

# Generazione eolica

## TIPI DI TURBINE

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# Contenuto

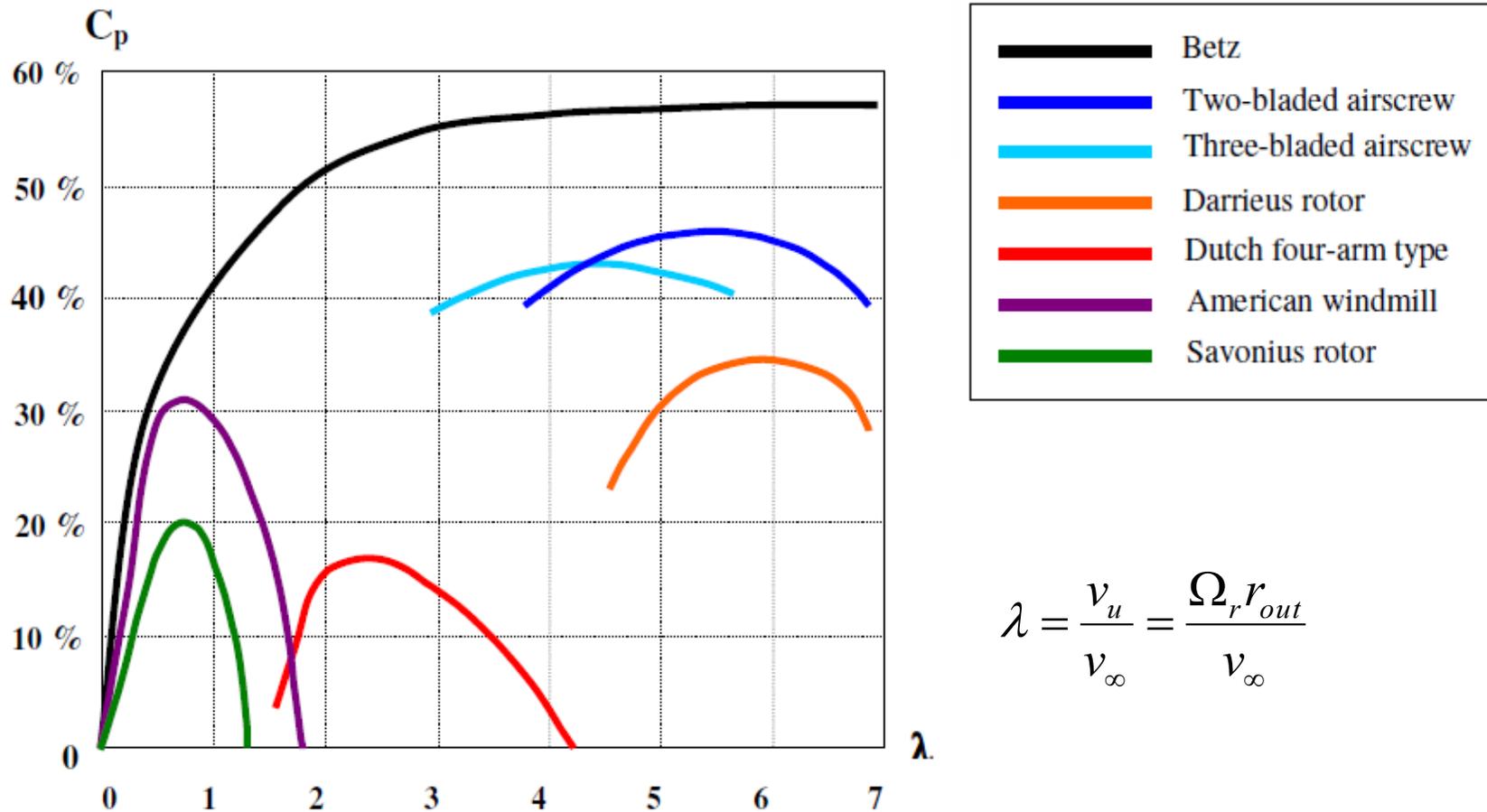
## Introduzione

1. Savonius
2. Darreius
3. Savonius-Darreius
4. Asse orizzontale downwind
5. Asse orizzontale upwind



# 1. Introduzione

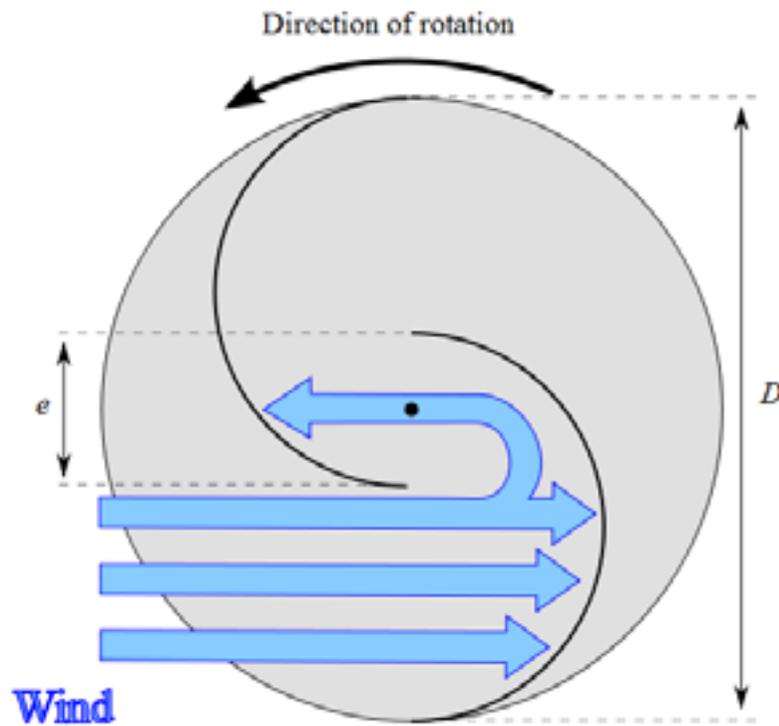
## Suddivisione per Tip Speed Ratio

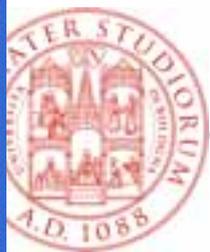


$$\lambda = \frac{v_u}{v_\infty} = \frac{\Omega_r r_{out}}{v_\infty}$$

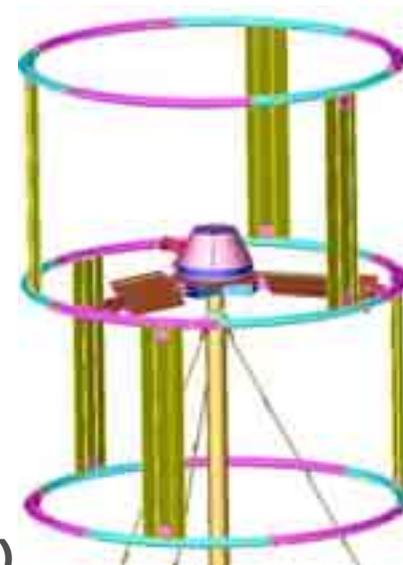


# 1. Savonius





# 1. Savonius



Wind sail (Russia)



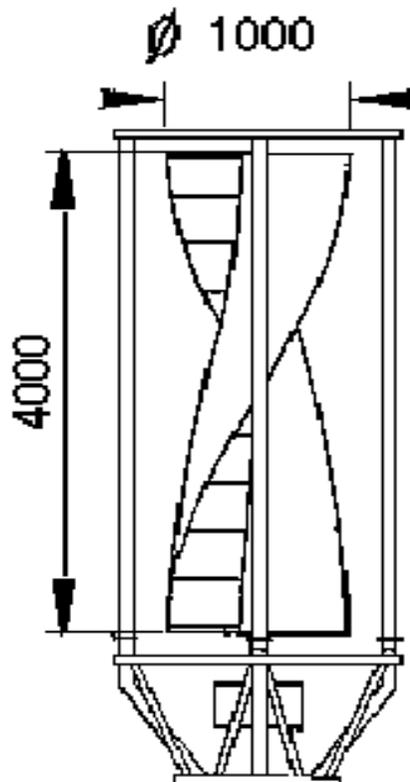
# 1. Savonius

Wind side (USA)

