“Go Big or Go Away?” An Investigation into the Potential for Small-Scale Tidal Energy Development in Canada, and Factors that May Influence its Viability

by

Jordan T. Carlson

Submitted in partial fulfilment of the requirements
for the degree of Master of Environmental Studies

at

Dalhousie University
Halifax, Nova Scotia
January 2017

“We can see only a short distance ahead, but we can see plenty there that needs to be done.” – Alan Turing

Table of Contents

List of Tables

List of Figures

Abstract

Recent studies have questioned the validity of the tidal energy industry's focus on utility-scale devices, and have called for investigation of the potential for small-scale tidal energy development. This thesis provides an early assessment of this potential, in three inter-related parts. First, the question of whether a tidal resource exists that is viable for small-scale extraction is addressed, alongside an assessment of electricity markets where this resource would prove attractive. Second, through financial modeling, an estimate of the upper cost thresholds for small tidal projects to prove viable is developed. Finally, a review of the social and socioeconomic factors that may influence a project's acceptability in a given community—and thus its chance of success—was conducted. Together, these pieces offer a picture of the contexts in which small-scale tidal energy projects may prove worthwhile, and the hurdles that may stand in the way of developers are highlighted.

List of Abbreviations and Symbols Used

APERC: Asia Pacific Energy Research Centre

A**:** cross-sectional area of flow

CAD: Canadian Dollar

CEDIF: Community Economic Development Investment Fund

COMFIT: Community Feed-in Tariff

D**:** decommissioning cost

DFO: Department of Fisheries and Oceans

E**:** annual electricity generated

EA: Environmental Assessment

EIA: Environmental Impact Assessment

EMEC: European Marine Energy Centre

ENM: Enhanced Net Metering

FIT: Feed-in Tariff

FORCE: Fundy Ocean Research Center for Energy

g**:** acceleration due to gravity, 9.81 m/s^2

I**:** initial investment cost

IBA: Impact Benefit Agreement

IEA: International Energy Agency

IPP: Independent Power Producers

IRR: Internal Rate of Return

L_0**:** characteristic length of channel

LCOE: Levelised Cost of Energy

LRS: Licensed Renewable Supplier

MRE: Marine Renewable Energy

n**:** project lifetime

NIMBY: Not In My Back Yard

NPV: Net Present Value

NREL: National Renewable Energy Laboratory

NS: Nova Scotia

NSDOE: Nova Scotia Department of Energy

NSPI: Nova Scotia Power Inc.

OERA: Offshore Energy Research Association

OMB: Office of Management and Budget

O&M: annual operations and maintenance cost

P: power

PV: photovoltaic

ρ: density of seawater, ~1020-1029 kg/m^3

R_H: hydraulic radius of channel

R_t: revenue in year t

r: discount rate

RES: Renewable Energy Strategy

RtR: Renewable to Retail

SEA: Strategic Environmental Assessment

TEK: Traditional Ecological Knowledge

UARB: Utility and Review Board

UNEP: United Nations Environment Programme

$\check{V}$: Depth-averaged flow velocity

v: velocity of flow

Acknowledgements

First and foremost, I would like to thank my supervisor, Michelle Adams for her support and guidance throughout the process of conducting the research and writing that went into this thesis. She has made me a much better academic, and person, over the past two years. Likewise, my co-supervisor, Bruce Hatcher, provided invaluable support and guidance—and gave the initial impetus to investigating small-scale tidal energy as a field, before I even arrived in Halifax. Rounding out my committee, John Colton helped me better understand the importance of social and human factors in energy projects, and provided some much-appreciated encouragement whenever I found myself lost or confused when considering social or political project implications.

I also owe thanks to the Government of Nova Scotia's Nova Scotia Graduate Scholarship programme, which allowed me the opportunity to do this work at Dalhousie. The Offshore Energy Research Association, and Bjoern Elsaesser of Queen's University Belfast, also have my gratitude, for funding and facilitating (respectively) my trip to Belfast, where I attended a week-long course on tidal energy engineering and visited SeaGen before its decommissioning. Without the support of Dalhousie University's School for Resource and Environmental Studies, and Cape Breton University's Verschuren Centre for Sustainability in Energy and the Environment, and the communities within both, this work could not have been completed.

Finally, I would like to thank my friends and family for their support, patience, and tolerance for my ups and downs over the past two and a half years. In particular, I have to say that Halifax would not have been the same without Adam, Caitlin, Rebecca, Sarah, Sophie and Stephanie. I may not always be the most expressive of it, but I couldn't have asked for a better group of friends to go through SRES and explore the east coast with.

Chapter 1: Introduction

1.1 Research Aims

This thesis was undertaken with the goal of addressing one overarching question: Under what conditions can small-scale tidal energy projects be made feasible? As a necessarily broad question, investigating it required several related, supporting questions to be answered. In simplest form, these questions are:

1. Is there a significant enough resource and market for small-scale tidal energy development to prove worthwhile?
2. Are small-scale tidal projects being pursued in Nova Scotia, or elsewhere? If not, why not?
3. Aside from electricity generation, what benefits can small tidal provide to individuals, communities, and society?
4. What are the costs associated with extracting energy from the tides (environmentally, socially, culturally, and financially)?
5. What environmental, sociopolitical, economic, and technical considerations are relevant to the deployment of small-scale tidal energy devices?
6. How can a community, project proponent, regulator, or individual decide whether pursuing a small-scale tidal project is worthwhile?

Each of these questions is addressed, in some form, throughout the thesis. This chapter will focus on providing the reader with the relevant background and introduction to the body of literature related to various aspects linked to tidal energy development. Chapter 2 provides the context and analysis necessary to address questions 1, 2 and gives some consideration to question 3; Chapter 3 addresses question 4, and Chapter 4 addresses questions 5 and 6, while also revisiting question 3.

The rest of this introductory chapter provides some necessary background on tides, tidal energy, and the concepts of distributed energy and energy security. The three chapters that follow have been written in the format of papers to be submitted for publication at a later date; as such, there is some degree of repetition of information in each chapter. However, each discusses a different issue central to considering the potential for small-scale tidal development. Chapter 2 comprises an extensive literature review designed to determine whether a resource appropriate for small-scale tidal energy devices exists, and whether markets exist where there would be demand for such devices. Chapter 3 presents the results of a financial modeling exercise that was undertaken in the *@Risk* software package, designed to determine a set of baseline cost parameters for tidal developers to target if they wish to pursue economically viable small-scale tidal projects. Chapter 4, another literature review, provides both an introduction to the concept of social license—a vital consideration for any energy project (Devine-Wright, 2005; Ricci, Bellaby & Flynn, 2010; Fast & Mabee, 2015)—and an overview of the concerns likely to influence whether a given small tidal project receives social license from a host community. As Chapters 2 and 4 are literature reviews, their methods are relatively self-explanatory; Chapter 3 therefore contains its own methods section, and no further methods explanation is given in this introduction. Finally, Chapter 5 is formatted as a brief conclusion and summary of the results of this thesis.

1.2 Background

1.2.1 A Note on Terminology

Throughout this thesis, the terms "utility-scale" and "small-scale" will be used to refer to differently sized energy projects. The emphasis of the tidal energy sector, to-date, has been on devices with capacities in the range of 0.5 to 2 megawatts [MW] that are intended for deployment in energy farms of sizes from 5 to 60 MW (MacGillivray et al., 2015; MacDougall, 2015; Roberts et al., 2016). This thesis considers devices in this range (0.5 to 2 MW), and exceeding it, to be "utility-scale." However, many tidal energy devices exist with rated capacities below 0.5 MW, in the kilowatt [kW] range (Roberts et al., 2016). Such devices range from capacities of just 5 to 15 kW up to 50 to 150 kW, and anything in between (Roberts et al., 2016). This thesis will call devices within this range (5 to 150 kW) "small-scale" tidal energy devices, or "small tidal."

One could note that this leaves two ranges of devices uncategorised—those with capacities below 5 kW and those between 150 kW and 500 kW. The first of these categories is what the literature would refer to as "micro-turbines" (Roberts et al., 2016); it will not be discussed further in this thesis, as micro-turbines are typically only relevant at the scales of individual or very small collections of households. This thesis is interested in determining whether, and how, small-scale tidal energy projects to contribute meaningfully to local, regional, and national electricity grid systems. Thus, household-sized energy projects are too small to consider.

In contrast, the 150 kW to 500 kW exclusion is a result of modeling considerations for Chapter 3; most tidal energy devices are intended for deployment in multi-device arrays (MacGillivray et al., 2015; Roberts et al., 2016), and as such, consideration of arrays must be made in this thesis. Therefore a "small-scale threshold" had to be selected. For devices exceeding 150 kW by any significant fraction (e.g. 175 kW, 200 kW), an array of more than two turbines would cross the selected threshold (500 kW) into equivalent power capacity with small "utility-scale" devices. In order to emphasise the small-scale nature of the devices being considered, and guarantee that arrays of at least three devices would remain "small-scale," an upper threshold for device size of 150 kW was selected. It could be argued that this selection is somewhat arbitrary, but for the purposes of this thesis, this exclusion is considered necessary.

1.2.2 Marine Renewable Energy Development

As global recognition of the role of anthropogenic carbon dioxide emissions in climate change has increased, many have begun to search for alternatives to carbon-intensive fossil fuels as energy sources. This is especially true of governments, at all jurisdictional levels, many of which have instituted programs in attempts to "decarbonise" their energy systems. The government of the Canadian province of Nova Scotia is one such government. In 2009, they pledged to generate 25% of the province's electricity from renewable sources by 2015, and 40% by 2020, from a baseline of 12% renewable electricity (Nova Scotia Department of Energy [NSDOE], 2010). The first of these goals has been achieved (NSDOE, 2015a). The province has achieved these goals, to-date, largely through the development of wind power (NSDOE, 2016); however, provincial plans (NSDOE, 2015a) suggest that achieving the 40% renewable electricity goal by 2020 will depend on the completion of an interconnection plan with Newfoundland and Labrador, as well as a new hydro dam in that province, Muskrat Falls. This hydroelectric project has been publicly called a "boondoggle" by the CEO of the provincial utility of Newfoundland and Labrador (Roberts, 2016) and is behind schedule, which suggests Nova Scotia may miss its renewable electricity targets. That the province has expressed interest in diversifying its energy mix in the coming years, with particular emphasis on the potential for harnessing the vast marine energy potential Nova Scotia's extensive coastline offers (NSDOE, 2015a), may help mitigate this risk.

While the past few decades have seen considerable progress made in the development of wind, solar, bio, and geothermal power around the world (Ellaban, Abu-Rub & Blaabjerg, 2014), only in the past ten to fifteen years have significant efforts to develop marine renewable energy (MRE) sources been put into motion (Kerr et al., 2014). Broadly, "marine renewable energy" describes any energy extracted from an ocean or marine environment for human use, whether it is from the tides, waves, deep ocean currents, or thermal or salinity gradients within the water (Wiersma & Devine-Wright, 2014). Some authors (Alexander, Wilding & Heymans, 2013; Wiersma & Devine-Wright, 2014) also include offshore wind energy as a "marine renewable;" however, as offshore wind turbines draw their energy from the air, rather than the ocean's movements or gradients, it is excluded from the definition of MRE used in this thesis. This choice to exclude offshore wind energy from MRE is also made by others, including MacGillivray, Jeffrey and Wallace (2015), Ellaban et al. (2014), and Flynn (2015), among others.

Each MRE technology has seen interest from a wide variety of parties worldwide. Tidal barrages—similar to traditional hydroelectric dams—were first built across estuaries in the 1960s, and a handful of such projects exist around the world today, in France, Canada, the Republic of Korea, Russia, and China. Later, the United Kingdom led early efforts to investigate harvesting waves for electricity generation in the 1970s and 1980s (Flynn, 2015); efforts which intensified in light of post-2000 European Union renewable energy obligation commitments. The fate of the United Kingdom's MRE sector is, at the time of this writing, in question, because of the June 2016 referendum in which the UK voted in favour of leaving the European Union. Many MRE experiments and projects in the UK have been the result of heavy EU funding (EMEC, 2016a; 2016b); should the UK leave the EU without securing new sources for this funding, these projects may languish. This uncertainty will be resolved in the coming years as the political shape of this so-called "Brexit" becomes clear, but it is noted here simply for its relevance to the UK's position as a leader in the MRE sector. Elsewhere, several companies have been exploring ocean thermal technology, most notably in the south and central Pacific (e.g. Hawaii, Indonesia) (Flynn, 2015). Finally, over the past fifteen to twenty years, focus on developing tidal stream technologies (more similar to an underwater wind turbine than the traditional dam of a barrage) has increased, with a number of companies emerging in Europe and North America to develop such devices.

Each of these technologies comes with its own unique drawbacks and challenges, while providing an equivalent end product: usable energy, in either mechanical or (more commonly) electrical forms. Barrages face many of the same challenges as hydroelectric dams, including the imposition of severe change on local environmental conditions such as sediment and current flows, fish and wildlife habitat, and some risk of coastal flooding or erosion (Morris, 2013; Flynn, 2015). Consequently, public support for proposed new tidal barrages has been virtually non-existent (Flynn, 2015) over the past twenty years; in part due to exorbitant costs. As such, few barrages have been built in the past two decades, and recent proposals to build barrages across the Severn Estuary (UK) and Scot's Bay (Canada) have encountered resistance (Delaney, 2014; Flynn, 2015). Wave energy projects, despite having significantly lower environmental impacts, have also struggled to reach implementation. This has largely been due to the immaturity of the technologies involved, the difficulties of operating devices in wave environments energetic enough to create significant extractable power, and the considerable costs of deploying experimental devices at sea (MacGillivray, Jeffrey, Winskel & Bryden, 2014; MacGillivray et al., 2015). Similar difficulties have been faced by ocean thermal and tidal stream projects, with high costs and highly experimental technologies being major causes cited in discussions of industry delays (MacGillivray et al., 2014; 2015).

Of the different types of MRE, tidal stream energy is most often cited as the "closest to market"—meaning it is viewed as being the most cost-competitive with established technologies, or at least as being the most likely MRE technology to achieve cost-competitiveness in the near future. In 2012, the government of Nova Scotia claimed that tidal stream power cost between \$440-\$510/MWh for initial deployments (Province of Nova Scotia, 2012), with the expectation that costs would fall rapidly towards grid parity (around \$50-100/MWh, in Atlantic Canada, where most Canadian tidal energy efforts have been focused) over a five- to ten-year period. Yet, only one tidal stream project has come online in Canada (Withers, 2016), six years later. Elsewhere, very few non-experimental, grid-connected deployments occurred in that time period, with the most notable installations being those of the defunct MCT's SeaGen in Northern Ireland, ORPC's TidGen system in Cobscook Bay, Maine, Verdant Power's turbines in New York City, OpenHydro's January 2016 deployment in France, the Meygen deployment in Scotland's Pentland Firth, and the five 100 kW turbines deployed as an array in the Shetland Islands in late 2016.

Despite this dearth of successes, the province of Nova Scotia has promised four projects—each utilising different tidal stream technologies—a guaranteed Feed-in Tariff (FIT) rate of between \$450/MWh and \$540/MWh, for fifteen year contract terms, should those projects come online (NSDOE, n.d.). However, MacDougall (2015) has suggested that these subsidy rates are not yet sufficient to encourage deployment of tidal energy devices in Nova Scotia. Similar arguments have been put forward about the suitability of policy mechanisms and readiness of the industry for large-scale development in the UK (MacGillivray et al., 2014), with several authors attempting to highlight areas for improvement (Denny, 2009; MacGillivray et al., 2014; Vazquez & Iglesias, 2015). Largely, these arguments revolve around the idea that the financial risks of pursuing projects remain too high, while rewards remain too low. Such risks are a consequence of the number of unknowns in tidal project development. These unknowns include, but are not limited to: uncertainties in device performance, environmental impacts, and device lifetimes (MacGillivray et al.,2015); unknown levels of public support for projects (de Groot, Campbell, Ashley & Rodwell, 2014; Wiersma & Devine-Wright, 2014); and the unknown economic benefits of project development, including jobs created, technical training required, and related factors (Denny, 2009; Kerr et al., 2014). Such unknowns are all a result of the slow pace of the tidal energy industry's development.

There are several possible explanations for this pace, but one of the most salient is simple: the tidal sector has yet to see deployment in large enough numbers to drive large-scale cost reductions and attract investment (MacGillivray et al., 2014; 2015). This view is best understood through what the International Energy Agency [IEA] calls the "learning rate" of a given technology. Defined as the percentage of initial costs by which unit price falls for each doubling of deployed volume (IEA, 2000), the learning rate of a given technology can be understood as an analogy for its maturity relative to other technologies. Learning rates can be extrapolated to approximate the time at which a new technology will become competitive with other, more-established alternatives. However, learning rates are not intended to be definitively predictive (IEA, 2000; McDonald & Schrattenholzer, 2001); instead, when applied in outlooks, the learning rate of a technology highlights the rate at which a technology's costs will decline so long as investment continues. Key to understanding learning rates are two facts: (i) learning cannot occur without *doing*, which in the case of energy technologies means deploying units in the field; and (ii) learning is a cumulative, non-linear process, wherein early deployments will yield greater learning than late ones, following a pattern akin to an inverse exponential function (IEA, 2000). Figure 1, from the IEA's "*Experience Curves for Energy Technology Policy*" report (2000), demonstrates this relationship for the case of solar photovoltaics (PV). Note that the "progress ratio" of a technology is simply the complement of its learning rate (IEA, 2000); a progress ratio of 82%, as shown, indicates an industry learning rate over the depicted period of 18% (i.e. PV module costs fell by 18% from 1976-1992). Thus, in order for industry-level learning to occur quickly for a given technology, there must be a large number of deployments happening as early in the development process as possible.

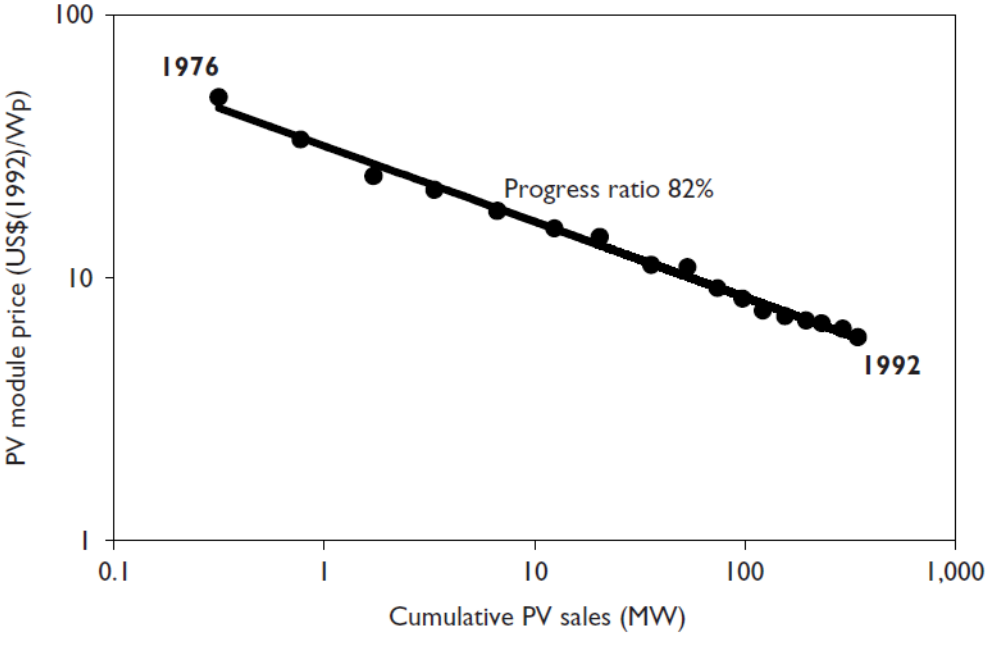

Figure 1: Progress ratio for solar PV modules, 1976-1992 (from IEA, 2000)

Despite the wide use of learning rates in the assessment of technology readiness of other renewables (McDonald & Schrattenholzer, 2001), the MRE sector seems to have chosen not to integrate such lessons into development strategies. MacGillivray, Jeffrey and Wallace (2015) highlighted this when comparing the development of coal combustion plants, natural gas turbines, wind turbines, and modern MRE devices; they found that hundreds to thousands of small-scale pilot project deployments were required before "full-scale" power plants and devices from any of the proven (coal, natural gas, wind) technologies became "established." In their words:

"Within each of the historic technologies analysed, it is clear that the initial devices deployed were a fraction of the capacity of the upper asymptote value (0.0005%, 10%, and 0.2% of *T* for steam turbines, gas turbines, and wind turbines, respectively). At the point in which the establishment of significant growth in the rate of unit-level up-scaling took place, unit capacities still represented only a portion of the asymptote value (13%, 21%, and 6% of *T* for steam turbines, gas turbines and wind turbines, respectively)." – MacGillivray et al., 2015, p. 549.

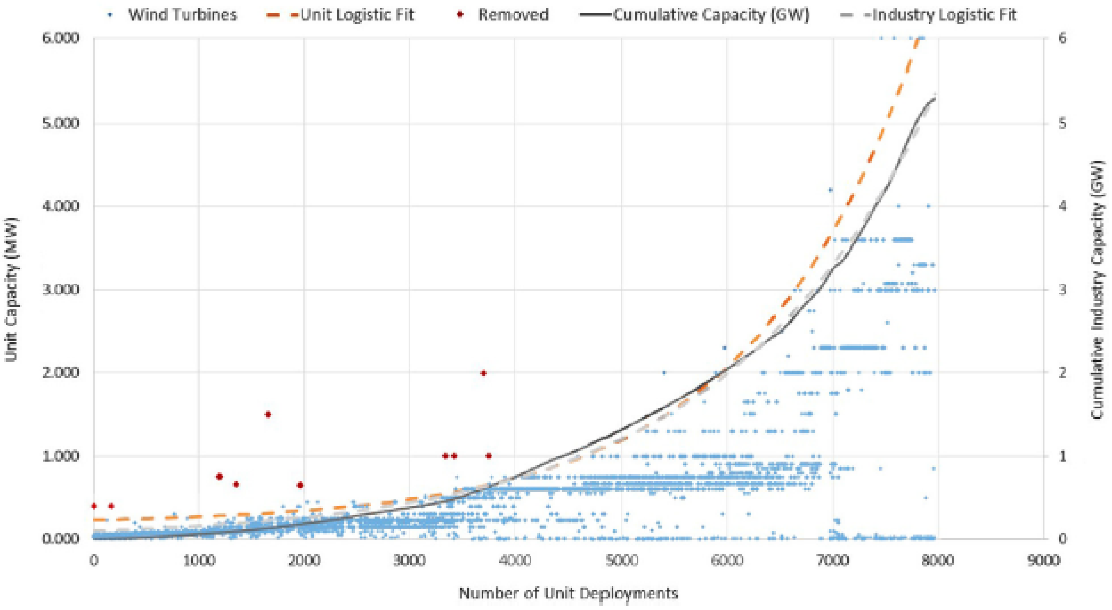

Figure 2: Global wind turbine unit capacity, deployment numbers, and cumulative industry capacity (from MacGillivray et al., 2015)

That is: at the point at which historic energy technologies began to be deployed commercially en masse, their average unit capacity was only a small fraction of the maximum-size devices of their type, and still significantly smaller than what is now considered a standard-sized facility (see Figure 2, above). In contrast, the MRE sector was found to have rushed towards development of its self-declared “full-scale” target devices (ranging from 1 to 3 MW in rated power), with very few small-scale deployments, and vanishingly few long-term pilot projects below this scale (MacGillivray et al., 2015). As a result of this almost exclusive focus on large-scale, windfarm-style projects, the MRE sector has seen little growth, a great deal of expense, and little in the way of cost reductions over time. Given the significant investments made in MRE, particularly in tidal energy, by national and subnational governments, this continuing lack of progress presents a problem for both the taxpaying public and the industry itself.

This thesis investigates these issues in greater detail, and offers potential solutions with emphasis placed on identifying and working with communities where smaller-scale, iterative tidal energy projects would be environmentally, economically, and socio-culturally appropriate. Due to both past and present energy policies that supported tidal energy development in the province, Nova Scotia is used as a case study for such projects, and recommendations regarding policy development are aimed particularly at the province. However, any such policy recommendations and potential guidelines to support community decision-making, along with the wider industry analysis conducted, are intended to be general enough that they can be adapted to the local context of other jurisdictions with ease. As such, this work can be relevant to any scholars, industry or government personnel, project developers, or local community members who wish to understand the opportunities and risks of small-scale tidal development.

1.2.3 Tides & Tidal Energy

In most of the world’s coastal areas, tides are a daily feature of life. Once or twice each day, depending on latitude, the tidal wave propagates onto the shore (known as a flood tide), halts during high slack water, and then recedes back down the shore (known as an ebb tide) to halt at low slack water before repeating the sinusoidal cycle. These events advance slightly in time with each tide, and vary in amplitude depending on local geomorphological and bathymetric factors over the lunar monthly Spring-Neap cycle (Pond & Pickard, 1983). Besides periodically wetting and drying the intertidal zone of the shoreline, the flows of water associated with the advance and recession of tides deposit and remove sediment, soil and detritus from the world’s shores, contributing to coastal accretion and erosion (Pond & Pickard, 1983). They also deliver inorganic and organic nutrients to coastal ecosystems and export organic materials and terrestrial runoff to the adjacent ocean ecosystems, thereby aiding the many natural processes of production and decomposition that characterize the coastal zone (Mann, 1982).

The ocean's tides have been studied with varying precision since at least the Ancient Greeks, who were among the first to harness tidal currents to drive grain mills (Lewis, 1997; Hardisty, 2009). Driven primarily by the gravitational forces exerted by the sun and moon upon the Earth (and its vast bodies of water), tides vary in time, intensity, amplitude, and phase with location about the surface of the earth, local bathymetry, and the relative positions of the sun and moon (Pond & Pickard, 1983; Hardisty, 2009). While other astronomical bodies have some influence, due to distance and the masses involved, the moon and sun are the dominant causes of tidal forcing. As such, the most noticeable and regular variation in tides at any site can be observed to match the phases of the moon (Hardisty, 2009).

Peak tidal ranges and currents are observed in any location during "spring" tides; these occur when the sun and moon are in line with the Earth (Hardisty, 2009). Conversely, when the moon is aligned at a right-angle to the sun-Earth system, "neap" tides are experienced, the peak heights and maximum flow speeds in any tidal stream are at their lowest values (Hardisty, 2009). Thus, one may link spring tides with New and Full Moons, while neap tides coincide with Half Moons (Hardisty, 2009). Knowing this, one can predict the relative strength of a day's tidal flows based upon the phase of the moon on that day. This link between lunar cycle and tidal intensity also explains the fact that high, low and slack water occur at different times each day (Pond & Pickard, 1983; Hardisty, 2009). As the lunar cycle is approximately 28.5 days long, the tidal events this cycle results in cannot remain at fixed times each day. The actual water flow speed in a given case varies as the net result of other forcing mechanisms besides the tidal wave, including wind velocity and duration, the fetch (area of water over which the wind flows), surface wave breaking, storm surges, internal waves and seiches (Pond & Pickard, 1983; Hanson, 2004). Additional factors that modify a site's tidal velocities include the depth of the water column, shoreline shape and slope, and seabed composition and roughness (Hanson, 2004; Hardisty, 2009).

In terms of tidal energy, we must account for this variance because the energy contained in a tidal flow is a direct function of its velocity (Garrett & Cummins, 2004; Bryden & Melville, 2004). This relationship is best understood by beginning with understanding the kinetic energy flux in a given area of a tidal flow; that is, the amount of energy passing through a given area at any moment in time. Equation 1 (Karsten, McMillan, Lickley & Haynes, 2008) shows the basic relationship between the variables which influence the power present in a flow; P is the kinetic energy flux (also known as power), ρ is the density of seawater (typically 1020 to 1029 kg/m^3), A is the area of flow being considered, and $\check{V}$ is the depth-averaged velocity of the flow.

$$P = \frac{1}{2}\rho A \check{V}^3$$

Equation 1: Total power in an open channel flow (Karsten et al., 2008)

Equation 1 represents the total power available in a channel cross-section, but extracting all of this energy is both impractical from an engineering perspective (Bryden & Melville, 2004; Cummins, 2012) and environmentally harmful (Bryden & Melville, 2004; Karsten et al., 2008). To address this, Garrett & Cummins (2004) calculated the theoretical maximum extractable power in a tidal channel; they found that this maximum varies with channel geometry and device design, from 19 to 24% of the total available power. However, it must be noted that extracting this maximum power can have significant environmental effects. Karsten et al. (2008) found that extracting the maximum power from the Minas Passage in Nova Scotia would result in a change in near-field tidal amplitude of greater than 30%—and have upstream impacts throughout the Gulf of Maine, with Boston and Portland experiencing changes in local tidal amplitude greater than 15%.

The extreme environmental changes that could result from tidal energy extraction have resulted in efforts to be conservative in pursuing tidal development. From these efforts emerged Bryden and Melville's (2004) now-industry-standard estimate that up to 10% of the energy in a generic tidal stream could be extracted without significant adverse effects on the stream's total velocities and general ecology. Broadly, this has been confirmed by the modeling work of others, including Karsten et al.'s (2008) results, which suggested that extracting 2500 MW (7-9% of theoretically available power) from the Minas Passage would result in tidal amplitude changes locally of about 5% (and less elsewhere). This work has yet to be confirmed in the field, due to a lack of device deployments at these scales.

However, it can and should be noted that Equation 1 is a first approximation of the behaviour of bulk fluids in channels, valid in smooth, steady flows. In real tidal channels, more complex dynamics will call this behaviour into question, including bottom- and side-friction forces, bathymetry, seabed and shoreline geology, and turbulence, among others (Chanson, 2004; Garrett & Cummins, 2004; Hardisty, 2009; Cummins, 2012). In such situations, the relatively simple calculation of tidal energy potential in a flow that results from Equation 1 proves inaccurate, due to the scale at which many of these forces operate relative to the scale which Equation 1 is designed to describe. To understand the behaviour of a turbulent flow, and design infrastructure to survive and operate within it, engineers most often use simulation and scale models (Chanson, 2004). These models are able to scale accurately to the real flow's conditions due to a match in Froude number (Chanson, 2004), a representation of the ratio of the inertial forces in the fluid and the external forces acting upon it (usually gravity). Defined in Equation 2 (Hardisty, 2009), wherein v represents the velocity of the flow, g the acceleration due to gravity (9.81 m/s^2), and L_o the characteristic length of the channel, the Froude number is dimensionless. For an open channel with a free surface (e.g. a tidal estuary), L_o is usually taken to be the hydraulic radius, R_H, which is the ratio of the channel's cross-sectional area (A) to its wetted perimeter (P).

$$Fr = \frac{v}{\sqrt{gL_o}}$$

Equation 2: Froude Number (Hardisty, 2009)

While models and scaled experiments based around the Froude number can allow greater accuracy of results than bulk flow calculations, real channels still introduce inaccuracies relative to calculations. The effects of seabed slope, friction, internal waves, free surface interactions (i.e. wind and wind-driven waves), and other influences (Chanson, 2004; Hardisty, 2009) mean that current models cannot prove completely accurate. Further, the low number of deployed tidal energy devices, as noted by MacGillivray et al. (2014) and MacDougall (2015), has limited the amount of information available to confirm the validity of Froude number-based scale model estimates of turbine performance.

Note that this confirmation is required for tidal energy modeling despite Froude number simulacra models being long- proven for other fields (Chanson, 2004). This is because in-stream tidal energy harvesting is a novel field, as many devices operate on or near the seabed (Hardisty, 2009; Roberts et al., 2016). Near the channel's bed, the complex interplay of turbulence, wind and wave effects, bathymetry and seabed characteristics makes the accuracy of calculations normally applied to mid-stream or near-surface channel behaviour (and human activity within it) questionable. Although it is entirely possible (Voulgaris & Trowbridge, 1998; Trowbridge, Geyer, Bowen & Williams, 1999; Hay, Zedel, Cheel & Dillon, 2012) for measurement to be carried out in these environments, much of the energy dissipation that occurs due to turbulence (and the wear such dissipation would have on devices) occurs on scales (nm to cm) too small to be useful for energy extraction. However, events within the tidal stream at these small spatial scales can still influence the efficiency and effectiveness of energy harvesting from tidal environments (Torrens-Spence, Schmitt, Mackinnion & Elsaesser, 2015). This is true regardless of device size (Torrens-Spence et al., 2015). Consequently, much effort has been devoted to understanding the behaviour of tidal flows at these scales; to-date, however, much remains unknown. So long as these unknowns remain, the accuracy of tidal energy resource estimates and the survivability of tidal device designs will be difficult to confirm except through direct deployment.

1.2.4 Tidal Industry Background

Though tides were first harnessed for mill work in pre-Roman times (Lewis, 1997; Hardisty, 2009), interest in generating electricity from them is relatively novel. Early proposals for tidal barrages arose in the 1920s and 30s, with sites of particular interest including the Bay of Fundy in Canada and the Severn Estuary in the United Kingdom (Hammons, 1993; Hardisty, 2009; Flynn, 2015). Such proposals saw little progress due to prohibitive costs (Hammons, 1993) until the 1960s, when the French built the world's first tidal barrage at La Rance, in Brittany. A 240 MW facility, it remained the world's largest tidal barrage until the late-1990s, when South Korea completed the 254 MW Sihwa Lake facility. In the interim, smaller barrages were built in Canada (Nova Scotia), Russia, and China, all smaller than 25 MW (Flynn, 2015). However, these facilities remain extremely expensive to construct, and the environmental impact of their erection and operation are highly controversial (Hardisty, 2009; Flynn, 2015). Consequently, the tidal energy sector has turned its focus towards so-called in-stream tidal energy devices, in myriad forms.

Seen as more environmentally friendly (Wiersma & Devine-Wright, 2014; Flynn, 2015; Dalton et al., 2015), in-stream tidal energy devices have been undergoing considerable research for most of the past two decades. With a wide range of designs, from horizontal-axis turbines similar to wind turbines to a seabed-tethered kite (Roberts et al., 2016) to a shore-tethered, drifting barge (Gorman, 2016), no one approach has yet been proven more effective than others (MacGillivray et al., 2014; 2015). This has led to a great deal of competition for funding in the sector, especially in Europe, where most firms involved in tidal energy device design and research are dependent upon public funding from national, regional, or EU-level governmental bodies (MacGillivray et al., 2014). These issues of competition and limited funding have exacerbated the tendency of firms to tightly control their data, leading to very little information being shared between firms, even when the mutual benefits of cooperation vastly outweigh the risks.

The culmination of these tendencies, to-date, has been an industry that is very slow to progress, with few projects in the water beyond first-test stages. Several tidal firms have become insolvent in recent years (Clean Current, 2015), while some have changed hands multiple times; for example, MCT's transition from independent, to Siemens, to Atlantis Resources (Atlantis Resources Ltd., 2015). With this purchase, Atlantis Resources became one of the few firms in the industry to have multiple utility-scale tidal turbine designs that are not simply smaller or larger variations of a single design. However, such consolidation has caused some issues with data sharing at a sectoral level (MacGillivray et al., 2014), as the once publicly-funded research held by one company is concentrated into a single firm, rather than shared among its competitors to offer more minds the chance to find new solutions. A similar pattern has been noted in the related wave energy industry, and parallels are often drawn between the two sectors as a result (Garrad, 2012).

As a nascent industry, ultimately, very little is known of the operation, effects, and survivability of tidal devices (Dalton et al., 2015; MacDougall, 2015; Roberts et al., 2016; Tethys, n.d.). Data generated regarding the effects of any device on the environment, material wear over time, and device performance variation with different flow characteristics are thus extremely valuable to both individual firms and the sector as a whole (Huckerby, 2012; Tethys, n.d.). While some of this data—particularly regarding specific device performance parameters—is reasonable to protect on intellectual property grounds, much of it is generalizable and applicable to most industry actors (Huckerby, 2012). This is especially true for data regarding device interactions with fish and other marine life, the cumulative impacts of device deployments as arrays grow in size, and the impact of energy extraction on the surrounding environment. Sharing such data between firms to accelerate industry advancement would not be unreasonable, and has precedent in past renewable energy technology development efforts, including the wind sector (Garrad, 2012; Huckerby, 2012; Tethys, n.d.). Despite calls for such data sharing throughout the tidal energy literature (Huckerby, 2012; Kerr et al., 2014), it is presently unknown if this data sharing is actually occurring industry-wide. That said, the US Pacific Northwest National Laboratory has spearheaded the creation of an online database, Tethys (n.d.), for information on MRE projects globally, especially regarding their environmental effects. While comprehensive, the extent of Tethys's reach and user base is unknown.

Although these unknowns loom over the industry, utility-scale deployment efforts continue. Examples of these deployments include Marine Current Turbines' 1.2 MW SeaGen (Kregting & Elsaesser, 2014), Verdant Power's Roosevelt Island Tidal Energy Project [RITE] (1.05 MW) (Federal Energy Regulatory Commission, 2012), Ocean Renewable Power Company's Cobscook Bay project (900 kW) (S. Kist, Personal communication, February 10, 2016), OpenHydro's deployments in France (500 kW) (OpenHydro, 2016) and Nova Scotia, at FORCE (2 MW) (Withers, 2016b), and Atlantis Resources and Andritz Hydro's (Meygen, 2016) installation of the first turbines in their (6 MW) Meygen project in northern Scotland. Though SeaGen was the first of these projects, installed in 2008, as of late 2016 these projects were all delivering electricity to national or subnational electricity grids. Plans for expansion of the Meygen project exist

(Meygen, 2016), while several partners in Nova Scotia's Fundy Ocean Research Centre for Energy (FORCE) have plans for deployments in 2017 (Withers, 2016b). Despite this, apart from SeaGen, RITE, and the Cobscook Bay project, none of these installations have been operational for more than a year as of this writing. As such, their survivability remains in question, and plans to expand these facilities are likely to be contingent upon proven performance over several years (MacDougall, 2015). Until one or several of these device designs has a demonstrated record of reliability, investors are likely to be cautious, and deployments consequently slow. Barring an unforeseen change in deployment incentives policies (MacGillivray et al., 2014; 2015; MacDougall, 2015; Dalton et al., 2015), the literature agrees that the near-term outlook for tidal energy deployment appears to be one of slow growth, if any.

1.2.5 Tidal Energy in Nova Scotia

A detailed summary of the state of Nova Scotian efforts to pursue and encourage tidal energy development is included in Chapter 2. However, a brief summary of why tidal energy matters to the province, and recent activity in the sector, is relevant here. Nova Scotia has proven a region of great interest to tidal energy developers around the world, due to its high potential for tidal energy development along the southern shore of the Bay of Fundy. One area of this bay, the Minas Passage, has been estimated to hold a harvestable tidal resource of 2500 MW of power (Karsten et al., 2008). Assuming continuous, year-round operation (unlikely, but useful as an outer estimate), this would be enough to provide for the energy use of more than 800,000 average homes in Canada (Statistics Canada, 2016). While Nova Scotia and its fellow Maritime provinces of New Brunswick and Prince Edward Island are home to approximately 760,750 households (Statistics Canada, 2011a; 2011b); thus, the energy represented by the tidal flows in the full Bay of Fundy is well in excess of their needs. But their southwestern neighbours in New England present a unique market opportunity (Province of Nova Scotia, 2012), should large-scale development of the bay's tidal resource be pursued.

However, to take advantage of this opportunity, Nova Scotians must first find a way to reliably harness the Bay of Fundy's immense, violent tidal currents. To-date, only two tidal energy devices (1 MW and 2 MW OpenHydro turbines) has been deployed in the Bay, at the jointly privately-, federally-, and provincially-funded Fundy Ocean

Research Center for Energy [FORCE]. The first, 1 MW deployment, in the late autumn of 2009 (Alberstat, 2013), resulted in device failure in a matter of weeks, and no further device was deployed until November 2016 (Withers, 2016b). Even this updated, 2 MW version of the OpenHydro design was to be deployed in the summer of 2016, an injunction launched by the Bay of Fundy Inshore Fishermen's Association delayed the process until November of that year (McMillan, 2016; Withers, 2016b). Despite this deployment, the Fisherman's Association still hopes to delay further development until after an appeal is heard against the government's decision to grant FORCE and its partners a permit for turbine installation (Rhodes, 2016). Other partner companies in the FORCE project have announced plans to deploy their own tidal energy turbine designs at the site in 2017 and 2018, but it is unknown if these will proceed without similar incidents.

One of the foremost issues put forth by the fishermen's organisation has been their concerns with the environmental assessments (EA) carried out by FORCE and its contractors that were the basis of the provincial government's approval of the tidal energy operations at the site (Rhodes, 2016; Withers, 2016a). The association claims that these assessments were inadequate, and too little is understood about the ecological impacts of turbine installation on marine life to allow these projects to go forward at this time (Withers, 2016a). While a Fisheries and Oceans Canada (informally, "Department of Fisheries and Oceans" [DFO]) review of the EA process for FORCE found significant deficiencies (DFO, 2016), it still recommended that turbine installation go forward in order to answer some of the questions regarding the environmental impacts of turbine installation. This recommendation, and a court ruling agreeing with it, led to the November, 2016 installation of Cape Sharp Tidal's first turbine, and the first grid-delivered power from in-stream tidal energy in Nova Scotia on November 22nd (Withers, 2016b). Whether or not more devices will be installed in Nova Scotia in the near-term remains in question, due to the aforementioned appeal (Rhodes, 2016) against FORCE's permitting approvals, which will go before the provincial court in February of 2017.

1.3 Distributed Energy & Community Energy

1.3.1 "Distributed" & "Community" Energy Definitions

A "distributed" energy system, often called a decentralised energy system, is one that generates energy at multiple sites as close as possible to the locations of end use, rather than generating power at one or several large, centralised facilities and then transporting it to distant end users (Pepermans, Driesen, Haesedonckx, Belmans, & D'haeseleer, 2005). Distributed systems have been very well studied, and Pepermans et al. (2005), Hain, Ault, Galloway, Cruden & McDonald (2005), and Allan et al. (2015) each provide comprehensive reviews of the subject. However, distributed energy systems are relevant in the discussion of tidal energy because it is an inherently distributed resource: harvestable tides occur only where there are coastlines.

In the literature, "distributed generation" has historically referred to off-grid communities that relied on diesel generation systems for their electricity. These communities generally have comparatively small scale energy systems, with peak demands in the range of 100 kW to 5 MW (Allan et al., 2015). Frequently, these systems are very high-cost, yet remain in operation without replacement due to the much higher cost of building the necessary infrastructure to import energy from centralised grids (Zeriffi, 2007). Increasingly, due to either social pressures or price volatility, discussions of distributed generation are being had in the context of traditional, centralised grid systems (Pepermans et al., 2005; Hain et al., 2005; Allan et al., 2015). This has given rise to some debate (Hain et al., 2005; del Rio & Burgillo, 2008; 2009; Alvial-Palavicino, Gamido-Echeverria, Jiménez-Estévez, Reyes, & Palma-Behnke, 2011) over the potential to extend renewable energy capacity through so-called "community energy" projects: widely-distributed, small (from 10 kW to ~10 MW) renewable energy projects that provide power locally but also contribute to subnational and national grid systems. Various models have been put forward for community energy, including communal ownership by local people or organisations (NSDOE, 2010), local co-ownership (del Rio & Burgillo, 2008; 2009), and operation of energy facilities by local businesses (del Rio & Burgillo, 2008; 2009).

