A RENEWABLE ENERGY OPTION

SMALL WIND POWER

Hydro Québec

WIND POWER

SMALL WIND POWER:

KINETIC ENERGY OF THE WIND CONVERTED INTO ELECTRICITY BY SMALL WIND TURBINES

CURRENT STATE OF KNOWLEDGE

After a slowdown in 2013, wind power development continued to grow in 2014, with a record 52 GW of new installed capacity. By year end, global installed wind power capacity totalled 370 GW.

Large wind dominates the market, that is, wind turbines connected to electric power grids and operated by electric power companies. Today's development efforts focus on building wind turbines with a capacity of at least 2 MW. These large turbines are designed for integration into an electric power grid, a trend that will only intensify.

Small wind (<100 kW), on the other hand, is much less widespread, and the small wind turbines that produce it are owned by small power producers. Total installed small wind capacity in 2013 was 755 MW, produced by 870,000 turbines, a 12% increase over 2012. China is home to more than 41% of these facilities, the United States 30% and the United Kingdom 15%. Average installed capacity of these small wind turbines seems to be increasing, but not by much—from 0.66 kW in 2010 to 0.85 kW in 2013.

Supported by government strategies, the large wind industry has grown substantially over the last ten years. Small wind, on the other hand, is virtually non-existent in Québec.

Cover: Small horizontal-axis wind turbine.

Opposite: Light-colored wind turbine for a more discrete presence.

WIND POTENTIAL

Wind is a very plentiful resource and it is widely distributed throughout the world. Studies have demonstrated that wind could meet the global demand for power many times over. However, constraints of all sorts limit development possibilities, and market forecasts remain the best indicators of the real potential for wind power development.

In 2013, the International Energy Agency forecast that total installed wind capacity would reach 611 GW by 2020 and 1,684 GW by 2050. Forecasts for the year 2014 have already been surpassed. The Global Wind Energy Council's forecasts are even higher, with predictions of a total installed wind capacity of 801 GW in 2020 and 4,042 GW by 2050. As for small wind, the World Wind Energy Association predicts a total installed small wind capacity of 2 GW by 2020. In other words, expectations are that small wind's market share will remain marginal.

Wind conditions are favorable in Québec, making it one of the best regions in North America for development of wind power. However, despite the interest in small wind, its potential remains largely unharnessed because of unfavorable market conditions.

LEARN MORE

- Small wind categories
- Types of wind turbines
- Relative size
- Operating conditions
- Characteristics of small wind turbines
- Climate change and air quality
- Life cycle assessment
- Ecosystems and biodiversity
- Health and quality of life
- Land use
- Regional economy
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OUTPUT AND COSTS

Theoretically, wind turbines can convert to electricity up to 59% of the kinetic energy of the wind. In practice, however, the average is much lower. In this respect, small wind fares worse than large wind, as its development is never the object of major technological innovations or investments. Annual utilization factors average between 15 and 25%.

The cost of small wind generation is difficult to establish because the price of the equipment varies widely. In addition, it all depends on a key variable: the quality of the winds at the site of the facility. Furthermore, small wind turbines are not always certified, because of the limited financial capacity of many of the manufacturers. Without a basis for comparison, it is thus impossible at the time of purchase to make an informed technological choice and to obtain guarantees of the desired performance. The way things are now, it is very difficult to know the cost (¢/kWh) of the electricity produced by small wind. Given existing market conditions, there is no indication that small grid-connected wind facilities could become an economically viable option in Québec in the short term. Off grid, however, small wind is an excellent option for a wide variety of uses.

ADVANTAGES AND DISADVANTAGES

- Variable production (including times when little or no electricity is produced, especially if only one wind turbine is installed) that is difficult to predict with limited means
- Often cost effective in remote areas, far from the power grid
- In remote areas, can be used in tandem with other energy options, such as a diesel generator
- Energy independence: self-generation for residential, institutional or agricultural purposes or for small communities or small businesses

SUSTAINABLE DEVELOPMENT

- Zero interference with television and radar signals, and low electromagnetic wave emissions
- Zero emissions of greenhouse gases and air contaminants during operation
- Small environmental footprint over the life cycle
- Significant visual impact at some sites: successful integration with the environment is crucial
- Noise pollution varies depending on the type of equipment and the host environment
- Bird and bat fatality rates lower than with other types of infrastructure or attributable to domestic cats