$A v_{\infty} = 10 \text{ m/s}; P_n = 288 \text{ W}$

Green tecno (CH)

$P_n = 2,2 \text{ kW @ } v_{\infty} = 10 \text{ m/s};$





# 1. Savonius

## CARATTERISTICHE

1. Turbine 'lente' (basso  $\lambda$ )
2. Efficienza ridotta (basso  $C_p$ )
3. Adatte ad essere utilizzate in un range di velocità di vento limitato (in genere basso vento)
4. Controllo di velocità necessario per mantenere  $C_p$  accettabili
5. Pale fisse. Problematica riduzione della superficie aerodinamica per velocità di vento superiore alla nominale



# 1. Savonius

## CARATTERISTICHE

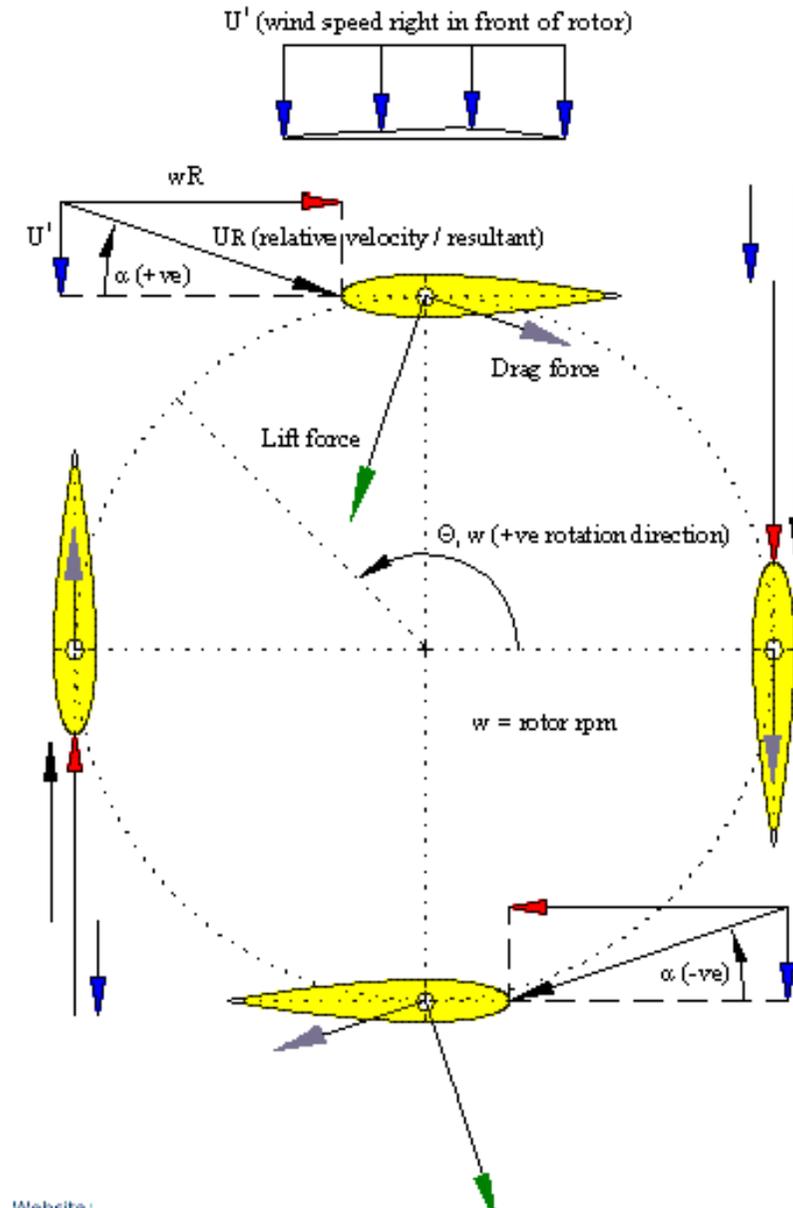
6. In genere per velocità superiore alla nominale la turbina è fermata con un dispositivo meccanico
7. Elevata superficie esposta, necessità di struttura pesante per resistere a eventi atmosferici eccezionali
8. Utilizzate solamente in applicazioni di piccola potenza
9. Bassa rumorosità



## 2. Darreius



Quite revolution (USA)



Mahelha



## 2. Darreius



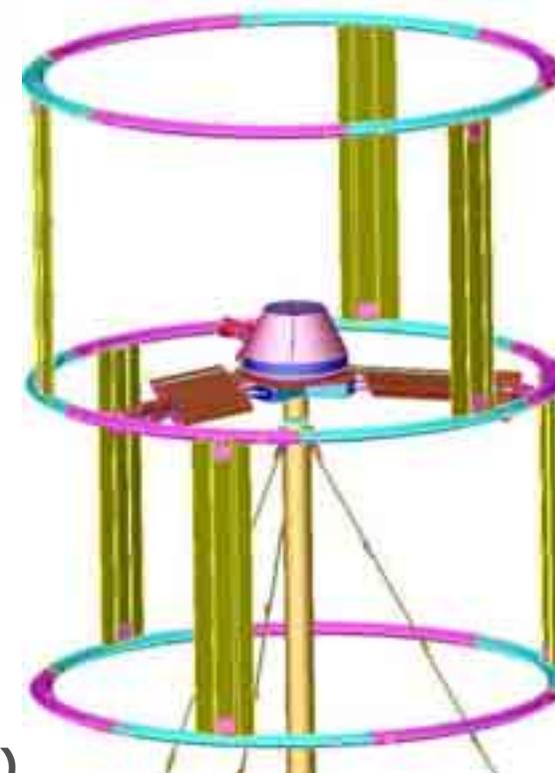
**Pac wind (USA)**



# 1. Savonius



Wind Harvest International Windstar 1500



Wind sail (Russia)



## 2. Darreius



Quite revolution (USA)





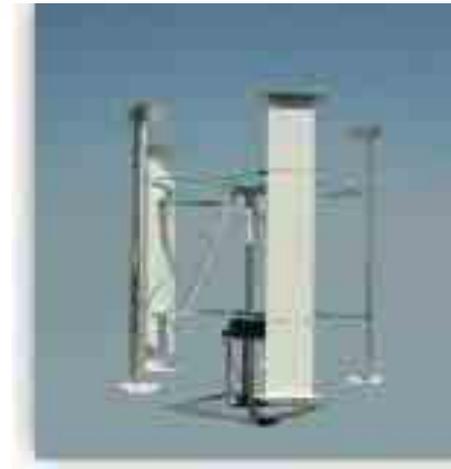
## 2. Darreius

### Pale ad H



Econoidi (IT)

$P_r = 1,3 \text{ kW} @ v_\infty = 12 \text{ m/s}$



[www.sawt.com.cn](http://www.sawt.com.cn) (China)

$P_r = 6 \text{ kW} @ v_\infty = 12 \text{ m/s}$

$D = 6 \text{ m}; H = 6.2 \text{ m}$



## 2. Darreius

**Pale ad H**



**Ropatec (IT)**

**$P_r = 2.2 \text{ kW}$  @  $v_\infty = 14 \text{ m/s}$**



**Ropatec (IT)**

**$P_r = 7 \text{ kW}$  @  $v_\infty = 10 \text{ m/s}$**



## 2. Darreius



**Silent Future-TEC (D) - 2kW**



**TRE (IT)**



## 2. Darreius

### CARATTERISTICHE

1. Turbine 'veloci' ( $\lambda$  medio alto)
2. Efficienza ridotta (basso  $C_p$ )
3. Adatte ad essere utilizzate in un range di velocità di vento limitato (in genere basso vento)
4. Controllo di velocità necessario per mantenere  $C_p$  accettabili
5. Pale fisse. Problematica riduzione della superficie aerodinamica per velocità di vento superiore alla nominale



