Turby

The wind turbine for the built-up environment

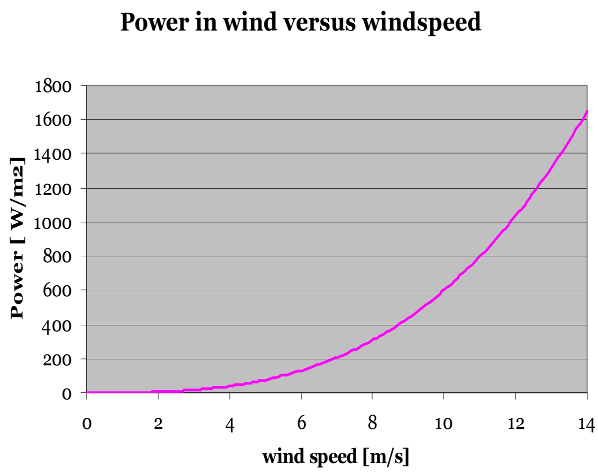
Introduction.

Turby is a revolutionary vertical axis wind turbine especially designed for use in an urban or built-up environment. This document is written as a guide for anyone interested in its development and application.
The characteristics of different types of wind turbines in general and the physical principles of Turby in particular are explained. Attention is given to the behaviour of wind, especially in an urban or built-up area. The behaviour of Turby is analyzed and conclusions are drawn regarding the optimum position for a vertical axis wind turbine on the roof of a building. Finally potentially adverse effects on the building are discussed.
It is hoped that after reading this guide, you will be able to determine whether the application of Turby in your specific situation is practical and attractive.

Wind energy and power

Wind turbines use the kinetic energy of the wind. The kinetic energy of a moving body is known through the formula: $E_{kin}=½.m.v^2$, in which m is the mass of the moving body and v is its speed.

This formula is applicable for wind if one calculates for the mass the amount of air flowing per second through an area of 1 m^2. The result is energy per second, power [W] instead of energy.
For a wind turbine with a swept area of A m^2 the total mass passing per second through the rotor is equal to the swept area A times the speed of the air v times the density of air ρ, in formula: $m = \rho.v.A$.
Substitution of the latter formula in the former one leads to the formula for the power offered by the wind to the turbine: $P_{wind} = ½. \rho.v^3.A$
Since the density of air is 1.2 kg/m^3 the available power per m^2 rotor area is equal to $0.6 \times v^3$ Watt.
At a wind speed of 4 m/s, $v^3 = 64$ and the power per m^2 swept area: 0.6 x 64 = 38 W. At 5 m/s wind speed, the power is 75 W and at 6 m/s wind speed 130 W! See the graph below.
Note: The swept area of Turby is 5,3 m^2.



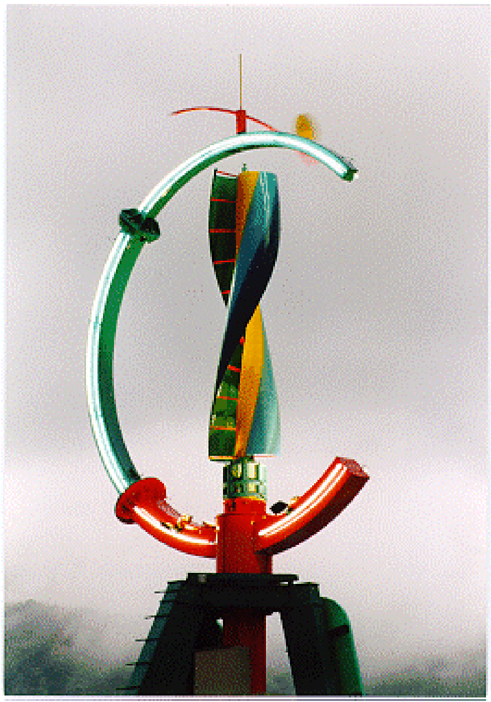
It is important to understand this phenomenon well since it explains why a relatively small difference in average wind speed results in a big difference in the energy output of a wind turbine!

Wind turbine types and efficiency

There are two essentially different types of wind turbines:
Impulse type wind turbines
(Savonius rotors) are vertical axis wind turbines with blades covering the whole swept area and shaped to offer a high resistance to the wind coming in, in the direction of the rotation and as little as possible resistance to wind blowing to the other side of the blade.
Aerodynamic wind turbines have wingshaped blades covering a small percentage of the swept area; the wind flow along these blades generate a lift force – as with airplanes – perpendicular to the flow.

Not all the energy in the wind can be converted by a wind turbine because the wind speed directly behind the rotor would become zero, thus clogging a further flow through the rotor. Newly arriving wind would be forced to choose its way around the rotor and the energy in that wind is not converted. In reality part of the air will flow through the rotor and part around it; the ratio of these parts determines the efficiency of the turbine. The physicist Betz has theoretically proven (1919) that this efficiency depends on the type of rotor. A modern aerodynamic turbine has a maximum theoretical efficiency of 59% and impulse type turbines 19%. It may be counter-intuitive that devices covering the whole swept area have such a low efficiency, but sailors will recognize this: “Sailing before the wind” is far less energetic than "close hauled” or "half wind".
It can also be understood from the formula derived above. The blades of impulse type turbines are dragged by the wind in the direction of the wind; the faster the rotor turns the lower the difference in speed between blades and wind and consequently the lower the transfer of power.

