential implications of TEC development, the pressures, known as stressors, are assessed to evaluate their potential impact on the receptors. The table below lists the predicted stressors and the potential environmental effects associated with each stressor. **Please note**: the listed effects have only the potential to occur, and thus require evaluation; the <u>list is not a forecast of what *will* happen.</u>

Predicted Stressors and Potential Environmental Effects

STRESSOR	POTENTIAL ENVIRONMENTAL EFFECTS
Changes in Current Energy	Change in water movement characteristics and patterns in close proximity to TEC device, altering local sediment dynamics (scour, sediment deposition, and transport). Alteration of regional and/or coastal/shoreline habitat due to alteration of sediment dynamics (alteration of substrates, erosion, transport, and deposition pattern) and tidal patterns (timing, height, mixing patterns, velocity).
Presence of Physical Infrastructure	Loss or modification of benthic or pelagic habitat structure and complexity due to scour and presence of device base and submarine cables. Attraction, avoidance, or exclusion of species from habitat areas leading to changes in biological community structure and function.
Physical Interactions with Infrastructure	Physical contact with device or stress induced by pressure flux or turbulence causing injury or death of marine organisms. Altered movement and migration patterns due to avoidance.
Noise, Vibrations, and Light Emitted from Devices	Increased stress, physical or physiological damage to auditory systems, or behavioural changes (e.g. habitat avoidance/attraction, change in movement patterns, decreased mate and prey detection).
Emitted Electromagnetic Fields	Increased stress, physical or physiological damage, and behavioural changes (avoidance/attraction, communication, movement, and migration patterns).
Release of Contaminants	Chemical pollution from paints, antifoulants, and lubricants affecting water chemistry and marine organism health.
System-scale Effects	Impacts on the stability and dynamics of the local population, with possible trickle down effects on local, regional, and potentially remote population and biological community structure and function, particularly when migratory species are affected.

It is important to recognize the great amount of scientific uncertainty associated with TEC developments. The listed environmental impacts have been recognized as potential effects that require pre-deployment assessment, with monitoring continuing throughout the device's operational phase and beyond device decommissioning.

The probability and magnitude of the potential effects are difficult to gauge for a number of reasons. Every environment is unique and complex. Additive or *cumulative effects* caused by the combination of past, present, or future human activities should be anticipated, but are difficult to predict. Changes to critical ecosystem processes may appear small and incremental, but may change, intensify, or only become detectable over a period of time. Acting in concert with other activities, a seemingly minor disturbance may well result in a major impact on a critical aspect of the environment or other established resource use. Developments, particularly commercial-scale arrays, will need to be reassessed at regular intervals to address these elements of uncertainty.

In addition to the environmental complexities, the potential effects are difficult to predict because in-stream tidal energy generation is still in the early stages of research and development. Numerous TEC technologies have been developed, but few full-scale devices have been tested for prolonged periods of time. To date, environmental monitoring has largely focused on the *near-field* (in the immediate vicinity of the turbine) impacts of a single device. Monitoring studies have been limited by the duration and scope of the test projects, as well as by the lack of available monitoring technologies and techniques suitable for high-energy marine environments. New methodologies for data collection and environmental monitoring techniques are being developed alongside the emerging industry, and thus, have not yet been verified as effective and accurate. Because the aforementioned factors combine to create a substantial degree of scientific uncertainty, environmental monitoring results from one project should not be used to predict the potential environmental effects of TEC developments elsewhere. Additionally, the outcomes of one project should not be used to make inferences about another project because environmental effects are likely to be technology-, scale-, and site-specific.

Due to the uncertain environmental risks, a set of principles for the objective review of proposed TEC projects is presented to facilitate environmentally responsible advancement of this developing industry. These principles include:

1. adequate consideration of ecosystem-scale and cumulative effects;
2. a precautionary and adaptive management approach;
3. the need for appropriate and early initiation of baseline studies;
4. the need for risk evaluation criteria and indicators that are relevant, flexible, and can be consistently applied to projects of any type, size, or location;
5. consideration of other human uses of the ecosystem; and
6. early and on-going First Nations engagement.

See Module 5 for further information pertaining to these principles.

Module 5 presents a series of steps (framework), best practices, and criteria/indicators to guide project planners and reviewers in assessing the environmental risks of a proposed project and planning for the appropriate adaptive mitigation and monitoring of the identified risks. The table below describes the steps.

