Chapter 12
The Re-invention of the Tower House for the Construction of Green Buildings NZEB, Integrated With the Vertical Axis Small Wind System

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Abstract Nowadays the cultural and economic context aims to create a sustainable "carbon zero" society through energy-efficient green buildings NZEB, but it has so far overlooked a construction type widely spread throughout Europe, especially in the Middle Ages, and that in Italy still characterizes the most beautiful landscapes of Tuscany and other cities: the tower-house. The aim of the research was to verify the possibility of reinventing the type of the familiar tower-house, which is intrinsically directed to conquer the height and therefore higher wind conditions, assuming the installation on the top of a small wind system to use wind energy, to make the building energetically self-sufficient. This building is designed from a wooden structure of a deciduous tree widespread in the Italian region of Basilicata, the Turkish Oak, which, subject to processes of hygrothermal conditioning, can be transformed into the base material to compose laminated timber beams and pillars, able to guarantee a load of exercise, to bending stress, equal to 40.9 N/mm^2, as followed by tests in the Laboratory of Engineering of the University of Basilicata, Potenza. With normal wind conditions in the city of Potenza (average of 6.5 m/s), a 5 kW wind turbine mounted at 25 m tall on a 13 m high building is able to provide all the energy the building needs, with its attractive tapered oval top that minimizes turbulence. Entirely made with structures, finishes and natural insulation, the building is a sign in the landscape, history and future together.

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12.1 Introduction

In the landscape of the renewable sources, the exploitation of wind energy presents itself as the most dynamic factor in the market.

In Italy, according to the GSE (Electricity Manager), the target of 26.4 % of electricity from renewable sources by 2020, has already been reached. "*In 2012, the production of electricity from renewable sources was 92,222 GWh, with an installed capacity of 47,345 MW. At the first place hydropower, which provided 41,875 GWh [45.4 %], followed by solar (photovoltaic) with 18,862 GWh [20.5 %], and with 13,407 GWh from wind sources [14.5 %]. Bioenergy have provided 12,487 GWh [13.5 %] and geothermal 5,592 GWh [6.1 %]*".[1]

The Global Wind Energy Council estimated that by 2020 the wind power could easily cover up to 12 % of electricity world production, avoiding the emission of about 10 billion tons of carbon dioxide.

All analysts are convinced that, in the short run, no other renewable sources can offer a contribution on a global scale than wind power in reducing "*climate-altering*" emissions. The spread of such wind power plants is favored, as well as to the possibility of installation of offshore fields (the seas are areas of wind with the greatest speed, even in Italy), by reducing the size of the installations, their typological evolution, with the spread of vertical axis turbines, more easily integrated into a building structure, and their study as an object not only functional, but of design, after which they make up appendages consciously formalized in the profile of the building against the sky (see Fig. 12.1).

There are some research that place in relation the efficiency and performances of different types of wind turbines, depending on the speed of the wind expected in the implantation site, and it is therefore possible to optimize the choice of the system in function of the specific characteristics of the project (Fig. 12.2 displays Johnson's performance comparison of power coefficient versus tip speed ratio for some of the most common wind turbine designs).

12.2 Aim of the Research

The European Community, with the Directive 2010/31/EU, transposed into Italian with DL n. 63 of 4 June 2013, decided that starting from the 1st January 2019 all public buildings, and from the 1st January 2021 all private, must be *Net Zero Energy Building*, which, despite being connected to the network, must have reduced consumption of power for heating, cooling and domestic hot water production, and will have to produce renewable electricity they need for their operation.

[1] www.infoprogetto.it/202020/ date 17/09/2013.

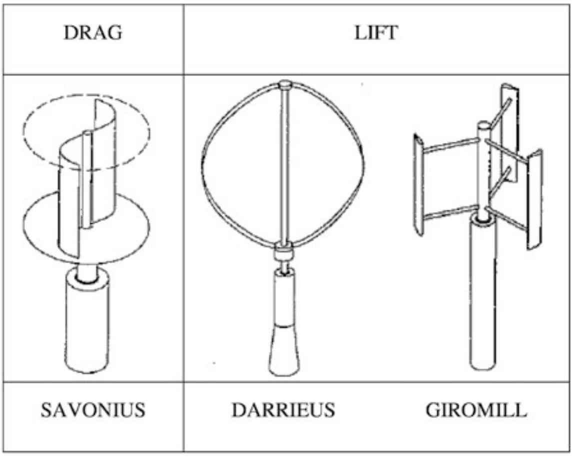

Fig. 12.1 Wind turbine classification according to the mechanism of operation

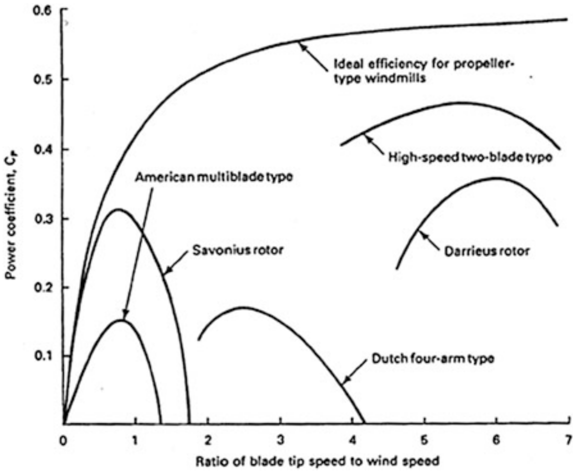

Fig. 12.2 Typical performances of wind energy systems (wind turbine $C_p - \lambda$ comparison) [1]

For this reason it's probable that in the future mini-wind turbines integrated into buildings will develop, and it seems necessary to rethink the building types in this direction, as it has done for the integration of photovoltaic panels in the building volumes.