1.3.2 Distributed & Community Tidal Energy

The arguments for, and potential of, distributed, community-based tidal energy projects makes up the bulk of Chapter 2. However, a brief introduction to the arguments is worthwhile here. The relevance of tidal energy in distributed contexts is that it offers interested communities both on- and off-grid specific opportunities. For those communities already connected to a larger grid network, tidal energy represents a way to supplement or replace the electricity they pull from the grid in a predictable manner that will minimise the risk of disrupting the local grid's stability. This tidal electricity could then be either consumed locally, or sold to the grid operator, offering the option to supplant potentially higher-carbon grid electricity at both the local and the grid level.

The view taken in this thesis is that encouraging distributed, small-scale tidal electricity generation is of interest for two reasons. The first is that distributed generation can allow for increases in the energy available in local grid networks without expensive upgrades to centralised generation facilities and transmission lines (Pepermans et al., 2005), thus saving on overall capital expenditures at a societal level. The second is the theoretically corresponding increase in energy security as communities move from often imported, fossil-based fuel systems to local, readily accessible resources. This can save costs in the long-term by avoiding supply contracts for fuels, transport, and associated equipment, while also avoiding the long-term negative impacts associated with burning fossil fuels, both for local health and global climates (Weis & Ilanca, 2010).

In off-grid contexts, tidal energy offers similar benefits; a source of clean electricity that can be used to supplant a portion of any diesel generation currently in use. Note that, as an intermittent power source, tidal energy (in the absence of storage technologies) is not capable of providing consistent, baseload electricity to off-grid communities or consumers. Off-grid, tidal's greatest potential as an energy source lies in its ability to predictably and reliably reduce the need for diesel consumption, allowing diesel generators to be dispatched and shut off as the tidal device output varies in time. Thus, tidal energy can act as a direct substitute for a portion of an off-grid community's yearly diesel fuel consumption, reducing costs and increasing the security of the community's energy supply through reducing reliance on importation of fuel.

1.4 Tidal Energy Projects & Energy Security

The concept of "energy security" is often debated in energy literature, and it has been given many definitions by many authors. A basic definition of energy security is provided by the IEA (2010): energy security is "uninterrupted physical availability at a price which is affordable, while respecting environment concerns." However, what exactly this means is the subject of much debate; Hughes (2012) undertook an effort to define, if not a standardised definition, a simplified, generic framework for describing energy security in different systems. That framework hews close to the work of the Asia Pacific Energy Research Centre [APERC] (2007), who defined a "secure" energy source is one that is reliably (i) affordable, (ii) available, (iii) accessible, and (iv) acceptable. These conditions are often referred to as the "Four As," though Hughes (2012) prefers to join the accessibility (simply, "can one obtain it?") and availability ("is the energy where it needs to be?") conditions into one overarching "availability" condition to create only "Three As." This thesis will use the Four As approach, as this separation is largely one of semantics, with the separation of availability and accessibility essentially being the distinction between having a resource present, and being able to utilise it. That is, an energy source is *available* to a given user base if it is present in their vicinity, or on the market; it is *accessible* only if there are few to no barriers obstructing that user base's ability to utilise the resource. Barriers that prevent accessibility can include political (national and international resource conflicts), geographical (resource location/remoteness), technological readiness, and economic (e.g. skilled labour availability, infrastructure) concerns (APERC, 2007).

In the context of tidal energy development and particularly in the context of small, community-based tidal energy, the premise of energy security is worth considering. Current estimates suggest that tidal devices remain very high cost; thus, tidal developers require subsidies to compete with existing electricity sources (MacDougall, 2015). In conventional grid arrangements, with large, centralised power plants, this would suggest tidal energy projects are presently unaffordable. However, there are markets (Hart & Christensen, 2002; Pepermans et al., 2005; Zeriffi, 2007; Weis & Ilanca, 2010; Singh & Ephraim, 2016) where electricity prices are very high ($0.40-1.00/kWh), such as the Canadian arctic and remote parts of the developing world. In these contexts, despite estimated prices in the range of $0.44-0.51/kWh (Province of Nova Scotia, 2012), tidal energy may prove an attractive alternative to existing, costly systems.

Obviously, tidal energy is only available in regions with sufficient tidal flows to contain enough power to turn a turbine at appreciable speed, thus generating power. However, there is some debate over what this threshold tidal velocity must be; for unrestricted turbines placed directly in the flow (like most of the current market-leading designs), evidence suggests flows must be at minimum 1.5 m/s to surpass the cut-in velocities of most existing turbine designs, and thus produce power (Hasham, El-Shafie & Karim, 2012; Blunden, Bahaj & Aziz, 2013). For other turbine designs (Hasham et al., 2012; Roberts et al., 2016), including Archimedes screws, tidal kites, and ducted turbines, lower velocity flows may prove viable. But, even with these devices, a minimum threshold for harvestable velocities is likely to exist; it simply has yet to be determined. Thus, a definitive limit for what qualifies as an “available” tidal resource cannot yet be stated; that said, currently available devices tend towards cut-in velocities of 1.5 m/s, so this can serve as a near-term guideline.

It must be noted, the lower the velocity of a flow, the nearer the end user must be to avoid exorbitant costs. This is simply a result of the economics of electricity transmission; the further you wish to transmit electricity, the more you must extend the grid, and the more you must pay to do so. Thus, the determinant of the accessibility of a tidal resource is its proximity to either its end-user or to grid infrastructure that can transmit electricity to other users. A resource located farther offshore is, by nature, less accessible; similarly, while parts of the Canadian Arctic have considerable tidal resources (Tarbatton & Larson, 2006), the remoteness of these tidal resources from any grid infrastructure and market makes them inaccessible. In contrast, a tidal estuary that has a city built around it is a highly accessible tidal resource—this is the logic behind the RITE project in New York City. Ultimately, the accessibility of a tidal resource is simply a function of its distance to users.

Finally, whether or not a tidal project proves acceptable to users is dependent upon several factors. Not the least of these factors is the relative affordability of energy produced by the project, compared to existing energy prices in the region it will serve (APERC, 2007). Socioeconomic factors, such as the number of jobs created (or negatively impacted) by the project (Delvaux et al., 2013; Wiersma & Devine-Wright, 2014; Dalton et al., 2015), also have influence in the acceptability of a project. The greatest unknown in the industry at present, tidal energy extraction's environmental impacts (Shields et al., 2011; Frid et al., 2012), is also likely to be a major concern for making projects acceptable as providers of energy to local people. Should acceptability not be achieved for the industry, it is unlikely that tidal energy projects will be implemented in any jurisdiction, regardless of their affordability, availability, or accessibility. Thus, though influenced by the other three factors, from the perspective of tidal energy developers, making their projects acceptable to local people must be a high priority. These concerns, and other energy security concerns, are addressed at greater length in the context of Chapter 4's discussion regarding social license for small tidal energy projects.

1.5 References:

Alberstat, J. (February 27, 2013). Tidal developer delays Bay of Fundy project. The Chronicle Herald, newspaper. Accessed January 17, 2016. Retrieved from: http://thechronicleherald.ca/business/800676-tidal-developer-delays-bay-of-fundy-project

Alexander, K.A., Wilding, T.A., & Heymans, J.J. (2013). Attitudes of Scottish fishers towards marine renewable energy. *Marine Policy, 37,* 239-244. doi: 10.106/j.marpol.2012.05.005

Allan, G., Eromenko, I., Gilmartin, M., Kockar, I., & McGregor, P. (2015). The economics of distributed energy generation: a literature review. Renewable and Sustainable Energy Reviews, 42, 543-556.

Alvial-Palavicino, C., Gamido-Echeverria, N., Jiménez-Estévez, G.. Reyes, L. and Palma-Behnke, R. (2011). A methodology for community engagement in the introduction of renewable-based smart microgrid. Energy for Sustainable Development 15, 314-323.

APERC. (2007). *A Quest for Energy Security in the 21st Century.* Asia Pacific Energy Research Centre. Accessed November 20, 2016. Retrieved from: http://aperc.ieej.or.jp/file/2010/9/26/APERC_2007_A_Quest_for_Energy_Security.pdf

Atlantis Resources Ltd. (April 29, 2015). Acquisition of Marine Current Turbines Limited from Siemens. Press release. Accessed January 12, 2016. Retrieved from: http://atlantisresourcesltd.com/media-centre/atlantis-annoucements/79-2015-annoucements/360-acquisition-of-marine-current-turbines-limited-from-siemens.html

Clean Current Inc. (May 29, 2015). Clean Current exits industry. Press release. Accessed January 17, 2016. Retrieved from: http://www.cleancurrent.com/news#news-item-link-1

Cummins, P. (2012). On the extractable power in a tidal channel. *Journal of Waterway, Port, Coastal and Ocean Engineering, 138*(1)*,* 63-71.

Dalton, G., Allan, G., Beaumont, N., Georgakaki, A., Hacking, N., Hooper, T., Kerr, S., O'Hagan, A.M., Reilly, K., Ricci, P., Sheng, W., & Stallard, T. (2015). Economic and socio-economic assessment methods for ocean renewable energy: Public and private perspectives. Renewable and Sustainable Energy Reviews, 45, 850-878. doi: 10.1016/j.rser.2015.01.068

de Groot, J., Campbell, M., Ashley, M., & Rodwell, L. (2014). Investigating the co-existence of fisheries and offshore renewable energy in the UK: Identification of a mitigation agenda for fishing effort displacement. *Ocean & Coastal Management, 102,* 7-18. doi: 10.1016/j.ocecoaman.2014.08.013

Delaney, G. (February 4, 2014). *Tidal power proposal for Scots Bay meets with skepticism.* The Chronicle Herald. Accessed January 30, 2016. Retrieved from: http://thechronicleherald.ca/novascotia/1184437-tidal-power-proposal-for-scots-bay-meets-with-skepticism

Delvaux, P.A.G., Rabuteau, Y. and Stanley, K. (2013). Civil society involvement and social acceptability of marine energy projects: Best practices of the marine energy sector. MERiFIC: France.

Denny, E. (2009). The economics of tidal energy. Energy Policy, 37, 1914-1924. doi: 10.1016/j.enpol.2009.01.009

Devine-Wright, P. (2005). Beyond NIMBYism: towards an integrated framework for understanding public perceptions of wind energy. Wind Energy, 8, 125-139.

Devine-Wright, P. (2011a). Enhancing local distinctiveness fosters public acceptance of tidal energy: A UK case study. Energy Policy, 39(1), 83-93. doi: 10.1016/j.enpol.2010.09.012

Devine-Wright, P. (2011b). Place attachment and public acceptance of renewable energy: a tidal energy case study. Journal of Environmental Psychology, 31, 336–43.

DFO. (2016). *Review of the environmental effects monitoring program for the Fundy Tidal Energy Project*. Fisheries and Oceans Canada. Accessed October 1, 2016. Retrieved from: http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ScR-RS/2016/2016_022-eng.pdf

Ellaban, O., Abu-Rub, H., & Blaabjerg, F. (2014). Renewable energy resources: Current status, future prospects and their enabling technology. Renewable and Sustainable Energy Reviews, 39, 748-764. doi: 10.1016/j.rser.2014.07.113

EMEC. (2016a). About us. Accessed February 12, 2016. Retrieved from: http://www.emec.org.uk/about-us/

EMEC. (2016b). Funders. Accessed February 12, 2016. Retrieved from: http://www.emec.org.uk/about-us/funders/

Federal Energy Regulatory Commission. (2012). Order issuing pilot project license (minor project). Project No. 12611-005. Accessed March 29, 2016. Retrieved from: http://www.theriteproject.com/uploads/01-23-12-order.pdf

Flynn, B. (2015). Ecological modernisation of a ‘Cinderella renewable’? The emerging politics of global ocean energy. Environmental Politics, 24(2), 249-269. doi: 10.1080/09644016.2014.1000638

Garrad, A. (2012). The lessons learned from the development of wind energy that might be applied to marine industry renewables. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 370*, 451-471. Doi: 10.1098/rsta.2011.0167

Garrett, C. & Cummins, P. (2005.) The power potential of tidal currents in channels. *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences, 461*, 2563-2572.

Gorman, M. (June 6, 2016). *Could this 'no-brainer' concept be the key to harnessing the power of the Bay of Fundy tides?* CBC News. Accessed October 30, 2016. Retrieved from: http://www.cbc.ca/news/canada/nova-scotia/big-moon-power-bay-of-fundy-tidal-kinetic-keel-nova-scotia-1.3615567

Hain, J.J., Ault, G.W., Galloway, S.J., Cruden, A., & McDonald, J.R. (2005). Additional renewable energy growth through small-scale community orientated energy policies. Energy Policy, 33, 1199-1212.

Hammons, T.J. (1993). Tidal power. *Proceeding of the IEEE, 8*(1), 419-433.

Hardisty, J. (2009). *The Analysis of Tidal Stream Power.* Chichester, West Sussex, UK: Wiley-Blackwell. 321 pp.

Hay, A.E., Zedel, L., Cheel, R., & Dillon, J. (2012). Observations of the vertical structure of turbulent oscillatory boundary layers above fixed roughness beds using a prototype wideband coherent Doppler profiler: 1. The oscillatory component of the flow. *Journal of Geophysical Research: Oceans, 117,* 1-20.

Huckerby, J. (2012). International collaboration in ocean energy. *OES Annex IV Webinar.* Ocean Energy Systems: An IEA Technology Initiative. Accessed July 30, 2016. Retrieved from: https://tethys.pnnl.gov/sites/default/files/2012-04-03-2-John-Huckerby.pdf

Hughes, L. (2012). A generic framework for the description and analysis of energy security in an energy system. *Energy Policy, 42,* 221-231. doi: 10.1016/j.enpol.2011.11.079

IEA. (2000). Experience curves for energy technology policy. Accessed January 2, 2016. Retrieved from: http://reaccess.epu.ntua.gr/LinkClick.aspx?fileticket=Driek6XFOMs%3D&tabid=582&mid=10 6.

IEA. (2010). *Energy Security*. International Energy Agency. Accessed December 4, 2016. International Energy Agency. Retrieved from: http://www.iea.org/subjectqueries/keyresult.asp?KEYWORD_ID=4103.

Karsten, R.H., McMillan, J.M., Lickley, M.J. & Haynes, R.D. (2008). Assessment of tidal current energy in the Minas Passage, Bay of Fundy. Proceedings of the Institute of Mechanical Engineers, Part A: Journal of Power and Energy, 222, 493-507.

Kerr, S., Watts, L., Colton, J., Conway, F., Hull, A., Johnson, K., Jude, S., Kannen, A., MacDougall, S., McLachlan, C., Potts, T., & Vergunst, J. (2014). Establishing an agenda for social studies research in marine renewable energy. *Energy Policy, 67*, 694-702.

Kregting, L. & Elsaesser, B. (2014). A hydrodynamic modeling framework for the Strangford Lough Part 1: Tidal model. Journal of Marine Science and Engineering, 2(1), 46-65. doi: 10.3390/jmse2010046

Lewis, M.J.T. (1997) *Millstone and Hammer: the origins of water power*. University of Hull Press, Hull, UK, 180 pp.

MacDougall, S.L. (2015). The value of delay in tidal energy development. *Energy Policy, 87,* 438-446. doi: 10.1016/j.enpol.2015.09.034

MacGillivray, A., Jeffrey, H., Winskel, M., & Bryden, I. (2014). Innovation and cost reduction for marine renewable energy: A learning investment sensitivity analysis. *Technological Forecasting & Social Change, 87,* 108-124.

MacGillivray, A., Jeffrey, H., & Wallace, R. (2015). The importance of iteration and deployment in technology development: A study of the impact on wave and tidal stream energy research, development and innovation. *Energy Policy*, *87*, 542–552. doi: 10.1016/j.enpol.2015.10.002

Mann, K.H. 1982. The Ecology of Coastal Waters: a Systems Approach. University of California Press, 322pp.

McDonald, A., & Schrattenholzer, L. (2001). Learning rates for energy technologies. *Energy Policy, 29*(4), 255-261. doi: 10.1016/S0301-4215(00)00122-1

McMillan, E. (July 27, 2016). “Bay of Fundy inshore fishermen want court to overturn tidal turbine approval.” CBC News. Accessed October 1, 2016. Retrieved from: http://www.cbc.ca/news/canada/nova-scotia/bay-of-fundy-inshore-fishermen-wants-judicial-review-1.3697080

Meygen. (2016). About Phase 1a. Retrieved from: http://www.meygen.com/about-phase-1a/

Morris, R.K.A. (2013). Geomorphological analogues for large estuarine engineering projects: A case study of barrages, causeways and tidal energy projects. *Ocean & Coastal Management, 79*, 52-61. doi: 10.1016/j.ocecoaman.2012.05.010

NSDOE. (2010). Renewable electricity plan. Accessed January 8, 2016. Government of Nova Scotia, Halifax, Nova Scotia, Canada. Retrieved from: http://energy.novascotia.ca/sites/default/files/renewable-electricity-plan.pdf

NSDOE. (2015a). Our electricity future: Nova Scotia's electricity plan 2015-2040. Government of Nova Scotia, Halifax, Nova Scotia, Canada. Accessed January 8, 2016. Retrieved from: http://energy.novascotia.ca/sites/default/files/files/FINAL%20Our%20Electricity%20Future%281%29.pdf

NSDOE. (2016). *COMFIT Projects Status List.* Accessed December 1, 2016. Retrieved from: http://energy.novascotia.ca/sites/default/files/files/Copy%20of%20DRAFT%20Comfit%20Status%20as%20of%20October%206%2C%202016.pdf

NSDOE. (n.d.) *Developmental tidal feed-in tariff program.* Province of Nova Scotia. Accessed December 3, 2016. Retrieved from: http://energy.novascotia.ca/renewables/programs-and-projects/tidal-fit

OpenHydro. (January 20, 2016). The first of two OpenHydro tidal turbines on EDF's Paimpol-Brehat site successfully deployed. Press release. Accessed February 27, 2016. Retrieved from: http://www.openhydro.com/news/OpenHydroPR-2016-01-20.pdf

Pepermans, G., Driesen, J., Haesedonckx, D., Belmans, R., & D'haeseleer,W. (2005). Distributed generation: definition, benefits and issues. Energy Policy, 33, 787-798.

Pond, S., Pickard, G.L.. (1983). Introductory Dynamical Oceanography. Butterworth-Heinemann Ltd. 331pp.

Province of Nova Scotia. (2012). Marine Renewable Energy Strategy. Accessed January 20, 2016. Retrieved from: http://energy.novascotia.ca/sites/default/files/Nova-Scotia-Marine-Renewable-Energy-Strategy-May-2012.pdf

Rhodes, B. (October 25, 2016). Tidal turbines can be put in Bay of Fundy, at least for now. CBC News. Accessed December 1, 2016. Retrieved from: http://www.cbc.ca/news/canada/nova-scotia/minas-passage-tidal-turbines-injunction-ruling-1.3820564

Roberts, A., Thomas, B., Sewell, P., Khan, Z., Balmain, S., & Gillman, J. (2016). Current tidal power technologies and their suitability for applications in coastal and marine areas. Journal of Ocean Engineering and Marine Energy, 2, 227-245. doi: 10.1007/s40722-016-0044-8

Roberts, T. (June 24, 2016). *It's official: Muskrat Falls a boondoggle, says Stan Marshall.* CBC News. Accessed September 13, 2016. Retrieved from: http://www.cbc.ca/news/canada/newfoundland-labrador/stan-marshall-muskrat-falls-update-1.3649540

Statistics Canada. (2011a). *Household size, by province and territory (2011 Census) (New Brunswick, Quebec, Ontario).* Census of Population and Statistics Canada catalogue no. 98-313-XCB. Accessed December 4, 2016. Retrieved from: http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/famil53b-eng.htm

Statistics Canada. (2011b). *Household size, by province and territory (2011 Census) (Newfoundland and Labrador, Prince Edward Island, Nova Scotia)*. Census of Population and Statistics Canada catalogue no. 98-313-XCB. Accessed December 4, 2016. Retrieved from: http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/famil53a-eng.htm

Statistics Canada. (2016). *Table 153-0161 - Household energy consumption, Canada and provinces, every 2 years.* CANSIM (database). Accessed December 4, 2016. Retrieved from: http://www5.statcan.gc.ca/cansim/a26?lang=eng&retrLang=eng&id=1530161&tabMode=dataTable&srchLan=-1&p1=-1&p2=9

Tarbatton, M. & Larson, M. (2006). *Canada Ocean Energy Atlas (Phase 1): Potential Tidal Current Energy Resources Analysis Background.* Canada Hydraulic Centre, Natural Resources Canada. Accessed November 26, 2014. Retrieved from: http://www.marinerenewables.ca/wp-content/uploads/2012/11/Canada-Ocean-Energy-Atlas-Phase-1-Potential-Tidal-Current-Energy-Resources-Analysis-Background.pdf

Tethys. (n.d.) *About Tethys.* Pacific Northwest National Laboratory. Accessed October 8, 2016. Retrieved from: https://tethys.pnnl.gov/about-tethys

Trowbridge, J.H., Geyer, W.R., Bowen, M.M., & Williams, A.J. (1999). Near-bottom turbulence measurements in a partially mixed estuary: turbulent energy balance, velocity structure, and along-channel momentum balance. *Journal of Physical Oceanography, 29*(12), 3056-3072.

UNEP. (n.d.) Cities and Coastal Areas. United Nations Environment Programme. Accessed November 9, 2015. Retrieved from: http://www.unep.org/urban_environment/issues/coastal_zones.asp

Vazquez, A. & Iglesias, G. (2015). Device interactions in reducing the cost of tidal stream energy. *Energy Conversion and Management, 97,* 428-438.

Voulgaris, G. & Trowbridge, J.H. (1998). Evaluation of acoustic Doppler velocimeter (ADV) for turbulence measurements. *Journal of Atmospheric and Oceanic Technology, 15*(1), 272-289.

Weis, T.M., & Ilinca, A. (2010). Assessing the potential for a wind power incentive for remote villages in Canada. Energy Policy, 38, 5504-5511.

Wiersma, B. and Devine-Wright, P. (2014). Public engagement with offshore renewable energy: a critical review. *Wiley Interdisciplinary Reviews: Climate Change 5,* 493-507. doi: 10.1002/wcc.282

Withers, P. (October 20, 2016a). *Bay of Fundy tidal turbines case opens in Halifax court.* CBC News. Accessed December 1, 2016. Retrieved from: http://www.cbc.ca/news/canada/nova-scotia/bay-of-fundy-tidal-turbines-legal-court-challenge-halifax-1.3813853

Withers, P. (November 22, 2016b). *Massive tidal turbine in Bay of Fundy generating electricity for 1st time.* CBC News. Accessed December 1, 2016. Retrieved from: http://www.cbc.ca/news/canada/nova-scotia/tidal-power-bay-of-fundy-turbine-electricity-emera-hydro-1.3862227

Wright, G. (2014). Strengthening the role of science in marine governance through environmental impact assessment: a case study of the marine renewable energy industry. Ocean & Coastal Management, 99, 23-30. doi: 10.1016/j.ocecoaman.2014.07.004

Wright, G. (2015). Marine governance in an industrialised ocean: A case study of the emerging marine renewable energy industry. Marine Policy, 52, 77-84. doi: 10.1016/j.marpol.2014.10.021

Zeriffi, H. (2007). Making small work: Business models for electrifying the world. Working paper #63, Program on Energy & Sustainable Development, Freeman Spogli Institute for International Studies, Stanford University, California. Accessed Nov 10, 2015. Retrieved from: http://fsi.stanford.edu/publications/small

Chapter 2: Identifying priorities for small-scale tidal energy research and implementation, with insight from Nova Scotia's tidal energy development efforts.

2.1 Introduction:

In the past decade, interest in the development of in-stream tidal energy has increased. A form of marine renewable energy [MRE], which also includes energy harvested from the ocean's waves, tides, and thermal gradients, in-stream tidal energy development efforts have thus far seen deployments in Canada, the United States, the United Kingdom, France, Norway, Belgium, and others (Flynn, 2015). Although some authors also include offshore wind energy in their definitions of MRE (Davies, Watret & Gubbins, 2014; Wiersma & Devine-Wright, 2014; Dalton et al., 2015), we exclude offshore wind from our definition because it relies on proven technologies and known engineering, while other MRE technologies remain largely emergent. The focus of this chapter is further narrowed to in-stream tidal energy extraction, cited by some as the "closest-to-market" of the MRE technologies (Denny, 2009; Rourke, Boyle & Reynolds, 2010; MacGillivray, Jeffrey & Wallace, 2015; Vasquez & Iglesias, 2015). Many of the arguments of this work may prove applicable to other MRE technologies (particularly wave energy), but that is an effort left for others to consider.

MRE research has received considerable funding from governments in the European Union, Canada, and the United States, with more recent studies arising in China and elsewhere. The United Kingdom leads much of Europe's research efforts, with the world-leading European Marine Energy Centre [EMEC] in Orkney (Scotland) serving as the central hub for much of that continent's research and device testing (EMEC, 2016a). However, the future of such EU-UK cooperation is unknown due to the June, 2016 "Brexit" vote, in which British citizens voted to leave the European Union. Many scientists have suggested that EU-funded research projects in the UK will be put at risk of losing their funding as a result of Brexit (Sample, 2016; Bradshaw, 2016; Dickman, 2016); as EMEC is largely EU-funded (European Commission, 2015; EMEC, 2016b) the centre of European MRE research may relocate, at some point in the near future. In Canada, the locus of MRE activity to-date has been the small Atlantic province of Nova Scotia (NS), at the Fundy Ocean Research Center for Energy [FORCE] along the Bay of Fundy's Minas Passage. To-date, the vast majority of Canada's tidal research has focused on devices designed for high-energy environments, and utility-scale generation capacities (i.e. devices with rated capacities ≥1 MW). However, recent studies have called into question whether this focus on utility-scale is likely to lead to continued successful deployments and industry growth.

For example, MacDougall (2015) considered the tidal energy deployment incentive programs of Nova Scotia using real options analysis. Using the case of the tidal energy development leases at the FORCE test site, MacDougall (2015) argued that from a financial investment perspective, the uncertainty and risks currently dominating the tidal sector make the cost of first-entry in the market significantly higher than the opportunity cost of delaying development. In other words, at the present level of industry development, utility-scale tidal deployment remains very (financially) risky for firms to pursue. Consequently, in the existing policy and investment climate of Nova Scotia, MacDougall (2015) suggests the most financially sound decision for tidal energy developers is to own the option to develop, but to delay development until uncertainty and risk in the industry are reduced. While it is difficult to say whether this is true in other jurisdictions, especially those with higher electricity prices or stronger decarbonisation policies than Nova Scotia, this financial argument may help to explain the slow pace of tidal (and perhaps MRE generally) development worldwide. With several major pilot projects around the world scheduled to come online in 2016 (CBC News, 2015; Atlantis Resources Ltd., 2016), such studies make clear the importance of assessing the direction of policy and research designed to support or advance tidal energy.

To this end, a review has been conducted to analyse the present direction of the tidal energy sector in Nova Scotia, and discuss what lessons it offers for policymakers in other jurisdictions. First, the policy environment and incentive programs offered for tidal energy development in Nova Scotia are discussed, along with the program outcomes to-date. This discussion informs the next question we address: why look to small-scale tidal energy projects? Here, the question of whether a significant resource exists that utility-scale devices would be inappropriate for is addressed; the market potential for small-scale devices is also considered. In the next section, we consider subsections of this market, and discuss relevant considerations and motivations for targeting these areas for small-scale tidal energy development. These discussions inform the conclusions and recommendations that round out this chapter.

2.1.1 A Brief History of Tidal Energy

Humans have harnessed the energy of the ocean to do work for millennia, with records of tidal mills dating to at least the Ancient Greeks (Lewis, 1997; Oleson, 2000). Interest in developing tidal power plants arose early in the history of electricity, though the earliest modern MRE facilities were built only about 50 years ago. These facilities were all tidal barrages, created by barricading the mouth of a bay or tidal estuary to impound the tide as it flowed in, then releasing it back into the sea through turbines, similar to a traditional hydroelectric dam (Flynn, 2015). However, barrages remain controversial due to their potentially substantial effects on local environments, which can include sedimentation, beach erosion, water quality impacts, foreshore lengthening or shortening, disruption of fish migration patterns, and other undesirable effects (Hooper & Austen, 2013; Morris, 2013). As such, while some tidal barrage projects continue to be proposed, most have been slow to gain public acceptance and regulatory approval (Flynn, 2015).

In the face of opposition to tidal barrages, the attention of developers, researchers, and governments interested in tidal power has increasingly turned towards in-stream devices. Unlike barrages, in-stream tidal energy generators do not require any impoundment walls to be placed into the marine environment. Instead, these devices are placed such that they capture the tidal stream directly, with moorings either fixing them to the seabed or floating them from the surface (Frid et al., 2012; Sanchez, Carballo, Ramos & Iglesias, 2014). Testing of in-stream devices requires intensive, ongoing research, with many questions yet to be answered. Research to date, however, suggests that the environmental impacts of in-stream tidal generators are less severe than those of tidal barrages (Boehlert & Gill, 2010; Shields et al., 2011; Frid et al., 2012; Broadhurst, Barr & Orme, 2014; Flynn, 2015). Work on developing in-stream devices has made up the bulk of activity in the tidal energy sector in the past ten to fifteen years, and it is these efforts that this analysis seeks to assess.

2.1.2 A Note on Terminology

Throughout this chapter, reference will be made to both "small-scale" and "utility-scale" renewable energy devices. The former is defined here, for convenience, relative to the latter. Many tidal device developers have focused their efforts on designing devices with rated capacities similar to those of on-shore wind turbines, with most tidal device capacities falling between 0.5 and 2 MW (MacGillivray, Jeffrey & Wallace, 2015; Roberts et al., 2016). Thus, in our work, "utility-scale" devices shall be taken to refer to tidal turbines in this range. Such a definition would also include designs meant to be deployed in matched pairs, such as the 1.2 MW dual-turbine SeaGen manufactured by Marine Current Turbines, which utilises two 600 kW rotors mounted on a central crossbeam and common support structure. "Small-scale" renewable energy devices are those smaller than this, ranging from a few kW up to about 150 kW. Though somewhat loose, this definition (devices ≤150 kW in rated capacity) will be used to delineate small-scale devices designed for deployment singly or in small arrays from those designed for larger, utility-scale array deployment.

With this distinction made, another definition is required: an upper capacity limit on a "small-scale tidal array." This second definition is required because it would not be difficult for a developer to design a "small-scale" turbine that could be flexibly deployed in singlets, arrays of just a few devices, or in sufficient numbers to challenge the MW-scale devices other developers seem to favour. In fact, this tidal device design strategy is already evident in the work of some companies; Schottel's (Schottel, n.d.) 54 to 72 kW turbines, designed for both their 1.5 MW Triton platform (Blackrock Tidal Power, n.d.) and for use in smaller arrays like the two-turbine, 100 kW PLAT-O design (Sustainable Marine, 2016), serve as an example. Consequently, we must separate the "utility-scale" from the "small-scale" arrays before proceeding.

As this study is embedded in the context of Nova Scotia's energy policy, we will delineate these array sizes based upon provincial definitions. The Nova Scotia Department of Energy [NSDOE] (2015b) has set 500 kW as the lower limit for single-platform capacity eligible for its Developmental Tidal Feed-in Tariff Program [Developmental FIT], which is designed to target utility-scale demonstration projects. Thus, 500 kW will be taken as the upper limit for small-scale tidal arrays, as a convenient (though not necessarily firm) dividing line in provincial policy between "small" and "large" scale projects. This capacity range is also in line with general definitions used in the literature for the device capacities used for distributed energy systems (Weis & Ilinca, 2010; Allan, Eromenko, Gilmartin, Kockar & McGregor, 2015), which will be discussed below. Such off-grid or distributed markets may prove to be competitive ones for tidal and marine energy systems prior to utility-scale competitiveness being achieved.

2.2 The Nova Scotian context

Nova Scotia is a small, maritime province located on Canada's southeastern edge. With a population of approximately 940,000 people (Statistics Canada, 2016a), it is Canada's fourth-smallest province. Approximately one-third of the province's population lives in its capital and largest city, Halifax, located on the central Atlantic coast. Despite the dominance of urbanisation in other parts of Canada, the province remains heavily rural, with 43% of the population residing outside of urban areas (Statistics Canada, 2016b). A considerable portion of this rural population lives along the southern shore of the Bay of Fundy, in the province's best agricultural land. It is this region of the province that has proven to be of considerable interest to the tidal energy sector.

2.2.1 Nova Scotia as a Case Study of the Tidal Energy Industry

Nova Scotia has long been considered an ideal location for tidal energy development. This interest has been driven by its proximity to the Bay of Fundy, which possess the highest tides in the world (Taber, 2014). Initial proposals for tidal barrages in the bay arose both in and outside the province in the 1960s (Hammons, 1993), though none were successful until the 20 MW tidal barrage completed in 1984 at Annapolis Royal. As in Britain and other jurisdictions, new barrage proposals in more recent times have been unsuccessful (Delaney, 2014; Flynn, 2015). The province's naturally abundant resource, combined with public opposition to new barrages and the commitment of successive provincial governments to aggressive renewable energy deployment goals (detailed in section 2.2), has led the province to pursue in-stream tidal energy development.

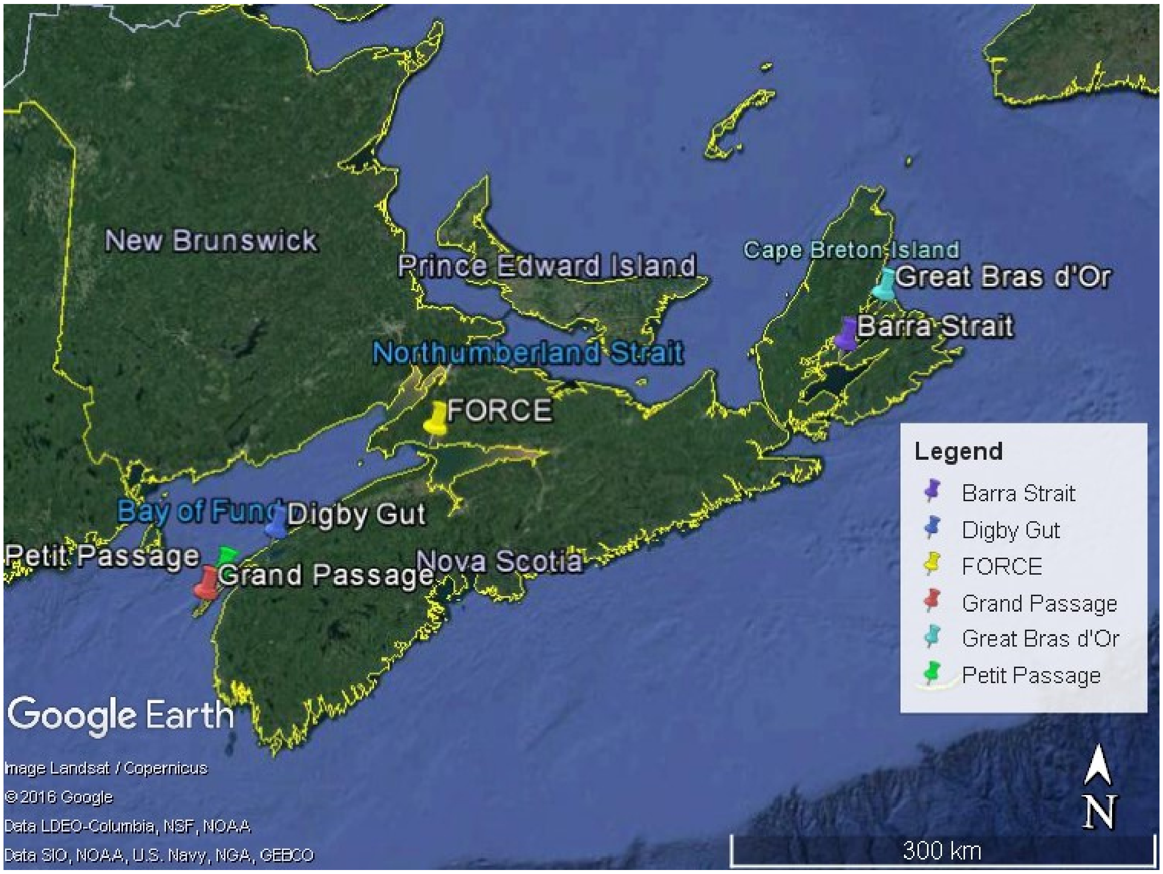

Figure 3: Location of the proposed and actual tidal energy sites within Nova Scotia (from Google Earth, 2016)

The locus of in-stream tidal energy in Nova Scotia is FORCE: the Fundy Ocean Research Centre for Energy. Located in Parrsboro, on the northern shore of the Minas Passage (see Figure 3), FORCE is a tidal energy demonstration site developed in partnership between a number of world-leading tidal energy firms, the Nova Scotian government, and the privately-held provincial utility Nova Scotia Power Inc. [NSPI], funded in part by each of the partners and by a variety of federal government agencies. Each tidal firm active at FORCE is a leaseholder for one of the five grid-connected "berths" located offshore. The current leaseholding firms are: Cape Sharp Tidal (a joint venture of Nova Scotia Power Inc. and the French-owned OpenHydro), Black Rock Tidal Power (a branch of the German Schottel Hydro), the Minas Tidal Limited Partnership (owned 50% by Canadian firm International Marine Energy and 50% by Tocardo Tidal Power, a Dutch company), and Atlantis Operations Canada Limited (a partnership between the British Atlantis Resources Inc. and the Irish DP Energy) (FORCE, n.d.). The fifth berth at FORCE does not yet have a leaseholder.

FORCE is significant in the context of the global tidal energy industry because the Bay of Fundy is viewed as one of the greatest tidal resources available on Earth (Hammons, 1993; Rourke, Boyle & Reynolds, 2010). While each of the current berth holders has been licensed for projects ranging from 4 to 5 MW, Karsten et al. (2008) estimated that 2500 MW of power could be extracted from the Minas Passage alone without significant adverse effects on the environment within the passage or the larger Bay of Fundy it connects to. While much of the tidal industry's testing and development work is based in Europe, especially around EMEC in Scotland, several European academics have cited the Bay of Fundy as being a major site of interest for tidal power development (Rourke et al., 2010; Wright, 2014). This interest is evidenced by the dominant presence of European tidal energy firms in licensing the demonstration berths at FORCE—not one of the berth-holding partnerships lacks a European partner. In fact, it is the Europeans partners bringing the turbine technology to the field. Yet despite this interest, opposition from some elements of the public, particularly fishermen, continues to cause delays (McMillan, 2016).

Fishermen's concerns, and the general public's, where expressed, in Nova Scotia have been focused on environmental harms that tidal energy projects may pose. The Bay of Fundy Inshore Fishermen's Association spokesperson, Colin Sproul, told CBC News that the association believed that "if [the device's] effects are underestimated or not observed at all… the environmental effects will be dramatic" (McMillan, 2016). This concern is in line with public concerns noted in studies elsewhere in the world, including the UK (de Groot et al., 2014). The unknown nature of the possible environmental impacts of tidal development is also a common theme of the literature (Shields et al., 2011; Kerr et al., 2014; Wiersma & Devine-Wright, 2014). Thus, understanding Nova Scotia's tidal energy policies, public concerns, and experiences may offer insight for other jurisdictions pursuing tidal energy development.

2.2.2 Renewable Energy Policy in Nova Scotia, 2009-Present

In the fall of 2009 (Adams, Wheeler & Woolston, 2011), the province of Nova Scotia undertook a comprehensive stakeholder consultation process to develop a renewable energy policy direction that was considered acceptable by a clear majority of energy industry stakeholders. Based upon input from environmentalists, the provincial Department of Energy, the privately-held provincial utility Nova Scotia Power Inc., present and aspirational Independent Power Producers (IPPs), and others, this process was facilitated by a group of academics at Dalhousie University's Faculty of Management (Adams et al., 2011). The result of these consultations (Adams & Wheeler, 2009) was the province's Renewable Energy Strategy [RES], released in 2010. This document introduced the Nova Scotian government's targets for renewable energy deployment; specifically, to generate 25% of the province's electricity from renewable sources by 2015, and 40% by 2020. Importantly, the RES also called for extensive development of tidal energy in the province, with focus on both small and utility scale deployments (Adams & Wheeler, 2009). At the time of the RES's announcement, Nova Scotia generated more than 80% of its electricity from coal, and less than 10% from renewables (Adams et al., 2011); as of 2014, renewable energy accounted for more than 24% of the province's energy, while coal (through new natural gas plant construction) had fallen further to 60% (NSDOE, 2015a).

To support the RES's call for tidal energy development, Nova Scotia undertook a series of Strategic Environmental Assessments (SEAs). Conducted either by the government's Offshore Energy Research Association (OERA) or environmental services companies with academic support from the province's universities, these SEAs were designed to determine potential sites of interest for tidal energy development, public opinions and concerns regarding tidal energy, and the species of interest that may be put at risk by projects. To-date, SEAs have been completed for the Bay of Fundy region (OERA, 2008; AECOM Canada Ltd., 2014), Cape Breton Island (AECOM Canada Ltd., 2012), and South and Southwestern Nova Scotia (Hay et al., 2013). The Bay of Fundy SEA identified eight sites of interest for utility-scale development; the most promising of these was the Minas Basin, which led to the establishment of FORCE to take advantage of that opportunity. Smaller-scale sites of interest identified in the Bay of Fundy include the Minas Channel, the Digby Gut, Petit Passage, and Grand Passage (OERA, 2008), though all sites considered had harvestable capacity in excess of 4 MW.

In Cape Breton and Southwestern Nova Scotia, no large-scale development opportunities were found. However, small-scale tidal sites were identified in each region. For Cape Breton, an estimated 8 MW of tidal power could be installed island-wide, with the most promising site being the Great Bras d'Or Channel with 3 MW of potential at its estuary (AECOM Canada Ltd., 2012). In Southwestern Nova Scotia, potential sites were few, but some were still suggested to be places of interest for small-scale development; Indian Sluice, near the town of Argyle, was highlighted by the report as the most promising of these sites (Hay et al., 2013). Both the Cape Breton Island and Southwest Nova Scotia SEAs recommended small-scale tidal development be pursued in these locations in order to contribute to the broader provincial tidal energy industry, and to the province's renewable energy commitments (AECOM Canada Ltd., 2012; Hay et al., 2013).

