Distributed Wind Energy

ELDER Eolic StreetLight Distributed Energy Resource
HAMMURABI Vertical Axis Confined Mills

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Abstract

Wind energy is becoming very popular on the world market and in particular on the European one as the most important renewable energy source after hydropower. The following table, taken from data of EWEA (European Wind Energy Association) published in 2009, highlights the importance of the sector, which covers 3.8% of European electricity, and the growth in double digits in almost all countries.

Table 1:% rate column gives the average annual growth projected from 2004 to 2010, the column wind / tot gives the percentage of energy produced by wind power.

Country\year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2010**	**rate %**	**wind/tot**
Austria	77	94	140	415	606	819	965	982	1200	**10,3%**	3,3%
Belgium	13	32	35	68	96	167	194	287	800	**35,4%**	0,7%
Bulgaria					10	10	36	70	200	**53,4%**	0,5%
Czech Rep			3	9	17	28	54	116	250	**46,8%**	0,4%
Denmark	2417	2489	2889	3116	3118	3128	3136	3125	4150	**4,2%**	21,3%
Finland	39	39	43	52	82	82	86	110	220	**15,1%**	0,3%
France	66	93	148	257	390	757	1567	2454	5300	**45,2%**	1,2%
Germany	6113	8754	11994	14609	16629	18415	20622	22247	25624	**6,4%**	7,0%
Greece	189	272	297	383	473	573	746	871	1500	**17,9%**	3,7%
Ireland	118	124	137	190	339	496	746	805	1326	**21,5%**	8,4%
Italy	**427**	**682**	**788**	**905**	**1266**	**1718**	**2123**	**2726**	**4500**	**19,9%**	**1,7%**
Netherlands	446	486	693	910	1079	1219	1558	1746	3000	**15,7%**	3,4%
Portugal	100	131	195	296	522	1022	1716	2150	3500	**31,2%**	9,3%
Spain	2235	3337	4825	6203	8264	10028	11623	15145	20000	**13,5%**	11,8%
Sweden	231	293	345	399	442	510	571	788	1665	**20,9%**	1,3%
UK	406	474	552	667	904	1332	1962	2389	5115	**28,1%**	1,8%
TOTALE	**12877**	**17300**	**23084**	**28479**	**34237**	**40304**	**47705**	**56011**	**78350**	**12,6%**	**3,8%**

Italy has an increase of 20% in the sector, which implies that, despite the current economic crisis, the investment in 2009 will be in the order of one billion €.

The real strength of Aeolian energy lies in the economic competitiveness as shown in the two figures that follow, both taken from the 2009 EWEA reports.
Figure 1 shows the distribution of the cost among various components for a wind power plant of more than 1 MW and gives a total value of 1227 euros per installed kW.
Figure 2 shows that the cost per kWh ranges from 5 to 10 euro cents, depending on the price of the installed kW, which can vary between 1200 and 1400 euros, and on the wind level of the area. This price is in line with the European average of the industrial cost of kWh which is about 8 cents, and that means that the field of macro-Aeolian can compete without subsidies with those of fossil fuels and nuclear energy.

	INVESTMENT (€1,000/MW)	SHARE OF TOTAL COST %
Turbine (ex works)	928	75.6
Grid connection	109	8.9
Foundation	80	6.5
Land rent	48	3.9
Electric installation	18	1.5
Consultancy	15	1.2
Financial costs	15	1.2
Road construction	11	0.9
Control systems	4	0.3
TOTAL	**1,227**	**100**

Figure 1: table of the costs of large power plants (more than 1 MW)

