Renewable Generation Supply Chain Opportunities in Atlantic Canada

Prepared for the Atlantic Energy Gateway Initiative
of the
Atlantic Canada Opportunities Agency

March 30, 2012

TABLE OF CONTENTS

Executive Summary

Introduction

Members of the Atlantic Energy Gateway ("AEG") have asked Concentric Energy Advisors, Inc. ("Concentric") to examine a range of issues associated with opportunities for Atlantic Canadian firms in the supply chain for various renewable generation technologies, including:

- Onshore wind;
- Offshore wind;
- Tidal energy;
- Biomass energy; and
- Systems to power remote on- and off-grid communities.

As directed by the AEG, this report explores the following questions related to each of these technologies:

1. What are the major supply chain constraints in Atlantic Canada today?
2. Which elements of the above supply chains are presently or can evolve as major challenges to further Atlantic Canadian business development/deployment?
3. What solutions/best practices might governments and the private sector look to in order to address these constraints?
4. Based on a review of capacity in Atlantic Canada, what are the best opportunities for firms in Atlantic Canada to access these supply chains in order to generate new sales?

Methodology

Concentric conducted this study using a two-tiered approach. First, a literature review of existing studies evaluating renewable energy supply chains was performed to establish a base of knowledge on the subject. A bibliography of Concentric's primary documentation sources is contained Appendix B.

Concentric then also conducted extensive phone interviews with industry participants, trade organizations, and electric utilities in Atlantic Canada to provide an enhanced local context to its analysis. While these interviews influenced Concentric's assessments, all of the opinions and conclusions in this report are attributable to Concentric. A listing of Concentric's interviews is provided in Appendix A.

While the definition of a "renewable energy supply chain" may include upstream activities such as research and development, resource studies, site preparation, environmental assessments, etc., for the purposes of this report, Concentric has limited the definition of the supply chain to those activities commencing with the manufacture of plant components (or in the case of biomass, the procurement of plant feedstock) and continuing through to the operation and maintenance of generation facilities. This decision was based on the time and resources available under the scope of this project as well as Concentric's general observation that geography offers little competitive advantage for local companies to provide these upstream functions.

Through the above efforts, Concentric documented existing constraints and future supply chain challenges faced by the region in search of opportunities for the regional economy to have greater involvement in these supply chains. As further detailed in this report, Concentric has identified the following supply chain opportunities:

Summary of Opportunities

1. The supply chain for **onshore wind** is currently robust, but still offers a number of service-related opportunities to Atlantic Canada, including crane services for installations, operations and maintenance ("O&M"), and logistics services. Each of these services was noted in our interviews as being vulnerable to supply constraints. In addition, blade manufacturing, especially for smaller, community-scale projects, also provides an opportunity for industrial expansion.
2. Supply chain development for **offshore wind** and **tidal** power, has to-date been limited in the region due to the nascent state of these technologies. However, should these technologies reach commercialization, the resulting supply chains, which have much in common, will offer significant opportunities to the economies of Atlantic Canada. Local fabrication capacity can be employed to provide turbine substructures and assembly services at or near existing port facilities. Similarly, existing offshore oil & gas and marine service providers have the infrastructure and experience to become major contractors in marine renewable energy supply chains, offering deployment, installation, and O&M services. While current business opportunities to serve offshore wind and tidal power are very limited, Atlantic Canada is well positioned – in both geography and industrial infrastructure – to contribute substantially to these supply chains as they mature.
3. A healthy **biomass** supply chain is already established in Atlantic Canada, but opportunity exists to expand this supply chain. Increasing demand for biomass coupled with diminishing supplies of mill residue create the potential to make greater use of forest residue and low-grade timber, requiring expanded feedstock procurement equipment and service offerings. Thermal energy applications, especially exports, present the greatest opportunity for growth, but electric generation appears to offer less potential.
4. Potential supply chain opportunities also exist related to the development of **systems to power on- and off-grid applications** that displace diesel generation with renewable

resources. Local firms involved in wind/hydrogen demonstration projects may benefit from forming partnerships to develop a standardized control system that would allow for turnkey replication of these wind/hydrogen facilities. The off-grid use of biomass for district heating and/or cogeneration was also analyzed, and may offer further supply chain opportunities through greater application in district heating and remote communities.

Onshore Wind

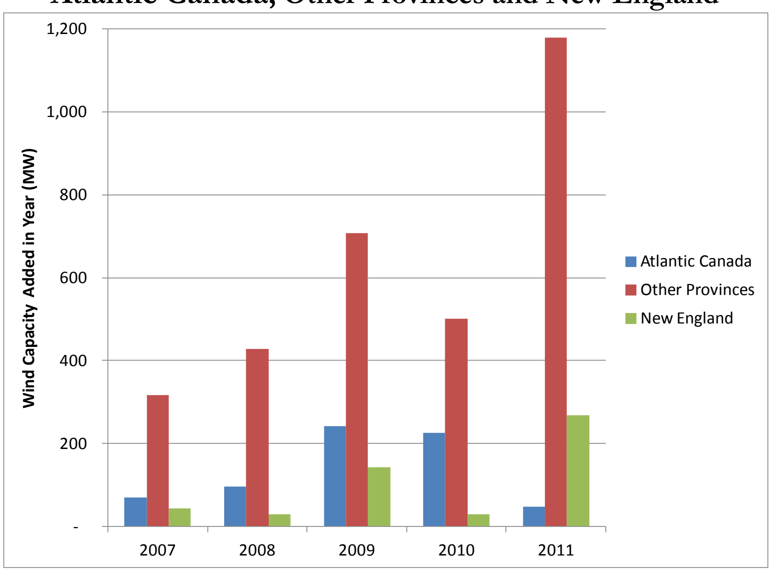
Overview

The supply chain for onshore wind in Atlantic Canada is robust. A strong chain of equipment and services suppliers has been developed to serve the substantial Feed-in-Tariff ("FIT") markets in Ontario and Quebec, along with U.S. states having to comply with Renewable Portfolio Standards ("RPS"). These markets are within economic transport distance to most locations in Atlantic Canada. Meanwhile, the pace of new wind project development in North America is expected to slow slightly in 2012 as a result of a weak economy and inconsistent policy. This may leave a slight overcapacity in the wind supply chain, especially for servicing Maritime markets.

Current Onshore Wind and Supply Chain Activity

Wind development in Atlantic Canada has historically been a strong contributor to overall Canadian wind development, and has outpaced development in New England. However, this was not the case in 2011, as policy drivers in New England, Ontario and Quebec were behind a significant increase in new wind capacity in that year.

Figure 1 – Annual Wind Capacity Additions, Atlantic Canada, Other Provinces and New England



Sources: CanWEA; SNLi.

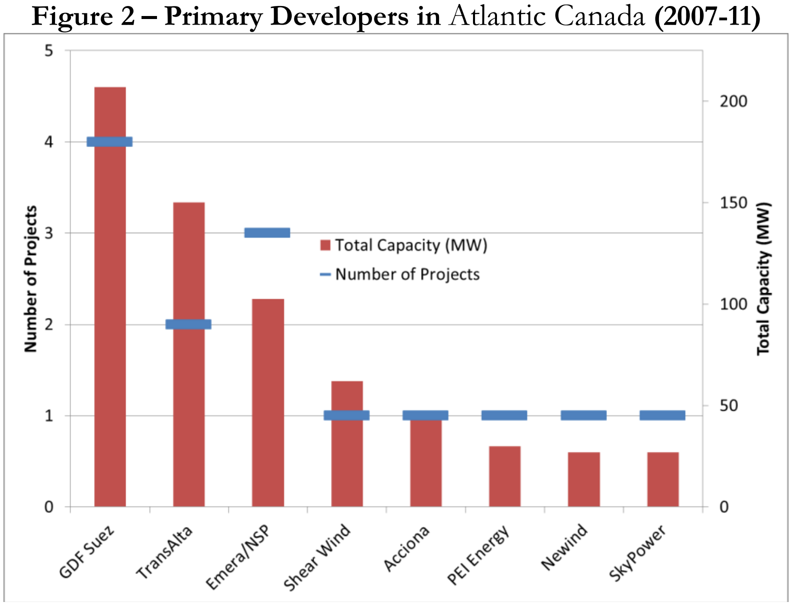
The surge in new wind capacity additions in Canada and New England has attracted a deep supply chain ready to serve new projects. This is particularly true in Ontario and Quebec, each of which has attracted new turbine manufacturing facilities in recent years. This growth is largely the result of the local content requirements embedded in their respective feed-in tariff programs. Concurrently, the recent relative decline in new wind capacity additions in Atlantic Canada coinciding with the economic downturn has meant that these few projects have been able to benefit not only from supply within the region, but also from strong sources of supply in eastern Canada and New England. Competition for supplies from eastern Canada and New England are expected to ramp back up as the regional economies are reinvigorated.

Key Industry Participants

The supply chain in the wind industry starts with the developer, which is typically responsible for selecting the original equipment manufacturer for the turbine (the "Turbine OEM"). The Turbine OEM then typically subcontracts for various turbine components.

As shown in the Figure below, the most active wind developers in Atlantic Canada over the past five years have been GDF Suez and TransAlta, which together have developed slightly more than one-half of the wind capacity in Atlantic Canada during that period. The remaining developers include a diverse group of smaller independents, utilities and municipalities. GDF Suez's projects have been primarily in New Brunswick and PEI, where it developed the Caribou and West Cape projects, respectively. TransAlta was responsible for the Kent Hills projects in New Brunswick. Recent Nova Scotia projects have been developed by Shear Wind and Nova Scotia Power ("NS Power"), along with a variety of other developers.

Figure 2 – Primary Developers in Atlantic Canada **(2007-11)**

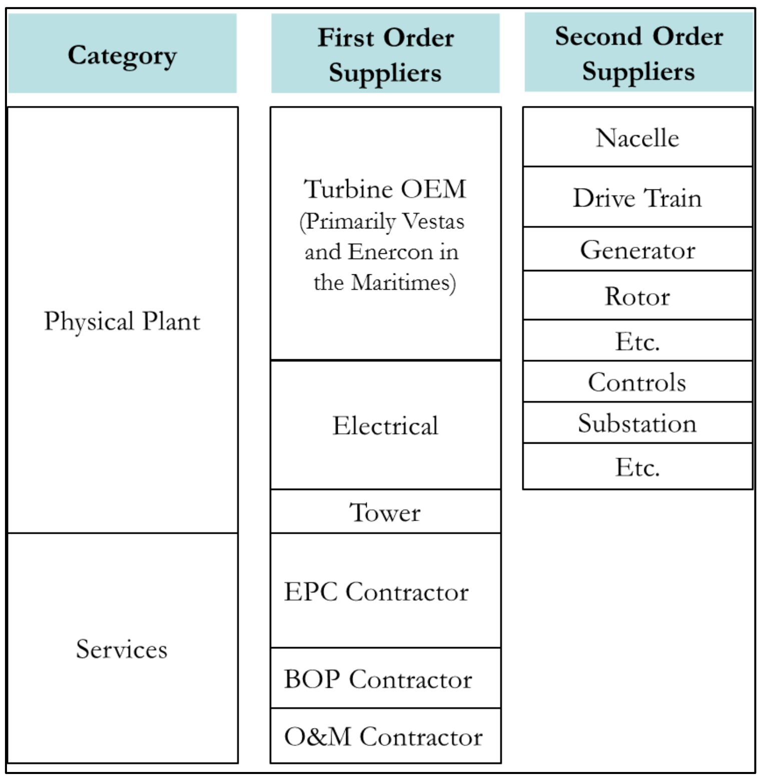


Source: CanWEA

Value Chain Components

First Order Suppliers: As noted above, the Turbine OEM is the first purchasing decision for a wind project developer. According to CanWEA, the turbine makes up approximately 70-75% of the total project cost, with engineering, site service and construction making up the balance.[1] Site electrical work and the steel tower structures may or may not be included in the Turbine OEM package. The EPC contractor typically works with the Turbine OEM in order to complete construction. Roads and foundations and electrical substation work is completed either by the EPC contractor or a subcontract. Commercial operating and maintenance services are also provided to owners that either do not have that capability in-house or to those who wish to alternatively deploy capital toward the development of subsequent projects. Together, these functions comprise the "First Order Suppliers" as shown in the Figure below.

