A RENEWABLE ENERGY OPTION

SMALL WIND POWER

THE ENERGY **FROM THE WIND**

WHAT IS SMALL WIND POWER?

SMALL WIND POWER IS THE KINETIC ENERGY OF THE WIND CONVERTED INTO ELECTRICITY BY SMALL WIND TURBINES.

CURRENT STATE OF KNOWLEDGE

Wind power continues to make strides all around the world. In 2019, global installed capacity climbed by 59 GW, the second-highest yearly increase on record. Total capacity reached 622 GW by year-end (IRENA, 2020).

The market is dominated by large wind, meaning wind farms that are connected to electric power grids and operated by specialized power companies. Current development efforts focus on building wind turbines with a capacity of more than 2 MW. These large turbines are designed for integration into electric power grids, a growing trend. Offshore wind turbines have capacities of 5 MW or more.

Small wind (<100 kW), on the other hand, is much less widespread and remains the domain of small power producers. Total installed small wind capacity in 2018 was 1,727 MW, a 38% increase over 2013. China is home to more than 33% of these facilities, while the United States and United Kingdom account for about 9% (Moreira Chagas et al., 2020). The average installed capacity of small wind turbines is increasing, but remains low. It stood at 0.85 kW in 2013.

Supported by government strategies, Québec's large wind industry has grown substantially over the last 10 years. Small wind, on the other hand, is virtually non-existent in Québec.

WIND POTENTIAL

Wind is a very plentiful resource that is widely distributed throughout the world. Numerous studies have shown 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 2019, the International Energy Agency (IEA) forecast that total installed wind capacity would increase from 622 GW to 917 GW by 2024 according to its baseline scenario, and to nearly 1,000 GW under its accelerated scenario. For small wind, the World Wind Energy Association predicts a total installed capacity of approximately 2 GW by the end of 2020. In other words, wind's market share is expected to remain minimal.

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

Cover: Small horizontal-axis wind turbine.

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

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
- Social acceptability

OUTPUT AND COSTS

Theoretically, wind turbines can convert up to 59% of the wind's kinetic energy into electricity. In practice, however, the average is 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 determine because equipment prices vary widely. In addition, it depends on a key variable: the quality of the winds at the generating site. Furthermore, small wind turbines are not always certified because of the limited financial capacity of many manufacturers. Without a basis for comparison, it is therefore impossible at the time of purchase to make an informed technological choice and to obtain the desired performance guarantees. As things now stand, it is very difficult to determine the cost (¢/kWh) of the electricity produced by small wind, and existing market conditions do not provide any 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 a good option for a wide variety of uses.

ADVANTAGES AND DISADVANTAGES

- Often cost effective in remote areas, far from the power grid
- In remote areas, it can be used in tandem with other energy options, such as diesel generators
- Energy independence: self-generation for residential, institutional or agricultural purposes or for small communities or small businesses
- Output is variable and often low or nil, especially with a single wind turbine
- Output is difficult to predict with limited means

SUSTAINABILITY

- No interference with television and radar signals
- Low electromagnetic wave emissions
- Zero emissions of greenhouse gases and air pollution during operation
- Small environmental footprint over facility life cycle
- Significant visual impact at some sites: successful integration with the environment is important
- Noise pollution varies depending on the type of equipment and host environment
- Bird and bat fatalities

A SUSTAINABLE **RESSOURCE**

SMALL WIND APPLICATION

	CATEGORY		
	BATTERY CHARGING AND SMALL SEASONAL LOADS	**RESIDENTIAL AND LARGE SEASONAL LOADS**	**COMMERCIAL, INSTITUTIONAL, FARMS AND OFF-GRID SYSTEMS**
Installed capacity (kW)	Less than 1	1 to 49	50 to 300
Connection	Mainly off-grid	Grid-connected	Grid-connected, connected to an off-grid system or 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 (>1 acre) with wind- or battery-powered equipment, and locations with access to a net metering program › Second homes or outfitters supplied mainly by wind power › Off-grid rural homes on large lots (>1 acre)	› Grid-connected or off-grid large farms › Grid-connected or off-grid commercial or institutional buildings › Off-grid systems in which wind supplements diesel energy or another energy source › Small off-grid farms where small wind supplements a diesel generator, a photovoltaic solar system or both

Small wind categories

The criteria for classifying small wind projects (installed capacity and grid connection voltage) depend on the standard consulted—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).