Aerodynamic turbines derive their power by moving perpendicular to the wind; an increase in blade speed will in first instance effect in an increase of the power transfer instead of a reduction! Due to their low blade speed impulse type turbines are assumed to produce little noise. This is only marginally true. The “air speed” of the returning blade is equal to the wind speed plus the speed of the dragged blade, near twice the wind speed; the rotor of an impulse type turbine has to be at least three times larger than an aerodynamic rotor to generate the same energy. Since the noise level of an object moving through the air is determined by its speed and its size, the noise level of both types of turbines generating similar amounts of energy is practically the same.

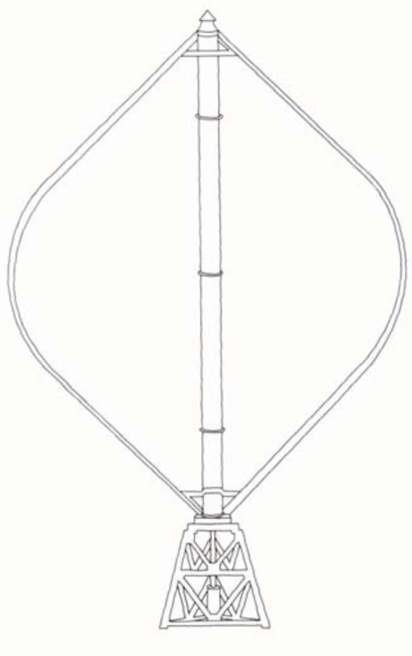


A typical Savonius type turbine

Turby

Aerodynamic wind turbines.

Aerodynamic wind turbines can be divided into two main types, horizontal axis wind turbines [HAWT] and vertical axis types [VAWT].
All big wind turbines are horizontal axis engines, just like the traditional Dutch windmills. Perhaps this familiarity has given the development of horizontal turbines a higher priority than that of vertical turbines. Modern HAWTs have usually a rather high efficiency but their construction is expensive. They have to be directed in the direction of the wind, either manually or by the use of a sensor-based control mechanism- adding again to its costs! Vertical-axis turbines do not need such a control system; it is completely irrelevant from which side the wind blows; the position of the rotor is always right.



Darrieus-Rotor. 100 kW-Anlagen werden in großer Zahl in Holland und Großbritannien gebaut. Eine Anlage im Megawattbereich läuft im Probebetrieb in Kanada.

The first aerodynamic vertical axis wind turbine was developed by the Frenchman Georges Darrieus and first patented in 1927. Its principle is a blade speed being a multiple of the wind speed resulting in an apparent wind throughout the whole revolution coming in as a headwind with only a limited variation in angle. Cyclist will recognize that effect, if one goes fast enough there is always headwind.
Seen from the blade the rotational movement of the blade generates a headwind that combines with the actual wind to the so called “apparent wind”. If the angle of attack of this apparent wind on the blade is greater than zero the lift force has a forward component that propels the turbine. The angle should not exceed 20° since at higher angles the flow along the blade is no longer laminar – which is required for a lift force - but becomes turbulent. This phenomenon is known as “stall”; it was the cause why mid 20th century small airplanes literally fell from the air when they climbed to steeply.
An angle of attack between zero and 20° requires a sufficiently high blade speed. Therefore a Darrieus turbine cannot be self starting; it needs to be brought to a sufficiently high blade speed by external means. But the lack of a control system to pint the turbine into the wind amply compensates for the disadvantage of not being self-starting.

The original Darrieus turbine suffered from negative features such as violent vibrations, a high noise level and a relatively low efficiency, thereby severely limiting its success.

Turby’s developers have analysed why these less favourable characteristics occur, and based upon their analysis developed a significantly improved concept for a vertical axis wind turbine - the Turby! Turby’s design eliminates all of the less desirable characteristics of Darrieus.
Note: Obviously the angle of attack during a revolution varies between – 20° and + 20°.

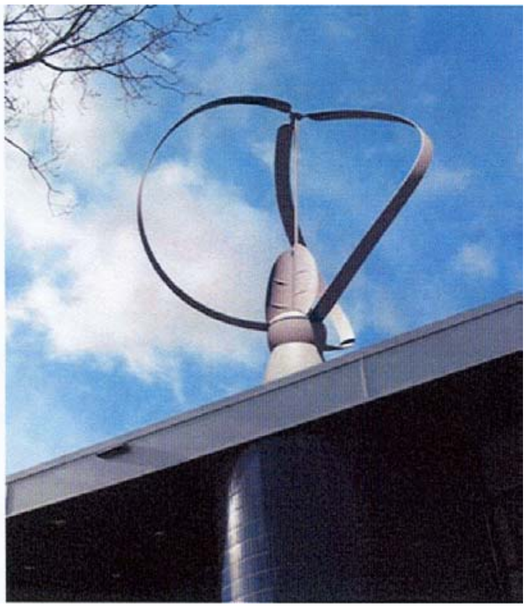
The Turby concept

The strong vibrations, high noise levels and the low efficiency characterising the Darrieus turbine are caused by the flow of air around the blade.
As explained the angle of attack of the apparent wind should not exceed 20°. The rotational speed of the turbine is for all parts of the blades the same, but since on a Darrieus turbine the distance between blade and shaft varies, the blade speed varies also.
On the blade parts near the shaft the self-generated headwind is low; at the curve of the blade, at the greatest distance from the shaft, its reaches a maximum.
The low blade speed close to the shaft results in an angle of attack of the apparent wind that over large parts of a revolution exceeds the allowable value with stall as a consequence.
There are moments of laminar flow and moments of turbulence resulting in intermittent lift power and drag on the blades and this causes vibrations.
Obviously the contribution of these blade parts to the driving force of the turbine is negligible.
In the curve of the blade, the speed of the headwind is high. The angle of attack of the apparent wind is small - almost zero – with the consequence that the component of the lift force in the direction of the rotation also nears zero. Also these parts of the blades do not contribute to the driving force.
However given to their high speed they do generate a high level of noise.
This explains why the Darrieus turbine vibrates heavily, makes a lot of noise and has a low efficiency.

