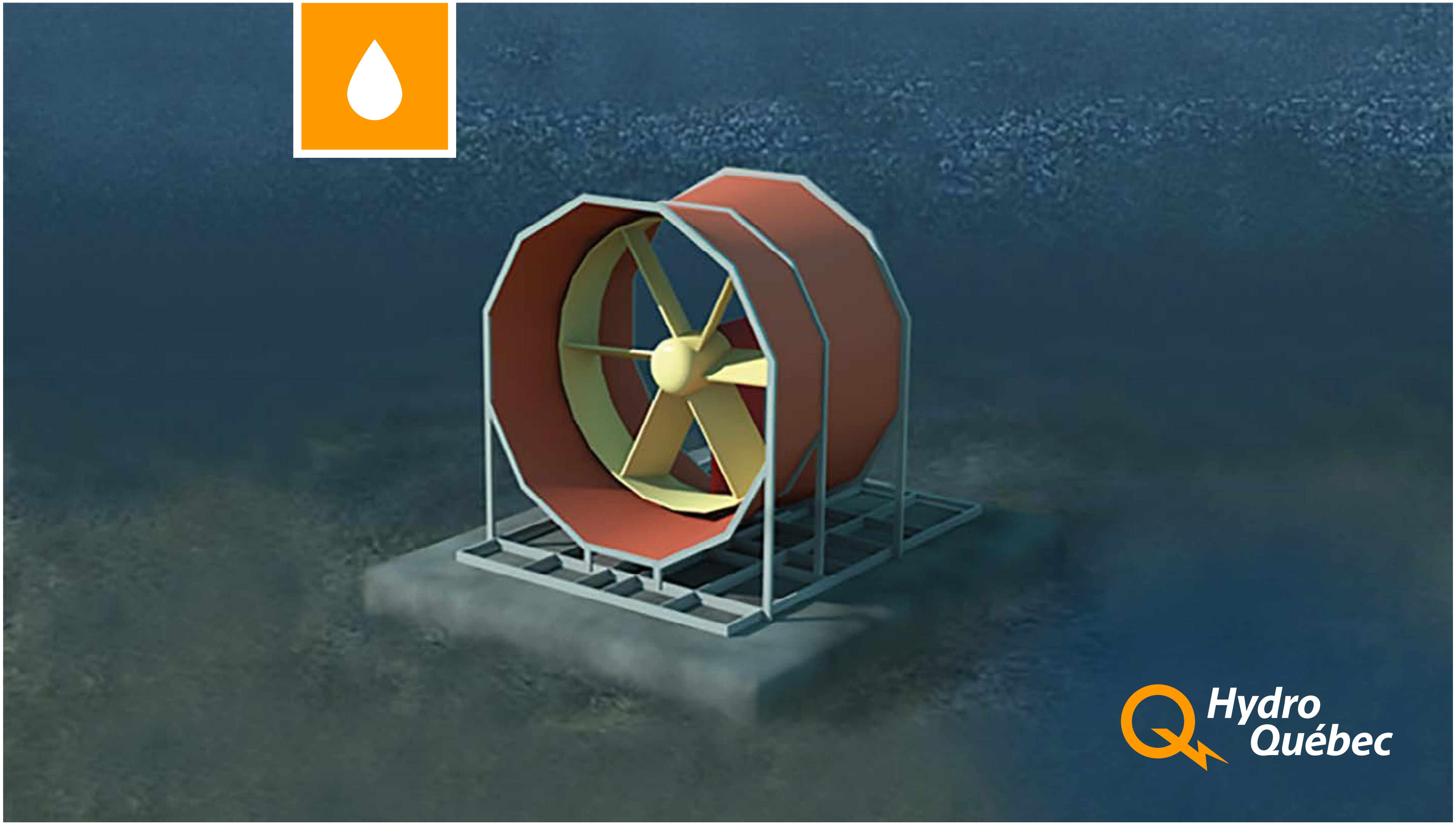
A RENEWABLE ENERGY OPTION

HYDROKINETIC POWER



THE ENERGY OF **WATER**

HYDROKINETIC POWER: THE KINETIC ENERGY OF TIDAL, OCEAN AND RIVER CURRENTS THAT IS CONVERTED INTO ELECTRICITY BY MEANS OF A TURBINE.

CURRENT STATE OF KNOWLEDGE

These days, ocean current turbines are currently seeing large-scale development because of their considerable potential, given the current speed and depth of water in the ocean. Their rated output can reach 1 MW or more. River current turbines, which operate at lesser depths, are necessarily smaller, and their rated output rarely exceeds 400 kW, even in very strong currents of 4.5 m/s.

In Québec, hydrokinetic power is in the experimental and pre-commercialization stage. In September 2010, a first industrial prototype was connected to the Hydro-Québec grid. The RER Hydro turbine was submerged in the Fleuve Saint-Laurent (St. Lawrence River) near the Old Port of Montréal. With a planned capacity of 100 kW, it fed electricity into the Hydro-Québec grid from 2010 to 2013.

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

In theory, the global hydrokinetic potential of ocean and tidal currents near shorelines is 7,800 TWh/year. That's roughly 40% of the world's total electricity output in 2013. The hydrokinetic potential of tidal currents alone accounts for 10% to 15% of the total. Current strength varies around the globe, depending primarily on local submarine morphology (bathymetry) near shorelines.