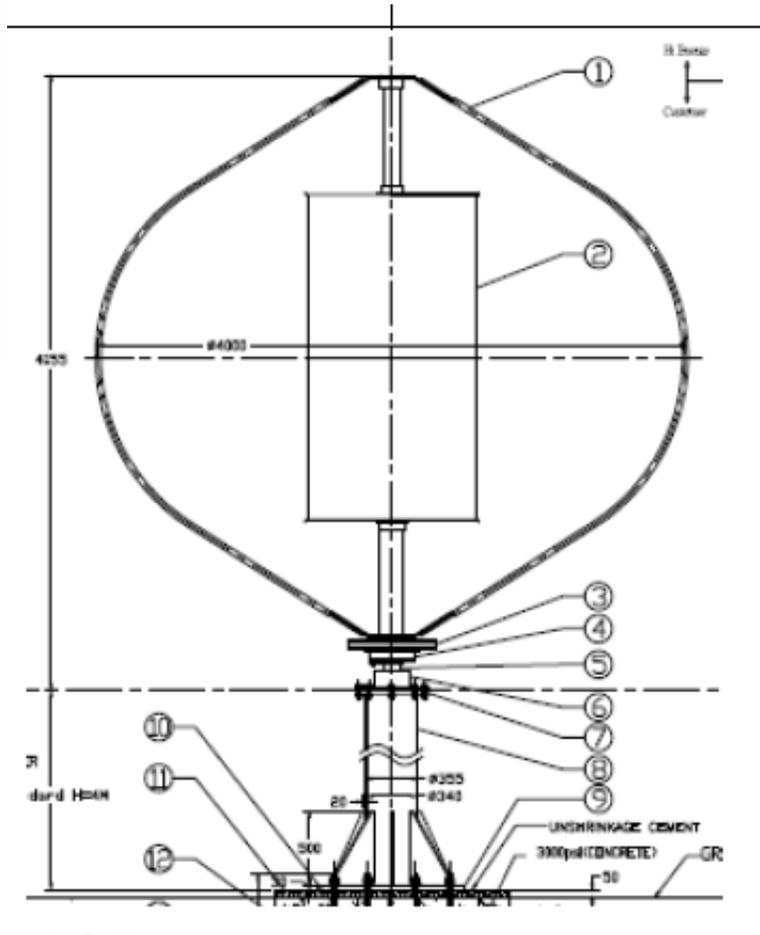
## **2. Darreius**

### **CARATTERISTICHE**

- 6. In genere per velocità superiore alla nominale la turbina è fermata con un dispositivo meccanico**
- 7. Superficie esposta inferiore a Savonius, necessità di struttura non troppo pesante per resistere a eventi atmosferici eccezionali**
- 8. Utilizzate solamente in applicazioni di piccola potenza**
- 9. Bassa rumorosità**
- 10. In grado di operare con venti turbolenti**



### 3. Darreius + Savonius



**Hi Energy**

$P_r = 2.2 \text{ kW} @ v_\infty = 12 \text{ m/s}$



**Mega System**

$P_r = 3 \text{ kW} @ v_\infty = 12 \text{ m/s}$



### 3. Darreius + Savonius

#### CARATTERISTICHE

1. **Combinano i vantaggi di entrambe le soluzioni ( $\lambda$  basso e  $\lambda$  medio alto)**
2. **Si incrementa l'efficienza della turbina su un range di vento più ampio**
3. **Controllo di velocità necessario per mantenere  $C_p$  accettabili**
4. **Pale fisse. Problematica riduzione della superficie aerodinamica per velocità di vento superiore alla nominale**
5. **Elevata superficie esposta al vento. Problemi di resistenza meccanica.**



## 4. Asse orizzontale

### Elica intubata (diffusore)

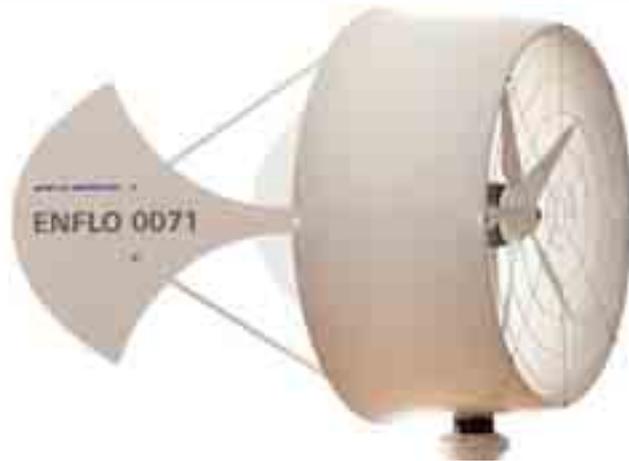


### CARATTERISTICHE

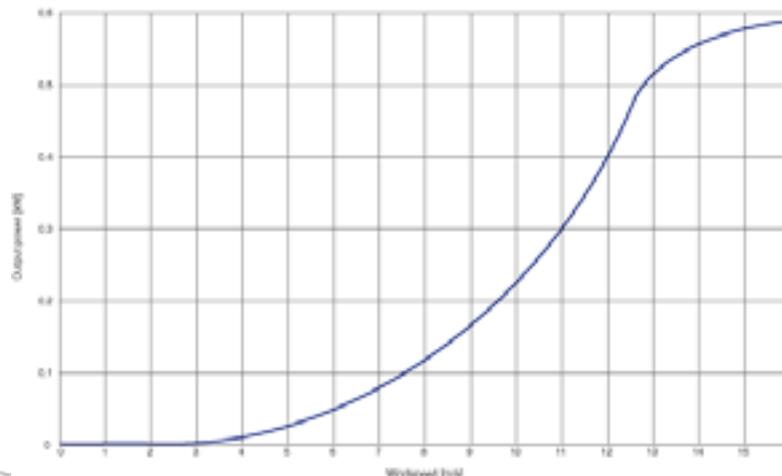
1. Aumenta la velocità del vento nella sezione. Aumenta la velocità di rotazione delle pale (e quindi il generatore è più piccolo)
2. Maggiore peso della struttura

## 4. Asse orizzontale

### Elica intubata (diffusore)



Power Diagram ENFLO 0071



#### Leistung

Nennleistung	0,5 kW
Nennwindgeschwindigkeit	12,5 m/s
Einschaltwindgeschwindigkeit	2,5 m/s
Abschaltwindgeschwindigkeit	25 m/s
Überlebensgeschwindigkeit	55 m/s

#### Rotor

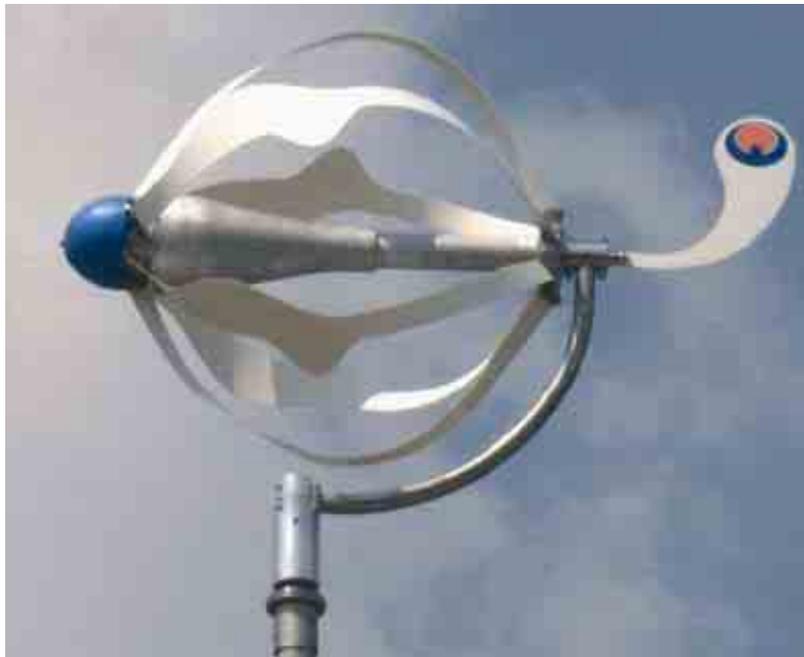
Durchmesser	0,71 m
Überstrichene Fläche	0,40 m <sup>2</sup>
Blattzahl	5
Nennzahl	1200 U/min
Material	PA

