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From landscape modeling to landscape design of wind farms: an integrated approach to sustainable RES development in Parma Province, Italy.*

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RSE-Research on Energy System

Abstract. This research focused on elaborating a methodology to improve the localisation and design of wind turbines by analysing the structure of the local landscape, identifying its basic elements and forecast the visual impact of the new constructions.
The first part of the research has been the construction of a GIS based model of the local landscape to aid the public administration in project approval and planning tasks.
Secondly a site specific research has been conducted on several test-areas, in order to translate the landscape feature analyzed by the model into design indications.

Keywords: Renewable Energy Sources, Wind farm construction, Landscape modeling, GIS, Landscape design.

1. Introduction

The shift towards renewable energy source (RES) aims to address problems linked to climate change and to the exhaustion of fossil energy at global scale but is also seen as a great opportunity to achieve sustainability objectives and target locally, thus going beyond the energy related thematics to include social acceptance, land use and land use management issues.

"*A RES-based energy model implies complex re-organisation of the territory with, usually, increased decentralisation of energy production and consumption and the use of widely-diffused energy resources*" [1]. This re-organization implies a change in the role of places that were traditionally marginal for human activities, and draws attention on landscape transformation and land anthropization. At present day the Local authorities (Regions and Provinces) are charged of the planning and management of RES development, and often find themselves unprepared facing the complexity of the task: the planning process lacks of an integrated approach capable of addressing at the same time problems like energy demand and a growing public concern on environment and land anthropization. In particular, in many Italian regions, there is an absolute lack of clear guidelines on landscape compatibility. This leads either to unsustainable constructions heavily opposed by local communities or to the risk of endless bureaucratic procedures rising the cost of installations. Our thesis is that a closer relationship between the study of territory, energy planning and RES design can be the leverage to ensure the sustainability of the local energy system as well as help remove the social and administrative obstacles.

In collaboration with the Local Authority of Parma Province (Emilia Romagna region, center north of Italy), this research is an attempt to create a methodology to aid the planning and management of wind farm, merging the most recent scientific researches with the requirements of the national and local regulations. The attention is centered on the consideration of the territorial heritage and on a strong link between landscape analysis, planning and design of wind farms. On several selected test-sites, a prototypical wind farm project has been made to translate the model results into practical design guidelines.

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2. A quali-quantitative landscape model to assist planning and design of wind farms

2.1. Combining landscape features, territorial heritage and visual impact in a GIS-based model

The heterogeneity of the potential stakeholder group and the bureaucratic complexity of the authorisation process, as well as the importance of the physical transformation at stake, stresses the need for a common informative base, comprehensible by people with different backgrounds and roles and applicable to future scenarios. A qualitative description of the territory is particularly important when we discuss the effects of a landscape transformation, because the value of it can't rely only on objective assessments, but has to comply with the inhabitants' sensitivity, and their historical relationship with the territory. [2]

The aim of this part of the research was to create a knowledge base to describe landscape values and structure both to give a clear indication for designers, and to support the Local Administration in evaluating the projects.

Four categories of landscapes structural elements where identified, based upon the specific scientific literature, and the national and local planning guidelines [3]:

- An initial analysis was carried out to describe the local human-environment relationship, especially in terms of spatial distribution of natural and anthropic phenomena using the Corine Land Cover database.
- Secondly the landscape's notable elements where examined. At this stage 15 categories of punctual elements where identified both from field work and from the analysis of local plans. Each element has been valued through several qualitative indicators who allowed assessing its socio-historical relevance.
- Thirdly land use was examined diachronically to understand landscape changes and the evolution of anthropic presence in the area. Several areas were identified as "*long-lasting territorial marks*" [4], hence inserted into the GIS model.

The viewpoints represent the last category of elements considered, functional to the evaluation of visual exposure and to the forecast of visual impact of future wind farms.

