'Some form of natural power resource is essential for bluewater cruising'

Above: We decided the best way to test the turbines was to mount them on poles in an open field. The outputs were logged using a Datacell and laptops

THE BIG TEST: WIND TURBINES

NOT ENOUGH POWER TO RUN ALL YOUR FANCY ELECTRONICS? DUNCAN KENT TESTS NINE DIFFERENT WIND TURBINES TO SEE WHICH PERFORMS BEST

Power, or the lack of it, is fast becoming quite a problem for the modern cruising yachtsman. Never before have sailing yachts carried so much electrical and electronic equipment – all of which requires a huge amount of electrical power to support when away from the grid. For this reason, pretty much every yacht equipped for long offshore passages or extended stays away from a marina will have some means of charging its battery banks using the power of nature wherever possible.

The humble marine wind generator has been around for a few decades now and has been refined to a high degree of efficiency. Better alternators, CAD-designed blades and smart charge controllers all play their part in making the latest devices extremely powerful, yet as quiet as possible.

How many blades?

The most noticeable difference between the batch of turbines we tested were the number and size of their blades. There appear to be two schools of thought here, with some having six blades and others just three.

Since the introduction of the more powerful types a decade or so ago, three-bladed models have become increasingly popular. One of the first, the Air-X, worked very well as a generator, especially in high winds, but was so noisy that neighbouring boats would either complain loudly, or move away as far as possible in an anchorage. Not the best way to meet friendly cruising folk!

Since then three blades are still found on many of the high-power turbines, but the latest CAD blade design technology has helped considerably in reducing noise levels while retaining their electrical 'grunt'. Saying that, they are still louder than the shorter, multi-bladed models in a strong blow.

Installation

If you plan to install the turbine yourself, we would suggest you ask your supplier what items will be necessary for your installation. Otherwise you'll probably spend

THANKS TO
Merlin Equipment Ltd **(merlinequipment.com)**, for supplying the batteries, cables and Datacell power logging equipment. Orolia Ltd **(www.mcmurdolimited.com)** for supplying the Davis Instruments Vantage Vue weather station and WeatherLink logging software

more time and money having special poles fabricated and drilled to suit.

For the common three-pole tower mount at the pushpit of a sailing vessel, the turbine will require a central mast (through which the cables are usually fed) that is strong enough to support the weight of the unit and of thick enough section to resist the side forces produced under strong wind conditions. This pole must also be long enough to place the blades well above the crew's heads – usually 3m (10ft) or more above deck level.

Alternative mounting positions are at the head of a mizzen mast on a ketch. Masthead mounting on a sloop, however, is not recommended for two reasons: top hamper (too much weight at the top of the mast) and distance from the batteries (too high a voltage drop).

Having had several turbines on my last three yachts I would also recommend you try to include some form of 'damping' between the support poles and the deck, to reduce vibration noise below decks. A heavy rubber insulator between the main support tower and deck will make a world of difference if you have to leave it running while you're asleep!

Right: The turbines were mounted on scaffold poles attached to well buried fence posts
Below: The Vantage Vue sytem enabled us to record wind speed every second

One other thing – we suggest you put a dab of Loctite or similar on all the bolts during assembly, to prevent them vibrating loose. Alternatively, use Nyloc nuts.

Charge control

At some point your battery bank is likely to become fully charged and any further energy being produced by the wind turbine is no longer required. In very high winds this excess charge current could well damage your batteries, unless they are protected in some way.

Turbine manufacturers do this in several different ways, but they all offer some sort of charge controller or regulator, usually as an optional extra. For example, the regulator for the Ampair 300 came in a large blue metal box containing a complex arrangement of useful instruments including an on/off switch, circuit breakers and volt and ampere meters. The Silentwind also has a smart box with on/off controls and an LCD display for performance monitoring.

But the simplest form of electrical regulation is for the skipper to simply switch the turbine off when no further charge is needed. Most turbines can be electrically 'braked' by shorting their output wires immediately after the turbine and before any external regulation equipment. A high-current (50A-plus) two-pole switch is used for this and a suitable model can normally be ordered as an optional extra. This action usually slows the blade rotation to a crawl, making it safer to approach and tie off if necessary.

Charge controllers or regulators usually come as an optional extra

You could make this function automatic by including a voltage-sensitive on/off switch that would trigger at a pre-set threshold. One turbine – the Air Breeze – has this system built-in.