The blades of Turby are designed with a fixed distance to the shaft.

To reduce the inevitable vibrations due to the change of the angle of attack between + 20° and – 20° resulting in a change of the mechanical stress in the blade two times per revolution, Turby's developers chose an odd number of blades (3) of a helical shape, making all changes pass off gradually.

As a result of these design choices, both vibrations and noise disappeared! And Turby showed an excellent efficiency.



Darrieus turbine
&

Turby

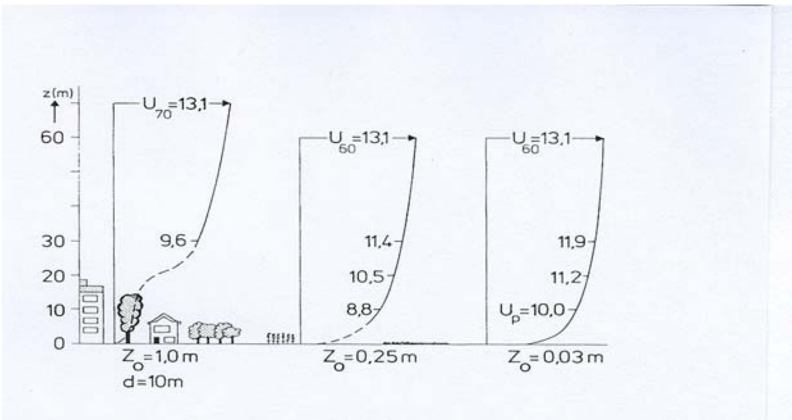
Wind

Wind is the result of pressure differences in the atmosphere; the speed and the direction of wind are determined by the ratio of the pressure differences and the distance between the centres of high and low pressure.
At sufficient height (100 meters) wind speed and direction will be the same in a large area. Closer to the ground the pattern changes due to the resistance the wind has met on its way.
At ground level wind speed is practically zero. Depending on the terrain over which the wind blows, speed increases faster or slower with increasing height. A surface of water offers little resistance and therefore at little height the wind is already very noticeable. That's why we always experience wind on the water[1].
In urban or built-up areas the wind is severely obstructed. There is air movement between buildings, but that is turbulence, not wind. Only above the average building height does the air movement become wind; the "reference height level" for wind in an urban or built-up area is 10 meters and higher.
Wind speed data are normally collected at a height of 10 m above ground level or are converted to that height. On the basis of the average wind speed at 10m height, the terrain roughness, and the geographic location, the expected wind speed distribution for an intended turbine placement can be calculated.

In summary:
The wind speed at a certain location is determined by the geographical location, the height and the terrain roughness.

[1] With thanks, this figure has been taken from [1] Wind Climate of the Netherlands

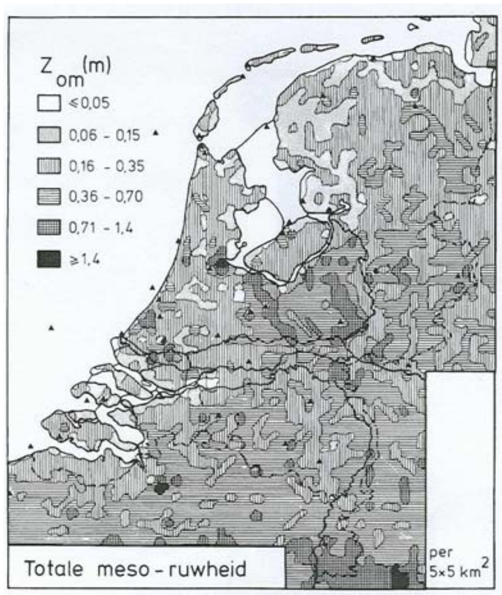
Figure 3.24



Windspeed profiles above different terrain roughness z_0 (and displacement height d) at a mesoscale wind speed
Um=13.1 m/s at approx. 60m

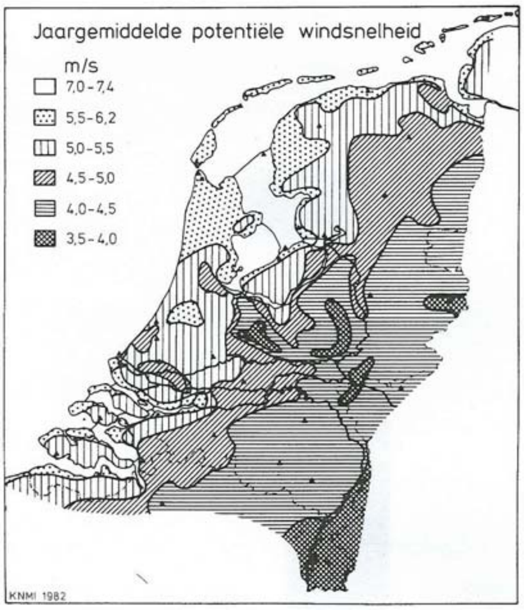
Note: the terrain roughness is indicated as the "roughness length" of the terrain and stated as a measure of length.
For the Netherlands the KNMI[2] has depicted these data in a "stain chart"[3].