Recently, Nova Scotia has updated its renewable energy policy. In the fall of 2015, the province announced an updated renewable energy plan, *Our Electricity Future: 2015-2040* (NSDOE, 2015a). The result of Department of Energy-led consultation sessions, this plan called for deployment of 18-22 MW of tidal energy devices at FORCE by the "early-mid 2020s" (NSDOE, 2015a); in essence, a commitment to execute the current FORCE contracts. While the report goes on to suggest a target of 300 MW of tidal energy deployments "within the next decade," (i.e. by 2025) such scaling up seems unlikely to be realistic from 18-22 MW by 2020-2022. The document also introduces several policy mechanisms—enhanced net metering, Renewable to Retail, and as-yet undelivered promises for "competitive pilot projects,"—that are detailed below. However, the promise for competitive, small-scale pilot program supports has not been detailed (NSDOE, 2015a), with no indication as to how such programs will function.

2.2.3 Policy Support Mechanisms for Tidal Energy in Nova Scotia

To meet the RES' targets, the provincial government announced a host of policy mechanisms. In the RES itself, the most prominent of these mechanisms were the Developmental Tidal Feed-in Tariff and the Community Feed-in Tariff [COMFIT]. These two programs were designed with the same intent as feed-in tariffs [FITs] elsewhere in the world: to provide a fixed, predictable price for electricity from emerging renewable energy technologies and enable their entry into a market dominated by fossil fuels. More recently, the province introduced an Enhanced Net Metering program, through which individuals and companies can install small-scale renewable energy devices to meet their own electricity consumption needs, and sell their excess to the grid. Finally, the provincial Utility and Review Board [UARB] approved Nova Scotia Power Inc.'s "Renewable to Retail" program in June, 2016, under which NSPI agreed to pay independent renewable energy producers specified rates in exchange for providing grid access and grid stability management services, among other things.

2.2.3.1 COMFIT & Tidal Energy

The COMFIT program functioned from 2011 to 2015. Through it, the Nova Scotian government offered a renewable electricity generation incentive program that was intended to encourage firms to pioneer development in community-owned renewable energy system – including small-scale tidal energy. Under COMFIT, the province guaranteed eligible renewable electricity producers a set price (determined by electricity source: wind, hydro, tidal, or biomass) for electricity provided to the local distribution grid, with the price determined by the type of energy harnessed. Eligibility was limited to specific community related groups, including cooperatives, not-for-profits, First Nations, universities, Community Economic Development Investment Funds (CEDIFs), and municipalities (Province of NS, n.d.). These limitations on ownership existed because the COMFIT program was designed to meet two goals: increasing renewable energy supply, while encouraging economic diversification in the province's communities (Province of NS, 2012). In the case of tidal devices, the COMFIT price was set at $0.652/kWh (Province of NS, n.d.) – the highest of any rate offered under the program. Originally, the COMFIT program allowed any size of renewable energy project, so long as it was community-owned. The bulk of projects implemented under the program were wind projects of capacities between 2 and 10 MW. In 2014, the provincial government set a project size cap of 500 kW on COMFIT projects; shortly thereafter, new applications to the COMFIT program were put on indefinite hold while the program was under review. Since then the program has been discontinued, but not before well over 200MW of capacity was approved for installation by various community enterprises across the province (NSDOE, 2016).

Although the COMFIT program generated some interest in small tidal projects, only one company, Fundy Tidal Inc, pursued tidal energy licenses under COMFIT. Fundy Tidal was granted licenses for development of five small-scale tidal projects, with three located in the Bay of Fundy, and two located in Cape Breton Island's Bras d'Or Lake Biosphere Reserve. The projects in the Bay of Fundy are clustered around the southern end of the province, specifically Petite Passage, Grand Passage, and the Digby Gut. Fundy Tidal's Cape Breton projects were located in the Great Bras d'Or Channel and the Barra Strait. However, the company's COMFIT licenses in Cape Breton expired due to a failure to pursue development by April, 2015. Shortly thereafter, Nova Scotia's government ended the COMFIT program. Although Fundy Tidal maintains grandfathered COMFIT licenses for its projects in Grand Passage, Petite Passage, and the Digby Gut, none of these projects has yet deployed any tidal energy devices. In fact, Fundy Tidal Inc. never announced selection of any technology partner for their COMFIT licenses; they were effectively an energy development company without any means of generating electricity. This lack of a specific technology partner is likely the primary factor in the lack of progress in developing the company's COMFIT licenses.

As mentioned, by the time of its cancellation, the COMFIT program had resulted in more than 200 MW of installed renewable energy capacity in Nova Scotia. Approximately 85% of this capacity was in wind projects (NSDOE, 2016). The government cited the inflationary effects that further COMFIT projects would have on provincial electricity rates if the incentives were continued at their previously-established levels, and thus canceled the entire program. However, no tidal energy COMFIT projects have reached completion; thus, tidal COMFITs have yet to impact electricity prices. Yet the province still removed the support that COMFIT represented for small-scale tidal energy, while maintaining the FIT for utility-scale tidal development. This suggests a significant change of policy from Nova Scotia's original Marine Renewable Energy Strategy (Province of NS, 2012), which specifically highlighted the opportunity represented by small, community-scale tidal energy projects. A federally-funded industrial-academic workshop organised by the Natural Science and Engineering Research Council (Hatcher, 2015) also called for further research and support for small-scale tidal energy in Nova Scotia, as well as internationally. In light of past commitments and research calls, it is curious that the tidal COMFIT was cancelled with the rest of the COMFIT renewables incentives. However, it is not the purpose of this study to address or question the motives behind provincial policy changes; here, they are simply noted.

2.2.3.2 The Developmental Tidal FIT

Nova Scotia's Developmental Tidal Feed-in Tariff is designed to support large, utility-scale demonstration projects in the province. Under Developmental Tidal FIT, developers are offered a per-kWh rate of either \$0.42/kWh or \$0.53/kWh, depending upon the total power delivered to the grid per year. The lower value is paid to projects delivering >16,640 MWh per year; the higher value is paid to those delivering less (NSDOE, 2015b). As of 2016, the only tidal energy projects to have been guaranteed the Developmental Tidal FIT rates are those who are partners in the FORCE project in the Bay of Fundy. Cape Sharp Tidal became the first in-stream tidal energy installation to deliver electricity to Nova Scotia's grid on Nov 22, 2016 (Withers, 2016)—with an installed capacity of 2MW. Other FORCE partners are expected to install their first turbines in 2017.

2.2.3.3 The Enhanced Net Metering Program & Tidal Energy

Shortly after the province ended COMFIT, Nova Scotia included tidal energy under the list of eligible technologies for its new Enhanced Net Metering (ENM) program, announced in November, 2015. However, the incentive offered—market payer rates of \$0.148/kWh (Nova Scotia Power Inc. [NSPI], 2015)—is significantly lower (77%) than that available under COMFIT. In addition, the ENM program limits the maximum capacity of devices installed, by customer type. Residential customers may install only devices with combined rated power capacities under 100 kW, and commercial or industrial customers may install only devices with cumulative capacities between 100 and 1000 kW (NSPI, 2015). While these capacities are well within the definition used for "small tidal," the hard limit on iterative growth of licenses beyond initial turbine installations is counter-intuitive for broader industry growth in the province. The program also fails to allow for collaborative or cooperative ownership, as the COMFIT program did. Consequently, the costs of devices installed under the ENM program must be borne by singular, private individuals or companies, rather than by a community group or partnership, which is likely to limit uptake. Given that tidal energy remains an emergent sector, and utility-scale devices have been called financially risky at the rates offered by the Developmental Tidal FIT (MacDougall, 2015), it is unlikely that the ENM rates are sufficient to encourage small-scale tidal energy deployment.

2.2.3.4 Renewable to Retail & Tidal Energy

On March 23rd, 2016, the public regulator for the electricity sector in Nova Scotia (the Utility and Review Board [UARB]) approved Nova Scotia Power Inc.'s proposal for the "Renewable to Retail" (RtR) program (UARB, 2016). The RtR program allows interested renewable energy developers to obtain a license to become licensed renewable suppliers (LRS), and thus to sell electricity from their projects directly to retail electricity consumers in Nova Scotia. Tidal energy projects are among the eligible technologies for interested RtR developers, along with wind, solar, and other renewables. Due to a near-total monopoly on distribution and transmission infrastructure held by NSPI, most RtR LRS applicants must utilise NSPI's grid infrastructure; a number of tariffs are levied by NSPI on LRS-run renewables projects. These tariffs include charges for distribution, generation costs for NSPI to provide for LRS customers when LRS projects are offline due to intermittency, and grid stability management equipment. The grid-related costs to developers of being a LRS under RtR are thus clear. However, no production incentive is offered under the RtR program; LRS may only charge market rates for their electricity. Presently, fixed-rate home use charges in Nova Scotia peak at $0.145/kWh. Given the high costs currently associated with tidal energy projects (Roberts et al., 2016), it is unlikely that any tidal energy projects will be pursued under the RtR program at these electricity rates.

2.2.3.5 The Marine Renewable-energy Act

In November, 2015, the Nova Scotia Legislature introduced its *Marine Renewable-energy [sic] Act* (2015) (henceforth, "the Act" or "MRE Act"). This Act declared the creation of "areas of marine renewable-energy priority," and clarified the regulatory process for developers interested in pursuing tidal energy development licenses in the province. This clarification involved specifying the definitions of a variety of terms (from "marine renewable energy" or "generator" to "permit" and "license") (MRE Act, 2015, s. 3(1)) which are relevant to the governance of tidal energy; however, of greater relevance here is the province's "areas of marine renewable energy priority" and "marine renewable electricity areas."

The first of these, "areas of marine renewable energy priority," are legally defined (in MRE Act, 2015, s. 10-12), bounded areas in which the province has decided to allow interested developers to apply for (and obtain) licenses to deploy tidal energy generators. These generators can be intended either as demonstration projects, or as test deployments to inform iterative design improvements; a license is still required to undertake a field deployment in Nova Scotia. The Act declared the Bras d'Or Lakes and the Bay of Fundy to be areas of marine renewable energy priority (MRE Act, 2015, s. 10). The Act does include specific rules for the establishment of future areas of MRE priority, but no other areas of MRE priority have been designated as of late 2016.

Marine renewable electricity areas are specific, bounded, licensed areas in which marine renewable energy projects have been granted licenses for development. The only marine renewable electricity area named in the Act is the FORCE site (MRE Act, 2015, s. 13), which is licensed only for in-stream tidal energy development; other forms of MRE are not permitted to be deployed at FORCE. Marine renewable electricity areas differ from areas of marine renewable energy priority in that they are defined areas for which specific development licenses have been granted, and the process of designating (or removing designation of) a location a marine renewable electricity area is laid out specifically (MRE Act, 2015, s. 18-20). This process entails a mandatory public consultation process (undertaken according to the requirements of the Act), and insurance than steps are taken to avoid conflicts with existing MRE projects and aquaculture licenses using sea space (MRE Act, 2015, s. 16). In the case of new marine renewable electricity area designations, the Act requires (MRE Act, 2015) that a strategic environmental assessment is undertaken, which must take into account both socio-economic and environmental impacts of possible tidal energy extraction from a given area.

The MRE Act names only two areas of MRE priority and one marine renewable electricity area and specifically disallows the development of tidal or other MRE projects outside of these designated areas (MRE Act, 2015). In doing so, the province of Nova Scotia has sent a clear message regarding its priorities; what remains is for industry to respond. As of late 2016, the only industry projects heading towards completion were those located at FORCE, though interest from developers outside of FORCE has begun to make the news (Gorman, 2016). Yet, the Act also specifies that developers may only apply for a license to deploy devices in accordance with a call for applications from the government (MRE Act, 2015), a process which is left to the discretion of the Minister of Energy. The eligibility of license holders for provincial FIT programs is also left to the Minister of Energy's discretion. The Act does allow for "permit" applications, but specifies that tidal energy permits may only be used for generators that are not connected to the provincial grid or selling to commercial customers (MRE Act, 2015); in contrast, tidal energy licenses in Nova Scotia are specifically designed for developers selling electricity into the grid or to direct customers. Permits are thus most likely to be of interest to device developers looking to test their devices in the pre-commercialisation stage. Permits do not require a call for proposals be issued from the Minister of Energy.

2.3. Why look to small tidal?

Nova Scotia has undertaken significant efforts to pursue the development of tidal energy over the past decade. Beginning with strategic environmental assessments, successive provincial governments have identified geographic areas they believe are worthy of the tidal sector's time and investment, and have crafted provincial regulations to target support for projects in these regions. Though the province previously offered a generous ($0.654/kWh) feed-in tariff to small-scale tidal projects through COMFIT, the absence of tidal projects completed under COMFIT suggests that the small-scale segment of the industry was likely not yet prepared to enter the Nova Scotian market. Even if the industry has moved forward in the past few years, the substantively reduced incentives offered by the RtR and ENM programs are unlikely to motivate small-scale tidal development.

In contrast, the Developmental Feed-in Tariffs offered to FORCE partners remains in effect, and the first grid-connected tidal energy devices are expected to be installed at FORCE in 2017. As mentioned, Cape Sharp Tidal Venture's first turbine has already been connected to the grid and is delivering power as of November 2016; the other three FORCE partners are planning to install devices in the near future. If successful, the first of these projects will come online some time in 2017. However, the weakened support for small-scale tidal energy projects in the province represents an abandonment of considerable time and policy-development efforts. To consider whether Nova Scotia's past efforts to pursue policy encouraging small-scale tidal energy were wasted, we ask two questions: first, does a resource appropriate for small-scale tidal energy extraction exist around the world? Second, does a market for small-scale tidal energy devices exist?

2.3.1 Global Tidal Energy Resource Estimates: Does Small Tidal Potential Exist?

While climate change and a desire for non-polluting sources of energy are considerable motivations for tidal development, many other factors have driven interest in developing marine areas for energy harvesting. Foremost among these is the simple fact that the ocean contains a truly immense quantity of energy—with a theoretical maximum potential in excess of 7400 EJ/yr (Ellabban, Abu-Rub, & Blaabjerg, 2014)—although the politically, environmentally, and socially acceptable capacity is accepted to be only a fraction of the theoretically available resource. In the case of tidal energy specifically, technically harvestable resources have been estimated to be far lower, in the range of 1.8 to 7.2 EJ/yr (Mercure & Salas, 2012). However, technical potential estimates are presently very conservative as to-date, they are a simple summation of published field assessments and region-specific modeling efforts; as few such assessments have been done, technically harvestable tidal energy potential is likely vastly underestimated.

Supporting this view, Jacobson and Delucchi (2011) found that global tidal power potential was 3.7 TW, with 0.8 TW of this power available in high-energy locations. These "high-energy" locations are not defined by Jacobson and Delucchi, but can reasonably be assumed to be areas currently considered to be of high interest for tidal development, such as Nova Scotia's Bay of Fundy or the neighbouring Gulf of Maine, the waters around Scotland's Orkney Islands, or other similar regions with tidal velocities exceeding 2.5 m/s. Yet simple division of Jacobson and Delucchi's (2011) figures show that these high-energy sites represent only 21.6% of the total tidal power available on Earth. Even if the dissipation suspected in the deep ocean (1 TW) and ocean-Earth friction (0.2 TW) (Hermann, 2006) is excluded, the globe's high-energy sites still account for only 32% of global tidal power potential.

Further to this, if 0.8 TW of power is present in the globe's high-energy sites, the technical potential estimate of Mercure and Salas (2012) is even more conservative.

Through simple multiplication of the power estimate by the number of hours in a year (8760), 0.8 TW of tidal power would imply an annual dissipation of 7008 TWh of energy in these high energy sites. Mercure and Salas's lower estimate of 1.8 EJ/yr (500 TWh) thus translates to a technically harvestable capacity factor of only 7.1% from these high-energy sites; at the upper 7.2 EJ/yr (2000 TWh) estimate, a global tidal capacity factor of 28.5% could be achieved. Yet focusing only upon these high-energy sites still excludes 68% of the tidal power potential located on continental shelves. The total energy dissipated annually in global tidal flows over the continental shelf is calculated to be approximately 21,900 TWh, meaning Mercure and Salas's estimates capture only 2.3 to 9.1% of the theoretically available energy. Bryden and Melville's (2004) estimated that up to 10% of a tidal stream's energy could be harnessed without significant adverse effect on the surrounding environment, for singular streams; while global impact thresholds would be more difficult to establish, we have demonstrated that even Mercure & Salas's (2012) maximum estimate falls short of this 10% threshold figure. Harnessing all of this potential is obviously impossible, but failing to consider the opportunity represented by lower-energy sites (and failing to design devices appropriate to them) excludes from consideration the vast majority of the tidal resource on the planet.

Interest in tidal development is further driven by the prevalence of human settlements on coastlines; more than 50% of the global population lives within 60 km of a coast (United Nations Environment Programme [UNEP], n.d.). While relatively few parts of the world possess high-energy tidal resources, it is clear that the vast majority of tidal resources are in low-energy locations (Jacobson & Delucchi, 2011). The tidal industry's efforts, to-date, have largely excluded such sites. However, there is demand for tidal devices that could generate electricity from low-energy locations; studies in the developing world in particular (Hassan, El-Shafie, & Karim, 2012; Blunden, Bahaj, & Aziz, 2013; Lim, Lam & Hashim, 2015) have recently put forward some preliminary options for doing so, including the introduction of ducts to accelerate flow into turbine blades, among other methods. Such devices could allow for deployment of smaller, localised tidal energy projects in many locations of the world not yet widely considered for tidal development, harnessing local resources and potentially (depending upon location) displacing the use of fossil-fuel energy systems. A comprehensive review of devices, design choices, and likely candidates for successful small-scale installations was conducted by Roberts et al. (2016); based upon their findings, it is likely that commercially viable axial-flow and cross-flow turbines could be designed for small-scale applications.

2.3.2 – Does a Market Exist for Small-Scale Tidal Applications?

Small-scale tidal energy devices may prove relevant in decentralised energy systems. A decentralised energy system, rather than generating energy in one location and transporting it to distant users, generates energy at multiple sites as close as possible to the locations of end use (Pepermans, Driesen, Haesedonckx, Belmans, & D'haeseleer, 2005). Such a system has both advantages and disadvantages when compared with the conventional, concentrated energy systems that dominate most Western societies today. For comprehensive reviews of the debate over centralised versus decentralised energy systems, see Pepermans et al. (2005), Hain, Ault, Galloway, Cruden & McDonald (2005), and Allan et al. (2015). However, some discussion of the key points is merited here.

In the past, distributed generation has primarily referred to off-grid communities which relied on diesel generation systems. Such systems tend to have relatively low rated capacity, typically in the range of 100 kW to 5 MW (Allan et al., 2015). Consequently, distributed energy systems are relevant to the present discussion of small-scale tidal energy (devices ≤150 kW, arrays ≤500 kW). As concern regarding the effects of climate change and volatile oil prices on remote communities has increased, investigations have been conducted to determine the feasibility of integrating renewable energy into these systems as a way to reduce diesel consumption and improve local energy security (Byrnes, Brown, Wagner & Foster, 2016; Beaty, Wild, & Buckham, 2010; Weis & Ilinca, 2010). Most communities relying on distributed generation must use high-cost diesel fuel, but well-designed policy mechanisms have the potential to make renewable energy technologies cost-competitive with local electricity prices with significantly less investment than in areas with lower energy prices (Weis & Ilinca, 2010). In the context of tidal energy, such mechanisms could be used to allow firms to generate profit while devices are still undergoing iterative development, prior to attempts to implement large, traditional-grid oriented tidal farms. While Schottel Hydro's efforts at small- and large-scale platform development for their tidal turbines have largely been concurrent (Black

Rock Tidal Power, n.d.; Sustainable Marine, 2016), the company's approach of developing a line of individual small-scale turbines that can be deployed in both small and large numbers serves as one industry example of a company taking this approach. Similar efforts are apparent in the device and installation designs pursued by Verdant Power (2016), Tocardo (2016), and others.

In this distributed grid context, tidal energy development offers coastal communities access to a locally available energy source, limiting the need for transmission infrastructure. Since tidal energy generation is inherently distributed and highly predictable, it may prove ideal for further grid decentralisation efforts even in traditional grid contexts. In the case of isolated or remote communities, where populations may be too sparse to justify a private or government utility bearing the cost of transmission grid extension (Zeriffi, 2007), tidal may offer a comparatively low-cost source of electricity. This is especially true when compared to the alternatives of extending transmission grid infrastructure or using fossil fuel-based off-grid energy sources such as diesel generators (Pepermans et al., 2005; Hain et al., 2005; Allan et al, 2015). Similarly, in a more conventional grid system that is facing a choice between costly centralised plants and transmission infrastructure upgrades, or increased regional generation facilities, distributed plants may prove more cost competitive (Pepermans et al., 2005; Hains et al., 2005), and tidal energy may serve well in this niche.

A reasonable question, then, is why an actor developing renewable energy would pursue as-yet unproven technology like tidal over the more mature wind or solar energy sectors. While it is true that very few tidal devices have thus far been deployed (MacGillivray, Jeffrey & Wallace, 2015), the sector is attracting research and investment interest, and is developing quite rapidly. Initial studies (McLachlan, 2009; Bailey, West & Whitehead, 2011; Devine-Wright, 2011a; Devine-Wright, 2011b; Delvaux, Rabuteau & Stanley, 2013; Wiersma & Devine-Wright, 2014) suggest that, broadly speaking, tidal energy is generally acceptable to the public. That said, conflict is possible when engaging certain users of marine space such as the fishing and shipping industries (de Groot, Campbell, Ashley & Rodwell, 2014); a more extensive review of the economic and social conflicts of MRE is presented by Dalton et al. (2015). Negotiating such conflicts, particularly those concerning the safety exclusion zones around tidal devices, is an ongoing process (Dubbs, Keeler & O'Meara, 2013; Davies, Watret & Gubbins, 2014; Janssen, Arciniegas, & Alexander, 2014; Wright, 2014; Wright, 2015). As marine areas are often treated as an international "commons" (Hardin, 1968), open for use by many users, none of whom "own" the resource and all of whom share access to it, this conflict can be very divisive. This is a stark contrast to land-based renewable energy development, which typically occurs on privately owned land, and thus poses less risk of disrupting use of public resources (Wiersma & Devine-Wright, 2014). That said, some have argued that land-based renewables disrupt the 'visual landscape' of a region, resulting in interrupted use of the commons (Wiersma & Devine-Wright, 2014). However, with most existing tidal designs, visual impacts are limited – particularly for submerged designs that do not penetrate the water's surface.

While tidal devices have yet to converge around any dominant designs, the majority of prototypes are either entirely submerged or have relatively low-profile surface structures that act as floating supports for the turbines (Lago, Ponta & Chen, 2010). This implies that tidal is more acceptable to the public than other renewable energy technologies (especially wind), due to its low visual impact upon the seascape (McLachlan, 2009; Devine-Wright, 2011a; Devine-Wright, 2011b). Whereas a wind or solar farm requires a number of large towers or panels that are visible from a considerable distance, most tidal technologies will have an unobtrusive visual profile.

Finally, one of the most significant motivations for pursuing tidal energy is its predictability (Denny, 2009). The timing of ocean tides is predictable to the minute and rarely varies in unpredictable ways; with good local survey data and a regional model it is possible to attain tidal amplitude and flow predictions with a high degree of accuracy for future periods of days, weeks, and months (Carballo, Iglesias & Castro, 2009). Although there is significant variation in tidal velocity on very small spatial and time scales due to turbulence in the stream (Bryden, et al., 2004), over periods of hours, days, or longer, the average energy within a tidal stream can be predicted quite accurately. Therefore, output from tidal stations will vary with time, but the natural component of this variability is reasonably predictable, and thus any stress on local or regional grids could be planned for comparatively well. Conversely, wind and solar power output are significantly affected by changes in local weather; power generation can both start and stop in very short time frames (Beaudin, Zareipour, Schellenberglabe, & Rosehart, 2010) due to shifting cloud and light conditions or wind patterns. It should be noted, however, that the mechanical reliability of tidal energy devices remains unproven in many areas of interest for tidal development; in contrast, wind and solar energy project breakdown rates are well-established. Thus, tidal energy offers a more predictable resource, but mechanical reliability questions remain unclear, when compared to other renewables. Answering these questions and establishing the breakdown rates of tidal energy projects is a necessary step to determine the final predictability of output from any given tidal energy installation. From a utility perspective (whether local, regional, or national), the predictability of tides is considered desirable, as a grid with fewer stress events is a more stable one (Denny, 2009).

2.4. A Path for Small-Scale Tidal Energy: Finding Competitive Markets

Clearly, there is a tidal resource best-suited for small-scale tidal energy projects, and there are markets that exist where small-scale tidal projects may prove attractive. How, then, can tidal energy firms target these markets? Here, we put forward an industry-led model: it suggests tidal energy firms target specific markets where their competitors' costs are high as a point of first market entry. From this view, it is suggested that firms develop tidal energy devices designed for locations and environments where other energy technologies struggle with economies of scale, efficiency problems, and other challenges that drive up costs. If the trends of so-called "creative creation" and "creative destruction" (Christensen, 1997; Hart & Christensen, 2002) observed in many other industries apply to the tidal energy sector, such an approach could allow tidal energy firms to develop a market for their products at the high-cost margin of competing technologies, and encroach upon the low-cost markets their competitors thrive in over time, as the tidal sector matures.

2.4.1 Targeting the Bottom: Tidal Energy Opportunities at the Low-Margin Side of the Electricity Market

While observing market innovation across sectors, Clayton Christensen noted what he termed the "innovator's dilemma" (1997). In simplest form, this concept can be summarised as a question: why do established firms tend to lose market share to disruptive technologies? That is, technologies that provide the same service through new means, and thus disrupt the previous market order. Christensen's response to this question is focused on the fact that disruptive technologies in any industry emerge first as alternatives that address market niches that typically offer lower margins to firms, and are thus less competitive, than established technologies (Christensen, 1997). Due to their un-competitive nature in mainstream markets, disruptive technologies have been historically successful first at the margins of the markets they operate in, with slow expansion into the mainstream market as the entrant disruptive firms developing these technologies gain experience and either lower their costs, or improve their product quality or service standards (Christensen, 1997). This pattern has been observed in computer disk storage, construction equipment, steel-milling, and other industries (Christensen, 1997). Bompard, Masera and Nutall (2015), among others, have suggested that renewable energy is also a disruptive technology, in terms of its impact on traditional electricity grids; this view informs the rest of this section.

To-date, the tidal energy sector has remained focused on large-scale development, which has necessitated that tidal energy firms compete directly with conventional, proven electricity technologies. This has put tidal energy developers at considerable disadvantage; the entrenched fossil fuel technologies (Hart & Christensen, 2002; IEA, 2014) and other renewables including wind and solar (IEA, 2014) have lower costs than entrant tidal energy firms. In the absence of mitigating policy to even the playing field, there are few established, centralised-grid markets where tidal energy projects can compete with other energy technologies. But these centralised markets are not the only potential markets for tidal energy firms to target.

2.4.2 Rural Electrification Opportunities: Addressing Energy Poverty with Small Tidal Devices

More than 1.2 billion people on Earth live without access to electricity (IEA, 2016). Even more live without sufficient access to electricity (or other forms of energy) to meet their needs; a state of living known as 'energy poverty' (IEA, 2016). Energy poverty can be a result of many factors, but the most common are: a lack of sufficient local energy resources; a lack of infrastructure to import energy to communities; excessively high energy prices making energy unaffordable; and a lack of technologies of appropriate scale to meet the community's needs (IEA, 2016). Many communities that experience energy poverty are located in far-flung, remote regions of the world, in both developed and developing countries. In such locations, reliance upon diesel generators is common; the Canadian arctic is one region of a developed country experiencing energy poverty, while Bermuda and Jamaica are small island states where tidal energy may be of interest, and remote areas of Indonesia and Malaysia serve as examples in the developing world.

While many of those experiencing energy poverty certainly live inland, there are many coastal and estuarine areas of the world where populations also lack sufficient access to energy. Recent studies have highlighted the potential for tidal energy as a solution to energy poverty in the developing world (Hammar et al., 2012; Hassam et al., 2012; Blunden et al., 2013; Lim et al., 2015). In particular, Hammar et al. (2012) emphasised the potential of small-scale tidal developments, and put forth methods to carry out low-cost, medium-accuracy tidal energy resource assessments, focused on rural Mozambique. Similarly, preliminary modeling studies have been carried out by researchers interested in tidal development in Malaysia (Hassam et al., 2012; Lim et al., 2015) and Indonesia (Blunden et al., 2015), looking to the possibility for projects to aid in rural electrification efforts along the two island states' coasts. Efforts to develop tidal devices that can survive arctic sea ice conditions have been underway at the University of Alaska-Fairbanks (n.d.) for several years, with the intent of developing devices that can compete with, supplement, and perhaps eventually supplant the diesel generators many arctic communities rely on. For regions where steel is rare or expensive, Anyi and Kirke (2010; 2011) even put forward design and construction methods intended to create ultra-low-cost, local, wooden turbine blades and mooring structures, in an effort to enable community-based maintenance of tidal devices in highly rural areas lacking industrial capacity.

The uniting factor of all these exploratory studies is a simple one: the focus on relatively low-capacity devices designed to supply isolated, rural communities. Such communities are, historically, most often reliant upon diesel generators when pursuing electrification (Pepermans et al., 2005). Largely, this is a result of simple economics; connecting remote, rural areas to the grid is costly, and quite often more costly than shipping diesel fuel (Pepermans et al., 2005; Weis & Ilinca, 2010; Allan et al., 2015). Due to the dominance of diesel in this market, consumer electricity prices in such communities are quite high. In existing diesel markets, prices vary from about \$0.40/kWh CAD in the Caribbean to more than \$1.00/kWh CAD in the Arctic (Weis & Ilinca, 2010); such prices could be expected (or exceeded) in many areas pursuing rural electrification. Yet communities exist that, rather than pursuing new electrification, are already reliant upon diesel generators.

2.4.3 Off-Grid Electricity Provision: Supplementing Diesel-Reliant Systems

There are many parts of the world that have small, isolated electricity grids that rely on diesel generators. These include much of the Canadian and United States' Arctic, many Caribbean states, island communities throughout the developed and developing world, and remote, low-population regions where the cost of connection to a national grid is prohibitive relative to the cost of importing diesel to these communities (Weis & Ilinca, 2010; Singh & Ephraim, 2016). Such grids are numerous, yet very high-cost. Inherent in these high costs is a motivation to pursue any technology that can deliver lower-cost energy. The health and environmental impacts of burning diesel (Weis & Ilinca, 2010) provide further (and perhaps stronger) motivation. Yet the relatively small-scale of many diesel-electric plants (especially in the arctic and the developing world) provides a challenge to renewable alternatives.

The costs (per-kW of capacity) of small-scale wind and solar energy technologies are quite high, relative to the costs of utility-scale wind and solar facilities (Weis & Ilinca, 2010; Allan et al., 2015). Both wind and solar energy require either storage technology or backup (fossil-based) generators as a result of their intermittent nature, which increases costs (Allan et al., 2015). Further, these technologies can be unavailable for long periods of the year—especially at high northern (or southern) latitudes, in the case of solar—and are predictable only on relatively short timescales (the accuracy window of a weather forecast) (Weis & Ilinca, 2010). Such availability problems pose a genuine risk to small, vulnerable grids (Pepermans et al., 2005; Beatty, Wild & Buckham, 2010); a smaller grid inherently lacks the capacity to absorb and distribute system shocks that a larger grid might handle (Beatty et al., 2010). As a result, should prolonged periods of inclement weather (i.e. clouds or a lack of wind) recur regularly in a location, solar and wind technologies may prove undesirable as diesel supplements, as they may not be available frequently enough to contribute to diesel use reduction. This inconsistency in year-round availability and predictability is avoidable with tidal energy technologies, due to the extensive knowledge already available regarding tidal cycles.

Due to its cyclical nature, the timing and approximate strength of the tide can be predicted to a high degree of accuracy (Bryden & Melville, 2004). While there are fluctuations in any tidal current's speed and direction on short timescales (milliseconds to minutes), the average flow can be reasonably predicted, as can the time at which flows will increase and decrease (Bryden & Melville, 2004; Torrens-Spence, Schmitt, Mackinnon, & Elsaesser, 2015). Importantly, while there is seasonal variation in tidal flows at any location, this variation is predictable over decadal time periods. For isolated, vulnerable grids, this predictability is a great asset, as it allows energy managers and decision makers to plan for backup systems to ensure their jurisdiction does not experience outages or grid failure. These backup systems could be either energy storage technologies (batteries, flywheels, compressed air, hydro storage, etc.) or diesel generators (Liu et al., 2016. In the case of diesel backup systems, "tidal-diesel hybrid systems" may be attractive, following the model of wind-diesel hybrid systems that have been discussed in the literature (Weis & Ilinca, 2010; Beatty et al., 2010) and implemented in several jurisdictions. Given its more predictable nature, tidal energy may make for a more attractive hybrid diesel-renewable system technology than wind; however, this remains uninvestigated. Compared to solar-diesel systems, tidal energy's attractiveness would almost entirely depend upon local solar and weather conditions, as this would dictate the relative availability of both resources.

There are two primary drivers of whether a tidal-diesel hybrid system would be an attractive means of reducing a community's reliance on diesel generation for power. The first is the cost of the tidal system itself, from manufacturing to delivery to end-of-life removal and disposal; these costs are, largely, in the hands of the device designers and tidal energy firms. The second driver, in contrast, is dependent upon the host community and its planners, managers, and decision makers: their preferences, desires, and tolerances regarding the cost, reliability, and availability of their electricity. It is likely safe to assume that any typical community would want the first of these conditions minimised, and the latter two maximised. These issues are, in essence, the pillars of energy security: the "four A's" of affordability, accessibility, availability, and (combining the other three) acceptability (Asia Pacific Energy Research Centre [APERC], 2007). Thus, in the relatively energy insecure markets that rely on diesel generation rather than traditional utility-scale grid connections (Weis & Ilinca, 2010; Beatty et al., 2010), the security of tidal energy relative to other renewable resources may prove its best feature.

This presents an opportunity for the tidal energy sector such as the development of small-scale devices capable of addressing some of the demands of rural, isolated-grid communities. In the near-term, the smallest of such devices could serve the needs of communities that do not yet have electrical services of any sort; short of introducing a number of new complimentary services, it is unlikely a previously unconnected community will require hundreds of kW. But over time, should use and demand grow, tidal energy firms could introduce such newly-connected communities to larger devices originally developed to supplement (or replace, where storage technologies are available) diesel generation systems. In turn, as their share of the existing and newly-connected distributed grid market grows, tidal energy firms could begin to turn their attention towards "up-market" applications of their technologies, expanding into the traditional, centralised-grid market. Such a strategy would be in line with the theories of market innovation and "creative creation" put forward by Clayton Christensen and his various collaborators (Christensen, 1997; Hart & Christensen, 2002) regarding how entrant firms and technologies in established markets can come to compete with and displace the prior market dominators. In particular, the arguments of Hart and Christensen (2002) regarding market entry at "the base of the [market] pyramid"—where costs may be high and profit margins low—may prove applicable to the tidal energy sector, should the sector pursue a "market creation" approach.

2.4.4 Future Applications for Small Tidal in Grid Decentralisation

While the market for off-grid diesel generation devices is considerable, small-scale tidal devices may be of interest to areas pursuing a more general phase-in of distributed generation. Studies have suggested that a renewables-based grid will by necessity be a more distributed grid, with different communities relying on different renewable resources for their primary source of power (Beaudin et al., 2010; Delucchi & Jacobson, 2013; IEA, 2014) and drawing from the larger grid only when their endogenous renewables are not available. In the case of highly rural areas, these distributed systems are unlikely to require large capacities (Pepermans et al., 2005; Zeriffi, 2007; Weis & Ilanca, 2010; Hammar et al., 2012), and there may be cost-related pressures to pursue distributed generation in such locations very soon. This is because the cost of grid extension and maintenance to remote locations is often quite high (Pepermans et al., 2005). While utility-scale developments generally appear more attractive from a financial perspective in areas that have excess grid capacity or where the grid can be easily upgraded, this does not hold for areas with limited or unstable grid systems (Pepermans et al., 2005; Weis & Ilanca, 2010; Beatty et al., 2010). It is thus likely that in the case of limited grid capacity regions, small-scale, distributed energy system solutions will thus be of lower-cost than either grid extension and connection to a new centralised generation facility, or upgrading of local grid systems to enable a utility-scale plant to be developed locally. Consequently, a tidal energy firm with a ready-made small-scale tidal energy device capable of being deployed singly or in arrays would be well-positioned to aid in the decentralisation of electrical grids. If decentralisation is pursued further, larger, utility-scale arrays of such devices may become economically attractive, at sites where the necessary resource to support them exists.

As decentralisation of electricity generation is pursued, the primary concern for many grid operators will be maintenance of a consistent level of electricity in the grid system. Here, for territories with significant coastlines, tidal power can prove particularly helpful. The timing and amplitude of tidal velocities naturally vary between different places along a given coast, simply because the astronomical forces driving the tides take time to act on different locations (and the masses of water being affected take time to move from one location to another); this effect results in a “lag” in tidal phase between different locations. That is, while the tide may be at peak flood velocities in one location, another may be experiencing slack water as the tide just begins to turn a few hundred kilometers away. Iyer et al. (2013) discussed the implementation of a number of carefully-distributed tidal energy plants in the UK, taking advantage of this tidal phase lag that exists around the country’s coasts to ensure a consistent amount of power is delivered to the national grid. Similar plans could be implemented in other places in the world, so long as sufficient time-lag exists between different sites. While Iyer et al.’s study considered utility-scale deployments, an increased number of small-scale tidal devices may be able to similarly meet the requirement of providing consistent grid-delivered power, while further distributing the economic benefits associated with tidal development to more disperse locations. However, no study has yet been conducted to confirm the suitability of small-scale tidal development for this purpose, so this supposition remains hypothetical.

2.5. Conclusions & Recommendations

2.5.1 Conclusions

As of December, 2016, Nova Scotia has yet to successfully develop any small-scale tidal energy plants, despite early policy efforts to encourage firms to pursue them. In 2015, the province significantly weakened the support mechanisms available to small-scale tidal energy projects with the cancellation of COMFIT, despite having invested considerable time and effort into the consideration and pre-screening of sites for small-scale tidal development during the province-wide Strategic Environmental Assessments process (OERA, 2009; AECOM Canada Ltd., 2012; 2014). Efforts to deploy utility-scale devices at FORCE continue, but these efforts also face opposition from the public that may exacerbate previous delays (McMillan, 2016). This opposition has been framed around perceived (though not necessarily proven) environmental risks, especially those posed to fish (McMillan, 2016). The lack of widespread deployment of in-stream tidal energy devices elsewhere has driven many of these perceptions, with the fishing industry citing a lack of scientific evidence that tidal energy devices are environmentally safe. Despite this opposition, industry and governmental organisations have installed the first tidal energy turbine at FORCE, with further deployments planned in 2017 (Withers, 2016).

No change has been signalled regarding Nova Scotia’s approach to small-scale tidal energy development. The existing three COMFIT licenses held by Fundy Tidal Inc. for tidal projects in the southern regions of the Bay of Fundy remain valid (NSDOE, 2016), but no announcements regarding device deployment or site preparation have been made since. Given MacDougall’s (2015) finding that the lower-valued Developmental FIT was not sufficient to encourage tidal energy device deployment, it is possible that the COMFIT rate offered is also insufficient, and that this is the reason Fundy Tidal has not yet deployed devices. Further, with COMFIT’s cancellation, no other small-scale tidal projects are eligible for the same level of subsidy. No known ENM contracts utilising tidal energy have been announced. Thus, it appears that small-scale tidal energy development is, at best, stalled in Nova Scotia. At worst, the conditions for successful small-scale tidal development in Nova Scotia may simply not exist. Despite the problems faced in Nova Scotia, we believe opportunities exist for small-scale tidal energy development in the world. Firms seeking to exploit these opportunities are advised to follow a "market-creation" approach to small-scale tidal energy development. Working from Clayton Christensen's discussions of innovation in technology development, it is posited that tidal energy devices would prove more attractive in markets where they are either providing a new service (i.e. markets lacking electricity) or providing a service at competitive prices (i.e. markets with very high electricity costs). Such markets already exist, especially in the developing world and remote, off-grid areas of the developed world. While the industry-leading tidal energy designs to-date have been designed to operate in high-energy tidal flows to generate large amounts of electricity for conventional, centralised electricity grids, such devices are likely to be oversized and overpriced for the markets where small-scale tidal energy may be most attractive. Yet, few small-scale devices presently exist, and fewer have seen commercial grid-connected deployments. In light of this, several recommendations can be made to tidal energy firms, policymakers and regulators interested in encouraging or pursuing small-scale tidal energy. We conclude with some directions for future research.

2.5.2 Recommendations for Tidal Energy Companies

Firms that wish to capture part of the small-scale tidal energy market discussed above should first decide which segment of the market they would like to target. Devices designed to supplement off-grid diesel generation systems must keep a close eye on costs, so as to avoid becoming uncompetitive with diesel and other small renewables that have already begun competing with, or supplementing, diesel generation in off-grid communities. In contrast, tidal devices designed for electrification efforts may have fewer cost ceilings, depending on the target environment. Locations likely exist where tidal flows are either a more abundant or more reliable resource than solar, wind, or bioenergy; in such locations, tidal energy devices would prove more attractive as a means of electrification than other renewables. However, in both cases, one of the most significant costs is external to device design: resource assessment.

Investments by small-scale tidal energy device designers in low-cost tidal resource assessment methods would be a significant step towards small-scale tidal becoming viable. Early attempts to find such low cost methods exist (Hammar et al., 2012), but their present imprecision—with errors against observed flows exceeding 30%—remains a barrier. As resource assessment can be a significant cost factor in remote regions (Hammar et al., 2012), finding an accurate, low-cost means of carrying out these assessments could broaden the number of financially viable small-scale tidal projects and locations by a wide margin. Such methods would also be useful in reducing costs for utility-scale projects elsewhere.

Similarly, to increase the number of viable small-scale tidal energy project sites, tidal energy firms should investigate means of harnessing low-velocity tidal flows. Engineers have already put forth a number of means of accelerating the incident flow approaching a turbine blade, with the most common means of doing so being the use of a ducted turbine (Hassan et al., 2012; Blunden et al., 2013). However, ducts have been cited as a significant increase in materials use and costs (Hassan et al., 2012), creating a trade-off between project costs and the lower limit of harvestable tidal velocities for a given device design. Non-turbine tidal energy device designs have been put forward, such as Archimedes screws, tidal kites, and others (Roberts et al., 2016); further investigation of whether these devices can prove economically viable at low tidal flows may be warranted.