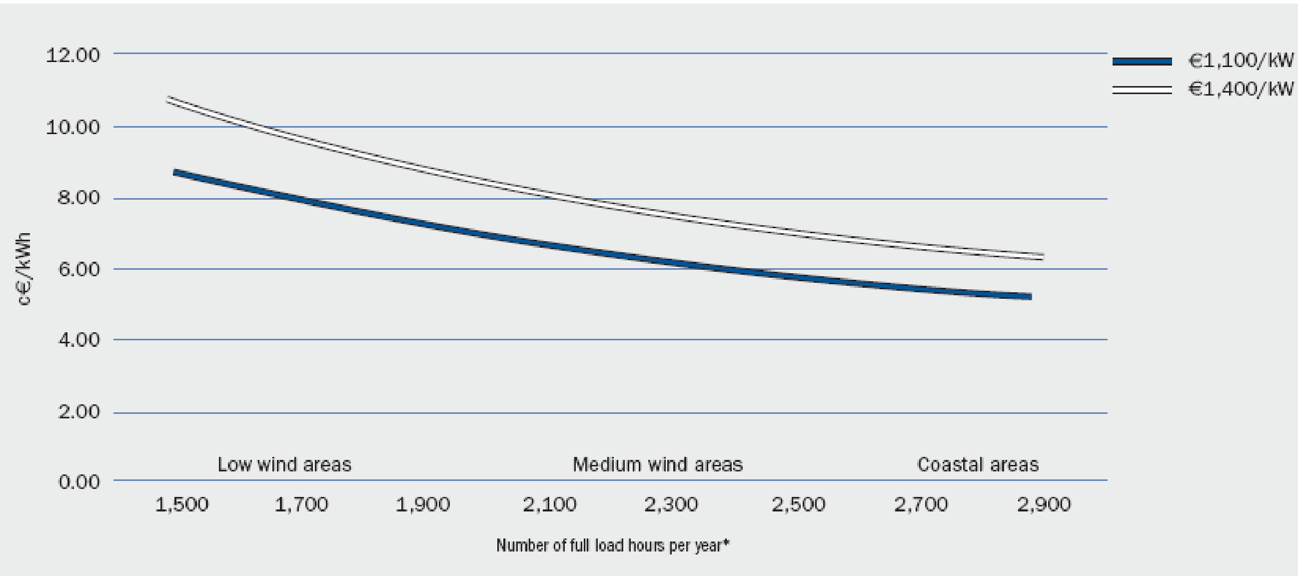

Figure 2: cost of kWh depending on the number of hours of wind per year

The limitations of wind energy are the large size and the risk of accidents. Large sizes are used to achieve economies of scale and to comply with low price standards strongly requested by the market. This obviously implies a high environmental impact, which can be minimized in off-shore solutions in spite of some technical problems, but which is visually evident for example on the Tuscan hills.
Accidents, generally due to extreme weather events, are an unavoidable and inherent risk of the technology. The figures that follow illustrate these issues.

Figure 3: blade for a wind turbine of 1.5 MW

Figure 4: collapse of a windmill February 2007

Figure 5: July 2005

Figure 6: impact of megaturbines on the landscape

Despite these limitations, the economies of scale and the interest of major manufacturers have moved the market towards big plants. The chart below illustrates this phenomenon.

FIGURE 1.14: Average size of wind turbines installed in a given year in the EU (1990-2007)