The roughness:



[2] =Royal Netherlands Meteorological Institute
[3] With thanks, figures have been taken from [1] Wind Climate of the Netherlands

The average windspeed:

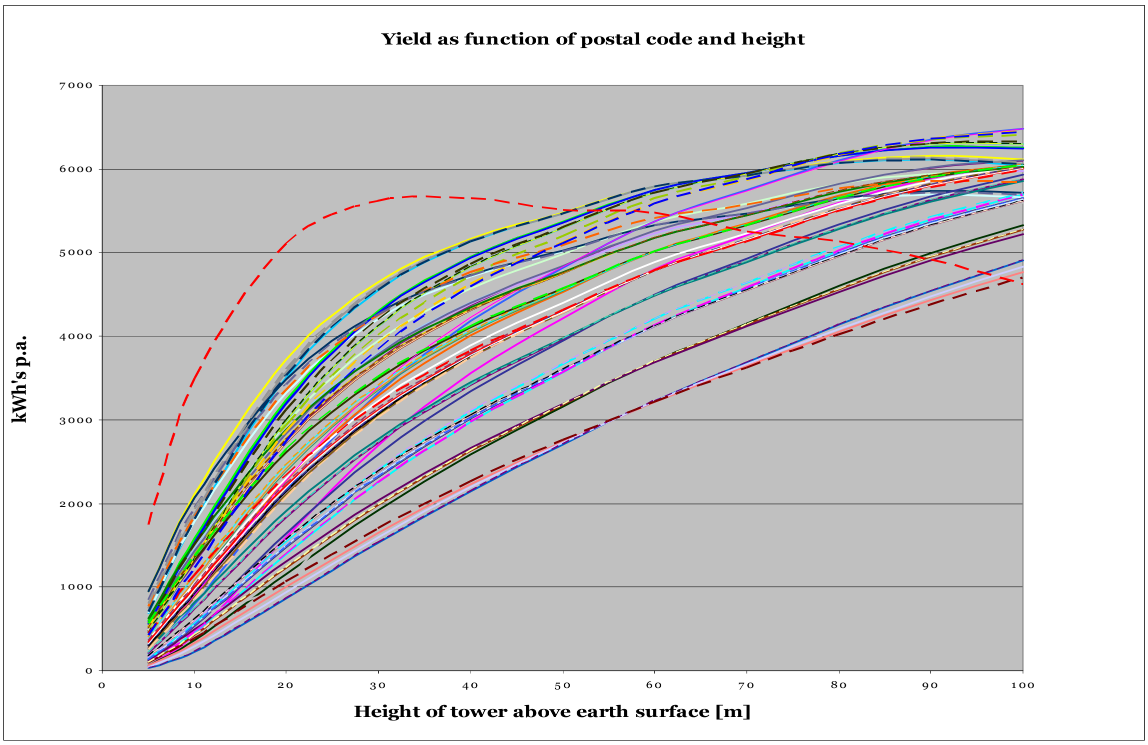


In cooperation with the Institute for Wind Energy of the Delft University of Technology the Turby team has developed a program to calculate the wind speed distribution at different heights and terrain roughnesses and used that to calculate the yield for one hundred areas in the Netherlands (distinguished by the first two numbers of the postcode) based on these data.

The wind speed distribution describes how many hours per year the wind blows at a certain speed at that location and at that height. Together with the power curve of the wind turbine, an output prognosis for *that* particular wind turbine at *that* particular location and *that* particular height can be calculated.

N.B. *For that reason it makes little sense to ask what the output of a wind turbine might be, as this question cannot be answered simply or in general terms. Knowledge of precise wind speed distribution data, at a proposed turbine height, for a particular location (terrain roughness), is essential to predict the power output of a wind turbine.*

As an example the results of these calculations for a hundred areas in the Netherlands are depicted in the diagram above. Note the increase in annual yield with increasing height, which is a result of the cube relationship between wind speed and wind energy.



Wind in built-up areas

In the preceding text the macro behaviour of wind was discussed. However, for wind turbines like Turby the micro behaviour is decisive and this can deviate significantly.

Wind follows the path of least resistance by going around obstacles. Along the edges of these obstacles the wind speed and the density increase. If a wind turbine is capable to utilize this increase in speed and density its energy production can be up to two times higher than when standing in an undisturbed flow.

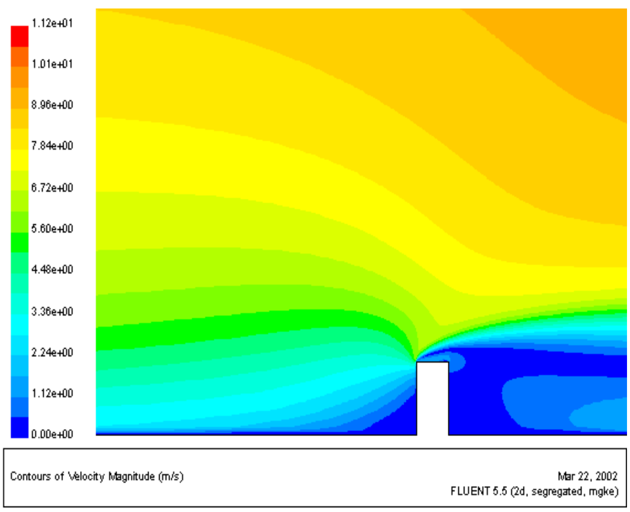
But placed on the lee side of a big obstacle, the output will reduce to half of the yield normally expected.

