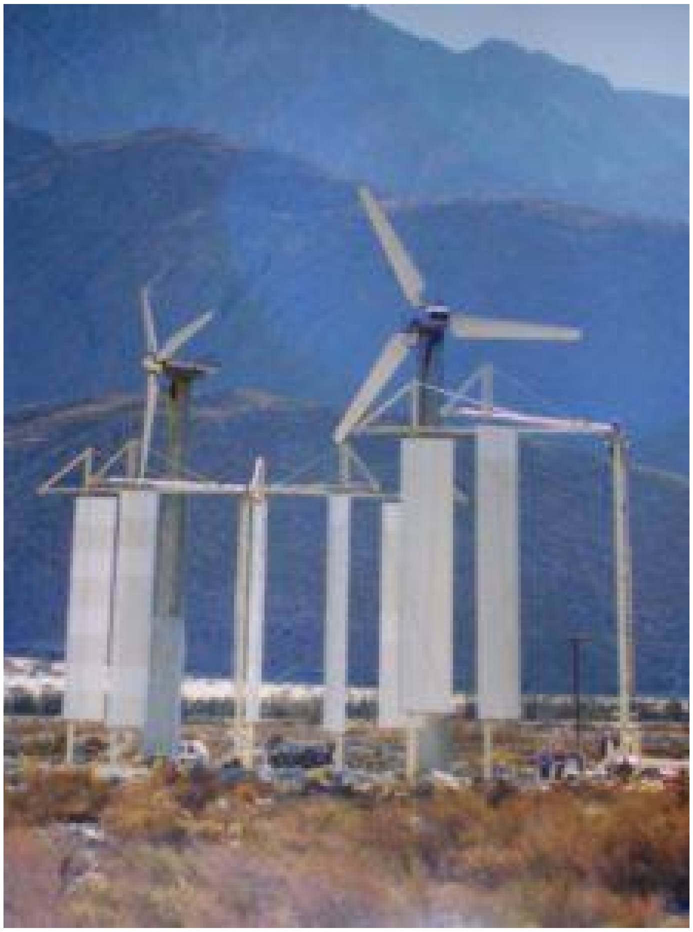
Wind Harvest Company Prototype - Windstar 1066

Whitewater, CA | Installed 1991, Removed 1994

The Model 1066 was designed to be built in Harbin, China. However, the first prototype was made in Los Angeles with an all-Chinese crew from Harbin.

Model 1066 Specifications	
Rated power (kW)	50
Rotor Diameter (m)	41.2
Swept Area (m²)	325
Blade length (m)	9.2
Blade cord (m)	.89
Stator cord (m)	2.3
Number of modules	1
Number of blades per module	4
Number of stators	5
Rotor RPM	40
Solidity	33%
Generator	Induction
Voltage	460
# of phases	3
Generator RPM	1810



The turbine consisted of the following features:

- Single module, larger than the multi-module Model 530.

- Blades 3 times longer than the Model 530 with about twice the cord.
- Blade aspect ratio was 10.2.

A single large rotor has fewer blade/blade arm connections and a lower blade arm fairing reference area to blade reference area ratio. A higher overall averaged lift to drag ratio is expected for the 1066, which results in higher energy output.

Data from the same power curve monitor used to measure the Model 530 power curve produced the Model 1066 Cpe vs. Vbl/Vw curve.

Aerodynamic efficiency of the 1066 blades paid off at higher tip speed ratios beginning on the 'stall' side of the maxima extending to the high blade to Vbl/Vw intercept. The Model 1066 blades were made from fiberglass and had mid-blade cable restraints that were set to engage at rotor speeds below generation speed. They were needed to restrain flexure, that is, to keep the blades from striking the columns. The turbine started in winds between 8 and 10 mph. Our tests were done at a rotor speed of about 35 rpm, equivalent to 70 rpm for the Model 530. The blades weighed about 500lbs each.

Structurally, the frame had 5 columns (stators) and top column support arms meeting at the turbine center where a bearing supported the main shaft. The columns were stabilized with guy cables between adjacent columns stretching from near the top of one to the bottom of the adjacent one and visa versa. The columns were mounted on concrete footing that anchored the guy cables as well. The top cable connection was located more than 3 ft. out radially from the top of the column to an extension of the column arm. This was required to provide sufficient clearance of the guy cables for the rotating stators. The stators were designed to rotate on the column, that is, to weather cock in high winds thus reducing wind loading in high winds. (It seamed like a good idea at the time.) The performance curve was measured with the fairings in a fixed design position of radial alignment of the stator cord.

There were many problems encountered with the rotatable stators so in the end we concluded that it was not a good design approach. However, they did provide some interesting visual evidence of the turbine flow field. A very strong stationary vortex was created by the rotor that interacts with the wind flow field resulting in a combined flow field acting on the rotor blades to produce torque. This observation eventually helped in leading us to the Coupled Vortex patent. Calculating turbine torque/power by vector adding wind velocity to blade tangential velocity yielded results that were way lower than measured performanc (Angle of attack of the blade being the angle between the resultant and tangential velocity vectors with pitch angle being zero.) The assumption made in the calculations of uniform undisturbed wind flow provides resultant wind velocity vectors higher than resultant velocity vectors of the combined flow field. Therefore, dynamic pressures in the uniform flow field are higher than in the combined flow field.

Consequently, the higher measured torque/power must derive from a more optimal flow direction field relative to the blades and not from augmented resultant velocity. That is, in reality, flow attachment to the blade must occur over a much longer arc of the circular path of the blade. With flow attachment, the blade experiences high lift to drag ratios producing high net positive torque. Flow separation from the upper side of the blade (stall) results in low lift /drag and low or negative torque.

The fixed stators must provide flow direction alteration, which produced the augmented performance.

Another important visual observation was made of main shaft movement in moderate to high wind conditions. Cyclic shaft bending was occurring equaling 4 cycles per rotor revolution or each time a blade passed through a sector of one revolution. The blade cables, as mentioned before, support a portion of blade centrifugal force, which is a constant for each blade because rotor speed is constant. Aerodynamic forces acting on the blades are not constant. They vary depending on wind speed and blade angle of attack. On the downwind semi-circular side, normal force on the blade acts radially outward. The reverse is true of the blade moving along the upwind semi-circular side; normal force acts radially inward. Aerodynamic normal force adds to centrifugal force to the blade on its downwind swing and subtracts on its upwind swing. The wind was coming out of the west. The shaft was bending in a plane 45 deg. to the wind vector. Looking down on the rotor, the plane was angled 45 deg. to the south on the upwind side and to the north on the down wind side of the rotor centerline. The rotor was rotating clockwise viewed from above. The aerodynamic forces were deflecting the shaft in a 45 deg. north easterly direction from its original straight position. We concluded that the blade on its upswing into the wind in the southwestern quadrant experiences centrifugal force unloading and in the northeast quadrant blade loading. Blade unloading forces are much higher than the loading ones because relative velocity on the upswing side is much higher than on the downswing side. This effect is exaggerated with increasing wind speed.

Overhang of frame cable attachments were a problem, allowing for frame flexure opening up the possibility for fatigue failure. We only operated the turbine in low to moderate winds for data gathering purposes and vowed never to employ overhang again into a design.

Our testing operation suddenly ended when the leaseholder sold the lease to another wind farm developer who ordered all turbines removed from the property within a relatively short period of time. We removed the turbines and stored them on another property owned by Wintec. the people we leased the Whitewater site from. They would eventually find another site for us. Meanwhile, operations temporarily ceased for Wind Harvest.