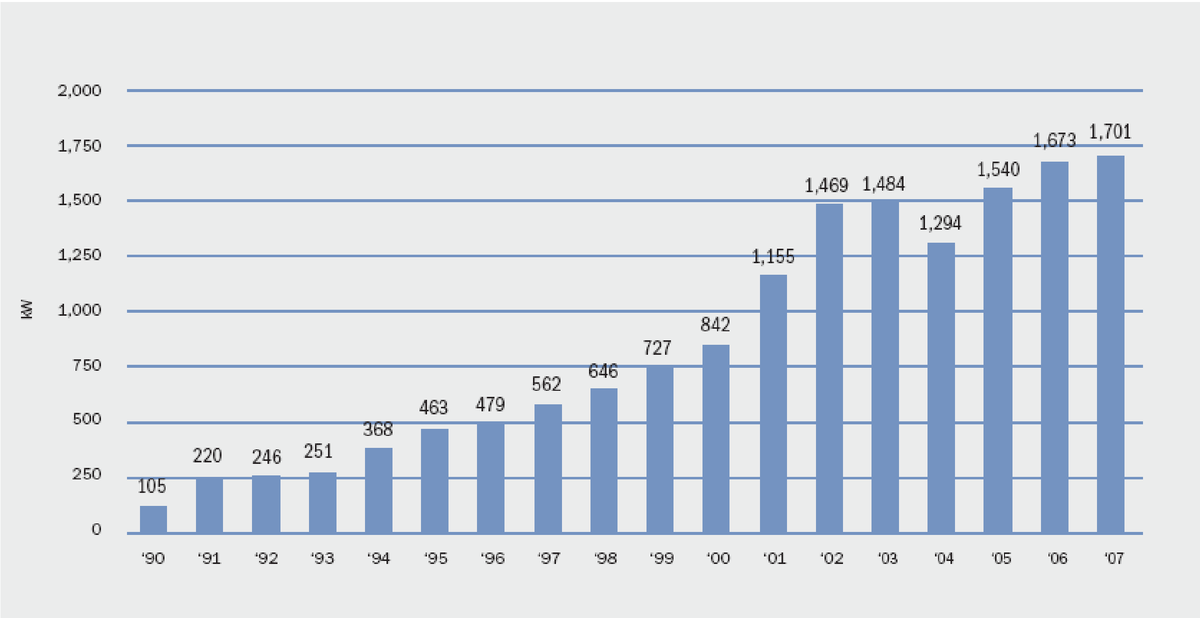

Figure 7: size of the installed power

In fact there was neither a proper industrial investment nor a corresponding development of research and this void begins to be filled only now.
In Italy the law of January 2009 restricts the development of large plants and promotes the mini and micro aeolian by assigning green credits to small plants.

The micro Aeolian

Wind is a distributed source of energy and therefore it is actually interesting to use small and distributed systems.
There are currently two market niches:

• range 100 kW -1 MW. Few systems have been produced in this range because the blade has a strong environmental impact and does not realize the economies of scale achievable with the MW and above

• range 0.5 - 100 kW. The interval, which is defined micro Aeolian, can be applied to small customers, including households, and offers a wide variety of models and solutions.

This latter niche is of great interest and has a big expansion potential even though some basic problems have to be solved:

a) The wind blade is a rotor mechanical device which is seen, rightly, as a potentially dangerous object. There is a certain psychological resistance that can be partly solved by using wind turbines with a vertical axis.

b) The wind blade must be used at the maximum possible distance from the ground because wind increases rapidly with altitude. Therefore appropriate support is needed and this may affect buildings used for habitation.
c) Costs are higher and efficiencies reduced but these problems can be overcome by a careful study of materials and innovative designs of blades and with an active control of the system.

As far as vertical axis blades go, the market offers already a variety of choices. Some examples, which are not exhaustive, are given in the figures below.


Giromill


Savonius


Gorlov


Darreius+ Savonius


2kW PackWind


Turbina in camera a vento

Figure 8: Some models with vertical axis

ELDER: Microeolico applied to streetlight poles

Eolic StreetLight Distributed Energy Resource

Small plants pose different problems of which the most relevant are:

- higher cost of KW installed. These are costs of 1500-2500 € / kW

- a small environmental impact but major difficulties of installation. If we exclude farmhouses, it is very difficult to integrate the system to buildings used for habitation and it is not worth managing micro Aeolian in remote and isolated locations.
- if we focus on the vertical axis blades we should also take into account a lower conversion efficiency.

