

Ocean Energy: Global Technology Status, Opportunities and Challenges for Canada

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1.0 FORMS OF OCEAN ENERGY AND ESTIMATED GLOBAL AND RELEVANT CANADIAN RESOURCES

Ocean energy resources are classified into five principal categories: Tides, wave, marine current, salinity gradient and thermal gradient. The estimated global supply from these ocean resources are:

- Tides – 0.03 TW
- Wave – 1 to 10 TW
- Tidal (Marine) Current – 5.0 TW
- Salinity – 2.6 TW
- Thermal Gradient - 2.0 TW

1.1 Tides and Tidal Barrage

The conversion process is similar to conventional hydroelectric power, i.e., involves building a dam but across an estuary and potential energy is converted to electricity using conventional turbine. This type of plant could be developed economically at locations having a tidal range of >5 m. In Canada, a 20 MW plant was built at Annapolis Royal by the Bay of Fundy in 1984. France has an operating plant of 240 MW capacity. Russia and China have smaller plants. These installations are operated as commercial plants. There are few suitable locations in Canada and worldwide. However, this type of energy conversion may cause significant changes to the estuarine ecosystem. This would prevent widespread deployment. However, in-depth analysis of the existing installations would provide crucial elements to help policy makers for any such new projects.

1.2 Salinity

When fresh water flows into the ocean, it creates an osmotic pressure difference between fresh water and seawater. By developing appropriate conversion technologies (membrane or turbine), this energy could be harnessed. The conversion technologies are at an early stage of development. Companies from Norway and the USA are at the early stage of technology development.

1.3 Thermal Gradient

This process uses the Rankine or Ureah Thermodynamic Cycle to convert natural thermal gradient in the sea to electrical energy. Cold water condenses ammonia gas in the condenser, and then the liquid ammonia is pumped to an evaporator near the surface where warm seawater evaporates the ammonia. The ammonia vapour is de-pressurized by driving a turbine, before returning to the condenser. The conversion technology is known as Ocean Thermal Energy Conversion (OTEC) process. This form of ocean energy is not relevant to Canada. However, thermal energy associated with ocean water could be utilized for air conditioning of high-rise buildings,

1.4 Tidal (Marine) Current

Tidal currents are caused by the rise and fall of tides, salinity, thermal, and underwater topography. For Vancouver Island and the B.C. Mainland, a recent resource assessment has identified 55 sites with a current speed of >2 m/s. Twelve specific sites, each having more than 10 MW potential, have been identified. A resource study, being undertaken by the Canadian Hydraulic Research Centre in Ottawa, in collaboration with DFO, Triton Consulting, and Powertech, will establish an available tidal current resource for the Canadian coasts, including the Arctic Ocean. The first phase of the assessment will be completed by March 2006. An EPRI study is presently identifying demonstration sites for New Brunswick and Nova Scotia.

For Vancouver Island and the B.C. mainland, a recent resource assessment has estimated a theoretical energy potential from the 55 sites of more than 20 TWh/year. For Canada, considering the Pacific, Atlantic and Arctic coasts, the available theoretical resources could be more than 50 + TWh/y.

1.5 Wave

Ocean waves are generated by the action of winds blowing over the ocean surface. The energy transport per metre width of the wave front is a function of the square of wave height and the wave period. Attractive wave climates are found within the +/- 30-degree latitude and energy is at its greatest in the winter months. Offshore wave power is higher than that of near-shore due to energy losses such as seabed friction and wave breaking. The Canadian Pacific and Atlantic coastlines and offshore areas have favourable wave energy resources: the average near-shore wave power for the west coast of Vancouver Island is 33 kW/meter width of wave front.

The average theoretical near-shore average wave energy potential for the west coast of Vancouver Island (VI) has been estimated to be 60 TWh/y. For Canada, it could be more than 100 + TWh/y.