A **SUSTAINABLE** RESSOURCE

SMALL WIND APPLICATIONS

	CATEGORY		
	BATTERY CHARGING AND SMALL SEASONAL LOADS	**RESIDENTIAL AND LARGE SEASONAL LOADS**	**COMMERCIAL, INSTITUTIONAL, FARMS AND OFF-GRID SYSTEMS**
Installed capacity	0-1 kW	1-50 kW	50-300 kW
Connection	Mainly off-grid	Grid-connected	Grid-connected, off-grid or connected to an off-grid
Applications	› Outdoor activities: sailing, recreational vehicles, etc. › Seasonal activities: small chalets, hunting and fishing camps, etc. › Rural or suburban homes (small loads) › Special uses: remote radar, telecommunications or weather stations, data acquisition instruments, etc. › Business parks and camps › Electric fences	› Grid-connected rural homes on large lots (generally > 1 acre) with wind- or battery-powered equipment or access to a net metering program › Second homes or outfitters supplied mainly by wind energy › Off-grid rural homes on large lots (generally > 1 acre)	› Grid-connected or off-grid large farms › Grid-connected or off-grid commercial or institutional buildings › Off-grid standalone systems in which wind is used to complement diesel energy or another energy source › Small off-grid farms where small wind complements a diesel generator, a photovoltaic system or both

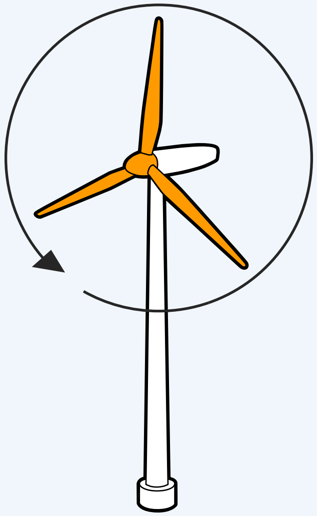
Classifying small wind

Criteria for classifying small wind (installed capacity and grid connection voltage) differ depending on the standard consulted—the international standard IEC 61400, provincial standards or the standards of wind energy associations such as the Canadian Wind Energy Association (CanWEA) and the American Wind Energy Association (AWEA).

According to CanWEA (2010), a small wind system is a system with a rated capacity of 1 to 300 kW. This is further broken down into three categories with a variety of applications that correspond to the realities of the Canadian market.

Types of wind turbines

There are two main types of wind turbines: the horizontal axis wind turbine, with blades that spin about an axis parallel to wind flow; and the vertical axis turbine, with its axis perpendicular to the wind. Size varies depending on turbine capacity and type.

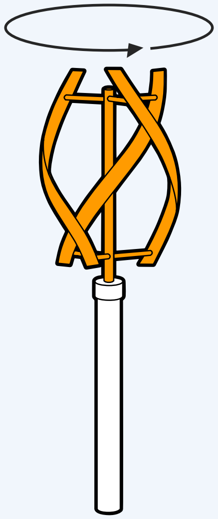


Horizontal axis wind turbines

In a horizontal axis wind turbine, the rotor drives a generator contained in a nacelle located at the top of the tower. The blades are rotated to face the wind by an active or passive "yawing" or orienting system.

The number of blades on a horizontal axis wind turbine varies. For example, the wind turbines used by US ranchers to pump water for cattle have a lot of blades. These turbines are generally very robust, with powerful driving torque, but they turn slowly and are not very efficient for generation of electricity.

Three-bladed wind turbines, on the other hand, with their yawing and blade-pitch control systems, are renowned for their efficiency. However, they require more monitoring and substantial investment to maximize their operation. Small wind performance is often not optimal, as the market does not justify the required investment. Though most small horizontal axis wind turbines are three-bladed, there is a wide variety of designs.