Figure 3 – Onshore Wind Supply Chain Diagram

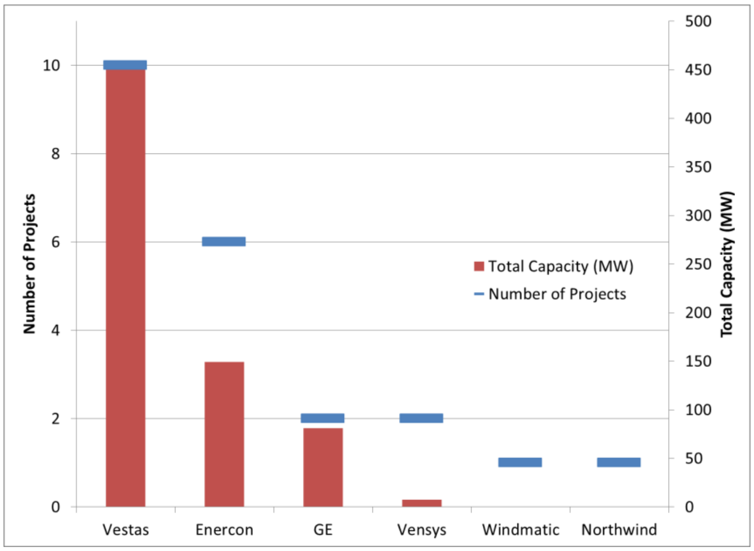


The Turbine OEM package includes the turbine, but may also include the blades and any or all of the "Second Order Suppliers" components listed above. For example, Enercon, a Germany-based Turbine OEM and leading supplier to wind projects in the region, can provide not only the turbine, but also the gearbox, electrical controls, the tower and the foundation. Enercon's plant in Matane, Quebec, which opened in June 2011, manufactures all of these components and/or assembles them from parts shipped from Germany, providing delivery with reasonable transport costs to points in Eastern Canada. Enercon has a unique concrete tower structure, which avoids the higher shipping cost of steel tower sections.

[1] CanWEA / CME Wind Industry Supply Chain, Opportunities for Canadian Manufacturers," Canadian Wind Energy Association, Canadian Manufacturers and Exporters, 2009, at 9.

As shown in the figure below, Vestas has been the most commonly used Turbine OEM in Atlantic Canada over the past five years, followed by Enercon and GE. Other Turbine OEMs are focused primarily on turbines designed for smaller-scale projects.

Figure 4 – Top Turbine OEMs for Atlantic Canada Projects (2007-11)



Source: CanWEA.

Second Order Suppliers: Like Enercon, most of the larger Turbine OEMs provide second-order components under a single contract, but local firms have found opportunities remaining. For example, for its 99 MW Caribou wind park in New Brunswick, developer GDF Suez hired Vestas to provide everything associated with the wind turbine, but Emera provided the collection system and substation, AV Cell in New Brunswick provided civil works, and the Halifax office of Stantec provided engineering. According to GDF, they did not hire an EPC contractor to oversee 2009 project construction, since few EPC alternatives were available. GDF indicates that alternatives such as Mortenson Construction, White Construction (U.S. firms) and Sunny Corners (New Brunswick) are all viable EPC alternatives they would consider if they were building those same projects today.

Many second-order components are also manufactured by others under subcontract. For example, Vestas, headquartered in Denmark but with manufacturing facilities in Colorado, can and does provide almost all first and second-order turbine supplies under a single Turbine OEM contract. However, Vestas will look to other companies for its gearbox needs, and occasionally for generators, castings and towers. This is particularly true when these bulkier components can be shipped from a manufacturing facility that is closer to the project than Vestas' Colorado facilities. Similarly, GE, which only has manufacturing capabilities for the turbine, electrical controls and gearbox, will always subcontract for the remaining second-order supplies.

Towers in particular have provided an opportunity for firms in Atlantic Canada to fulfill a supply chain need. In 2011, Daewoo, in partnership with the government of Nova Scotia, opened the DSME Trenton facility in order to build towers. Given its accessibility to rail and proximity to potential demand in eastern Canada and the US Northeast, DSME Trenton expected a significant opportunity to supply towers to these regions. A representative of Shear Wind confirmed that towers were indeed in short supply before the DSME facility was brought on line. Driven by supportive tax policy in the US, demand for towers was strong. At the time, the Marmen facility in Quebec was the only tower manufacturers in Eastern Canada. However, demand for towers in the last six months has been weaker than expected, due in part to expiring US tax credits and slowing installations in Atlantic Canada. Moreover, new tower makers, such as DMI (US-based) and CS Wind (Korea-based) have entered Eastern Canada to support the Ontario and Quebec feed-in tariffs. These factors have caused in a slowdown at DSME Trenton over the last six months.

Nonetheless, DSME Trenton representatives maintain a positive outlook for the company. The company just began to make 7-9-meter turbine blades, for use on community-scale projects, such as those being proposed under the Nova Scotia Community Feed-In Tariff ("COMFIT"). The company is separately considering the manufacture of larger blades in order to serve the larger turbines that are being used to create smaller wind farm footprints, as well as a nascent offshore wind market.

Effects of International Trends in the Onshore Wind Supply Chain

Several current trends in the international wind supply chain have the potential to affect the supply chain in Atlantic Canada, including increasing vertical integration of Turbine OEMs, and increasing specialization by turbine size. As noted above, all of the top Turbine OEM's serving Eastern Canada are foreign companies, including, Vestas (Denmark), Enercon (Germany), GE (U.S.), and Vensys (Germany), and each of these companies has increased its vertical integration in recent years. This influx of substantial foreign capital into wind turbine manufacturing is a potential barrier to the development of new independent local businesses serving under the Turbine OEM umbrella of suppliers, given the well-capitalized competition.

The size and configuration of wind turbines is evolving in the international market. The need for more efficient larger turbines on increasingly smaller sites has increased the need for larger blades, while a significant market for smaller community-scale blades is also increasing. LM Glasfiber (a Danish company, with manufacturing facilities in Quebec, has captured a significant share of the larger blade market in Canada, and is currently manufacturing a 61.5-meter blade to be used for 5 MW offshore applications in Europe. However, LM Glasfiber's smallest blade is 29.5-meters, which is designed for a 1.3 MW turbine.

A medium-scale (50-550 kW) blade market has also developed to serve remote locations and in response to renewable energy feed-in tariffs. Seaforth Energy, based in Dartmouth, Nova Scotia, has been successful in this medium-scale space marketing its 50 kW AOC 15/50 turbine in response to the COMFIT and similar international incentives. Seaforth manufactures its own blades in Nova Scotia and its control panels and drive train components are sourced from Halifax and Quebec respectively. The supplier base for small-scale blades (<50 kW) is decentralized, and demand is increasing due to the Nova Scotia COMFIT and to recent development of other community projects across the region.

Supply Chain Bottlenecks and Vulnerabilities

None of the developers or Turbine OEM's interviewed expressed any concern about their ability to source adequate supply for their projects. Nonetheless, as described below, several supply chain vulnerabilities became evident as a result of Concentric's research and interviews.

- Tower manufacturer DSME Trenton, which imports steel plate from Nucor Steel in the US, indicated that steel prices continue to increase due in part to high transportation costs. This could create vulnerability for tower production should the previous pace of turbine new-builds resume.
- At least two studies identify bearings, forgings and gearboxes as the second-order components that are generally the most vulnerable to supply chain disruption.[2] All of these components have significant technological barriers to entry and high technology risk, which have deterred many companies from entering these markets. Further, several players in these areas have been integrated into Turbine OEMs, such as Suzlon's 2006 acquisition of gearbox manufacturer Hansen. This creates a relatively small manufacturing base that is vulnerable to surges in demand.
- After reviewing the primary erector/construction providers of several Atlantic Canada projects, it became evident that the supply and expertise of crane and other tower assembly services was concentrated in a limited number of firms in the region.
- Given that there are few wind O&M service providers focused on the Canadian market, existing wind projects are potentially vulnerable to an inability to procure these services when their warranty contracts with Turbine OEM's expire. At least one study identified a concern that "renewal of such contracts will be prohibitively costly and that there will be a shortage of adequate economic service and maintenance providers within the country."[3]
- Finally, several interviewees expressed that some of their wind development projects experienced delays as a result of logistical difficulties and documentation requirements as various project components were being shipped across provincial and national borders.

[2] "Wind Turbines: Industry and Trade Summary," U.S. International Trade Commission, June 2009, at 9, and "Opportunities for Canadian Stakeholders in the North American Large Wind Turbine Supply Chain," Delphi Group and Garrad Hassan for Industry Canada, September 2007, at 24.

[3] Opportunities for Canadian Stakeholders, op. cit., at iii.

The interviewees indicated that the more significant delays were due to inter-provincial and international import requirements.

Potential Opportunities

Based on the above, Concentric sees the following potential opportunities for fulfilling onshore wind supply chain requirements in Atlantic Canada:

- **Blade manufacturing** – As noted above, there is an increasing need for smaller community-scale blades. While Seaforth does already serve this market, and DSME Trenton is in the process of entering the market, there may be room for other participants to take advantage of this growing opportunity.
- **Crane services** – Concentric's observation that many new projects in Atlantic Canada have turned to a small group of crane owners and operators – particularly in Nova Scotia – leads us to believe that construction firms with appropriate crane equipment may be able to move into the local wind project space.
- **O&M service providers for small projects** – Most Turbine OEMs will provide long-term service agreements with the sale of their turbines. Given the current slowdown in turbine sales, OEMs have recently been providing especially long agreements (10-years+) as a sales enticement. Also, some developer/owners will elect to self-maintain following contract expiration. Nonetheless, smaller projects that do not use the major Turbine OEMs, including projects bidding into the current COMFIT, many be candidate customers for O&M service agreements in coming years.
- **Logistical services** – As noted above, transportation of major components can be both a logistical and political challenge. There may be a niche service role for a firm familiar with logistics and importing in Atlantic Canada.