Since wind turbines for urban areas are small, averaging does not diminish these phenomena that consequently largely determine the yield.

Wind over buildings

Depicted below are the results of computer calculations showing the effect of an obstacle on the wind flow around that obstacle.

The picture below shows the influence of a long obstacle (e.g. a building) on the wind in the vicinity of that obstacle. Note that the deviations start long before the wind reaches the obstacle and continue far beyond it.

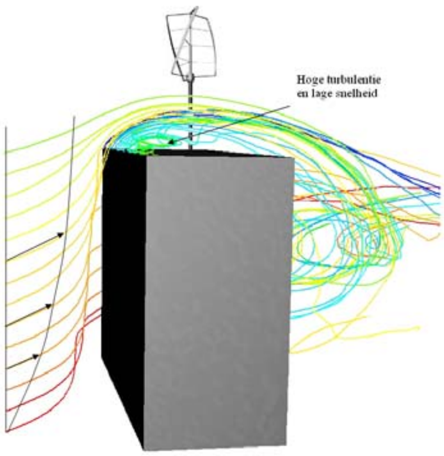


This figure makes it apparent that wind passes at an upward angle of 30 to 40 ° from the leading edge over the roof of the building. Underneath that line there is only turbulence and no wind. For that reason the turbine must be placed on a mast of sufficient height to bring it turbine above the turbulence.

But if we do that a potential advantage arises since the wind speed directly above the turbulence layer is 20-40% higher than that prior to encountering the building.

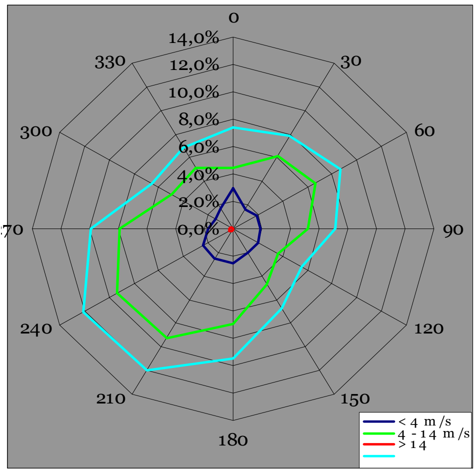
This 20 – 40% higher speed raised to the cube ($1,4^3 = 2,7$) offers a 2 - 3 times higher power than the undisturbed horizontal wind flow. This is potentially very interesting, provided that the wind turbine can utilize the wind approaching from such an angle.

Turby has been designed for just this purpose!



Prevailing wind direction and optimal position on the roof.

As explained a wind turbine on a roof should be placed above the turbulence layer. Consequently the closer a turbine is placed to the leading roof's edge for the prevailing wind the lower the turbine can be placed. And a lower mast is advantageous from the perspective of costs and height restrictions.
This would be true if the number of hours the wind blows from other directions than the prevailing one is negligible; however in Western Europe the percentage of time the wind blows from the prevailing direction as compared to an equal distribution is not that prominent.

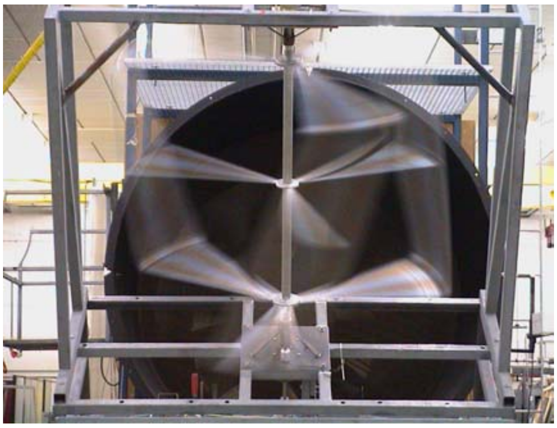


The chart above shows as an example the wind distribution for Schiphol airport. For the wind speeds relevant to small rooftop turbines (4–14 m/s range) the wind is about 35 % of the time blowing from the south-westerly quadrant; the remaining 65 % of the year the winds blows from other directions.

Conclusions:
The (only) correct placement is close to the middle of the roof on a mast with an approximate height of 5 m or above. If placed near the prevailing wind roof edge the yield will be reduced to about 1/3 of that of a centrally placed turbine.

Turby in the urban or built-up area

In the wind tunnel at Delft University of Technology, the Turby team has researched the reaction of its wind turbine to winds approaching from an angle from below, just as it occurs over buildings. The pictures below show the test set up.



The results bewildered the researchers. Horizontal axis wind turbines reach their optimum output when the wind comes in perpendicularly to the rotor.

Turby performed during these tests as if the wind came in perpendicularly at its full speed and showed an aerodynamic efficiency of close to 40%!

There are two explanations for this performance:

1 due to the helix-shaped blades an upward-slanting wind passes the airfoil perpendicularly in a nearly ideal way;
2 as a consequence of the 3-D character of the Turby rotor such a wind hits the blades on the leeside at full speed delivering extra driving power.