That purpose became obvious, although until now anyone attempted it, designers have the objective of re-thinking and re-inventing the building type of tower-houses, which grew steadily higher in the Middle Ages both for defense needs and social status, to have a profound effect on the creation of urban landscapes of cities, which are now famous because of their tower-houses, especially in Tuscany and Emilia-Romagna, such as S. Gimignano, Monteriggioni, Lucca, but also Pavia, Bologna, and many other Italian cities.

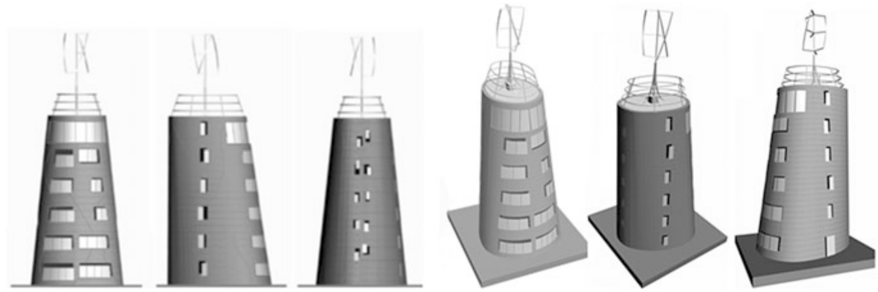

Fig. 12.3 Elevations (from the *left*: Sud, Est-West, Nord) and axonometric views

This building type has been almost completely abandoned after the spread of firearms, in the fifteenth century, as it proved too vulnerable for them, to the benefit of other types, such as that of the palace.

12.3 Content of the Research

The research was focused on the building program of a single-family detached house, in a real context in the city of Potenza (latitude 40°38′43″0.08, climate zone E, degree days 2,472, design outside temperature −3 °C, heating days 183, height 819 m above sea level), designing it according to the principles of *bioclimatic* and *passive solar architecture*: extreme compactness (S/V ratio of 0.5) (see Fig. 12.3), trapezoidal profile, wider in the South side that to the North, to maximize free solar gains (see Fig. 12.4), with large convex windows (supported by external shading) to the South, almost closed in the North [2, 3]; overlap in height of different internal spaces, to gain the height necessary to the optimal operation of the mini-wind installation, with the roof slab at 19.50 m and turbine height of 25 m; ovoid profile tapered from the bottom to the top, to minimize turbulences, and to create advantage to the wind turbine blade operation.

From structural point of view, all design has been performed in accordance with EN 1995-1-1 2004 Code, with antiseismic beam-column wooden structure in Turkish Oak glued laminated timber [4], modified trough a purpose-made thermo-hygrometric treatment, which gives it incredible structural qualities, with a load of exercise, to bending stress, equal to 40.9 N/mm^2, as followed by tests in the Laboratory of Engineering of the University of Basilicata, Potenza, Italy (see Fig. 12.5).

The housing is designed to be that of a “passive house”, with an optimal behavior in both winter and summer (see Fig. 12.6): an envelope of 20 cm oak as blockhouse, 20 cm of super-compressed high density cork, and a ventilated rainscreen for the protection in winter from rain and in summer from the sun, with a U transmittance of 0.167 K/(m^{2}K).