Offshore Wind

Overview

While Atlantic Canada has attractive offshore wind resources, the high development costs and local energy market dynamics have not provided adequate incentive for development to date. Electricity prices in Atlantic Canada vary by province but, in general, the region pays power prices that are considerably lower than the current cost of offshore wind. In a February 2011 study, the U.S. Department of Energy estimated the cost of offshore wind generation (exclusive of transmission and distribution costs) at 27 cents per kilowatt-hour.[4] This is approximately two times the average total cost of electricity in Atlantic Canada.[5] The region's backbone transmission grid is also fragmented and inadequate to accommodate the addition of offshore wind power at quantities that would justify development. Newfoundland and Labrador are not connected to the mainland transmission grid and have insufficient load to warrant offshore wind development on their own. This combination of market factors provides little economic basis for offshore wind development in Atlantic Canada.

Most of the provinces in Atlantic Canada have enacted renewable energy mandates creating a potential market for offshore wind; however, these renewable energy mandates are currently being fulfilled using lower cost renewable resources like onshore wind.

Setting aside for a moment the current economics of offshore wind, in terms of supply chain involvement, Atlantic Canada possesses industrial experience in a number of fields—from steel fabrication and shipbuilding, to marine services and engineering—that have the potential to add value to a local offshore wind supply chain. The proximity of the region to the northeastern U.S., where additional offshore wind developments are underway, also offers an opportunity to expand the market for these supply chain services beyond Atlantic Canada. Many barriers remain to offshore wind development in the region, but as market experience in Europe and elsewhere drives down costs, a number of supply chain opportunities may lie ahead for the region.

Current Offshore Wind and Supply Chain Activity

There are currently no offshore wind farms in North America. In Canada, Windstream Energy Inc. is developing the 300 MW Wolfe Island Shoals wind farm in Lake Ontario near Kingston, Ontario. Windstream was awarded a power purchase agreement with Ontario Power Generation through the province's feed-in tariff program in April 2010, but in February 2011, the Ontario provincial government imposed a moratorium on offshore wind developments. Ontario cited the need for

[4] U.S. Department of Energy, A National Offshore Wind Strategy: Creating an Offshore Wind Energy Industry in the United States, February 2011.
[5] Manitoba Hydro (Based on residential bills of 750 kWh per month).

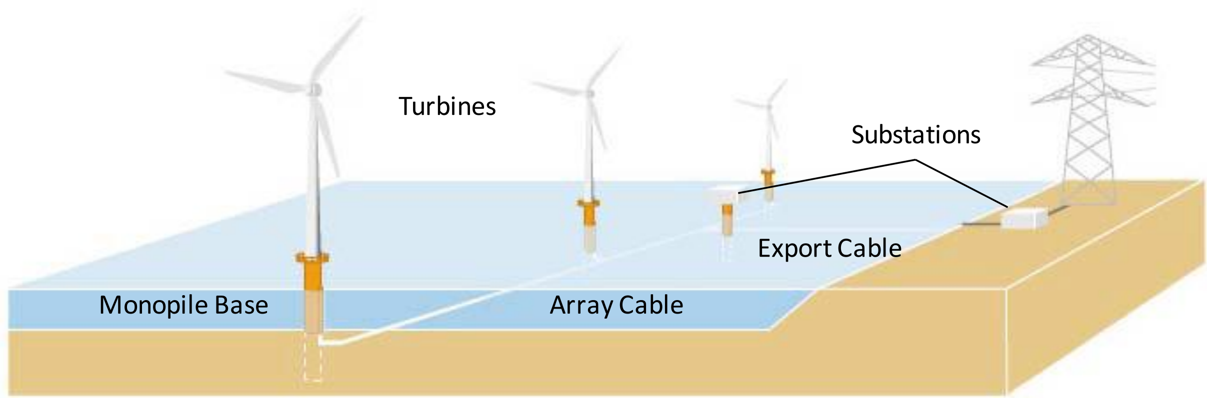
further scientific research, and the moratorium is still in effect. No offshore wind farms have been proposed to date in Atlantic Canada.

A number of offshore wind projects are under development in the U.S., with the majority occurring off the Atlantic coast. Of these projects, Cape Wind's planned 420 MW facility in Nantucket Sound off the southern coast of Massachusetts has advanced the farthest. Cape Wind has been approved for construction and operation and is currently searching for financing. A number of other Atlantic states are pursuing offshore wind projects in their jurisdictional waters and the federal government is working with Atlantic states to promote the development of offshore wind facilities on the Outer Continental Shelf.

Europe is currently the global leader in offshore wind development. Offshore wind facilities have been operational in Europe since 1991, and total installed capacity at the end of 2010 surpassed 2.9 GW. Offshore wind developments have progressed in Europe despite the high development costs and associated power prices largely due to the European Union's commitment to carbon dioxide reductions.

Value Chain Components

Figure 5 – Offshore Wind Supply Chain Diagram



Source: BWEA (adapted by Concentric)

While the mechanical and electric plant components of an offshore wind project are almost identical to those of an onshore wind installment, the offshore location of these arrays adds a number of components to the necessary supply chain. Offshore turbines are typically larger in scale than those for onshore installations making water transport the only feasible method of moving components. This has led to an increasing decoupling of the onshore and offshore wind supply chains. This section highlights the major components of the offshore wind value chain.

Turbines: The manufacture of offshore wind turbines is dominated by European firms like Siemens, Vestas and Repower that also have a major presence in the onshore turbine industry. As the industry matures, new turbine manufacturers are entering the market, bolstering supply and competition. Because offshore wind deployments have occurred almost exclusively in Europe, the manufacturing operations have thus far also been located in Europe. The wind turbine manufacturing supply chain is increasingly being characterized by vertical integration of subcomponents (generators, gearboxes, bearings, etc.) The technical requirements of turbine manufacturing make new entry into this market difficult; however, if an offshore wind industry develops in Atlantic Canada or the U.S. look for existing turbine manufacturers to open new plants in North America to feed these markets.

Substructures: The substructures for offshore wind turbines are not technically sophisticated, but account for a significant portion of the capital expenditures associated with a project. These factors make substructure manufacturing an attractive entry point for local businesses into the offshore wind supply chain. The fabrication of substructures requires a coastal manufacturing facility on a sizeable plot of land in order to provide lay-down yards for oversized components. Manufacturing related to an offshore wind supply chain would likely be located along the Atlantic Coast of Nova Scotia. Existing facilities along Nova Scotia's Atlantic coast have the fabrication skill and capacity to support the manufacturing of turbine bases and substructures for initial projects in the region. Full-scale commercial development would require strategic expansions of well-positioned yards.

Electrical Plant: The electric equipment required for an offshore wind facility—generators, converters, transformers, switchgear, etc.—is typically manufactured and delivered by global electrical engineering companies (Siemens, ABB, Alstom Grid, and General Electric). These firms are based mainly in Europe and North America, but have established manufacturing facilities across the globe. No supply shortages are anticipated in the market for electrical plant components, as a robust supply chain already exists to support the onshore electric distribution and transmission industry.

Cables: Subsea array cables are required to transmit the power from the offshore turbines either directly to an onshore substation or to an offshore substation where it is converted to a higher voltage and then transported via a high-voltage subsea transmission cable to an onshore connection to the electric grid. The manufacturing of subsea transmission cables is concentrated among a handful of European firms (Nexans, Prysmian, ABB) due to the growing offshore wind industry in that region. While these companies tend to have multi-national operations, the manufacture of subsea transmission cables tends to occur in a single location with the cables then shipped to the project site. Atlantic Canada does not possess the manufacturing capacity to produce subsea cable. With constrained manufacturing capacity and lead times of up to two years for subsea cable, there is the potential for this to become a bottleneck in the offshore wind supply chain.

The installation of subsea cable is typically handled by a separate entity. In Europe, offshore construction firms like Technip and Global Marine exist to do this work, but electric and telecommunication companies operating in Atlantic Canada may also have the expertise to handle cable-laying.

Vessels: A variety of vessels are required to construct an offshore wind array. Vessels are needed to haul components and transport personnel to the offshore site, to provide cranage and erection services, to lay and connect cables, and to retrieve and service equipment. Offshore wind deployments (i.e., erection) are predominantly conducted using dynamic positioning ("DP") vessels borrowed from other industries such as oil & gas. However, as the offshore wind industry has matured in Europe, an increasing number of project developers are constructing purpose-built vessels for their deployments. Few suitable DP vessels (Class 2 or 3) are available in Atlantic Canada and additional DP vessels based in the Gulf of Mexico or Europe would have to be employed for deployments in Atlantic Canada. The vessel requirements for offshore wind servicing and maintenance are less stringent and local marine service yards can repurpose or build vessels to serve this need. Nova Scotia-based, A.F. Theriault currently builds purpose-built vessels for offshore wind turbine servicing.

Port Facilities: The large size of offshore wind turbines dictates that component parts be transported by water. This market dynamic necessitates that the manufacturing and assembly of components occur at or very near port facilities. Experiences in Europe indicate that two types of port facilities will be required. Manufacturing ports, where the manufacturing facilities are located on the water to facilitate the transportation of completed components directly to the installation site or to a central mobilization point located close to the installation site. These mobilization ports, the second type of port facility, are used to receive and collect the components where they are then loaded onto installation vessels or other barges for transport to the installation site. The Marine Renewable Energy Infrastructure Assessment conducted by the Nova Scotia Department of Energy estimated that in order to support a construction base of 100 turbines per year, port facilities would have to offer eight hectares of lay-down area and 200-300 meters of quayside for assembly and deployment.[6] The same report notes that the collective capacity of the industrial ports on Nova Scotia's Atlantic coast should be capable of providing this capacity.

O&M: In order to provide operations and maintenance services for an offshore wind facility, additional supply chain components are required. An onshore facility in close proximity to the installation will be required for monitoring equipment and staff. Many of the same modified offshore oil & gas vessels will be required for major turbine repairs and cable retrieval, while less sophisticated classes of vessels or helicopters can be used for more minor repairs.

[6] Nova Scotia Department of Energy, Marine Renewable Energy Infrastructure Assessment, August 2011.

Effects of International Trends in the Offshore Wind Supply Chain

International supply chain developments, particularly in Europe, will be integral to the development of an offshore wind industry in Atlantic Canada. The maturing of the European offshore wind industry and the advancements along the learning curve that commercial experience in that region will provide offer the best opportunity to reduce the development costs of offshore wind. As the supply of offshore turbines proliferates, and marine service firms gain experience and streamline the deployment processes, development costs should come down. Such supply chain innovations in Europe—and perhaps along the U.S. Atlantic Coast—will be necessary precursors to an offshore wind industry in Atlantic Canada. In the meantime, opportunities may exist for port facilities and marine service firms in Atlantic Canada to become part of the supply chain for offshore wind projects off the U.S. Atlantic coast as well.

Supply Chain Bottlenecks and Vulnerabilities

Any discussion of potential bottlenecks or gaps in the offshore wind supply chain in Atlantic Canada must be largely theoretical as the region has yet to develop any offshore projects for such a supply chain to serve. That being said, much can be inferred from an analysis of the offshore wind industry's growth in Europe coupled with a survey of existing industry and services available in the region. Concentric identified the following supply chain vulnerabilities:

- Atlantic Canada has some capability to utilize local vessels currently dedicated to the marine and offshore oil & gas industries for many functions, but DP vessels will be necessary for deployments and erection. Such vessels and contractors are available in the Gulf of Mexico or from Europe, but they are expensive and availability may be limited. The local construction of purpose-built vessels is cost-prohibitive unless a robust offshore wind industry develops in the region.

