The image of modern wind turbines has finally crept into the public consciousness. At long last, the Dutch windmill and the Great Plains wind-powered water pump have been supplanted by something sleek and futuristic: a tower that is 10, 20, even 30 stories tall with a rotor comprising two or three thin blades.

But the image does not fully account for the reality. Anyone not directly involved in the wind turbine industry might be forgiven for thinking that all wind turbines face into the wind, with a horizontal axis of rotation. But there is another, less familiar, type of wind turbine, with a vertical axis. It has origins going back much farther in history than the common propeller-type, horizontal-axis turbines.

Horizontal-axis wind turbine technology is likely to peak in the next few years, largely because of the limitations of the blades and their effects on the machine. The power output of a wind turbine is directly related to the swept area of its blades. The larger the diameter, the more power it is capable of extracting from the wind. The larger the blades, the stronger they need to be to withstand the higher levels of centrifugal force and stresses caused by their additional size and weight. The extra mass for strength adds further to the structure’s weight and so compounds the problem.

Furthermore, the bending moments across the swept area of the blade can vary considerably, with a possible difference of several meters a second in wind speeds between the top and the bottom of the blade’s rotation. This all adds up to a substantial increase in fatigue, not only in the blade structure, but also in the machine’s hub, bearing, driveshaft, and support tower. With a 31-meter (100-foot) blade weighing around 4.5 tons and a 54-meter (177-foot) blade weighing about 13 tons, the weight of the blade for a horizontal-axis turbine is not proportional to the size and power rating of the machine.

Along the Vertical Axis

I believe that horizontal-axis machines will prove unable to meet the growing demand for larger, more cost-effective wind turbines—particularly with the recent trend to build on more costly, but more productive sites offshore. We need to look back in history and concentrate on further developing the simpler vertical-axis designs. Without the same structural limitations, vertical-axis turbines can be produced much larger and so take advantage of significant economies of scale.

Vertical-axis windmills are not some futuristic concept. There is evidence of their existence dating back as far as the
seventh century B.C. However, all the different designs can be categorized into two basic principles—pushed by the wind or pulled by the wind. The push principle is the oldest by far, originally consisting of two or more vertical sails or paddles that are blown around their vertical axis by the wind. A Persian vertical-axis design dating from about 200 B.C. channeled the wind with walls towards the paddles of the machine, which were then pushed around by the wind.

Finnish engineer S.J. Savonius substantially updated this basic concept in 1922, when he replaced the sails with cups or half oil drums with their open sides opposing each other and fixed to a central vertical shaft. The cup in line with the wind flow catches the wind and so turns the shaft 180 degrees, bringing the opposing cup into the flow. This cup then repeats the process, causing the shaft to rotate a further 180 degrees and complete a full rotation. There have been numerous variations on the same theme, some with additional cups or drums on the same shaft and some with their cups or drums set at different angles or positions on the shaft.

In recent years, this principle has undergone further significant development, noticeably by two Finnish companies, Shield Oy and Windside Production Ltd. Both of these companies produce small helical or fluted bladed machines, where the drums of the Savonius rotor have evolved into spiral-formed vanes. These machines are ideal for use on buoys, offshore platforms, buildings, signs, and posts, where small amounts of power are required. They are often used to charge battery backup systems or to supplement low-voltage photovoltaic solar panels, used to power signs, public telephones, low-voltage transmitters, and other small systems.

These devices benefit from being extremely rugged, quiet, and omnidirectional. They are more efficient than the conventional Savonius machine and exert less stress on their support structures. There are ambitions to scale up these types of machines to megawatt size, but research and development funding for vertical-axis turbines is scarce.

The other option, using the pull principle, shows more promise. In 1931, a French engineer, George J. M. Darrieus, invented a new type of vertical-axis wind turbine. The Darrieus type of machine consists of two or more flexible airfoil blades, which are attached to both the top and bottom of a rotating vertical shaft, giving the machine the appearance of a giant egg whisk. The wind blowing over the airfoil contours of the blade creates aerodynamic lift, which actually pulls along the blades.

Although nowhere near as much research has been carried out on these types of machines as on horizontal-axis turbines, both the United States and Canada had large research programs working on the Darrieus design in the 1970s and ’80s. This work culminated with the building of a 4.2 MW machine called Eole C in Cap Chat, Quebec.

There were also a number of commercial wind farms built in the United States using the Darrieus machine design, most of which were built by a company called The FloWind Corp. On the whole, the machines proved to be quite efficient and reliable.

However, there was a problem with fatigue on the blades, which were designed to flex, thus allowing for the extra centrifugal forces in high winds and at high rotation speeds. Unfortunately, this flexing led to premature fatigue of the blade material, and led to a number of blade failures. Furthermore, the bottom fixing of the blade is only a few feet above ground level. While this makes the generating plant easily accessible, the machines cannot take advantage of the higher wind speeds that a tall support tower offers.

**VARYING THE GEOMETRY**

Some researchers began to look at improving the Darrieus machine by rationalizing the geometry of the blades. One such group, led by Peter Musgrove at Reading University in England, hit upon straightening out the blades of a Darrieus-type wind turbine. The hope was that this would overcome the blade fatigue problem and improve performance. But at the time, it was believed that the simplest solution—an H-shape blade configuration—could over-speed and become dangerously unstable under excessively windy conditions. To avoid this, Musgrove proposed that a reefing mechanism be incorporated in the machine’s design, thus allowing the blades to be feathered in high winds. These earlier machines with feathering blades were known as “variable geometry” vertical-axis wind turbines.