2.5.3 Recommendations for Policymakers & Regulators

Policymakers and regulators considering methods they can use to encourage small-scale tidal energy development must be careful in selecting which mechanisms they put forward. First and foremost, they must analyse the present electricity sector in their jurisdiction to determine what goals small-scale tidal energy projects may help them pursue. In traditional, centralised-grid contexts, small tidal developments would be most appropriate as a means of long-term planning towards decentralisation. In this context, small tidal policy should be designed to target areas with relatively weak electrical infrastructure (i.e. few transmission-grid interconnection points and high vulnerability to grid failures). Small tidal development policies in such jurisdictions should thus include the costs—both in maintenance, repair, and lost economic productivity—of these electrical service interruptions in consideration of the economic viability of small tidal deployments. However, even in areas with relatively strong, reliable grids, small-scale tidal may be useful as a means of increasing grid reliability through taking advantage of tidal phasing over large land areas. Planning tidal energy leases and developments in order to smooth out grid stresses through phasing effects may thus be worth investigation for centralised-grid policymakers and regulators.

Off-grid, diesel-reliant electricity systems have other policy priorities. These include reducing diesel consumption in a cost-effective way, reducing carbon dioxide emissions, increasing energy security through decreasing reliance on fuels imported to the community, and maintaining or improving their energy system's reliability. Where tidal resources exist, small-scale tidal projects may be able to meet all of these goals. First, although most tidal energy devices remain experimental, their costs could be brought in line with diesel generation systems over time. Second, simply by providing non-diesel energy, small tidal energy projects would allow a community to reduce its carbon emissions—so long as embodied emissions in the tidal devices are lower than the lifetime diesel emissions avoided. Finally, by nature of being a localised, renewable resource, with a predictable output over given time periods, tidal energy can allow policymakers to reduce communities' reliance on imported fuels, and create a predictable grid load. Yet, despite its predictability, tidal energy remains intermittent. As such, in the absence of energy storage technologies or other renewables capable of more continuous operation, tidal energy is unlikely to fully replace diesel generation in remote communities; it would instead merely supplement diesel systems and reduce consumption of fuel. Each of these concerns has direct implications for the financial and economic viability of small tidal projects in a given jurisdiction. Thus, it is recommended that policymakers working with diesel-reliant off-grid electricity systems evaluate increases in energy security and grid reliability, along with reduced carbon emissions, against the lifetime costs of the small tidal systems being considered. This is necessary in order to ensure an accurate picture of the real benefits and costs of small tidal in these off-grid contexts.

Finally, policymakers concerned with using small-scale tidal energy for rural electrification projects must carefully consider their options. Similar to off-grid areas, these communities must be concerned with costs, energy security, carbon emissions, and the reliability of the system. Yet because the end goal is simply to provide energy to communities that lack it, the priorities are different from those in isolated diesel-grid contexts. Rural electrification projects in much of the developing world have often relied on very high-cost solutions, such as diesel generators feeding into car batteries that are then used to power lights and small appliances in homes (Zeriffi, 2007; Hammar, 2012; Lim et al., 2015). Small-scale renewables, especially solar and wind, have also been used in similar efforts. Here, the solution that will be of lowest economic cost to the local community is the most likely to be implemented, unless incentives (such as FITs) are in place to subsidise higher-cost, more environmentally-friendly solutions (Weis & Ilanca, 2010). Thus, if policymakers wish to use small-scale tidal energy devices to pursue rural electrification, they must first create a standardised method of evaluating the lifetime costs of rural electrification options. As with the recommendations for off-grid policies, this would include calculation of the relative costs associated with the security and reliability of different solutions, and the carbon emission costs (or savings), for any technologies being considered. The reliability and time-availability of systems in newly-electrified areas may prove particularly important; tidal energy may be attractive specifically because of its predictability relative to wind and solar technologies, but its intermittency may make it less appealing in regions with abundant bioenergy resources. Therefore, if policymakers desire to specifically deploy small-scale tidal energy projects, addressing this intermittency through either supporting renewables, diesel generators, or energy storage solutions will prove necessary.

In any of the above contexts, it would be advisable for policymakers and regulators to avoid the involvement of third party “middlemen,” at least in the near term. That is, given the low profit margins inherent in the early stages of technology development, partnerships for small-scale tidal projects would be best pursued with direct cooperation between tidal energy device firms and local government partners. In the right conditions, organised community groups may also prove viable partners for small tidal projects, but as the tidal sector remains emergent and faces many unknowns, partnerships with organisations that hold political decision-making power are likely to prove more reliable due to their increased ability to ensure projects will be approved. Thus, policies designed at the regional (state/provincial) or federal level to encourage firms to seek direct partnerships with municipal (or regional) governments are recommended.

Finally, due to the nascent nature of the tidal sector, if governments truly wish to encourage small-scale tidal development, simplifying regulations and shortening turnaround time in review processes would be advisable. Designing a "one stop shop" for regulatory approvals—as the United Kingdom has done (Wright, 2014)—for tidal projects, with one minister and one government agency to deal with, rather than several, would significantly reduce the time and complexity of getting initial projects evaluated. This reduction in time and complexity would mean less time spent languishing between design iterations and testing information, and in theory could allow for faster development of devices, and thus earlier commercial deployments. While most tidal devices remain unproven and their environmental effects unknown, the likelihood of the small, sub-150 kW devices discussed here causing irreparable harm to the marine environment is suspected to be low. As such, it may be of interest to loosen regulations over small tidal projects in order to accelerate their deployment, and widen the range of such devices that may prove commercially viable due to reduced regulatory costs.

2.6 References

AECOM Canada Ltd. (2012). *Marine Renewable Energy: Background Report to Support a Strategic Environmental Assessment (SEA) For the Cape Breton Coastal Region, inclusive of the Bras D'Or Lakes.* Halifax: Offshore Energy Research Association of Nova Scotia. Accessed Sept 18, 2016. Retrieved from: http://www.oera.ca/marine-renewable-energy/strategic-environmental-assessment/

AECOM Canada Ltd. (2014). *Tidal energy: Strategic Environmental Assessment Update for the Bay of Fundy.* Halifax: Offshore Energy Research Association of Nova Scotia. Accessed Sept 17, 2016. Retrieved from: http://www.oera.ca/marine-renewable-energy/strategic-environmental-assessment/

Allan, G., Eromenko, I., Gilmartin, M., Kockar, I., & McGregor, P. (2015). The economics of distributed energy generation: a literature review. *Renewable and Sustainable Energy Reviews, 42,* 543-556.

Anyi, M. & Kirke, B. (2010). Evaluation of small axial flow hydrokinetic turbines for remote communities. *Energy for Sustainable Development, 14,* 110-116.

Anyi, M. & Kirke, B. (2011). Hydrokinetic turbine blades: Design and local construction techniques for remote communities. *Energy for Sustainable Development, 15,* 223-230.

APERC. (2007). *A Quest for Energy Security in the 21st Century.* Asia Pacific Energy Research Centre. Accessed November 20, 2016. Retrieved from: http://aperc.ieej.or.jp/file/2010/9/26/APERC_2007_A_Quest_for_Energy_Security.pdf

Atlantis Resources Ltd. (April 29, 2015). Acquisition of Marine Current Turbines Limited from Siemens. Press release. Accessed January 12, 2016. Retrieved from: http://atlantisresourcesltd.com/media-centre/atlantis-annoucements/79-2015-annoucements/360-acquisition-of-marine-current-turbines-limited-from-siemens.html

Atlantis Resources Ltd. (2016). Meygen Project Update Spring 2016. Accessed March 1, 2016. Retrieved from: http://atlantisresourcesltd.com/images/pdf/Meygen%20Newsletter%20201602.pdf

Bailey, I., West, J., & Whitehead, I. (2011). Out of sight but not out of mind? Public perceptions of wave energy. *Journal of Environmental Policy and Planning, 13*, 139–57.

Beatty, S.J., Wild, P. & Buckham, B.J. (2010). Integration of a wave energy converter into the electricity supply of a remote Alaskan island. *Renewable Energy, 35,* 1203-1213.

Beaudin, M., Zareipour, H., Schellenberglabe, A., & Rosehart, W. (2010). Energy storage for mitigating the variability of renewable electricity sources: An updated review. *Energy for Sustainable Development, 14*(4), 302-314. doi: 10.1016/j.esd.2010.09.007

Black Rock Tidal Power. (n.d.) *Technology.* Black Rock Tidal Power Ltd. Accessed September 19, 2016. Retrieved from: http://www.blackrocktidalpower.com/technology/

Blunden, L.S., Bahaj, A.S., & Aziz, N.S. (2013). Tidal current power for Indonesia? An initial resource assessment for the Alas Strait. *Renewable Energy, 49,* 137-142.

Boehlert, G.W. & Gill, A.B. (2010). Environmental and ecological effects of ocean renewable energy development: A current synthesis. *Oceanography, 23(2),* 68-81.

Bompard, E., Masera, M. & Nuttall, W. (2015). High tension electricity New multi-scale complexities in the electricity system. *Technological Forecasting & Social Change, 96*, 327–333

Bradshaw, J. (Nov 5, 2016). *UK could miss out on EU science grants post-Brexit.* The Telegraph. Retrieved Nov 8, 2016: http://www.telegraph.co.uk/business/2016/11/05/uk-could-miss-out-on-eu-science-grants-post-brexit/

Broadhurst, M., Barr, S., & Orme, C.D.L. (2014). In-situ ecological interactions with a deployed tidal energy device; an observational pilot study. *Ocean & Coastal Management*, *99*, 31-38.

Bryden, I.G. & Melville, G.T. (2004). Choosing and evaluating sites for tidal current development. *Proceedings of the Institute of Mechanical Engineers Part A: Journal of Power and Energy, 218*(8), 567-577.

Byrnes, L, Brown, C., Wagner, L, & Foster, J. (2016). Reviewing the viability of renewable energy in community electrification: The case of remote Western Australian communities. *Renewable and Sustainable Energy Reviews*, 59, 470–481.

Carballo, R., Iglesias, G., & Castro, A. (2009). Numerical model evaluations of tidal stream energy in the Ría de Muros (NW Spain). *Renewable Energy, 34,* 1517-1524. doi: 10.1016/j.renene.2008.10.028

CBC News. (November 12, 2015). Bay of Fundy tidal power installation delayed until spring. Accessed January 17, 2016. Retrieved from: http://www.cbc.ca/news/canada/nova-scotia/bay-fundy-turbines-delay-1.3315959

Dalton, G., Allan, G., Beaumont, N., Georgakaki, A., Hacking, N., Hooper, T., Kerr, S., O'Hagan, A.M., Reilly, K., Ricci, P., Sheng, W., & Stallard, T. (2015). Economic and socio-economic assessment methods for ocean renewable energy: Public and private perspectives. *Renewable and Sustainable Energy Reviews, 45*, 850-878. doi: 10.1016/j.rser.2015.01.068

Davies, I.M., Watret, R., & Gubbins, M. (2014). Spatial planning for sustainable marine renewable energy developments in Scotland. *Ocean & Coastal Management, 99*, 72-81. doi: 10.1016/j.ocecoaman.2014.05.013

de Groot, J., Campbell, M., Ashley, M., & Rodwell, L. (2014). Investigating the co-existence of fisheries and offshore renewable energy in the UK: Identification of a mitigation agenda for fishing effort displacement. *Ocean & Coastal Management, 102,* 7-18. doi: 10.1016/j.ocecoaman.2014.08.013

Delaney, G. (February 4, 2014). *Tidal power proposal for Scots Bay meets with skepticism.* The Chronicle Herald. Accessed January 30, 2016. Retrieved from: http://thechronicleherald.ca/novascotia/1184437-tidal-power-proposal-for-scots-bay-meets-with-skepticism

Delucchi, M.A., & Jacobson, M.Z. (2013). Meeting the world's energy needs entirely with wind, water and solar power. *Bulletin of the Atomic Scientists, 69*(4), 30-40.

Delvaux, P.A.G., Rabuteau, Y. and Stanley, K. (2013). Civil society involvement and social acceptability of marine energy projects: Best practices of the marine energy sector. MERiFIC: France.

Denny, E. (2009). The economics of tidal energy. *Energy Policy, 37,* 1914-1924. doi: 10.1016/j.enpol.2009.01.009

Devine-Wright, P. (2011a). Enhancing local distinctiveness fosters public acceptance of tidal energy: A UK case study. *Energy Policy, 39*(1), 83-93. DOI: 10.1016/j.enpol.2010.09.012

Devine-Wright, P. (2011b). Place attachment and public acceptance of renewable energy: a tidal energy case study. *Journal of Environmental Psychology, 31*, 336–43.

Dickman, S. (Nov 21, 2016). *Sounding the Alarm: UK Biotech Struggles to Cope with Brexit.* Forbes. Retrieved Nov 24, 2016: http://www.forbes.com/sites/stevedickman/2016/11/21/sounding-the-alarm-uk-biotech-struggles-to-cope-with-brexit/

Dubbs, L., Keeler, A. G., & O'Meara, T. (2013). Permitting, risk and marine hydrokinetic energy development. *The Electricity Journal*, *26*(10), 64–74. doi: 10.1016/j.tej.2013.11.002

Ellabban, O., Abu-Rub, H., & Blaabjerg, F. (2014). Renewable energy resources: Current status, future prospects and their enabling technology. *Renewable and Sustainable Energy Reviews, 39*, 748-764. doi: 10.1016/j.rser.2014.07.113

EMEC. (2016a). *About us.* Accessed February 12, 2016. Retrieved from: http://www.emec.org.uk/about-us/

EMEC. (2016b). *Funders.* Accessed February 12, 2016. Retrieved from: http://www.emec.org.uk/about-us/funders/

European Commission. (2015). EU support for ocean energy. Last updated: 11-08-2015. Accessed February 12, 2016. Retrieved from: http://ec.europa.eu/research/energy/eu/index_en.cfm?pg=research-ocean-support

Flynn, B. (2015). Ecological modernisation of a 'Cinderella renewable'? The emerging politics of global ocean energy. *Environmental Politics, 24*(2), 249-269. doi: 10.1080/09644016.2014.1000638

FORCE. (2016). *FORCE Test Site.* Accessed February 12, 2016. Retrieved from: http://fundyforce.ca/about/force-test-site-2/

FORCE. (n.d.) *Technology.* Accessed February 19, 2016. Retrieved from: http://fundyforce.ca/technology/

Frid, C., Andonegi, E., Depestele, J., Judd, A., Rihan, D., Rogers, S.I., & Kenchington, E. (2012). The environmental interactions of wave and tidal energy devices. *Environmental Impact Assessment Review, 32,* 133-139. doi: 10.1016/j.eiar.2011.06.002

Google Earth. (2016). Nova Scotian Tidal Energy Sites Map. Prepared by Carlson, J. Data from GEBCO, LDEO-Columbia, NGA, NOAA, NSF, SIO, & US Navy.

Gorman, M. (June 6, 2016). *Could this 'no-brainer' concept be the key to harnessing the power of the Bay of Fundy tides?* CBC News. Accessed October 30, 2016. Retrieved from: http://www.cbc.ca/news/canada/nova-scotia/big-moon-power-bay-of-fundy-tidal-kinetic-keel-nova-scotia-1.3615567

Hain, J.J., Ault, G.W., Galloway, S.J., Cruden, A., & McDonald, J.R. (2005). Additional renewable energy growth through small-scale community orientated energy policies. *Energy Policy, 33,* 1199-1212.

Hammar, L., Ehnberg, J., Mavume, A., Francisco, F., & Molander, S. (2012). Simplified site-screening method for micro tidal current turbines applied in Mozambique. *Renewable Energy, 44,* 414-422.

Hammons, T.J. (1993). Tidal power. *Proceeding of the IEEE, 8*(1), 419-433.

Hardin, G. (1968). The tragedy of the commons. *Science, 168*(3859), 1243-1248. doi: 10.1126/science.162.3859.1243

Hart, S.L. & Christensen, C.M. (2002). The great leap: Driving innovation from the base of the pyramid. *MIT Sloan Management Review, 44(1),* 51-56.

Hassan, H.F., El-Shafie, A., & Karim, O.A. (2012). Tidal current turbines glance at the past and look into the future prospects in Malaysia. *Renewable and Sustainable Energy Reviews, 16,* 5707-5717.

Hatcher B.G. (Editor) 2015. Marine Renewable Energy: Engineering & Ocean Technology Research. Final Report, NSERC Partnership Workshop, 8-9 Dec. 2014. Bras d'Or Institute, Cape Breton University, Sydney, N.S. 25pp.

Hay, A., Karsten, R., Towse, G., Morin, D., Webster, T., McMillan, J., O'Flaherty-Sproul, M., Schillinger, D., Cheel, R., Marshall, E., Crowell, N., & Collins, K. (2013). *Southwest Nova Scotia Resource Assessment: Final Report.* Offshore Energy Research Association of Nova Scotia. Accessed July 19, 2016. Retrieved from: http://www.oera.ca/wp-content/uploads/2013/07/SWNT_Final-Report_Executive-Summary.pdf

Hermann, W.A. (2011). Quantifying global exergy resources. *Energy, 31*(12), 1685-1702. doi: 10.1016/j.energy.2005.09.006

Hooper, T. & Austen, M. (2013). Tidal barrages in the UK: Ecological and social impacts, potential mitigation, and tools to support barrage planning. *Renewable and Sustainable Energy Reviews, 23,* 289-298. doi: 10.1016/j.resr.2013.03.001

IEA. (2000). Experience curves for energy technology policy. Accessed January 2, 2016. Retrieved from: http://reaccess.epu.ntua.gr/LinkClick.aspx?fileticket=Driek6XFOMs%3D&tabid=582&mid=1096.

IEA. (2014). World Energy Outlook 2014. Paris: OECD.

IEA. (2016). *Energy poverty.* International Energy Agency. Accessed December 1, 2016. Retrieved from: http://www.iea.org/topics/energypoverty/

Jacobson, M.Z. & Delucchi, M.A. (2011). Providing all global energy with wind, water and solar power, Part I: Technologies, energy resources, quantities and areas of infrastructure, and materials. *Energy Policy, 39*(3), 1154-1169. doi: 10.1016/j.enpol.2010.11.040

Janssen, R., Arciniegas, G, & Alexander, K.A. (2014). Decision support tools for collaborative marine spatial planning: identifying potential sites for tidal energy devices around the Mull of Kintyre, Scotland. *Journal of Environmental Planning and Management, 58*(4), 719-737. doi: 10.1080/09640568.2014.887561

Karsten, R.H., McMillan, J.M., Lickley, M.J. & Haynes, R.D. (2008). Assessment of tidal current energy in the Minas Passage, Bay of Fundy. *Proceedings of the Institute of Mechanical Engineers, Part A: Journal of Power and Energy, 222,* 493-507.

Kerr, S., Watts, L., Colton, J., Conway, F., Hull, A., Johnson, K., Jude, S., Kannen, A., MacDougall, S., McLachlan, C., Potts, T., & Vergunst, J. (2014). Establishing an agenda for social studies research in marine renewable energy. *Energy Policy, 67*, 694-702.

Lago, L.I., Ponta, F.L., & Chen, L. (2010). Advances and trends in hydrokinetic turbine systems. *Energy for Sustainable Development, 14*(4), 287-296. doi: 10.106/j.esd.2010.09.004

Lewis, M.J.T. (1997) *Millstone and Hammer: the origins of water power*. University of Hull Press, Hull, UK, 180 pp.

Lim, X.L., Lam, W.H., & Hashim, R. (2015). Feasibility of marine renewable energy to the Feed-in Tariff system in Malaysia. *Renewable and Sustainable Energy Reviews, 49,* 708-719.

Liu, M., Li, W., Yu, J, Ren, Z., & Xu, R. (2016). Reliability evaluation of tidal and wind power generation system with battery energy storage. *Journal of Modern Power Systems and Clean Energy, 4*(4), 636-647.

MacDougall, S.L. (2015). The value of delay in tidal energy development. *Energy Policy, 87,* 438-446. doi: 10.1016/j.enpol.2015.09.034

MacGillivray, A., Jeffrey, H., & Wallace, R. (2015). The importance of iteration and deployment in technology development: A study of the impact on wave and tidal stream energy research, development and innovation. *Energy Policy*, *87*, 542–552. doi: 10.1016/j.enpol.2015.10.002

Marine Renewable-energy Act. (2015, c. 32). Nova Scotia Legislature. Accessed October 24, 2016. Retrieved from: http://nslegislature.ca/legc/bills/62nd_2nd/3rd_read/b110.htm

Marine Renewables Canada. (2011). Charting the Course: Canada's Marine Renewable Energy Technology Roadmap. Accessed January 8, 2016. Retrieved from: http://www.marinerenewables.ca/wp-content/uploads/2012/09/MRE_Roadmap_e.pdf

McLachlan, C. (2009). 'You don't do a chemistry experiment in your best china': Symbolic interpretations of place and technology in a wave energy case. *Energy Policy, 37*(12), 5342-5350. doi: 10.1016/j.enpol.2009.07.057

McMillan, E. (July 27, 2016). "Bay of Fundy inshore fishermen want court to overturn tidal turbine approval." *CBC News.* Accessed October 1, 2016. Retrieved from: http://www.cbc.ca/news/canada/nova-scotia/bay-of-fundy-inshore-fishermen-wants-judicial-review-1.3697080

Mercure, J.-F., & Salas, P. (2012). An assessment of global energy resource economic potentials. *Energy*, *46*, 322-336. doi: 10.1016/j.energy.2012.08.018

Meygen. (2016). *About Phase 1a.* Retrieved from: http://www.meygen.com/about-phase-1a/

Morris, R.K.A. (2013). Geomorphological analogues for large estuarine engineering projects: A case study of barrages, causeways and tidal energy projects. *Ocean & Coastal Management, 79*, 52-61. doi: 10.1016/j.ocecoaman.2012.05.010

NSDOE. (2010). Renewable electricity plan. Accessed January 8, 2016. Government of Nova Scotia, Halifax, Nova Scotia, Canada. Retrieved from: http://energy.novascotia.ca/sites/default/files/renewable-electricity-plan.pdf

NSDOE. (2015a). Our electricity future: Nova Scotia's electricity plan 2015-2040. Government of Nova Scotia, Halifax, Nova Scotia, Canada. Accessed January 8, 2016. Retrieved from: http://energy.novascotia.ca/sites/default/files/files/FINAL%20Our%20Electricity%20Future%281%29.pdf

NSDOE. (2015b). *Developmental Tidal Feed-in Tariff Program.* Accessed January 8, 2016. Retrieved from: http://energy.novascotia.ca/renewables/programs-and-projects/tidal-fit

NSDOE. (2016). *COMFIT Projects Status List.* Accessed December 1, 2016. Retrieved from: http://energy.novascotia.ca/sites/default/files/files/Copy%20of%20DRAFT%20Comfit%20Status%20as%20of%20October%206%2C%202016.pdf

NSPI. (2015). *Enhanced Net Metering.* Accessed January 11, 2016. Retrieved from: http://www.nspower.ca/en/home/for-my-home/make-your-own-energy/enhanced-net-metering/default.aspx

Offshore Energy Research Association. (2008). *Fundy Tidal Energy Strategic Environmental Assessment.* Halifax: Offshore Energy Research Association of Nova Scotia. Accessed Sept 17, 2016. Retrieved from: http://www.oera.ca/marine-renewable-energy/strategic-environmental-assessment/

Oleson, J.P. (2000), "Water-Lifting", in Wikander, Örjan, *Handbook of Ancient Water Technology*, Technology and Change in History **2**, Leiden: Brill, pp. 217–302

Pepermans, G., Driesen, J., Haesedonckx, D., Belmans, R., & D'haeseleer,W. (2005). Distributed generation: definition, benefits and issues. *Energy Policy, 33,* 787-798.

Province of Nova Scotia. (2012). Marine Renewable Energy Strategy. Accessed January 20, 2016. Retrieved from: http://energy.novascotia.ca/sites/default/files/Nova-Scotia-Marine-Renewable-Energy-Strategy-May-2012.pdf

Province of Nova Scotia. (August 6, 2015). Minister announces COMFIT review results, end to program. Press release. Accessed January 11, 2016. Retrieved from: http://novascotia.ca/news/release/?id=20150806001

Province of Nova Scotia. (n.d.). Community Feed-in Tariff Program Facts. Electronic factsheet. Accessed January 11, 2016. Retrieved from: http://energy.novascotia.ca/sites/default/files/comfit_facts.pdf

Roberts, A., Thomas, B., Sewell, P., Khan, Z., Balmain, S., & Gillman, J. (2016). Current tidal power technologies and their suitability for applications in coastal and marine areas. *Journal of Ocean Engineering and Marine Energy, 2,* 227-245. doi: 10.1007/s40722-016-0044-8

Rourke, F.O., Boyle, F. & Reynolds, A. (2010). Tidal energy update 2009. *Applied Energy, 87*, 398-409.

Sample, I. (July 12, 2016). *UK scientists dropped from EU projects because of post-Brexit funding fears.* The Guardian. Retrieved Oct 18, 2016, from: https://www.theguardian.com/education/2016/jul/12/uk-scientists-dropped-from-eu-projects-because-of-post-brexit-funding-fears

Sanchez, M., Carballo, R., Ramos, V., & Iglesias, G. (2014). Floating vs. bottom-fixed turbines for tidal stream energy: A comparative impact assessment. *Energy, 72,* 691-701. doi: 10.1016/j.energy.2014.05.096

Schottel. (n.d.). *SIT Instream Turbine.* Schottel Group. Accessed September 19, 2016. Retrieved from: https://www.schottel.de/schottel-hydro/sit-instream-turbine/

Shields, M.A., Woolf, D.K., Grist, E.P.M., Kerr, S.A., Jackson, A.C., Harris, R.E., Bell, M.C., Beharie, R., Want, A., Osalusi, E., Gibb, S.W., & Side, J. (2011). Marine renewable energy: The ecological implications of altering the hydrodynamics of the marine environment. *Ocean & Coastal Management, 54,* 2-9.

Singh, A. & Ephraim, J. (2016). Ocean energy: The new energy frontier for the Eastern Caribbean Small Island Developing States. *Energy Policy, 99,* 1-3.

Statistics Canada. (2016a). *Population, by year, by province and territory (Number).* Government of Canada. Accessed September 6, 2016. Retrieved from: http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/demo02a-eng.htm

Statistics Canada. (2016b). *Population, urban and rural, by province and territory (Nova Scotia).* Government of Canada. Accessed September 6, 2016. Retrieved from: http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/demo62d-eng.htm

Sustainable Marine. (2016). *Tidal energy turbine platform technology.* Sustainable Marine Energy Ltd. Accessed September 19, 2016. Retrieved from: http://sustainablemarine.com/technology

Taber, J. (November 16, 2014). Project seeks to harness – and harvest – the force of Fundy. *The Globe and Mail*, newspaper. Accessed February 15, 2016. Retrieved from: http://www.theglobeandmail.com/news/national/project-seeks-to-harness-and-harvest-the-force-of-fundy/article21609715/

Tocardo. (2016). *Tidal, river, and ocean current turbines.* Tocardo B.V. Accessed December 1, 2016. Retrieved from: http://www.tocardo.com/

Torrens-Spence, H., Schmitt, P., Mackinnon, P., & Elsaesser, B. (2016). Current and turbulence measurement with collated ADP and turbulence profiler data. Current, Waves and Turbulence Measurement, 2015, IEEE/OES Eleventh. doi: 10.1109/CWTM.2015.7098131

UNEP. (n.d.) *Cities and Coastal Areas.* United Nations Environment Programme. Accessed November 9, 2015. Retrieved from: http://www.unep.org/urban_environment/issues/coastal_zones.asp

University of Alaska-Fairbanks. (n.d.) *Alaska Hydrokinetic Energy Research Center*. Accessed January 29, 2016. Retrieved from: http://acep.uaf.edu/programs/alaska-hydrokinetic-energy-research-center.aspx

UARB. (2016) *Renewables to Retail tariffs approved, as amended in this decision* (2016 NSUARB 33, M06214). Halifax, Nova Scotia: Nova Scotia Utility and Review Board.

Vazquez, A. & Iglesias, G. (2015). Device interactions in reducing the cost of tidal stream energy. *Energy Conversion and Management, 97,* 428-438.

Verdant Power. (2016). *Kinetic Hydropower System.* Verdant Power Inc. Accessed December 1, 2016. Retrieved from: http://www.verdantpower.com/kinetic-hydropower-system.html

Weis, T.M., & Ilinca, A. (2010). Assessing the potential for a wind power incentive for remote villages in Canada. *Energy Policy, 38,* 5504-5511.

Wiersma, B. and Devine-Wright, P. (2014). Public engagement with offshore renewable energy: a critical review. *Wiley Interdisciplinary Reviews: Climate Change 5,* 493-507. doi: 10.1002/wcc.282

Withers, P. (November 22, 2016). *Massive tidal turbine in Bay of Fundy generating electricity for 1st time.* CBC News. Accessed December 1, 2016. Retrieved from: http://www.cbc.ca/news/canada/nova-scotia/tidal-power-bay-of-fundy-turbine-electricity-emera-hydro-1.3862227

Wright, G. (2014). Strengthening the role of science in marine governance through environmental impact assessment: a case study of the marine renewable energy industry. *Ocean & Coastal Management, 99*, 23-30. doi: 10.1016/j.ocecoaman.2014.07.004

Wright, G. (2015). Marine governance in an industrialised ocean: A case study of the emerging marine renewable energy industry. *Marine Policy, 52*, 77-84. doi: 10.1016/j.marpol.2014.10.021

Zeriffi, H. (2007). Making small work: Business models for electrifying the world. Working paper #63, Program on Energy & Sustainable Development, Freeman Spogli Institute for International Studies, Stanford University, California. Accessed Nov 10, 2015. Retrieved from: http://fsi.stanford.edu/publications/small

Chapter 3: Financial modeling to determine the cost thresholds at which small-scale tidal energy projects could prove profitable in Nova Scotia and Nunavut, Canada

3.1 Introduction:

Over the past decade and a half, a great deal of investment has flowed into research and development of in-stream tidal energy. The United Kingdom and the Canadian province of Nova Scotia, in particular, have invested heavily in studies and technologies that will allow them to take advantage of their rich natural tidal resources. However, to-date, much of this R&D has been focused on utility-scale projects (MacGillivray, Jeffrey, Winskel & Bryden, 2014; MacGillivray, Jeffrey & Wallace, 2015), although recent studies have called into question the economic viability of such devices under current industry conditions (MacGillivray et al., 2014; 2015; MacDougall, 2015). MacGillivray et al. (2015) and Roberts et al. (2016) have called for an increased focus on small-scale tidal energy development in order to reduce early-phase industry risk and costs. Such an approach (MacGillivray et al., 2015) would require a large number of small devices and installations to be deployed over time to begin the tidal energy sector's path to commercial competitiveness; the premise is to follow the development pathways of previously successful energy technologies including coal plants, natural gas turbines, and wind turbines (Garrad, 2012; MacGillivray et al., 2015). Such an approach would obviously require the development of small-scale devices that could be deployed in the requisite numbers.

Yet a working definition of what qualifies as a "small-scale tidal energy device," or a "small-scale tidal energy installation," has not been presented explicitly in the literature. Given the wide variety of devices presently on the market, establishing this definition is not a trivial task. However, the review conducted by Roberts et al. (2016) focused specifically upon small-scale tidal development options. The commercially available in-stream tidal energy devices reviewed by Roberts et al. range in capacity from 35 to 1000 kW. Devices not reviewed in Roberts et al.'s study show that there has been a recent glut of relatively large tidal energy devices entering the testing and deployment stage, with some landmark projects deploying what their proponents call "utility-scale" turbines in 2016. The Meygen (2016) project in Scotland, the OpenHydro (2016) deployment in Paimpol-Brehat, France, and Cape Sharp Tidal deployment in Canada

(Withers, 2016) serve as examples of these utility-scale projects. In all three cases, the turbines deployed have rated capacities not less than 500 kW, and both Meygen and the Cape Sharp project have rated per-device capacity between 1 and 2 MW. Thus, the tidal industry itself has set a workable range for "utility-scale tidal energy devices:" 0.5-2 MW, with these early projects having additive capacities ranging from 1 to 6 MW. Should turbines greater than 2 MW be created, they would by nature extend the definition of "utility-scale" for tidal energy projects upwards.

From this information, we choose to define small-scale tidal energy devices to be those of less than or equal to 150 kW rated capacity, deployed either singly or in arrays. This choice is made specifically to allow small-scale tidal arrays to be constructed without breaching the lower (apparent) limit of the industry's championed utility-scale devices—500 kW. Examples of existing devices in this range include Schottel's (n.d.) SIT InStream Turbines, ranging in capacity from 50 to 74 kW and Verdant Power's (2016) 35 kW Gen5 turbine, among others. Obviously, such devices could be deployed in numbers sufficient to make up a utility-scale array; indeed, Schottel intends to do exactly that with their 40-turbine, 2.5 MW Triton platform (Black Rock Tidal Power, 2016), and Verdant Power has been licensed for an array of 30 turbines operating at their Roosevelt Island test site in New York City since 2012 (Federal Energy Regulatory Commission, 2012). Thus, an upper limit on a "small-scale" renewable energy installation must be selected. Based upon the literature (Pepermans, Driesen, Haesendonckx, Belmans & D'haeseleer, 2005; Hain, Ault, Galloway, Cruden & McDonald, 2005; Allan, Eromenko, Gilmartin, Kockar & McGregor, 2015), a common dividing line between "utility" and "small" scale energy projects is the range between 500 kW and 1 MW. For this thesis, the lower of these values (500 kW) is taken as the cut-off between a "small" and "large" scale facility. Hence, "small-scale tidal device" shall specifically refer to a single energy generator with capacity less than or equal to 150 kW, while "small-scale tidal facility" and "small-scale tidal installation" will refer to a collection of such generators with cumulative capacity not exceeding 500 kW.

While MacGillivray et al. (2014; 2015) have suggested small tidal turbines could generate knowledge useful to larger-scale projects, these turbines have potential applications beyond simply informing future utility-scale developments. Many sites with large tidal energy resources exist in areas that have relatively low electricity demands; a device developed for servicing a traditional-scale utility grid would prove oversized and overpriced in such locations. The Canadian Arctic is one such example; it is estimated to have at least 33,591 MW worth of extractable tidal power (Tarbatton & Larson, 2006), but is very sparsely populated, with little infrastructure to take advantage of this resource. Similar environments, with rural communities lacking grid access close to tidal environments, exist in Malyasia (Hassan, El-Shafie & Karim, 2012), Indonesia (Blunden, Bahaj & Aziz, 2013), and elsewhere. Many communities in such remote areas were either connected to a national electricity grid at great cost or are reliant upon off-grid systems, often diesel generators. In the latter case, due to their remoteness, the price of shipping diesel in for power can be excessive. Canada's remote arctic communities serve as examples of this reliance, with electricity prices for the most part exceeding $0.80/kWh (Qulliq Energy, 2016), compared to prices in the southern provinces of the country varying from $0.07/kWh to $0.15/kWh. Similar prices exist in many remote areas of less developed countries (Hassan et al., 2012; Blunden et al., 2013), especially small island nations (Singh & Ephraim, 2016)—though some governments choose to alleviate the effects of these prices through subsidies that reduce the consumer's price (Lim, Lam & Hashim, 2015).

No tidal technology has yet proven grid-competitive. Yet these off-grid, coastal markets offer the tidal industry an opportunity to potentially compete directly with existing electricity systems (or supplement them) while still generating knowledge on device effectiveness, impacts, and possible improvements. Though some emerging firms in the tidal turbine industry have recently put forward designs that may suit off-grid communities, as noted, most firms remain focused on utility-scale devices with capacities ranging from 1 to 2 MW. The competitive advantage represented by the relatively early-design-phase revenue stream of off-grid community tidal projects thus remains unclaimed, to-date.

Few studies have addressed why this may be the case, although MacGillivray et al. (2015) and MacDougall (2015) have suggested that there is presently too much uncertainty in the tidal sector for projects to prove financially sound as investment opportunities. Similarly, others (Kerr et al., 2014; Wright, 2014; 2015; Laws & Epps, 2016; Roberts et al., 2016) have suggested that the level of uncertainty in the industry results in limited public support, cautious government policy support mechanisms, and high risk for investors. This is a result of the sheer number of unknowns about project specifics, with very little known about the employment generated, device lifetimes or the environmental impacts of tidal projects. As most investors are generally assumed to be risk-averse (MacGillivray et al., 2014), this limits investment in projects, lengthening the time from initial design to first field testing, and in turn from field testing to first utility-scale projects. These unknowns also apply to small-scale projects (Roberts et al., 2016). Calls for further research into small-scale tidal technology has been made (MacGillivray et al., 2014; 2015; Hatcher, 2015; Roberts et al., 2016), both for the sake of the technology itself (Hatcher, 2015; Roberts et al., 2016) and for the knowledge such research may generate that could be transferable to utility-scale projects (MacGillivray et al., 2015).

This work attempts to contribute to this needed body of work by investigating the hypothetical project cost ceilings for small scale operations in two environments against a backdrop of the existing marketplace for small-scale energy generation. Financial modeling and optimisation for two specific cases was carried out: (1) providing power to a regional, well-supplied grid system from a low-intensity tidal site in Cape Breton Island, Nova Scotia, and (2) supplementing and partially replacing diesel generation for a coastal community in the Canadian arctic territory of Nunavut. The results of this modeling effort, carried out in the @Risk software extension for Excel, made by Palisade Corporation (2016), are presented in Section 3. This model was developed with the intent of answering three questions, based on several assumptions. Those questions are:

1) What is the per-device cost-per-kW ($/kW installed) target tidal device developers should pursue to be competitive in the considered markets, under the described policy conditions?
2) What is the effective electricity rate ($/kWh) that a project must earn in order to be profitable over the assumed contract period of 15 years?
3) What is the internal-rate-of-return (IRR) (%) for small-scale tidal energy projects that, at the least, break even under the assumptions made?

All data used in these cases is gathered from other studies, cited in the following sections. While the cost considerations put forward are specific to the Canadian context under which they were developed, they should prove largely transferable to other political contexts, and apply equally well after currency conversion and policy adaptation.

3.2 Methods

3.2.1 Parameterization of a Tidal Energy Installation in Financial Terms

In order to model the viability of small-scale tidal energy facilities, we must first decide how this viability will be measured. As we wish to examine the financial viability of projects, we must determine the factors that drive a project's ability to generate revenue. The foremost of these is the installation's size, S (Equation 3), measured in kW; this is a simple product of the number of devices deployed, N (no units), and the per-device capacity, C_d (in kW). Next, we must know the capital cost of a project. While there are some fixed costs associated with installing devices in the environment (e.g. power line and pole erection, transformers and switchgear, resource assessment), which will be discussed later, for the moment we are interested only in the cost of the devices themselves. Device capital cost is determined by Equation 4, in which M is the capital cost, D_c is the per-kW-installed cost of devices, and S is again the installation size (kW). We must also determine how much electricity (E, in kWh) the facility generates in a given year; this is determined by Equation 5, wherein S is again the size of the facility and O_H is the total number of operating hours the facility has that year. Finally, we must know the annual revenue generated by a project in a given year t, R_t ($), to determine the balance of revenues and expenditures in each year of the project's life. Annual revenue is determined by Equation 6, in which E is taken from Equation 5, and E_R ($/kWh) is the effective rate the project's electricity is sold for.

$$S = N * C_d$$

Equation 3: Installation Size

$$M = S * D_c$$

Equation 4: Capital Cost of Devices

$$E = S * O_H$$

Equation 5: Annual Electricity Generation

$$R_t = E * E_R$$

Equation 6: Annual Revenue

While these figures may be estimable or known for other, well-proven, widely-applied energy technologies, in the case of tidal energy (and especially small-scale tidal), there remains a great deal of uncertainty over the per-kW capital costs of projects, the number of operating hours a facility will have in a year, and other factors. Similarly, the appropriate size of a project—both in terms of number of devices and the size of the devices themselves—will be a location- and context-specific question, as any tidal energy installation must be designed to both meet local electricity needs, and respect local environmental (and regulatory) limitations. The effective price that producers can sell their electricity for is also a context-specific question, dependent upon a number of factors, including local electricity prices, the availability of government-run renewables incentives programs such as feed-in tariffs, and the willingness of customers (whether the grid or private entities off the grid) to pay rates that make the project viable.

In light of these uncertainties and context-specific questions, an approach that allows consideration of a range of possible values for these variables is needed. The approach selected for this study was Monte Carlo simulation; the reasons for this are detailed in Section 3.2.2, below.

3.2.2 Financial Viability Scenario Modeling in @Risk

A financial model of a potential small-scale tidal energy project was designed, using the @Risk extension for Microsoft Excel (Palisade Corporation, 2016); specifically, this model utilises the RiskOptimizer functionality. This software package was used to generate randomised inputs for the uncertain values (N, C_d, D_c, O_H, and E_R) in Equations 3, 4, 5, and 6. These randomised inputs were generated within user-specified ranges, and Monte Carlo simulation was carried out with these inputs through a user-set number of iterations to determine the optimal values of these variables, based on the financial calculations in these equations, and Equations 7 and 8, below. In the case of this study, the model developed was designed to with conditions specified for four values that describe the financial viability of an energy project:

(1) the Net-Present Value (*NPV*) of a project;

(2) the Levelised Cost of Energy (*LCOE*) of a project;

(3) the project's Internal Rate of Return (*IRR*); and

(4) the effective rate (E_R) a project's electricity must be sold for under the specified conditions in order for the project to be financially viable.

Note that E_R can be either the local price of electricity, or an incentive rate offered by government policies (e.g. a feed-in tariff); it is in effect the rate in the model that producers are allowed to charge for their electricity. As the effective rate is determined through optimisation, rather than a direct calculation of model inputs and outputs, it is explained later. *NPV* and *LCOE* are, respectively, calculated by the formulae in Equations 7 and 8. As *IRR* cannot be solved for analytically, it does not have an equation; instead, IRR is the *r* value (found via trial and error or algorithmic calculation) for which NPV is 0 – meaning a "breakeven" point for the investor.

$$NPV = \left(\sum_{t=0}^{n} \frac{R_t - C_t}{(1+r)^t} \right) - I - D$$

Equation 7: Net Present Value

$$LCOE = \sum_{t=0}^{n} \frac{I + D + (O\&M)(1+r)^{-t}}{E(1+r)^{-t}}$$

Equation 8: Levelised Cost of Energy

In the above equations:

- R_t is the revenue generated in year, *t*, determined by Equation 6.
- *r* is the discount rate, set to 10%.
- *n* is the project lifetime (*n*=15 years).
- *I* is the initial investment cost of the project ($CAD), which is the sum of baseline installation costs, *i,* (including site preparation, resource assessment, power line and transformer construction, etc.) and the total device-related capital cost, *M*, from Equation 4. The installation costs are assumed by case study, and explained later; device-related costs are determined via the *RiskOptimizer* algorithm.
- *O&M* is the annual operations and maintenance cost ($CAD); this is the sum of annual labour and breakdown costs. Both of these values are explained below.
- *D* is the decommissioning cost ($CAD), assumed to be equal to the non-device-related installation costs. This value is not discounted, as it is assumed to be paid in full before the project can enter the water; this is explained below.

- E is the annual electricity generated (in kWh), determined by Equation 5.