- Shortages of most electrical infrastructure required are unlikely as a well-established supply chain for this equipment exists to serve the electrical transmission and distribution business. The exception here is the supply of subsea high voltage transmission cable. Limited supply chain capacity exists and is located almost exclusively in Europe. A recent study of the European offshore wind supply chain predicts that the European demand for high voltage subsea cable alone could result in supply shortages by 2015 without capacity expansions.[7] The lead time to bring new manufacturing capacity on-line is three to four years. The supply of subsea array cables is more diverse, with regional manufacturing available.

- Atlantic Canada currently has limited capacity to manufacture turbine subcomponents (DSTN's Trenton facility being an important exception). Turbines should not be in short supply, and if there is a strong market signal for offshore wind development in Atlantic

[7] European Wind Energy Association, Wind in our Sails: The coming of Europe's offshore wind energy industry, November 2011.

Canada foreign manufacturers will likely expand their operations to the region in order to exploit cost advantages. In the absence of a strong signal for offshore development in the region, foreign turbines should still be available, just at a higher price due to the cost of importation.

Potential Opportunities

The dynamics of an offshore wind supply chain offer a number of growth opportunities for the economies of Atlantic Canada. As noted in the previous section, and onshore wind supply chain already exists in Atlantic Canada, and the region is endowed with a wealth of marine-focused industrial capacity and experience. These existing industrial capabilities can also serve as the foundation for an offshore wind supply chain.

- **Fabrication and Port Facilities** - The large size of offshore turbine components requires coastal manufacturing facilities and necessitates transportation of components by water. These factors offer a considerable cost advantage for component manufacture and assembly at locations in the proximity of the installation site. Regional firms have an opportunity to leverage existing expertise in fabrication and marine services to play a significant role in the supply chain. Local manufacturing can construct substructures and locally-sourced jack-up barges can be used to assemble turbines at the port facility. Ports like Dartmouth/Halifax, Canso, and Sydney have the capacity to support such manufacturing. Local marine service firms can then be used to deploy turbines to the installation site as well as providing erection and repair services. The location of Atlantic Canada's existing port facilities and coastal manufacturing are also well-located for offshore wind deployments.

  Though currently stalled by the Ontario moratorium, the Wolf Island Shoals development in Ontario is a good example of the supply chain value that can be captured by local economies in the development of offshore wind. Bermingham Foundation Solutions will place the wind turbines in Lake Ontario, Walters Group will fabricate the substructures, and McKeil Marine will use its vessels to tow the turbines to the installation site and then will erect the turbines. All three of these companies are located in Hamilton, Ontario. Overall, Windstream Energy Inc. has been able to sign supply agreements with local firms to provide 60% of the content for its Wolf Island Shoals facility.

- **Major Contracting Services** - In Europe, there is a growing trend of regional offshore oil and gas firms emerging as major contractors as they gain more experience in the industry. The same opportunity exists for the transformation of local offshore oil & gas firms into EPC contractors. Atlantic Canada possesses a strong tradition of maritime industrial activity from shipbuilding, to offshore oil & gas, to salvage operations. These firms have an opportunity to leverage their existing infrastructure and experience to become contractors for the deployment and installation of offshore wind projects. Companies like JD Irving, with both shipbuilding and marine service divisions, have the capability to become major contractors in the offshore wind industry. These contracting opportunities for oil & gas and marine service firms are also not restricted to Atlantic Canada. If an offshore wind industry materializes in the U.S., these same firms would have an opportunity to provide contracting services to the entire Atlantic coast and the Great Lakes region as well.

Tidal

Overview

Due to the lack of commercial tidal installations, a dedicated supply chain has yet to emerge in the tidal industry. Demonstration project deployments to date have relied upon strategic partnerships between technology developers, electrical engineering firms, and local manufacturers and marine service firms. For example, Atlantis Resources has partnered with Lockheed Martin and JD Irving to test its AR 1000 turbine at an innovative tidal technology demonstration and testing center in Nova Scotia. This site, the Fundy Ocean Research Center for Energy ("FORCE"), is described in greater detail below.

In Atlantic Canada, Nova Scotia will continue to lead the way in the development of tidal power. A supportive policy environment has allowed for the establishment of the FORCE facility which has attracted tidal technology developers from across the globe. The future of tidal power in Atlantic Canada is now likely dependent upon the results of the FORCE demonstration projects and the industry's ability to reduce costs. Both Nova Scotia and New Brunswick have enacted renewable energy mandates, generating substantial appetites for renewable generation. Whether or not tidal energy plays a major role in meeting these mandates will depend upon its ability to compete economically with wind and other renewable resources.

If tidal developers are successful at deploying technologies capable of withstanding the harsh conditions of the Bay of Fundy and through their experiences can advance along the learning curve to bring down the costs of tidal power, commercial deployments are likely. Successful demonstration projects could also motivate other provinces like New Brunswick to pursue tidal power. New Brunswick also sits along the excellent tidal resources of the Bay of Fundy, and the port of Saint John—with its deep water, shipbuilding infrastructure and related industrial capacity—is well-suited for assembly and deployment.

Current Tidal and Supply Chain Activity

The tidal energy industry is at a very early stage of development. Canada has been one of the early-movers in this industry and, along with the United Kingdom ("UK"), is a leader in technology development. Other countries such as the United States and South Korea have also begun to pursue tidal energy developments.

In Atlantic Canada, FORCE, located in Nova Scotia in the Minas Passage area of the Bay of Fundy, is a four-berth utility-scale demonstration project that anticipates an installed capacity of 5 MW in the next two years. With financial backing from the federal government, the Province of Nova Scotia and private corporations, FORCE provides shared infrastructure for the trial deployment and operation of turbine technologies. NS Power has already deployed and tested an OpenHydro turbine at the FORCE site and is now considering its own tidal array in the Bay of Fundy. On a smaller scale (<500 kW), Fundy Tidal, Inc. is developing two distribution-connected tidal facilities in Nova Scotia.

Along with Canada, the United Kingdom has also taken the lead in tidal power development. The government-funded European Marine Energy Centre ("EMEC") in Orkney, Scotland serves the same function as the FORCE site in Canada. Its multi-berth tidal test site is connected to the UK grid by subsea cable and allows tidal developers to test their respective technologies. OpenHydro, Atlantis Resources, Hammerfest Strom and a number of other developers have deployed commercial-scale demonstration projects at the EMEC site. Marine Current Turbines has also deployed a 1.2 MW turbine in Northern Ireland and has plans to develop several larger projects. In the U.S., small-scale tidal demonstration projects are underway in select northeastern states. Earlier this year, Verdant Power received the first commercial tidal license issued in the U.S. to develop a 1 MW pilot project in New York City's East River.[8] Another developer, Ocean Renewable Power Company ("ORPC"), has received approval to install a 300 kW commercial tidal facility in Eastport, Maine at the mouth of the Bay of Fundy. ORPC's Eastport project employs a modular turbine technology and planned expansions will bring the eventual capacity to 3 MW.[9]

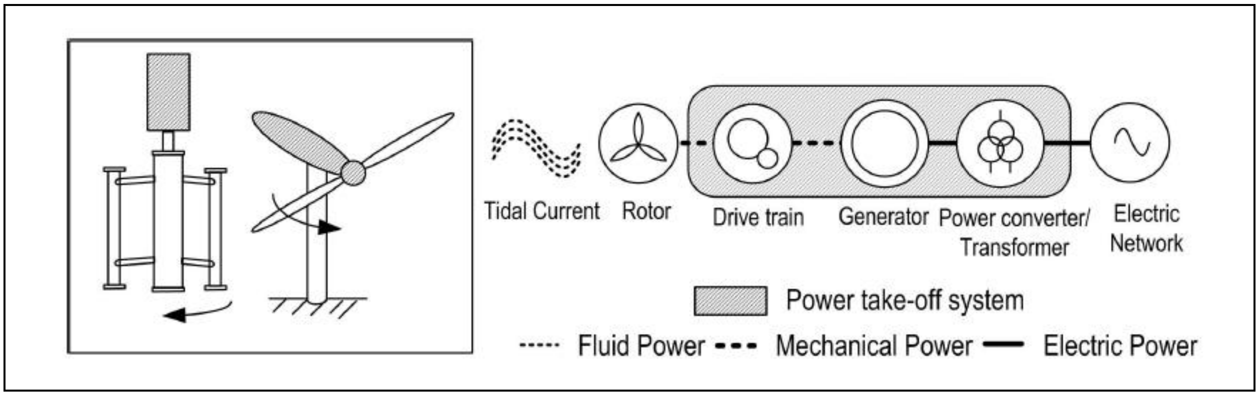
The off-takers of power from tidal facilities in Atlantic Canada would be the region's electric utilities. Nova Scotia Power, the privately-held electric utility in Nova Scotia would be the recipient of all power generated by the FORCE facility and any other commercial tidal projects in Nova Scotia. Should tidal power projects be developed in New Brunswick, the power from these facilities would be off-taken by New Brunswick Power, a Crown corporation.

Value Chain Components

Tidal energy is still a nascent technology across the globe and, thus, the components and parameters of a dedicated supply chain are still being developed as different technologies are being pursued. Acknowledging this supply chain ambiguity, the section below presents a high-level overview of the essential supply chain components thought to be necessary to develop a tidal energy facility.

8 FERC News Release, "FERC Issues First Pilot License for Tidal Power Project in New York", January 23, 2012.
9 http://www.orpc.co/default.aspx

Figure 6 – Tidal Energy Supply Chain Diagram



Source: Canmet Energy, Evaluation of Electrical Technology Solutions in Marine Energy

Turbines: The mechanical plant consists of the turbines and supporting hydraulic systems that serve to harness the energy from tidal flows. None of the large-scale tidal turbines that have been or are being deployed in demonstration projects around the world are constructed in Atlantic Canada. Leading developers of large tidal turbines such as OpenHydro, Marine Current Technologies (Siemens), and Alstom have operations based in Ireland, the United Kingdom, and France respectively. In terms of small-scale tidal, the two facilities being developed by Fundy Tidal, Inc. in Nova Scotia will employ turbines from Calgary-based New Energy Corporation and Ocean Renewable Power Corp. based in Maine. At this point, however, the pre-commercial nature of the tidal industry means that commercial manufacture of turbines has not yet become entrenched in any country or region. Unlike the wind industry, tidal energy has seen little vertical integration in the manufacturing of turbine subcomponents to date. Many of these turbine subcomponents are made of steel and could be fabricated locally in Atlantic Canada to avoid the added cost of shipping components across the Atlantic.