It isn't an ideal long-term or storm-force wind solution, however, so the most commonly used regulatory system for wind turbines is, in fact, the use of 'dump' load resistors. These are very high-load (usually around 500W/0.5 ohm) and burn off unwanted charge by heating up to dissipate the energy. While this method works well, it isn't ideal in hot climates where any additional heat below decks is not appreciated.

Another alternative is to automatically switch the turbine's output to open circuit – ie. disconnect it from the batteries. While this won't damage the turbine, it will often allow the blades to rotate even faster than normal, resulting in increased noise levels.

Storm conditions

Leaving a turbine spinning in seriously high winds (Force 8 or higher) risks it flying apart, burning out the cabling or destroying your battery banks. Some models incorporate a thermal cut-out, which disconnects the generator from the batteries if it overheats. Others have feathering blades that either flatten out or turn edge into the wind to regulate turning speed at wind speeds over 25 knots or so. This is a simple and effective method of slowing the blades, although it can be noisy unless you also turn the turbine out of the wind and tie the blades off.

Be sure that when you tie a line around the blade and mounting pole, that it can't simply drop down with the force of the wind or movement of the blade as it tries to rotate, or you'll be back to square one very quickly! Taking a turn or two around the blade itself before tying it off will help.

Costs

In addition to the cost of the turbine, you will need to consider the cost of installation hardware, charge control, cabling and instrumentation. All of these can add a considerable amount to the bill – often equivalent to the cost of the turbine itself!

Do not be tempted to save on cable size, however, as this will adversely affect the performance of your turbine and present a fire risk.

CABLING

SIZE – The size (or, more accurately, the cross-sectional area) of the cable required depends on the distance from the turbine to the batteries. Too small a cable will increase resistance and voltage drop and can also create a fire risk at full power. Consult your turbine supplier for specific recommendations, but the table below gives a rough guide to safe cable sizes.

WIRE SIZES (CROSS-SECTIONAL AREA IN MM²)

Max current	Total circuit distance (turbine to battery and back)			
	<9m	<15m	<18m	<21m
10A	2.5mm²	4mm²	6mm²	6mm²
20A	4mm²	6mm²	10mm²	10mm²
30A	6mm²	10mm²	16mm²	16mm²
40A	10mm²	16mm²	16mm²	25mm²

TYPE – Always use tinned, multi-stranded marine cable to ensure best performance. Solid conductors should not be used as they are more likely to break if subjected to continuous movement.
PROTECTION – All suppliers will recommend the minimum fuse or circuit breaker size required for the output cabling. It must always be installed before any other device is encountered.
RECTIFIER – Wind turbines initially produce AC current, but most convert this to DC with a rectifier inside the housing. This leaves just a positive and negative wire to be connected. A few have three AC wires, which have to be connected through a diode rectifier to convert to DC. This can be installed separately or fitted inside the charge controller. AC cabling suffers less voltage drop than DC.

TEST CONDITIONS

After consulting the manufacturers and other experts we decided to set the turbines up on a north–south line across an open field, 400m clear of any tall trees or buildings. This is considered a better option than roof-top testing or wind-tunnel testing, which fails to replicate the gusty nature of the wind. The results capture the turbines' performance in typical UK weather conditions. Readings taken when the wind blew within 10° of the N–S line were ignored in case any turbine was adversely affected by turbulence from another.

We wired the turbines to a test rig containing 90Ah AGM batteries and a Merlin Datacell power-logger that measured amps, volts , amp-hours and state of charge of each battery/turbine combination over two, 24-hour test periods in winds varying from 3 knots to 24 knots. Unusually for October, there were no gales during our tests, so we couldn't log performance in very high winds.

Wind measurements were logged using a Davis Instruments' Vantage Vue weather station with accompanying WeatherLink PC logging software.

No form of regulation or charge control was used during the trials. The batteries were kept at 50 per cent charge at all times so that the turbines would perform to their maximum.

TESTED

AEROGEN 6

from £1,363

This is the largest and most powerful turbine in the Aerogen family, which includes the Aerogen 2 and 4, as well as the Aquagen wind/water combi unit. It is quite a bulky unit that is probably best suited to larger cruising yachts of 45ft-plus LOA, although if it's bang for buck that you are looking for this model is one of the more powerful of the units tested, despite rotating quietly at moderately low speeds.

Output is 12V or 24V DC and a dump load regulator is optional. The charge controller has two outputs, separated by diodes, to feed into two different batteries, one of which (engine start battery usually) will be given charge priority.