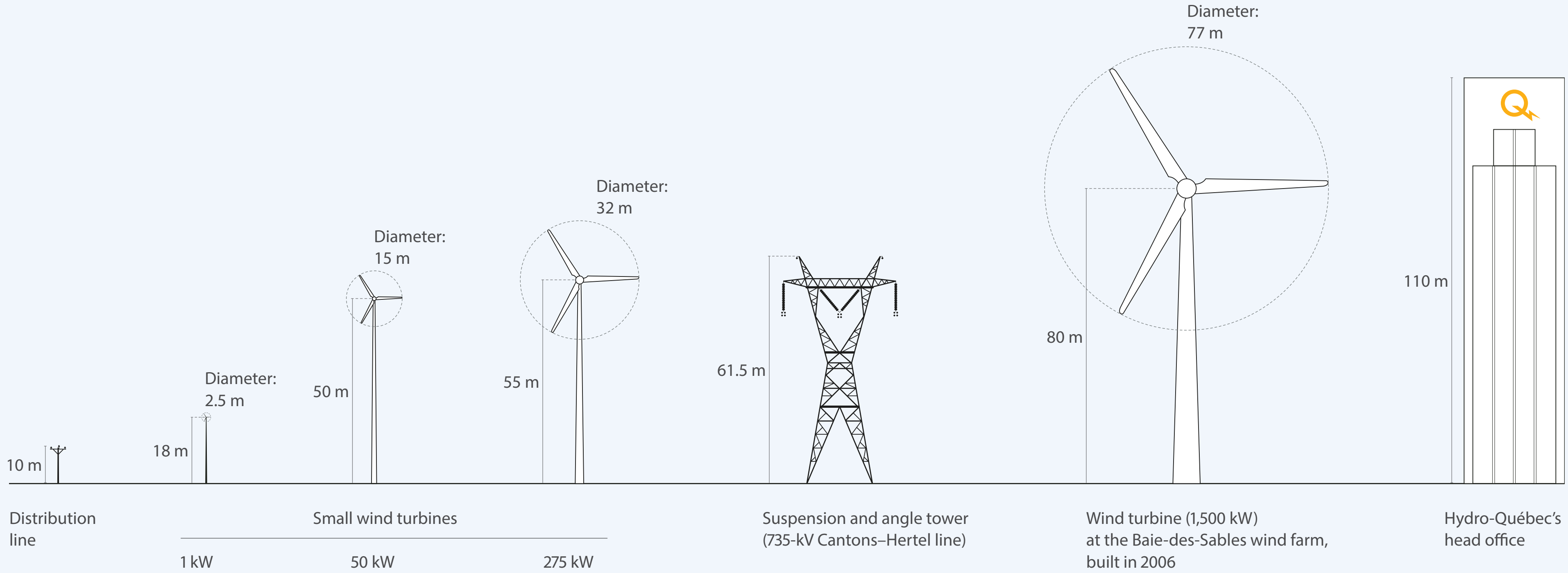


Vertical axis wind turbines

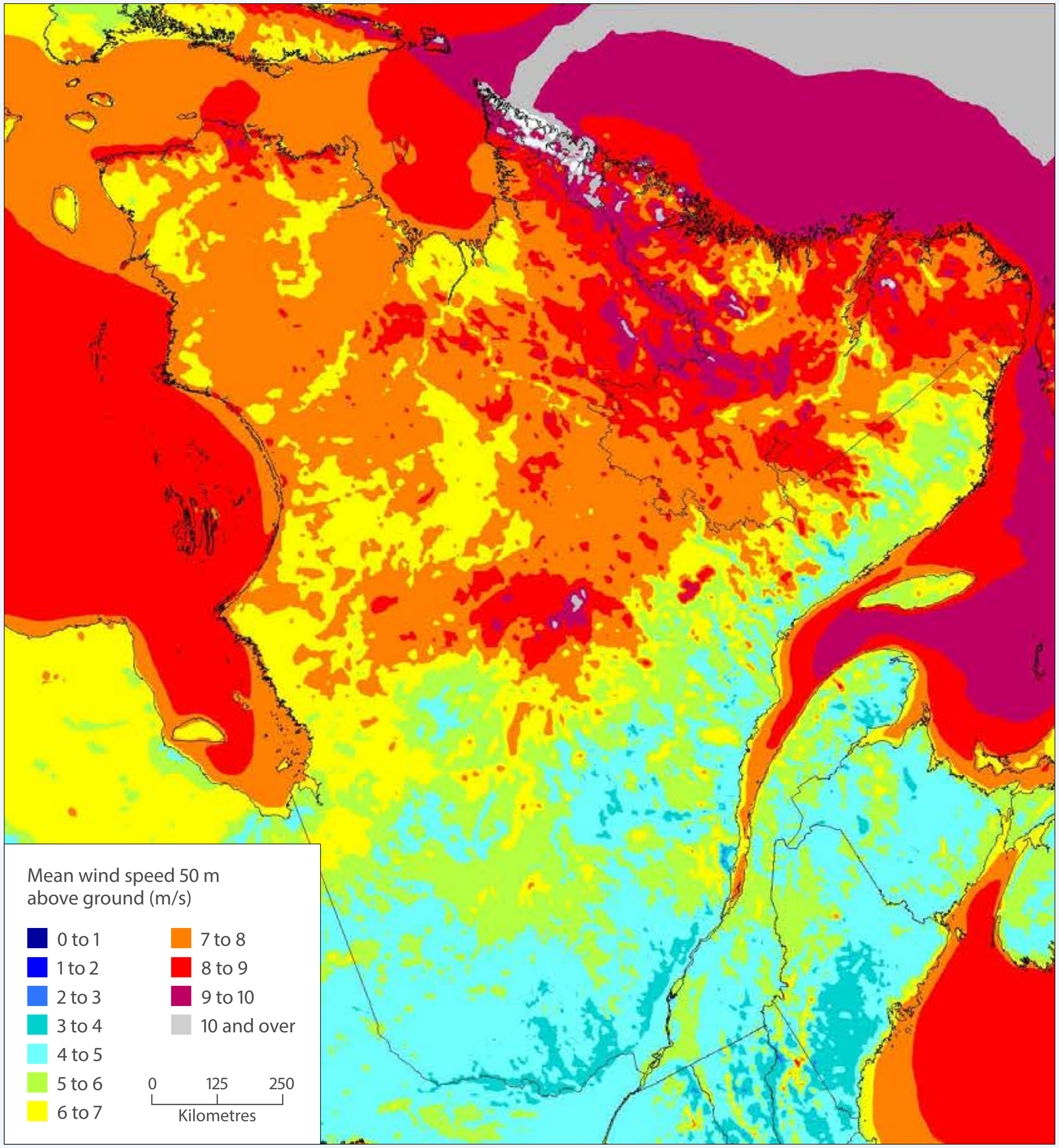
In a vertical axis wind turbine, the rotor drives a generator located at the base of the turbine. Omnidirectional, these wind turbines have no orienting system and generally have struts.

Some vertical axis wind turbines use aerodynamic lift force to propel the blades and turn the rotor. Their efficiency is similar to that of a horizontal axis wind turbine. Others use aerodynamic drag force to push the blades and make the rotor turn, but these turbine are less efficient in generating electricity.

RELATIVE SIZE



WIND MAP



Source: Canadian Wind Energy Atlas www.atlaseolien.ca/en/EU_50m_national.pdf

Operating conditions

For optimal small wind performance, careful siting of wind turbines is essential. It is crucial to know not only local wind potential but all environmental constraints with respect to energy capability, power-grid connection, equipment maintenance, safety and environmental protection. In general, open environments are best, a good distance from obstacles able to substantially affect wind and from peopled areas—where there are homes, for example.

The amount of electricity generated by a wind turbine is proportional to the cube of the wind speed, and wind speed increases exponentially with distance from the ground. This is why a wind turbine must be mounted as high as possible and sited where there is little ground clutter, so that air currents can circulate freely.

For logistical and economic reasons, however, self-generators often install their wind turbines close to the ground and near buildings, severely limiting their productivity. Others install the turbines on the roofs of buildings, without considering the vibrations generated, the loading capacity of the supporting structure, possible equipment failure, ice fall, reduced energy capability, etc.

Challenging winter weather (frost, freezing rain, wet snow) is another key factor to consider, as it can interfere with the operation of wind turbines, designed for a limited range of operating conditions. In some places (where there is salt spray, for example) components may deteriorate rapidly. In case of extreme events, wind turbines should be customized for the specific nature of the environment—by using low-temperature materials and lubricants, for example, an anti-corrosion finish. Such customization is costly, however, relative to the cost of installing a small wind turbine.