Substructure: The substructures—consisting mostly of steel and concrete—that house the turbines and drive train can either be attached to the seabed via moorings or by piles/pins. The size and weight of these substructures dictate that they be manufactured at coastal facilities in the vicinity of the tidal installation. The demonstration projects carried out in Atlantic Canada have proven that regional companies have the necessary fabrication capacity and experience to manufacture these substructures. OpenHydro contracted with Cherubini Metal Works out of Dartmouth for its substructure. Fundy Tidal, Inc. relied on Clare Machine Works, also based in Nova Scotia, for its substructure. Other local manufacturers like JD Irving and DSME Trenton have the capacity to provide substructure fabrication and other manufacturing needs.

Electrical Plant: The electrical equipment requirements for a tidal facility—generators, converters, transformers, switchgear, etc.—are identical to those for an offshore wind project. These components are manufactured by the likes of Siemens, ABB, Alstom Grid, and General Electric. These firms are based mainly in Europe and North America, but have established manufacturing facilities across the globe. No supply shortages are anticipated in the market for electrical plant components, as a robust supply chain already exists to support the onshore electric distribution and transmission industry.

Cables: As with offshore wind, subsea array cables are required to transmit the power from the tidal generators to either an onshore substation or to an offshore substation where it is converted to a higher voltage and then transported via a higher voltage subsea transmission cable to an onshore connection to the electric grid. The manufacturing of subsea transmission cables is concentrated among a handful of European firms (Nexans, Prysmian, ABB). While these companies tend to have multi-national operations, the manufacture of subsea transmission cables tends to occur in a single location with the cables then shipped to the project site. Atlantic Canada does not currently possess the manufacturing capacity to produce subsea cable.

The installation of subsea cable is typically handled by a separate entity. In Europe, offshore construction firms like Technip and Global Marine exist to do this work, but local electric and telecommunication companies may also have the expertise to handle cable-laying. The subsea cables for the FORCE site were manufactured in Italy by Prysmian, but were installed by IT International Telecom Inc. out of their port facility in Halifax.

Vessels: Numerous vessels are required to deploy and install tidal arrays and also to conduct maintenance operations once the plant is in service. As the tidal industry is in the early stages of development, a number of strategies are being employed regarding vessel requirements. Some technology developers have undertaken the construction of vessels customized to their specific technology. OpenHydro commissioned the construction of the OpenHydro Installer, a twin-hulled, first-of-its-kind barge for its Scottish deployments. For its FORCE deployment, OpenHydro again contracted for the construction of a purpose-built barge with Halifax-based Atlantic Towing. Other developers have utilized crane barges and other vessels that typically support the offshore oil & gas industry. In addition, some European developers have access to dynamic positioning ("DP") vessels used to install offshore wind facilities, but the usage of DP vessels is seen to be prohibitively expensive for the tidal industry. For demonstration deployments, existing vessels capable of holding station in harsh currents can be borrowed from the offshore oil & gas industry, but a commercial tidal industry would require innovative new vessels designed to optimize efficiency during the workable portion of the tidal cycles.

Port Facilities: As is the case with offshore wind, the large size of tidal turbines dictates that component parts be transported by water. Economic efficiency necessitates that the manufacturing and assembly of components occurs at or very near port facilities. These port facilities will need to have significant manufacturing capacity, enabling developers to construct the substructure and possibly some turbine subcomponents in close proximity to the deployment site. There are currently few ports in the Bay of Fundy—Saint John, New Brunswick being the major exception—that meet these requirements.

O&M: Once operational, a tidal array will also require an operations and maintenance contractor. The O&M contractor will need monitoring equipment, an onshore control center in close proximity to the installation site as well as vessels to transport personnel, recover turbines, and cables, and to make repairs. Due to the tidal cycles in the Bay of Fundy, vessels employed for recoveries and repairs will have to be capable of completing their tasks within very short time windows. Existing monitoring equipment has performed poorly in the tumultuous conditions within the Bay of Fundy, and future equipment will have to be customized to local conditions.

Effects of International Trends in the Tidal Supply Chain

The tidal power industry is still in the demonstration phase and Atlantic Canada has been a leader when it comes to research and development, but similar efforts are afoot in Europe and the U.S. as well. If demonstration projects translate into commercialization in Europe or the U.S. before Atlantic Canada then these regions would have a leg up in establishing supply chain strength in turbine manufacturing and purpose-built vessel design and construction. Due to the more modest scale of global tidal resources compared to offshore wind, the industry may not support the manufacturing of such supply chain components in more than one location. In this sense, many of the tidal supply chain developments in Europe and the U.S. serve as competition to Atlantic Canada's supply chain interests.

Supply Chain Bottlenecks and Vulnerabilities

A dedicated supply chain for tidal power has yet to emerge as this technology remains in the demonstration phase. While existing manufacturers and service provides from other industries can be leveraged or repurposed to serve many of the industry's supply chain needs, certain key gaps in this supply chain are apparent.

- The location and configuration of existing fabrication capacity and port facilities in Atlantic Canada are inadequate to economically support commercial tidal power installations. The scale of tidal installations and the characteristics of tidal flows where the resources are strongest create the specific need for port facilities with fabrication capacity and a wet dock in close proximity to the installation site. The large size of tidal devices dictates that fully-assembled structures can only be transported to and from the installation site by water. The Marine Renewable Energy Infrastructure Assessment released by the Nova Scotia Department of Energy in August 2011 states that the high cost of such transportation necessitates the location of port facilities used for assembly and deployment within 150 km of the installation site.[10] This parameter greatly restricts the number of viable ports in the proximity of the Bay of Fundy. The majority of Atlantic Canada's coastal manufacturing and fabrication facilities are located in the Dartmouth-Halifax region of Nova Scotia or in Newfoundland. For its FORCE deployment, OpenHydro relied upon Cherubini Metal Works located in Dartmouth, NS. Cherubini assembled the device at its facility and then transported the device around the southwestern end of the province to the installation site. While the deployment from Cherubini's Dartmouth facility went smoothly, the transportation costs associated with towing components around the southern tip of Nova Scotia to the Bay of Fundy are prohibitive and the sea conditions in that area can be treacherous.

- The harsh conditions created by extreme tidal flows in the Bay of Fundy pose additional problems to tidal developers. Bay of Fundy tides cycle roughly every six hours with differentials ranging from 3.5 to 16 meters.[11] Traditional, floating platform vessels borrowed from the offshore oil & gas industry can hold station in the Bay of Fundy's currents, but they are expensive and they are also not designed for operation in the brief windows afforded by the tidal cycle. For a commercial tidal industry, purpose-built vessels designed to optimize functionality during these workable windows in the tidal cycle will be required.
- The limited manufacturing capacity of high voltage subsea cable also presents a potential vulnerability in the tidal energy supply chain. Few companies manufacture such cable, and Atlantic Canada currently does not have the capacity to manufacture subsea cable within the region. Growing demand from the offshore wind and oil & gas industries is already testing global supplies, with supply shortages predicted as soon as 2015. The lead time to expand the existing European manufacturing capacity of high-voltage subsea cable is estimated at three to four years.[12]
- Small-scale tidal developers face the additional obstacle of connecting their arrays to the region's electric grid. Whereas the utility-scale demonstration projects at the FORCE test site have benefitted from a connection to the region's transmission grid that was funded by the federal and Nova Scotia governments, smaller developers will bear the full cost of connecting their projects to the grid. Depending on the remoteness of potential installation sites, access to the grid may not be available at all.

[10] Nova Scotia Department of Energy, Marine Renewable Energy Infrastructure Assessment, August 2011.
[11] Nova Scotia Department of Energy, Marine Renewable Energy Infrastructure Assessment, August 2011.
[12] European Wind Energy Association, Wind in our Sails: The coming of Europe's offshore wind energy industry, November 2011.

Potential Opportunities

The tidal energy supply chain requirements are in many respects similar to those of the offshore wind industry. It should come as no surprise, then, that many of the opportunities for supply chain developments related to offshore wind also apply to tidal power.

- **Local Fabrication** - As with offshore wind, a large portion of the tidal value chain is related to the fabrication of array substructures. The construction of substructures, consisting mostly of steel and concrete, is not technically very challenging and there is local fabrication capacity to provide this function. The high costs associated with transporting components manufactured abroad to a local deployment site provide an added incentive for local industry to provide these fabrication services. Many of the subcomponents of tidal turbines are also made of steel and these too could be fabricated at local manufacturing facilities.

- **Major Contracting Services** - Local engineering and marine service firms will also be well placed to emerge as major contractors for tidal deployments and repairs. The local offshore oil & gas industry has vessels that can be used to deploy demonstration projects and decades of experience operating in the region's harsh maritime conditions.

- **Marine Technology & Services -** The lack of global supply chain developments to support the tidal industry also offers Atlantic Canada an opportunity to leverage its existing expertise in engineering, shipbuilding, and marine services to become a global leader in providing marine services for the tidal industry. Demonstration projects will have to cope with the harsh maritime conditions in the region and the dramatic tidal cycles experienced in the Bay of Fundy. If technologies and services developed to overcome these harsh conditions can be developed, there is a global opportunity to market this expertise for use in tidal installations across the globe. Unlike with offshore wind, where such technologies and services are already being developed to serve the European market, Atlantic Canada still has the opportunity to be a first-mover with tidal power.

- **National Shipbuilding Procurement Strategy** - Canada's National Shipbuilding Procurement Strategy ("NSPS") offers another valuable opportunity for the establishment of a tidal supply chain in Atlantic Canada. The combat contract portion of the NSPS was awarded to JD Irving in 2011. Under this contract, JD Irving will provide all defense-related large ship construction—21 vessels over a 20-30 year period—at its shipyards throughout Atlantic Canada. The NSPS combat contract will revitalize shipbuilding in the region while also providing an economic boost to related industries such as steel fabrication and manufacturing. The enhanced fabrication and manufacturing capacity located at or near major port facilities can also better enable the region to capture value in the tidal (and offshore wind) supply chain. The Industrial and Regional Benefits ("IRB") policy that applies to the NSPS combat contract, which requires all prime contractors to pursue business activities within Canada equal to 100% of the contract value, will provide an incentive for global manufacturers involved in the shipbuilding contract to utilize local contractors and supply chain capacity. The supply chain relationships that local contractors form with major international firms have the potential to offer residual benefits in the form of further collaboration on tidal deployments. Many of the major international manufacturers that will be attracted to Atlantic Canada by the NSPS (i.e., Rolls Royce and Lockheed Martin) have experience and skills that would translate well to the offshore wind industry. In cases where NSPS contracted work is undertaken outside of Canada, there may also be opportunities for the offshore wind industry to be the benefactor of IRB provisions requiring these large contractors to make commensurate investments in Canada.

Biomass

Overview

Biomass used for electricity generation can come from a number of sources—wood waste, municipal waste, etc.—but for the purposes of this study, we have focused exclusively on woody biomass. Woody biomass is currently the most abundant type of biomass available in Atlantic Canada, and is already being used to generate power with supply chains in place. All further references to "biomass" in this report refer to woody biomass.

Like onshore wind, the biomass industry in Atlantic Canada is well-established. In addition to being used as a feedstock for electricity generation, biomass is burned throughout the region by residential and small commercial and industrial customers to generate heat and is also now being exported to Europe for co-firing in fossil fuel plants.