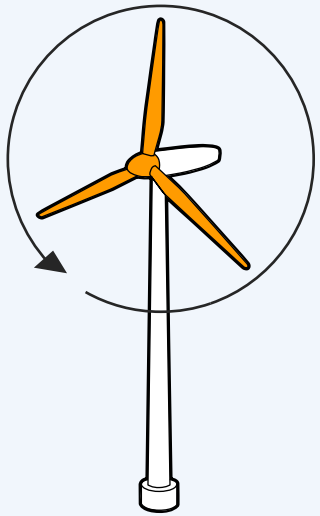
According to CanWEA (2010), small wind systems had a rated capacity of 1 to 300 kW. They are broken down into three categories with a variety of applications relevant to the Canadian market.

Types of wind turbines

There are two main types of wind turbines:

- horizontal-axis wind turbines, with an axis parallel to the wind direction
- vertical-axis wind turbines, with an axis perpendicular to the wind direction

Sizes and heights vary depending on turbine capacity and type.

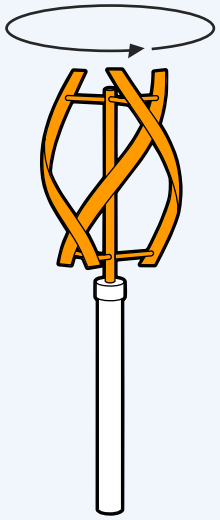


Horizontal-axis wind turbines

In a horizontal-axis wind turbine, the rotor drives a generator housed at the top of a tower, in a nacelle. The blades are positioned to capture the wind either by a "yawing" or orienting system, or by the wind itself.

The number of blades can vary. For example, the wind turbines used by US ranchers to pump water have many blades. These turbines are generally very sturdy, with powerful driving torque, but they spin slowly and are not very efficient for generating 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 investments to optimize their output. Small wind performance often suffers as a result, since the market does not justify the required investment. Though most small horizontal-axis wind turbines are three-bladed, there are a wide variety of designs.

