Micro-aeolic in residential districts. A case study in S. Arsenio (South Italy)

Dora Francese

Full Professor

CITTAM

Via Tarsia 31, Naples, Italy

+390812538403

francese@unina.it

Emanuela Adamo

PhD Student

Department of Architecture

"Federico II°" University

Via Forno vecchio, Naples, Italy

+390812538414

emanuela.adamo@unina.it

Shoaib Khanmohammadi

Department of Mechanical Engineering,

Guilan University, Iran

shoaib.khanmohammadi@gmail.com

Abstract

The renewable energies are the sources of energy that are derived from inexhaustible natural resources. In other words, they are regenerated at the same speed of which they are consumed and that the people have at their disposal. In new millennium, we can find multiple typologies of renewable energies, such as the sun and wind.

The latter has had great development and evolution due to both the incentives that have been issued and the greatest attention that it is giving to the environment protection. At the beginning, the integration of wind power in the people life was very difficult, because the first plants had very big dimensions that result in a big trauma to the world population, named "NIMBY" (Not In My Back Yard). For this reason wind plant was evolved in a more soft idea that has brought both the change in the daily life of the modern society and the respect of the morphology, the urbanism and the city architecture. In Europe, the wind energy had a big increase getting better than the one in United States of America. Germany and Denmark are the greatest producers of wind energy, thanks to the quantity of the available rural spaces but also to the correct effect political strategies, among which the constant subsidies from the governments. in Italy, instead, the wind energy boom occurred at the end of the nineties. Anyhow the Mediterranean country is reaching the standards of the other European countries through the numerous installations in Puglia, Sicily and Campania,. However, so far we have only referred to megawatt or multi-megawatt plants, that have a big size and are installed outside the urban context or in ample hilly plains. For instance, in Italy such plants are installed in the great green plain in Puglia or along the Apennines's. Different is the micro wind plant that can be installed in an urban context and inside buildings thanks to the advanced technology and to the reduced dimensions . This kind of plant had a notable development in the last years and can easily fit with the daily life in Europe as well in other parts of the world. A case study of micro wind power in the new scenario is the (here proposed) case of Sant'Arsenio in Campania. It is a small and uninhabited village, that would allow the insertion of the equipment because of the free green spaces: this experimental work we describe here is aimed at promoting the coming back of citizens into the village.

1. Introduction

The natural evolution of an ancient village can be that of being employed for different use destination, or that of leaving the historic walls being decayed and the pre-industrial dwellings to be abandoned. In fact, mainly in the Italian internal regions, a great number of small towns of medieval settlement have been neglected either from the local authority or from the inhabitants' young sons and daughters, who preferred to settle their homes along the valley and forgetting the hilly zones with old stoned fabrics. These minor historic centres have lately being interested by phenomena of revival in which the first solution - promoting a new employment - has become the new target of local sensitive administrations and citizens.[1] After the national law which established the Recovery Plans (n. 457 /78), a number of old villages have been object of rehabilitation and requalification, but very seldom the object of these works actually brought again the life into them.

This paper deals with a research which has been carrying out between the University of Naples "Federico II", the "Guilan University" (Iran), the Municipality of Sant'Arsenio and the Association GAV[2], in which the old historical part of Sant'Arsenio, the so called "Borgo Serrone", will become object of test actions. The centre is in fact abandoned and needs to get a new destination, which has been proposed as touristic experimental settlement thus becoming a manifesto for the young generations. Some renewable energy systems will be installed, after the design of peculiar and appropriate technologies, and an experimental work will be carried out for evaluating the noise levels of such systems, in particular the wind catchers and the aeolic micro-structures.

2. Renewable energy: the wind

Being the main objective of Kyoto protocol that of reducing the Earth overheating due to greenhouse gasses produced by various nations, including Italy, the use of renewable sources of energy is requested to such countries so as to achieve this target.