Assembly

Assembly requires you to set the pitch of the blades by aligning the marks on the blades with those on the hub. We weren't keen on the way it attached to the pole as there is a risk of chafing the wires as you slide the clamp over the yaw shaft.

Trials

This is a very quiet model that starts to spin in the slightest of breeze and produces decent power from 7 knots upwards.

The multiple blades and large tail fin manage to keep the turbine from yawing wildly in the gusts, which helps to improve its overall efficiency.

Apparently the output is able to rise steadily all the way up to 40 knots of wind, when the specs say it will produce an impressive 28A.

VERDICT: ★★★★☆
Quiet when running and quick to start and output is well above average at all wind speeds. It looks very well made, though wouldn't win any prizes for styling.
▶ www.xylemflowcontrol.com

AMPAIR PACIFIC 300 from £1,594

Ampair has been making turbines for over 25 years and now produces 100W, 300W and 600W models in 12V, 24V and 48V guises.

The Pacific 300 model utilises 12 rare-earth (neodymium) permanent magnets on its shaft rotor, with a three-phase AC stator, all installed within a tough and waterproof, powder-coated cast aluminium casing with sealed shaft bearings.

The unit delivers AC power, which is converted to DC by fitting the rectifier supplied as standard, or using the one built into the optional charge controller. The latter is a large, 10kg blue metal box that contains a rectifier, dump load resistor, parking switch, circuit breakers, ammeter and voltmeter. It also has an input for solar panel(s).

Storm protection is provided by a PowerFurl system, which flattens the pitch of the blades in winds over 25 knots, using a centrifugal governor.

Assembly

This model proved a little tricky to assemble as the pre-drilled mounting holes in the blades needed reaming out to size before the bolts would fit.

Trials

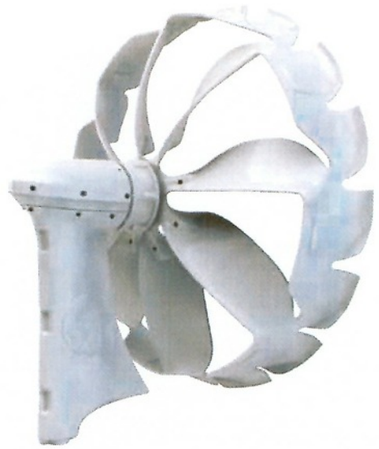
The Pacific 300's steep blade root pitch allows it to start rotating at around 6 knots – slightly better than some three-bladed models. The stiffness of the GRP blades reduced flexing at high speed, with a positive effect on noise.

Its performance in our trials was as reliable as expected, with outputs close to the manufacturer's stated performance in all winds.

VERDICT: ★★★★☆

Ruggedly built, solid technology and above average performance. Although not particularly competitively priced the Ampair is a genuine fit-and-forget device, thanks to its blade furling system, and the whole unit has been designed to withstand the corrosive marine environment.

▶ **www.ampair.com**



ANAKATA A-007 from £1,000

Brand new to the market, this strange-looking beast appears to have been designed primarily for the terrestrial turbine market.

The blades are joined with an outer ring and it is designed to work downwind, having no tail fin – only a cowl over the support pole. This seems to put a lot of weight/strain on the pole and the bulky blade arrangement looks likely to fall away to leeward on a heavily heeled yacht.

Our test unit was a prototype, so wasn't made from the same non-corrosive materials as the final production model will be, but the generator and blades are the same.

Anakata claims the rotor design forces wind to accelerate through it, yielding greater rotation speed and power than other devices on the market.

Assembly

There's no need to assemble the blades as the rotor comes as one moulded unit. Assembly is simply a case of bolting on the rotor blade, screwing up the cowling, then mounting. At 17kg, it ties with the flexible Duogen as the heaviest unit we tested.

Trials

In high winds, this turbine looks rather like the forward fan of a jet engine and makes a strange whining sound, but its output is pretty impressive. It's also very stable, even in gusty winds, despite us forgetting to put the cowl on first time.

Output is in AC, so a small external rectifier is supplied to convert it to DC before connecting it up to your batteries. The turbine relies on an external charge controller and dump load resistor.

VERDICT: ★★☆☆☆

Reasonably productive electrically and stable, but none of our testers wanted one on their boat – for reasons of aesthetics and practicality.

▶ **www.anakatawindpower.com**

DUOGEN D400 from £1,250

Available in 12V, 24V and 48V versions, this unit is incredibly heavy so it will need to be mounted using a very stout tower. I suspect this is designed more as a terrestrial unit, although it is fully waterproof, corrosion resistant and probably bombproof too!