#### Abmessungen

Aussendurchmesser	0,87 m
Tiefe (Diffusor)	0,39 m
Tiefe (inkl. Windfahne)	1,02 m
Material	PU / Hartschaum / Aluminium
Leistungselektronik, Mast	ca. 25 kg

**Enflo WindTec (CH) - 500W**

## 4. Asse orizzontale

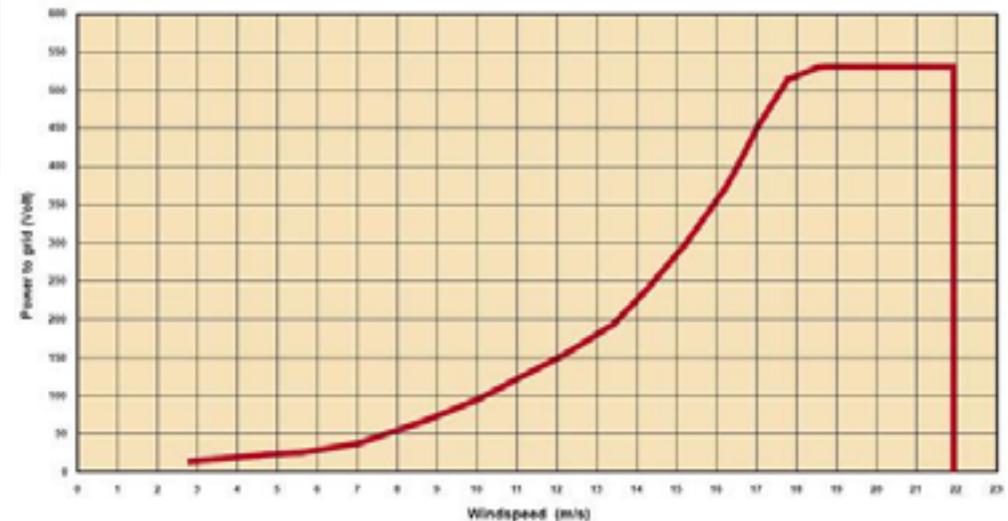


**Energy Ball V100(S) –**  
 **$P_r = 100 \text{ W} @ v_{\infty} = 10 \text{ m/s}$**

Rated power at 10 m/s	100	Watt
Maximum power at 17 m/s	500	Watt
Cut in wind speed	2	m/s
Survival wind speed	40	m/s

Rotor diameter	1,1	Meter
Rotor weight	circa 30	Kilogram
Rotor surface	1	m <sup>2</sup>
Rotor volume	1	m <sup>3</sup>
Height Energy Ball V100	1,3	Meter
Height of mast	Variable	

Type	Neodim permanent magnet
Number of poles	12 (brushless)
Number of phases	3





## 4. Asse orizzontale

### Downwind



#### 13. APPROXIMATE SYSTEM DESIGN WEIGHTS

100' Lattice Tower	3,210 kg (7,080 lb)
100' Monopole Tower	7,281 kg (16,051 lb)
Rotor & Drive Train	2,420 kg (5,340 lb)

### Entegriety (USA) - EW 50

#### 1. SYSTEM

Type	3 $\phi$ Grid Connected
Configuration	Horizontal Axis
Rotor Diameter	15 m (49.2 ft)
Centerline Hub Ht.	31.1 m (102 ft)

#### 2. PERFORMANCE PARAMETERS

Rated Electrical Power	50 kW @11.3 m/s (25.3 mph)
Wind Speed Ratings	
Cut-in	4.0 m/s (8.9 mph)
Shut-down (high wind)	25 m/s (56 mph)
Design Speed	59.5 m/s (133 mph)

#### 3. ROTOR

Type of Hub	Fixed Pitch
Rotor Diameter	15 m (49.2 ft)
Swept Area	177 m <sup>2</sup> (1902 ft <sup>2</sup> )
Number of Blades	3
Rotor Solidity	0.077
Rotor Speed @ 50kW	65 rpm
Nameplate Capacity	
Location Relative to Tower	Downwind
Cone Angle	6°
Tilt Angle	0°
Rotor Tip Speed	51 m/s (114 mph) @ 60 Hz
Design Tip Speed Ratio	6.1

#### 4. BLADE

Length	7.2 m (23.7 ft)
Material	Epoxy /glass fiber
Blade Weight	150 kg (330 lbs) approximate

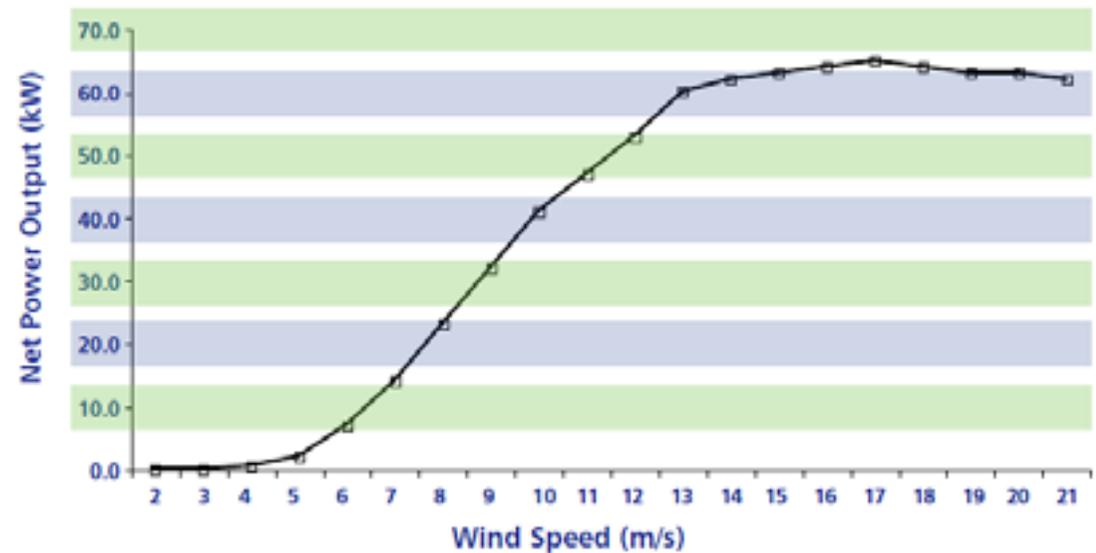


## 4. Asse orizzontale

### Downwind



EW 50 Power Curve (Sea Level)



### 11. ROTOR SPEED CONTROL

Running  
Start-up  
Shut-down

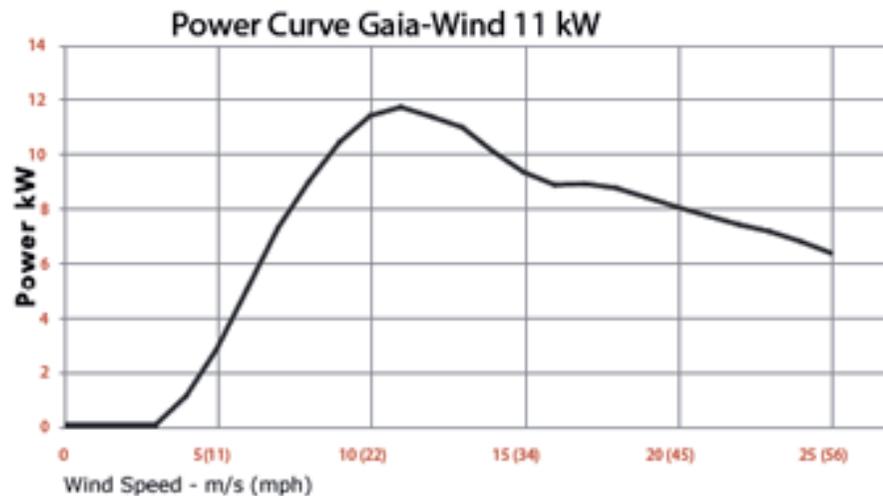
Passive stall regulation  
Aerodynamic  
Aerodynamic tip brake  
Parking brake for servicing