As it is known, the renewable sources are the primary fonts that can produce almost unlimited energy without any risk of pollution that is instead caused by carbon fuel. A renewable energy source is commonly called as renewable or alternative.[3]

The production of clean energy can be based on the following sources:

- Solar radiation, which produce chemical energy, thermal energy and electric energy;
- biomass fuel, which is used for feeding plants for thermal energy and cogeneration of heat and electricity;
- sea flooding and waves;
- meteoric downfall, which produces hydroelectric energy by means of level difference;
- wind, which produces dynamic and electric energy.

The production of wind energy is based on the Eolic Plants, which are technological systems employing the wind energy in active and passive way. In particular, on one hand, the passive wind energy systems use the elements constituting the plant without any external action. A typical example is the wind tower, mainly used in middle east building. On the other hand, the active wind energy is derived from external component which produce power to be transformed in energy.

The installation of this latter category of plants strictly depends on the wind speed which provides maximum efficiency to the plant. The tool used to evaluate the proper installation conditions is the anemometer and a flag with a wind direction marker.

Figure 1: Typical anemometer for wind catching (search http://www.directindustry.it/prod/vaisala/product-7108-473884.html)

[1] See for the minor historic centres' destiny: Guidoni E., *L'architettura popolare italiana*, La Terza, Bari 1980; Ausiello G., Calvino C., *La tradizione costruttiva mediterranea*, Luciano ed., Napoli 1999; D Francese, *Il benessere negli interventi di recupero edilizio*, Diade, Padova 2002.

[2] Gruppo Architetti Vallo di diano (Team of Architects of the region Valley of Diano)

[3] See the definition in *Treccanni Dictionary* available:

The verification of wind intensity is very complex and the outcomes are often not much reliable. Therefore, the identification of wind energy capability for a particular area is better obtained through data on long-time base regarding the direction and speed of the wind with respect to the height; in particular, the zone morphology impacts on the wind speed at ground level: more the ground is corrugated (i.e. slope gradients, woods, buildings) more the wind will face obstacles and thus reduce its speed.

In addition to the wind analysis, a territorial analysis should be carried out about the diversity in type of houses, historical and artistic assets and landscape values. Therefore, multiple simulations are required to optimize the overall production on yearly basis. In fact, it is important to evaluate the advantages of information on the environment and their impact on the targets.

After the above mentioned analysis, the type of wind farm shall be selected according to the subject area. Basically, those systems can be classified as follows: Low power plants up to 20 kW, known as “micro-aeolic”, and plants with nominal power between 100 kW and 1,5 MW, as known as “mega-aeolic”.

Figure 2: Micro-aeolic (left) and Mega-aeolic (right) plants (by http://www.syncronia.com/microeolico-made-in-italy/it3049f) (http://www.iltaccoditalia.info/sito/index-a.asp?id=13407)

The first category is also called “domestic wind farm” since they are usually installed within civil buildings or in urban centres so as to produce sufficient energy to satisfy the need of a single family (2 or 3 persons) or to feed lighting systems in open spaces. This kind of plants is characterized by a reduced height and a small size.
Differently, the mega wind farm are composed by a supporting tower with an height over 100 meters and some blades of about 12 meters diameter. The blades, which are part of the wind generator and collect the wind transforming it in kinematic energy, are usually placed at a distance equal to 3-5 times the diameter of the blade, if the turbines are installed on the same line. Otherwise, if the turbines are installed on the same row (typical configuration of the “wind farm”), the blades are placed at a distance equal to 5-7 times the diameter of the blades.

In addition to the above classification, the wind plants can be also categorized in

- Horizontal Axis Wind Turbine ;
- Vertical Axis Wind Turbine.

In case of an historical centre, we believe that the best solution is a plant with the vertical axis because the position of the turbine actually helps to gain all the wind power, especially where there is low pressure like the one available within such centres.