The service life of a wind turbine varies depending on the operating conditions—very turbulent winds, extreme cold, extreme dustiness, highly corrosive conditions, etc. A crane is generally required to put up or take down a small wind turbine of only a few kilowatts. The higher the installed capacity of the turbine, the more time-consuming and costly it is to repair, especially on rough terrain. Costs to communities in northern Québec are generally higher, mainly because of the remoteness of the sites, the availability and cost of the heavy equipment that is sometimes required and the operating and maintenance costs.

CHARACTERISTICS OF SMALL WIND

	CATEGORY		
	BATTERY RECHARGING AND SMALL SEASONAL LOADS	**RESIDENTIAL AND LARGE SEASONAL LOADS**	**COMMERCIAL, INSTIUTIONAL, FARMS AND OFF-GRID SYSTEMS**
Installed capacity	0-1 kW	1-50 kW	50-300 kW
Service life	10-15 years	20 years	25 years, generally with replacement of one major component after 15 years
Cost of a grid-connected wind turbine in the US (2014)	US28¢/kWh	US20¢/kWh	US16¢/kWh

Climate change and air quality

The manufacture and installation of small wind facilities results in emissions of greenhouse gases and air contaminants. The operation of small wind facilities, however, does not generate such emissions.

Life cycle assessment

Life cycle analysis shows that small wind generally has a slightly greater environmental impact than solar power of the same capacity or the electricity distributed by Hydro-Québec. Key elements in the life cycle analysis of small wind include wind conditions, production capacity and equipment manufacture.

Comparing Power Generation Options and Electricity Mixes and Small-Scale Distributed Electric Power Generation: full reports available in French only.

Ecosystems and biodiversity

The impacts of wind turbine operation on wildlife and biodiversity vary depending on the environment. As wind turbines are installed in environments already altered by human activity (urban areas and farmland), small wind turbines have little impact on ecosystems.

Many people are concerned about the risks to birds and bats. However, bird and bat fatality rates associated with wind turbines are lower than those associated with other infrastructure, such as buildings, or with domestic cats. To limit fatalities, a site far from bird migration corridors must be selected. Fatality rates appear to be lower with small wind than with large wind.

Health and quality of life

The noise generated by wind turbines depends on a number of factors: installed capacity, number of turbines, turbine characteristics and spacing, site topography, presence and nature of vegetation, ambient noise and wind speed and direction. Some turbines built with older technologies are noisier than recent models. No studies demonstrate that infrasound that may be emitted by wind turbines has any health effects.

On sunny days, a wind turbine casts a shadow on the ground, and this can be bothersome. For example, the shadow cast by turbine blades rotating near a home can have a stroboscopic effect, which is normally of short duration. With small wind, this effect is very weak.

A small wind turbine can be dangerous in the event of equipment breakage (given the speed of the rotor) or in winter weather (pieces of ice breaking off). However, the risks seem less than those posed by violent weather events, such as lighting or falling trees in a storm.

Small wind turbines do not create interference with television, radar or other signals. And they are not considered a major source of electromagnetic waves.

Land use

Wind turbines definitely have a visual impact on the landscape. To lessen this impact, light-colored materials are used. When planning small wind facilities, the following must be considered: the right-of-way; tower height and spacing relative to land use and neighbors; the growing number of tall facilities in the particular environment; and the tourist attraction or heritage value of the landscape. In all cases, it is best if a wind turbine does not appear prominent at a distance of more than two kilometres.

For harmonious integration of small wind turbines in their host environments, installation standards and applicable municipal bylaws must be respected.

Regional economy

It's costly to manufacture a small wind turbine, but the local economic spinoffs can be substantial if the owner, the installer and the materials that go into turbine manufacturing come from the host environment. This will also facilitate local maintenance of the equipment, as the necessary resources are likely to be available.

Though it is widely believed that the presence of wind turbines causes housing prices to drop, a US study has demonstrated that this is not the case.

Social acceptability

As with large wind, if small wind starts to spread throughout Québec, we must be ready to answer the concerns of communities affected—about impacts on the landscape, wildlife and health and about compensatory measures. Municipalities already have regulations for these types of projects and for management of their impacts.

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