A RENEWABLE ENERGY OPTION

HYDROKINETIC POWER

THE ENERGY **OF WATER**

WHAT IS HYDROKINETIC POWER?

HYDROKINETIC POWER IS THE ELECTRICITY GENERATED BY HARNESSING THE KINETIC ENERGY OF TIDES AND OCEAN OR RIVER CURRENTS USING A TURBINE.

Hydrokinetic turbines transform the water's energy into mechanical energy, just like wind turbines transform the wind's energy. That energy is then converted into electricity.

There are three main types of hydrokinetic turbines:

- Vertical-axis hydrokinetic turbines
- Horizontal-axis hydrokinetic turbines
- Oscillating-foil hydrokinetic turbines

CURRENT STATE OF KNOWLEDGE

The main countries developing this form of power are the United Kingdom, Ireland, France, Spain, China, Japan, South Korea, Canada and the U.S. The United Kingdom leads the way because it is able to harness substantial tide and wave energy in its waters. The European Marine Energy Centre, in Scotland, is very active in hydrokinetic R&D. In the United States, Alaska accounts for over 50% of the country's theoretical potential, making it the ideal state for demonstration and commercialization projects. Since 2011, a number of hydraulic turbine manufacturers have played an active role in developing hydrokinetic turbines. However, some of them (such as Siemens) were active in the field for only a short time.

Cover: Model of a horizontal-axis hydrokinetic turbine

Opposite: Installation of the RER Hydro turbine in the Fleuve Saint-Laurent (St. Lawrence River) near the Old Port of Montréal.

HYDROKINETIC POTENTIAL

The United Kingdom is one of the countries with the greatest theoretical potential, which is why many demonstration projects are carried out there. Although the country has also been home to a number of commercial projects since 2016, the industry is still in its infancy. Other countries with significant potential for hydrokinetic energy, regardless of the type, are the following:

- Canada, particularly in Baie d'Ungava (Ungava Bay), in Québec, and the Bay of Fundy, in Nova Scotia
- the United States, mainly in Alaska
- Argentina
- Russia, in the Kislaya Guba fjord
- France, in the Rance river region
- Australia
- New Zealand
- India
- South Korea, at Sihwa Lake

The global potential for tidal hydrokinetic power could be as much as 17,500 TWh/year (Stelzenmuller and Aliseda, 2014).[1] The tidal form offers the greatest potential worldwide.

Canada's hydrokinetic potential is estimated to be 42,000 MW for tidal currents and 15,000 MW for river currents. For Québec in particular, those potentials are roughly 4,288 MW (38 TWh/year) and 1,000 MW, respectively. Hydro-Québec has tested several hydrokinetic turbines in the Fleuve Saint-Laurent (St. Lawrence River).

OUTPUT AND COSTS

The cost per kilowatthour of electricity generation at a generating station operating at least 10 hydrokinetic turbines installed in a string is US$0.25 for ocean currents, US$0.41 for tidal currents and US$0.80 for river currents (Neary et al., 2014).

1. The potential output is calculated on the basis of the manufacturing, installation, operating and maintenance costs, as well as the annual generation potential. The $/kWh value is the minimum value for achieving the breakeven point.

ADVANTAGES AND DISADVANTAGES

Cross-flow turbines are generally less efficient than axial-flow turbines. However, they generate electricity regardless of the direction of water flow, a significant advantage when harnessing tidal currents (Laws and Ebbs, 2016).

Most R&D focuses on tidal currents rather than river and ocean currents. The reasons are simple and come down to operating costs and the quantity of energy available to be harnessed. For example, even though ocean turbines can produce large amounts of power, the generating costs per kilowatthour remain very high as a result of prohibitive installation and operating costs. For river currents, few sites have flow rates that are relatively consistent throughout the year and sufficient to generate electricity at an affordable cost (Laws and Ebbs, 2016).

In the pre-commercialization stage, initial demonstration tests generally involve a single turbine. Some projects seek to harness all the kinetic energy of a given flow using several turbines positioned in a string. Although essential from an environmental standpoint, the countless studies of sediment transport and the

The RER Hydro turbine had a planned capacity of 100 kW.

LEARN MORE

- Types of hydrokinetic turbines
- Canada's hydrokinetic potential
- An ideal site
- Climate change and air quality
- Life cycle assessment
- Ecosystems and biodiversity
- Health and quality of life
- Land use
- Regional economy
- Social acceptability

surrounding areas' flora and fauna delay project implementation. Moreover, it often takes considerable time, even years, to obtain the operating permits. For comparison purposes, hydrokinetic technologies are currently at the stage where wind power was about 15 years ago.