Framework to Reduce Risk

STEPS	EXPLANATION
1. Define the scope of the review.	Clearly delineate the scope of the project and review. This includes identifying the activities and ecosystem components to be reviewed, defining the spatial and time scale of the project, and the review, integrating ecosystem-scale and cumulative effects and recognizing the potential for staged developments.
2. Evaluate the project site characteristics.	Assess the interrelationship between the scale of the development and the site characteristics. TEC developments may be found in three different site types: through the narrow entrance of a coastal basin, through multiple passages between landforms, or in certain coastal areas offshore. The characteristics of the site, as well as the presence of a species or habitat of high conservation concern, will influence the implications of the TEC development.
3. Evaluate the environmental risk of the project proposal based on a set of standard defined criteria and indicators.	Evaluate risk based on multiple qualitative and numerical science-based evaluation criteria and indicators, which are adjustable to particular project designs and sites. Criteria in the categorization of risk levels of TEC development include: 1. Extent of Habitat Alteration Due to the Presence of Physical Infrastructure; 2. Effect on Water Movement and Sediment Dynamics; 3. Timing of Short Term Projects; 4. Physical Obstacle to Marine Organisms; 5. Noise, Vibrations, and Turbulence Effects on Marine Organisms Due to Turbine Operation; and 6. Effects of Other Signals Emitted by Project Infrastructure. To determine the risk level, risk indicators within each of these criteria will need to be evaluated based on the probability, detectability, spatial extent, significance, duration, and reversibility of the forecasted effect.
4. Identify risks of interference with other human uses of the ecosystem.	Determine the risk level for interference with other human uses of the marine and coastal ecosystem (e.g. fisheries, recreation). While many activities will be able to coexist with TEC developments, some may be displaced or disrupted. Marine spatial planning, socioeconomic impact assessment, and/or consultations with stakeholders can assist in evaluating the risks and planning mitigation measures.
5. Categorize the overall risk of the proposed project and make a management decision.	With the risk level of each of the criterion established and weighted equally, assess the overall risk level of the entire project. Each risk level (low, moderate, high, extremely high) couples with a management decision on the project's appropriateness to proceed as proposed.
6. Propose supplementary mitigation measures to reduce the overall risk of the project, when applicable.	Mitigation measures can be used to downgrade the overall risk of the project, potentially avoiding rejection, delays, and/or added costs associated with the need for a more in-depth review, baseline studies, and monitoring program. Mitigation measures may involve site relocation, change in the timing of project activities, adjustments to the size or configuration of the development, or use of mitigation devices such as erosion protection, or fish/marine mammal deterrents.
7.) Prepare the environmental monitoring and follow-up activities, and an adaptive management program for an approved project.	Design a long-term adaptive environmental monitoring and management program for an approved project, including monitoring requirements, timelines, and/or conditions for re-assessment, and an adaptive management response plan. These follow-up activities are key to reducing scientific uncertainty and allow improved decisions to be made in the future. Monitoring confirms the predictions of the environmental assessment, exposing the effectiveness of the mitigation measures and identifying lower than anticipated and/or unanticipated changes that necessitate adaptive management measures. An adaptive response plan can ensure appropriate and timely actions are taken to mitigate the cause of unanticipated effects.

See Module 5 for further information pertaining to these steps.

MODULE 6 - STAKEHOLDER AND COMMUNITY ENGAGEMENT

Author: Dr. John Colton

Effective community and stakeholder engagement is critical in the development of tidal energy. There is no better strategy for mitigating the risks associated with developing a tidal energy project than to develop a stakeholder engagement process that is inclusive of all stakeholders. Stakeholder and community engagement is particularly relevant to tidal energy development as there is likely to be a wide range of stakeholders affected. Experience shows that participatory processes facilitate consensus and conflict management, build local pride, and create confidence, trust, and greater cooperation.

Once stakeholders have been identified, it is important to work to understand their concerns. Stakeholders form opinions on renewable energy developments based on their perception of the environmental, socio-economic, and emotional impacts the proposed development has on them and their community. When considering the potential for tidal energy development in an area, it is important to also identify any First Nation communities in the region. Keep in mind that these communities do not have to be necessarily close to the proposed tidal energy site to be considered an important stakeholder. Treaty rights can extend across hundreds and, in some cases, thousands of square kilometers, including both terrestrial and marine ecosystems. The Crown or government has the legal authority to consult with First Nation communities, but it is incumbent on tidal energy developers to play a role as well.