Efficiency

The main limitation of micro Aeolian is the low efficiency of the type of turbines used. The Savonius model is activated even by moderate winds (1-2 m / s) but has a performance less than 20% while Darreius has a better efficiency (around to 25%) but operates only with winds greater than 5 m / s.
A useful alternative proposed by various models is the coupling of the two systems into a single rotor that exceeds the limits of efficiency of the Savonius and can work even with low speed winds.

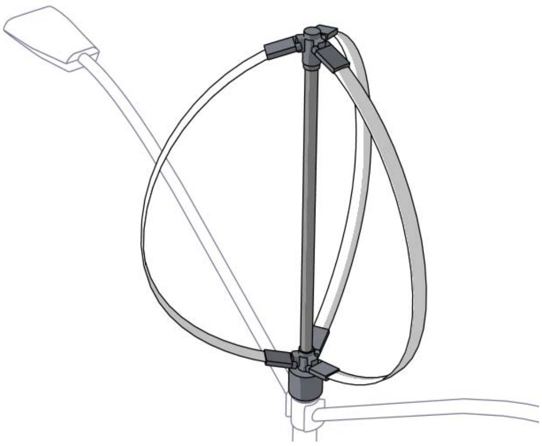

Figure 9: Darreius Model

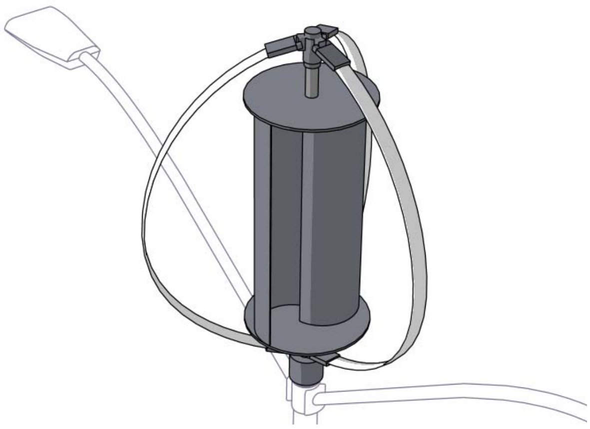

Figure 10: Savonoius-Darreius Integrated Model

Recently a system was devised on the basis of the Gorlov 2001 U.S. patent that seems to be the ideal candidate for low power installations. In fact it has the following characteristics:

- high efficiency (30%)
- lightweight
- excellent aesthetics

In the figure below you see some Gorlov systems already in commerce.Work is under way for the design and implementation of a lightweight (10-15 kg) system, made of composite and fiber, in both versions 0.75 and 1 kW and with a custom design. The dimensions are 2x1.5 m and 3x2 m, respectively.

Gorlov1

Gorlov2

Gorlov3

Figure 11: Some models of the Gorlov turbine in commerce

Distributed system and environmental impact

The use of small vertical axis wind turbines can be integrated to existing poles (typically poles for street lighting): e.g. ELDER Eolic StreetLight Distributed Energy Resource.

Alternatively the distributed system can be located in small poles on the roofs of apartment buildings.

The purposes of these solutions are many:

1. **Distributed use –** small size of 0.5-2 kW. This is a basic element of the project. The choice of small size allows the installation of generators on poles of 6-8 meters
2. **Streetlight poles** – it is possible to use the potential of the poles currently in use. A replacement of the pole may be necessary but the essential point is to exploit the sites and structures already in place. Of all the existing structures (power poles, towers, masts, roofs of buildings) streetlight poles seem to be the most suitable structures.
3. **Flat roofs of the houses** – even the roofs of tall houses can be used with vertical wind turbines using fairly short poles (3-4 meters) to secure access to the roof.
4. **Innovative design –** it is essential to select solutions and develop designs that are not only acceptable but desirable.
5. **Agreement with local authorities** for the management of distributed wind factories – Italian municipalities, large and small, are managing very large lighting parks. The park of Turin, for example consists of 79,000 points of light, that of Genoa of 50,000. The reference number used is a light point every ten inhabitants. Of course not all the points of light can be used but even installing plants only in the outskirts and along dual carriageways with space for installation, the estimate is that 20% of existing poles can be used. We can conclude that it is possible to install a power of 20 W per capita in a distributed micro aeolian way (1 KW per plant, a plant every 50 inhabitants of any Italian municipality), using only 20% of the existing lamp posts. In Italy this is equivalent to 1.2 GW that is a little less of the power installed so far.