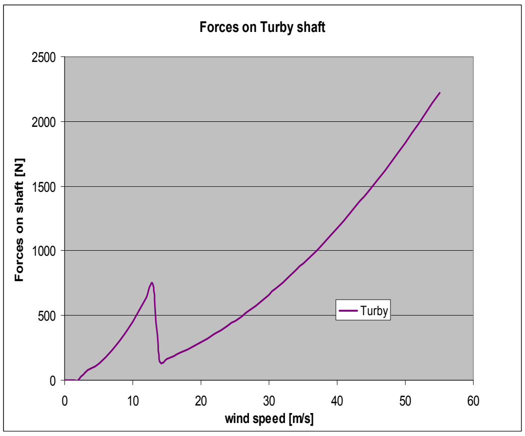
The tests indicate that the energy yield may well be up to two or more times higher than expected from the swept area of the rotor. Horizontal axis wind turbines cannot take advantage of an upwardly slanted incoming wind but suffer from the stronger forces on their rotors from such a wind.
Whether other vertical axis turbines can use this effect is unknown; in our research, no turbines similar to Turby have been found.

Typical placement.

The figure shows a Turby prototype on top of an apartment building placed approximately in the center of the roof, as indicated above.

Constructional provisions

The forces exercised on Turby and in turn by Turby on the roof are low. The chart below shows the relation between wind speed and force on the turbine.
Generally Turby is placed on a steel cross frame connected to the roof by chemical anchors or kept in position by ballast on its footplates.



The easiest type of roof to put Turby on is a concrete roof; channel plate-, gasconcrete -, or steel skeleton roofs generally require positioning of the fastening points on internal walls or rafters. Elevator shafts and similar rooftop structures are very suitable as a basis for Turby since they offer next to sufficient strength additional height: the mast can be shorter reducing the forces on the roof accordingly.

The building contractor familiar with its construction is capable to determine the proper location for the fastening points. Also the architect who knows both the building as the local building legislation can decide about the best location for a wind turbine.
The Turby team will be glad to supply the required data and is on demand available to coordinate between the experts involved.
The fitting of the fastening points and the cable throughput on the roof needs to be done by the roofing contractor to preserve the existing roofing warranties.

Masts

Turby is supplied with two different mast types depending on the required height. Up to 6 m height we supply spring supported masts and from 7.5 m onwards freestanding tubular masts. Examples of both are shown in the pictures below.
See also the dimensional drawing.
Both types are available in stainless steel and galvanized.

10 m freestanding stainless steel mast

6 m spring supported galvanized steel mast

Vibrations

"Vibration" and "resonance" deserve special attention. Although Turby is dynamically balanced to a balance quality of G 6.3 (ISO 1940/I) and therefore to a large extent vibration free, it is and remains a dynamic system that may introduce vibrations into the building it is attached to.

This occurs when the resonance frequency of the combination of mast and roof falls within the operating frequency range of the turbine, viz 1 - 10 Hz. In order to prevent adverse effects due to these dynamic phenomena we designed the two mast types having a resonance frequency just below 1 Hz.
The amplitude of a potential vibration of the support structure (and building) is in practice determined by the mass of the system.
A concrete roof will not pose problems since its resonance frequency is low and its mass high. A resonance - if occurring - will not be noticeable. This may be different with roof using a steel skeleton or wood construction. It is complicated to calculate the occurring resonance frequencies for these roofs; measuring is far simpler and cheaper.
Turby can offer you this service.

Turby on family houses

Turby is designed for use on higher buildings. Calculations show that at heights from 20 m upwards, a good yield can be expected. Below that height the yield is uncertain. A three storey family house has a height of about 10 m.
Since the turbine must be situated above the turbulence layer, a mast of at least 5 meters is required. The top of Turby will be at least 8m above the roof, which – from an esthetical point of view – is in most cases much too high for a family house. Furthermore the roof construction of family houses is in general too light to withstand the forces that extreme winds can exercise and the roof construction may not be suitable due to vibrations.

Conclusion:
Turby is not especially suited for use on family houses, but apartment buildings are certainly within its remit.

Turby

Economy

Renewable energy is not yet competitive with traditional electricity generated from large power plants.
The depreciation period for big power plants, whether oil-, coal-, natural gas-, or even nuclear fuelled, is in general 20 years. These plants operate 8000 hours per annum at an average load of 80%; the degree of utilization of the installed capacity is 73 %. Each kW generates 6400 kWh p.a. The investment per kW installed is in average €1500; an investment per kWh p.a. of € 0.24.

Turby has a nominal power of 2.5 kW and generates in average 3500 kWh p.a. The investment per kW Turby is €6000 (price level 2005); each kW delivers 1400 kWh p.a.; an investment of € 4.28.
Conclusion: The financial burden of Turby per kWh p.a. is 18 times higher than those of a traditional power plant.

An unbridgeable gap?

The fuel for Turby is free; there is neither maintenance required nor personnel to run it. Its operational costs are nil!
Turby's kWhs do not need to be delivered to the customer - they are already there on his roof. No costs for the use of electricity networks and no grid losses in those networks. (10 % of traditionally generated electricity is lost during transport and distribution).
No administrative, or overhead costs.

In average the sales price of traditionally generated kWhs is about ten times the depreciation costs.

Taking that into account, the costs comparison between Turby kWhs and traditionally generated electricity is far better than concluded earlier; a factor of 1.8 remains. Electricity from Turby is currently more expensive than traditional generation, but what will the future bring? Cost increases as:

- rising fuel costs
- wage hikes
- environmental requirements

will effect the costs of traditionally generated electricity, but not Turby's.
No doubt that these factors will within a few years change the economics of power generation in favour of Turby.
And, built in series, the price of Turby will reduce with about 20 – 40 %.
How will this effect the economy over Turby's life expectancy of 20 years?