The D400 has been designed as a slow running device in order to keep noise to a minimum. The camber of its carefully-designed aerofoil blades vary continually from root to tip, making for a low speed start-up and quieter running in high winds. It also incorporates a high-efficiency, 12-pole, 3-phase alternator with twin stators for high output.

Its regulator utilises a resistive load to dump unwanted power and it can also be braked using an optional park switch, although being so powerful it can often overcome the brake and keep turning. Tying off in high winds is therefore highly recommended!

Assembly

Fairly straightforward to assemble, although not the quickest and made more awkward by the sheer weight of the generator.

Trials

The five-bladed D400 was one of the quietest on test and started rotating very quickly, putting out an increasingly progressive rate of charge. It also appeared far less prone to yaw from side to side than many of the others, keeping its head into the wind and ensuring a more stable output.

Its sturdy build allows it to continue operating in very high winds, where it would be in its element producing a staggering 50A-plus in a strong gale!

VERDICT: ★★★★☆

Good output in high winds and quiet and steady in operation. It is, though, extremely heavy so you wouldn't want to mount it too high off the deck. It's also close to the top of the price range, but represents good value for money in the bang-for-buck stakes.

▶ **www.duogen.co.uk**

LEADING EDGE LE-300 from £480

Fairly recent to the marine market, Leading Edge is a UK company that supplies wind turbines for both marine and terrestrial installation.

The LE-300 is available in 12V, 24V and 48V versions and remarkably light (6kg), making it ideal for sailing yacht installation – even at the spreaders. It is also very competitively priced.

A run/stop switch is supplied that brakes the turbine by shorting the output. The unit can also be supplied with a charge controller (DL-300), which is a dump load style regulator that allows you to leave the turbine on 24/7 without fear of the batteries overcharging.

Assembly

Very easy to assemble and light enough to carry or hold in one hand. Output is simply via two DC wires.

Trials

The LE-300 is very light compared to all the other turbines we tested and one of the quietest of the three-bladed models.

Its blades are shorter than most, which means less noise at high speeds, though this appears to reduce its power output as well. However, it started up in only 6 knots of wind, which was towards the better end of the performance spectrum.

VERDICT: ★★☆☆

Inexpensive, but comparatively poor performance in terms of amps.

▶ **www.leturbines.com**

The LE-300's dump load resistor is housed in a box

PRIMUS AIR BREEZE

from £1,135

This 12v/24v unit has an all-in-one cast aluminium housing and internal regulation, with an LED on the bottom to indicate which mode it is in. When charging, the LED is permanently on. An electrical brake cuts in at wind speeds of 45 knots and slows the blades to tickover speed until the wind drops. In this mode the LED flashes once per second. The regulator also monitors battery voltage, going into braking mode at a pre-programmed voltage (Range 13.6–17.0V, default 13.6V), set by the user by turning an adjuster screw on the unit.

Assembly

A doddle to assemble as everything is in one casing, requiring a simple and quick blade assembly before being ready to mount.

Trials

This derivative of the original Air-X turbine has had its blades cropped to reduce noise, but it was still the noisiest unit on test by far. Worth noting it is compatible with the quieter Silentwind blades (cost c£400)

It was a little slow to start, as were many of the other three-blade models, but was soon charging at a reasonable, if not spectacular rate – maxing out at around 13A in 24 knots of wind. Nice not to have dump resistors to mount somewhere as well.

VERDICT: ★★★★☆

Popular with the testers for its simplicity and internal regulator, but not as productive as some at higher wind levels. If it is sheer grunt in a gale you're after, this wouldn't be your first choice, but in the average UK conditions it should be very good – if a tad noisy! Good value too, considering the regulator is included.

▶ **www.barden-uk.com**

RUTLAND 914i

from £630

This is the most powerful of the UK-built Rutland range of marine wind generators, which also includes the popular 913 and 504 models.

They have all proven reliable over many years of operation on both leisure craft and in commercial applications (channel light markers, railway signalling equipment etc.) and this latest version should be no different.

Rutland's 914i has the same physical attributes and dimensions as its earlier 913, only it features so-called 'maximum power point tracking'. This is a technology that makes the most of the turbine's generating power by matching voltage and rotation speed, smoothing its output and giving 30 per cent more power than its predecessor.