For hydrokinetic turbines harnessing tidal currents, 76% are horizontal-axis models, 12% are vertical-axis models, and 12% are other types (oscillating foil, Venturi, etc.). Three quarters of all R&D investments go to horizontal-axis turbines (auteur, date) .

As a rule, floating hydrokinetic turbines are easier to install and maintain than those sitting on the river bed or ocean floor (Laws and Ebbs, 2016).

SUSTAINABILITY

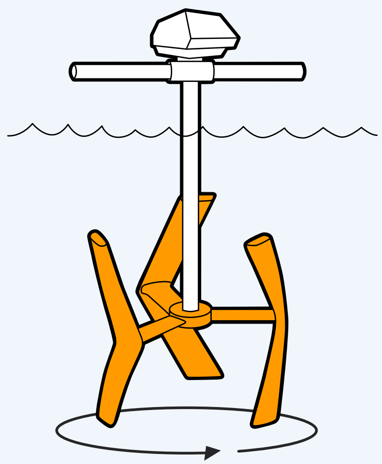
Since there are very few hydrokinetic turbines in operation at this time worldwide, information on sustainability issues is still incomplete. Here are the main potential impacts:

- Modifications to currents, wake effect and noise masking
- Modifications to sedimentary dynamics that may affect the estuary regime
- Modifications to substrates and the transportation and deposit of sediments: variable, depending on the type of anchor and underwater cables
- Habitat modification, including benthic organism habitat
- Modification of vegetation and possible impact on aquatic fauna
- Interference with the circulation and migration of certain aquatic species, particularly as a result of magnetic fields generated by electrical cables
- Risk of animal injury or death in the event of contact with moving machinery
- Noise pollution during construction and operation
- Possible conflicts with shipping, fishing, recreational boating, etc.
- Zero greenhouse gas and atmospheric contaminant emissions during operation
- Small environmental impact over the facility's life cycle

A SUSTAINABLE **RESSOURCE**

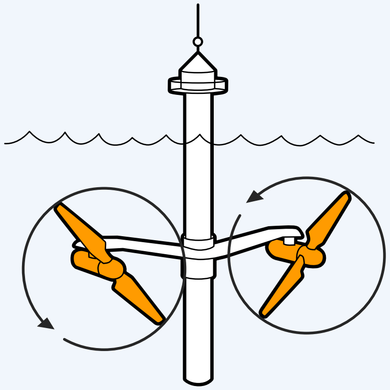
Types of hydrokinetic turbines

Hydrokinetic turbines transform the water's energy into mechanical energy, just like wind turbines transform the wind's energy. That energy is then converted into electricity. There are three main types of hydrokinetic turbines.



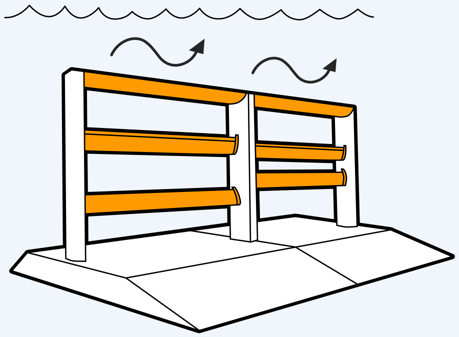
Vertical-axis hydrokinetic turbines

These turbines work very much like vertical-axis wind turbines. The force of the water turns the turbine, driving a generator that produces electricity. The entire assembly is attached to an anchored floating platform.



Horizontal-axis hydrokinetic turbines

These turbines work like horizontal-axis wind turbines. They can be fixed to the riverbed or seabed, to an anchored platform or to a rigid tower that sticks out of the water. Models that are fixed to the riverbed or seabed are the most common; although access is harder, they are more unobtrusive visually. At this time, they are the main hydrokinetic turbines in development around the world.



Oscillating-foil hydrokinetic turbines

These turbines imitate the movement of a fish's fins. A blade is attached to an arm that is moved up and down by the water. That movement drives a generator, which produces electricity.