There were a number of such designs, which had different ways of feathering their blades. During the late 1970s, English research, which included wind tunnel tests and the building of a few prototype machines in the 40 kW to 100 kW range, culminated in a final design: a reefing arrowhead blade for a large 25-meter, 130 kW-rated machine. The machine, known as the VAWT 450, was built at Carmarthen Bay in South Wales and was funded by the U.K. Department of Trade and Industry.

The research carried out on the VAWT 450 established that the elaborate mechanisms used to feather the blades were unnecessary. Instead, the drag/stall effect created by a blade leaving the wind flow would limit the speed at which a connected blade in the wind flow could move forward. This led the way to a fixed straight-bladed design—the H-rotor.

The developer of the Model 450, VAWT Ltd., went on...
to build a larger straight-bladed machine at Carmarthen Bay, called the VAWT 850, which had a rated power output of 500 kW. The VAWT 850 was extensively tested and proved that the simplicity of the basic H-blade configuration was practical. The machine was not without its problems. Extremely high levels of torque created by the rotation of the blades led to the failure of the power transmission arrangement on several occasions. The machine’s main generating plant was housed in the center of the support tower and the blades’ rotation was transferred via gearboxes and a torque tube. The high stresses exerted on the torque tube caused it to fail and proved difficult to overcome. The catastrophic failure of the main bearing, coupled with the withdrawal of government research funding, signed the machine’s death warrant. The VAWT 450 and VAWT 850 machines at Carmarthen Bay were both demolished at the turn of the century, in accordance with the original plan.

Advances in horizontal-axis turbines in Europe have slowed of late, and governments and industry have begun to reassess the promise of vertical-axis designs. Several vertical-axis designs are currently available, among them a number of build-it-yourself kits for conventional Savonius rotor wind turbines. Mostly designed around two halves of an oil drum, these are all small machines and are used mainly for battery charging or for irrigation pumping.

The two Finnish companies, Shield Oy and Windside Production, produce the fluted type of Savonius machine. The machines are simple, rugged, and reliable, but at present come only with outputs up to 25 kW. They are ideal for isolated areas with severe weather, in applications such as sign or buoy lighting, telecommunications, and backup power supply. Both companies plan to expand their range of machines and develop the principle into megawatt scale devices.

RADICALLY DIFFERENT MACHINES

There are at least two new research and development programs into the design of Darrieus machines, planned in the United States and Canada. These new machines will use the latest composite materials to maximize the fatigue resistance of their blades and prolong the overall useful life of the machine. The Canadian Chinook 2000, manufactured by Sustainable Energy Technologies, is the only large Darrieus type of machine currently in production, to my knowledge. It is rated at 250 kW and the manufacturer claims that it can be erected in remote
areas without the use of a crane.

The H-rotor design has not disappeared, either. There are two companies currently producing H-rotor type turbines—Heidelberg Motor GmbH of Germany and Solwind Ltd. of New Zealand. Both companies offer a range of machines rated up to 300 kW. The machines use a low-speed magnetic levitation alternator, which means that the turbines have only one moving part, making them extremely quiet and reliable.

There are numerous patents issued for all sorts of variations of vertical-axis turbines, but the only radically different machines to reach the market are the Turby wind turbine from the Netherlands and the Ropatec from Italy. The Turby machine is designed to be used in the built environment, on posts, roofs of buildings, fixed to walls, etc. It uses an all-in-one bearing hub/alternator, has a peak output of 3 kW, and is rated at 2.5 kW. The Ropatec hybrid design is a mix of H-rotor and Savonius. These machines are very robust and are suitable for isolated mountainous regions or for offshore platforms.

Eurowind Developments Ltd. is planning to introduce a modular turbine that will have power outputs ranging from 1 MW to more than 10 MW. The concept combines the most up-to-date but proven wind turbine, shipbuilding, and construction technology. The modular design is intended for a number of applications, ranging from offshore to various land installations, in wind farms or standing alone.

The machine can be mounted on certain types of industrial structures, such as chimneys and other similar tall structures, without inhibiting their normal use. Rather than having a wind turbine that exerts a specific load onto its support tower, Eurowind's modular system is designed to tailor the wind turbine—and, therefore, its load—to the known reserve strength of the host structure. The interface between structure and turbine would then absorb the most significant stress loads produced by the rotation of the machine's blades, to prevent excessive stressing of the structure.

When built, the machine will be the world's first megawatt-class, H-rotor, vertical-axis turbine and will be the only modularly constructed wind turbine. These features will enable machines of varying proportions and power outputs to be assembled using standardized components, with a considerable cost savings. Tall masonry structures of the sort that are suitable for the Eurowind turbines were once a common sight in industrial cities and towns across the globe. However, as technology changed, many of these structures became obsolete. Indeed, the structures have lent their name to an entire subset of old-fashioned, low-tech businesses: smokestack industries.

With luck, we will soon be able to turn that sobriquet on its head. Smokestacks (and other remnants of the industrial past) will provide clean, green, and efficient energy by sprouting high-tech devices capable of wringing energy from the flowing wind.