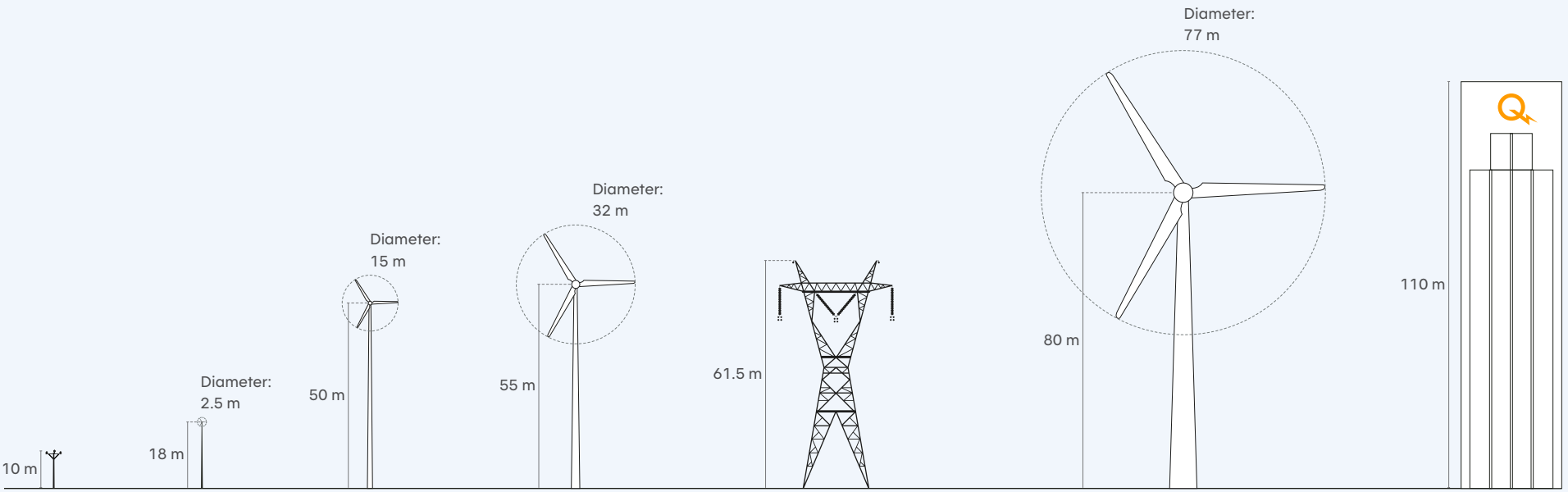


Vertical-axis wind turbines

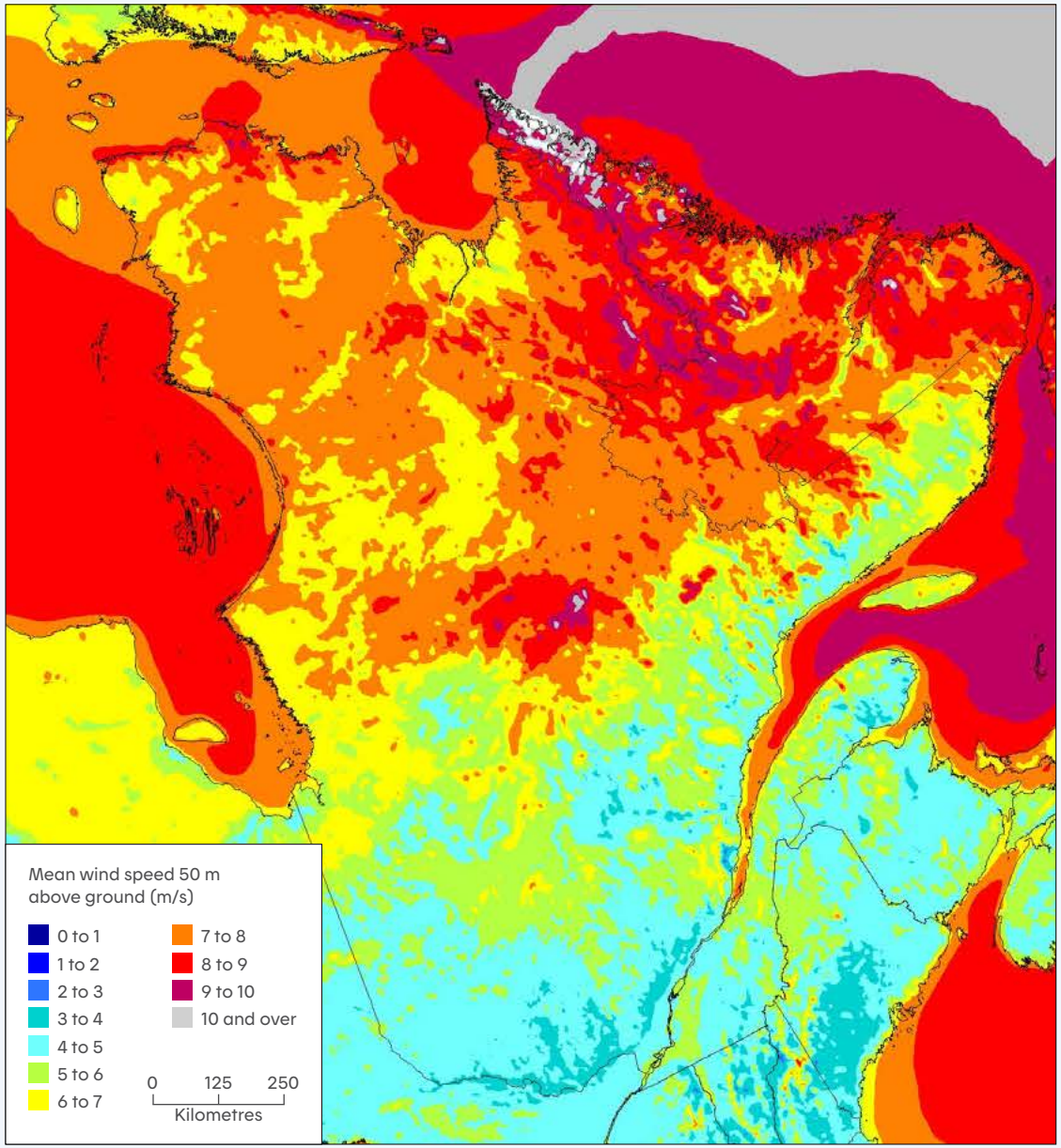
In a vertical-axis wind turbine, the rotor drives a generator located at the base of the turbine. These 360° wind turbines have no orienting system and are generally supported by guy wires.

Some vertical-axis wind turbines use aerodynamic lift to propel the blades and drive the rotor. Their efficiency is similar to that of horizontal-axis wind turbines. Others use aerodynamic drag to drive the rotor, but they are less efficient at generating electricity.