**Entegrety (USA) - EW 50**



## 4. Asse orizzontale

### Downwind



#### SYSTEM

Type	3 $\Phi$ Grid Connected
Configuration	Horizontal Axis
Rotor Diameter	13 m
Centerline Hub Height	18.3m

#### PERFORMANCE PARAMETERS

Rated Electrical Power	11 kW @9.5 m/s
Wind Speed Ratings:	
cut-in	3.5 m/s
shut-down (high wind)	25 m/s
design speed	59 m/s
Number of Blades	2
Rotor Speed @ rated wind speed	56 rpm
Location Relative to Tower	Downwind
Cone Angle	40°
Tilt Angle	20°
Rotor Tip Speed	38 m/s (85 mph) @ 50 Hz
Design Tip Speed Ratio	4:0

#### BLADES

Length	6.5 m
Material	Epoxy /glass fibre
Blade Weight	170 kg (375 lbs) approximate



## 4. Asse orizzontale

### Downwind



**Aerostarwind 10kW**

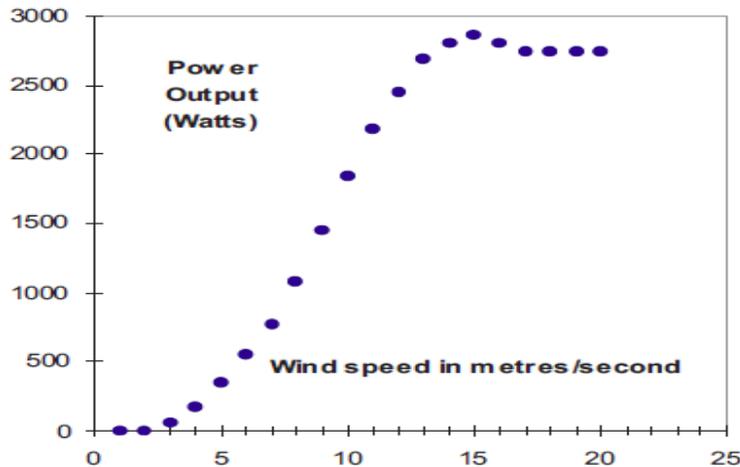
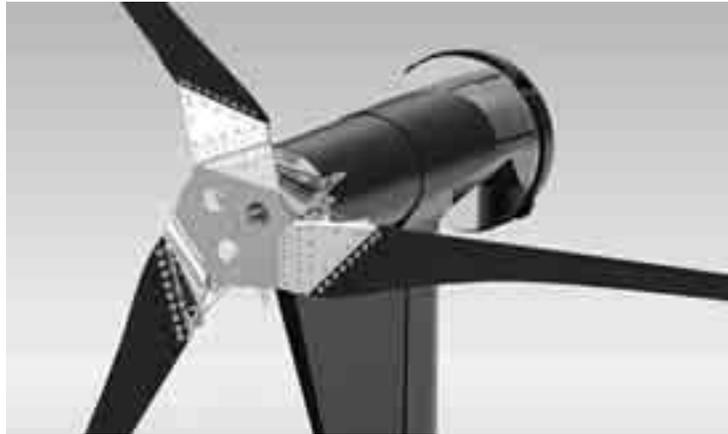
#### AEROSTAR® 6 Meter Specifications

Rotor Diameter:	22' (6.7 M)
Rotor Type:	2 Blade Teetering, Self starting
Blades:	Tapered, Twisted Fiberglass
Overspeed:	Articulating Blade Tips. Failsafe Rotor Brake.
Swept Area:	380 Sq. Ft. (35.3 Sq. M)
Generator:	10 kW Induction 240 VAC Single phase or 3 phase
Rated Capacity:	10 kW
Cut-in WS:	8 MPH
Shut Down WS:	50 MPH, automatic reset
Control:	Microprocessor Optional Over/Under Voltage (+10%, -12%)  Optional Over/Under Frequency (+/- 0.5 Hz) Power Factor: > 0.95
Weight:	650 lbs. (281 kG)
Noise:	43 dBA at 100' at 10 MPH
Approvals:	UL/CSA - Control Box, Electrical components. (At the time of this writing UL has no category for induction generators)



## 4. Asse orizzontale

### Downwind



### PROVEN ENERGY (UK)

#### MODEL

Cut In (m/s) <sup>1</sup>	2.5
Cut Out m/s)	None
Survival m/s)	70
Rated (m/s)	12
Rotor Type	Downwind, Self Regulating
No. of Blades	3
Blade Material	Polypropylene
Rotor Diameter(m)	3.5
Generator Type	Brushless, Direct Drive, Permanent Magnet

Battery charging  
Grid connect with  
*Windy Boy Inverter*

#### Proven 2.5 (2.5kW)

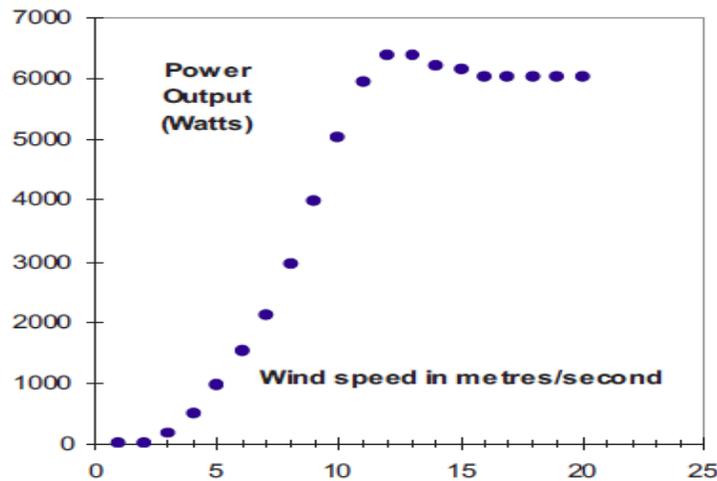
	230Vac 50Hz or 240 Vac 60Hz
	240Vac
Direct Heating	300
Rated RPM	2,500-5,000 kWh
Annual Output <sup>2</sup>	190
Head Weight (kg)	Tilt-up, tapered, self-supporting, no guy wires (Taller guyed towers also available on request)
Mast Type	6.5 or 11

Hub Height (m)	1.6x1.6x1 or 2.5x2.5x1
WT Found (m)	0.65x0.65x0.65 or 1x1x1
Winch Found (m)	241 or 445
Tower Weight (kg)	Yes
Mechanical Brake	40 dBA
Noise <sup>3</sup> @ 5m/s	60 dBA
Noise @ 20m/s	5
Rotor Thrust (kN)	



## 4. Asse orizzontale

### Downwind



### PROVEN ENERGY (UK)

#### MODEL

Cut In (m/s)<sup>1</sup>

Cut Out m/s

Survival m/s

Rated (m/s)

Rotor Type

No. of Blades

Blade Material

Rotor Diameter(m)

Generator Type

Battery charging

Grid connect with

*Windy Boy Inverter*

Direct Heating

Rated RPM

Annual Output<sup>2</sup>

Head Weight (kg)

Mast Type

Hub Height (m)

WT Found (m)

Winch Found (m)

Tower Weight (kg)

Mechanical Brake

Noise<sup>3</sup> @ 5m/s

Noise @ 20m/s

Rotor Thrust (kN)

#### Proven 6 (6kW)

2.5

None

70

12

Downwind, Self Regulating

3

Glassthermoplastic Composite

5.5

Brushless, Direct Drive,  
Permanent Magnet

48V DC

230Vac 50Hz or 240 Vac 60Hz

ac

200

6,000-12,000 kWh

600

Tilt-up, tapered, self-supporting,  
no guy wires (Taller guyed towers  
also available on request)