Two multi-stage charge regulators are available, including one with dual outputs for start and service battery banks. Both will also accept an input for a solar panel array of up to 160W.

These regulators work electronically to gradually brake the turbine in high winds or as the batteries near full charge situations, rather than using resistive dump loads.

Assembly

Slightly more fiddly to assemble than some of the others, and the blades, which slot in at an angle, are a tight fit.

Trials

Very quiet in operation and the quickest off the mark in light winds. Well made, its heavy metal hub acts as a flywheel, giving it enough momentum to smooth out the pauses during brief lulls in the wind. Not a particularly high output, though, even in a good blow.

VERDICT: ★★★☆☆

Quiet and probably ideal to keep the start battery topped up on a mooring, but the unit is not really powerful enough for serious offshore cruising. Suitably priced, however, for a mid-range battery maintenance turbine.

▶ **www.marlec.co.uk**

SILENTWIND 400

from £1,306

Another three-bladed model with moulded tail fin, the Silentwind turbine is heavier than it first looks because it has a higher-power generator than similar look-alikes – up to 420W, in fact.

Available in 12V, 24V and 48V versions, it has a three-wire AC output designed to be connected to a proprietary smart charge controller with LCD display and integral brake switch, although you could just run it through a rectifier for a direct DC connection to a large battery bank.

Assembly

As with most of the three-blade turbines, this was an easy model to assemble – helped by the no-hassle integral tail fin and a single bolt for each blade.

Trials

The Silentwind caused much mirth at first as it resolutely refused to start spinning – causing us to assume it was silent because it never did anything! However, once the wind rose above 10 knots it finally started turning and immediately began pumping out a useful amount of power. After its various bearings had been 'run in' for a while it managed to start at around 7–8 knots.

VERDICT: ★★★★☆

Despite taking a while to start, it produces some serious amps, making it the fourth most effective at 12 knots and the second most powerful in winds over Force 6. Pricey, though.

▶ **www.barden-uk.com**

SUPERWIND 350

from £1,376

The redesigned blades are very steeply pitched towards the hub, for an earlier start speed, and now have tiny fins along their length to make them much quieter at high speeds.

The blades incorporate a similar kinetic rotor control system to those on the Ampair. And they are designed to feather in very high winds, so with a charge controller in the circuit, the turbine can be left spinning in all weathers.

The SCR Marine controller supplied with the Superwind has two independent outputs, for start and service banks, and dissipates unwanted energy as heat via two dump loads.

Assembly

Not difficult, despite its unusual diameter shaft. With the nylon bush in place (glued on in our case) your tower pole needs an internal diameter of 55mm; otherwise it is 44mm.

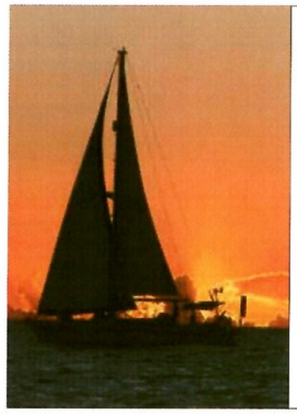
Trials

Certainly one of the quieter three-bladers, although we didn't run it in a gale. Slow to start, but when it did the charge output rose pretty quickly to a useable level. At higher winds it just seem to keep going up, giving us the highest recorded charge current of any tested in 24 knots of wind. Its larger than most high aspect tail fin kept it facing the right way.

VERDICT: ★★★★★

Simple, well made, not too heavy, reasonably quiet and a good output at both low and high wind levels. What more could you want?

▶ **www.mactrashop.com**



CONCLUSION

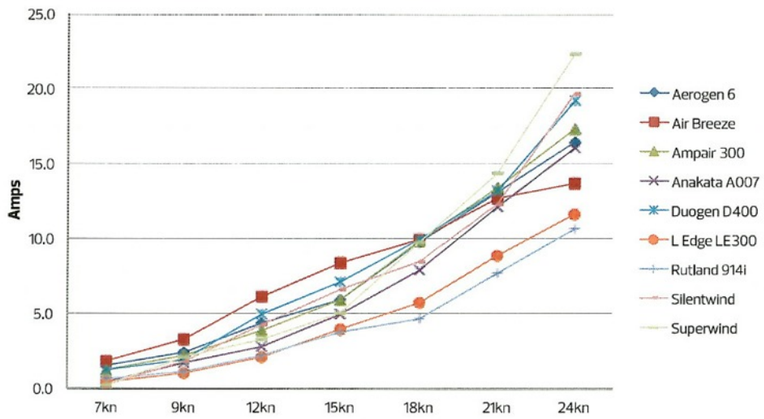
For UK cruising, where the wind usually blows between 8 and 15 knots, the quickest off the mark was the Air Breeze, which gave an impressive 1.8–8.4A between 7 and 15 knots of wind. The next nearest was the Duogen D400, giving 1.9–7.1A in the same conditions, followed closely by the Silentwind. The latter two were definitely the quietest, while the Air Breeze was easily the loudest of all.

