A RENEWABLE ENERGY OPTION

OSMOTIC POWER

THE ENERGY **OF WATER**

WHAT IS OSMOTIC POWER?

OSMOTIC POWER IS THE ENERGY DERIVED FROM THE DIFFERENCE IN SALINITY BETWEEN SEAWATER AND FRESH WATER, WHICH IS HARNESSED USING A TURBINE TO GENERATE ELECTRICITY.

When fresh water is separated from seawater by a semipermeable membrane, the fresh water moves by osmosis through the membrane into the seawater, raising the pressure on the seawater side. This osmotic pressure, combined with the permeation flow rate, turns a hydraulic turbine, generating electricity.

OSMOTIC POTENTIAL

In Canada, the mouths of large rivers hold considerable long-term potential for osmotic development.

In Québec, Hydro-Québec's research institute estimated the exploitable osmotic potential for the 30 large rivers emptying into salt water to be 1,860 MW in 2011. Fourteen of them (1,060 MW) empty into the Golfe du Saint-Laurent (Gulf of St. Lawrence) and its estuary. The challenge today is to generate osmotic power at a cost that is competitive with other energy sources.

From February 2012 to December 2013, Statkraft and Hydro-Québec carried out a joint osmotic power R&D project. Their main goals were to develop techniques for pretreating water, assess the impact of water quality on membrane performance and evaluate the process's repercussions for sustainable development.

OUTPUT AND COSTS

It is currently estimated that once osmotic power can be commercialized, gross costs will be between 7¢ and 14¢/kWh. Net costs should be based on generating station efficiency estimates of 60% to 75%.

ADVANTAGES AND DISADVANTAGES

- Steady, predictable output.
- Adaptable for small or large generating stations.
- Scalable design (membranes can be added as required), making it possible to increase installed capacity.
- Generating sites near load centers, reducing power transmission needs.
- Good potential for power plant sites.
- Technology similar and complementary to that of hydroelectric power, with osmotic power plants able to be built on already-harnessed rivers.
- High risk of clogging and gradual degradation of semipermeable membranes, necessitating pressure-filtering pretreatment of fresh water and periodic membrane replacement (every 5 to 7 years).

Cover: Statkraft's prototype osmotic power plant in Norway

LEARN MORE

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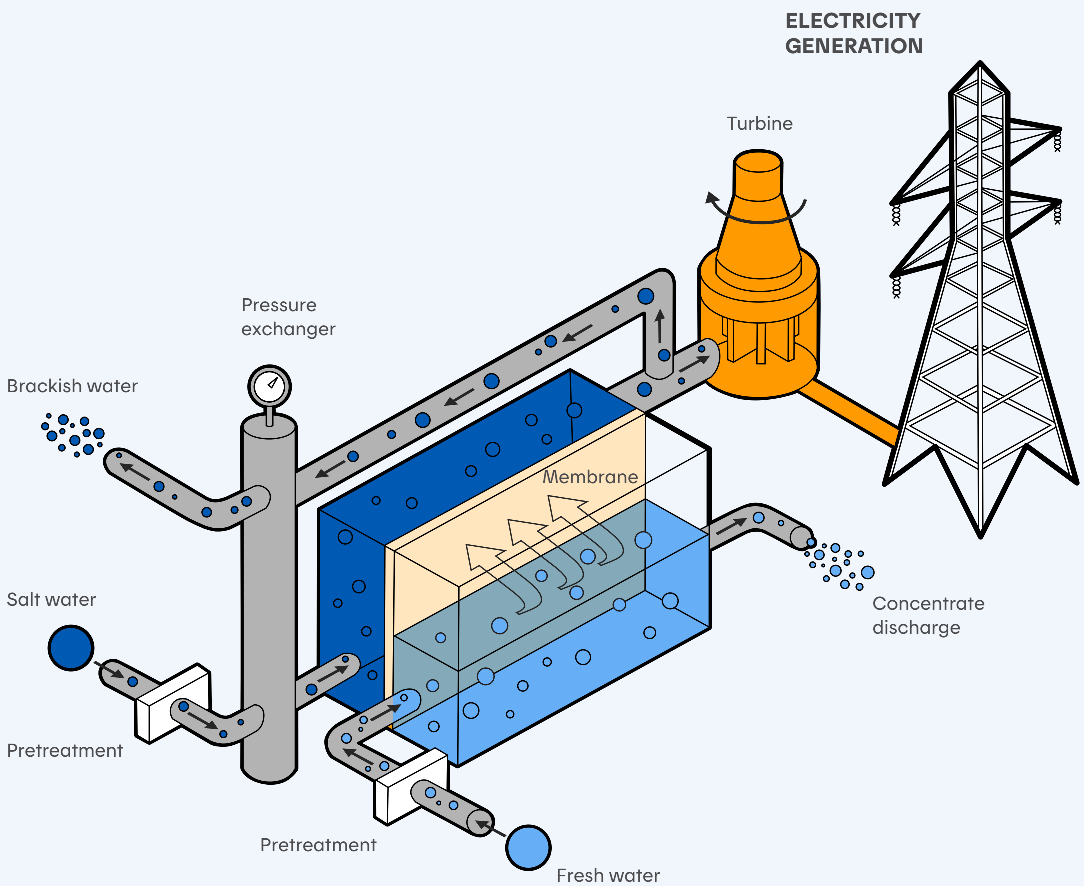
SUSTAINABILITY