If you:

- share our view that the stock of fossil energy is finite and the first signs of shortage are there;
- expect a rapid increase of the oil price as predicted recently by Matthew Simmons former adviser of the president of the USA Mr. G.W. Bush to US$ 200 – 250 a barrel;
- recognize the threat that in the coming decade's wars will be waged for the possession of the last barrels of oil;
- dare to be a pioneer, to show your conviction, your green heart and your innovativeness;
- want our children to inherit a liveable world,

then invest in a Turby.

Turby b.v.
Heuvelenweg 18
NL 7241 HZ Lochem
Tel + 31 573 256 358
Fax + 31 573 254 420
www.turby.nl
mail@turby.nl

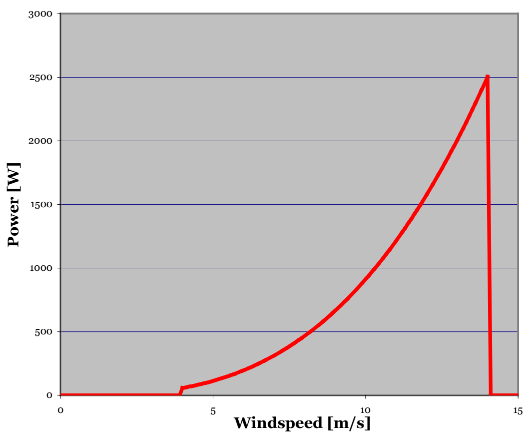
Turby *or not to be....*

![Turby]

Specification sheet January 2006

Operation		
Cut-in wind speed	4	m/s
Rated wind speed	14	m/s
Cut-out wind speed	14	m/s
Survival wind speed	55	m/s
Rated rotational speed	120 - 400	rpm
Rated blade speed	42	m/s
Rated power at 14 m/s	2.5	kW

Powercurve



Turbine		
Overall height	2890	mm
Weight (inc. blades)	136	kg
Base flange		
Diameter	250	mm
Bolt circle	230	mm
Bolt holes	6 x M10	
Rotor		
Diameter	1999	mm
Height	2650	mm
Rotorblades		
Number	3	
Material	composite	
Weight (3 blades)	14	kg

Generator		
Type	3-phase synchronous permanent magnet generator	
Rated voltage	250 V	
Rated current	6.3 A	
Peak brake current	60 A	during 250 ms
Rated Power	2.5 kW	
Overload	20 %	120 min
	50 %	30 min
	100 %	10 min

Converter			
Type	4 -quadrants AC-DC-AC		
Rated power	2.5 kW		
Peak power	3.0 kW		
Output	220-240 V	50 Hz	*60 Hz in development*
Weight	15 kg		
Integrated functions			
Control	Maximum Power Point tracker		
Start	Starting is achieved by the generator in motor operation		
Brake	Electrical, short circuiting of the generator		
Protection	Grid failure, anti-islanding, system faults, short circuit, mechanical faults, vibrations, blade rupture, imbalance.		
Overspeed protection	Two independent detection systems each triggering an independant brake action: - Generator frequency measurement in the converter - Generator voltage measurement on the generator terminals		

Standard masts

Spring supported				
Height	5.0 meter		6.0 meter	
Material	Galvanised steel	Stainless steel	Galvanised steel	Stainless steel
Diameter	159 mm	168 mm	159 mm	168 mm
Weight	235 kg	219 kg	252 kg	232 kg

Freestanding				
Height	7.5 meter		9.0 meter	
Material	Galvanised steel	Stainless steel	Galvanised steel	Stainless steel
Diameter	165 mm	168 mm	168 mm	168 mm
Weight	143 kg	154 kg	235 kg	263 kg

Standard foundations

Cross-frame	HEA 160, galvanised			
Basepoint	2 x 2 m	3 x 3 m	4 x 4 m	5 x 5 m
Weight	95 kg	160 kg	335 kg	550 kg

Tube	
Height	3 m
Diameter	300 x 280 mm

Other masts and foundations than mentioned in the specification are possible on request

Above specifications are subject to change without prececeding announcement and not binding the manufacturer.

Turby

Literature:

[1] Windklimaat van Nederland
J. Wieringa en P.J. Rijkoort
KNMI
ISBN 90 12 04466 9

[2] European Windatlas
Risø National Laboratory
ISBN 87/550/1482/8

[3] Klimatologische gegevens van Nederlandse stations
Publikatie nummer 150-27
KNMI
ISBN 90-369-2013-2

[4] Windwerkboek
Chris Westra en Herman Tossijn
Ekologische Uitgeverij Amsterdam
ISBN 90 6224 025 9

[5] Wind Energy Explained
Manwell, McGowan & Rogers
John Wiley & Sons Ltd
ISBN 0 471 49972 2