In Atlantic Canada, biomass is a byproduct rather than a primary resource. In the current market environment, the supply of biomass is dictated by activity levels in the forestry and mill industries. These industries have contracted in the past several years due to the global economic downturn, but as the U.S. and Canadian economies recover activity in these industries should rebound creating a greater supply of readily-available biomass feedstock.

Based on the current demand for biomass, the industry has been able to obtain most of the necessary feedstock from mill residue, with forest residue used to supplement feedstock supplies when required. The availability of mill residue at the site of co-generation facilities makes it the least cost and most attractive form of biomass feedstock. The development trends in the region's biomass industry will largely be determined by the relative growth of demand for biomass and forestry/mill production. If production from the timber industry and from saw, pulp and paper mills outpaces growth in biomass demand for co-generation and pelletization then mill residue will likely be able to continue to serve as the dominant biomass feedstock.

On the other hand, if the demand for wood pellets and biomass-fired electric generation outpace production growth from forestry and mill operations, the industry will be forced to obtain a greater percentage of its feedstock from forest residue. This would present the biomass supply chain with both challenges and opportunities. Forest biomass is more expensive than mill residue as it must be collected from the forest and transported to the combustion site. However, if these higher costs can be overcome, the utilization of forest biomass could greatly expand the market and thus supply chain opportunities for biomass.

Current Biomass and Supply Chain Activity

The most common application of biomass for electricity generation is co-generation; in which biomass is burned to produce both electric and thermal energy. In Europe, biomass is commonly co-fired with fossil fuels in power plants to reduce greenhouse gas emissions. Scandinavian countries generate a large portion of their electricity from biomass and have been innovators in the development of a supply chain to provide biomass feedstock. Biomass is also being used, to a limited degree, to generate electricity in the U.S. in compliance with state renewable energy standards.

Atlantic Canada has only recently begun to utilize its biomass resources to generate renewable electricity, but a fully-developed supply chain for the procurement of biomass already exists to support the region's long history of using biomass to produce thermal energy. The added component of feedstock procurement inherent to the biomass supply chain creates a number of opportunities for the region's industry and labor force. While largely outside the scope of this report, the pelletization of biomass for usage in thermal energy systems, both domestically and abroad, requires additional processing that offers further supply chain opportunities.

The biomass supply chain is fully developed, but the scale of this supply chain in the region has been limited by economic and political factors. Biomass in the region has, to date, been a byproduct of the timber industry. Saw, pulp and paper mills produce residue (sawdust, bark, waste wood) that can be chipped for combustion. Forest harvesting also leaves residue (tops, branches, low-grade timber) that can be used as a biomass feedstock. The dependence of biomass on the timber industry has restricted its development to the provinces with active forestry industries—namely New Brunswick and Nova Scotia.

While the woodlands in these two provinces offer ample supplies of forest residue and low-grade timber biomass, both New Brunswick and Nova Scotia have implemented policies capping the amount of forest biomass that can be harvested annually to ensure sustainable forestry management. In 2008, New Brunswick announced a Biomass Policy, under which up to one million dry tonnes of forest harvest residues would be made available for bioenergy projects.[13] Nova Scotia's Renewable Electricity Plan, released in 2010, established annual caps on the harvesting of forest biomass for new electric generation (500,000 dry tonnes) and thermal co-generation (150,000 dry tonnes).[14] Nova Scotia subsequently released a Natural Resource Strategy in 2011 that reduced the cap on biomass for renewable electricity generation to 350,000 dry tonnes per year.[15]

In New Brunswick, Crown-owned New Brunswick Power, ("NB Power") currently does not use biomass as a feedstock in any of its own generation facilities; however, it does purchase electricity generated from several biomass co-generation facilities located in the province. AV Group, Group Savoie, JD Irving, and Twin River Papers all utilize biomass cogeneration at their industrial

[13] Climate Change Solutions, Canada Report on Bioenergy 2010, September 2010.
[14] Nova Scotia Department of Energy, Renewable Electricity Plan, April 2010.
[15] Nova Scotia Department of Natural Resources, The Path We Share, A Natural Resources Strategy for Nova Scotia 2011-2020, August 2011.

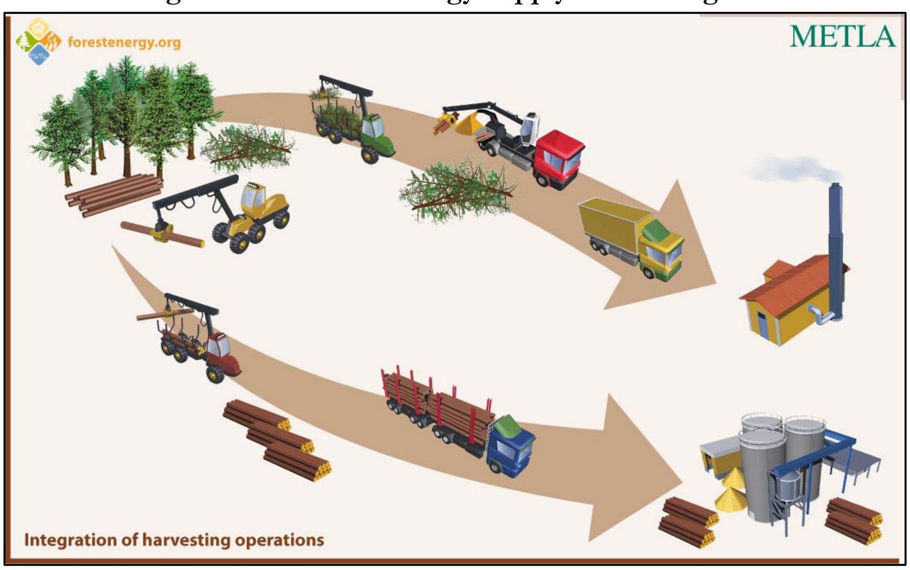
facilities. In Nova Scotia, privately-held NS Power currently uses biomass as a feedstock in its 22 MW Brooklyn co-generation plant and is developing a 60 MW facility at the site of the former NewPage paper mill in Port Hawkesbury. Northern Pulp Corporation also operates a 23 MW cogeneration facility at a pulp mill to meet its electricity needs and can sell its excess power to NS Power.

Developers of biomass plants in New Brunswick and Nova Scotia are typically existing mills looking to optimize their facilities' operations. NB Power and NS power are the off-takers of all electricity generated by these biomass projects in New Brunswick and Nova Scotia respectively.

Value Chain Components

The supply chain for biomass is distinct from the other technologies covered in this report in that it still requires a feedstock (i.e., wood). Unlike the value chains for wind or tidal energy, where manufacturing and installation costs dominate, the biomass value chain is focused in large part on the procurement of this feedstock.

Figure 7 – Biomass Energy Supply Chain Diagram



Source: Forestenergy.org

The biomass supply chain begins with the feedstock. The three basic types of feedstock are: 1) mill residue, 2) forest residue, and 3) low-grade timber. The procurement of biomass feedstock consists of a number of functions, each requiring specific equipment. In some cases, all of the procurement services are provided by a single contractor, while in others these functions are divided amongst multiple contractors. The procurement supply chain also varies with the nature of the feedstock. Mill residue is conveniently located at the mill site where co-generation occurs and must only be chipped. The procurement of forest residue and low-grade timber, on the other hand, requires an expanded supply chain to harvest and collect the biomass before it is chipped and then to transport it to the combustion facility. The general functions involved in the procurement of biomass feedstock are detailed below.

Timber Harvesting: The majority of the biomass in Atlantic Canada originated in the region's forests, and the first step in procuring this resource is the harvesting of the timber. Mill and forest residue are both byproducts of the timber industry so in these cases the timber harvesting function falls outside the biomass supply chain. Low-grade timber stands are not of any interest to the timber industry though, so the supply chain to derive biomass from this resource would require harvesting. Biomass from low-grade timber stands offers additional opportunity for existing timber and land-clearing contractors in the region to provide this service.

Collection/Forwarding: While mill residue is conveniently gathered and available at mill sites, forest residue must be collected from scattered and often remote forestry sites. Forest residue requires additional equipment to forward and pile the feedstock at the roadside. The forwarders used to collect forest residue are customized equipment typically sources from Europe or elsewhere in North America, but local distributors (e.g., ALPA Equipment, Atlantic Cat) sell and provide parts for major brands such as Ponsse and Rottne.

Chipping/Grinding: Once the woody feedstock has been collected, it must be chipped or ground into wood chips for combustion. This process, known as comminution, can be achieved using either a chipper or a grinder. Chippers and grinders come in various forms. For forest residue, they can be mounted on forwarding equipment to chip or grind the biomass as it's collected, or mobile chippers/grinders can be delivered to the roadside residue piles for roadside chipping. For mill residue, stationary chippers or grinders can be located either at the mill site or at the biomass plant where it will be combusted. Chippers and grinders, like forwarders, are also typically ordered from European and North American manufacturers via the same regional distributors.

Transportation: Mill residue has the advantage of being located at the site of combustion. Forest residue, on the other hand, must be transported (typically as wood chips) to the biomass plant where they are combusted to generate electricity. Wood chips are transported using trucks, and these trucks can be owned by the same contractors that provide the forwarding and chipping services or by separate contractors. Alternatively, mill and forest residue can be transported whole and chipped or ground at the biomass plant, but this process is more costly due to the higher moisture content of the whole wood forest residue.

Transportation of the chipped feedstock to biomass plants is the costliest aspect of biomass procurement. Transportation costs account for a substantial portion of supply chain costs due to the scattered nature of forestry and mill sites as well as the additional weight of cargoes from the moisture content of wood in chip form. According to a 2007 report by Climate Change Solutions, the economic distance that forest residue can be transported is generally considered to be about 150 km, and escalating oil prices threaten to narrow this range even further.16

Combustion: Once the biomass has been procured it is delivered to a power plant where it is combusted—either on its own or co-fired with natural gas—to generate power. These biomass plants require technological components—steam turbines, generators, boilers, and condensers—that must be customized for biomass combustion. Many of these components are sourced from Europe and Asia, but some North American manufacturing is available as well. Biomass plants will also require a standard kit of electrical equipment—transformers, switch gear, etc.—to connect the plant to the electric grid. As with the other technologies covered in this study, electrical equipment is typically provided by global electric engineering firms based in Europe and the U.S., most of whom have North American manufacturing capacity.

The construction of these biomass facilities is typically overseen by international EPC contractors such as AMEC. Other local contractors are often also employed in the construction of such plants. The O&M function is either conducted in-house if the plant is owned by an electric utility, or can be contracted out for independently-owned cogeneration plants.

Effects of International Trends in the Biomass Supply Chain

There are some encouraging international supply chain developments that could greatly benefit the biomass industry in Atlantic Canada. Whereas the local usage of forest biomass is a fairly recent concept, the biomass industry in Scandinavia has been utilizing forest residue for decades. Through this experience with forest biomass supply chains, Scandinavian countries have had considerable success at reducing the cost involved in the procurement of this feedstock. In Sweden, costs related to forest biomass procurement fell 2% annually between 1983 and 2003 due to continuous supply chain innovation.[17] In Finland, early supply chain experiments with bundling—where whole energy wood is bundled for transport and then chipped at the end-use site—have the potential to reduce overall costs in the forest biomass supply chain. Such innovations in the forest biomass supply chain could be imported to Atlantic Canada where, if employed, they could reduce the cost of forest biomass and thereby greatly expand the supply of economical biomass feedstock.