At this time, little is known about the social and environmental impacts of osmotic generating station operations and maintenance. To some degree, they are similar to those of water purification plants that use membrane filtration, which are well documented:

- Modification of habitat and vegetation, with potential repercussions on aquatic fauna. Among other things, changes in salinity and regular large-volume discharges of brackish water may affect the natural mix of river water and seawater.
- Potential impact of cleaning products.
- Production of wet waste (sludge and used membranes).
- Impact on the host environment if a dike or basin has to be built to optimize a site's potential.
- Possible conflicts with shipping, fishing, etc.
- Zero greenhouse gas and atmospheric contaminant emissions during operation.
- Social acceptability difficult to achieve for power plants built on natural sites.
- Potentially significant visual pollution.

A SUSTAINABLE **RESSOURCE**



How an osmotic generating station works

When fresh water is separated from seawater by a semipermeable membrane, the fresh water moves by osmosis through the membrane into the seawater, raising the pressure on the seawater side. This is referred to as "osmotic pressure" and is used to drive a turbine.

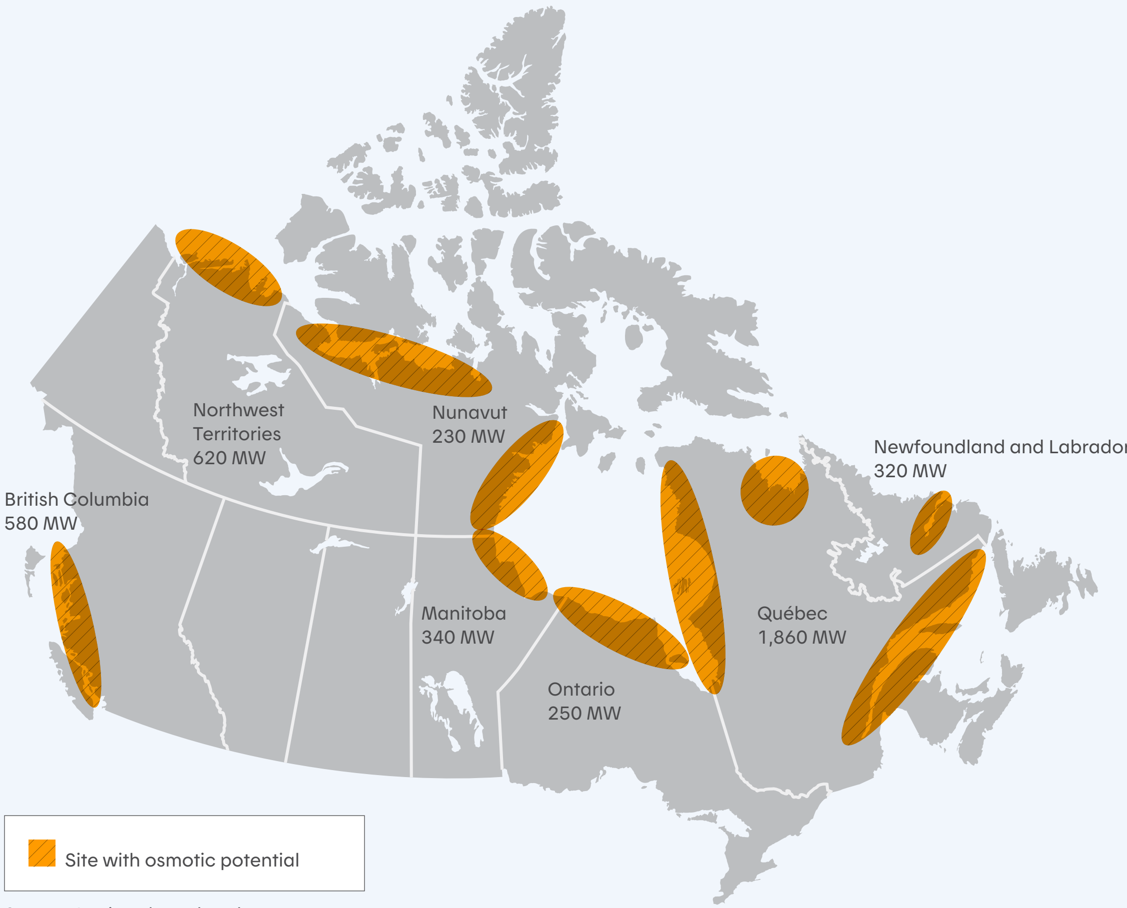
Osmotic pressure is the cornerstone of the energy-generating method conceived by American Sydney Loeb in the 1970s but developed and put into practice by Norway's Statkraft Group between 1997 and 2013.

An osmotic generating station has a limited number of components:

- A semipermeable membrane contained in modules
- Freshwater and seawater filters that optimize membrane performance
- A turbine that generates a driving force based on the osmotic pressure and permeation flow rate