An installation of 25 kW

The figure illustrates the possible implementation of a 25 kW plant that uses the poles of a parking lot.

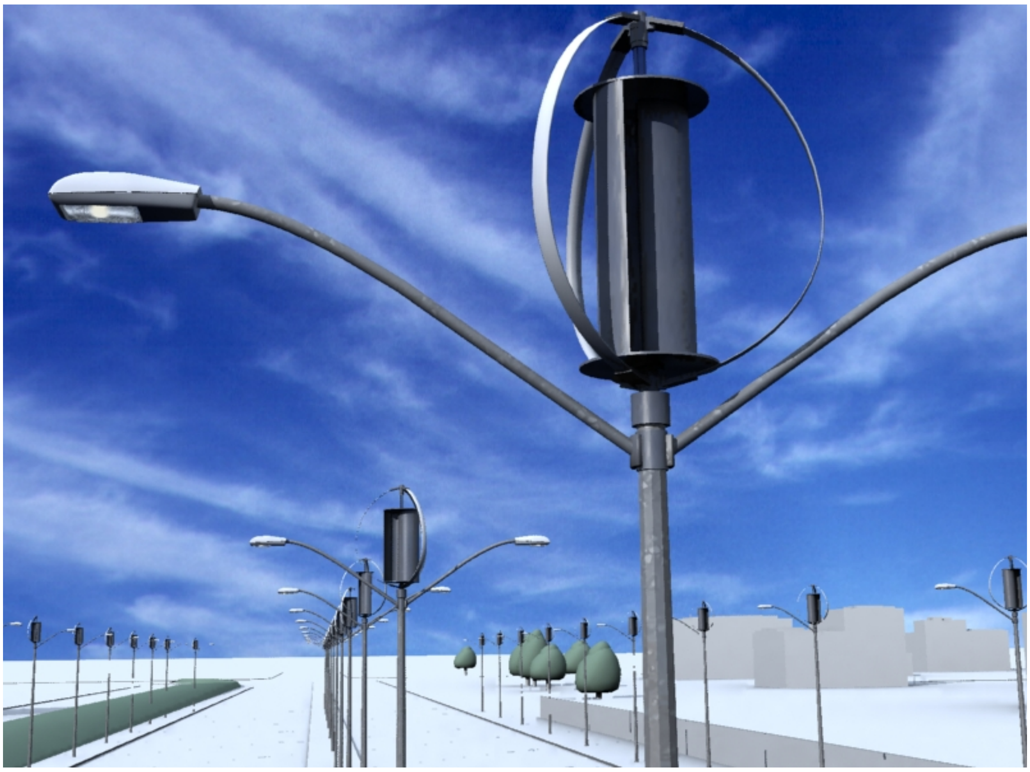

Figure 12: Micro Aeolian in a parking lot

The system consists of :

a) 50 poles with 0.5 kW turbines
b) Study of techniques for strengthening the support pole and its possible replacement
c) Generator coaxially coupled to the wind blade.
d) Inverter located at the base of the pole.
e) Wiring exploiting the existing channel.
f) Monitoring and controlling distributed and wireless

The material is available commercially and, if no time is spent for the improvement of wind turbines, the time for completion is in the order of 10 months.
The figure below shows the study for a wind farm to be installed and managed on a promenade. A type of Gorlov turbine was chosen for aesthetic reasons but also because we need a system capable of starting up with weak breezes and of having a good conversion efficiency.
A version of carbon fiber and composite Gorlov blade is currently under study.