Canada's hydrokinetic potential

TIDAL CURRENT POTENTIAL BY PROVINCE AND TERRITORY

PROVINCE OR TERRITORY	TIDAL CURRENT POTENTIAL (MW)	NUMBER OF SITES	MEAN POWER (MW)
Northwest Territories	35	4	9
British Columbia	4,015	89	45
Québec	4,288	16	268
Nunavut	30,567	34	899
New Brunswick	636	14	45
Prince Edward Island	33	4	8
Nova Scotia	2,122	15	141
Newfoundland and Labrador	544	15	36
Total	**42,240**	**191**	**221**

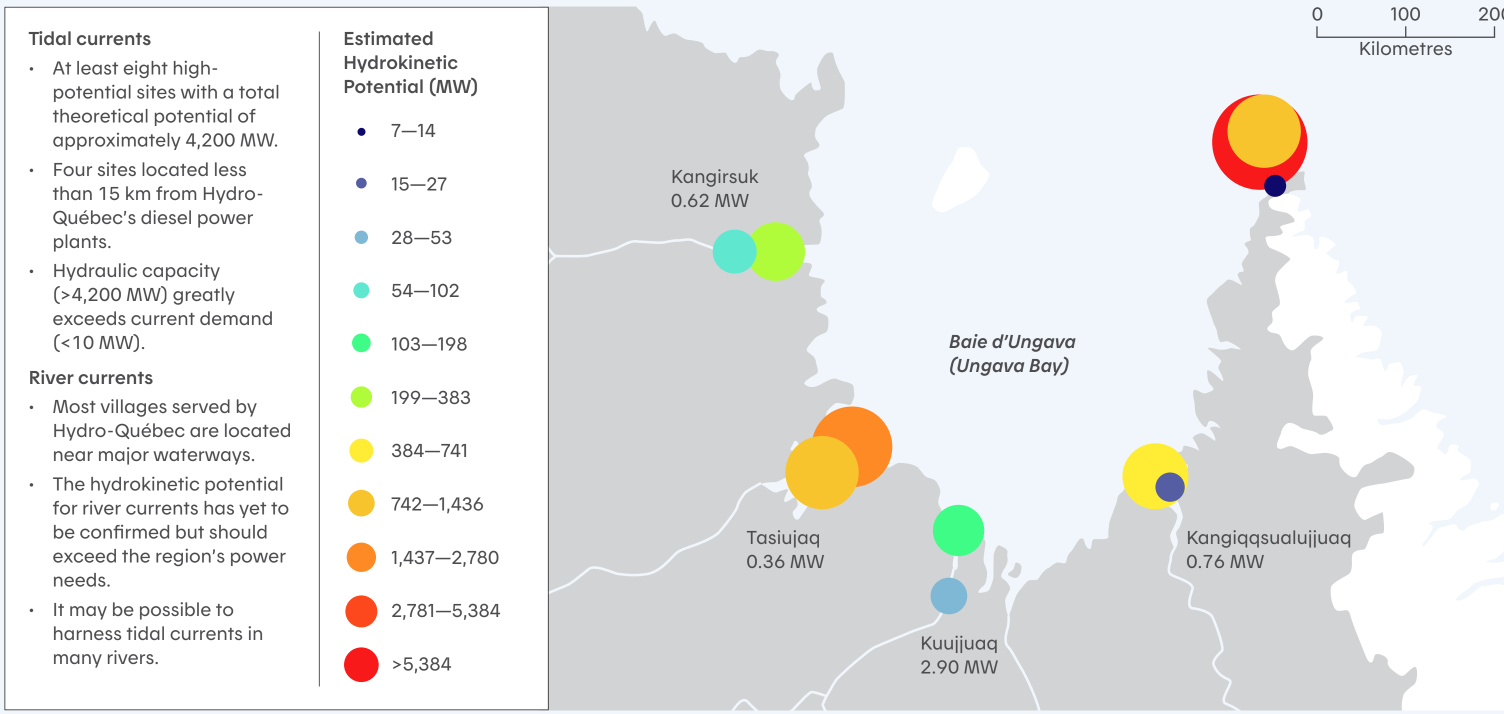
An ideal site

The Minas Passage in the Bay of Fundy is an ideal site for generating hydrokinetic power. The Fundy Ocean Research Centre for Energy (FORCE) operates a research centre there with the aim of installing Canada's first hydrokinetic turbines. For the project, EPRI has estimated a long-term gross generating cost of 3.9¢ to 4.6¢/kWh. However, it has since been shown that this figure greatly underestimates installation, operating and maintenance costs for the marine environment.

Climate change and air quality

In hydrokinetic power, greenhouse gas and air contaminant emissions are produced solely during infrastructure manufacturing and installation. During the operations phase, hydrokinetic turbines do not generate any emissions.