For trade-wind destinations such as the Caribbean, I would opt for a turbine that can use the extra wind strength. The Duogen is the most powerful we tested and, with a charge controller fitted, should cope with near hurricane blows. It is closely followed by the Silentwind, although output is limited to 35A. All the turbines offer safe regulation in strong winds, provided you fit a suitable charge controller.

The final factor is build quality and maintenance. Turbines such as the Ampair, Aerogen and Duogen all have well-established pedigrees and withstand the harsh marine environment with little care. The others may well be just as good, but they've just not been in production long enough to be sure.

Going by the figures alone, the best all-round performance in all winds came from the Silentwind, closely followed by the Aerogen 6 and the Ampair 300.

Test results



Although the turbines' claimed output ran as high as 55A for the Duogen, our top wind speed of 24 knots did not allow this to be tested

SUPPLIERS' CONTACTS

Aerogen 6 – Xylem, 01992 450145 www.xylemflowcontrol.com

Air Breeze – Barden UK 01489 570770 www.barden-uk.com

Ampair A300 – Ampair Energy 01258 837266 www.ampair.com

Anakata A700 – Anakata Wind Power +44 (0) 1865 236242 www.anakatawindpower.com

Duogen D400 – Eclectic Energy 01623 835400 www.duogen.co.uk

LE300 – Leading Edge Turbines 0845 652 0396 www.leturbines.com

Rutland 914i – Marlec Engineering 01536 201588 www.marlec.co.uk

Silentwind 400 – Barden UK 01489 570770 www.barden-uk.com

Superwind 350 – Mactra Marine 01934 517288 www.mactrashop.com

MODEL DETAILS			PRICING			BLADES			AS TESTED				MANUFACTURERS' FIGURES					
Make	MODEL	W'NTY	TURBINE	REGULATOR	MOUNT KIT	NO.	MATERIAL	DIA	START SPD	NOISE	A@12KT	A@24KT	MAX PWR	WEIGHT	OUTPUT	REGULATOR	BRAKE	POLE DIA
AEROGEN	A6	1yr	£1,363	£218	£395	6	GRP/nylon	1.20m	6.5kn	Low	4.3	16.4	360W (30A)	15.1kg	DC	Resistive	No	38mm
AMPAIR	Pacific 300	2yrs	£1,594	£456	£320	3	GRP	1.20m	6.0kn	Med	3.8	17.3	300W (25A)	10.5kg	AC	Resistive	Opt	40mm
ANAKATA	A007	5yrs	£1,000	£195	n/a	8	ABS	1.08m	6.5kn	Med	2.8	16.0	300W (25A)	17.0kg	AC	Resistive	Opt	48mm
DUOGEN	D400	2yrs	£1,250	£219	n/a	5	GRP/nylon	1.10m	5.0kn	Low	4.9	19.2	600W (55A)	17.0kg	DC	Resistive	Opt	50mm
LEADING EDGE	LE-300	5yrs	£480	£120	£400	3	GRP/nylon	1.00m	6.0kn	Low	2.1	11.6	300W (25A)	6.0kg	DC	Resistive	Yes	50mm
PRIMUS	Air Breeze	5yrs	£1,135	inc	£510	3	Composite	1.17m	5.5kn	High	5.1	13.7	160W (15A)	6.0kg	DC	Braked	Yes	48mm
RUTLAND	914i	2yrs	£630	£75	£120	6	Nylon	0.91m	5.0kn	Low	2.2	10.6	260W (18A)	12.0kg	DC	Braked	Yes	41mm
SILENTWIND	400	3yrs	£1,306	inc	£510	3	GRP/carbon	1.15m	7.0kn	Low	4.2	19.7	420W (35A)	12.0kg	AC	Braked	Yes	48mm
SUPERWIND	350	3yrs	£1,376	£318	£309	3	ABS/carbon	1.20m	7.5kn	Med	3.2	22.3	350W (30A)	11.5kg	DC	Resistive	Opt	44/55mm