In the LCOE equation, it is worth noting that both the operations and maintenance and electricity generated terms are discounted; this is done to account for the declining value of money over time (and, as a commodity, the similarly declining value of a kWh of electricity). This is in line with the US National Renewable Energy Laboratory's [NREL] established practice for calculating the LCOE of different energy technologies (Short, Packey & Holt, 1995). We make one departure from the NREL's practice: due to the as-yet unproven nature of tidal energy technologies, we assume all decommissioning funds must be set aside at the outset of the project. That is, "decommissioning" is treated as an up-front, paid-in-full cost, rather than a discounted future cost. This treatment is justified due to the difficulty likely to be associated with securing insurance for unproven technologies. By assuming all funds for decommissioning are set aside as an initial cost, we are making the assumption that developers are (by choice or due to regulation) hedging against their projects failing while operating without insurance. Though these funds would most likely be set aside in a bank and thus earn interest, in this model, this interest accumulation is ignored for two reasons. First, the assumption is made that this cost is paid in full; it is not recoverable regardless of the project's success or failure, except through electricity sales. Second, such accumulation is unlikely to occur at a greater rate than the 10% discount rate selected; as such, the profit from this interest would be small compared to the degree to which it is discounted.

While these equations are well-established, the necessary inputs to determine them—that is, the variables calculated by and used within Equations 3 through 6—in the context of a nascent field like tidal energy are not. As such, we have elected to utilise six of these uncertain parameters to design our model, which then went through the *RiskOptimizer* optimisation algorithm to determine the values for which projects could be financially viable under the conditions imposed.

1) The per-kW cost of the tidal energy device itself, D_c, is defined as an even distribution from a minimum value of \$3000/kW to a maximum of \$6000/kW.
2) The installation cost of the tidal energy facility, i, less device costs, including all required earthworks, grid connection gear, transformers, moorings, etc. (assumed fixed; \$1,250,000 in Cape Breton, \$1,500,000 in Nunavut.)

3) The assumed decommissioning cost of the whole facility, D (assumed to be equal to the installation cost, and paid in full before project operation begins).
4) Annual operating hours, O_H, generated for each year in a fifteen year assumed project lifetime. O_H was modeled as a triangular distribution with minimum 2628 hrs, peak 3066 hrs, and maximum 3504 hrs, corresponding to 30%, 35%, and 40% capacity factors, respectively. A triangular distribution was selected due to the nature of the *@Risk* program; it allowed a "peaky" distribution to be defined, whereas a normal distribution or similar selection would have had very long tails (including, potentially, \$0/kW), due to the requirement in the software to define standard deviations, rather than minima and maxima.
5) A discount rate, set to 10% for both case studies.
6) Project size, S, in kW. This was determined via Equation 3, and required the model to first generate both the number of turbines (N), and the size of turbines to be deployed (C_d). C_d was defined as a discrete distribution with minimum 50 kW and maximum 150 kW, and a 10 kW step-change; N could be of either 1, 2, 3, or 4 turbines.

The assumptions and considerations above that are defined as distributions (i.e. all but the discount rate) are summarised in Table 1, below.

Table 1: Distributions Used for Generating Values of E_R, C_d, N, and O_H

Parameter	Distribution Type (notes)	Minimum Value	Maximum Value
E_R (\$/kWh), Cape Breton	Even	0.15	0.654
E_R (\$/kWh), Nunavut	Even	0.15	0.896
C_d (\$/kW)	Triangular (peak: 4500)	3000	6000
N (#)	Even (step change: 1)	1	4
O_H (hrs)	Triangular (peak: 3066)	2628	3504

To better assess the costs associated with operation of the facilities modeled, two steps were taken. First, it was assumed that for small-scale tidal facilities, persistent maintenance and labour needs would be low, and thus likely to be contracted out to third parties external to the project operator. Thus, annual labour costs were assumed to be a retainer fee, set at $60/hr for 10 hrs per week, year round (that is, $31,200/yr, before discount rates are applied). Second, a simplified breakdown model, based on the work of Nowe (2014) (itself an extension of Maples, Saur, Hand, van de Pietermen & Obdem's (2013) work on offshore wind turbine breakdown frequency), was implemented. Nowe (2014) used four breakdown categories: remote resets (where the only cost is lost generation time), inspections with small repairs, small part replacements, and replacement of large parts.

Following Nowe (2014), the breakdown model assumed a set frequency of occurrence for three categories of device failure, and assigned set costs as a percentage of device costs associated with repairing those failures based on the equipment and sea vessels required to do so. The choice of only three breakdown categories is a result of the choice to merge the "inspection and small repair" and "replacement of small parts" categories Nowe, due to the relative simplicity of small-scale tidal devices compared to the utility-scale turbines considered by Nowe. Nowe's breakdown rate for inspections was used for normalisation; that is, as Nowe considered an 8-turbine array, the fixed number of breakdowns Nowe assumed per array per year, it was necessary to normalise this per-array breakdown frequency into a percent-chance of occurrence per device present. Thus, the normalised breakdown rates reported in column 5 of Table 2 are one-eighth the per-array rates used by Nowe (reported in column 2). The exception to this is the Large Parts repair category; as a 0.25/array chance would translate to approximately a 3.1%-per-turbine chance of such a repair being necessary after normalisation, a value of 10% was used instead to increase the potential for such breakdowns and thus ensure a greater likelihood of accounting for such breakdown costs in our model.

Further, because of the limited physical size of small-scale tidal devices compared to utility-scale devices (Roberts et al., 2016), it was assumed that the largest classification of vessels considered by Nowe ("jack-up vessels") would not be necessary in maintenance efforts for small tidal installations; thus, fixed repair costs are lower for the replacement of large parts category. As Nowe (2014) modeled an eight turbine, 10 MW tidal array (i.e. 1.25 MW/turbine) in the Bay of Fundy, slight adjustments of Nowe's figures were necessary; for this model, Nowe's figures were simply normalised to a probability-per-turbine. Nowe's original figures, along with our adjusted values, can be found in Table 2, below.

Table 2: Breakdown categories, their probabilities, and associated costs used by Nowe (2014) and in this study

Type of Repair	**Nowe's (2014) breakdowns (# per farm per year)**	**Nowe's (2014) costs**		**Modeled per-turbine normalised* breakdown chance/year (%)**	**Modeled Costs per Breakdown**	
		Parts (% of device)	Vessels, Labour, Revenue Loss ($)		Parts (% of device cost)	Vessels, Labour, Revenue Loss ($)
Remote Reset	5	0	2 hrs revenue	62.5	0	2 hrs revenue
Inspections & Small Parts	2.75	1	240,170	34.375	1	4391
Large Parts	0.25	10	710,338	10	10	105,000

* - Note: while remote resets and inspection & small part replacements are normalised versions of Nowe's figure, a probability of 10% was assigned to large repairs, rather than a normalised probability. This choice was made in order to ensure a high probability of at least one large parts repair per turbine per 15 year period, and thus to make the model more conservative.

Within the model, a check for the number of turbines generated in a given simulation iteration was built via Excel's IF function; for every year in the iteration, each turbine present (whether one or four), one random number between 0 and 1 was generated (via Excel's RAND() function) for every breakdown category. This random number was then compared with the thresholds established in Table 2 with further IF statements. If the random number generated was less than the probability of that type of breakdown, the associated cost from column 7 of Table 2 was assigned to that year; if the random number exceeded the probability threshold for that type of breakdown, the turbine did not break down in that way that year, and a cost of $0 was assigned. This is shown by Equation 9, below, which illustrates the Boolean logic check performed to assign breakdown costs for a given turbine in a given year. Note that here, *RR* is short for Remote Reset, *I&SP* for Inspection & Small Parts, and *LP* for Large Parts. Also note that the IF statements are written such that the term before the first comma is the check statement, the term(s) between the two commas are the value assigned if that check returns an affirmative response, and the final 0 in each statement means a cost of $0 is assigned, as that failure type did not occur in that year. This method of breakdown cost modeling implicitly assumes that no more than one breakdown of each type can occur per turbine in each year. However, as a value is generated for each turbine in a given iteration of the model, different turbines can undergo the same type of breakdown in each year.

$$Breakdown\ Cost = IF(RAND(RR) \leq 62.5{,}2 * S * E_R, 0) + IF(RAND(I\&SP) \leq 34.375{,}4391{,}0) + IF(RAND(LR) \leq 10{,}105{,}00{,}0)$$

Equation 9: Annual Per-Turbine Breakdown Cost Summation

It must here be noted that these cost figures include several assumptions regarding the types of vessels and equipment needed to repair a small tidal energy device. Most notably for this model, it was assumed that should a small turbine be irreparably damaged, replacing it would immediately make the project financially unviable. As such, the "replacement" category of failure used by Nowe (2014) and Maples et al. (2013) was excluded from the @Risk model developed. This exclusion is justified on the grounds that most small-scale tidal energy devices would not be likely to be deployed in waters capable of causing significant damage to them. Further to this, including a random chance for many iterations of the model to prove unviable (that is, fail one or more of the viability conditions defined in Table 3) could significantly bias the results of the study; while total device failure is certainly a condition worthy of considering in project planning, it is not a consideration that helps to understand the conditions under which small scale projects may prove viable if a "safe" operating environment is already known. This model also makes the assumption that devices have no insurance, as noted earlier, due to the unproven nature of tidal energy devices; therefore, all mechanical failures, whether due to construction or exogenous events (e.g. collisions) qualify as the same types of breakdowns. Further, the costs of breakdowns and parts replacements (and dismantling of the project for removal during decommissioning) fall entirely on the project proponent. Given our focus on establishing baseline conditions for small tidal projects' viability, this exclusion is believed to be reasonable.

With the basic model equations known and assumptions in place, we utilised @Risk's RiskOptimizer (Palisade Corporation, 2016) to attempt to minimise the NPV of the modeled projects—and thus obtain an idea of the limits on different financial parameters that would determine whether a project could prove viable. The RiskOptimizer function allows the program user to input several conditions to meet as one or more input variables are randomly modified through user-specified ranges for a set number of trials. For this study, several conditions were set to separate "valid" trials from invalid ones. First, the bottom quartile of mean NPV values was required to be greater than 0; a condition necessary, given the minimisation target for the mean NPV, to avoid the model returning non-viable project results (i.e. mean NPV<0 for all cases). Second, as a guard against simulations with unrealistically high device failure counts (e.g. multiple "major repair" events every year), an upper limit was placed on the device LCOE: $1.00/kWh. Third, to exclude results bias towards maximum-sized facilities at maximum effective electricity rates, an upper limit of 20% on installation IRR was set. This limit is a result of our desired end-result: uncovering the conditions for *minimum viability* in project planning and design, not the highest-return conditions, for small-scale tidal energy projects. Thus, we have chosen to exclude unusually high-return cases. Finally, a location-specific installation size limit was imposed on projects, based upon available resource assessments and modeling data. In the Cape Breton Island case, this maximum was set to 360 kW; in the Nunavut case, it was set to 500 kW. All of these conditions are summarised in Table 3.

Table 3: Validity Conditions Placed on Model Parameters

Parameter	**Condition Imposed in *RiskOptimizer***
LCOE ($/kWh)	$LCOE \leq 1.00$
IRR (%)	$IRR \leq 20$
Bottom 25% of NPV ($)	$NPV_{B25\%} \geq 0$
S (kW), Cape Breton	$S \leq 360$
S (kW), Nunavut	$S \leq 500$

With these conditions set, RiskOptimizer was set to modify the effective electricity rate, number of tidal devices, and device size variables. Table 2, below, provides the maximum, minimum, and step-change values allowed for each of these variables; the reasons for the selected effective electricity rates and the maximum device sizes are expanded upon in Section 3.2.2. RiskOptimizer was then used to run 1000 simulations (each with 1000 internal iterations) to attempt to find an optimal combination of effective electricity rate, device size, and number of devices to achieve a financially viable project under the given conditions. The results of these simulations are outlined in Section 3.3.

3.2.3 Case Study Site Selection

Two case studies were chosen for application of this model. The first, located at Carey Point in Cape Breton Island, Nova Scotia, Canada, was selected due to being the most energetic of the sites considered in the province's official Strategic Environmental Assessment of the island (McMillan, Trowse, Schillinger, Hay & Hatcher, 2012). Based upon that assessment's finding that a 10 m diameter horizontal axis turbine with water-to-wire efficiency of 40% would have access to a maximum of 367 kW of extractable power at this site (McMillan et al., 2012), 360 kW was used as the upper limit of installation size for this case. Cape Breton Island, and Nova Scotia in general, are particularly worth considering as proving grounds for small-scale tidal devices because the province has several policies to support tidal energy development. Most prominently, these include a feed-in tariff (FIT) program for developers (currently limited to installations >500 kW), offering rates between \$0.42 and \$0.53/kWh (NSDOE, 2016) and designated Marine Renewable Electricity Areas in provincial planning laws (Marine Renewable-energy Act, 2015). Nova Scotia previously offered a higher incentive of \$0.654/kWh to small-scale tidal energy projects, defined as those with a maximum capacity of 500 kW, through its Community Feed-in Tariff (COMFIT) program (Province of Nova Scotia, n.d.). Though the COMFIT program was canceled in 2015, if there was strong support for further development of tidal energy at multiple scales – as has been demonstrated by previous Provincial governments, it is not unreasonable to assume that it could be reinstated; as such, \$0.654/kWh was used as the upper limit for the effective electricity rate in Nova Scotia.

The other case is a hypothetical deployment of a small tidal turbine in one of several remote coastal communities in Nunavut that currently rely on costly diesel generators for their power. The Canadian Ocean Energy Atlas (Tarbotton & Larson, 2006) identified several regions in Nunavut as having high tidal energy resources, especially around the Hudson Strait, where more than 29,000 MW of tidal power could be safely harvested. Nunavut communities in this area include Cape Dorset (population: 1363), Kimmirut (population: 455), and Coral Harbour (population: 834) (Birjandi & Bibeau, n.d.). However, no field study of the tidal resource in Nunavut or the Hudson Strait has, to-date, been conducted; the results from Tarbotton and Larson (2006) are from models. Thus, unlike in the Cape Breton case, this study is unable to choose a specific point community or study area in Nunavut; instead, a generic "Nunavut case", assumed to be in a community along the Hudson Strait, is modeled.

Due to the remote and isolated nature of the grid of the three communities identified, it is unlikely that the massive potential of the local tides will ever be fully harnessed, due to the exorbitant cost of the grid extensions necessary to bring that electricity to a market capable of using it (e.g. Southern Canada or the United States). Thus, small-scale tidal devices are of greater local interest, as contributors to a community's grid. Currently, the average cost of electricity in Nunavut is $0.8926/kWh; this provides the upper limit for the effective electricity rate in this model case.

3.2.4 A Note on Installation & Decommissioning Costs

It was assumed that these costs would scale linearly for devices at each site, in accordance with the rated output of the turbine; this may or may not prove to be a valid assumption in practice. Economies of scale would traditionally suggest that larger turbines will, in fact, have lower installation costs relative to their size and lifetime generation capacity than smaller turbines. This is particularly true with different grid connection considerations, different transportation costs, and variance in local contractor rates between sites, especially between jurisdictions. For simplicity, a conservative estimate was made for these costs in both case study locations: $1,250,000 in Cape Breton, and $1,500,000 in Nunavut. As this study is a first estimate of potential viability conditions for small-scale tidal projects, this assumption is necessary, but should be adjusted for consideration of more detailed analysis in the future, when more data on site preparation and equipment costs for tidal energy projects is available.

3.3 Results

This section provides tables and figures that detail the input values and results from the RiskOptimizer simulations run for this study; discussion of these results follows in Section 3.2. All simulations were run with RiskOptimizer set to minimise the Mean NPV of the tidal project being considered. Table 4 provides the number of valid trials that resulted from both the Nunavut and Cape Breton. Table 5 provides the best-fit case and median case results for the Carey Point, Cape Breton case. Table 5 provides the same information for the more generic case of Hudson Strait communities in Nunavut. Finally,

Table 6 shows the share of total fixed costs (i.e. excluding operations, maintenance, and labour) represented by turbine device costs themselves in the best-fit and median results for both the Cape Breton and Nunavut cases. Figures 4 and 5, respectively, depict the range of NPV values in the 1000 iterations of the best-fit trial for the Cape Breton and Nunavut cases. An explanation of why only the best-fit trial is reported is below.

Table 4: Summary of trial counts

Case Site	Number of Trials	Number of Valid Trials
Nunavut	1000	374
Cape Breton Island	1000	259

Table 5: Best and median case simulation results for Minimum Mean NPV, Cape Breton

Case	Device cost ($/kW)	Device Size (kW)	# of Devices	Effective Electricity Rate ($/kWh)	NPV ($)				IRR (%)	LCOE ($/kWh)
					Mean	Max	Min	Std Dev		
Best	3131.81	80	4	0.600	122,075	646,877	-679,354	191,183	19.4	0.556
Median	3120.70	80	4	0.600	139,370	678460	-570558	200311	18.6	0.574

Table 6: Best and median case simulation results for Minimum Mean NPV, Nunavut

Case	Device cost ($/kW)	Device Size (kW)	# of Devices	Effective Electricity Rate ($/kWh)	NPV ($)				IRR (%)	LCOE ($/kWh)
					Mean	Max	Min	Std Dev		
Best	3184.92	110	2	0.770	94,185	492,245	-616242	160,935	19.3	0.748
Median	3233.08	110	2	0.775	111,826	529,824	-488699	159,926	19.1	0.753

Table 7: Fixed costs of installation, decommissioning, and devices, with shares of total costs

Case	Inst. Cost ($)	Decom. Cost ($)	Best Case Device Cost ($)	Median Device Cost ($)	Fixed Costs Share (Best)	Fixed Costs Share (Median)	Device Share (Best)	Device Share (Median)
Cape Breton	1,250,000	1,250,000	1,002,179	998,624	71.4%	71.5%	28.6%	28.5%
Nunavut	1,500,000	1,500,000	700,682	711,277	81.1%	80.8%	18.9%	19.2%

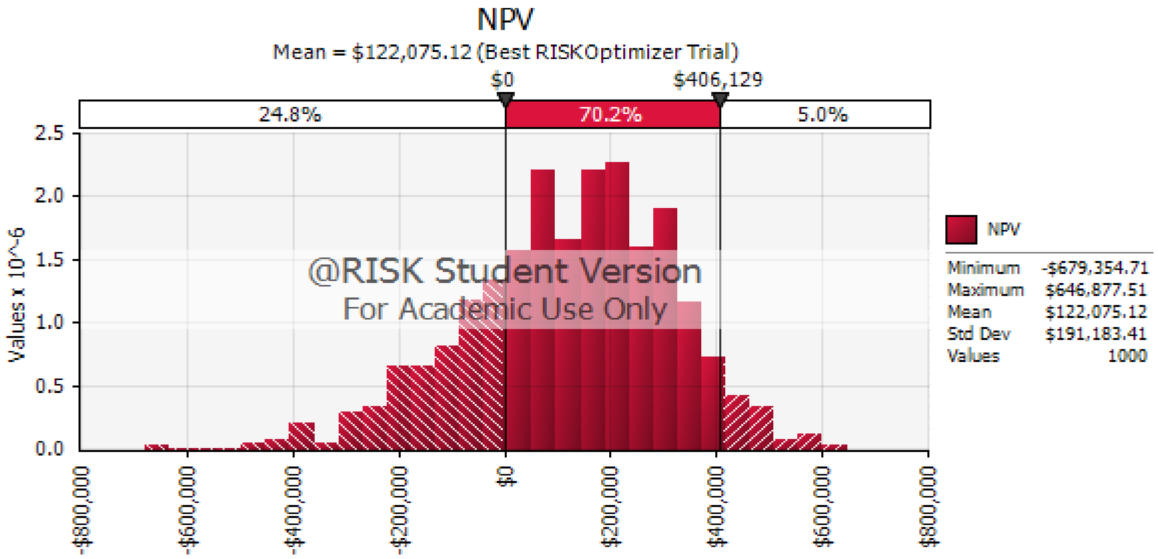

Figure 4 – Best-case NPV trials for Carey Point, Cape Breton

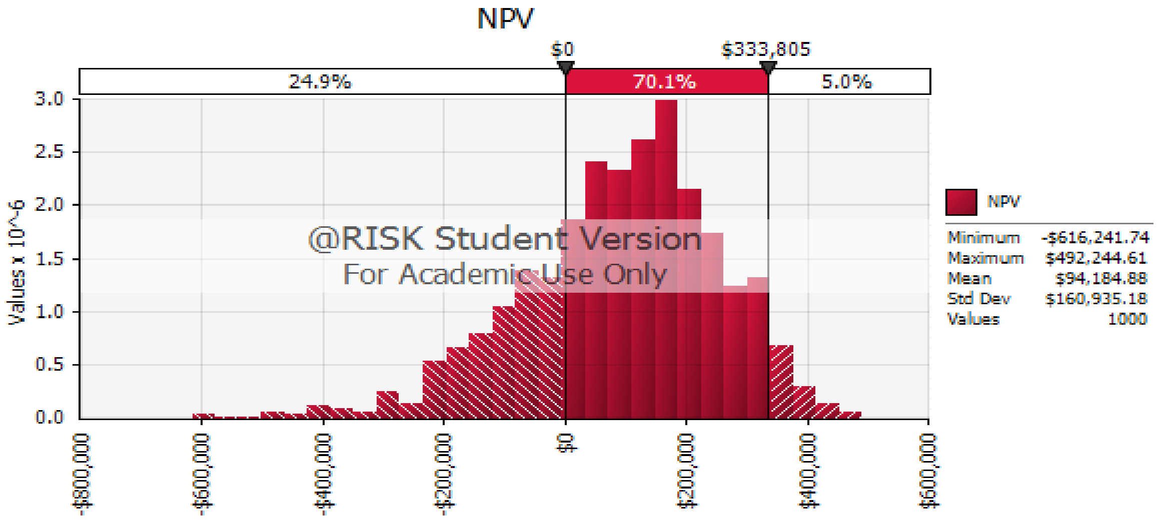

Figure 5 – Best-case NPV trials for Nunavut

The results of our model suggest that small-scale tidal devices may prove to be financially viable in both Nunavut, and Cape Breton Island. Figures 4 and 5 make clear that the bottom-quartile NPV exclusion condition that was set was met in both Nunavut and Cape Breton. As such, we can state that our model has found minimum financial parameters for projects to have at least a 75% chance of financial success. Although the IRR rates are rather high compared to most projects, it must be noted that this is a result of two factors. First, our model uses a significant discount rate of 10%; the US National

Renewable Energy Lab recommends (Short et al., 1995) the use of the US Office of Management and Budget's [OMB] discount rates for government investment be used by renewable energy project planners. For 2016, the OMB's recommended nominal discount rate for a 20 year project is 3.2% (OMB, 2016). We justify this higher discount rate due to our intent to design a conservative estimate of feasible projects, as a higher discount rate entails a greater emphasis on near-term results. Second, this model was built with nominal cash flows, rather than real flows indexed to a specific year's currency value; consequently, a higher discount rate is required to offset this indexing, and the internal rate of return similarly adjusts upwards.

The median results of the models are similar to the best-case results. This is especially true with regard to effective electricity rates, which vary from the best-fit simulations by only 0.65% in Nunavut, and do not vary from best-fit simulations in Cape Breton. LCOE values are similarly close, with median values standing within 1.04% (Nunavut) and 3.24% (Cape Breton) of the best-fit case. Median modeled device costs in Nunavut are within 1.51% of the best-fit simulation's device costs; in Cape Breton, median device costs were even closer, with less than 0.35% variance from the best-fit case. Similarly, in both the Nunavut and Cape Breton cases, the best-fit and median device size and device count variables were identical, yielding installations of two 110 kW tidal energy devices in Nunavut and four 80 kW tidal energy devices in Cape Breton. However, while these factors are similar between median and best cases, the mean, maximum, minimum, and standard deviation of NPV varied more significantly. As the model was designed to specifically minimise NPV, and thus generate the most costly project that could prove viable under the conditions set, this close agreement between median and best-fit cases suggests such project parameters have been found for both cases.

The Carey Point best-fit and median cases demonstrate +14.2% difference in the mean NPV results (Table 5); in Nunavut, this divergence is greater, at +18.7% (Table 6). The minimum NPV values vary by similarly high rates for both locations, with a divergence from median to best-fit of +16.0% in Cape Breton (Table 5) and +20.7% in Nunavut (Table 6). In contrast, the best-fit maxima in both the Cape Breton and Nunavut cases vary from the median maxima significantly less; with differences of only +4.88%

(Table 5) and +7.63% (Table 6), respectively. The standard deviation in trials within a given simulation also varies little: +4.77% in Cape Breton (Table 5), and a thin -0.630% (Table 6) in Nunavut. Notably, with the exception of a very slight decrease in standard deviation for the median case trial in Nunavut, all of these differences are increases. As such, the median cases in both locations considered indicate the most frequent expectation of the model is a greater net present value than the best-fit case small-scale tidal energy projects. Or, more simply: a project that meets or exceeds the conditions we have set can be expected to generate at least some modest revenue for its proponents over its lifetime.

It should be noted that the exact cause of the discrepancy between mean NPV, minimum NPV, and maximum NPV variances between the median and best-fit cases in our trials is somewhat obfuscated by the black-box nature of RiskOptimizer. While RiskOptimizer generates a set of output data for all trials it runs, providing the mean, minimum, maximum, and standard deviation of the target variable (NPV, in our model), it does not provide for access to the details of the 1000 @Risk trial instances that inform each RiskOptimizer trial. The program does provide access to the data for the best-fit RiskOptimizer trial (see Figures 4 and 5), but it does not allow the user to access the relevant trial data for the other 999 RiskOptimizer iterations. Consequently, informed reasoning is our only recourse to explain these divergences.

Due to the fact we are utilising a minimisation algorithm, it is very likely that the resultant best-fit case is one with the highest costs and the lowest revenues. Thus, though we cannot confirm this, we can presume a major factor in the observed divergences in NPV values between best-fit and median cases is due to the two varying factors not recorded in the RiskOptimizer outputs: annual operating hours, and annual device breakdowns. Operating hours are key for the simple reason that they determine annual revenue potential; breakdowns are noteworthy, especially the large parts category, due to their high costs. In the Nunavut case, the additional half-cent (Table 6: \$0.775/kWh vs \$0.770/kWh) earned in the median case may also be a likely contributor to this discrepancy, as this would translate to an additional dollar for every 200 kWh delivered to the grid—that is, \$1.10 for each hour of full-capacity operation. However, in the assumed annual capacity factor window (30% to 40%), this would translate to only \$2890.80 to

$3854.40 in additional revenue. These values, respectively, account for 16.4% and 21.8% of the discrepancy between the best-fit and median cases in Nunavut. Clearly, more must be at play; most likely the aforementioned variances in breakdown counts and annual operating hours. The black-box nature of the model, however, limits the degree of insight we can gain into these discrepancies.

Table 5 shows one key point regarding small-scale tidal's feasibility: the primary capital cost driver is not the devices themselves, but the required infrastructure and equipment to make them useful. This infrastructure necessarily includes grid connection equipment such as transformers, isolation connections in case of disruptions, fuse boxes, and power lines, among other things. While not necessarily a field that tidal energy device designers could exert much control over the costs of, especially given the highly regulated and standardised nature of electricity grid management, the fact that the majority of capital costs tied to projects fall in this realm is noteworthy. Device designers and project planners may be able to find ways to reduce these costs through careful design choices; here, it is simply noted that, for this model, infrastructure-related costs were assumed to make up the lion's share of the total capital costs of the project.

As shown in Figures 4 and 5, only the bottom (approximate) 25% of NPV results are losses, regardless of location. This means that in 25% of the 1000 iterations in the best-fit trial in RiskOptimizer, the projects do not pay off, as designed for in our conditions. This suggests that our model has identified small scale tidal energy facility parameters for which at least 75% of projects would prove financially successful. As median NPV values from the simulation's valid trials were generally higher, we can state that the median project outcome is likely to be more successful than the best case calculated by our optimisation process. Given that our model has been specifically designed to determine the minimum conditions for financial viability of small-scale tidal energy projects in the locations considered, then, the best-fit cases found can be taken as these minimum conditions; any project capable of outperforming these conditions should prove viable.

3.4 Discussion

The results of this model are novel in the context of the broader literature, which has for the most part considered the cost of energy from utility-scale tidal energy projects.

Two studies are relevant, however. First, Denny (2009) considered the economics of tidal energy penetration into the Irish grid, with a capacity range from 0 MW to 560 MW. Denny's findings include break-even capital costs for 15 year periods at set capacity levels across this range; the lowest of these (Denny, 2009), 80 MW, requires a €510,000/MW (about $715,000 CAD/MW) capital cost to break even within 15 years. In the 560 MW limit Denny (2009) considered, this cost falls to €210,000/MW (about $295,000 CAD/MW). As Denny's capital cost assumptions include the cost of installation, grid-connection, moorings, and other related costs, we can draw some comparison to our own results—though we must first note Denny's low- and high-deployment figures translate to $715/kW and $210/kW, respectively, in Canadian dollars. Obviously, our study has not assumed costs for small tidal devices are will approach this threshold in the near term. Per-device capital costs in Cape Breton were found to exceed $3100/kW (Table 5) before site preparation and other costs were considered; likewise, in Nunavut, per-device costs could be expected to be around $3200/kW (Table 6).

However, as Denny was considering the economics of a utility-scale tidal energy industry, and our study is an attempt to establish baseline viability parameters, the discrepancy between these costs makes sense. Given the large capacity Denny assumes Ireland might deploy, the potential effect of economies of scale may take precedence and drive costs down in that case. In contrast, this study considers only the minimum financial conditions necessary for a single tidal energy project to prove viable in isolation in Cape Breton and Nunavut. As such, costs can be expected to be higher than utility-scale systems; thus, Denny's estimates suggest our results are sound.

With respect to the Cape Breton case, MacDougall's (2015) study on the value of delaying deployment in the tidal sector in Nova Scotia should be discussed. MacDougall (2015) conducted real options analysis on the case of a 10 MW tidal energy array in the Bay of Fundy, with the intent of determining whether it was more profitable for a company to own the option to develop, but delay deployment of devices, or to pursue early entry. This was considered in the context of Nova Scotia's developmental tidal feed-in tariff, assumed to be $0.474/kWh (MacDougall, 2015). For a 10 MW array, MacDougall (2015) found that the NPV of the array's electricity sales, less costs, after a fifteen year lifetime would be about $2,600,000. However, if the option to develop was held, but investment avoided until risk was reduced, with the investment instead held in a bond with risk-free interest rate of 2.61%, an assumed 40% volatility (i.e. variance due to uncertainty) in project costs, and a leakage rate (opportunity cost) of 6.67% annually, MacDougall found that the value of delaying development was in excess of $14,700,000. That is, owning the right to develop a utility-scale tidal energy project in Nova Scotia—and securing the developmental feed-in tariff rate through such ownership—but not paying to deploy devices is more profitable than pursuing near-term utility-scale development (MacDougall, 2015).

Practically, this means that finding locations where tidal energy devices (of any size) can be deployed with reasonably near-term expectations of return may prove the best approach to governments or developers interested in encouraging rapid development of a tidal energy sector. MacDougall states this somewhat differently: "Developers may opt to pick the "lowest hanging fruit" by developing the most amenable sites and jurisdictions first, gather operating data, and gain investor confidence" (MacDougall, 2015, p. 444). Our study provides upper limits on the costs that small-scale tidal energy projects can provide returns under in the specific case of Carey Point, Cape Breton, Nova Scotia, and the more generic case of coastal settlements in Nunavut. Should any developer find a way to design a project with costs below those found in this model, they may be able to begin "picking the lowest hanging fruit," as MacDougall suggests.

3.5 Conclusions

A model has been constructed in @Risk that can be flexibly adapted to determine the minimum viability conditions for small-scale tidal energy projects in various locations. This model was applied to two case studies: one at Carey Point, in the Great Bras d'Or Channel of Cape Breton Island, Nova Scotia, Canada; and the other a somewhat more generic consideration of a small-scale tidal energy installation supporting a remote, coastal community in Nunavut, Canada (with several villages identified as possible cases for further examination in the future). The model's outcomes, though operating under many assumptions, suggest that small-scale tidal energy projects can prove competitive under the price regimes modeled—that of the average cost of electricity in Nunavut communities, and the previous Community Feed-in Tariff renewable electricity generation incentive program offered by the Nova Scotian government. Further to this, as the model was designed conservatively, with costs estimated to be very high, the results of this study provide a benchmark for future tidal energy firms interested in the small-scale tidal energy market to outperform.

This outperformance must come in the form of reduced costs. While lowering the cost of turbines themselves is a worthy effort, the non-device costs associated with projects are likely (Hammar et al., 2012) to make up a significant portion of project costs. Consequently, reducing non-device installation and decommissioning costs—through low-cost site assessment, reduced materials use, and other means—may prove necessary for small tidal installations to go forward. Therefore, cost reduction efforts must go beyond device optimisation if they are to be successful. Though this study aggregated these non-device costs into relatively homogenous categories, several areas of focus can easily be identified; mooring structures, device monitoring and maintenance methods, and resource assessment methods are all areas that could realise significant cost savings. These are each particularly worthy of investigation in the case of small tidal, where revenue—even over long terms—is likely to prove limited due to the small size of devices. Also of note is the potential of using hardier materials and improving devices' protective coatings, in order to resist damage and reducing maintenance costs.

Future modeling work in this field should disaggregate these cost factors and attempt to determine what areas of research could best contribute to accelerating the decline in small tidal device costs. Interviews and discussions with firms active in the industry may prove helpful in efforts to achieve this disaggregation, and perhaps in identifying priority areas for cost reductions. Applying this model as a first pass to estimate the required parameters for small tidal projects to prove viable in non-Canadian jurisdictions may also prove worthwhile; at the least, this model may provide a means of high-level site-screening in such cases. This model should also be revisited and updated at a time when the tidal industry is better established and the cost factors it operates upon are better understood, in order to improve its ability to act as a site-screening tool for those interested in small tidal development.

3.6 References

Allan, G., Eromenko, I., Gilmartin, M., Kockar, I., & McGregor, P. (2015). The economics of distributed energy generation: a literature review. Renewable and Sustainable Energy Reviews, 42, 543-556.

Birjandi, A. & Bibeau, E. (n.d.) *Electricity rate database.* Canadian Hydrokinetic Turbine Test Centre. Accessed May 30, 2016. Retrieved from: https://www.google.com/maps/d/viewer?mid=16fcbjgd67ufxc7Xu965EZ47haKQ&ll=63.832039437660676%2C-72.528154825&z=5

Black Rock Tidal Power. (n.d.) Technology. Black Rock Tidal Power Ltd. Accessed September 19, 2016. Retrieved from: http://www.blackrocktidalpower.com/technology/

Blunden, L.S., Bahaj, A.S., & Aziz, N.S. (2013). Tidal current power for Indonesia? An initial resource assessment for the Alas Strait. Renewable Energy, 49, 137-142.

Federal Energy Regulatory Commission. (2012). Order issuing pilot project license (minor project). Project No. 12611-005. Accessed March 29, 2016. Retrieved from: http://www.theriteproject.com/uploads/01-23-12-order.pdf

Garrad, A. (2012). The lessons learned from the development of wind energy that might be applied to marine industry renewables. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 370*, 451-471. Doi: 10.1098/rsta.2011.0167

Hain, J.J., Ault, G.W., Galloway, S.J., Cruden, A., & McDonald, J.R. (2005). Additional renewable energy growth through small-scale community orientated energy policies. Energy Policy, 33, 1199-1212.

Hassan, H.F., El-Shafie, A., & Karim, O.A. (2012). Tidal current turbines glance at the past and look into the future prospects in Malaysia. *Renewable and Sustainable Energy Reviews, 16,* 5707-5717.

Hatcher B.G. (Editor) 2015. Marine Renewable Energy: Engineering & Ocean Technology Research. Final Report, NSERC Partnership Workshop, 8-9 Dec. 2014. Bras d’Or Institute, Cape Breton University, Sydney, N.S. 25pp.

Kerr, S., Watts, L., Colton, J., Conway, F., Hull, A., Johnson, K., Jude, S., Kannen, A., MacDougall, S., McLachlan, C., Potts, T., & Vergunst, J. (2014). Establishing an agenda for social studies research in marine renewable energy. *Energy Policy, 67*, 694-702.

Laws, N.D. & Epps, B.P. (2016). Hydrokinetic energy conversion: Technology, research and outlook. *Renewable and Sustainable Energy Reviews, 57*, 1245-1259. Doi: 10.1016/j.rser.2015.12.189

Lim, X.L., Lam, W.H., & Hashim, R. (2015). Feasibility of marine renewable energy to the Feed-in Tariff system in Malaysia. Renewable and Sustainable Energy Reviews, 49, 708-719.

MacDougall, S.L. (2015). The value of delay in tidal energy development. *Energy Policy, 87,* 438-446. doi: 10.1016/j.enpol.2015.09.034

MacGillivray, A., Jeffrey, H., Winskel, M., & Bryden, I. (2014). Innovation and cost reduction for marine renewable energy: A learning investment sensitivity analysis. *Technological Forecasting & Social Change, 87,* 108-124.

MacGillivray, A., Jeffrey, H., & Wallace, R. (2015). The importance of iteration and deployment in technology development: A study of the impact on wave and tidal stream energy research, development and innovation. *Energy Policy*, *87*, 542–552. doi: 10.1016/j.enpol.2015.10.002

Maples, B., Saur, G., Hand, M., van de Pieterman, R., & Obdam, T. (2013). *Installation, operation, and maintenance strategies to reduce the cost of offshore wind energy*. National Renewable Energy Laboratory. Goldon, Colorado: United States.

Marine Renewable-energy Act. (2015, c. 32). Nova Scotia Legislature. Accessed October 24, 2016. Retrieved from: http://nslegislature.ca/legc/bills/62nd_2nd/3rd_read/b110.htm

Meygen. (2016). About Phase 1a. Retrieved from: http://www.meygen.com/about-phase-1a/

Nowe, K.M. (2014). *A Model for the Estimation of Emergency Maintenance Cost for a 10 MW Tidal Energy Conversion Installation.* BSc Honours Thesis. Acadia University: Wolfville, Nova Scotia.

Office of Management and Budget. (2016). *Circular A-94 Appendix C: Discount Rates for Cost-Effectiveness, Lease Purchase and Related Analyses.* The White House. Accessed September 30, 2016. Retrieved from: https://www.whitehouse.gov/omb/circulars_a094/a94_appx-c

OpenHydro. (January 20, 2016). The first of two OpenHydro tidal turbines on EDF's Paimpol-Brehat site successfully deployed. Press release. Accessed February 27, 2016. Retrieved from: http://www.openhydro.com/news/OpenHydroPR-2016-01-20.pdf

Palisade Corporation. (2016). @Risk (Student License Version). [Software]. Available from: http://www.palisade.com/risk/

Pepermans, G., Driesen, J., Haesedonckx, D., Belmans, R., & D'haeseleer,W. (2005). Distributed generation: definition, benefits and issues. Energy Policy, 33, 787-798.

Province of Nova Scotia. (n.d.). Community Feed-in Tariff Program Facts. Electronic factsheet. Accessed January 11, 2016. Retrieved from: http://energy.novascotia.ca/sites/default/files/comfit_facts.pdf

Qulliq Energy. (2016). *Customer Types.* Qulliq Energy Corporation. Accessed September 14, 2016. Retrieved from: http://www.qec.nu.ca/node/176

Roberts, A., Thomas, B., Sewell, P., Khan, Z., Balmain, S., & Gillman, J. (2016). Current tidal power technologies and their suitability for applications in coastal and marine areas. Journal of Ocean Engineering and Marine Energy, 2, 227-245. doi: 10.1007/s40722-016-0044-8

Schottel. (n.d.). SIT Instream Turbine. Schottel Group. Accessed September 19, 2016. Retrieved from: https://www.schottel.de/schottel-hydro/sit-instream-turbine/

Short, W., Packey, D.J. & Holt, T. (1995). *A Manual for the Economic Evaluation of Energy Efficiency and Renewable Energy Technologies.* National Renewable Energy Laboratory, US Department of Energy. Golden, Colorado: United States.

Singh, A. & Ephraim, J. (2016). Ocean energy: The new energy frontier for the Eastern Caribbean Small Island Developing States. Energy Policy, 99, 1-3.

Tarbatton, M. & Larson, M. (2006). *Canada Ocean Energy Atlas (Phase 1): Potential Tidal Current Energy Resources Analysis Background.* Canada Hydraulic Centre, Natural Resources Canada. Accessed November 26, 2014. Retrieved from: http://www.marinerenewables.ca/wp-content/uploads/2012/11/Canada-Ocean-Energy-Atlas-Phase-1-Potential-Tidal-Current-Energy-Resources-Analysis-Background.pdf

Verdant Power. (2016). Kinetic Hydropower System. Verdant Power Inc. Accessed December 1, 2016. Retrieved from: http://www.verdantpower.com/kinetic-hydropower-system.html

Withers, P. (November 22, 2016). *Massive tidal turbine in Bay of Fundy generating electricity for 1st time.* CBC News. Accessed December 1, 2016. Retrieved from: http://www.cbc.ca/news/canada/nova-scotia/tidal-power-bay-of-fundy-turbine-electricity-emera-hydro-1.3862227

Wright, G. (2014). Strengthening the role of science in marine governance through environmental impact assessment: a case study of the marine renewable energy industry. Ocean & Coastal Management, 99, 23-30. doi: 10.1016/j.ocecoaman.2014.07.004

Wright, G. (2015). Marine governance in an industrialised ocean: A case study of the emerging marine renewable energy industry. Marine Policy, 52, 77-84. doi: 10.1016/j.marpol.2014.10.021

Chapter 4: A review of six key factors in attaining social license for small-scale tidal energy projects.

4.1 Introduction

Obtaining social acceptance from the community that will host a project is a vital and necessary component of pursuing any renewable energy project. Many studies have explored the importance of social, environmental and economic factors (rather than technical, engineering, and financial) to renewable energy projects' successful completion. These studies have, over the years, covered topics ranging from the causes of local community support or opposition to given projects (Devine-Wright, 2005; Wolsink, 2007; 2010), the role that perceptions of place and infrastructure play in community opinion (Hindmarsh & Marshall, 2008; Batel, Devine-Wright & Tangeland, 2013), the types of financial and non-financial benefits project proponents can provide to incentivise support (and their relative success) (Cass, Walker & Devine-Wright, 2010), as well as what qualifies as a "community" in the context of a given project (Barnett et al., 2012), among many other topics. These concerns tie in to one major theme, which arose initially from the industrial mining sector: the necessity of attaining "social license" for a project from the people who must live with its effects, day-to-day (Thomson & Boutilier, 2011; Hall et al., 2015). Social license has, thanks both to this literature and the experience of companies pursuing projects around the world, been widely-recognised as being of vital importance to the success of renewable energy projects. This importance is simply explained: with some exceptions, if local people oppose a project, it can be very difficult for proponents and regulatory agencies to force it to completion. This chapter explores key factors in developing a social license in small scale tidal energy development, working from a review of the existing literature on social license, renewable energy development, and the tidal energy sector.