River current potential

Canada's potential is estimated to be 15,000 MW. In Québec, which has approximately 35% of the country's annual surface flow, the potential can be estimated at 5,250 MW on a proportional basis. Given the level of technical feasibility noted above (10%–15%), the province's deliverable potential would be between 525 and 788 MW.

Ocean current potential

- According to the National Research Council of Canada's Canadian Hydraulics Centre, Canada has 190 sites with a theoretical capacity exceeding 1 MW. The country's total potential is 42,000 MW.
- Québec's theoretical potential is estimated to be 4,288 MW (38 TWh/year), only a portion (10%–15%) of which would be technically feasible. Over 97% of the resource is near the Ungava Bay coast, a region far removed from Hydro-Québec's transmission system and major load centres.

OUTPUT AND COSTS

- **River turbines:** It is rare to find locations with all the right operating conditions (depth > 6 m and current speed > 2 m/s). Moreover, although their energy conversion efficiency is 30% to 40%, the maximum capture rate for a body of water's total kinetic energy is 15% because a significant quantity of water is diverted around the turbine. Once this energy source has reached maturity, the estimated cost of electricity generated by a river turbine is expected to be over 15¢/kWh.
- **Ocean turbines:** Energy conversion rates are identical to those of river turbines, but these turbines are usually much larger and generate power measured in megawatts. Since this source of energy is in its infancy, investment costs are currently high and vary depending on the developer. Once the energy source has reached maturity, the gross production cost will be over 11¢/kWh and start-up costs will vary from $3,000 to $5,000/kW, according to most developers. Estimated costs for ocean turbines are comparable to those of offshore wind turbines. Eventually, the cost of hydrokinetic power may come down slightly thanks to technological advances in underwater connections for wind turbines.

ADVANTAGES AND DISADVANTAGES

- In terms of output, more predictable than wind power
- No retaining structure, and few or no civil engineering works required
- Discreet or even invisible due to the turbine components' near-total immersion
- Winter operations possibly problematic: to optimize power output throughout the year, local variations in water levels have to be considered—a complex challenge

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

LEARN MORE

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

SUSTAINABLE DEVELOPMENT

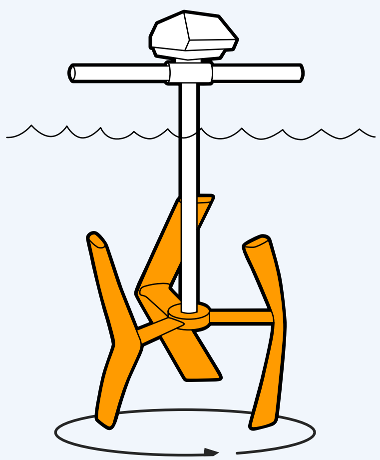
Since there are very few hydrokinetic turbines in operation at this time, information on sustainable development issues is still incomplete. Here are the main potential impacts:

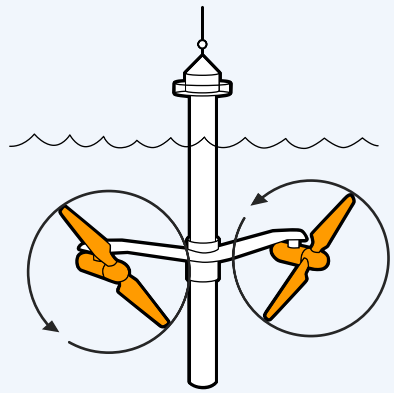
- Modifications to currents, wake effect and noise masking
- Modifications to sedimentary dynamics that may affect the estuary regime
- Modifications to substrates and the transportation and deposit of sediments: variable, depending on the type of anchor and underwater cables
- Habitat modification, 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

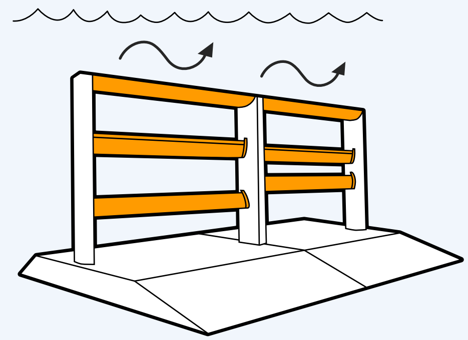
A **SUSTAINABLE** RESSOURCE

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**

Scenarios under consideration

In 2008, the U.S.-based Electric Power Research Institute (EPRI) and UK-based Carbon Trust estimated that the costs of offshore hydrokinetic power and offshore wind power would ultimately be similar and considerably higher than those of onshore wind power. In 2013 and 2014, the cost of electricity generated by commercial or pre-commercial offshore hydrokinetic turbines ranged from 33¢ to 66¢/kWh, depending on the model and the quality of the resource at the generating site. In terms of the area required, offshore hydrokinetic turbines have a greater energy density (at 30–50 MW/km^2) than onshore wind turbines (at 10–20 MW/km^2).

According to the Carbon Trust, offshore hydrokinetic turbines are just as efficient as onshore wind turbines for sites with superior energy density potential.

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, in 2015 and 2016. 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.

Other projects being carried out in the Bay of Fundy target a cost of roughly 15¢/kWh for an initial turbine installation, equivalent to the anticipated cost of the electricity generated by proposed hydroelectric power plants along the lower Churchill River.

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.

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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