Figure 13: Micro Aeolian in the sea

Hammurabi

The limit of the efficiency of wind blades is partly due to the fact that the flow of wind is not confined so that the conversion of the flow is only very partial. A very different case is the structure of the hydro systems where the confinement of the flow can reach very high yields above 90%. This concept is used in old mills. The tradition traces the first models back to Hammurabi, king of Babylon who in 1700 BC put an end to the power of the Sumerians and unified Mesopotamia. The use of observation towers to support mills with vertical axis is shown in the figure below.

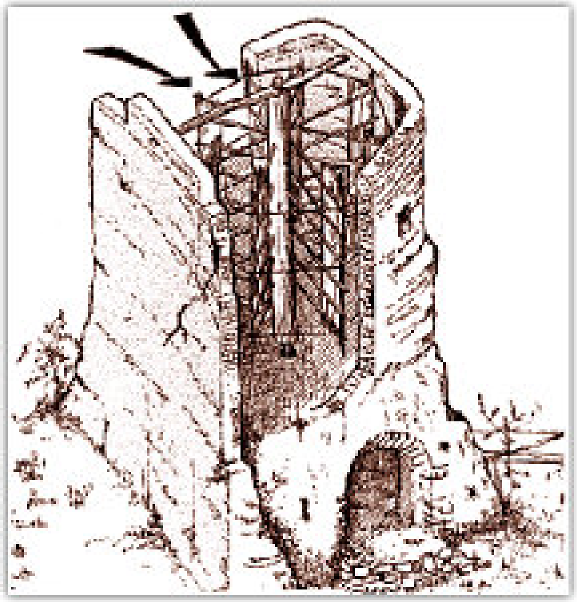

Figure 14: Drawing of an ancient Persian mill

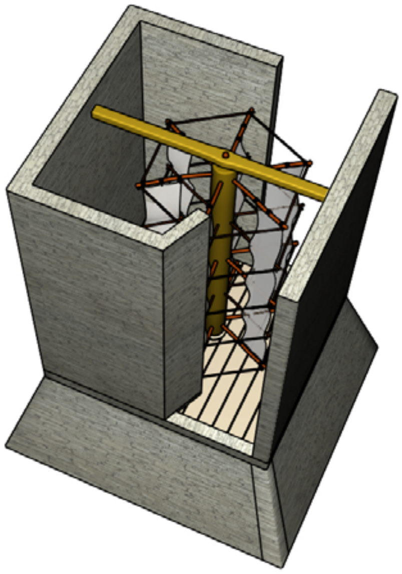

Figure 15: Diagram of the mill

The photos represent realizations of the concept. The ruins date back to 1500 years ago.

Figure 16: The ruins of an ancient Persian mill

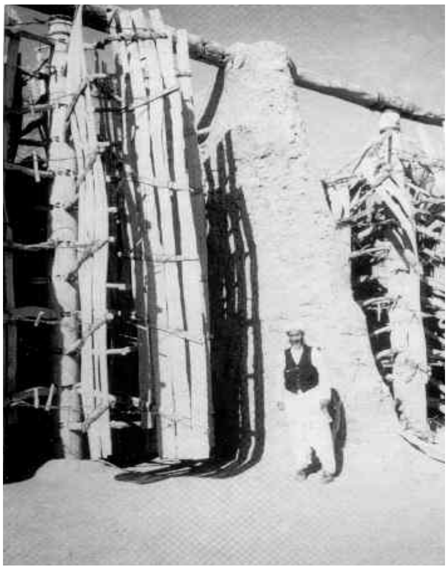

Figure 17: Mill of the late 19th C

The limit of the Persian mill is its low efficiency. These systems do not exceed 15% but with current techniques we can do much better.