Methods for stakeholder engagement vary and are numerous. Planning ahead and choosing the right community and stakeholder tool is important, as some methods are better suited for specific points in the development process. The *Spectrum of Community Engagement* provides an outline of engagement goals and the methods associated with each goal. Understanding the right mix of methods and their use will provide better opportunities for communicating information and learning the perspectives of community and business stakeholders. More importantly, basing the community and stakeholder engagement process on principles of transparency and respect will foster the collaborative spirit necessary to engage in a discussion on a tidal energy project.

MODULE 7 - FINANCIAL EVALUATION AND THE COST OF ENERGY

Author: Dr. Shelley MacDougall

The electricity generated from tidal energy will be expensive at first, but the cost is expected to decline over time as experience, efficiency, technology improvements, and economies of scale are gained. The goal is for tidal energy to be competitive with other forms of renewable energy, such as wind.

Though the energy of the tides is freely available, the cost of harvesting it is high. The cost of the energy comes from the research and development costs, site assessment and permitting, capital costs of tidal energy converters, bases, monitoring devices, subsea cables and on-shore connection to the electrical grid, installation, environmental monitoring and reporting, lease and insurance costs, maintenance and periodic overhauls, and decommissioning costs.

An example of a 1 MW tidal energy investment is detailed in the toolkit. A 1 MW device would be required in the deep and fast waters of the Minas Passage. The median cost of electricity of the single 1 MW device at the demonstration stage is estimated to be $683 per MWh or $0.683 per KWh. The estimated energy output is estimated to be 3,500 MWh per year. To achieve economies of scale, an array of tidal energy converters would need to be connected to the underwater cables and electrical grid. The profits generated from the sale of the power to Nova Scotia Power Inc. (NSPI) would go to the project developer, the project's lenders, and shareholders. The four tidal energy test berths in the Minas Passage are leased by consortia of large companies that include technology developers such as Marine Current Turbines and Atlantis Resources and their partner companies, Minas Basin Pulp and Power, Irving Shipbuilding, and Lockheed Martin.

Small scale tidal energy devices, designed to produce less than 0.5 MW of electricity, can be placed in arrays in smaller, lower flow areas such as Digby Gut, and Petit and Grand Passages. The cost of energy generated by early stage tidal energy converters in the development stage was estimated by Synapse Consulting to be $652 per MWh or $0.652 per kWh. Each device could deliver an estimated 1,620 MWh to the distribution system. The small scale projects fall under the Nova Scotia Community Feed-in Tariff program if they are at least 51% owned by local communities. The profits generated from the sale of the power would go to the local owners who are partnering with companies that have developed tidal energy conversion technology or assisted with project development.

MODULE 8 - OPPORTUNITIES AND STRATEGIES FOR COMMUNITIES

Authors: Alan Howell and Dr. John Colton

SECTION 1: BENEFITS OF TIDAL ENERGY DEVELOPMENT FOR COMMUNITIES.

Tidal energy represents a unique opportunity for communities across Nova Scotia. Tidal energy development will create jobs, support research, and provide cleaner energy. Understanding the opportunities and challenges of tidal energy can help communities make informed choices and support community buy-in.

What are the Opportunities Both Large and Small Scale?

Small scale projects that are COMFIT eligible are currently the primary opportunity for communities. Being awarded a COMFIT provides a community a guaranteed price for the energy it produces. While the initial revenue will likely be used for debt repayment, the life of a project can span decades and can contribute to the long term stability of a rural coastal community. A COMFIT award can also be an opportunity for partnership. Organizations or groups who may not have the capital necessary to develop a project alone have the opportunity to partner with other entities to support a COMFIT project.

Large scale opportunities are also available to communities, but long term benefits will not materialize until the tidal energy industry matures in Nova Scotia. Communities across Nova Scotia will have something to gain from the development of a large scale tidal energy industry. Communities that are located near tidal energy deployment and servicing sites will likely see the greatest proportion of benefits.