2.0 WAVE AND TIDAL CURRENT ENERGY CONVERSION TECHNOLOGIES:

Main conversion technologies could be summarized as follows:

2.1 Tidal Current:

- Mounted on the seabed or suspended from a floating platform
- Use a turbine rotor, axial – flow rotors (propeller-type, horizontal axis)
- Use a turbine rotor, cross-flow rotors (Darrieus-type turbine)

- Use of hydro-foil, hydraulic ram, and others

2.2 Wave Energy:

- Shore-based over-topping technology
- Oscillating water column – near-shore and offshore (floating)
- Off-shore over-topping device
- Pitching devices for offshore
- Point absorbers for offshore
- Submerged direct generation

3.0 STATUS OF WORLDWIDE OCEAN ENERGY R&D AND DEMONSTRATION PLANTS:

3.1 International R&D and D and IEA-IA-OES

The International Energy Agency (IEA) was formed in 1974 in response to the oil crisis, as an autonomous, intergovernmental agency. In 2001, the IEA formed an Implementing Agreement (IA) on Ocean Energy Systems (OES), for which Powertech Labs is the Canadian representative.

Present members for the IEA IA-OES are: EU, UK, Portugal, Denmark, Ireland, Japan, Canada, and USA. Australia, the Netherlands, Norway, Italy and Brazil are observers. The tenth meeting of this international committee will be held in Vancouver in May 2006, hosted by the B.C. Provincial government. Various countries presently active on R&D and demonstration of ocean energy can be summarized as follows:

- Wave and Tidal Current: Participating regions and countries are EU, UK, Portugal, Ireland, Denmark, Italy, Sweden, Norway, Japan, China, India, USA, Australia, Canada, Brazil, South Africa
- OTEC: Japan, USA, India – 1 MW OTEC demonstration plant and laboratory scale hydrogen conversion using electricity produced by OTEC
- Salinity: Norway, USA

It should be noted that presently, the UK Government has taken a very proactive role in implementing various policy and funding strategies for wave and tidal current conversion technologies with a long-term goal to playing a leading role in exporting relevant technologies to the rest of the world.

3.2 Demonstration Plants for Wave and Tidal Current

Status of wave and tidal current demonstration plants could be summarized as follows:

Tidal Current:

At this stage, there are several tidal current demonstration projects that have been built and are being demonstrated: a 300 kW seafloor plant using marine current turbine (horizontal axis) in UK, a 130 kW Enermeer plant using a vertical Kobold turbine in Italy, and a 300 kW (horizontal axis) Hammerfest project in Norway. A 150 kW Stingray tidal current project (using reciprocating wing - hydrofoil - technology) was also demonstrated in UK. Recently, a

1 MW size lunar energy tidal current device has been awarded funding from the UK government for demonstration at the European Marine Energy Centre in Scotland. In Canada, a 65 kW non-integrated plant using a clean current ducted turbine is being built at Race Rock. The plant will be in operation in 2006.

Wave

- UK: shore-based Wavegen's 500 kW Oscillating Water Column (OWC) commercial-scale generator called LIMPET.
- UK: 750 kW wave energy modular converter (offshore pitching) called Pelamis, Ocean Power Delivery, undergoing full-scale sea trials at the European Marine Energy Centre.
- Portugal: shore based 400 kW OWC- Pico Plant
- Denmark: 1:4 scale offshore, floating overtopping wave energy converter called Wave Dragon.
- Portugal: 2 MW direct generation Archimedes Wave Swing (AWS) plant has been demonstrated in undersea installation.
- India: 140 kW near-shore OWC generating electricity was converted to a desalination plant
- Japan: shore based OWC plant for compressed air and electricity for aquaculture
- Japan: floating OWC – Mighty Whales
- Norway: 350 kW shore based overtopping device called the Norway
- Ireland: McCabe Wave Pump - slack-moored floating desalination device
- Australia – 400 kW OWC plant near Sydney using Energetech technology
- China: on-shore 3 kW OWC supplies power to Dawanshan Island.

3.3 Status of Canadian Activities:

At this stage, one ocean energy plant is operational in Canada, i.e., the Annapolis Royal tidal barrage plant (20 MW) in Nova Scotia - in operation since mid-80s.