The explanatory factors of what causes social license to be granted—or revoked—from a given project are not simple. Projects can gain or lose support from different parts of the public due to many factors, and oversimplifying the causal relationships between a given community's granting or refusing social license to a project can obfuscate many of these factors. The most common explanation for opposition to renewable energy projects, so-called "NIMBYism" ("Not In My Back Yard-ism"), suggests that while in most

Western countries much of the public supports renewable energy development in theory, they do not wish to live in proximity to these developments (Devine-Wright, 2005; Wolsink, 2007; Delvaux, Rabuteau & Stanley, 2013; Hall et al., 2015). Yet, time and again, NIMBYism has been found sorely lacking in explaining the actual feelings and attitudes of local peoples towards renewable energy projects (Devine-Wright, 2005; Wolsink, 2007). This has caused many prominent authors, including Devine-Wright (2005), and Wolsink (2007; 2010) to largely reject the NIMBY explanation for opposition to renewable energy projects.

With reductionist NIMBYism excluded, what must companies and governments consider when designing renewable energy projects and policy? The literature here is diverse, and its results complex to interrelate. As noted, studies on social license for renewable energy projects must consider concerns as diverse as the scope and definition of the term “community”, how local people perceive and value their local environment, landscape and seascape, the social and economic impacts of new job creation on the community, and many additional factors. While these issues have been well-studied from the context of hydroelectric, wind, biomass, and solar energy projects, relatively few studies have yet looked to the more nascent marine renewable energy [MRE] technologies. Wiersma and Devine-Wright (2014) conducted an early review of studies on community acceptance factors for tidal, wave, and offshore wind energy projects; their findings, along with those of Devine-Wright (2011a; 2011b), Delveau, Rabuteau & Stanley (2013), Kerr et al. (2014), and Dalton et al. (2015) are informative, but preliminary. Further, these studies were largely either (1) focused upon hypothetical projects that had not yet been deployed (Wiersma & Devine-Wright, 2014), or (2) targeted specifically to policy-makers as a set of somewhat general recommendations to avoid project opposition (Delveaux et al., 2013). These studies have yet to find any deeper explanatory causes of community acceptance or rejection; whether unifying, transferable causes for support or opposition to MRE projects exist is thus an open question.

In addition, studies have, to-date, focused almost exclusively upon utility-scale (>500 kW) tidal energy projects. Given the wide availability of tidal resources unsuitable for utility-scale development, but for which smaller-scale tidal projects may prove viable (as outlined in Chapter 2), understanding how social license may be influenced at these smaller scales is worthwhile. Thus, this chapter draws on the existing literature regarding the influence of socio-economic factors on the success of renewable energy projects, and the preliminary literature on social acceptance of marine renewable energy projects in particular, to contextualise these factors in terms of their relevance to small-scale tidal energy projects. This is done in spite of the aforementioned limitations; although many valid questions remain to be answered regarding social license and marine energy projects, the existing literature can, at least, serve to provide some guidelines for developers and future research. It is hoped that this work can provide insight into the key areas towards which proponents and communities must direct their efforts to facilitate social acceptance of a small-scale tidal energy project, and thus also guide future research efforts in the field.

4.2 Socioeconomic Factors in Renewable Energy Project Successes & Failures

4.2.1 Background & Purpose

Many have investigated the influence of different social and economic factors on local acceptance of renewable energy projects. These studies first emerged because, although there was and is a growing consensus on the need for energy transitions to avoid catastrophic climate change around the world, opposition to renewable energy projects has often been found at the local level (Wustenhagen, Wolsink & Burer, 2007; Hindmarsh & Matthews, 2008; Ricci, Bellaby & Flynn, 2010; Barnett et al., 2012; Batel, Devine-Wright & Tangeland, 2013). That is, despite a general agreement among decision makers, scientists, business, and the public that renewable energy projects are necessary to a sustainable future for society, people are often found to oppose the imposition of renewable energy infrastructure in their own towns, landscapes, and regions. Understanding the cause of this opposition has been the focus of a concerted research effort in many countries.

Opposition to renewable energy projects has been observed in every country that has pursued them. Landmark studies on the causes of opposition to renewable energy were conducted by Devine-Wright (2005), Wolsink (2010) and Walker (2008); each identified many factors. The most salient of these factors, the premise of social license, is discussed in Section 4.2.2. Others have searched for best-practice advice for renewable energy developers and policy-makers, as in the case of Delvaux, Rabuteau and Stanley (2013). These best-practice recommendations form the basis of Section 4.2.3, which in turn informs Section 4.3, where we consider what steps should be taken to achieve social acceptance of small-scale tidal energy projects.

4.2.2 Understanding social acceptance and social license

Social license refers, at its most basic, to whether or not the community surrounding or concerned by a development project—whether it is an energy project, a mine, new construction, or anything else—accepts the presence of that project and its proponents into their lives (Hall et al., 2015). Social license is not a literal “license,” granted to a project proponent by a government agency or minister, but instead a flexible description of the relationship between a project’s host community and the project proponent (Hall et al., 2015). Thus, social license exists as a continuum. A community may outright reject a project and its proponents, be suspicious of them, tolerate their presence but distrust them, accept the company and the project, or even be fully supportive of the project. This is illustrated in Figure 6, below (from Thomson & Boutilier, 2011), as a pyramid representing the “levels” of a company’s social license to operate, and the boundaries between each level. The “social acceptance” (or “acceptability”) of a given project is, in this view, a subjective measure of the degree of social license a community affords a given project and its proponents. How this measure can be understood is explained below.

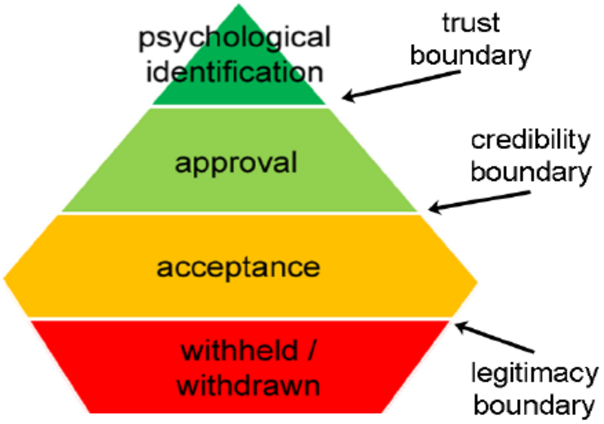

Figure 6: The “pyramid” model of social license proposed by Thomson & Boutilier (2011)

A proponent can move between the social license levels depicted in Figure 6 throughout a project's lifetime, depending upon their response to (and management of) any issues that arise with the project (Thomson & Boutilier, 2011). An initially hostile community that refuses the presence of a project may come to accept (i.e. tolerate) its presence if the proponent agrees to certain conditions, e.g. local hiring or stringent environmental monitoring. In the same way, that acceptance can evaporate if the proponent is perceived to have failed to deliver on their promises (Corscadden et al., 2012; Fast & Mabee, 2015). Typically, successful projects will exist somewhere in the "acceptance" and "approval" levels of the pyramid—indicating that a project and its operators are, at the very least, tolerated (acceptance), or generally considered to be a positive influence in the community (approval). The top tier, "psychological identification," indicates a rarer level of community-project or community-proponent co-identification. Put another way, the "acceptance," "approval" and "psychological identification" levels of Thomson and Boutilier's pyramid represent different levels of social acceptance for a given project, and the corresponding degree of positive social license granted to that project and its proponents. The "withheld/withdrawn" level, in contrast, indicates social rejection and opposition of a project, indicating no social license has been granted.

In the context of renewable energy, the highest tier, psychological identification, is worth some specific discussion. For renewable energy projects, psychological identification at the community level would imply that the community hosting the project has incorporated the project's presence (and clean energy output) into their local cultural identity; an example of this occurring with a tidal energy project exists in the SeaGen device in the Strangford Lough of Northern Ireland. Devine-Wright (2011b) found that this device was seen to "enhance local distinctiveness," and through such enhancement became identified with the community—and accepted by it. Depending upon the actions of a project proponent, and the conditions the local community exists within, any given project's social acceptance level can both ascend and descend between levels on this pyramid.

4.2.3 Factors Affecting the Granting or Revocation of Social License by a Community

This section provides a review of six of the most vital socioeconomic factors for successful renewable energy projects. These factors are, in order of appearance (but not necessarily priority): (1) the technical and skilled work capacity of a potential host community; (2) the environmental risks posed by a project; (3) the proximity and availability of infrastructure and resources; (4) the 'fit' of projects with local visions for the future; (5) the level of impact on indigenous peoples' lives, and their involvement in project planning; (6) and how a community is perceived to benefit from the project. All of these concerns can ultimately influence the key measure of a project's sociocultural viability, the aforementioned "social license" (Corscadden, Wile & Yiridoe, 2012; Wiersma & Devine-Wright, 2014; Fast & Mabee, 2015; Hall, Lacey, Carr-Cornish & Dowd, 2015). The rest of this section explains these factors; later, section 4.3 will use these factors as a lens to understand social license for small-scale tidal projects.

Technical Capacity

In the context of renewable energy projects, if the potential host community lacks the necessary technical (engineering and planning) capacity to be involved in the project planning directly, or the skilled workers (electricians, welders, etc.) to install the project with a local workforce, the likelihood of resistance to the project is going to be higher due to a perception of fewer benefits for local people (del Rio & Burgillo, 2008; 2009). In rural areas, the specialised engineering and environmental services companies that typically provide much of this work may not be locally established. Where these companies are not local, opportunities to create new revenue streams for existing businesses in land and water transport, equipment rental, and other supply chain services may prove the most viable way of creating local employment through renewable energy projects (Walker, 2008; Alexander, Potts & Wilding, 2013). Failure to create such opportunities may result in reduced acceptance, and thus a lower level of social license granted to the development firm. Similarly, projects perceived to be environmentally risky are considerably less likely to receive social license from local people (Devine-Wright, 2011a).

Environmental Impacts

The environmental impacts of a project can be opposed on environmental preservationist grounds (i.e. preserve the environment for its own sake), or for the impact's influence on specific elements of the environment people feel attachment to (i.e. specific flora or fauna identified with a location) (Devine-Wright, 2011a; Wiersma & Devine-Wright, 2014). Whether these risks are real, as in the threat of increased bird and bat mortality around wind turbines (Barrios & Rodriguez, 2004; Kunz et al., 2007), or imagined, as in the case of misattributed illnesses, is irrelevant to the end result for a project's social license (Baxter, Morzaria & Hirsch, 2013). That is, both scientifically-confirmable and non-confirmable concerns that the public put forward can influence whether a given community is willing to host any particular project (Baxter et al., 2013; Fast & Mabee, 2015). That said, some proven risks associated with different technologies are well-known; bioenergy facilities often result in land use change and cultivated energy cropping, risking habitat destruction for wild species (Firbank, 2008); hydroelectric dams and tidal barrages cause localised flooding and can have significant upstream and downstream effects on rivers and tidal channels (Flynn, 2015); in-stream tidal energy devices are suspected to pose a threat to marine mammal and fish populations in the event of collisions (Broadhurst, Barr & Orme, 2014; Romero-Gomez & Richmond, 2014; Shen et al., 2016). Thus, each renewable energy technology poses its own unique environmental risks. Having a great deal of information available regarding the environmental impacts of a proposed development, and being able to communicate it clearly to a wide audience, is absolutely vital for any renewable energy project's success.

Infrastructure Concerns

Both environmental and financial risks associated with renewable energy projects will, to some extent, increase as a function of the project's distance from the infrastructure necessary to support it. The sufficiency of local infrastructure to support a project is also dependent upon the local availability of contractors and equipment able to carry out the required work (del Rio & Burgillo, 2008; 2009); thus, it would be tempting to classify infrastructure as part of a community's technical capacity to support a project. However, developers sometimes pay for the creation of new infrastructure, or subsidise its creation through work contracts with local businesses—that is, project proponents can contribute to the infrastructure available to their projects directly (Ricci et al., 2010). As such, treating infrastructure as part of the pre-existing technical and skilled work capacity of a jurisdiction is misleading.

Should something go wrong, it will be easier to address problems for a project located near the necessary infrastructure to maintain or access it than it will be for one that is remote. In the context of renewable energy projects, 'infrastructure' takes on a specific, multi-faceted meaning; it includes the electrical grid to which the project must connect, as well as the access roads, repair facilities, harbours, and industrial capacity necessary to install and decommission the project, as well as those necessary to address any mid-life repairs or upgrading the project may require (del Rio & Burgillo, 2008; 2009). This dependency of projects on local infrastructure and assets is one of the areas where a project proponent can best attempt to woo a community's support, to gain social license through the provision of upgrade funding, or construction of new facilities the community can use (Wustenhagen et al., 2007). In cases (Wustenhagen et al., 2007; Ricci et al., 2010; Fast & Mabee, 2015) where communities that did not perceive developments as being otherwise profitable or beneficial to them (in part due to a lack of appropriate infrastructure to support the project), community leaders have seen success convincing renewable energy developers to provide other benefits to local people. These benefits—often the result of formal or informal Impact Benefits Agreements [IBAs] (Hitch & Fidler, 2007)—have included renewables developers paying for the creation or maintenance of facilities used by local communities, from small public parks to sports facilities, among other examples; this is further discussed later.

"Fit" with Community Desires

Most communities have, at some level, a community plan or growth strategy; whether a physical document or not, something that represents where the community sees itself heading in the near future. Sometimes, such documents are explicitly articulated as a "vision" for the town or region's future, though this is more typical in large cities with greater expenditures. Examples of these documents can be found in both large cities, such as Vancouver, British Columbia's Renewable City Strategy (City of Vancouver, 2015), and small towns, like Parrsboro, Nova Scotia's Strategic Plan (Town of Parrsboro, 2014). Whereas the Vancouver example is a document that explicitly calls for a 100% renewable energy-based city by 2050, the Parrsboro Strategic Plan is much simpler, with a focus on attracting in-migrants, new infrastructure funding, and creating new economic development opportunities within the township. Similar themes can be found in the near- and long-term development plans of local governments elsewhere. For many communities, especially in the relatively rural areas in which renewable energy projects are most often pursued (Wolsink, 2007; del Rio & Burgillo 2008; 2009; Hall et al., 2015), local job creation and skills development for residents, along with in-migrant attraction, are key goals in these plans (del Rio & Burgillo, 2008; 2009). Renewable energy projects could thus be perceived as being a "good fit" with local aspirations, due to their potential to provide exactly these opportunities (Devine-Wright, 2011a; 2011b; Wiersma & Devine-Wright, 2014). "Fit" can also refer to the degree to which a project connects with a community's perception of itself (Devine-Wright, 2011a), with more alignment generally corresponding with greater acceptance. Over time, with considerable effort, projects can in fact become a key part of a community's identity, beyond just "fitting" as a component of it. The islands of Orkney in northern Scotland are one such place, where the stark local environment, plentiful wind, wave, and tidal resources, local industries, and EU-funded European Marine Energy Centre (EMEC) have all contributed to the prideful self-identification of local people with marine renewable energy technologies as part of their current and future lives (Watts, 2010).

Indigenous Peoples' Involvement and Engagement with the Project

Within Canada, and many other parts of the world, one segment of the national community whose voice must be given special attention is the local indigenous population around any proposed development. Canadian history is rife with examples of indigenous peoples' treaty rights being ignored in favour of developments that benefitted the rest of society, but from which indigenous people gained little (and often lost much). Consequently, much of the literature regarding indigenous peoples' interactions with developers presents an adversarial view (Castro & Nielsen, 2001; Hitch & Fidler, 2007; Gordon & Webber, 2008). Despite this common portrayal, in Canada development proponents are bound by law to a "duty to consult" aboriginal populations regarding any project that may impact their lands or the use of their lands (Holburn, Loudermilk & Wilkie, 2014). Formally, this duty falls upon the provincial or federal government, as a representative of the Crown; in practice, most consultation is deferred to the proponent or their consultants (Holburn et al., 2014).

It is important to note that this duty entails only a vaguely defined requirement for "meaningful consultation" regarding the impacts of a project on aboriginal people and their lands. There is no legal statute that requires a project proponent and indigenous community to agree regarding the project's impacts nor their acceptability (Thomson, 2015). Instead, the extent and meaning of "meaningful consultation" has largely been shaped by court cases and the common law that results from them (Holburn et al., 2014). This has resulted in a slowly evolving, case-by-case set of standards for consultation between proponents, the government, and aboriginal peoples, requiring a unique approach to each new proposal (Holburn et al., 2014).

There are, however, success stories in projects undertaken with aboriginal groups in Canada. Cases exist of indigenous people not just tolerating projects—particularly renewable energy projects—but being enthusiastic supporters of them (Krupa, 2012). One example of this is the Dokis First Nation in Ontario, which has developed a 10 MW run-of-river hydropower plant in cooperation with the Quebec-based company Hydromega (Ireland, 2016). The Dokis First Nation owns a 40% share of the plant, and receives an equal proportion of revenue; Hydromega owns the rest of the plant. Such co-ownership arrangements were also observed in Nova Scotia, under the province's now-canceled Community Feed-in Tariff Program (Millbrook First Nation, 2014); they have also been observed elsewhere in Canada and other countries. Thus, one path to indigenous participation in renewable energy development is clear: co-ownership. The emergence of co-ownership of renewable energy projects by indigenous and non-indigenous peoples could be seen as analogous to the co-management practices that emerged in extractive resource sectors in the early-to-mid-1990s, and similar problems to those discussed by Castro & Nielsen (2001) may arise. However, there are other routes to success with renewables projects when indigenous people are concerned.

Consultation with indigenous groups during the development process is key, whether or not co-ownership is viable, as indigenous peoples' and communities' rights may be impeded or affected by a project's impacts. When indigenous people have been involved directly in development proposals, treated as equal partners, and given the opportunity to benefit, their support for renewable energy has been quite forthcoming (Krupa, 2012). When indigenous people have instead felt that they were consulted only due to statutory requirements, and they were excluded from project planning opportunities or felt the project was being imposed upon them or their lands, their opposition to the projects was quite clear (The Canadian Press, 2016). Such opposition has, as a result of a combination of bad press, constitutionally protected Treaty and aboriginal rights in Canada, and mounting public support for these indigenous rights among settler populations, caused severe delays for projects, both in renewable energy (The Canadian Press, 2016) and outside of it (Markusoff & Patriquin, 2016). Getting indigenous support for a project is similar to gaining support from the general public in any given community (Krupa, 2012); the difference lies in the often distinct worldviews indigenous and settler communities will bring to development proposal debates. When fundamentally unresolvable issues arise from these differences, indigenous peoples in Canada are increasingly able to halt or delay projects they disagree with, as their legal rights become more recognised (Murphy, Duncan & Piggott, 2008; The Canadian Press, 2016). Consequently, working closely with affected indigenous peoples to address their needs and concerns must be a priority for any renewable energy proponent.

Community "Benefits"

Finally, there is the matter of how a community benefits from a proposed development. In the context of renewable energy, "community benefit" can mean a host of things, from obtaining clean(er) electricity, to sharing (or controlling) the revenues of the project, to guaranteeing investments in local parks or sports facilities, to skills training and jobs creation (del Rio & Burgillo, 2008; 2009; Hindmarsh & Matthews, 2008; Cass, Walker & Devine-Wright, 2010; Wolsink, 2010). The literature around whether a community can (or should) obtain any of these benefits from renewable energy projects is highly contested. In interviews conducted by Cass et al. (2010), some stakeholders suggested that residents of a given place have no specific right of ownership to the wind, solar, tidal, or other renewable resources of that place. As such, these stakeholders (largely industry players) believed that no 'benefit' is owed beyond the contribution of the project to its shareholders' revenues and to providing clean power to the national or regional grid (Cass et al., 2010). In particular, these stakeholders argued that more traditional energy projects rarely offer ownership opportunities, revenue sharing, or other 'benefits' to communities beyond the employment opportunities in the project itself, and thus questioned why renewable energy projects are expected to do more. Other interviewees (Cass et al., 2010), while agreeing that an area's residents do not "own" the renewable energy inherent to their geography, have suggested that providing benefits of some sort to project host communities is simply good business, as it smooths over opposition to projects, creating tolerance if not outright support. Wolsink's (2010) findings support this suggestion, with conflict a frequent result of siting decisions if communities do not perceive benefits from infrastructure imposed on their lands. Given the geographically dispersed nature of renewable energy resources, renewable energy projects tend to in some way harness a resource that is identified with a given location's people and culture (Devine-Wright, 2010; Fast & Mabee, 2015). As such, one could interpret harnessing such resources as putting local culture at risk and thus view the provision of alternative benefits to the community as a form of compensation. In all cases, if and how a community should benefit from renewable energy projects is a frequent theme during public consultation processes about the project (Hindmarsh & Matthews, 2008; Ricci et al., 2010; Fast & Mabee, 2015). In Canada, such consultations are mandatory for communities affected by proposed developments, just as they are for affected aboriginal groups. However, as is the case with aboriginal groups, there are concerns over the adequacy of consultation processes in ensuring community concerns are heard and incorporated into project plans—within Canada and outside of it (Hindmarsh & Matthews, 2008; Ricci et al., 2010; Hall et al., 2015).

In situations wherein there is little opportunity for direct participation by community members in a given renewable energy project, other means exist through which communities can realise benefits from the project. Some renewable energy proponents have stated their belief, in interviews (Wustenhagen et al., 2007), that the creation of clean energy itself should be a satisfactory benefit, even when delivered to a national or regional grid outside the area in which the energy is harvested. However, studies on social license for renewable energy projects suggest these proponents are unlikely to convince local populations of their views (Devine-Wright, 2005; Wustenhagen et al., 2007; del Rio & Burgillo, 2008; Wolsink, 2010). This need for social license being granted to a project before it can proceed has led to the development of the aforementioned Impact Benefit Agreements (Hitch & Fidler, 2007), or in some cases legally-mandated "community benefit requirements" (as in the case of Ontario's *Green Energy Act 2009* or Nova Scotia's Community Feed-in Tariff program—see Province of Nova Scotia, n.d.; Fast & Mabee, 2015). Though IBAs are typically designed for indigenous contexts, they can provide lessons for other types of community benefit arrangements. A detailed review of IBAs for indigenous communities affected by a variety of development projects can be found in the work of Hitch and Fidler (2007). That said, a discussion of the general types and coverage of "benefits" covered in such agreements and other regulatory requirements is all that is necessary for this paper. IBAs and community benefit regulations vary widely in nature, from simple cash transfer agreements between project proponents (Batel et al., 2013; Fast & Mabee, 2015), to guaranteeing a certain percentage of the project is owned by local people or companies (Province of Nova Scotia, n.d.; Fast & Mabee, 2015), to the establishment of so-called "legacy projects" on the proponent's dime. One example of such legacy projects is the creation of a local ice rink with a wind developer's construction equipment at Wolf Island, Ontario (Fast & Mabee, 2015); others exist elsewhere (Wustenhagen et al., 2007; Batel et al., 2013).

Summary

Each of the factors of social license described has a direct influence upon how a community can benefit from a renewable energy project. Jobs and skills training create direct economic benefits for communities, while any necessary infrastructure upgrades and construction for the project can have indirect benefits for local businesses (e.g. upgraded harbour facilities can aid fishing and tourism industries). Similarly, if a project has a close fit with a community's already-articulated, desired future—say, a town that has directed much of its energy towards a low-carbon transition—it is more likely to be perceived as beneficial (Devine-Wright, 2011a; 2011b; Fast & Mabee, 2015). Conversely, the greater the perceived environmental risks a project poses to a community's ecology or health, the less likely local people are to accept the benefits the project might otherwise represent as being valid. The views of indigenous people, especially where they or their values stand to benefit from or be harmed by a project, can also prove make-or-break on the perception of whether a community benefits from a given proposal. Thus, each of the factors discussed above can be viewed as a highly qualitative measure of "community benefit"—and community benefit, in turn, as a proxy for the potential of a given project to obtain (or maintain) social license.

4.3 Community Benefits & Social License in Small-Scale Tidal Energy Projects

Where Section 4.2 provided an overview of how community benefits and social license are addressed in the renewable energy project literature broadly, this section will focus upon how these two concepts apply to the small-scale tidal energy projects. The goal in this discussion is to identify key areas for small tidal proponents to focus their consultation and planning efforts to attain social license from the surrounding communities in the form of baseline acceptance, as described in Section 4.2.2. Should these efforts be successful, it may be possible for dedicated proponents to attain community approval, and eventually psychological identification. However, acceptance in the form of expressed toleration for the project's presence must be taken as a minimum goal.

As few tidal energy projects presently exist, this section is based on the preliminary studies on social acceptance and consultation that have been carried out regarding tidal energy by a number of academics and consulting firms. Consequently, many of the links between the elements of social license considered and tidal energy projects must be considered to be tentative rather than definitive links. This tentativeness should not be considered an invalidation, however, as these links are based upon studies and consultations held directly with people who may be affected by tidal energy projects. Their reported concerns can thus be taken as a baseline for companies or proponents interested in pursuing tidal developments, and incorporating such concerns may aid in attaining social license for any given project. Table 8 presents a summary of the subsections that follow, which discuss each factor at length.

Table 8: Realms of social license and their associated concerns for small-scale tidal projects

Social License Factor	Concerns for Small Tidal
Technical & Skilled Work	Availability of locals with required skills; opportunities to train local workers; in-migrant attraction & retention opportunities
Infrastructure Requirements & Upgrades	Suitability of existing infrastructure; side-benefits of any new infrastructure
Environmental Risks	Threats to local fishing, tourism industries; threats to endangered/protected species; threats to charismatic species
"Fit" with Local Desires	Alignment of renewable energy with local desires; mitigation of impact on existing sea industries; mitigation of impact on recreational sea uses
Indigenous Involvement	Strong indigenous concerns over unknown environmental impacts; support absolutely vital to project approval; potential partners in development
Community Benefits	"Add-on" effect; more a community sees self-benefit, more likely to support a project; cleaner local grid, reduced/subsidised electricity cost, local revenue reinvestment, among other options

4.3.1 Technical & Skilled Work Requirements in Small Scale Tidal Energy Projects

As tidal technology is still evolving, the skills that workers require to implement projects are still not clearly defined. Despite this fact, some assumptions may be made, and these assumptions can inform a community's plans—both for the project, and for targeting new in-migrants via providing work opportunities. Most obviously, any tidal energy project is going to require trained electricians or electrical linemen to install the associated power equipment, transformers, converters, and power lines. In the case of bottom-mounted or bottom-moored devices, diving technicians capable of installing any necessary moorings will be required, where conditions permit. Similarly, for shore-moored devices and surface-supported (e.g. bridge- or pier-mounted) designs, engineering technicians will also be required to ensure structural integrity is maintained. Regardless of mooring design, if underwater cabling is required, divers and a boat capable of laying the cable must be contracted—for small communities, this will most likely require outside contracting. Site preparation work, for small-scale tidal plants, should be relatively minimal and limited to land clearing and foundation-laying for any necessary on-shore power equipment. Most construction contractors should thus be suitable candidates to address site preparation concerns, and local firms may prove especially competitive here.

The availability of small-lift-capacity boats or tugs to bring the devices to the site (and the crews to run them) is also important to consider. These boats will certainly be needed for installing and decommissioning the device, but may also be required for mid-life maintenance activities. As such, the availability of local boats for intermittent contract work should be considered in the project feasibility assessment stage. Relatedly, mechanical failures will be an important factor in a project's long-term viability, and the presence or absence of trained marine mechanics in a community will influence its ability to extract added local value from a project's proponent. Due to the risk of high transportation costs, a community lacking local qualified mechanics would be much more limited in the types of small tidal projects they could pursue.

Finally, and most importantly, to determine the appropriate scale, location, and monitoring for the project, the community will require engineers and scientists. These workers may be those of the tidal device supplier, an external project proponent, the community itself (if it is the proponent), or local or external contractors. Their responsibilities would include determining the nature of the physical resource available, the best location to place the project, the best-fit scenario for the number and size of devices to deploy at the site, the potential environmental risks posed by the project, and the development of any required mitigation and monitoring plans to avoid these risks. Many environmental and engineering contracting companies have much of the capacity necessary to do this work, and such firms sometimes have satellite offices in smaller, regional centres with relevant resource industries in surrounding communities. Consequently, while it may be difficult for a truly rural community to source such skilled work "locally," they may be able to at take advantage of regional resources in this respect, helping nearby communities' economies. In order to secure local advantages, then, it is likely communities will have to secure contracts for the community's own downstream supply chain industries relevant to small-scale tidal, e.g. service boat rentals, local marine construction firms, equipment rental services, etc.

4.3.2 Infrastructure Requirements for Small-Scale Tidal Energy Projects to be Viable

Three primary infrastructure elements are required for a small-scale tidal energy project to be feasible. First, the desired deployment site must be located close to the electrical grid, so as to minimise the cost of interconnection through cable-laying and power line installation. The cost of underwater cabling, in particular, can be exorbitant; in

Nova Scotia, developers interested in small-scale tidal projects have seen project installation quotes shift by more than $1,000,000 (CAD) for an increased site distance from shore on the order of two to three hundred meters (Dana Morin, personal communication, June 8th, 2016). Given the likely low-revenue nature of small-scale tidal (Roberts et al., 2016), an increase of cost on that order could easily make such projects untenable. Consequently, grid proximity must be seriously considered during site selection for small tidal proposals.

Secondly, the proximity of a site to harbour facilities is of great interest. While it is unlikely a tidal project could be carried out within a harbour's boundaries, due to marine traffic concerns (Roberts et al., 2016), the closer a project is to a harbour, the more the fuel required to install or visit the site can be reduced. As small-scale tidal projects are unlikely to require heavy lift capacity or large industrial cranes (Roberts et al., 2016), small craft harbours such as those in many rural coastal communities may prove sufficient. As such, this infrastructure requirement—though important—is not one that is likely to be difficult to meet.

Finally, in order to access the tidal project's onshore electrical facilities in the event of a problem, access roads will be required. The creation of such roads may prove difficult or controversial, depending upon the location of the actual project site. While an 'ideal' tidal project may be one located near a coastal road with public land adjacent to the development site, which could be put into use as the host of the required power equipment, this is unlikely to always prove possible. In the event that the electrical cables must come onshore on privately owned land (or in, for example, a protected area such as a park), securing rights and access to the land may, hypothetically, prove the most difficult phase of the project. This hypothesis is based in the land use conflicts that have arisen in many parts of the world over wind and solar projects (Wolsink, 2007; Hindmarsh & Marshall, 2008; Baxter et al., 2010; Corscadden et al., 2013; Fast & Mabee, 2015), among others. While those conflicts are often attributed to the visual impact of such renewable energy devices on their landscape (Wolsink, 2007), private land access is a fraught concern for many types of environmental infrastructure (Wolsink, 2010) including water works, waste facilities, and energy technologies. Thus, despite the relatively minimal visible impacts of tidal devices (Wiersma & Devine-Wright, 2014), securing access to privately owned land that could serve as the best place to bring cables ashore may prove equally challenging—not just at the project's outset, but throughout its lifetime.

4.3.3 Environmental Risks Posed by Small Scale Tidal Energy Projects

The environmental impacts of tidal energy devices are, as-yet, largely unknown. Broadhurst et al. (2014) studied turbine-fish interactions in-situ and found fish tend to avoid tidal energy devices, but this study was limited to one device and very few species of fish; their results are thus difficult to call generalisable. Romero-Gomez and Richmond (2014) ran numerical models to estimate the probability of a fish being affected by blade-strike should a fish enter a turbine's path, and the resulting probability of fish mortality should a fish be struck by a turbine. They found that these values were, respectively: a 6-9% chance of blade-strike occurring, and a 96% chance of any given fish surviving a blade-strike event (Romero-Gomez & Richmond, 2014). Shen et al. (2016) modeled the probability of fish encountering tidal energy device blades, and found a similar value of 5.8% likelihood of a fish-blade interaction occurring in an open channel. However, the small number of deployed tidal energy devices in the field means these model results cannot yet be considered conclusive. Furness et al. (2012) conducted a preliminary assessment of the potential interaction of birds with marine renewable energy projects in Scotland, and found that tidal energy devices posed some threat to species of seabird that were likely to use tidal races as hunting grounds, such as the black guillemot (*Cepphus grylle*), razorbill (*Alca torda*), shag (*Phalacrocorax aristotelis*), and common guillemot (*Uria aalge*). While these species are considered at risk of colliding with tidal energy devices under Scottish conditions, it is likely that the species that risk being harmed by tidal installations will vary with location; identifying local species which may be harmed is thus a vital step in project planning.

Much of the literature on the environmental impacts of tidal energy has focused on the impact of extracting energy from ocean environments on surrounding environmental conditions. These studies have varied from those interested in modeling the upper "safe" limit on extractable power from a tidal stream (Bryden, Grinsted & Melville, 2004; Cummins, 2012) to those interested in the sensitivity of locally-acting environmental processes (e.g. sediment transport, coastal erosion, downstream tidal velocity, etc.) to tidal energy extraction (Frid et al., 2012). Others have investigated the wake field effects of tidal arrays (Shields et al., 2011), the impacts of different mooring designs (Kristov & Linfoot, 2012), or the potential for seabed scour effects (Chen & Lam, 2014). However, the general consensus seems to be that projects below certain thresholds will have negligible impacts upon the natural environment around them. These thresholds vary, but there is general agreement (Bryden & Melville, 2004) that up to 10% of the total power available in a tidal stream may be extracted without serious environmental impacts (e.g. radical changes in local or regional tidal systems and nutrient flows). Too few experimental studies and operational projects exist to confirm this estimate, but as a guideline, small-scale tidal developers should still attempt to follow it. That said, it should be noted that small-scale tidal devices are unlikely to be deployed in environments in which they can approach this threshold unless deployed in vast numbers, due to spatial concerns, shared waterway use conflicts, and the necessity of leaving at least part of any given waterway untouched for fish and other marine life to pass by the installation.

It should be noted here that the environmental effects the public fears tidal energy devices may cause have also been extensively investigated, and these fears vary from the ecologically-concerned to the self-interested. De Groot, et al. (2014) conducted interviews with a number of fishers in the area of a proposed tidal energy project in the United Kingdom, and found that concerns over loss of access to fishing sites and impacts on commercial fish species predominated. Others have found that concerns for marine mammals, protected species, and diving seabirds are also common (Wiersma & Devine-Wright, 2014). During Nova Scotia's Strategic Environmental Assessment process for tidal energy in the province, communities brought up specific concerns over impacts to commercial fisheries (especially herring [*Clupea harengus*], haddock [*Melanogrammus aeglefinus*], lobster [*Homarus americanus*], scallops [*Placopecten magellanicus*]), charismatic species relevant to tourism (any of twenty-three species of cetaceans, or grey [*Halichoerus grypus*] and harbour [*Phoca vitulina*] seals), and locally-identified species at risk and species of concern (Atlantic salmon [*Salmo salar*] and striped bass [*Morone saxatilis*], respectively) whose populations are in decline (Offshore Energy Research Association, 2008; AECOM Canada Ltd, 2012; 2014). Initial studies suggest many of these fears will be assuaged by the lack of such impacts occurring once development occurs, but it is still too early in the industry's development to be certain. Yet development may be difficult to pursue without first assuring the public that tidal energy devices will not adversely affect the species local people depend on for their livelihoods. To do this, further knowledge is required; an opinion obviously shared by the literature highlighting the need for further research into the environmental effects of tidal energy development is a key theme of the literature (Shields et al., 2011; Frid et al., 2012).

4.3.4 How Small Scale Tidal Energy Projects can "Fit" Local Desires for Communities

Increasingly, communities—both rural and urban—around the world are pursuing decarbonisation and climate adaptation plans. Most are also consistently interested in opportunities to create new local industries, or to encourage new partnerships that provide work to local businesses. Tidal energy projects, particularly at small, community-based scales, present the potential to meet these common goals by providing both clean energy and job opportunities. While larger-scale, utility-oriented tidal projects naturally offer greater numbers of jobs per project, the number of locations where such projects can prove viable is relatively small (Roberts et al., 2016). Small-scale tidal projects, on the other hand, can offer small numbers of jobs in a wide number of locations, allowing the dispersion of benefits across regions. In rural areas, even these smaller quantities of jobs can make a significant impact on communities (del Rio & Burgillo, 2008; 2009), especially in places where so-called rural decline has set in. While other renewable energy technologies offer similar benefits (del Rio & Burgillo, 2008; 2009; Roberts et al., 2016), tidal resources may prove most desirable due to the local availability of other options or due to its increased predictability throughout the year (or, indeed, other factors). Thus, small-scale tidal can help communities meet their economic development and low-carbon transition goals at the same time. In particular, due to tidal projects' need for maintenance, occasional repair, environmental monitoring, installation and decommissioning, communities can use existing industries to provide supply chain support to projects, generating benefits beyond the clean energy tidal turbines would produce.

4.3.5 Indigenous Involvement in Small Scale Tidal Energy Projects

This subsection, unlike the rest of section 4.3, is further split in three. First, this section discusses the role of consultation and the duty to consult indigenous people in Canada in the context of small-scale tidal energy. Second, an overview of how indigenous people can secure benefits from renewable energy projects on their lands is provided. Both of these sections are vital to understanding the opportunities to engage indigenous people in small-scale tidal energy projects, as they are unlikely to participate if they feel project proponents are disingenuous in their consultation processes or fail to offer local benefits to indigenous communities. A summary of these two discussions forms the third part, rounding out this subsection.

Consultation

The legal Duty to Consult "requires the Crown to engage in meaningful and good faith consultation with Aboriginal peoples regarding a proposed activity that might negatively impact their interests" (Murphy, Duncan & Piggott, 2008, p. 19)—whether these interests are their lands, ways of life, or other constitutionally guaranteed or Treaty rights., While this is often discussed, in modern Canadian contexts, with respect to large industrial projects that are subject to legally mandated EIA processes, it actually applies in any context in which indigenous peoples or their interests/rights are affected (Murphy, Duncan & Piggott, 2008), whether an EIA is being conducted or not. Thus, if a small tidal project will infringe on any such rights, e.g. fishing or waterway access, the Duty to Consult applies, and indigenous groups must be brought into the conversation around a project. Yet there are several reasons to consider this duty a best practice, rather than simple legal obligation.

In the case of an emerging, unproven technology like in-stream tidal energy, the foremost of these reasons is the simple fact that—despite small-scale energy projects being well below established thresholds for EIA—the ministers responsible for EIA, in most provinces and federally, have discretionary authority to call for EIA on any project they deem to be worthy of one (Noble, 2009). With the environmental effects of tidal energy extraction largely unknown, a cautious environment minister may thus choose to call for an appropriately-scoped EIA on any project proposing to deploy tidal energy devices, forcing the government (Crown) to become involved and carry out the Duty to

Consult. As the carrying out of procedural elements (that is, information sharing, holding meetings, etc.) of this Duty are often relegated to the proponent (Murphy, Duncan & Piggott, 2008), engaging with indigenous peoples and communities appropriately and respectfully prior to any government requirement to do so may facilitate greater social license or trust between indigenous peoples and small tidal developers. Some authors (Maclean et al., 2014; Wright, 2016) have put forth an argument that applying stringent EIA standards to experimental technologies like tidal energy is unfair, as it frequently puts (what is claimed to be) undue financial burden on firms to perform extensive monitoring they are not fiscally capable of sustaining. Even so, if tidal technologies are to prove their acceptability to the public, submitting to EIA standards (including carrying out the duty to consult indigenous peoples) is necessary. Thus, it is best to become familiar with this process even for very small projects.

There are other more positive reasons for proponents to consult with and involve indigenous peoples in their projects. The sharing of traditional ecological knowledge (TEK), which may provide insight into (among other things) seasonal or decadal variations in weather, animal migration patterns, and areas of potential interest for development (Huntington, 2000; Turner, Ignace & Ignace, 2000), is one such reason. Such insights could aid in project siting, both for obtaining optimal device performance and lifetimes, and for minimising environmental impacts. This knowledge aids developers in acquiring social license from indigenous people through two primary means. First, by allowing them to avoid siting their developments in areas of significance to indigenous people. Second, TEK studies can identify environmental patterns that are not always apparent or known to scientists and government regulators (Huntington, 2000), thus enabling better mitigation of potential device impacts on the environment through greater understanding of the risks.

Nova Scotia's Mi'kmaq Ecological Knowledge Studies, conducted as part of its Strategic Environmental Assessments for tidal energy, serve as examples of TEK studies (Membertou Geomatics Solutions [MGS], 2009; 2012). Through interviews, these studies identified ongoing Mi'kmaq hunting, fishing, and gathering activities within five (MGS, 2012) to ten (MGS, 2009) kilometer radii of the various proposed tidal energy development sites in Nova Scotia. This provided the province (and, by extension, tidal developers) with information on the frequency and importance of Mi'kmaq hunting and fishing for several key species in the regions considered, with several aquatic species identified in the two studies (MGS, 2009; 2012). Terrestrial and marine mammal species hunted in the study areas were also identified (MGS, 2009; 2012). Note that these studies do not cite Latin names, nor provide enough detail to determine which of the varieties present in Nova Scotia are being discussed specifically, for either terrestrial or aquatic species; to avoid misattribution, though educated guesses could be made, they have thus been excluded here. These interviews also included mapping exercises, in order to determine whether any proposed developments would pose a threat to either traditional Mi'kmaq fishing or hunting grounds, or known historical and burial sites which project infrastructure could damage (MGS, 2009; 2012). The results of these studies were used to inform project management decisions for tidal energy planning in Nova Scotia; while projects are still ongoing, if the TEK acquired from these studies is utilised properly, conflict between developers and the indigenous Mi'kmaq populations over land and sea rights may be minimised.

Increased environmental knowledge is not the only advantage to consulting indigenous people, however; financial opportunities can also arise when indigenous groups are engaged in a project. Should the aboriginal peoples in a region be interested in partnering with the developer, access to government funding programs specific to projects with aboriginal links may be granted (Krupa, 2012). Both the federal government and (some) provinces in Canada have funds and programs designed specifically to encourage aboriginal deployment of renewable energy farms (Krupa, 2012; Ireland, 2016; Millbrook First Nation, 2014); the "price-adder" available to aboriginal bands under Ontario's Feed-in Tariff programs stands as one example (Mabee, Mannion & Carpenter, 2012). For an industry with still uncertain costs, securing these additional funding sources may prove advantageous.

Indigenous Community Benefits

The concepts and issues related to how communities benefit from renewable energy projects discussed in Section 4.3.6 are all applicable and relevant to indigenous communities. However, there are some issues of benefits unique to indigenous communities, in part as a result of their oppressed history in many parts of the world.