The growing demand in Europe for Canadian-sourced wood pellets offers potential opportunities to the Atlantic Canada biomass supply chain as well. While the pellets burned in residential systems for thermal energy throughout Atlantic Canada require a higher-grade feedstock—typically sourced from certain types of mill residue—the pellets being exported to Europe to be co-fired in coal plants have lower quality standards. To meet this growing demand for exportable pellets, forest residue is increasingly being employed as a feedstock. The incentive pricing for Canadian wood

[16] Climate Change Solutions, Canada – Sustainable Forest Biomass Supply Chains, October 19, 2007.
[17] Climate Change Solutions, Canada – Sustainable Forest Biomass Supply Chains, October 19, 2007.

pellets is currently supporting the higher costs associated with harvesting forest residue where most Atlantic Canadian biomass markets currently do not. The supply chain development required to procure forest biomass for pelletization is equally applicable to forest biomass procurement for electric generation. If European incentives continue, innovations in forest biomass procurement for pellet exports could reduce the cost of forest biomass feedstock which would create the opportunity for expansion of the biomass supply chain.

Supply Chain Bottlenecks and Vulnerabilities

The largest supply chain constraint faced by the biomass industry is the potential shortage of mill residue as a low-cost feedstock. The supply of mill residue is entirely dependent upon the production of the saw, pulp and paper mills in the region. The global economic downturn has forced a number of the mills in Atlantic Canada to close their doors. While much of the saw mill production is expected to recover once economic climates improve, the pulp and paper industry was contracting even before the economic downturn. The difficulties faced by the saw, pulp and paper industries has reduced the supply of mill residue for use in biomass combustion plants. At the same time that mill activity has contracted, the overall demand for biomass has increased.

Many of the provinces in Atlantic Canada have implemented policies calling for a greater percentage of electric generation to come from renewable resources. This has, in turn, led to a greater interest in biomass combustion for power generation. Nova Scotia and New Brunswick have recently constructed a number of large-scale biomass cogeneration plants that have substantially increased the demand for biomass feedstock. The demand for wood pellets—which similarly rely upon mill residue as a feedstock—has also increased, creating further competition for the remaining supply of mill residue. In addition to the residential and small-scale commercial and industrial combustion of wood pellets to produce heat, European incentives for the co-firing of wood pellets in coal plants have also led to increased pellet production for export.

With insufficient supplies of mill residue, the industry must to look to forest residue to provide supplemental feedstock, and the recovery of forest residue requires additional supply chain components to forward the biomass to the roadside for chipping and to transport the chipped wood to the combustion plants. Conversations with industry participants did not reveal any pressing supply chain concerns. While most of the equipment required to procure forest residue are not manufactured in Atlantic Canada, local distributors sell all of the necessary equipment and parts and offer repair services.

Potential Opportunities

The opportunity exists for the expansion of existing biomass feedstock supplies through increased harvesting of forest residue and low-grade timber. Any such expansions will have to be weighed against concerns over forest sustainability, but would offer significant growth potential to the biomass supply chain.

- **Procurement Equipment Manufacturing** – The limited scale of the current forest biomass supply chain in Atlantic Canada has not warranted the local manufacture of the equipment needed to procure forest biomass. Atlantic Canada has significant untapped forest biomass resources, and should the provincial governments decide to harvest these resources in greater quantities there would be an opportunity for local manufacturers to enter the supply chain to provide such equipment. This scenario would likely also see existing equipment manufacturers from Europe and elsewhere in North America looking to expand into the region.
- **Forestry Contractors** – The expansion of biomass resources harvested in Atlantic Canada to include more forest residue and low-grade timber would require a more robust supply chain. The existing capacity of contractors providing forest biomass feedstock is currently rather modest due to low levels of demand and would have to be expanded. Biomass from low-grade timber would also require additional harvesting capacity. With the heavy equipment needs of such contracting operations and the high cost of transporting such equipment, locally-based contractors would have an advantage in this space.
- **Logistics** – Transportation costs account for a substantial portion of the forest biomass supply chain and, to date, have limited the usage of this resource. There is an opportunity for regional firms with expertise in logistics to apply their knowledge to the biomass industry. Should these efforts result in reductions to the cost of procuring forest biomass, they could also serve to greatly expand the quantity of cost-effective biomass feedstock.

Systems to Power Remote On- and Off-Grid Applications

This section of the report focuses on technologies that could be used to provide heat and/or power to remote communities in Canada in order to displace the current typical practice of running diesel-powered generators for power and burning heating oil for heat. Two such technologies have been designed with these functions in mind. The first technology, wind/hydrogen systems, has been tested on sites in Newfoundland and PEI. The Newfoundland site is in full-time use. The second technology, biomass for remote district heating, is commonly used in institutional settings such as universities and hospitals, but has not yet been adopted extensively by remote communities due primarily to its high up-front capital costs. The sections below provide a discussion of supply chain issues with respect to both of these technologies.

1) Wind/Hydrogen Systems

A wind/hydrogen system is a system designed to supplement or displace existing power sources in either on-grid or off-grid applications. The core of the system connects wind turbines to an electrolyzer, which pass the wind-generated electricity through water to split it into hydrogen and oxygen. The hydrogen can then be stored and used later to generate electricity using an internal combustion engine. Because it is able to store energy produced when the wind blows and generate power when it does not, the system solves the problem of intermittent generation that is inherent in a wind-only system. Intermittent generation from wind power is problematic since it requires an alternative source to come on line in order to serve load and balance the system when the wind is not blowing. Also, the constant ramping up and down of the alternative generator can cause excessive wear on that system. Intermittency is particularly acute in smaller off-grid systems, where a diversity of alternative generation sources is either lacking or non-existent. The wind/hydrogen system solves these problems by producing a relatively constant stream of firm energy.

There are at least ten wind/hydrogen systems in the world. Most of these systems are demonstration projects designed to showcase the capability of generating hydrogen for industrial uses. There are approximately six wind/hydrogen projects around the world that use the hydrogen to generate electricity at the plant level for on- or off-grid applications, approximately four of which are in continuous use by remote off-grid communities. Atlantic Canada hosts two such wind/hydrogen facilities, in Newfoundland and Prince Edward Island. Other wind/hydrogen plants are configured to produce hydrogen for transportation.

There are a variety of alternatives to using hydrogen as a storage medium, such as using compressed air, pumped hydro or batteries. For example, a demonstration project on a First Nations settlement in Saskatchewan is using battery storage in conjunction with an 800kW wind turbine, and is expected to come on line in the summer of 2012.[18] However, the most likely opportunity for Atlantic Canada to develop a wind/storage system for remote communities would be to replicate the wind/hydrogen systems in Newfoundland and PEI using the experience gained by developing and testing those systems.

The first wind/hydrogen system in the region was developed at the Wind Energy Institute of Canada at the North Cape testing facility in PEI. The project, developed by the PEI Energy Corporation and Frontier Power Systems, began with PEI Energy Corporation's installation of 5.3 MW of wind power in 2001 at the Atlantic Wind Test Site, which had been in operation since 1978. Wind power at the site was expanded to 10.6 MW in 2003. Federal and provincial funding to promote hydrogen production led to the idea to combine this existing wind production with hydrogen generation as a grid-connected system, but a cutback in federal funding led to plans for a more modest demonstration project.

Project developers also recognized that this small prototypical system would be relatively inefficient. Therefore, while energy from the 10.6 MW grid-connected North Cape wind facilities is sold into the PEI grid, the wind/hydrogen project was held to just 150 kW and is run intermittently for demonstration and testing purposes. PEI Energy indicates that, while a scaled project would be more efficient, high project levelized costs would still require that retail prices in the host community would need to exceed approximately $1.00/kWh in order to reach commercial viability.

Meanwhile, a second wind/hydrogen project was being developed on the off-grid community on the Island of Ramea, in Newfoundland, and was completed in 2011. Energy from this 400 kW project, which is owned by developer Frontier Power Systems, sells its energy to Nalcor under a PPA. This project is more efficient than the PEI project largely due to knowledge gained from completing that first system.

Value Chain Components

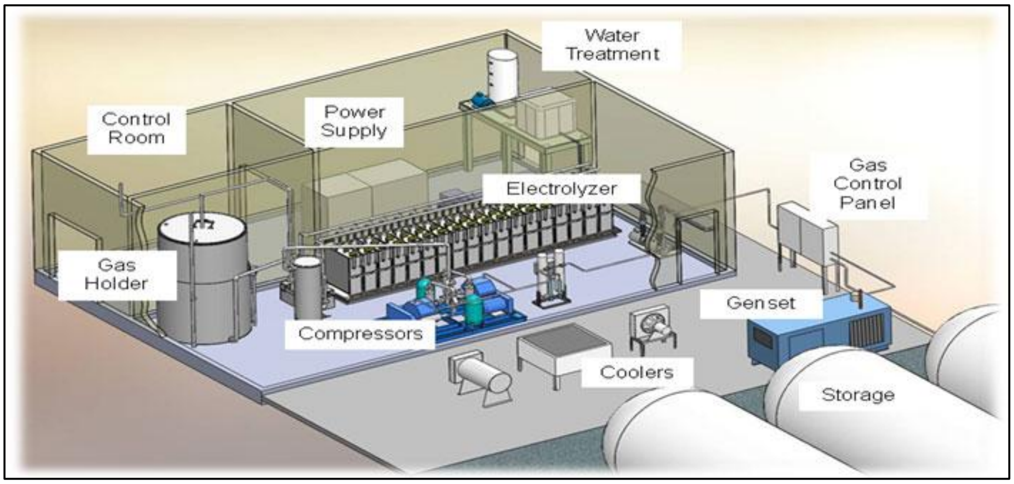
The primary components of a wind/hydrogen system are:

- a wind turbine/generator, and tower
- an electrolyzer
- a hydrogen compressor and storage tanks,
- a hydrogen-powered electricity generator or fuel cell ("Genset"), and
- a series of electronic controls to maintain the proper balance of wind generation, hydrogen production, hydrogen generation and diesel generation (or other alternative).

[18] "Cowessess Wind Turbine Battery Storage Project Gets a Boost," Blog Post, McNair Business Development, Inc., available at http://blog.mcnair.ca/2011/03/cowessess-wind-turbine-battery-storage.html.

The Figure below illustrates the typical configuration of these components:

Figure 8 – Primary Components Layout of a Wind/Hydrogen System



Source: PEI Energy Corporation.

In order to keep costs reasonably competitive, the turbines for both the PEI and Ramea projects are Daewoo models purchased from decommissioned California projects and reconditioned for the installation sites. Frontier Power Systems indicates that turbines for future projects would be sourced in the same way if they are available. Used turbine availability may become constrained if many more wind/hydrogen projects were developed. Further, the COMFIT may place additional demand for turbines of this approximate size, which are designed for community-scale projects. New community-scale turbines are readily available from companies such as Atlantic Orient (Nova Scotia-based) or Northern Power Systems (Vermont-based). Given their relatively small size, community-scale turbines can also be purchased from more distant manufacturing facilities than utility scale turbines.