9 or 15

2.5x2.5x1 or 3x3x1.2

1x1x1 or 1.5x1.5x1

360 or 656

Yes

45 dBA

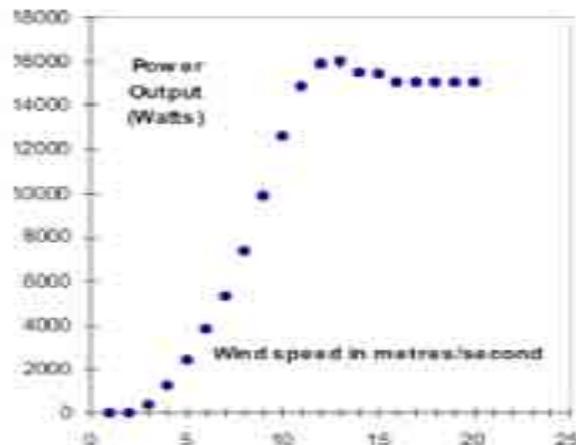
65 dBA

10



## 4. Asse orizzontale

### Downwind



### PROVEN ENERGY (UK)

#### MODEL

Cut In (m/s)<sup>1</sup>

Cut Out m/s)

Survival m/s)

Rated (m/s)

Rotor Type

No. of Blades

Blade Material

Rotor Diameter(m)

Generator Type

Battery charging

Grid connect with

*Windy Boy Inverter*

Direct Heating

Rated RPM

Annual Output<sup>2</sup>

Head Weight (kg)

Mast Type

Hub Height (m)

WT Found (m)

Winch Found (m)

Tower Weight (kg)

Mechanical Brake

Noise<sup>3</sup> @ 5m/s

Noise @ 20m/s

Rotor Thrust (kN)

#### Proven 15 (15kW)

2.5

None

70

12

Downwind, Self Regulating

3

Glassthermoplastic Composite

9

Brushless, Direct Drive,  
Permanent Magnet

48V DC

230Vac 50Hz or 240 Vac 60Hz

240V ac

150

15,000-30,000 kWh

1100

Tilt-up, tapered, self-supporting,  
no guy wires (Taller guyed towers  
also available on request)

15 or 25

3.7x3.7x1.2 or 5x5x2

1.5x1.5x1.2

(no anchor foundation for 25m)

1478 or 2794

Yes

48 dBA

65 dBA

26



## 4. Asse orizzontale

**Downwind**



**PROVEN ENERGY (UK)**



## 4. Asse orizzontale

### Downwind



**Skystream (USA)**

**$P_R = 1.9\text{kW}$**





## 4. Asse orizzontale

### Upwind



**ISKRA (UK)**

<b>Generator rating</b>	5 kW
<b>Rotor speed</b>	200 rpm nominal (variable)
<b>Cut-in wind speed</b>	3 m/s (6.7 mph)
<b>Survival wind speed</b>	60 m/s (134 mph)
<b>Rotor diameter</b>	5.4 m
<b>Rotor orientation</b>	Upwind
<b>Number of blades</b>	3
<b>Blade material</b>	GRP composite
<b>Control system</b>	Passive blade pitching
<b>Gearbox</b>	None
<b>Brakes</b>	Electro-dynamic
<b>Generator</b>	Permanent magnet alternator
<b>Yaw control</b>	Tail vane
<b>Tower height</b>	9m, 12 m & 15m
<b>Tower</b>	Free-standing or guyed.



## 4. Asse orizzontale

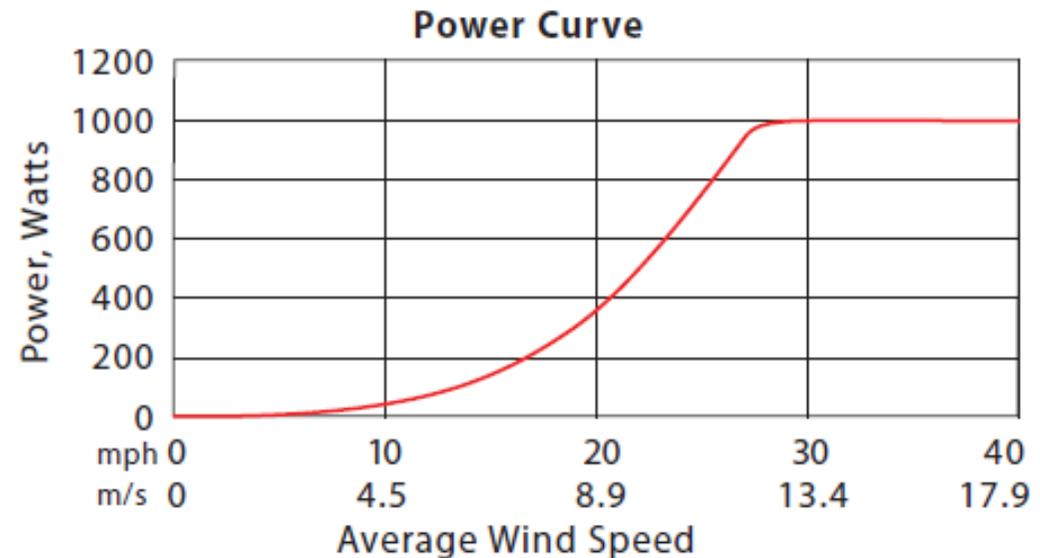
### Upwind



**AVX 1000 (USA)**

### TURBINE SPECIFICATIONS *Preliminary*

- Weight: 130 lbs
- Height and width: 8.5'x 6'
- Number of blades: 5
- Rated power: 1000 W
- Start up wind speed: 2.2m/s (5 mph )
- Output voltage: 250 VDC
- Designed for installation on concrete tilt-up or pre-cast building construction
- Designed to withstand 120 mph winds





## 4. Asse orizzontale

Upwind



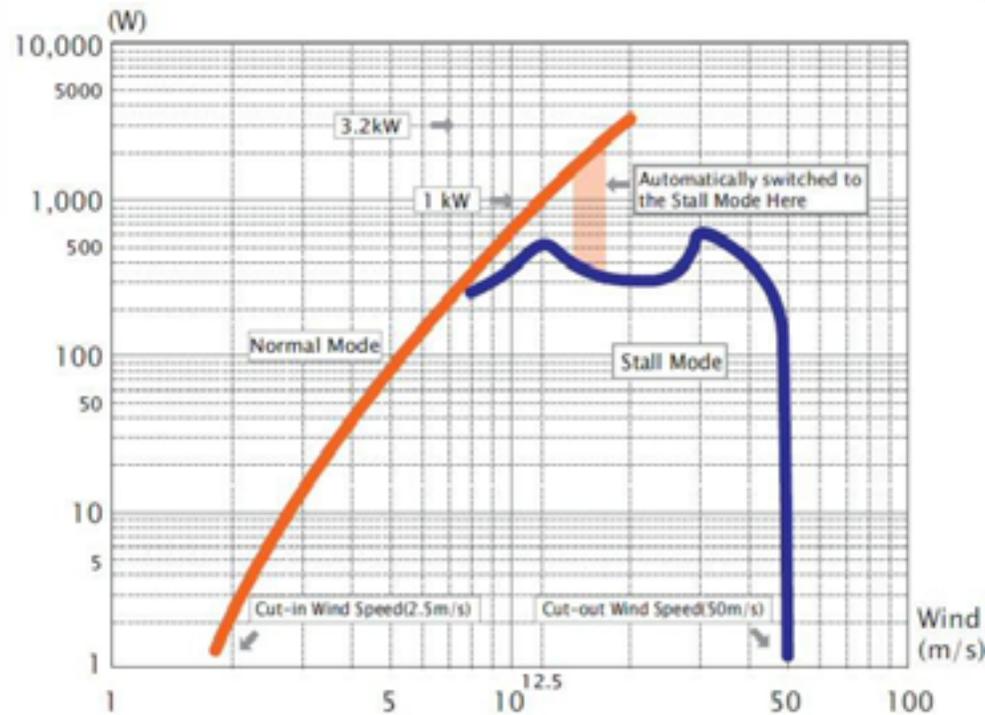
**Zephyr Airdolphin Z1000**

Wind Turbine Type	Horizontal axis, up-wind
Rotor Diameter	1800mm
Mass	17.5kg
Mount Diameter	48.6mm
Number of Blades	3
Blade Material	Carbon-fiber skin
Blade Mass (per piece)	380g
Blade Retention	Interlock hub mounting
Body Material	Aluminum diecast
Body Construction	Screw-free joints (based on traditional Japanese handi-crafts)
Product Finish	Teflon-based paint
Power Generator	Synchronous-type, three-phase power generator with permanent magnets (neodymium iron boron magnet)