Efficiency of the confined flow

The proposed system is a fiberglass rotating structure on a circular base with an opening suitable to channel and speed up the flow of air. This is driven at high speed onto a turbine, made of composite and carbon, which is small in size and discharges the flow into an opening at the back where the external structure creates a suitable depression.

This system does not achieve the efficiency of a Pelton water turbine but a first simulation suggests a yield of 50%, much higher than the best wind blades.

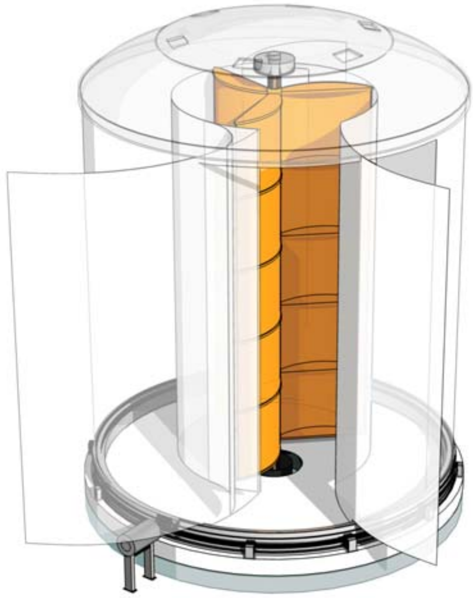

Figure 18: Adjustable structure made of fiberglass

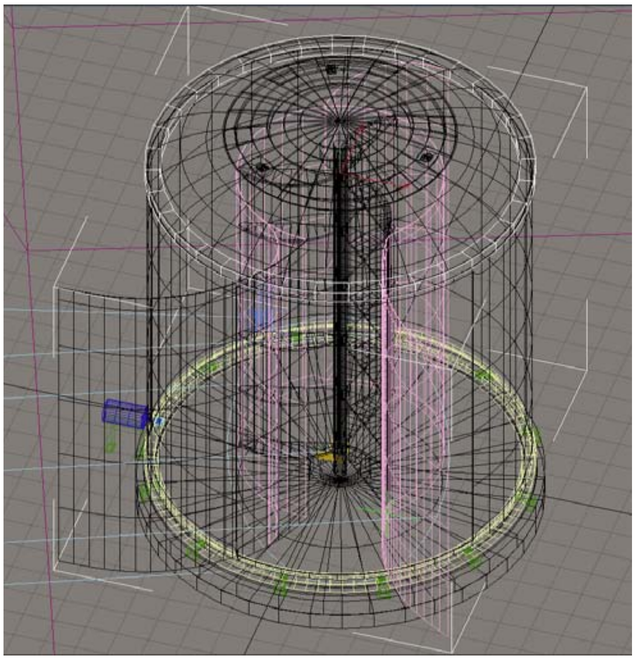

Figure 19: Meshing

There are several advantages in this structure:

a) Total security of the system that has no moving parts accessible from the outside
b) High efficiency. Depending on the wind velocity, yields between 40 and 50% are possible.
c) Start up even with very weak winds because the flow is channeled and the air impacts on a small and lightweight turbine.
d) Stability of the system which is essentially like a straight cylinder (base and height are approximately equal) and therefore it cannot be blown over even by strong winds.

The system is designed in two versions:
Micro: size of the cylinder 3x3 m. Power 10 m/s 3 kW
Mini: size 4x4 m. Power 10 m/s 5 kW

Localization of Hammurabi

A natural place in which to locate the fiberglass rods are the roofs of apartment buildings. These sites have a high altitude, 15-20 meters, and are naturally exposed to the wind. The visibility from the street is very limited and the invasivity is minimal.

Figure 20: Apartment building with an installation of three Hammurabi 5kW

Other solutions may come from existing facilities. In the figure you can see two examples of Cycladic mills (in Greece, there are currently thousands of these mills, abandoned and unused). It is not difficult to devise or reuse structures which are unobtrusive and have an internal part that can be used for the turbine.

Figura 21: Cycladic mills