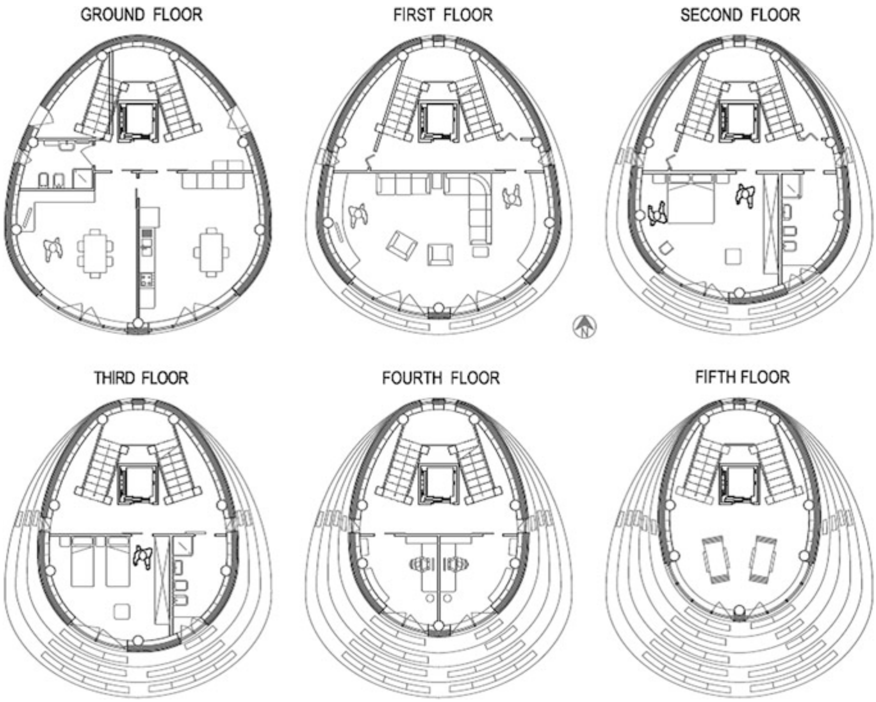

Fig. 12.4 Floors

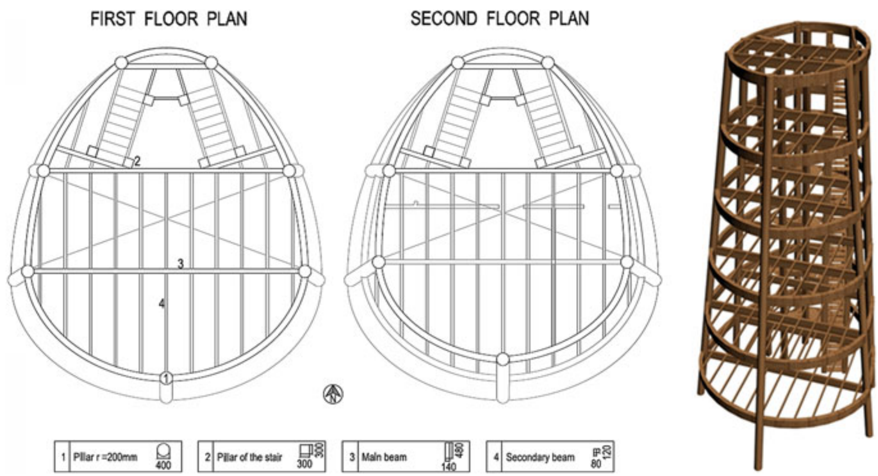

Fig. 12.5 Structure

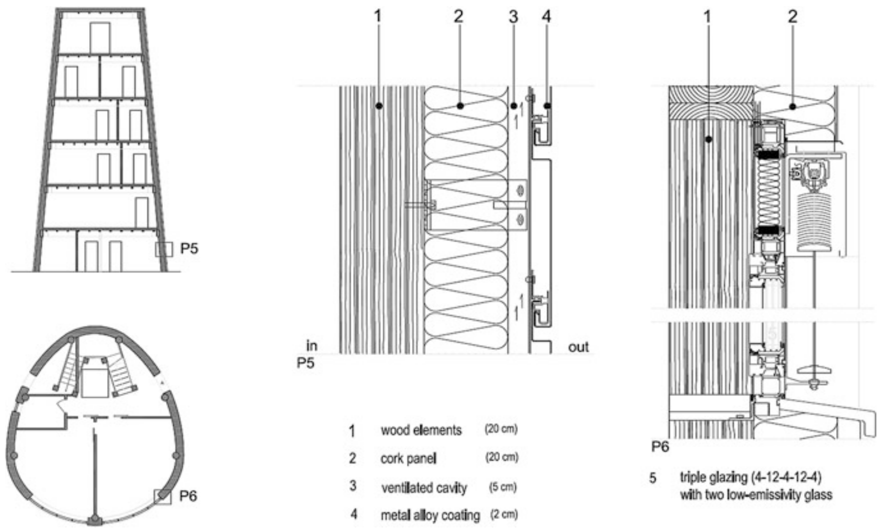

Fig. 12.6 Façade

Fig. 12.7 Integration of the building into the urban context

For the production of heat (heating and hot water), a heat air to air pump, with the yield of 16 kW and the absorption of 4 kW, was provided.

Primary energy demand EPI = 10 kWh/m^2 per year. Annual consumption of energy according to UNI TS 11300, about 3,000 kWh for heating, 3,050 kWh for cooling and 2,370 kWh for the production of domestic hot water [5]. All the requirement may be provided by a wind generator with a rated power of 5 kW, and the surface of 7.50 m^2, which provides an efficiency of 40 %, with the mean wind speed 6.5 m/s, Weibull factor 2.5, and can produce annually, considering this site, 8,550 kWh.

12.4 Conclusion

The research has shown that it is possible to rediscover and enhance the tower-house type to architecturally integrate mini-wind turbines on vertical axis, that are able to produce all the energy the building needs throughout the year and that with the mode of "*on-site metering*", balance the energy produced and fed into the grid with the one supplied from the power-distribution network.

A design careful to the sustainability aspects of the project, both during construction and in the management, and in that of disposal/recycling, allows to minimize the environmental impact of the building (see Fig. 12.7).

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