HYDROKINETIC POTENTIAL OF TIDAL AND RIVER CURRENTS IN THE BAIE D'UNGAVA REGION



Sources: CANMET-CHC and HQD

Life cycle assessment

There are very few studies on the life cycle of hydrokinetic turbines. The main environmental impacts of hydrokinetic power, including greenhouse gas emissions, are thought to be similar to those of hydroelectric and large onshore wind power developments. The materials used, along with manufacturing and transportation, are the most important factors in the analysis of this energy source's life cycle.

Ecosystems and biodiversity

Little is known about the environmental impacts of installing hydrokinetic turbines due to the lack of environmental monitoring for a sufficient number of projects. Here are some potential impacts:

- The turbines' creation of turbulence zones could prevent the deposit of sediment and even the development of aquatic flora. Ultimately, this could lead to the formation of dead zones or disturb relatively sedentary bottom-dwelling organisms (benthos). It could also lead to a greater number of nutrients remaining in suspension, stimulating the growth of plankton, which is fed on by certain fish species to the detriment of others.
- Capturing the energy of the current could lead to a decrease in the amount of energy needed to churn up nutrients and slow the residual current used by migratory species for traveling.
- During installation of anchors and foundations, the riverbed or seabed may be disturbed, resulting in a churning-up of material. The temporary impact would be slight if more-sensitive zones are avoided. Depending on the site, the benthic community would take from two to ten years to return to its initial state after work is completed.
- Fish, marine mammals and diving birds could collide with turbines. However, the risk of collision should be very low, because small and mid-sized fish would be repelled by the turbulence caused by the moving blades. Larger animals, which already tend to avoid boats and propellers, may have the same reflex when it comes to turbines. Some turbine models have blades that turn very slowly, minimizing risks considerably. However, the risk of collision for larger animals, although slight, may increase with rotor size.
- Maintenance products used to prevent the growth of algae and other organisms on the turbines could affect aquatic flora and fauna. An oil or chemical spill could pose a threat to the environment, but only to a limited extent, given the small amounts used.
- Depending on the materials used in the foundations, hydrokinetic turbines may have a reef effect, meaning that they could bring about a local increase in aquatic fauna populations and biomass and thereby encourage the establishment of coral.
- Because of their different frequencies, turbine operation noises and the sounds emitted by cetaceans would not interfere with one another. Moreover, when foundation piles are driven, marine mammals and fish would avoid the site and maintain a distance of up to 20 km. The impact of this noise on reproduction remains a concern, however, because certain fish species may take underwater channels while work is in progress. In some cases, noise could create a barrier effect for fauna.

- The electromagnetic fields generated by electric cables and connections may interfere with the electromagnetic fields used by fish such as sharks to locate their prey and navigate when migrating.
- The area marked off for a hydrokinetic turbine could serve as a reserve (a protected area similar to a nature reserve) for aquatic fauna, which may be beneficial for fish. However, it is not clear that smaller hydrokinetic facilities would have such an effect.

Health and quality of life

Being submerged, hydrokinetic turbines do not produce any audible noise at the surface. As a result, there is no anticipated impact on human health or quality of life.

Land use

As a rule, hydrokinetic facilities are largely unseen. Depending on the site, however, maintenance needs could require installing structures that stand above the waterline, creating a visual impact that, while minimal, would nevertheless be unsightly. Other infrastructure located on solid ground, such as transformer substations and electrical system connections, may have a more pronounced visual impact on the landscape.

Moreover, hydrokinetic complexes could affect activities such as the following:

- Fishing – A prohibition on fishing near hydrokinetic turbines could intensify the reserve effect, leading to an increase in fish populations around the site. However, there is little documentation on this hypothesis at this time.
- Water sports (sailing, diving, etc.) and coastal tourism
- Commercial and military navigation and recreational boating
- Archaeological work (heritage preservation) and off-limit zones (float plane base, dredging zones, etc.)
- Communications (submarine cables, microwave links)
- Aquaculture (shellfish culture, fish farming and algoculture)

Regional economy

Local economic benefits may be considerable if the turbine owner and installer, as well as the material used, hail from the host community. In addition, the infrastructure should be easy to maintain in the community, with local resources often available.

Social acceptability

A number of steps could enhance the social acceptability of hydrokinetic generating projects:

- Reducing the number of conflicts between users (see Land use)
- Working with users like professional fish harvesters to pinpoint the location of turbines and electric cables, among other things

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