RELATIVE SIZE



WIND MAP



Source: Canadian Wind Energy Atlas http://www.atlaseolien.ca/maps-en.php and http://www.atlaseolien.ca/doc/EU_50m_national.pdf

Operating conditions

To optimize small wind performance, turbine sites must be chosen carefully. It is crucial to have a good understanding not only of local wind potential, but also of applicable constraints and requirements regarding energy capability, power-grid connection, equipment maintenance, safety and environmental protection. As a rule, open environments located a good distance from areas of human occupation (such as residential areas) and from obstacles that can substantially affect wind are best.

The quantity 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. For that reason, wind turbines must be mounted as high as possible and located in relatively clear areas so that air currents can circulate freely.

For financial and logistical reasons, however, self-generators often install their wind turbines close to the ground and near buildings, significantly limiting their productivity. Others install their turbines on the roofs of buildings, without due consideration for the vibrations produced, the load capacity of the supporting structure, the possibility of equipment failure, icefall, reduced energy capability, etc.

Challenging winter weather (such as frost, freezing rain and wet snow) is another important factor to consider because it can interfere with the operation of wind turbines, which are designed for a limited range of operating conditions. In some places (where there is salt spray, for example) components may deteriorate rapidly. In areas subject to extreme weather events, wind turbines should be customized for the specific environment—for example, by using low-temperature materials and lubricants or applying an anti-corrosion finish. Such modifications add considerable expense, however, to the cost of installing a small wind turbine.

The service life of a wind turbine varies depending on the operating conditions, including exposure to very strong winds, extreme cold, dust, 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, the more time-consuming and costly the turbine is to repair, especially on rough terrain. Costs are generally higher for communities in the Nord-du-Québec region, primarily because of the remoteness of the sites, the cost and availability of the heavy equipment required, and the operating and maintenance costs.

CHARACTERISTICS OF SMALL WIND TURBINES

	CATEGORY		
	BATTERY RECHARGING AND SMALL SEASONAL LOADS	**RESIDENTIAL AND LARGE SEASONAL LOADS**	**COMMERCIAL, INSTITUTIONAL, FARMS, AND OFF-GRID SYSTEMS**
Installed capacity (kW)	Less than 1	1 to 49	50 to 300
Service life (years)	10 to 15	20	25 (if the primary component is replaced after approx. 15 years)
Average generating cost (¢/kWh) for a grid-connected wind turbine in the US (2014)	28	20	16

Climate change and air quality

The manufacture and installation of small wind power facilities produce greenhouse gases and air pollution. There are no such emissions during operation.

Life cycle assessment

Life cycle analysis shows that small wind generally has a slightly larger environmental impact than the same amount of photovoltaic solar power or electricity distributed by Hydro-Québec. Key factors in the life cycle analysis of small wind include system service life, wind conditions, generating capability and equipment manufacturing.

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. Since 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 should be selected. Fatality rates appear to be lower for small wind than for large wind.

Health and quality of life

The noise generated by wind turbines depends on a number of factors: installed capacity, turbine characteristics, number of turbines and placement, site topography, presence and type of vegetation, ambient noise, and wind speed and direction. Some turbines built with older technologies are noisier than recent models. There are no studies showing that the infrasound that may be produced by wind turbines has any adverse 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 limited.

A small wind turbine can be dangerous—for example, in the event of equipment breakage caused by the rotor speed or pieces of ice breaking off in winter. However, the risks appear to be less severe than those posed by violent weather events, such as lightning or falling trees in a storm.

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

Land use

Wind turbines clearly have a visual impact on the landscape. To lessen that impact, light-colored materials should be used. When planning small wind projects, it is important to consider rights-of-way, tower height and spacing relative to land use and neighbors, the number of tall facilities in the surrounding environment, and the tourism or heritage value of the landscape. Wind turbines should never be prominently visible at distances of more than two kilometres.

To ensure small wind turbines integrate harmoniously into their host environments, all applicable installation standards and municipal bylaws must be respected.

Regional economy

While it is costly to manufacture a small wind turbine, the local economic spinoffs can be substantial if the owner, the installer and the materials that go into turbine manufacturing come from the host community. In addition, equipment maintenance can easily be carried out by local sources, which are likely to be available.

It is widely believed that the presence of wind turbines causes housing prices to drop, but a US study has shown that this is not the case.

Social acceptability

As with large wind, if small wind becomes more common in Québec, we must be ready to address the concerns of host communities regarding impacts on the landscape, wildlife and health as well as compensatory measures. Municipalities already have bylaws in place to regulate these types of projects and manage their impacts.

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