Besides the Race Rock tidal current demonstration project using the local Clean Current technology, efforts are being made by other local, domestic and international technology developers; such as, Blue Energy Canada*, New Energy Corp*, Lunar Energy*, Ocean Power Delivery, Energetech, Aqua Energy, Sieber Energy, Wavemill and Waveberg, in planning for demonstration projects in Canada. (* Tidal current, and the rest are wave energy)

4.0 ECONOMICS OF WAVE AND TIDAL CURRENT

Currently, there are two commercial testing wave energy installations worldwide. Several wave and tidal current energy conversion scheme are currently being planned around the world. Learning curves and cost figures for wave and tidal currents are based on estimates. Economic assessments have been made by the Europeans and recently by EPRI for certain types of conversion technologies, as well as for site specific projects. The range of electricity costs for wave energy conversions based on OWC has been estimated to have decreased from 34-45 Euro cents/kwh in 1982 to 6-12 Euro cents/kWh in 2001. For the offshore wave energy conversion process, the assessment reflected a decrease in cost from 44-52 Euro cents/kWh in 1982 to 5-10 Eurocents/kwh in 2001. These estimates assume bulk production of components and perfect

powerplant behaviour. For wave energy, it has been estimated that global economic resources could be as high as Euro 50 b to 280 b.

5.0 SOCIAL AND ENVIRONMENTAL IMPACT OF OCEAN ENERGY

Wave and tidal current conversion plants would produce no gaseous, liquid or solid emissions and hence, in normal operation, these resources will be virtually a non-polluting source of energy. However, deployment of these types of plants could have a varied impact on the environment. Some of these effects may be beneficial and some potentially adverse. A European study has indicated the following potential environmental impacts of near-shore wave energy plants:

<i>Environmental Effect</i>	<i>Size</i>
Construction/maintenance sites	small
Recreation	small
Coastal erosion	small to medium
Sedimentary flow patterns	small
Navigational hazard	small
Fish and marine life	small
Acoustic noise	small
Device/mooring damage	small to medium
Visual impact	small to medium

The environmental impacts would be different for different conversion technology and would also be site specific.

A detailed evaluation of the socio-economic benefits of renewable is difficult and complex, considering primary and secondary benefits. This is technology specific as well as country specific. Scotland has carried out detailed likely socio-benefit implications of wave energy. This assessment has indicated that in terms of job opportunities “in the 21st century, offshore renewable could be to Scotland what shipyards were in the 19th century and offshore oil rigs in the 20th century”. This assessment included diversification of the rural economy.

6.0 PRESENT MARKET AND TECHNOLOGY BARRIERS FOR OCEAN ENERGY (OE) DEVELOPMENT

6.1 Market

- Industry visibility and credibility, including standards
- Understanding ocean resources, and areas where various technologies may be economical
- Environmental and aesthetic concerns about siting projects
- Cost

6.2 Technology

- Reliability and survivability
- Power quality issues
- Interconnection issues for distributed generation (grid constraints)
- Mooring and deployment methodology
- Standards

6.3 Intermittency/Predictability of Tidal Current and Wave Energy Plants

Integration of wave and tidal current energy conversion systems to an electrical grid could have the following issues:

- Impact on power quality: such as flicker, harmonics, voltage sags, etc.
- Impact on system security: such as effect on the system and local generation. The following disturbances of interests are thermal overloads, voltage declines/rise, frequency control, protection operations, stability (transient, small signal, voltage, frequency)

It should be noted that, once a tidal current technology is proven commercially, it would be very predictable and dependable for years to come. Tidal current resources are more dependable and predictable than any other renewable resource, including hydropower. For a particular site, once the tidal flow characteristics are defined precisely, a plant using a particular technology could be designed accordingly. The capacity factor of the plant could be high.

Tidal current energy production from a single site will be cyclic in nature (four cycles a day). Wave and tidal current resources are less intermittent than wind. Though there will be no generation from a specific tidal current plant at certain times of the day without any storage mechanism, these types of plants could be dispatchable and could be integrated to the grid to optimize load capacity by using different storage options. Moreover, potential sites in Canada having tidal current at different phases could reduce the impact of intermittence.

Any issue of integration of tidal current and wave energy conversion plants considering its cyclic production nature or intermittency, on power quality, reliability and firming etc. can be examined through appropriate study and investigation to determine appropriate operation and technical solutions. Specific system characteristics, such as, types of generation mixes, individual characteristics of ocean energy conversion process, including individual storage capacity if any, can be considered as part of any grid integration study.