3. Wind energy calculation

The energy of wind is the kinetic energy of stream of a flow of air of mass m at a speed of V. The calculation of m is a problem. One way to measure the density is to express it in terms of volume and density $\rho = m/V$. The volume can be written as $V = AL$. Here A is the cross sectional area perpendicular to the wind stream and L is the horizontal distance. If it is assumed $L = Vt$ wind energy (E) can be expressed as:

$$E = \frac{1}{2}\rho AV^3 t$$

If m is the mass of air passing through the wind turbine per unit of time the change in momentum is $P - m(V_2 - V_1)$ which is equal to the produced trust, where V_2 and V_1 are the downstream and upstream speeds at a considerable distance from the rotor. The absorbed power P and the rate of kinetic energy change can be written as:

$$P = m(V_1 - V_2)\bar{V}$$

$$E_k = \frac{1}{2}m(V_1^2 - V_2^2)$$

The two mentioned equation should be equal because the retardation of the wind before the rotor $/V_1 - \bar{V}/$ is equal to retardation of wind after behind it $/V_2 - \overline{V/}$ and also it is assumed that the velocity through the rotor is axial and velocity is uniform over the vane area. Then the power exerted by rotor can be shown as:

$$P = \rho A\bar{V}^2(V_1 - V_2) = \rho A\left(\frac{V_1 + V_2}{2}\right)(V_1 - V_2)$$

$$P = \rho A\frac{V_1^3}{4}[(1+\alpha)(1-\alpha^2)] \quad , \quad \alpha = \frac{V_2}{V_1}$$

Analytical calculation show that for $\alpha = \frac{1}{3}$ the power P is in the maximum case. It can be concluded that when the final wind velocity V_2 is equal to one third of the upstream velocity V_1 the power is maximum. Hence, the maximum power which can be recovered is $\rho AV_1^3\frac{8}{27}$ as compared with the energy of original wind which is $\frac{1}{2}\rho AV_1^3$; it can be said that an ideal wind turbine could recover $\frac{16}{27}$ (or 0.593) of the power in the wind.
Wind turbine manufacturers usually provide turbine power curves at different wind speeds. If the power curve of the turbine is not available, the following equation can be used to estimate the power output of a wind turbine:

$$P_{tur} = \begin{vmatrix} 0 & if & V < V_c \\ P_{er}\left(\dfrac{V^n - V_c^n}{V_r^m - V_c^n}\right) & if & V_c < V < V_r \\ P_{er} & if & V_r < V < V_f \end{vmatrix}$$

where I_{er} is the rated electrical power, V (m/s) is the wind speed, V_c (m/s) is the cut-in wind speed; V_r (m/s) is the rated wind speed, and V_f (m/s) is the cut-off wind speed. Setting m=2 is often sufficiently accurate for analysis of wind power systems.

4. Case Study: Borgo Serrone-Sant'Arsenio

The here described research has the intention of applying some of the aforesaid renewable technologies to a small historic centre in south Italy.

The first mentioned housing cluster is characterized, according to the meaning of its Greek name "Serrone", by the inaccessibility of the place. Among '500 and '700 it had its maximum development until becoming a unique model and a typical residential example in the whole valley context for its architectural characteristics and for the adopted rural typologies. It is situated on the highest part of the country and today it is easily accessible via stone stairways linked with roadway. The whole archaic urban structure is constituted by a series of houses built over the naked rock, whose entry is characterized by lithic portals. The linear urban conformation is unravelled upward by the lower part to whose vertex an ancient military-residential small fortress has been located since 1598. Thanks to its position the land has plenty of interesting natural sites and provides a breath-taking panorama where Vallo di Diano draws the main attention. [4]

The climatic data gathered from the closest weather station to the village, Palinuro station, show that the reference climatic zone is the zone D (1440 < DD* < 2100). DD (Degrees per Day)[5] is a unit to measure the thermal energy requirements. Such data are collected during a conventional heating period and represent the yearly sum of positive or negative difference between the nominal comfort temperature, 20° for Italy, and the daily average external temperature.