## 4. Asse orizzontale

Upwind



**Zephyr Airdolphin Z1000**

Protection Circuit	Built-in
Data Logger	Built-in
Yaw control	Free yaw (360 degrees)
Direction Control	Original Swing-Rudder System
Output Control	Non-stop output control (incl. Stall Mode)
Start-up Wind Speed	0m/s (Power-Assist Function)
Cut-in Wind Speed	2.5m/s
Cut-out Wind Speed	50m/s
Survival Wind Speed	65m/s
Rated Power	1kW (12.5m/s)
Rated Rotor Speed	1250rpm
Maximum Power	3.2kW (20m/s)
Maximum Rotor Speed	1600rpm (20m/s)
Mass per Watt	17.5g/W (at rated power)
Power per Square Meter	393W/m <sup>2</sup> (at rated power)

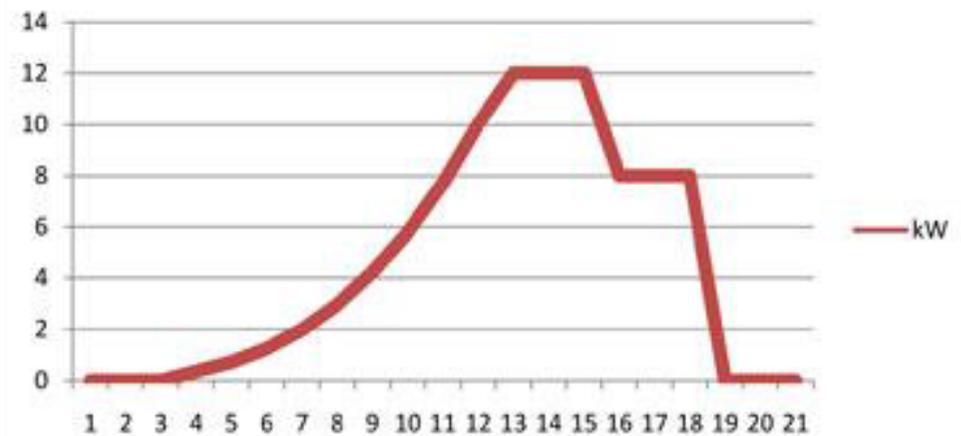


## 4. Asse orizzontale

Enwia (PL)



Power curve Enwia E12



Max output	12 kW
Number of windmill blades	3
Rotor diameter	5.98 m
Wind adjustment system	aerodynamic
Starting wind speed	3,5 m/s
Nominal wind speed	13 m/s
Max wind speed	20 m/s and auto-stop
Energy type	3-phase alternating current $U_{max}=400$ V $U_{max}=400$ V
Nacelle weight	400 kg
Load-bearing structure	Tubular mast or cage mast



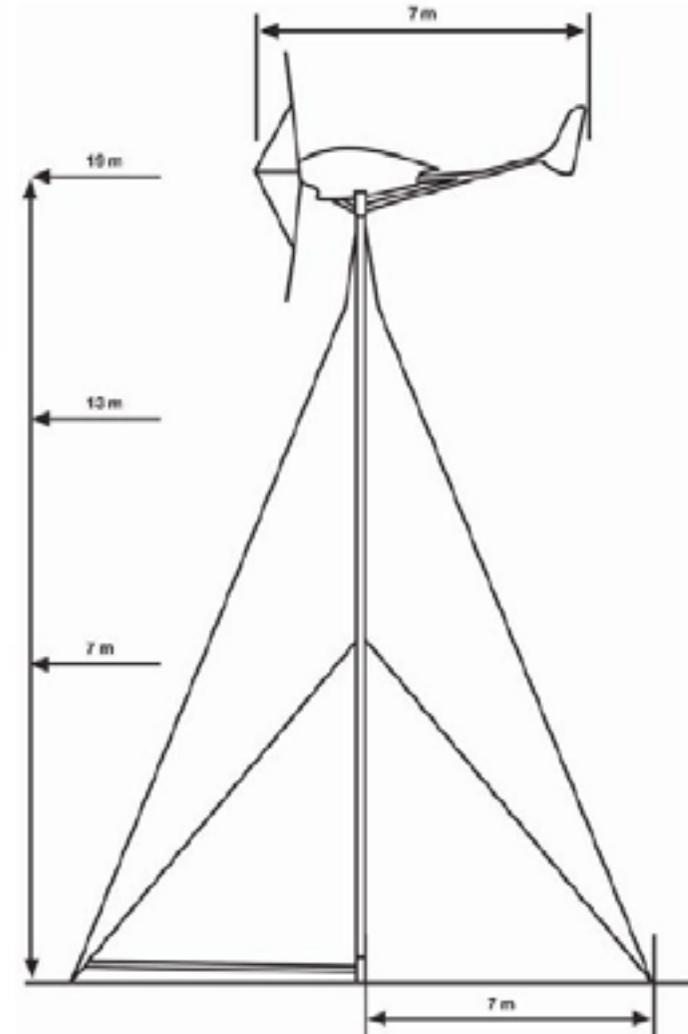
## 4. Asse orizzontale

### Upwind



Easy wind (D)

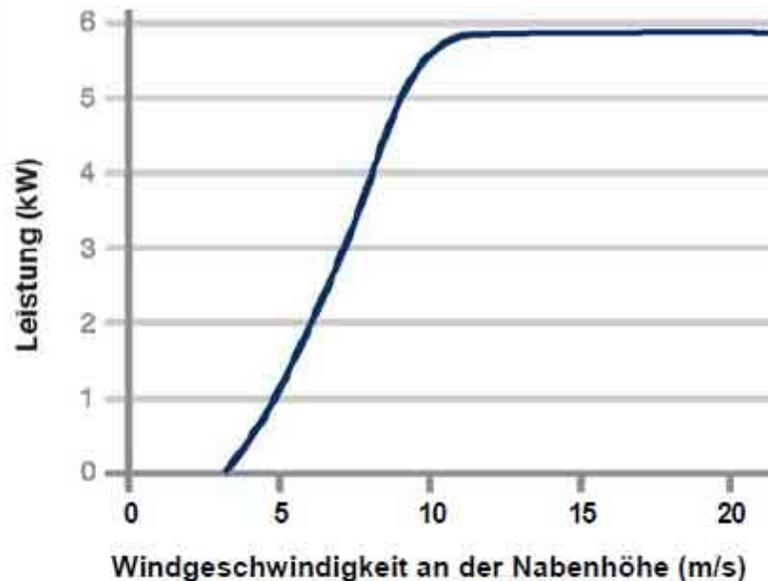
$P_R = 6\text{kW}$





## 4. Asse orizzontale

### Upwind



Easy wind (D)

$P_R = 6\text{kW}$

Durchmesser	6 m (19.7 ft)
Anzahl der Rotorblätter	4
Anordnung	Luvseitig
Nennzahl	83/124 1/min
Getriebebauart	Stirnradgetriebe 2- stufig $i = 12,1$
Nennleistung	6 kW
Einschaltgeschwindigkeit	3 m/s (7 mph)
Nennwind- geschwindigkeit	10,6 m/s (23.6 mph)
Abschaltungsgeschwindigkeit	Keine
Überlebensgeschwindigkeit	60 m/s (135 mph)

Aerodynamisch	Passive Blattwinkelstellung
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#### Gewichte