Within Canada, Krupa (2012) identified several major challenges to aboriginal participation in general renewable energy deployment programs. The first, availability of investable cash, can be addressed through working with an external partner or funding program (e.g. a private or public tidal project proponent, or a FIT); Ontario's Aboriginal ownership 'adder' for its FIT program serves as one example (Mabee et al., 2012). On-reserve capacity deficits can be similarly made up for through cooperation agreements; Krupa (2012) also suggests that finding ways to finance jobs training and education programs for reserve populations could help to develop sustainable on-reserve capacity to pursue projects either independently or with partners. Offering such funding or training is one way tidal developers could work with indigenous groups. Finally, Krupa's discussion of the unequal status of many aboriginal people compared to broader society is one that tidal developers may be able to design their projects to help address. This could be done through, for example, ensuring some share of revenues flows to the community's education or health programs, guaranteeing a certain number of jobs to the community, or other means secured through negotiation of, for example, an Impact Benefit Agreement like those common to other resource industries (Hitch & Fidler, 2007).

Summary

In practice, then, consultation with aboriginal peoples is of interest to small-scale tidal energy proponents. If a developer can secure aboriginal support for a project, implementation will be easier to complete. Should they instead be able to secure aboriginal participation, new funding sources and opportunities can be made available to the project, lessening the financial risks the developer or proponent must take on. Consultation with aboriginal communities does not necessarily require that they give their full support to projects, however, but it should be done to a sufficient extent for the communities to feel that their views have been considered and taken into account in project planning. That is, much like obtaining social license from society at large, the goal in consulting indigenous people is not so much approval as it is acceptance. However, there is historical precedent for projects going through despite strong indigenous opposition (Murphy, Duncan & Piggott, 2008), though such projects are becoming less common. As much of the obligations of the Duty to Consult have emerged through common law cases before the courts, rather than being legislated (Murphy, Duncan &

Piggott, 2008), this area remains emergent. Although the acceptance of a project by consulted indigenous people is not currently a requirement of the Duty to Consult (Murphy, Duncan & Piggott, 2008), attaining at least the barest level of acceptance will make a project's completion easier to pursue. Failing to attain this acceptance, long-term, will likely limit the ability of small tidal developers to operate in Canada, due to the nature of aboriginal rights and title in unceded territories such as those that make up the majority of Canada's coastal sites.

4.3.6 Community Benefits from Small Scale Tidal Energy Projects

Acceptability is a key theme in this paper, and achieving community acceptance is a key step towards attaining social license. The acceptability of any given project will depend to a large extent on how a community is seen to benefit from the project. As mentioned in Section 4.1, what exactly constitutes a "benefit" to a community (or indeed, what a "community" is) is a hotly debated subject. Methods for companies to provide benefits to communities hosting energy projects vary; from a small annual cash payout (Cass et al., 2010; Fast & Mabee, 2015), to funding for local sports teams or parks (Fast & Mabee, 2015), offering local people the opportunity to invest in the project (Delvaux et al., 2013), or even communal (co-)ownership of the project. Many (Walker, 2008; del Rio & Burgillo 2008; 2009; Cass et al., 2010; Wolsink, 2010) have, rightly, pointed out that job creation and in-migrant attraction ought to be counted among these benefits, as job creation in any community is an important benefit.

Yet these jobs must be weighed against any they put at risk. Marine spatial planners (Alexander et al., 2013; de Groot et al., 2014; Wright, 2015) have pointed out that many tidal projects will require exclusion zones to be imposed on areas of water, limiting the access of non-tidal energy industries to specific sea spaces. Should such exclusion areas interfere with fishing grounds, tourism industry uses such as diving or sea tours, or shipping routes, it is possible the economic losses a community faces from a tidal project may outweigh any gains it can create (Wright, 2015). Beyond economics, exclusive sea areas could interfere with local people's recreational use of their waters (de Groot et al., 2014), and thus cause the tidal project to be seen as affecting their way of life. While such impacts are unlikely to be financially significant at the small project scales of small-scale tidal (Roberts et al., 2016), that does not mean that local people will see them as inconsequential. Fishermen have expressed considerable concern over the limits imposed on their access to sea areas in various studies (Devine-Wright, 2011a; de Groot et al, 2014; Flynn, 2015), and other sea users are likely to feel similarly. Left unaddressed, such concerns could easily grow into opposition to a project, regardless of its relative size.

The principle benefit of a small-scale tidal energy project is the same as that of any other renewable energy project: clean, low-carbon electricity. This low-carbon energy can supplant at least a portion of a community's fossil fuel energy consumption. Due to the intermittent nature of tides, it is unlikely that a community could fully replace other sources of electricity with a small-scale tidal plant; however, this may be possible with storage techniques such as battery, compressed air, or pumped-water storage as they develop. An early pilot project investigating the use of tidal power with pumped-water storage is (as of September 2016) ongoing in British Columbia's Haida Gwaii islands, as part of a local effort to displace diesel fuel consumption (Dimoff, 2016). Other storage cases have yet to be investigated in anything but theoretical investigations (e.g. the study conducted by Manchester, Barzegar, Swann & Groulx (2013)). Should such energy storage options be proven both technically and financially viable over time, tidal projects with appropriate storage mechanisms could allow "full replacement" of a community's other electricity sources.

Even if storage options are not viable in the near-term, small-scale tidal energy projects offer a significant opportunity to increase a community's energy security. The "Four A's" of energy security—Availability, Accessibility, Affordability, and Acceptability (Asia Pacific Energy Research Centre, 2007)—are the most direct way to discuss the concept. As tides themselves are naturally intermittent, with periods of peak, middling, and null velocity each day, tides can be called *intermittently available.* In the many off-grid communities reliant on diesel power around the world, however, this intermittent availability may prove more reliable than costly diesel importation, despite a reduced level of control over the generator's operating times. While small-scale tidal projects will naturally be limited to areas that have tides of sufficient velocity, where the resource exists in a community's vicinity, it can be considered *accessible*. Both accessibility and availability for tidal resources can be improved through energy storage, as mentioned above. As far as affordability can be considered given the experimental nature of most tidal devices, the present high cost of tidal energy devices should, according to learning curve theories, fall over time as more devices are deployed and learning occurs within the industry (IEA, 2000). That said, in locations with high energy costs at present (e.g. isolated grid systems relying on diesel), tidal projects may prove cost-competitive with existing systems. Consequently, small-scale tidal projects may be able to prove *affordable* in specific contexts both now and in the near future.

The most elusive measure of improving energy security is the last; acceptability. In order for small-scale tidal energy projects to prove acceptable, their environmental, social, and financial impacts relative to existing energy sources in a given community must be considered. A community that receives most of its power from costly imported diesel while bearing the full, local cost of burning it, such as many of Canada's arctic villages, may be more keen to move to renewable power sources than a community that is connected to a centralised, distant national grid and is thus less immediately conscious of where their power comes from. Yet even so, familiarity and exposure can breed acceptance of infrastructure over time (Keilty, Beckley & Sherren, 2016), while the unknown and novel can cause fear (Watts & Wintherik, 2014). If the devices proposed for a given small tidal project are believed to pose a threat to wildlife, or to change their local environment (even at a visual level), local people may prove unwilling to accept it. Overcoming these acceptance barriers will require any proponent to consider their project—and the preceding elements of social license—very carefully.

For any tidal energy project, ascertaining a path towards net community benefits that local people agree with is vital. At small scales, the relatively low risk of impact on the environment and other sea users may make finding the necessary common ground to move forward easier. Yet this small scale also means that finances and timelines will have to be much tighter. Should sufficient local opposition arise against a small-scale tidal energy project to cause significant delays, the economic viability of the project could be threatened—along with any and all attendant benefits the community and proponent might receive from it. Thus, working with local people and industries to address their worries about a project is of vital importance for any small tidal developer. Finding avenues for local people and businesses to participate in the project, whether as owners, suppliers, or customers is one way to ensure community buy-in occurs, but far from the only way to create local benefit. Ultimately, what is important is ensuring the local community receives benefits that will satisfy enough of its population for the project to be, at the very least, a tolerated presence.

4.4 Conclusions

This chapter has discussed the concepts of social license and community acceptance of renewable energy projects, and specifically linked them to the consideration of small-scale tidal energy projects. Due to the inherently limited revenue of small-scale energy projects, obtaining social license for the project is vital. Thus, six key areas of consideration for obtaining social license for small-scale tidal energy projects were identified.

The first consideration must be a clear understanding of the technical and skilled work requirements of a project, and the ability of the proposed host community to meet these requirements—as well as the potential benefit to the community of attracting new migrants with those skills. Second, the suitability of local infrastructure to the project's needs (and advantages provided by new infrastructure, if required) must be assessed. Third, the environmental risks posed by the project in the context of local environs must be understood, especially with regards to any species of commercial or conservation interest. Each of these three factors has the potential to greatly influence whether a community will grant a project the required social license to operate within its borders, and, importantly, each of these factors can be understood through doing ground work prior to approaching a potential host community. Thus, these three considerations can be said to be largely in the control of project proponents; they should know their project's design, the approximate number of jobs required to implement it, the required infrastructure to support it, and its potential environmental impacts in advance of any contact with the public.

The next three considerations are more deliberative and dependent upon the people who live within and around the proposed project site; the community itself. Whether or not a proposed project "fits" within local desires is something that a project proponent (excluding when the community itself is the proponent) can hardly control, though proponents can perhaps adapt their proposals to allow greater fit. This fit cannot be achieved, however, where a community is adamantly opposed to the deployment of tidal energy devices in its waters, and this scenario may realistic—community opposition to wind or solar development has been quite adamant in many parts of the world (Devine-Wright, 2005). Similarly, while project proponents can reach out to indigenous communities, attaining their support for as-yet unproven tidal energy technology installations may prove difficult.

While consultation with indigenous peoples is mandated in many countries, few jurisdictions require proponents to gain their acceptance before proceeding with project implementation. This has resulted in a history of indigenous resistance to development projects around the world, including to renewable energy projects; such resistance has often delayed development. In the limited-revenue realm in which small tidal energy projects operate, such delays may prove disastrous, and it is thus vital that proponents gain at least conditional approval from indigenous communities before proceeding with project implementation. Finally, and relatedly, the question of whether a community benefits in some form from a proposed development will influence how people in that community react to the project. The key consideration here is that the proponent speaks to the community and ensures that they are seen as providing some benefit that outweighs any perceived risks the project poses.

In order to proceed with small-scale tidal energy projects, proponents must find a way to balance these key considerations in order to gain community acceptance. Importantly, this “acceptance” does not necessarily translate to widespread approval for the project, but at minimum it means that people are willing to tolerate the project’s presence. Approval, and perhaps psychological or cultural identification of the project as part of the community’s identity as a place, may come with time—or it may not. But as a bare minimum, a successful small-scale tidal energy installation’s proponents must balance these concerns in such a way that the public they interact with tolerates them.

4.5 References

AECOM Canada Ltd. (2012). *Marine Renewable Energy: Background Report to Support a Strategic Environmental Assessment (SEA) For the Cape Breton Coastal Region, inclusive of the Bras D'Or Lakes.* Halifax: Offshore Energy Research Association of Nova Scotia. Accessed Sept 18, 2016. Retrieved from: http://www.oera.ca/marine-renewable-energy/strategic-environmental-assessment/

AECOM Canada Ltd. (2014). *Tidal energy: Strategic Environmental Assessment Update for the Bay of Fundy.* Halifax: Offshore Energy Research Association of Nova Scotia. Accessed Sept 17, 2016. Retrieved from: http://www.oera.ca/marine-renewable-energy/strategic-environmental-assessment/

Alexander, K.A., Wilding, T.A., & Heymans, J.J. (2013). Attitudes of Scottish fishers towards marine renewable energy. *Marine Policy, 37,* 239-244. doi: 10.106/j.marpol.2012.05.005

APERC. (2007). *A Quest for Energy Security in the 21st Century.* Asia Pacific Energy Research Centre. Accessed November 20, 2016. Retrieved from: http://aperc.ieej.or.jp/file/2010/9/26/APERC_2007_A_Quest_for_Energy_Security.pdf

Barnett, J., Burningham, K., Walker, G., & Cass, N. (2012). Imagined publics and engagement around renewable energy technologies in the UK. *Public Understanding of Science, 21*(1), 36-50.

Barrios, L. & Rodriguez, A. (2004). Behavioural and environmental correlates of soaring-bird mortality at on-shore wind turbines. *Journal of Applied Ecology, 41*(1), 72-81. doi: 10.1111/j.1365-2664.2004.00876.x

Batel, S., Devine-Wright, P., & Tangeland, T. (2013). Social acceptance of low-carbon energy and associated infrastructures: A critical discussion. Energy Policy 58, 1-5.

Baxter, J., Morzaria, R., & Hirsch, R. (2013). A case-control study of support/opposition to wind turbines: Perceptions of health risk, economic benefits, and community conflict. *Energy Policy, 61,* 931-943.

Broadhurst, M., Barr, S., & Orme, C.D.L. (2014). In-situ ecological interactions with a deployed tidal energy device; an observational pilot study. *Ocean & Coastal Management*, *99*, 31-38.

Bryden, I.G., Brinsted, T., & Melville, G.T. (2004a). Assessing the potential of a simple tidal channel to deliver useful energy. *Applied Ocean Research, 26,* 198-204.

Bryden, I.G. & Melville, G.T. (2004b). Choosing and evaluating sites for tidal current development. *Proceedings of the Institute of Mechanical Engineers Part A: Journal of Power and Energy, 218*(8), 567-577.

Canadian Press. (Sept 12, 2016). *First Nations argue for reversal of Site C dam proposal.* Macleans. Accessed Sept 30, 2016. Retrieved from: http://www.macleans.ca/news/site-c-reversal-first-nations-b-c/

Cass, N., Walker, G., & Devine-Wright, P. (2010). Good neighbours, public relations, and bribes: the politics and perceptions of community benefit provision in renewable energy development in the UK. *Journal of Environmental Policy and Planning, 12*(3), 255-275.

Castro, A.P., & Nielseon, E. (2001). Indigenous people and co-management: implications for conflict management. *Environmental Science & Policy, 4*(4-5), 229-239.

Chen, L, & Lam, W.H. (2014). Methods for predicting seabed scour around marine current turbine. *Renewable and Sustainable Energy Reviews, 29,* 683-692.

City of Vancouver. (2015). Renewable City Strategy. City of Vancouver. Accessed Nov 30, 2016. Retrieved from: http://vancouver.ca/files/cov/renewable-city-strategy-summary.pdf

Corscadden, K., Wile, A., & Yiridoe, E. (2012). Social license and consultation criteria for community wind projects. *Renewable Energy, 44,* 392-397.

de Groot, J., Campbell, M., Ashley, M., & Rodwell, L. (2014). Investigating the co-existence of fisheries and offshore renewable energy in the UK: Identification of a mitigation agenda for fishing effort displacement. *Ocean & Coastal Management, 102,* 7-18. doi: 10.1016/j.ocecoaman.2014.08.013

del Rio, P. & Burgillo, M. (2008). Assessing the impact of renewable energy deployment on local sustainability: Towards a theoretical framework. *Renewable and Sustainable Energy Reviews, 12,* 1325-1344.

del Rio, P. & Burgillo, M. (2009). An empirical analysis of the impact of renewable energy deployment on local sustainability. *Renewable and Sustainable Energy Reviews, 13,* 1314-1325.

Devine-Wright, P. (2005). Beyond NIMBYism: towards an integrated framework for understanding public perceptions of wind energy. *Wind Energy, 8*, 125-139.

Devine-Wright, P. (2011a). Place attachment and public acceptance of renewable energy: a tidal energy case study. *Journal of Environmental Psychology, 31*, 336–43.

Devine-Wright, P. (2011b). Enhancing local distinctiveness fosters public acceptance of tidal energy: A UK case study. *Energy Policy, 39*(1), 83-93. doi: 10.1016/j.enpol.2010.09.012

Dimoff, A. (Aug 11, 2016). *Tidal power technology rolls into Haida Gwaii shores.* CBC News. Accessed Oct 28, 2016. Retrieved from: http://www.cbc.ca/news/canada/british-columbia/tidal-power-haida-gwaii-1.3717132

Fast, S. & Mabee, W. (2015). Place-making and trust-building: The influence of policy on host community responses to wind farms. *Energy Policy, 81,* 27-37.

Firman, L.G. (2008). Assessing the ecological impact of bioenergy projects. *Bioenergy Research, 1*(1), 12-19. doi:10.1007/s12155-007-9000-8

Flynn, B. (2015). Ecological modernisation of a 'Cinderella renewable'? The emerging politics of global ocean energy. *Environmental Politics, 24*(2), 249-269. doi: 10.1080/09644016.2014.1000638

Frid, C., Andonegi, E., Depestele, J., Judd, A., Rihan, D., Rogers, S.I., & Kenchington, E. (2012). The environmental interactions of wave and tidal energy devices. *Environmental Impact Assessment Review, 32,* 133-139. doi: 10.1016/j.eiar.2011.06.002

Furness, R.W., Wade, H.M., Robbins, A.M.C., & Masden, E.A. (2012). Assessing the sensitivity of seabird populations to adverse effects from tidal stream turbines and wave energy devices. *ICES Journal of Marine Science, 69*(8), 1466-1479. doi: 10.1093/icesjms/fss131

Gordon, T., & Webber, J.R. (2008). Imperialism and resistance: Canadian mining companies in Latin America. *Third World Quarterly, 29*(1), 63-87.

Hall, N., Lacey, J., Carr-Cornish, S., & Dowd, A.M. (2015). Social license to operate: Understanding how a concept has been translated into practice in energy industries. *Journal of Cleaner Production, 86,* 301-310.

Hindmarsh, R. & Matthews, C. (2008). Deliberative speak at the turbine face: Community engagement, wind farms, and renewable energy transitions in Australia. Journal of Environmental Policy and Planning 10(3), 217-232.

Hitch, M. & Fidler, C.R. (2007). Impact and benefit agreements: A contentious issue for environmental and aboriginal justice. *Environments Journal, 35*(2), 45-69.

Holburn, G., Loudermilk, M., & Wilkie, A. (2014). *The Duty to Consult and Accommodate Aboriginal Groups in Canada*. Ivey Business School: Energy Policy and Management Centre. Retrieved from: http://www.ivey.uwo.ca/energycentre/research/policy-briefs/

Huntington, H.P. (2000). Using traditional ecological knowledge in science: methods and applications. *Ecological Applications, 10*(5), 1270-1274.

IEA. (2000). *Experience curves for energy technology policy*. Accessed January 2, 2016. Retrieved from: http://reaccess.epu.ntua.gr/LinkClick.aspx?fileticket=Driek6XFOMs%3D&tabid=582&mid=10 6.

Ireland, N. (Nov 5, 2016). “First Nations see economic future in Canada’s growing clean energy industry.” *CBC News*. Accessed Nov 8, 2016. Retrieved from: http://www.cbc.ca/news/indigenous/first-nations-pursue-canada-clean-energy-economy-1.3829405

Keilty, K., Beckley, T.M., & Sherren, K. (2016). Baselines of acceptability and generational change on the Mactaquac hydroelectric dam headpond (New Brunswick, Canada). *Geoforum, 75,* 234-348.

Krivtsov, V. & Linfoot, B. (2012). Disruption to benthic habitats by moorings of wave energy installations: A modelling case study and implications for overall ecosystem functioning. *Ecological Modelling, 245,* 121-124.

Kunz, T.H., Arnett, E.B., Erickson, W.P., Hoar, A.R., Johnson, G.D., Larkin, R.P., Strickland, M.D., Thresher, R.W., & Tuttle, M.D. (2007). Ecological impacts of wind energy development on bats: questions, research needs, and hypotheses. *Frontiers in Ecology and the Environment, 5*(6), 315-324. doi: 10.1890/1540-9295(2007)5[315:EIOWED]2.0.CO;2

Mabee, W.E., Mannion, J., & Carpenter, T. (2012). Comparing the feed-in tariff incentives for renewable electricity in Ontario and Germany. *Energy Policy, 40,* 480-489.

Maclean, I.M.D., Inger, R., Benson, D., Booth, C.G., Embling, C.B., Grecian, W.J., Heymans, J.J., Plummer, K.E., Shackshaft, M., Sparling, C.E., Wilson, B., Wright, L.J., Bradbury, G., Christen, N., Godley, B.J., Jackson, A.C., McCluskie, A., Nicholls-Lee, R., & Bearhop, S. (2014). Resolving issues with environmental impact assessment of marine renewable energy installations. *Frontiers in Marine Science, 1,* 1-5.

Manchester, S., Barzegar, B., Swan, L., Groulx, D. (2013) Energy Storage Requirements for In-Stream Tidal Generation on a Limited Capacity Electricity Grid. *Energy*, *61*, 283-290.

Markusoff, J. & Patriquin, M. (Sept 29, 2016). “Why Trudeau and the oil industry are losing the pipeline battle.” *Macleans.* Accessed Sept 30, 2016. Retrieved from: http://www.macleans.ca/economy/why-trudeau-and-the-oil-industry-are-losing-the-pipeline-battle/

Membertou Geomatics Solutions. (2009). *Phase 1 – Bay of Fundy, Nova Scotia, including the Fundy Tidal Energy Demonstration Project Site: Mi’kmaq Ecological Knowledge Study.* Membertou Geomatics Consultants. Retrieved from: http://www.oera.ca/marine-renewable-energy/strategic-environmental-assessment/mikmaq-ecological-knowledge-studies/

Membertou Geomatics Solutions. (2012). *Phase 2 – Bay of Fundy, Nova Scotia, including the Outer Bay of Fundy Tidal Energy Project Site: Mi'kmaq Ecological Knowledge Study.* Membertou Geomatics Solutions. Retrieved from: http://www.oera.ca/marine-renewable-energy/strategic-environmental-assessment/mikmaq-ecological-knowledge-studies/

Millbrook First Nation. (2014). *Wind Energy Project under the C.O.M.F.I.T. Program.* Millbrook First Nation.Net. Accessed Nov 27, 2016. Retrieved from: http://millbrookfirstnation.net/initiatives/entry/wind-energy-project-under-the-c.o.m.f.i.t.-program

Murphy, A., Duncan, G., & Piggott, G. (2008). *Primer: Canadian Law on Aboriginal and Treaty Rights.* UBC Faculty of Law. Accessed January 25, 2017. Retrieved from: http://www.allard.ubc.ca/sites/www.law.ubc.ca/files/uploads/enlaw/pdfs/primer_complete_05_10_09.pdf

Noble, B.F. (2009). *Introduction to Environmental Impact Assessment: A Guide to Principles and Practice.* London: Oxford University Press. 288 p.

Offshore Energy Research Association. (2008). *Fundy Tidal Energy Strategic Environmental Assessment.* Halifax: Offshore Energy Research Association of Nova Scotia. Accessed Sept 17, 2016. Retrieved from: http://www.oera.ca/marine-renewable-energy/strategic-environmental-assessment/

Ricci, M., Bellaby, P. and Flynn, R. (2010). Engaging the public on paths to sustainable energy: Who has to trust whom? *Energy Policy 38,* 2633-2640.

Roberts, A., Thomas, B., Sewell, P., Khan, Z., Balmain, S., & Gillman, J. (2016). Current tidal power technologies and their suitability for applications in coastal and marine areas. *Journal of Ocean Engineering and Marine Energy, 2,* 227-245. doi: 10.1007/s40722-016-0044-8

Romero-Gomez, P. & Richmond, M.C. (2014). Simulating blade-strike on fish passing through marine hydrokinetic turbines. *Renewable Energy, 71,* 401-413.

Shen, H., Zydlewski, G.B., Viehman, H.A., & Staines, G. (2016). Estimating the probability of fish encountering a marine hydrokinetic device. *Renewable Energy, 97,* 746-756.

Shields, M.A., Woolf, D.K., Grist, E.P.M., Kerr, S.A., Jackson, A.C., Harris, R.E., Bell, M.C., Beharie, R., Want, A., Osalusi, E., Gibb, S.W., & Side, J. (2011). Marine renewable energy: The ecological implications of altering the hydrodynamics of the marine environment. *Ocean & Coastal Management, 54,* 2-9.

Thomson, I. & Boutilier, R. G. (2011). Social license to operate. In P.Darling (Ed.), *SME Mining Engineering Handbook* (pp. 1779-1796). Littleton, CO: Society for Mining, Metallurgy and Exploration.

Town of Parrsboro. (2014). Town of Parrsboro Strategic Plan. Town of Parrsboro. Accessed Nov 30, 2016. Retrieved from: http://www.town.parrsboro.ns.ca/index.php/strategic-plan.html

Turner, N.J., Ignace, M.B., & Ignace, R. (2000). Traditional ecological knowledge and wisdom of aboriginal peoples in British Columbia. *Ecological Applications, 10*(5), 1275-1287.

Walker, G. (2008.) What are the barriers and incentives for community-owned means of energy production and use? *Energy Policy, 36*, 4401-4405.

Watts, L. (2009). OrkneyLab: An archipelago experiment in futures. In T. Ingold and M. Janowski (Eds.), *Imagining Landscapes*. Asghate Publishing: Farnham, UK. Accessed March 7, 2015. Retrieved from: https://itu.academia.edu/LauraWatts/

Watts, L. & Winthereik, B. (2014). Energy as alien. In E. Monoian and R. Ferry (Eds.), New Energies: Land Art Generator Initiative, Copehagen. Retrieved from: http://alienenergy.dk/wp-content/uploads/2014/10/EnergyAsAlien_PDF.pdf

Wiersma, B. and Devine-Wright, P. (2014). Public engagement with offshore renewable energy: a critical review. *Wiley Interdisciplinary Reviews: Climate Change 5,* 493-507. doi: 10.1002/wcc.282

Wolsink, M. (2007). Planning renewables schemes: Deliberative and fair decision-making on landscape issues instead of reproachful accusations of non-cooperation. *Energy Policy, 35,* 2692-2704.

Wolsink, M. (2010). Contested environmental policy infrastructure: Socio-political acceptance of renewable energy, water, and waste facilities. *Environmental Impact Assessment Review, 30*, 302-311.

Wright, G. (2015). Marine governance in an industrialised ocean: A case study of the emerging marine renewable energy industry. *Marine Policy, 52*, 77-84. doi: 10.1016/j.marpol.2014.10.021

Wright, G. (2016). Regulating wave and tidal energy: An industry perspective on the Scottish marine governance framework. *Marine Policy, 65,* 115-126.

Wustenhagen, R., Wolsink, M., & Burer, M.J. (2007). Social acceptance of renewable energy innovation: an introduction to the concept. *Energy Policy, 35,* 2683-2691.

Chapter 5: Conclusion

5.1. Thesis Summary

This research was undertaken to address six interrelated questions relevant to the consideration of small-scale tidal energy development. Those questions, raised in Chapter 1, were:

1. Is there a significant enough resource and market for small-scale tidal energy development to prove worthwhile?
2. Are small-scale tidal projects being pursued in Nova Scotia, or elsewhere? If not, why not?
3. Aside from electricity generation, what benefits can small tidal provide to individuals, communities, and society?
4. What are the costs associated with extracting energy from the tides (environmentally, socially, culturally, and financially)?
5. What environmental, sociopolitical, economic, and technical considerations are relevant to the deployment of small-scale tidal energy devices?
6. How can a community, project proponent, regulator, or individual decide whether pursuing a small-scale tidal project is worthwhile?

The first of these questions was addressed at length in Chapter 2; a cautious affirmation can be given as its answer, as there are both significant markets globally for small-scale energy generation devices and a large global tidal resource that may prove impossible to fully or efficiently harness with utility-scale tidal power devices. Furthermore, there are many locations with strong tidal resources but very low electricity demand. In such areas, small-scale tidal may prove an environmentally and financially attractive source of energy, especially where it can supplant or replace (in concert with effective storage) fossil fuel energy sources.

The second question is more complicated; it relies primarily on evidence presented in Chapter 2. Although there were efforts to pursue small-scale tidal in Nova Scotia, to-date, there have not been any successful device deployments. The exact cause of this failure is unclear, but a significant softening of policy support mechanisms for small tidal development is a likely contributing factor, during the transition from the high subsidy prices available under COMFIT to the lower, market prices available since 2015.

Elsewhere, some small tidal projects appear to be proceeding, such as the 400 kW plant in the Shetland Islands, but such installations are vastly outnumbered by utility-scale tidal developments such as those being pursued at FORCE and Meygen. This research supports the notion that the primary limiting factors on small tidal development are as follows: a relative lack of available small-scale tidal devices and small tidal array platforms; high cost of devices and resource assessment per-site; uncertainty regarding environmental effects of tidal energy harvesting; and a lack of appropriate, stable policy mechanisms to encourage tidal deployments. Though these factors may change with time as the industry develops, in the near-term, addressing these concerns through further research, engineering, and policy design is necessary to enable the advancement of small tidal.

The benefits realized by individuals, communities and society through small tidal development is addressed most directly in Chapter 4, though it is also touched upon in other chapters. The exact answer to this question depends upon the context of the community where the devices are installed; the only constant across small tidal contexts is the generation of electricity with no emissions in the generation process. For example, remote, diesel-reliant or energy-poor villages will see more immediate local benefits from tidal energy development (displaced diesel fuel costs, less local air pollution, lower chance of a fuel or lubricant spill in the local environment, greater energy security) than those that are connected to a pre-existing, stable, and secure national grid system. However, a community can benefit from small tidal projects in ways beyond the energy such projects can generate. Securing local work contracts, especially as part of supply chain, maintenance, or monitoring operations can be a vital way to bring revenues from the project into the broader community, while local project (co-)ownership can allow residents or the community as a whole to directly profit from (or spread the cost of) local energy generation. In cases where direct profit from work on the project or sharing its revenues is untenable, small tidal developers could ensure communities benefit either from directly consuming the electricity, or from so-called legacy projects, such as reinvestment of revenues in local parks or recreational facilities. Through providing cleaner energy, as well as any local work opportunities, legacy project funding, revenue sharing, and increased energy security, small tidal can contribute meaningfully to communities, provided it is pursued appropriately. However, attaining these benefits is largely a question of context and consultation (Chapter 3); few projects are likely to provide all possible benefits in any given community.

The costs of tidal energy generation remain somewhat uncertain (Kerr et al., 2014; MacGillivray, Jeffrey, Winskel, & Bryden, 2014; Dalton et al., 2015; MacDougall, 2015; MacGillivray, Jeffrey & Wallace, 2015). While conservative estimates have been placed on the financial costs of hypothetical projects in Cape Breton, Nova Scotia and Nunavut were developed during this research, these estimates are subject to considerable variation should developers pursue aggressive cost reductions in the near-term, or government policy change radically. MacDougall (2015) noted this volatility in her assessment of the value of development. The nascent, rapidly-changing nature of the tidal sector could make any such estimates, whether presently available or to-be-developed, obsolete within just a few years. The environmental costs of tidal energy development (at any scale) remain largely unknown and unproven (Dubbs, Keeler, & O'Meara, 2013; de Groot, Campbell, Ashley & Rodwell, 2014; Maclean et al., 2015), particularly the risks to marine life. Though no tidal energy deployments have yet to be determined to cause known harm to fish, benthic, or marine mammal populations in their surrounding environments, too few deployments have been carried out to consider this absence of evidence to conclusively suggest that tidal energy extraction is environmentally benign. Furthermore, tidal devices have not been deployed in a wide enough range of environments for the transferability of observed effects (or lack thereof) to be considered.

Similarly, due to the small number of operational facilities (Flynn, 2015; MacGillivray, Jeffrey & Wallace, 2015; Roberts et al., 2016), it is difficult to conclude what the actual social and cultural effects of tidal energy development are on communities. As previously noted, researchers (Alexander, Wilding & Heymans, 2013; de Groot et al., 2014; Wright, 2015; 2016) have suggested that the need for exclusion zones around tidal projects, and the consequent loss of sea area access, may impact fishers and recreational water users adversely and require compensation. Similarly, we would suggest that, given the Duty to Consult (Murphy, Duncan & Piggott, 2008), any harms or limitations on access imposed by tidal developments on local environments may be difficult to reconcile with indigenous populations. Without a clear, implemented project and an actual measure of the sorts of community benefits arranged for with “typical’ tidal energy projects, conclusions drawn on the “costs” imposed by projects are speculative. At the present level of industry preparedness, what can instead be stated is that developers and communities must bear the known unknowns of the industry in mind. Thus, for any small tidal project, consideration must be given to whether the project will financially pay itself off, what the potential impact may be to local marine life, if there is a realistic risk of affecting local tidal patterns (and/or related community life and infrastructure), and whether device placement would limit access to areas previously used for business, recreational, or cultural/religious purposes. Balancing such potential costs against the benefits will be key to ensuring local people are willing to allow a project to proceed; thus, the answers to the fourth and fifth questions are intrinsically linked.

Obviously, the availability of a sufficient resource for tidal energy harvesting is the first condition necessary for a project to be considered viable. As discussed in Chapter 2, this technical constraint is presently limited by the cut-in speeds of the various tidal energy devices available; most are inoperable in flows below 1.5 m/s. The basic requirement is for a tidal flow to have a velocity in excess of a device’s cut-in speed for a sufficient amount of time per day in order to generate a reasonable amount of power holds. While a “reasonable amount of power” will always be a context-specific question (determined by project scale and community or grid electricity demand) the model used in Chapter 3 provides a reference point here. Projects should expect to have annual capacity factors somewhere between 30 and 40%. Should generation fall below this threshold, the (financial) operational costs may soon outweigh revenues. While capacity factors exceeding 40% are possible, the incremental cost (in design time, delayed deployments, and engineering fees) of pursuing such improvements for small-scale devices may not be made up by increased revenues (MacGillivray, Jeffrey & Wallace, 2015; Roberts et al., 2016).

With respect to sociopolitical considerations, the minimum condition must be a degree of project tolerance (but not necessarily support) from local people. Achieving this tolerance is likely (Wolsink, 2010; Kerr et al., 2014; Wiersma & Devine-Wright, 2014) to require (a) assurance or provision of some kind of community benefit, (b) avoiding negative environmental or business impacts from the project, and (c) extensive consultation with local people. Such consultations will need to engage both indigenous and non-indigenous communities, where indigenous peoples are addressed separately. Finding ways to address people's project-related concerns, through job creation, environmental monitoring and mitigation efforts, and providing local benefits is key.

Ultimately, the determination of whether a small-scale tidal energy project is worthwhile lies with its proponents. A viable project must be able to generate enough revenue (over its lifetime) to pay all of its associated costs. It must also be acceptable to the people affected by it, whether they are competing users (fishers, tourist businesses, shipping traffic, etc.), culturally affected (e.g. sacred area encroachment), or simply consuming the energy the project produces. Achieving this acceptance depends upon the balance of costs and benefits the project provides to the host community. In turn, such costs and benefits will depend upon the specifics of the energy system. Weighing each of these considerations, and determining the appropriate response to each is the responsibility of the project's proponents (whether a private business, community leaders, or another organisation) as they have final determination whether or not to proceed with the project.

5.2 Conclusions

It is clear that there is some potential for small-scale tidal development to contribute meaningfully to energy systems around the world. This is especially true in remote and coastal areas of the world that either lack energy access, or rely on costly forms of energy such as diesel generation. Small tidal devices intended for these unconventional energy contexts could, with some adaptation, also prove to be economically viable and socially acceptable means of supplying power if governments and electricity system operators chose to pursue grid decentralisation efforts. In both off-grid and more conventional grid contexts, properly planned small-scale tidal energy projects offer several potential benefits, including avoided carbon emissions, increased energy security, local employment opportunities, and (in some cases) a sense of psychological identification and place. However, attaining any of these benefits is—as with any energy project—contingent upon acquiring social license (as defined in Chapter 4) from the community that will host the project. To this end, it is necessary to provide as much information as possible to the public about the project and its impacts. Yet much of the information that communities may be concerned with (environmental risks, jobs impacted, or the cost of energy generated) remains unavailable outside of private firm documents.

Many unknowns remain to be addressed regarding the contexts in which small-scale tidal energy will prove attractive; the current state of knowledge related to these unknowns has been summarised in the preceding chapters. While much work remains to be done to develop a viable small-scale tidal energy industry (i.e. one that be sustained without subsidy) the potential for such an industry to succeed clearly exists. Though existing tidal firms seem to be focused on utility-scale projects, there are an increasing number of companies pursuing small-scale designs. It is vital to field-prove these devices in various environments and find ways to reduce both costs and environmental impacts (if any). However, before devices are deployed—even for testing—efforts should be made to attain permission from local people and users of marine areas and resources who may be concerned with project impacts. Early involvement may help to create social license for further development in the future, and alleviate issues arising around projects in the early phases. Early support could facilitate easier, and perhaps somewhat faster, development of knowledge to address the many unknowns in the sector. Some of the near- and long-term unknowns that should receive priority are discussed below.

5.3 Future Work

This thesis has identified several areas of interest for future research in small-scale tidal energy. While the existence of a small tidal resource has been inferred in this study from the literature and assessments made by others, a more comprehensive assessment of both general and specific small tidal resource characteristics would be a desirable step forward for the sector. Similarly, further exploration of the specific environmental conditions (e.g. flow velocities, turbulence levels) under which small tidal devices can prove financially and technically viable in the field is necessary. Contingently, the development of both devices and deployment platforms suitable to small-scale tidal development is necessary for any progress to be made. In order to improve the range of projects that can be financially viable, emphasis should be placed on research into low-cost designs and means to reduce the installation, decommissioning, and project-planning costs (e.g. site assessment, monitoring, and materials) associated with projects.

Furthermore, once a clearer idea of the cost-breakdown of tidal energy projects has been developed, the model developed in Chapter 3 could be updated and extended to determine the primary drivers of risk and uncertainty in project costs as industry development proceeds. Ongoing study of implemented small-scale tidal projects, both those that succeed and those that fail, will be vital to determine the best approaches for communities and developers in the future.

5.4 References

Alexander, K.A., Wilding, T.A., & Heymans, J.J. (2013). Attitudes of Scottish fishers towards marine renewable energy. *Marine Policy, 37,* 239-244. doi: 10.106/j.marpol.2012.05.005

de Groot, J., Campbell, M., Ashley, M., & Rodwell, L. (2014). Investigating the co-existence of fisheries and offshore renewable energy in the UK: Identification of a mitigation agenda for fishing effort displacement. *Ocean & Coastal Management, 102,* 7-18. doi: 10.1016/j.ocecoaman.2014.08.013

Dubbs, L., Keeler, A. G., & O'Meara, T. (2013). Permitting, risk and marine hydrokinetic energy development. *The Electricity Journal*, *26*(10), 64–74. doi: 10.1016/j.tej.2013.11.002

Flynn, B. (2015). Ecological modernisation of a 'Cinderella renewable'? The emerging politics of global ocean energy. *Environmental Politics, 24*(2), 249-269. doi: 10.1080/09644016.2014.1000638

Kerr, S., Watts, L., Colton, J., Conway, F., Hull, A., Johnson, K., Jude, S., Kannen, A., MacDougall, S., McLachlan, C., Potts, T., & Vergunst, J. (2014). Establishing an agenda for social studies research in marine renewable energy. *Energy Policy, 67*, 694-702.

MacDougall, S.L. (2015). The value of delay in tidal energy development. *Energy Policy, 87,* 438-446. doi: 10.1016/j.enpol.2015.09.034

MacGillivray, A., Jeffrey, H., Winskel, M., & Bryden, I. (2014). Innovation and cost reduction for marine renewable energy: A learning investment sensitivity analysis. *Technological Forecasting & Social Change, 87,* 108-124.

MacGillivray, A., Jeffrey, H., & Wallace, R. (2015). The importance of iteration and deployment in technology development: A study of the impact on wave and tidal stream energy research, development and innovation. *Energy Policy*, *87*, 542–552. doi: 10.1016/j.enpol.2015.10.002

Maclean, I.M.D., Inger, R., Benson, D., Booth, C.G., Embling, C.B., Grecian, W.J., Heymans, J.J., Plummer, K.E., Shackshaft, M., Sparling, C.E., Wilson, B., Wright, L.J., Bradbury, G., Christen, N., Godley, B.J., Jackson, A.C., McCluskie, A., Nicholls-Lee, R., & Bearhop, S. (2014). Resolving issues with environmental impact assessment of marine renewable energy installations. *Frontiers in Marine Science, 1,* 1-5.

Murphy, A., Duncan, G., & Piggott, G. (2008). *Primer: Canadian Law on Aboriginal and Treaty Rights.* UBC Faculty of Law. Accessed January 25, 2017. Retrieved from: http://www.allard.ubc.ca/sites/www.law.ubc.ca/files/uploads/enlaw/pdfs/primer_complete_05_10_09.pdf

Roberts, A., Thomas, B., Sewell, P., Khan, Z., Balmain, S., & Gillman, J. (2016). Current tidal power technologies and their suitability for applications in coastal and marine areas. *Journal of Ocean Engineering and Marine Energy, 2,* 227-245. doi: 10.1007/s40722-016-0044-8

Wiersma, B. and Devine-Wright, P. (2014). Public engagement with offshore renewable energy: a critical review. *Wiley Interdisciplinary Reviews: Climate Change 5,* 493-507. doi: 10.1002/wcc.282

Wolsink, M. (2010). Contested environmental policy infrastructure: Socio-political acceptance of renewable energy, water, and waste facilities. *Environmental Impact Assessment Review, 30*, 302-311.

Wright, G. (2015). Marine governance in an industrialised ocean: A case study of the emerging marine renewable energy industry. *Marine Policy, 52*, 77-84. doi: 10.1016/j.marpol.2014.10.021

Wright, G. (2016). Regulating wave and tidal energy: An industry perspective on the Scottish marine governance framework. *Marine Policy, 65,* 115-126.

Bibliography

AECOM Canada Ltd. (2012). *Marine Renewable Energy: Background Report to Support a Strategic Environmental Assessment (SEA) For the Cape Breton Coastal Region, inclusive of the Bras D'Or Lakes.* Halifax: Offshore Energy Research Association of Nova Scotia. Accessed Sept 18, 2016. Retrieved from: http://www.oera.ca/marine-renewable-energy/strategic-environmental-assessment/

AECOM Canada Ltd. (2014). *Tidal energy: Strategic Environmental Assessment Update for the Bay of Fundy.* Halifax: Offshore Energy Research Association of Nova Scotia. Accessed Sept 17, 2016. Retrieved from: http://www.oera.ca/marine-renewable-energy/strategic-environmental-assessment/

Alberstat, J. (February 27, 2013). *Tidal developer delays Bay of Fundy project*. The Chronicle Herald, newspaper. Accessed January 17, 2016. Retrieved from: http://thechronicleherald.ca/business/800676-tidal-developer-delays-bay-of-fundy-project

Alexander, K.A., Wilding, T.A., & Heymans, J.J. (2013). Attitudes of Scottish fishers towards marine renewable energy. *Marine Policy, 37,* 239-244. doi: 10.106/j.marpol.2012.05.005

Allan, G., Eromenko, I., Gilmartin, M., Kockar, I., & McGregor, P. (2015). The economics of distributed energy generation: a literature review. *Renewable and Sustainable Energy Reviews, 42*, 543-556.