- A pressure exchanger that pressurizes the seawater feed required to maintain high salinity levels downstream from the membrane

Canada's osmotic potential

SITES WITH OSMOTIC POTENTIAL



Source: Institut de recherche d'Hydro-Québec.

NB: Osmotic potential (MW) is calculated as 15% of the average flow of the indexed rivers.

The Statkraft prototype

Hurum osmotic generating station in the Oslo fjord, Norway

Statkraft installed its 4-kW prototype osmotic generating station in the Tofte paper mill in Hurum, Norway. The station used seawater from the fjord and fresh water from a nearby river circulating in two chambers separated by a semipermeable membrane. This type of technology is referred to as pressure-retarded osmosis, or PRO.

Research around the world

Since 2007, Deltares, the Dutch research centre on applied water, soil and subsurface technologies, has worked with businesses and other research centres to advance understanding of osmotic power. As part of the Netherlands government's ongoing Blue Energy demonstration project, efforts are being made to demonstrate the electricity-generating potential of pressure-retarded osmosis. In November 2014, a 50-kW generating station was commissioned in the Netherlands.

Wetsus, a centre of excellence for sustainable water technology, designs and develops reverse electrodialysis (RED) technology, also as part of the Blue Energy program. It works in partnership with KEMA and Redstack.

In conjunction with Yale University, the University of Connecticut has developed a closed-cycle osmotic heat engine that uses a H_2O-NH_3-CO_2 solution. First used to desalinate water by harnessing waste heat, this process, called Engineered Osmosis™, has been adapted to generate power. It has been commercialized by Oasys Water.