7.0 POLICY STATUS AND BARRIERS

At present, no specific Canadian national policy exists for ocean energy. However, following the publication of OREG's strategic framework for the development of Canada's ocean energy sector, Natural Resources Canada has mobilized an interdepartmental initiative of energy, fisheries, environment, industry departments, economic development agencies, and national laboratories. This group is using existing government resources and programs to launch projects such an Ocean Energy Atlas, an environmental scan for ocean energy development, technology screening and an analysis of the industry that will mobilize into the Canadian Ocean Power

Sector. Natural Resources Canada will be leading reviews of energy funding programs and incentive programs in 2005/6 and is addressing the ocean energy option in development of a renewable Energy Strategy in 2005.

The Ocean Energy sector has been identified as a promising emerging technology, and as a priority for review and action by four coastal provinces of the Canadian Council of Energy ministers.

In late 2004, British Columbia Premier's Technology Council developed a vision for British Columbia as a source of alternate electricity, power and alternate energy technology and projects. An Alternate Energy and Power Technology Task Force is expected to deliver an action plan in 2005 to realize these opportunities. Ocean energy has been clearly identified as a strategic opportunity for the region.

7.1 Present Barriers

- Lack of public awareness of the emerging RES in Canada
- Lack of Federal recognition of Ocean Energy as a renewable resource and creation of an Ocean Energy program within the relevant Energy and Economic Development departments
- Lack of federal funding sources available for R&D and demonstration projects within Canada as well as for collaboration with other countries
- Lack of a network of relevant research and academic institutions in Canada
- Lack of national demonstration test sites for enabling different technology development and addressing other technical issues, such as, reliability, integration, power quality, etc.
- Lack of streamlining of regulatory process for approval of ocean energy projects
- Lack of market incentives to spur investments in Ocean Energy technologies and projects, like investment credits, production tax credits, renewable energy credits, and the like
- Lack of utilities energy acquisition process as well as incentive for near-commercial ocean energy projects

8.0 ECONOMIC OPPORTUNITIES FOR CANADA

Canadian coastal waters (Pacific, Atlantic and Arctic) have tremendous opportunities for harnessing tidal current resources. Moreover, both the Atlantic and Pacific coasts and offshore have a huge amount of wave energy resources. Canadian tidal current and wave resources could be one and half times that of the UK's resources. Moreover, in the Pacific Northwest Economic Region (PNWER), ocean energy has the potential to play a major role in achieving a long-term goal of 20% of electricity generation from renewable for the region.

At present, globally the wave and tidal current energy sector remains a pre-commercial sector. There is no commercially leading wave or tidal current technology in the international and domestic market. At present, there are several Canadian ocean energy (wave and tidal current) technology developers trying to bring their technologies to the market place through further

technological development and demonstration. Canada has relatively strong ocean technology sectors in the Pacific and the Atlantic coasts associated with offshore, ship building, and aquaculture. These existing sectors could provide a regional advantage for enabling deployment of ocean energy conversion plants in Canada.

Potential Application of Ocean Energy for Canada could be as follows:

- Grid integrated primary renewable energy source: distributed generation
- Non-integrated: remote locations and offshore platforms, integrated with other renewable resources, such as wind and solar
- Desalination and aquaculture
- Hydrogen production
- Export of technology and expertise

Hence, considering the vast resource opportunity, the pre-commercial status of the technology sector, and already existing peripheral ocean technology industries, Canada has the opportunity to be a leader in the long run in harnessing this vast renewable resource in a cost-effective, reliable way as well as for export of the developed technologies and other peripherals expertise to other countries. This emerging ocean energy sector would also have synergy with the existing marine and offshore technology sectors along the Atlantic and Pacific Coasts.

9.0 CONCLUSIONS

- Canadian coasts and offshore regions offer an excellent ocean energy resource, and the potential for a primary renewable energy market is large.
- National and relevant Provincial energy strategies must include these emerging pre-commercial primary technologies for diversification of renewable energy resources.
- In the past decade, significant technological progress has been made for wave energy, resulting in several schemes at or near commercialization.
- Various technical, non-technical, as well as policy barriers remain to bring wave and tidal current energy conversion to its full potential.
- There is a need for a coordinated effort among local project and technology developers, universities, R&D organizations, marine industries, end users, municipal, provincial and federal government departments, and communities to enable the implementation of ocean energy technologies in Canada.

Please visit www.iea-oceans.org for various relevant links, reports, newsletters, and upcoming events.