Alvial-Palavicino, C., Gamido-Echeverria, N., Jiménez-Estévez, G.. Reyes, L. and Palma-Behnke, R. (2011). A methodology for community engagement in the introduction of renewable-based smart microgrid. *Energy for Sustainable Development, 15*, 314-323.

Anyi, M. & Kirke, B. (2010). Evaluation of small axial flow hydrokinetic turbines for remote communities. *Energy for Sustainable Development, 14,* 110-116.

Anyi, M. & Kirke, B. (2011). Hydrokinetic turbine blades: Design and local construction techniques for remote communities. *Energy for Sustainable Development, 15,* 223-230.

APERC. (2007). *A Quest for Energy Security in the 21st Century.* Asia Pacific Energy Research Centre. Accessed November 20, 2016. Retrieved from: http://aperc.ieej.or.jp/file/2010/9/26/APERC_2007_A_Quest_for_Energy_Security.pdf

Atlantis Resources Ltd. (April 29, 2015). *Acquisition of Marine Current Turbines Limited from Siemens*. Press release. Accessed January 12, 2016. Retrieved from: http://atlantisresourcesltd.com/media-centre/atlantis-annoucements/79-2015-annoucements/360-acquisition-of-marine-current-turbines-limited-from-siemens.html

Atlantis Resources Ltd. (2016). *Meygen Project Update Spring 2016*. Accessed March 1, 2016. Retrieved from: http://atlantisresourcesltd.com/images/pdf/Meygen%20Newsletter%20201602.pdf

Bailey, I., West, J., & Whitehead, I. (2011). Out of sight but not out of mind? Public perceptions of wave energy. *Journal of Environmental Policy and Planning, 13*, 139–57.

Barnett, J., Burningham, K., Walker, G., & Cass, N. (2012). Imagined publics and engagement around renewable energy technologies in the UK. *Public Understanding of Science, 21*(1), 36-50.

Barrios, L. & Rodriguez, A. (2004). Behavioural and environmental correlates of soaring-bird mortality at on-shore wind turbines. *Journal of Applied Ecology, 41*(1), 72-81. doi: 10.1111/j.1365-2664.2004.00876.x

Batel, S., Devine-Wright, P., & Tangeland, T. (2013). Social acceptance of low-carbon energy and associated infrastructures: A critical discussion. Energy Policy 58, 1-5.

Baxter, J., Morzaria, R., & Hirsch, R. (2013). A case-control study of support/opposition to wind turbines: Perceptions of health risk, economic benefits, and community conflict. *Energy Policy, 61,* 931-943.

Beatty, S.J., Wild, P. & Buckham, B.J. (2010). Integration of a wave energy converter into the electricity supply of a remote Alaskan island. *Renewable Energy, 35,* 1203-1213.

Beaudin, M., Zareipour, H., Schellenberglabe, A., & Rosehart, W. (2010). Energy storage for mitigating the variability of renewable electricity sources: An updated review. *Energy for Sustainable Development, 14*(4), 302-314. doi: 10.1016/j.esd.2010.09.007

Birjandi, A. & Bibeau, E. (n.d.) *Electricity rate database.* Canadian Hydrokinetic Turbine Test Centre. Accessed May 30, 2016. Retrieved from: https://www.google.com/maps/d/viewer?mid=16fcbjgd67ufxc7Xu965EZ47haKQ&ll=63.832039437660676%2C-72.528154825&z=5

Black Rock Tidal Power. (n.d.) *Technology*. Black Rock Tidal Power Ltd. Accessed September 19, 2016. Retrieved from: http://www.blackrocktidalpower.com/technology/

Blunden, L.S., Bahaj, A.S., & Aziz, N.S. (2013). Tidal current power for Indonesia? An initial resource assessment for the Alas Strait. *Renewable Energy, 49,* 137-142.

Boehlert, G.W. & Gill, A.B. (2010). Environmental and ecological effects of ocean renewable energy development: A current synthesis. *Oceanography, 23(2),* 68-81.

Bompard, E., Masera, M. & Nuttall, W. (2015). High tension electricity New multi-scale complexities in the electricity system. *Technological Forecasting & Social Change, 96*, 327–333

Bradshaw, J. (Nov 5, 2016). *UK could miss out on EU science grants post-Brexit.* The Telegraph. Retrieved Nov 8, 2016: http://www.telegraph.co.uk/business/2016/11/05/uk-could-miss-out-on-eu-science-grants-post-brexit/

Broadhurst, M., Barr, S., & Orme, C.D.L. (2014). In-situ ecological interactions with a deployed tidal energy device; an observational pilot study. *Ocean & Coastal Management*, *99*, 31-38.

Bryden, I.G., Brinsted, T., & Melville, G.T. (2004a). Assessing the potential of a simple tidal channel to deliver useful energy. *Applied Ocean Research, 26,* 198-204.

Bryden, I.G. & Melville, G.T. (2004b). Choosing and evaluating sites for tidal current development. *Proceedings of the Institute of Mechanical Engineers Part A: Journal of Power and Energy, 218*(8), 567-577.

Byrnes, L, Brown, C., Wagner, L, & Foster, J. (2016). Reviewing the viability of renewable energy in community electrification: The case of remote Western Australian communities. *Renewable and Sustainable Energy Reviews*, 59, 470–481.

Canadian Press. (Sept 12, 2016). *First Nations argue for reversal of Site C dam proposal.* Macleans. Accessed Sept 30, 2016. Retrieved from: http://www.macleans.ca/news/site-c-reversal-first-nations-b-c/

Carballo, R., Iglesias, G., & Castro, A. (2009). Numerical model evaluations of tidal stream energy in the Ría de Muros (NW Spain). *Renewable Energy, 34,* 1517-1524. doi: 10.1016/j.renene.2008.10.028

Cass, N., Walker, G., & Devine-Wright, P. (2010). Good neighbours, public relations, and bribes: the politics and perceptions of community benefit provision in renewable energy development in the UK. *Journal of Environmental Policy and Planning, 12*(3), 255-275.

Castro, A.P., & Nielseon, E. (2001). Indigenous people and co-management: implications for conflict management. *Environmental Science & Policy, 4*(4-5), 229-239.

CBC News. (November 12, 2015). *Bay of Fundy tidal power installation delayed until spring*. Accessed January 17, 2016. Retrieved from: http://www.cbc.ca/news/canada/nova-scotia/bay-fundy-turbines-delay-1.3315959

Chen, L, & Lam, W.H. (2014). Methods for predicting seabed scour around marine current turbine. *Renewable and Sustainable Energy Reviews, 29,* 683-692.

City of Vancouver. (2015). Renewable City Strategy. City of Vancouver. Accessed Nov 30, 2016. Retrieved from: http://vancouver.ca/files/cov/renewable-city-strategy-summary.pdf

Clean Current Inc. (May 29, 2015). *Clean Current exits industry*. Press release. Accessed January 17, 2016. Retrieved from: http://www.cleancurrent.com/news#news-item-link-1

Corscadden, K., Wile, A., & Yiridoe, E. (2012). Social license and consultation criteria for community wind projects. *Renewable Energy, 44,* 392-397.

Cummins, P. (2012). On the extractable power in a tidal channel. *Journal of Waterway, Port, Coastal and Ocean Engineering, 138*(1)*,* 63-71.

Dalton, G., Allan, G., Beaumont, N., Georgakaki, A., Hacking, N., Hooper, T., Kerr, S., O'Hagan, A.M., Reilly, K., Ricci, P., Sheng, W., & Stallard, T. (2015). Economic and socio-economic assessment methods for ocean renewable energy: Public and private perspectives. *Renewable and Sustainable Energy Reviews, 45*, 850-878. doi: 10.1016/j.rser.2015.01.068

Davies, I.M., Watret, R., & Gubbins, M. (2014). Spatial planning for sustainable marine renewable energy developments in Scotland. *Ocean & Coastal Management, 99*, 72-81. doi: 10.1016/j.ocecoaman.2014.05.013

de Groot, J., Campbell, M., Ashley, M., & Rodwell, L. (2014). Investigating the co-existence of fisheries and offshore renewable energy in the UK: Identification of a mitigation agenda for fishing effort displacement. *Ocean & Coastal Management, 102,* 7-18. doi: 10.1016/j.ocecoaman.2014.08.013

del Rio, P. & Burgillo, M. (2008). Assessing the impact of renewable energy deployment on local sustainability: Towards a theoretical framework. *Renewable and Sustainable Energy Reviews, 12,* 1325-1344.

del Rio, P. & Burgillo, M. (2009). An empirical analysis of the impact of renewable energy deployment on local sustainability. *Renewable and Sustainable Energy Reviews, 13,* 1314-1325.

Delaney, G. (February 4, 2014). *Tidal power proposal for Scots Bay meets with skepticism.* The Chronicle Herald. Accessed January 30, 2016. Retrieved from: http://thechronicleherald.ca/novascotia/1184437-tidal-power-proposal-for-scots-bay-meets-with-skepticism

Delucchi, M.A., & Jacobson, M.Z. (2013). Meeting the world's energy needs entirely with wind, water and solar power. *Bulletin of the Atomic Scientists, 69*(4), 30-40.

Delvaux, P.A.G., Rabuteau, Y. and Stanley, K. (2013). *Civil society involvement and social acceptability of marine energy projects: Best practices of the marine energy sector*. MERiFIC: France.

Denny, E. (2009). The economics of tidal energy. *Energy Policy, 37*, 1914-1924. doi: 10.1016/j.enpol.2009.01.009

Devine-Wright, P. (2005). Beyond NIMBYism: towards an integrated framework for understanding public perceptions of wind energy. *Wind Energy, 8*, 125-139.

Devine-Wright, P. (2011a). Enhancing local distinctiveness fosters public acceptance of tidal energy: A UK case study. *Energy Policy, 39*(1), 83-93. doi: 10.1016/j.enpol.2010.09.012

Devine-Wright, P. (2011b). Place attachment and public acceptance of renewable energy: a tidal energy case study. *Journal of Environmental Psychology, 31*, 336–43.

DFO. (2016). *Review of the environmental effects monitoring program for the Fundy Tidal Energy Project*. Fisheries and Oceans Canada. Accessed October 1, 2016. Retrieved from: http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ScR-RS/2016/2016_022-eng.pdf

Dickman, S. (Nov 21, 2016). *Sounding the Alarm: UK Biotech Struggles to Cope with Brexit.* Forbes. Retrieved Nov 24, 2016: http://www.forbes.com/sites/stevedickman/2016/11/21/sounding-the-alarm-uk-biotech-struggles-to-cope-with-brexit/

Dimoff, A. (Aug 11, 2016). *Tidal power technology rolls into Haida Gwaii shores.* CBC News. Accessed Oct 28, 2016. Retrieved from: http://www.cbc.ca/news/canada/british-columbia/tidal-power-haida-gwaii-1.3717132

Dubbs, L., Keeler, A. G., & O'Meara, T. (2013). Permitting, risk and marine hydrokinetic energy development. *The Electricity Journal*, *26*(10), 64–74. doi: 10.1016/j.tej.2013.11.002

Ellaban, O., Abu-Rub, H., & Blaabjerg, F. (2014). Renewable energy resources: Current status, future prospects and their enabling technology. *Renewable and Sustainable Energy Reviews, 39*, 748-764. doi: 10.1016/j.rser.2014.07.113

EMEC. (2016a). *About us*. Accessed February 12, 2016. Retrieved from: http://www.emec.org.uk/about-us/

EMEC. (2016b). *Funders*. Accessed February 12, 2016. Retrieved from: http://www.emec.org.uk/about-us/funders/

European Commission. (2015). *EU support for ocean energy*. Last updated: 11-08-2015. Accessed February 12, 2016. Retrieved from: http://ec.europa.eu/research/energy/eu/index_en.cfm?pg=research-ocean-support

Fast, S. & Mabee, W. (2015). Place-making and trust-building: The influence of policy on host community responses to wind farms. *Energy Policy, 81,* 27-37.

Federal Energy Regulatory Commission. (2012). *Order issuing pilot project license (minor project). Project No. 12611-005*. Accessed March 29, 2016. Retrieved from: http://www.theriteproject.com/uploads/01-23-12-order.pdf

Firman, L.G. (2008). Assessing the ecological impact of bioenergy projects. *Bioenergy Research, 1*(1), 12-19. doi:10.1007/s12155-007-9000-8

Flynn, B. (2015). Ecological modernisation of a 'Cinderella renewable'? The emerging politics of global ocean energy. *Environmental Politics, 24*(2), 249-269. doi: 10.1080/09644016.2014.1000638

FORCE. (2016). *FORCE Test Site.* Accessed February 12, 2016. Retrieved from: http://fundyforce.ca/about/force-test-site-2/

FORCE. (n.d.) *Technology.* Accessed February 19, 2016. Retrieved from: http://fundyforce.ca/technology/

Frid, C., Andonegi, E., Depestele, J., Judd, A., Rihan, D., Rogers, S.I., & Kenchington, E. (2012). The environmental interactions of wave and tidal energy devices. *Environmental Impact Assessment Review, 32,* 133-139. doi: 10.1016/j.eiar.2011.06.002

Furness, R.W., Wade, H.M., Robbins, A.M.C., & Masden, E.A. (2012). Assessing the sensitivity of seabird populations to adverse effects from tidal stream turbines and wave energy devices. *ICES Journal of Marine Science, 69*(8), 1466-1479. doi: 10.1093/icesjms/fss131

Garrad, A. (2012). The lessons learned from the development of wind energy that might be applied to marine industry renewables. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 370*, 451-471. Doi: 10.1098/rsta.2011.0167

Garrett, C. & Cummins, P. (2005.) The power potential of tidal currents in channels. *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences, 461*, 2563-2572.

Google Earth. (2016). Nova Scotian Tidal Energy Sites Map. Prepared by Carlson, J. Data from GEBCO, LDEO-Columbia, NGA, NOAA, NSF, SIO, & US Navy.

Gordon, T., & Webber, J.R. (2008). Imperialism and resistance: Canadian mining companies in Latin America. *Third World Quarterly, 29*(1), 63-87.

Gorman, M. (June 6, 2016). *Could this 'no-brainer' concept be the key to harnessing the power of the Bay of Fundy tides?* CBC News. Accessed October 30, 2016. Retrieved from: http://www.cbc.ca/news/canada/nova-scotia/big-moon-power-bay-of-fundy-tidal-kinetic-keel-nova-scotia-1.3615567

Hain, J.J., Ault, G.W., Galloway, S.J., Cruden, A., & McDonald, J.R. (2005). Additional renewable energy growth through small-scale community orientated energy policies. *Energy Policy, 33*, 1199-1212.

Hall, N., Lacey, J., Carr-Cornish, S., & Dowd, A.M. (2015). Social license to operate: Understanding how a concept has been translated into practice in energy industries. *Journal of Cleaner Production, 86,* 301-310.

Hammar, L., Ehnberg, J., Mavume, A., Francisco, F., & Molander, S. (2012). Simplified site-screening method for micro tidal current turbines applied in Mozambique. *Renewable Energy, 44,* 414-422.

Hammons, T.J. (1993). Tidal power. *Proceeding of the IEEE, 8*(1), 419-433.

Hardin, G. (1968). The tragedy of the commons. *Science, 168*(3859), 1243-1248. doi: 10.1126/science.162.3859.1243

Hardisty, J. (2009). *The Analysis of Tidal Stream Power.* Chichester, West Sussex, UK: Wiley-Blackwell. 321 pp.

Hart, S.L. & Christensen, C.M. (2002). The great leap: Driving innovation from the base of the pyramid. *MIT Sloan Management Review, 44(1),* 51-56.

Hassan, H.F., El-Shafie, A., & Karim, O.A. (2012). Tidal current turbines glance at the past and look into the future prospects in Malaysia. *Renewable and Sustainable Energy Reviews, 16,* 5707-5717.

Hatcher B.G. (Editor) (2015). *Marine Renewable Energy: Engineering & Ocean Technology Research*. Final Report, NSERC Partnership Workshop, 8-9 Dec. 2014. Bras d'Or Institute, Cape Breton University, Sydney, N.S. 25pp.

Hay, A.E., Zedel, L., Cheel, R., & Dillon, J. (2012). Observations of the vertical structure of turbulent oscillatory boundary layers above fixed roughness beds using a prototype wideband coherent Doppler profiler: 1. The oscillatory component of the flow. *Journal of Geophysical Research: Oceans, 117,* 1-20.

Hermann, W.A. (2011). Quantifying global exergy resources. *Energy, 31*(12), 1685-1702. doi: 10.1016/j.energy.2005.09.006

Hindmarsh, R. & Matthews, C. (2008). Deliberative speak at the turbine face: Community engagement, wind farms, and renewable energy transitions in Australia. Journal of Environmental Policy and Planning 10(3), 217-232.

Hitch, M. & Fidler, C.R. (2007). Impact and benefit agreements: A contentious issue for environmental and aboriginal justice. *Environments Journal, 35*(2), 45-69.

Holburn, G., Loudermilk, M., & Wilkie, A. (2014). *The Duty to Consult and Accommodate Aboriginal Groups in Canada*. Ivey Business School: Energy Policy and Management Centre. Retrieved from: http://www.ivey.uwo.ca/energycentre/research/policy-briefs/

Hooper, T. & Austen, M. (2013). Tidal barrages in the UK: Ecological and social impacts, potential mitigation, and tools to support barrage planning. *Renewable and Sustainable Energy Reviews, 23,* 289-298. doi: 10.1016/j.resr.2013.03.001

Huckerby, J. (2012). International collaboration in ocean energy. *OES Annex IV Webinar.* Ocean Energy Systems: An IEA Technology Initiative. Accessed July 30, 2016. Retrieved from: https://tethys.pnnl.gov/sites/default/files/2012-04-03-2-John-Huckerby.pdf

Hughes, L. (2012). A generic framework for the description and analysis of energy security in an energy system. *Energy Policy, 42,* 221-231. doi: 10.1016/j.enpol.2011.11.079

Huntington, H.P. (2000). Using traditional ecological knowledge in science: methods and applications. *Ecological Applications, 10*(5), 1270-1274.

IEA. (2000). *Experience curves for energy technology policy*. Accessed January 2, 2016. Retrieved from: http://reaccess.epu.ntua.gr/LinkClick.aspx?fileticket=Driek6XFOMs%3D&tabid=582&mid=10 6.

IEA. (2010). *Energy Security*. International Energy Agency. Accessed December 4, 2016. International Energy Agency. Retrieved from: http://www.iea.org/subjectqueries/keyresult.asp?KEYWORD_ID=4103.

IEA. (2014). *World Energy Outlook 2014*. Paris: OECD.

IEA. (2016). *Energy poverty.* International Energy Agency. Accessed December 1, 2016. Retrieved from: http://www.iea.org/topics/energypoverty/

Ireland, N. (Nov 5, 2016). “First Nations see economic future in Canada’s growing clean energy industry.” *CBC News*. Accessed Nov 8, 2016. Retrieved from:

http://www.cbc.ca/news/indigenous/first-nations-pursue-canada-clean-energy-economy-1.3829405

Jacobson, M.Z. & Delucchi, M.A. (2011). Providing all global energy with wind, water and solar power, Part I: Technologies, energy resources, quantities and areas of infrastructure, and materials. *Energy Policy, 39*(3), 1154-1169. doi: 10.1016/j.enpol.2010.11.040

Janssen, R., Arciniegas, G, & Alexander, K.A. (2014). Decision support tools for collaborative marine spatial planning: identifying potential sites for tidal energy devices around the Mull of Kintyre, Scotland. *Journal of Environmental Planning and Management, 58*(4), 719-737. doi: 10.1080/09640568.2014.887561

Karsten, R.H., McMillan, J.M., Lickley, M.J. & Haynes, R.D. (2008). Assessment of tidal current energy in the Minas Passage, Bay of Fundy. *Proceedings of the Institute of Mechanical Engineers, Part A: Journal of Power and Energy, 222*, 493-507.

Keilty, K., Beckley, T.M., & Sherren, K. (2016). Baselines of acceptability and generational change on the Mactaquac hydroelectric dam headpond (New Brunswick, Canada). *Geoforum, 75,* 234-348.

Kerr, S., Watts, L., Colton, J., Conway, F., Hull, A., Johnson, K., Jude, S., Kannen, A., MacDougall, S., McLachlan, C., Potts, T., & Vergunst, J. (2014). Establishing an agenda for social studies research in marine renewable energy. *Energy Policy, 67*, 694-702.

Kregting, L. & Elsaesser, B. (2014). A hydrodynamic modeling framework for the Strangford Lough Part 1: Tidal model. *Journal of Marine Science and Engineering, 2*(1), 46-65. doi: 10.3390/jmse2010046

Krivtsov, V. & Linfoot, B. (2012). Disruption to benthic habitats by moorings of wave energy installations: A modelling case study and implications for overall ecosystem functioning. *Ecological Modelling, 245,* 121-124.

Kunz, T.H., Arnett, E.B., Erickson, W.P., Hoar, A.R., Johnson, G.D., Larkin, R.P., Strickland, M.D., Thresher, R.W., & Tuttle, M.D. (2007). Ecological impacts of wind energy development on bats: questions, research needs, and hypotheses. *Frontiers in Ecology and the Environment, 5*(6), 315-324. doi: 10.1890/1540-9295(2007)5[315:EIOWED]2.0.CO;2

Lago, L.I., Ponta, F.L., & Chen, L. (2010). Advances and trends in hydrokinetic turbine systems. *Energy for Sustainable Development, 14*(4), 287-296. doi: 10.106/j.esd.2010.09.004

Laws, N.D. & Epps, B.P. (2016). Hydrokinetic energy conversion: Technology, research and outlook. *Renewable and Sustainable Energy Reviews, 57*, 1245-1259. Doi: 10.1016/j.rser.2015.12.189

Lewis, M.J.T. (1997) *Millstone and Hammer: the origins of water power*. University of Hull Press, Hull, UK, 180 pp.

Lim, X.L., Lam, W.H., & Hashim, R. (2015). Feasibility of marine renewable energy to the Feed-in Tariff system in Malaysia. Renewable and Sustainable Energy Reviews, 49, 708-719.

Liu, M., Li, W., Yu, J, Ren, Z., & Xu, R. (2016). Reliability evaluation of tidal and wind power generation system with battery energy storage. *Journal of Modern Power Systems and Clean Energy, 4*(4), 636-647.

Mabee, W.E., Mannion, J., & Carpenter, T. (2012). Comparing the feed-in tariff incentives for renewable electricity in Ontario and Germany. *Energy Policy, 40,* 480-489.

MacDougall, S.L. (2015). The value of delay in tidal energy development. *Energy Policy, 87,* 438-446. doi: 10.1016/j.enpol.2015.09.034

MacGillivray, A., Jeffrey, H., Winskel, M., & Bryden, I. (2014). Innovation and cost reduction for marine renewable energy: A learning investment sensitivity analysis. *Technological Forecasting & Social Change, 87,* 108-124.

MacGillivray, A., Jeffrey, H., & Wallace, R. (2015). The importance of iteration and deployment in technology development: A study of the impact on wave and tidal stream energy research, development and innovation. *Energy Policy*, *87*, 542–552. doi: 10.1016/j.enpol.2015.10.002

Maclean, I.M.D., Inger, R., Benson, D., Booth, C.G., Embling, C.B., Grecian, W.J., Heymans, J.J., Plummer, K.E., Shackshaft, M., Sparling, C.E., Wilson, B., Wright, L.J., Bradbury, G., Christen, N., Godley, B.J., Jackson, A.C., McCluskie, A., Nicholls-Lee, R., & Bearhop, S. (2014). Resolving issues with environmental impact assessment of marine renewable energy installations. *Frontiers in Marine Science, 1,* 1-5.

Manchester, S., Barzegar, B., Swan, L., Groulx, D. (2013) Energy Storage Requirements for In-Stream Tidal Generation on a Limited Capacity Electricity Grid. *Energy*, *61*, 283-290.

Mann, K.H. 1982. *The Ecology of Coastal Waters: a Systems Approach*. University of California Press, 322pp.

Maples, B., Saur, G., Hand, M., van de Pieterman, R., & Obdam, T. (2013). *Installation, operation, and maintenance strategies to reduce the cost of offshore wind energy*. National Renewable Energy Laboratory. Goldon, Colorado: United States.

Marine Renewable-energy Act. (2015, c. 32). Nova Scotia Legislature. Accessed October 24, 2016. Retrieved from: http://nslegislature.ca/legc/bills/62nd_2nd/3rd_read/b110.htm

Marine Renewables Canada. (2011). *Charting the Course: Canada's Marine Renewable Energy Technology Roadmap*. Accessed January 8, 2016. Retrieved from: http://www.marinerenewables.ca/wp-content/uploads/2012/09/MRE_Roadmap_e.pdf

Markusoff, J. & Patriquin, M. (Sept 29, 2016). "Why Trudeau and the oil industry are losing the pipeline battle." *Macleans.* Accessed Sept 30, 2016. Retrieved from: http://www.macleans.ca/economy/why-trudeau-and-the-oil-industry-are-losing-the-pipeline-battle/

McDonald, A., & Schrattenholzer, L. (2001). Learning rates for energy technologies. *Energy Policy, 29*(4), 255-261. doi: 10.1016/S0301-4215(00)00122-1

McLachlan, C. (2009). 'You don't do a chemistry experiment in your best china': Symbolic interpretations of place and technology in a wave energy case. *Energy Policy, 37*(12), 5342-5350. doi: 10.1016/j.enpol.2009.07.057

McMillan, E. (July 27, 2016). *"Bay of Fundy inshore fishermen want court to overturn tidal turbine approval."* CBC News. Accessed October 1, 2016. Retrieved from: http://www.cbc.ca/news/canada/nova-scotia/bay-of-fundy-inshore-fishermen-wants-judicial-review-1.3697080

Membertou Geomatics Solutions. (2009). *Phase 1 – Bay of Fundy, Nova Scotia, including the Fundy Tidal Energy Demonstration Project Site: Mi'kmaq Ecological Knowledge Study.* Membertou Geomatics Consultants. Retrieved from: http://www.oera.ca/marine-renewable-energy/strategic-environmental-assessment/mikmaq-ecological-knowledge-studies/

Membertou Geomatics Solutions. (2012). *Phase 2 – Bay of Fundy, Nova Scotia, including the Outer Bay of Fundy Tidal Energy Project Site: Mi'kmaq Ecological Knowledge Study.* Membertou Geomatics Solutions. Retrieved from: http://www.oera.ca/marine-renewable-energy/strategic-environmental-assessment/mikmaq-ecological-knowledge-studies/

Mercure, J.-F., & Salas, P. (2012). An assessment of global energy resource economic potentials. *Energy*, *46*, 322-336. doi: 10.1016/j.energy.2012.08.018

Meygen. (2016). *About Phase 1a*. Retrieved from: http://www.meygen.com/about-phase-1a/

Millbrook First Nation. (2014). *Wind Energy Project under the C.O.M.F.I.T. Program.* Millbrook First Nation.Net. Accessed Nov 27, 2016. Retrieved from: http://millbrookfirstnation.net/initiatives/entry/wind-energy-project-under-the-c.o.m.f.i.t.-program

Morris, R.K.A. (2013). Geomorphological analogues for large estuarine engineering projects: A case study of barrages, causeways and tidal energy projects. *Ocean & Coastal Management, 79*, 52-61. doi: 10.1016/j.ocecoaman.2012.05.010

Murphy, A., Duncan, G., & Piggott, G. (2008). *Primer: Canadian Law on Aboriginal and Treaty Rights.* UBC Faculty of Law. Accessed January 25, 2017. Retrieved from: http://www.allard.ubc.ca/sites/www.law.ubc.ca/files/uploads/enlaw/pdfs/primer_complete_05_10_09.pdf

Noble, B.F. (2009). *Introduction to Environmental Impact Assessment: A Guide to Principles and Practice.* London: Oxford University Press. 288 p.

Nowe, K.M. (2014). *A Model for the Estimation of Emergency Maintenance Cost for a 10 MW Tidal Energy Conversion Installation.* BSc Honours Thesis. Acadia University: Wolfville, Nova Scotia.

NSDOE. (2010). *Renewable electricity plan*. Accessed January 8, 2016. Government of Nova Scotia, Halifax, Nova Scotia, Canada. Retrieved from: http://energy.novascotia.ca/sites/default/files/renewable-electricity-plan.pdf

NSDOE. (2015a). *Our electricity future: Nova Scotia's electricity plan 2015-2040.* Government of Nova Scotia, Halifax, Nova Scotia, Canada. Accessed January 8, 2016. Retrieved from: http://energy.novascotia.ca/sites/default/files/files/FINAL%20Our%20Electricity%20Future%281%29.pdf

NSDOE. (2015b). *Developmental Tidal Feed-in Tariff Program.* Accessed January 8, 2016. Retrieved from: http://energy.novascotia.ca/renewables/programs-and-projects/tidal-fit

NSDOE. (2016). *COMFIT Projects Status List.* Accessed December 1, 2016. Retrieved from: http://energy.novascotia.ca/sites/default/files/files/Copy%20of%20DRAFT%20Comfit%20Status%20as%20of%20October%206%2C%202016.pdf

NSDOE. (n.d.) *Developmental tidal feed-in tariff program.* Province of Nova Scotia. Accessed December 3, 2016. Retrieved from: http://energy.novascotia.ca/renewables/programs-and-projects/tidal-fit

NSPI. (2015). *Enhanced Net Metering.* Accessed January 11, 2016. Retrieved from: http://www.nspower.ca/en/home/for-my-home/make-your-own-energy/enhanced-net-metering/default.aspx

Office of Management and Budget. (2016). *Circular A-94 Appendix C: Discount Rates for Cost-Effectiveness, Lease Purchase and Related Analyses.* The White House. Accessed September 30, 2016. Retrieved from: https://www.whitehouse.gov/omb/circulars_a094/a94_appx-c

Offshore Energy Research Association. (2008). *Fundy Tidal Energy Strategic Environmental Assessment.* Halifax: Offshore Energy Research Association of Nova Scotia. Accessed Sept 17, 2016. Retrieved from: http://www.oera.ca/marine-renewable-energy/strategic-environmental-assessment/

Oleson, J.P. (2000), "Water-Lifting", in Wikander, Örjan, *Handbook of Ancient Water Technology*, Technology and Change in History **2**, Leiden: Brill, pp. 217–302

OpenHydro. (January 20, 2016). *The first of two OpenHydro tidal turbines on EDF's Paimpol-Brehat site successfully deployed*. Press release. Accessed February 27, 2016. Retrieved from: http://www.openhydro.com/news/OpenHydroPR-2016-01-20.pdf

Palisade Corporation. (2016). *@Risk* (Student License Version). [Software]. Available from: http://www.palisade.com/risk/

Pepermans, G., Driesen, J., Haesedonckx, D., Belmans, R., & D'haeseleer,W. (2005). Distributed generation: definition, benefits and issues. *Energy Policy, 33*, 787-798.

Pond, S., Pickard, G.L.. (1983). *Introductory Dynamical Oceanography*. Butterworth-Heinemann Ltd. 331pp.

Province of Nova Scotia. (2012). *Marine Renewable Energy Strategy*. Accessed January 20, 2016. Retrieved from: http://energy.novascotia.ca/sites/default/files/Nova-Scotia-Marine-Renewable-Energy-Strategy-May-2012.pdf

Province of Nova Scotia. (August 6, 2015). *Minister announces COMFIT review results, end to program.* Press release. Accessed January 11, 2016. Retrieved from: http://novascotia.ca/news/release/?id=20150806001

Province of Nova Scotia. (n.d.). *Community Feed-in Tariff Program Facts*. Electronic factsheet. Accessed January 11, 2016. Retrieved from: http://energy.novascotia.ca/sites/default/files/comfit_facts.pdf

Qulliq Energy. (2016). *Customer Types.* Qulliq Energy Corporation. Accessed September 14, 2016. Retrieved from: http://www.qec.nu.ca/node/176

Rhodes, B. (October 25, 2016). *Tidal turbines can be put in Bay of Fundy, at least for now*. CBC News. Accessed December 1, 2016. Retrieved from: http://www.cbc.ca/news/canada/nova-scotia/minas-passage-tidal-turbines-injunction-ruling-1.3820564

Ricci, M., Bellaby, P. and Flynn, R. (2010). Engaging the public on paths to sustainable energy: Who has to trust whom? *Energy Policy 38,* 2633-2640.

Roberts, A., Thomas, B., Sewell, P., Khan, Z., Balmain, S., & Gillman, J. (2016). Current tidal power technologies and their suitability for applications in coastal and marine areas. *Journal of Ocean Engineering and Marine Energy, 2,* 227-245. doi: 10.1007/s40722-016-0044-8

Roberts, T. (June 24, 2016). *It's official: Muskrat Falls a boondoggle, says Stan Marshall.* CBC News. Accessed September 13, 2016. Retrieved from: http://www.cbc.ca/news/canada/newfoundland-labrador/stan-marshall-muskrat-falls-update-1.3649540

Romero-Gomez, P. & Richmond, M.C. (2014). Simulating blade-strike on fish passing through marine hydrokinetic turbines. *Renewable Energy, 71,* 401-413.

Rourke, F.O., Boyle, F. & Reynolds, A. (2010). Tidal energy update 2009. *Applied Energy, 87*, 398-409.

Sample, I. (July 12, 2016). *UK scientists dropped from EU projects because of post-Brexit funding fears.* The Guardian. Retrieved Oct 18, 2016, from: https://www.theguardian.com/education/2016/jul/12/uk-scientists-dropped-from-eu-projects-because-of-post-brexit-funding-fears

Sanchez, M., Carballo, R., Ramos, V., & Iglesias, G. (2014). Floating vs. bottom-fixed turbines for tidal stream energy: A comparative impact assessment. *Energy, 72,* 691-701. doi: 10.1016/j.energy.2014.05.096

Schottel. (n.d.). *SIT Instream Turbine*. Schottel Group. Accessed September 19, 2016. Retrieved from: https://www.schottel.de/schottel-hydro/sit-instream-turbine/

Shen, H., Zydlewski, G.B., Viehman, H.A., & Staines, G. (2016). Estimating the probability of fish encountering a marine hydrokinetic device. *Renewable Energy, 97,* 746-756.

Shields, M.A., Woolf, D.K., Grist, E.P.M., Kerr, S.A., Jackson, A.C., Harris, R.E., Bell, M.C., Beharie, R., Want, A., Osalusi, E., Gibb, S.W., & Side, J. (2011). Marine renewable energy: The ecological implications of altering the hydrodynamics of the marine environment. *Ocean & Coastal Management, 54,* 2-9.

Short, W., Packey, D.J. & Holt, T. (1995). *A Manual for the Economic Evaluation of Energy Efficiency and Renewable Energy Technologies.* National Renewable Energy Laboratory, US Department of Energy. Golden, Colorado: United States.

Singh, A. & Ephraim, J. (2016). Ocean energy: The new energy frontier for the Eastern Caribbean Small Island Developing States. *Energy Policy, 99*, 1-3.

Statistics Canada. (2011a). *Household size, by province and territory (2011 Census) (New Brunswick, Quebec, Ontario).* Census of Population and Statistics Canada catalogue no. 98-313-XCB. Accessed December 4, 2016. Retrieved from: http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/famil53b-eng.htm

Statistics Canada. (2011b). *Household size, by province and territory (2011 Census) (Newfoundland and Labrador, Prince Edward Island, Nova Scotia)*. Census of Population and Statistics Canada catalogue no. 98-313-XCB. Accessed December 4, 2016. Retrieved from: http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/famil53a-eng.htm

Statistics Canada. (2016a). *Population, by year, by province and territory (Number).* Government of Canada. Accessed September 6, 2016. Retrieved from: http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/demo02a-eng.htm

Statistics Canada. (2016b). *Population, urban and rural, by province and territory (Nova Scotia).* Government of Canada. Accessed September 6, 2016. Retrieved from: http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/demo62d-eng.htm

Statistics Canada. (2016c). *Table 153-0161 - Household energy consumption, Canada and provinces, every 2 years.* CANSIM (database). Accessed December 4, 2016. Retrieved from: http://www5.statcan.gc.ca/cansim/a26?lang=eng&retrLang=eng&id=1530161&tabMode=dataTable&srchLan=-1&p1=-1&p2=9

Sustainable Marine. (2016). *Tidal energy turbine platform technology.* Sustainable Marine Energy Ltd. Accessed September 19, 2016. Retrieved from: http://sustainablemarine.com/technology

Taber, J. (November 16, 2014). Project seeks to harness – and harvest – the force of Fundy. *The Globe and Mail*, newspaper. Accessed February 15, 2016. Retrieved from: http://www.theglobeandmail.com/news/national/project-seeks-to-harness-and-harvest-the-force-of-fundy/article21609715/

Tarbatton, M. & Larson, M. (2006). *Canada Ocean Energy Atlas (Phase 1): Potential Tidal Current Energy Resources Analysis Background.* Canada Hydraulic Centre, Natural Resources Canada. Accessed November 26, 2014. Retrieved from: http://www.marinerenewables.ca/wp-content/uploads/2012/11/Canada-Ocean-

Energy-Atlas-Phase-1-Potential-Tidal-Current-Energy-Resources-Analysis-Background.pdf

Tethys. (n.d.) *About Tethys.* Pacific Northwest National Laboratory. Accessed October 8, 2016. Retrieved from: https://tethys.pnnl.gov/about-tethys

Thomson, I. & Boutilier, R. G. (2011). Social license to operate. In P.Darling (Ed.), *SME Mining Engineering Handbook* (pp. 1779-1796). Littleton, CO: Society for Mining, Metallurgy and Exploration.

Tocardo. (2016). *Tidal, river, and ocean current turbines.* Tocardo B.V. Accessed December 1, 2016. Retrieved from: http://www.tocardo.com/

Torrens-Spence, H., Schmitt, P., Mackinnon, P., & Elsaesser, B. (2016). Current and turbulence measurement with collated ADP and turbulence profiler data. *Current, Waves and Turbulence Measurement, 2015, IEEE/OES Eleventh*. doi: 10.1109/CWTM.2015.7098131

Town of Parrsboro. (2014). Town of Parrsboro Strategic Plan. Town of Parrsboro. Accessed Nov 30, 2016. Retrieved from: http://www.town.parrsboro.ns.ca/index.php/strategic-plan.html

Trowbridge, J.H., Geyer, W.R., Bowen, M.M., & Williams, A.J. (1999). Near-bottom turbulence measurements in a partially mixed estuary: turbulent energy balance, velocity structure, and along-channel momentum balance. *Journal of Physical Oceanography, 29*(12), 3056-3072.

Turner, N.J., Ignace, M.B., & Ignace, R. (2000). Traditional ecological knowledge and wisdom of aboriginal peoples in British Columbia. *Ecological Applications, 10*(5), 1275-1287.

UNEP. (n.d.) *Cities and Coastal Areas*. United Nations Environment Programme. Accessed November 9, 2015. Retrieved from: http://www.unep.org/urban_environment/issues/coastal_zones.asp

University of Alaska-Fairbanks. (n.d.) *Alaska Hydrokinetic Energy Research Center*. Accessed January 29, 2016. Retrieved from: http://acep.uaf.edu/programs/alaska-hydrokinetic-energy-research-center.aspx

UARB. (2016) *Renewables to Retail tariffs approved, as amended in this decision* (2016 NSUARB 33, M06214). Halifax, Nova Scotia: Nova Scotia Utility and Review Board.

Vazquez, A. & Iglesias, G. (2015). Device interactions in reducing the cost of tidal stream energy. *Energy Conversion and Management, 97,* 428-438.

Verdant Power. (2016). *Kinetic Hydropower System*. Verdant Power Inc. Accessed December 1, 2016. Retrieved from: http://www.verdantpower.com/kinetic-hydropower-system.html

Voulgaris, G. & Trowbridge, J.H. (1998). Evaluation of acoustic Doppler velocimeter (ADV) for turbulence measurements. *Journal of Atmospheric and Oceanic Technology, 15*(1), 272-289.

Walker, G. (2008.) What are the barriers and incentives for community-owned means of energy production and use? *Energy Policy, 36*, 4401-4405.

Watts, L. (2009). OrkneyLab: An archipelago experiment in futures. In T. Ingold and M. Janowski (Eds.), *Imagining Landscapes*. Asghate Publishing: Farnham, UK. Accessed March 7, 2015. Retrieved from: https://itu.academia.edu/LauraWatts/

Watts, L. & Winthereik, B. (2014). Energy as alien. In E. Monoian and R. Ferry (Eds.), New Energies: Land Art Generator Initiative, Copehagen. Retrieved from: http://alienenergy.dk/wp-content/uploads/2014/10/EnergyAsAlien_PDF.pdf

Weis, T.M., & Ilinca, A. (2010). Assessing the potential for a wind power incentive for remote villages in Canada. *Energy Policy, 38*, 5504-5511.

Wiersma, B. and Devine-Wright, P. (2014). Public engagement with offshore renewable energy: a critical review. *Wiley Interdisciplinary Reviews: Climate Change 5,* 493-507. doi: 10.1002/wcc.282

Withers, P. (October 20, 2016a). *Bay of Fundy tidal turbines case opens in Halifax court.* CBC News. Accessed December 1, 2016. Retrieved from: http://www.cbc.ca/news/canada/nova-scotia/bay-of-fundy-tidal-turbines-legal-court-challenge-halifax-1.3813853

Withers, P. (November 22, 2016b). *Massive tidal turbine in Bay of Fundy generating electricity for 1st time.* CBC News. Accessed December 1, 2016. Retrieved from: http://www.cbc.ca/news/canada/nova-scotia/tidal-power-bay-of-fundy-turbine-electricity-emera-hydro-1.3862227

Wolsink, M. (2007). Planning renewables schemes: Deliberative and fair decision-making on landscape issues instead of reproachful accusations of non-cooperation. *Energy Policy, 35,* 2692-2704.

Wolsink, M. (2010). Contested environmental policy infrastructure: Socio-political acceptance of renewable energy, water, and waste facilities. *Environmental Impact Assessment Review, 30*, 302-311.

Wright, G. (2014). Strengthening the role of science in marine governance through environmental impact assessment: a case study of the marine renewable energy industry. *Ocean & Coastal Management, 99*, 23-30. doi: 10.1016/j.ocecoaman.2014.07.004

Wright, G. (2015). Marine governance in an industrialised ocean: A case study of the emerging marine renewable energy industry. *Marine Policy, 52*, 77-84. doi: 10.1016/j.marpol.2014.10.021

Wright, G. (2016). Regulating wave and tidal energy: An industry perspective on the Scottish marine governance framework. *Marine Policy, 65,* 115-126.

Wustenhagen, R., Wolsink, M., & Burer, M.J. (2007). Social acceptance of renewable energy innovation: an introduction to the concept. *Energy Policy, 35,* 2683-2691.

Zeriffi, H. (2007). Making small work: Business models for electrifying the world. Working paper #63, Program on Energy & Sustainable Development, Freeman Spogli Institute for International Studies, Stanford University, California. Accessed Nov 10, 2015. Retrieved from: http://fsi.stanford.edu/publications/small