Important Questions

Often, the first question community members ask is, “how many jobs will this create?” or “how will it benefit the economy?” These are valid and important questions. They are, however, difficult to answer precisely. The employment and economic benefits of tidal energy development are not well documented, largely because few projects have been completed to date. Also, the number of jobs created is highly contingent on the size of the project and who develops it, especially where the development is not a COMFIT. Large scale or tidal array developments will have greater demand for labour and expertise, which will mean more job creation opportunities; this is balanced against the complexity of such projects that may require materials, equipment, and expertise not available locally. Potential direct job ranges of 2 to 22 jobs per MW capacity have been cited by researchers and industry experts. It is almost certain that any tidal energy project will have an economic impact in the local community. Jobs can come from directly working on a project (welding, vessel operation, etc.) as well as from the increased demand for services in the community (lodgings, food, and retail). At the outset, it is expected that there will be a mix of direct and service related jobs. Other benefits to communities include increased economic diversity, tourism potential, education and research opportunities, and skills and capacity building for local organizations, workers, and administrators. Perhaps one of the most significant opportunities tidal energy presents is the ability to reduce reliance on energy sources that damage the air, water, and soil. Local renewable energy projects are part of a broader provincial, national, and international solution to improve the quality and sustainability of our environment.

What are the Challenges to Attaining Benefits?

Communities can face many challenges to attaining the benefits they want and not all benefits will be available for all communities. Geography, demographics, and local labour force characteristics may not support the development of local jobs. There are no local content rules for renewable energy development in Nova Scotia; however, using local expertise and materials is often in the developer’s best interest. Local opposition to tidal energy can stop projects in their tracks. Fostering good working relationships amongst tidal project teams and local communities members, especially if they come from very different backgrounds, can be time consuming and difficult. However, as has been shown in the United Kingdom, United States, British Columbia, and here in Nova Scotia, open, honest, and frank discussions of tidal energy can help to overcome challenges and result in both large and small benefits for local communities.

SECTION 2: STRATEGIES FOR COMMUNITIES AND BUSINESSES TO GARNER SOCIO-ECONOMIC BENEFITS

Nova Scotia and other Atlantic Provinces have a pool of knowledge, infrastructure, and services related to ocean and marine technology and industry. Collectively, this combination of knowledge, infrastructure, and services has been used to develop a state-of-the-art commercial fishery, ship building enterprises, oil and gas development, and barge hauling services. Local, regional, provincial, and federal governments have invested significant resources into exploring how the skills associated with these types of industries can be used in other industrial sectors. This is important, as communities are looking for strategies to become more *resilient* to weather the changes brought about by economic uncertainty and the *booms and busts* associated with certain industries. Exploring a community's infrastructure, skills and knowledge of its citizens, its services and amenities, and understanding how these can collectively contribute to and support tidal energy development may provide for greater resiliency and sustained community development.

Strategies for community development have evolved from a traditional top-down approach to a grass-roots approach. Traditional economic development models have focussed on job creation by encouraging greater economic diversity to stimulate economic growth in regions. Increasingly, this development approach is being replaced by a more holistic approach that focuses on socioeconomic growth. Inherent in this shift have been the role of the citizen and the focus of development. Citizens and other stakeholders in this new model of development become active agents in shaping their communities through harnessing local assets found in their communities and businesses. This approach to development moves beyond job creation by broadening its focus to *community* development. With this approach, the community is examined through another lens: that of *Community Capital*. Researchers have identified a variety of types of community capital: natural capital, physical capital, economic capital, human capital, social capital, and cultural capital.

Tidal energy development may provide rural, island, and other remote communities with energy that may allow for development of local small-scale industries such as greenhouses, tourism-related activities/facilities, or small-scale manufacturing. Any ownership model can produce these types of opportunities. Choosing the model will depend on resources available, the mix of stakeholders, and the willingness to take on the risks associated with ownership.

MODULE 9 - OPPORTUNITIES AND STRATEGIES FOR BUSINESSES

Authors: Elisa Obermann and Dr. Shelley MacDougall

The development of tidal energy projects will require a supply chain of multiple services, supplies, and expertise including marine scientists and engineers, mechanical and electrical technicians, vessels, sensory instruments, divers, steel fabricators, manufacturers and supporting expertise such as insurance, legal, transportation, and financial services. The building of a supply chain is important to support the advancement of tidal energy development and it also represents a new economic opportunity.

Due to the early stage of development of the tidal energy industry, there are presently supply chain gaps in capability and capacity regionally, as well as internationally. The current gaps identified are in device manufacturing, engineering construction, foundations, and anchoring. At the same time, Natural Resources Canada identified areas where Canada has evident strengths to support tidal energy development, including deep sea ports, marine construction, resource monitoring and analysis, environmental assessment, marine supplies, commercial diving, and transport. These challenges and strengths present opportunities for businesses, communities, and individuals in Nova Scotia with applicable expertise and skills sets to contribute to development domestically, nationally, and globally.