Turby

Price indication Januari 2006

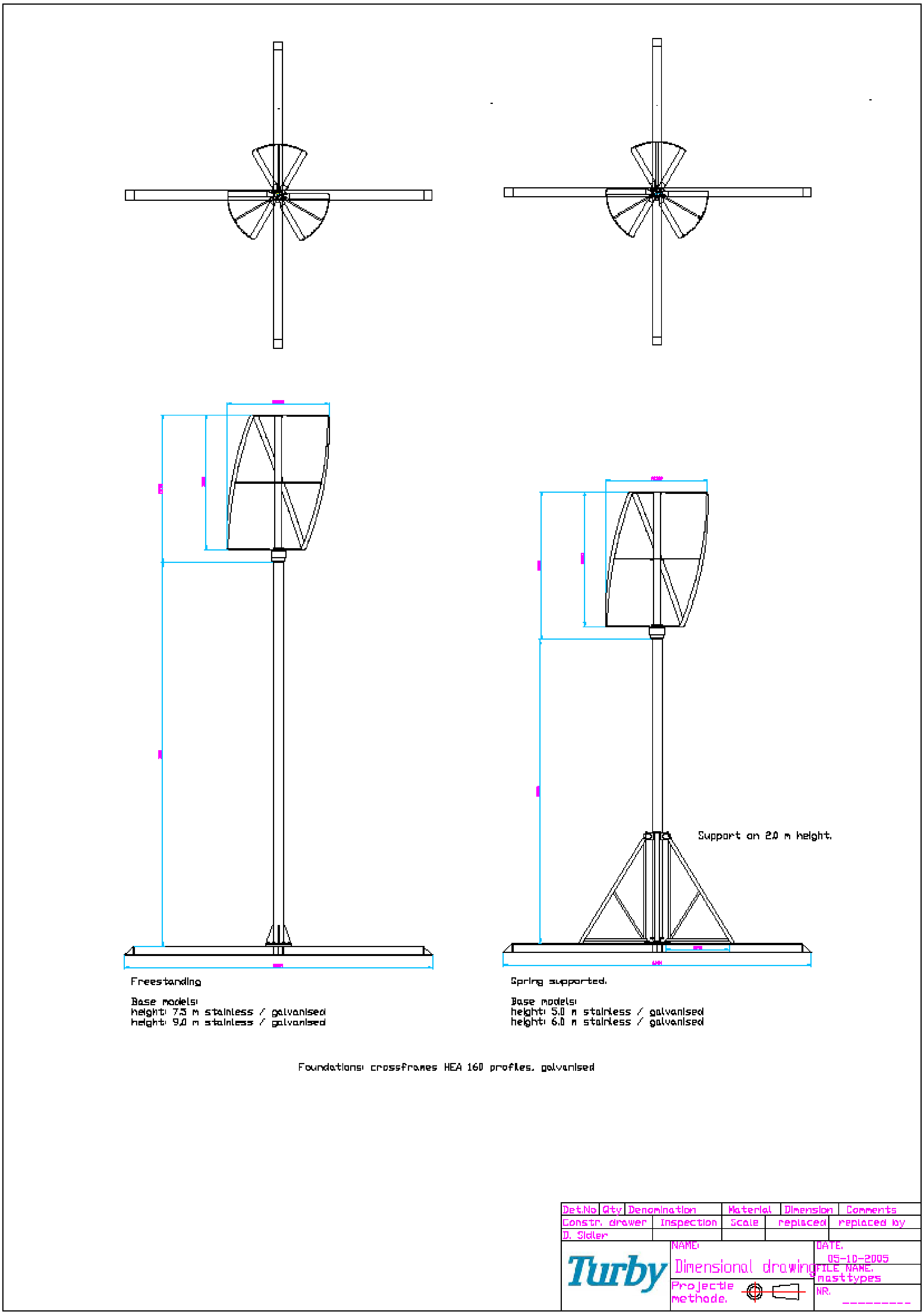
				Unit	Sales price
Turbine with convertor				piece	€ 11,466.00
Mast	Height [m]	Type			
	5,0 m	spring supported	galvanized	piece	€ 2,690.23
			stainless steel	piece	€ 3,718.32
	6,0 m	spring supported	galvanized	piece	€ 2,715.19
			stainless steel	piece	€ 3,857.16
	7,5 m	freestanding	galvanized	piece	€ 1,222.87
			stainless steel	piece	€ 2,138.28
	9,0 m	freestanding	galvanized	piece	€ 1,409.60
			stainless steel	piece	€ 2,464.80
Foundation	2 x 2 m	cross frame	HEA 160	piece	€ 837.07
	3 x 3 m	cross frame	HEA 160	piece	€ 1,017.73
	4 x 4 m	cross frame	HEA 160	piece	€ 1,447.92
	5 x 5 m	cross frame	HEA 160	piece	€ 1,962.83
	3 m	tube	Ø 300/280	piece	€ 1,932.43
Accessoires	mastdivision, optional		galvanized	piece	€ 445.20
			stainless steel	piece	€ 418.80
	e- connection	turbine - mast connection box		piece	€ 311.04
Installation	standard installation			piece	€ 1,725.00
	transport & packaging			km	p.m.
	vertical transport		Crane	hour	p.m.
	cabling between connection box and converter		à €15,83 pro m	m	p.m.
	cable throughput	supply of throughput in stainless steel		piece	€ 195.00
		labour: Drilling of hole Ø 50 x 100 mm max.		piece	€ 51.75
Civil works	calculation of roof loads			piece	€ 240.00
Consultancy	site inspection and consultancy (travel time included		à €126,50	hour	p.m.
	travelling costs and expenses				p.m.

General

Above prices are VAT excluded
valid for EC countries
ex works
and only binding with our order acceptance.

We expect to be able to present more competitive alternatives for the 5 and 6 m mast within a few months,
Other masts than mentioned in the price list are possible on request.

Turby


Support on 2.0 m height.
Freestanding
Base models:
height: 7.5 m stainless / galvanised
height: 9.0 m stainless / galvanised
Spring supported.
Base models:
height: 5.0 m stainless / galvanised
height: 6.0 m stainless / galvanised
Foundations: crossframes HEA 160 profiles, galvanised
Det.No
Qty
Denomination
Material
Dimension
Comments
Constr. drawer
Inspection
Scale
replaced
replaced by
D. Sidler
Turby
NAME:
Dimensional drawing
Projectie methode.
DATE.
05-10-2005
FILE NAME.
masttypes
NR.