Towers are also readily available from companies like Enercon, DSME Trenton and others, but they can be expensive for remote applications of any size given that high transport costs can be spread over only a few units. However, companies such as Acciona have begun to produce concrete towers on-site in order to reduce transport costs. While the Acciona application is designed specifically for very large towers to accommodate growing turbine sizes, it would also be beneficial where transport distances are relatively long. Frontier Power Systems is investigating the use of on-site concrete towers for new potential remote applications in Alaska, the NW Territories and the Yukon.

An electrolyzer, which uses electricity to split water molecules into hydrogen and oxygen, is a common piece of industrial equipment available from companies such as Hydrogenics, Teledyne, Proton and Norsk Hydro. This equipment is typically used for on-site generation of hydrogen and/or oxygen for various purposes such as power plant cooling, and military or aerospace applications. To save cost, the PEI project purchased a used Hydrogenics unit and refurbished it. The PEI unit is a standard efficiency unipolar type. The Ramea unit is higher efficiency bi-polar. The newest type, proton exchange membrane ("PEM") electrolyzers are the most efficient, scalable and responsive, but remain costly.

Compressors and tanks are also standard industrial equipment used for compressing and storing gasses of any type. The primary decision point for off-grid projects in this regard is whether hydrogen will be produced for vehicular use, as is done with PEI. Vehicular hydrogen must be compressed to very high pressures, requiring a larger compressor and tanks capable of handling these pressures.

Gensets can be either standard diesel engines, modified to accept hydrogen, or fuel cells, which convert hydrogen and oxygen to electricity without combustion. The Gensets for the PEI and Ramea projects are modified diesels. This set-up allows for fuel flexibility and use of technology already installed in remote locations, but it does require a retrofit in each new application, limiting scalability. Alternatively, a remote community in Bella Coola, BC has elected to use a fuel cell as the Genset for its hydro-hydrogen system. A fuel cell, also commonly procured from companies such as Ballard Power Systems or Plug Power (U.S.-based companies), has higher up-front costs but is more efficient than a converted diesel engine.

While all of the above components are used in existing industrial applications and are therefore generally available for purchase, the control systems that regulate a wind/hydrogen system are unique to this application. In each of the PEI and Ramea projects, the control technologies were engineered and built specifically for each project. Moreover, lessons learned from PEI are now integrated into the Ramea system. This capability, now resident in personnel at Frontier Power Systems, Nalcor and PEI Energy, may be an asset capable of replication in other settings, and could form the basis for a new design manufacturing capability in Atlantic Canada if wind/hydro systems were to proliferate.

Bottlenecks and Opportunities

As discussed above, the only piece of the physical supply chain for systems to power remote communities that appears to be lacking is the ability to procure a standardized control system that integrates the wind, hydrogen generation and Genset systems. This lack of a single affordable control system will remain until the number of new wind/hydro installations is great enough to allow for standardization within a single manufacturing entity. Therefore, development of a standardized control system to allow turnkey replication of the system in multiple communities is a niche opportunity. Given the experience recently accrued by PEI, Nalcor and Frontier Power Systems, any new enterprise would be advantaged by forming a partnership with one or more of those entities.

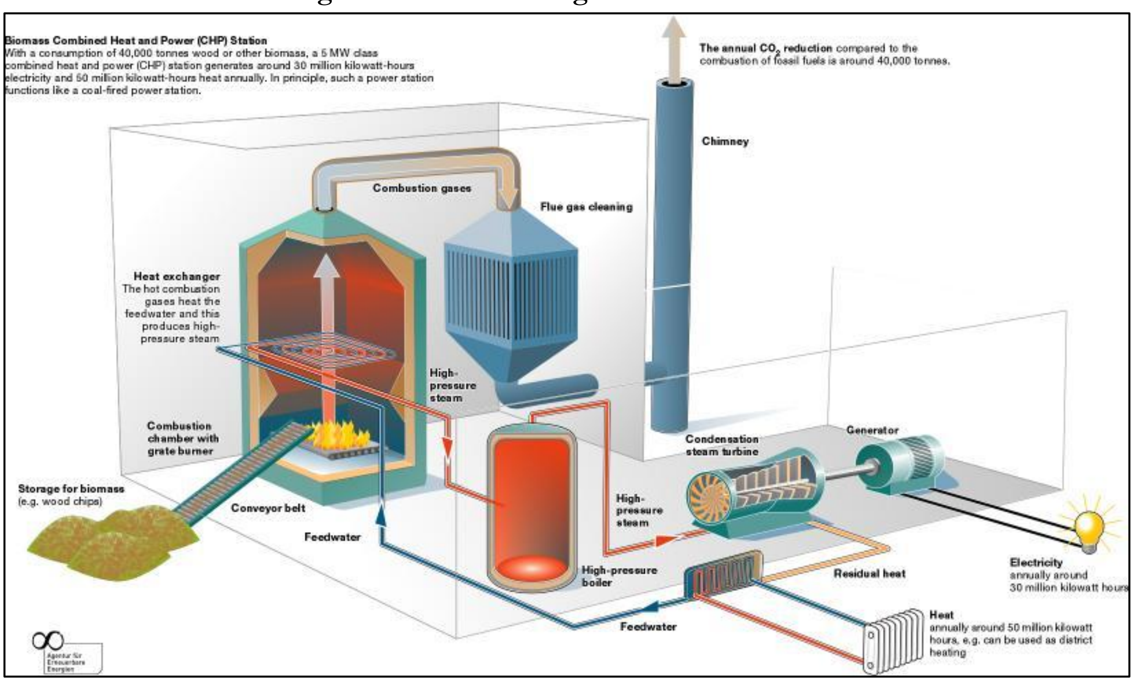
Policy drivers and human factors will be critical factors in the future success of these systems. Currently, the cost of wind/hydro systems significantly exceeds the cost of incumbent diesel generation, so policy support will be required in order to make development of these systems to be economic. In addition, given the complexity of wind/hydro systems relative to existing diesel, adoption of the new hydro systems will require the commitment of any adopting community to train and dedicate staff to operate and maintain the system in potentially remote locations and adverse environmental conditions.

2) Biomass for Remote District Heating

One additional consideration for displacing diesel in remote locations is to employ biomass fueled district heating and/or cogeneration. Compact Appliances (New Brunswick), in partnership with biomass pelletizer Group Savoie, has deployed these systems at institutions and hospitals in Atlantic Canada, and is looking to deploy them in remote locations. This approach follows a model used in Scandinavia, which uses biomass district heating and the State of Vermont which now heats many of the State's elementary schools with biomass.

The supply chain for biomass-fired district heating systems is composed primarily of fuel, and a boiler. According to Compact Appliances, opportunities to employ a cogeneration system in remote locations are probably limited. However, if the system is operated to co-generate electricity, then a steam turbine-generator is also employed as follows (a heat-only system would simply eliminate that component):

Figure 9 – Biomass Cogeneration Schematic



Source: German Renewable Energies Agency.

Bottlenecks and Opportunities

No specific bottlenecks were identified in this technology segment. Compact Appliances has had no difficulty procuring either the required fuel feedstock or the required boilers in order to install their systems. Boilers are currently purchased from either US or European manufacturers, and the company has the capability of completing an installation on a turnkey basis, including construction of a boiler enclosure and a fuel storage building, installation of equipment, and operation and maintenance. Further, suppliers to Compact Appliances have not expressed any supply chain issues aside from a 9-10-month lead time for delivery.

As mentioned in the Biomass section above, the thermal systems used for residential and district heating applications require pellets derived from high-quality mill residue. Growing constraints on the supply of mill residue in Atlantic Canada threaten to curtail the domestic growth opportunities of biomass for thermal combustion. On the other hand, innovations in these remote district heating systems that would allow for the usage of pellets created from forest biomass could greatly improve growth prospects.

Appendix A - List of Interviews

ORGANIZATION	INDIVIDUAL	TITLE
American Wind Energy Association	Chris Long	Manager, Offshore Wind and Siting Policy
Barrett Enterprises	Robin Barrett	(family owned)
Business New Brunswick	Eddie Kinley	Senior Project Executive
Canadian Biomass Association	Bruce McCallum	Director, Maritimes Working Group
Canadian Wind Energy Association		
Compact Appliances	Malcolm Fisher	Sales
DSME Trenton		
Enercon		
Fundy Ocean Research Center for Energy (FORCE)	Doug Keefe	Executive Director
Frontier Power Systems	Carl Brothers	President
Fundy Tidal, Inc.	Dana Morin	President
GDF Suez		
JD Irving	Graham Curren	Director of Marine Business Development, Irving Transportation Services
MacAskill Associates	Allan MacAskill	Director
The Maritimes Energy Association	Barbara Pike	Executive Director
New Brunswick Forestry Products Association	Mark Arsenault	President & CEO
Nova Scotia Power	Roger Burton Pam McKinnon Marie Thomas	Senior Director, Projects Director, Wind Energy Facility Representative
Ocean Renewable Energy Group	Chris Campbell	Executive Director
PEI Energy	Mark Victor	Special Projects Coordinator
Renewable Energy Services Ltd	Allison Leil Jr.	COO
Shaw Resources	Gordon Dickie	General Manager
Seaforth Energy	Mike Morris	President
Shear Wind	Ian Tillard	COO
Verboom Grinders	Jim Verboom	Partner/Founder

Appendix B – Bibliography

Canada's Marine Renewable Energy Technology Roadmap. Charting the Course – Canada's Marine Renewable Energy Technology Roadmap. October 2011

Climate Change Solutions. Canada – Sustainable Forest Biomass Supply Chains. October 19, 2007

Climate Change Solutions. Canada Report on Bioenergy 2010. September 15, 2010

European Commission (European Climate Foundation, Sveaskog, Sodra, Vattenfall). Biomass for heat and power – opportunity and economics, 2010

European Wind Energy Association. Wind in our Sails – The coming of Europe's offshore wind energy industry. November 2011

Federal Energy Regulatory Commission. FERC Issues First Pilot License for Tidal Power Project in New York. January 23, 2012

Frontier Power Systems. 2008 International Wind-Diesel Workshop. Wind-Diesel Technology: Getting It Right. April 23-25, 2008

Industry Canada. Opportunities for Canadian Stakeholders in the North American Large Wind Turbine Supply Chain. September 5, 2007

North America Wind Energy Advisory. Overview of North American Wind Energy Supply Chain, CanWEA 2009: Infinite Possibilities. September 20-23, 2009

Nova Scotia Department of Energy. Marine Renewable Energy Infrastructure Assessment. August 2011

Province of Nova Scotia. The Path We Share, A Natural Resources Strategy for Nova Scotia 2011-2020. August 2011

Scottish Government – Marine Energy Group. Marine Energy Group Supply Chain Survey. July 2009

SYNOVA International Business Development. A Study of Supply-Chain Capabilities in the Canadian Wind Power Industry. November 2004

US Department of Energy. A National Offshore Wind Strategy: Creating an Offshore Wind Energy Industry in the United States. February 7, 2011

US International Trade Commission. Wind Turbines Industry & Trade Summary. Office of Industries Publication ITS-02. June 2009