In 2009, the Tokyo Institute of Technology commissioned a prototype PRO generating station near the Uminonakamichi Nata Sea Water Desalination Center in Fukuoka, Japan. The goal was to extract energy from salinity gradients at the interface between concentrate from a seawater desalination plant and fresh water released from a waste water treatment plant. The prototype was part of the Mega-ton Water System project, which involved designing a seawater desalination plant with a capacity of one million cubic metres a day and was carried out between 2010 and 2013.

Climate change and air quality

In osmotic power, greenhouse gas and air contaminant emissions are produced solely during infrastructure manufacturing and installation. During the operations phase, osmotic generating stations do not produce any emissions.

Life cycle assessment

At this time, there are no available studies on the osmotic generating station life cycle. However, the environmental impacts of osmotic power are thought to be similar to those of other renewable energy sources. Except for biomass, all such sources all have one thing in common: there are no greenhouse gas or air contaminant emissions during the operations phase.

Ecosystems and biodiversity

Aquatic ecosystems in river mouths, deltas and estuaries are fragile. For that reason, it is important to have a solid grasp of the possible repercussions of building an osmotic generating station on the following:

- Topography and geomorphology (shoreline erosion, landslides, etc.)
- Sediment, riverbed and seabed properties (sediment displacement, increased turbidity, soil compaction)
- Water quality (chemical and wastewater spills)
- Hydrology (changes in flow rates and current directions, changes to fresh water/seawater mixing zones, etc.)
- Local aquatic animal and plant species
- Birds that feed in intertidal zone mudflats, which are rich in mollusks and microorganisms

Fresh water and seawater sampling and discharges of brackish water during plant operations could affect the profile of the fresh water plume at the mouth of a river. This could result in a degradation of the environment and possibly have an impact on the fauna and flora living in the affected area.

The ambient water temperature would rise because of the heat given off by the energy-generating process. However, this increase would be less than ½°C and would pose no danger to marine organisms.

Some chemicals used in pretreating water and cleaning membranes could become concentrated in the food chain, with repercussions for marine ecosystems. A well-known example is the anti-scale products released by desalination plants, a source of nutrients that stimulates primary production. As a result, they can lead to a proliferation of algae in environments that usually contain few such organisms.

Health and quality of life

There is no anticipated impact on human health or quality of life.

Land use

The presence of an osmotic generating station (the facility and associated power lines) has a visual impact on the landscape, just as a road or aqueduct would. When a station is built in an environment that has already been modified by human activity, the impact is mitigated.

An osmotic generating station may produce light pollution and obstruct the view of a picturesque landscape. To mitigate these nuisances, a suitable location must be found and the necessary infrastructure must be harmoniously integrated into the surroundings. Infrastructure can be built partly or entirely underground, considerably reducing the visual impact.

Operating an osmotic generating station at the mouth of a river could have an impact on fishing, recreational boating, water sports, coastal tourism, etc. Such operations could require the creation of exclusion zones where such activities are off-limits and may sometimes meet with opposition.

Regional economy

In Québec, the construction of osmotic generating stations would spur economic development in communities in the Côte-Nord, Baie-James, Baie d'Hudson and Baie d'Ungava regions. However, an in-depth evaluation of the social and environmental impacts on communities located at river mouths would be required. These impacts may include the following:

- Restrictions on commercial and recreational fishing
- Loss of community access to the site
- Use of a landfill or composting facilities for the disposal of sludge and used membranes

Social acceptability

A number of steps could enhance the social acceptability of osmotic generating projects. They include the following:

- Locating the generating station at the mouth of a river where a small community may already be found. This would eliminate or minimize the need to transmit electricity over significant distances, the scale of infrastructure required and the scope of associated activities.
- Integrating the facility harmoniously into the surrounding environment. This could involve building the powerhouse partly underground and adapting the building's architecture and colors to the surrounding environment.

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