Getting involved in the supply chain side of tidal energy development requires an understanding of the supplies, services, and skills required for a tidal energy project. Every project is different depending on location, size, and technology used and this could dictate the supplies and services required. There are **six project stages,** each requiring an array of technical as well as supporting and enabling services:

1. Research and Development: The research and development stage includes research and testing of tidal energy technologies to test and refine a prototype design that can be developed into a commercial-scale device. Typically, R&D activities are conducted by specialized centers belonging to companies, universities or government entities.

2. Site Screening and Project Feasibility: The first stage of project development is aimed at identifying potential sites, learning characteristics of the sites, and determining feasibility of a project at those sites. After a potential site has been identified through a site screening, a site resource assessment is completed. The next step is to conduct various feasibility studies that consider the resource identified, resulting in detailed modeling of potential constraints to the project.

3. Planning: During the planning stage, tidal energy developers engage in environmental and technical studies and activities to help inform project design and provide details necessary for determining what types of permits, licenses and authorizations will be required to move forward with the project.

4. Project Design & Development: Tidal energy developers typically progress to the project design and development stage if the outcome of feasibility assessments meets the project objectives. During this stage, a developer typically performs activities necessary for gaining project approvals and permits and as design progresses, technical information feeds into the regulatory process.

5. Project Fabrication: This stage focuses on the implementation of the selected procurement strategy for elements of the project that are to be contracted out. Device, project components, and infrastructure begins to be manufactured according to standards, timescales and costs agreed to in the contract.

6. Construction, Installation, and Commissioning: The construction, installation and commissioning stage starts once all permits and approvals have been received and the device and other components are complete and ready for final assembly. This includes onshore assembly, offshore installation activities, and on-site commissioning. A range of vessels are typically required including specialist, modified, standard and jack-up vessels. A number of suppliers are required to manage and deliver the safe, timely installation of expensive and relatively delicate technology in tough environmental conditions.

7. Operations and Maintenance: The project development process will be designed to ensure cost-effective and safe operation throughout the life of the project. Maintenance will be scheduled to enable efficient performance and mitigate environmental impact. This stage will likely require technical support from the installation contractor, equipment supplier, and technology developer at early stages of operation.

8. Decommissioning: Once a project reaches the end of its operating life, it will be decommissioned and the associated infrastructure removed in a safe and environmentally sustainable manner and in accordance with regulatory requirements.

Growth of the tidal energy sector in Nova Scotia and globally will be highly dependent on having a supply chain with the right businesses, skills, and expertise to support project and industry development. Nova Scotia and the Atlantic region are well suited to pursue involvement in the growing tidal energy industry by transferring skills and expertise from related sectors including: offshore petroleum, ocean technology, wind energy, marine structure fabrication and marine transport, and port facilities.

An effective strategy for taking up the commercial opportunities presented by tidal energy is industry clustering. An industry cluster is a geographic concentration of companies (suppliers of goods and services, their customers, and related companies) and organizations (research labs, universities, industry associations, standards associations) in the same industry. Companies in the cluster share common needs, opportunities, constraints, and obstacles to productivity. They both compete with one another and cooperate. The most famous of industry clusters is Silicon Valley in California.

To develop an industry, "cluster thinking" is needed: an orientation toward groups of organizations, rather than individual firms. Many of the pieces are in place for the Nova Scotia tidal energy industry to develop as a cluster.

One of the advantages of an industry cluster is strength in numbers. Another advantage is the proximity of suppliers and customers, which facilitates the development of new technologies and processes by being able to meet regularly, face-to-face. The rate of innovation in clusters tends to be greater than outside clusters, at least during the growth stage. Beyond the construction and deployment of the tidal energy devices in local waters, Nova Scotia has the opportunity to develop technologies and expertise associated with them that will be in demand worldwide. Developing and exporting innovative products and process expertise will generate local economic benefits. Industry clustering can help achieve these innovations.