CAPO PALINURO (SA) 185 m. s.l.m. (a.s.l.) – TEMPERATURE											
MM	Tm	Tx 1d	Tx 2d	Tx 3d	Txm	Tn 1d	Tn 2d	Tn 3d	Tnm	Tx P85-15	Tn P85-15
Gen(Jan)	10.5	13.3	13.4	13.2	13.3	7.8	7.8	7.7	7.8	4.6	5.6
Feb(Feb)	10.2	13.4	13.1	13.4	13.3	7.4	7.1	7.0	7.2	5.0	6.0
Mar(Mar)	11.7	14.0	14.7	16.0	14.9	7.7	8.3	9.4	8.5	5.4	5.6
Apr(Apr)	13.8	16.9	16.6	18.2	17.2	10.3	9.7	11.2	10.4	5.4	4.6
Mag(May)	17.9	20.0	21.4	22.9	21.5	13.0	14.3	15.5	14.3	6.2	5.0
Giu(Jun)	21.7	24.5	25.3	26.6	25.5	17.0	17.7	18.8	17.9	5.0	4.8
Lug(Jul)	24.4	27.6	28.2	29.1	28.3	19.8	20.6	21.2	20.6	3.8	4.2
Ago(Aug)	25.0	29.5	29.1	28.1	28.9	21.8	21.5	20.3	21.2	3.8	4.4
Set(Sep)	22.3	26.9	26.2	24.9	26.0	19.2	18.7	17.6	18.5	4.8	5.2
Ott(Oct)	18.6	23.2	22.4	20.3	21.9	16.4	15.8	13.9	15.3	5.6	6.0
Nov(Nov)	14.4	19.1	17.4	15.7	17.4	12.9	11.4	9.8	11.4	5.2	6.2
Dic(Dec)	11.7	14.8	14.6	13.9	14.4	9.0	9.2	8.6	8.9	4.4	5.6
MM	NgTn ≤ 0	NgTn ≤ -5	NgTx ≥ 25	NgTx ≥ 30	GrGi >0	GrGi >5	GrGi _18	Txx	An Tx	Tnn	An Tn
Gen(Jan)	0.3	0.0	0.0	0.0	328	172	233	19.6	1994	-0.8	1985
Feb(Feb)	0.1	0.0	0.0	0.0	288	148	218	23.4	1977	-0.2	1983
Mar(Mar)	0.2	0.0	0.0	0.0	368	211	198	26.2	1994	-0.4	1987
Apr(Apr)	0.0	0.0	0.3	0.0	421	269	129	28.4	1971	3.8	1973
Mag(May)	0.0	0.0	4.3	0.0	565	407	35	33.4	1973	8.0	1992
Giu(Jun)	0.0	0.0	17.9	1.6	651	501	1	36.4	1982	11.4	1976
Lug(Jul)	0.0	0.0	30.2	5.7	766	609	0	38.4	1988	14.6	1978
Ago(Aug)	0.0	0.0	29.9	9.2	772	618	0	37.6	1999	13.4	1977
Set(Sep)	0.0	0.0	21.5	1.4	676	524	2	34.0	1994	9.2	1977
Ott(Oct)	0.0	0.0	4.3	0.0	574	420	24	30.8	1990	6.0	1997
Nov(Nov)	0.0	0.0	0.2	0.0	416	271	107	27.4	1992	2.4	1981
Dic(Dec)	0.0	0.0	0.0	0.0	348	199	190	22.8	1989	0.4	1980

Figure 4: Climatic informations by clima.meteoam.it

According to the proposed experimental work, the dominant winds were analysed. The following main wind types have been recorded in the region:

- the “Tramontana” coming from the north;

Figure 5: Tramontana in Borgo Serrone drawing by Esposito-Orizzonte-Sportiello-Chianese

[4] See the history on http://www.comune.santarsenio.sa.it/pagina-8.html

[5] The Degree Days are defined and fixed by the Italian Law 10/91.

- the “Scirocco”, coming from south-east.