Gesamtgewicht Turmkopf	363 kg (800)
Mast 1-teilig, Nabenhöhe 7 m (23 ft)	Ca. 110 kg
Mast 2-teilig, Nabenhöhe 13 m (42 ft)	Ca. 220 kg
Mast 3-teilig, Nabenhöhe 19 m (62 ft)	Ca. 330 kg



## 4. Asse orizzontale

Upwind



Eol power (I)

$P_R = 6\text{kW}$

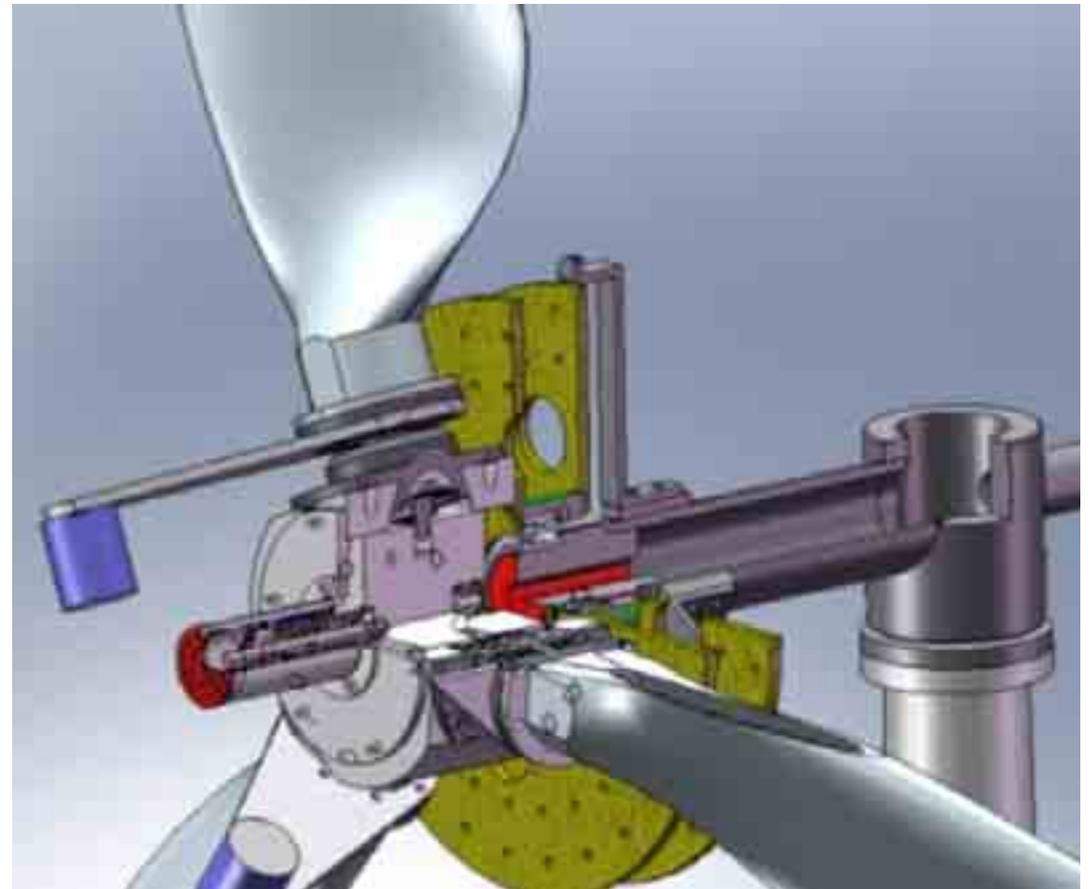




## 4. Asse orizzontale

### Upwind

- Rotor diameter: 5.8 m (disk area: 26.4 m<sup>2</sup>)
- Innovative profiles of blade sections
- 3 blades with *winglets* at tips, available in fiberglass or carbon fiber
- Rotation speed range: 50÷350 rpm
- Nominal rotation speed: 250 rpm



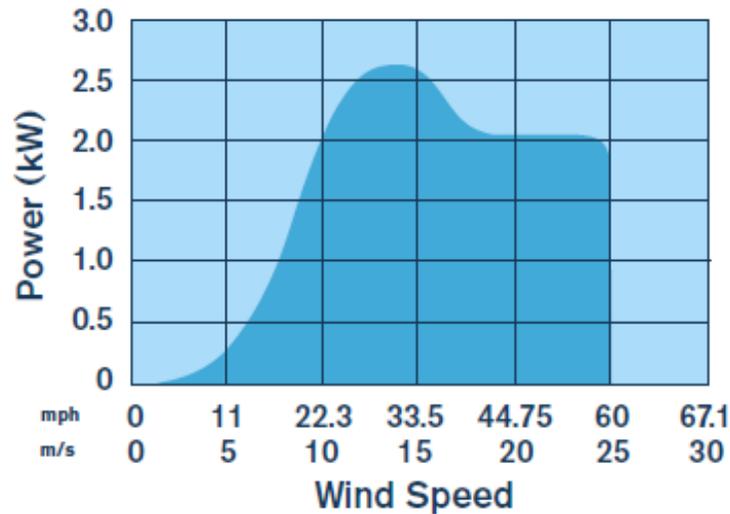
Eol power (I)

$P_R = 6\text{kW}$



## 4. Asse orizzontale

### Downwind



**Skystream (USA)**

**$P_R = 1.9\text{kW}$**

Model	Skystream 3.7
Rated Capacity	1.9 kW continuous output, 2.6 kW peak
Weight	170 lb (77 kg)
Rotor Diameter	12 ft (3.72 m)
Swept Area	115.7 ft <sup>2</sup> (10.87 m <sup>2</sup> )
Type	Downwind rotor with stall regulation control
Direction of Rotation	Clockwise looking upwind
Blades	3-Fiberglass reinforced composite
Rated Speed	50 - 325 rpm
Maximum Tip Speed	216.5 ft/s (66 m/s)
Alternator	Slotless permanent magnet brushless
Yaw Control	Passive
Grid Feeding	Southwest Windpower inverter 120-240 VAC 50-60 Hz
Battery Charging	Battery sensor available for battery charging systems
Braking System	Electronic stall regulation with redundant relay switch control
Cut-in Wind Speed	8 mph (3.5 m/s)
Rated Wind Speed	21 mph (9.4 m/s)



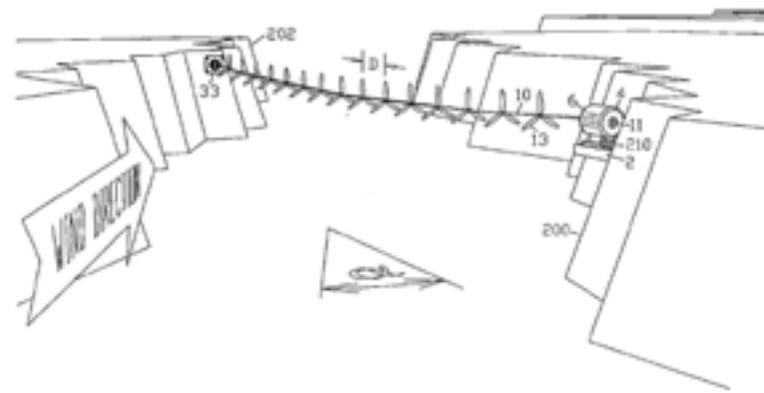
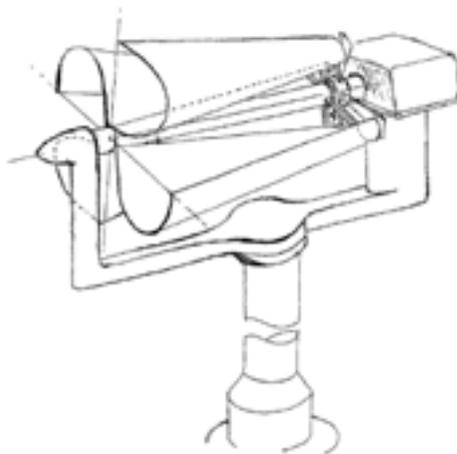
## 5. Altre soluzioni



VOA photo - C. Blumie



**Gambarota (Honk Kong)**



**Grazie per l'attenzione**

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