MODULE 10 - FINANCING, GOVERNMENT SUPPORTS, AND RISK

Authors: Dr. Shelley MacDougall and Melissa Beattie

Technologies for tidal energy conversion are in the early stages of development. Devices are still expensive to build and their performance in waters outside of test sites is still uncertain. Companies developing the technologies will seek to deploy them where electricity can be sold. Developing projects involves many steps: feasibility assessment, planning and permitting, design and construction, manufacture, installation, operation and maintenance, and finally, decommissioning. There are various supports provided by governments, mostly at the technology research and development stage. When the “heavy lifting” begins, finding financing is a considerable barrier for all but the very largest companies. Tidal energy projects have very large upfront costs and very long pay back periods.

There are also significant risks inherent in tidal energy projects. The largest is technology risk – simply the unpredictability of if and how well the new technology will perform once it is installed. Until devices and arrays are deployed commercially, setbacks are hard to predict and mitigate. Insurers do not have sufficient actuarial data to set insurance premiums. Besides technology risks, there are construction risks, potential problems with equipment and manufacturing accessibility, cost overruns, a lack of capable operators, and political and regulatory risk. Of course, health and safety of workers and other users of the waters, damage to the environment, and, in reverse, damage to the equipment by the environment and other users are significant risks. Another, less understood, risk is community dissent toward a development. There are steps that can be taken to mitigate many of the risks, but still, a substantial amount of remain.

Once tidal energy devices are in the water and operating, the rate of project development should increase as financing becomes easier to attract. However, government support is needed to help get the technology through the so-called “technology valley of death”: the pre-commercialization stage for which there is scarcity of financing. Supports being provided by the federal and provincial government through the various stages of technology and project development include legislated renewable energy targets, research and development funding, feed-in tariffs, community economic development investment funds (CEDIFs), flow-through shares, accelerated depreciation, and the Scientific Research and Experimental Development (SR&ED). There is still a need for further government interventions, such as loan guarantees, to enable developers to access financing in order to move forward.

MODULE 11 - ASSESSING THE POTENTIAL ECONOMIC IMPACTS OF A FIVE MEGAWATT TIDAL ENERGY DEVELOPMENT IN THE DIGBY AREA OF THE BAY OF FUNDY

Author: Dr. Brian VanBlarcom

The economic impacts of tidal energy development are largely unknown because few commercial scale developments exist to date; those that do exist have only been in operation for a short time. What we do know is that tidal energy projects involve multiple stages and inputs. Inputs cross multiple sectors. This module attempts to model the potential impacts of a theoretical 5MW tidal energy facility that consists of several tidal generation devices with a capacity of 0.5 MW or less and that is capable of being interconnected with the electrical grid through a distribution system. The total estimate cost for this project is $50 million.

Why the Digby Area?

Digby was chosen for analysis based on a number of potential sites being identified in that area. Fundy Tidal Inc. has received regulatory approval for a 1.95 megawatt tidal power project in Digby County. Small scale tidal developments are the focus of the case study since the applicable technology/costs/degree of local inputs, etc. for larger (150 MW range) developments are significantly less precise at this point in time. Impacts would be different in other areas of the province due to differences in the type and number of businesses and the make-up of the labour force.

The Input/Output (I/O) Model

An input/output (I/O) model is used to estimate potential economic effects. An input/output model attempts to estimate total impacts across all sectors in an economy by modeling the total demand for goods and services from, for example, the insertion of a tidal energy project into an economy. An I/O model attempts to estimate the total direct, indirect, and induced effects of a project. Direct effects occur when firms involved in tidal power development buy goods and/or services from local firms. Indirect effects occur when local firms buy local inputs (goods/services) as a result of the direct impact. The economic activity resulting from the re-spending of income generated by the direct and indirect effects is known as the induced effect. The induced impacts are additional expenditures resulting from increased income brought about by increases in final demand.

This module makes a few assumptions:

1. The cost of development is approximately $10 million per MW for a tidal energy facility.

2. A tidal project 5MW in size will take 5 years to complete and spending will be equal each year.

3. Seventy percent of all the required inputs for the facility will come from within the Digby area.

4. Those living and working in the Digby area will spend all of their earnings within that area.

5. The size and way the economy of Digby currently functions will remain static, with the only significant change being the 5MW tidal energy facility.

The model is not a precise tool for estimating economic and job growth; however, it does provide insight into the potential impacts of tidal energy development on the scale of 5MW in the Digby area.

The I/O model indicates that:

- A 5MW project would provide steady work for 48 people for the 5 years of the project develoment and construction, with an estimated annual income of $60,000 per person.

- Over the lifetime of the tidal facility (estimated at 20 years), an equivalent of two full-time jobs would be created.