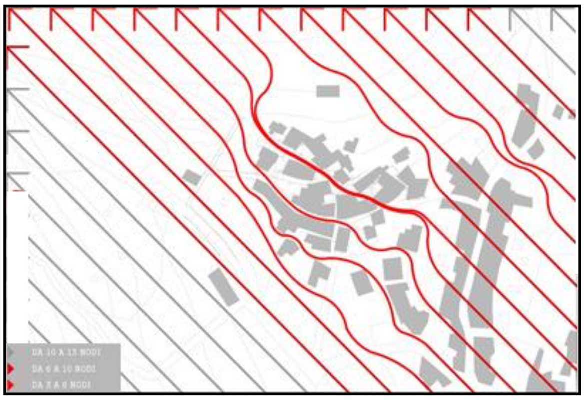

Figure 6: Scirocco in Borgo Serrone drawing by Esposito-Orizzonte-Sportiello-Chianese

The micro wind farm penetration in this village is bind with the historical nature of the place. Therefore, a solution was studied to overcome this obstacle and define a system that can integrate smoothly with the buildings and can create low impacts from visual, social and acoustic perspectives.

After having performed the historical and climatic study of the suburb, some solutions from both point of views, planning and energy saving, were developed. In the specific case, one has been already designed in the northern part of the village, and selected for a new use destination. The pre-existing plant was integrated with vertical micro-aeolic shovels that allows to satisfy the environmental requirement of total zero carbon impact.

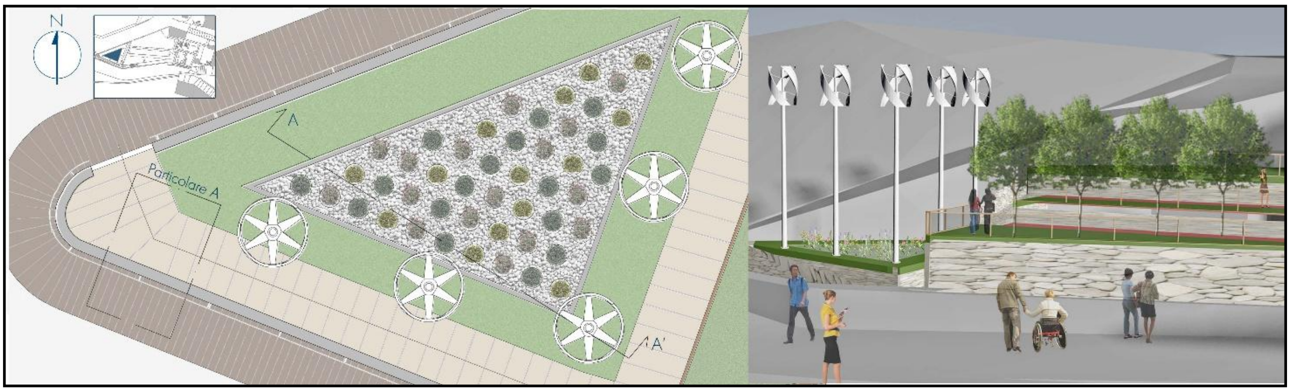

Figure 7: A new microeolic system designed by Arpino-Cerino-Cicchiello-Consalvo

The first two impacts can be mitigated through the integration with the fabrics and by stimulating the population about the needed changes and the methodology. Nevertheless, the mitigation of the acoustic impact is still a tough topic since so far the research has been focused on a solution to reduce the noise produced by big size wind generator. In fact, for the micro wind plants, the acoustic issue has not yet been analysed in a proper manner.

To mitigate this problem and to find a common solution, meaning to fit both the vertical and horizontal shovel plants, it will be needed to carry out an experimentation that could yield to the realization of various prototypes. The comparison of the mitigation levels or the removal of the noises coming from the single systems will definitely provide the optimal solution.

References

- AA.VV., 2013, *Sistemi eolici. Impianti micro, mini e multi megawatt,* Maggioli Editore, Rimini.
- AA.VV., 2008, *Architettura energetica. Ricerche e proposte per una visione energetica dell'ambiente costruito,* Gangemi Editore, Roma.
- Masullo, A., 2013, *Qualità vs Quantità. Dalla decrescita a una nuova economia*, Lit Edizioni, Roma.
- Palumbo, M., 2012, *Architettura produttiva:principi di progettazione ecologica*. Maggioli Editore, Rimini.
- Gazzetta ufficiale GU L 130 del 15.5.2002
- AA. VV., Treccani Dictionary. Available at: http://www.treccani.it/vocabolario/
- http://www.comune.santarsenio.sa.it/pagina-8.htm