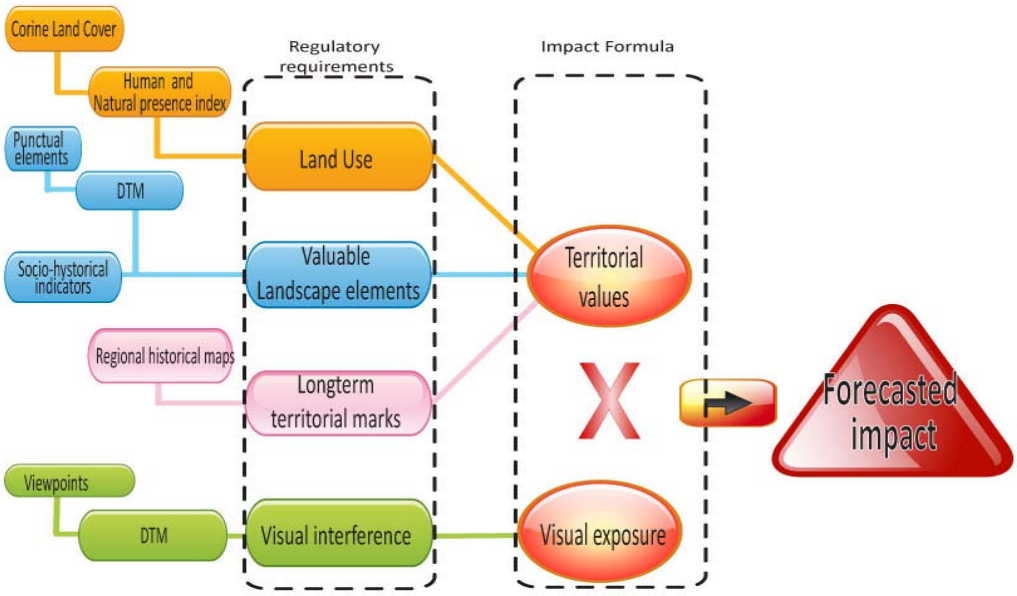

Fig. 1 Workflow for the construction of the landscape model

A quantitative value has been assigned to each of these landscape structural elements, which have been combined as shown in figure 1.

2.2. From quantification of Visual Impact to the description of visual interference

The concept of "*visual impact*" (VI) has been largely used to quantify the influence of wind turbines [5], on perceived landscape, especially through the measure of the angular dimension [6]. While the advantages

of an objective and quantitative measure such as the VI are obvious, its application in a complex and diachronically stratified territorial context, such as the one examined, appears rather simplistic.

To establish a method better suited for the local landscape, several factors had to be taken into account: GIS based Viewshed Analysis [7], angular dimension, presence of valuable elements and of viewpoints were combined in a fuzzy-logic equation. The result is a quali-quantitative estimation of the potential visual interference of an average wind turbine. The quantification is expressed in a 0 to 100 range on a 1 sq. km grid, while the qualitative information given refers to the number, type and localisation of viewpoints and valuable landscape elements.

2.3. Main results and applications of the quali-quantitative landscape model

The main result of the model application is the "Map of Forecasted Landscape Impact of Wind Farm Construction", which summarizes numerically the landscape features considered in the model. The gridded template used to spatialise the values can be used to perform calculations, can be effortlessly integrated with other numerical information such as the technical potential estimation and is immediately comprehensible by non-technicians.

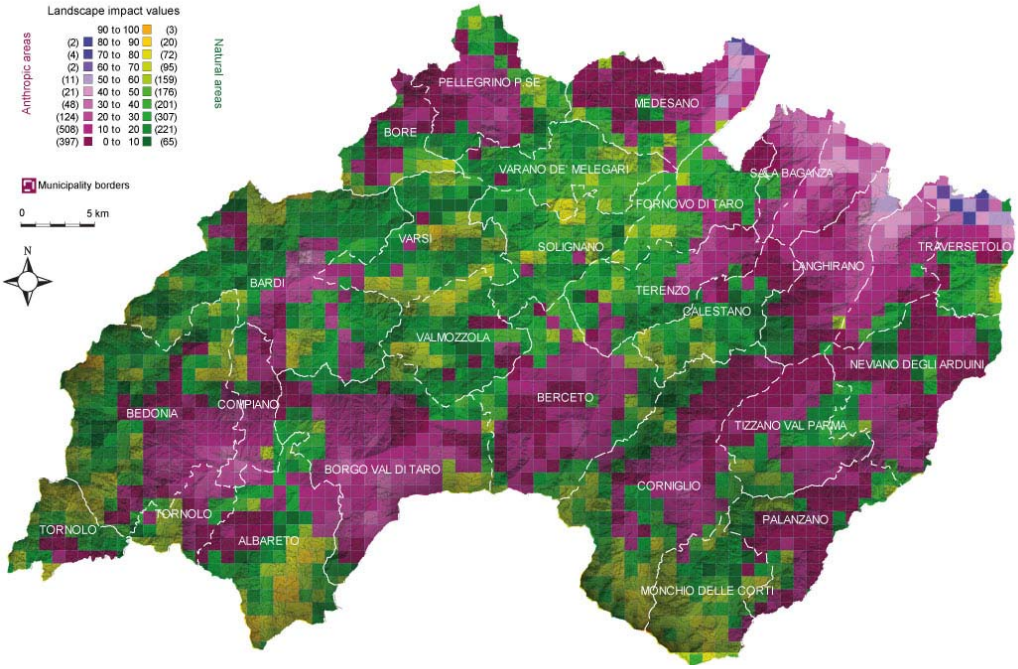

Fig. 2 Map of Forecasted Landscape Impact of Wind Farm Construction

The principal application of the Map of Forecasted Landscape Impact is to aid the Local Administration in the planning process which is, for the Italian law, centered on determining the areas that are not compatible with wind farm presence [†][8]. The map can help verify the Landscape WEA consistency and estimate the cumulative impact of a chosen RES development plan. If integrated with existing and proposed wind farms projects data, it could be used to follow the RES development process in Strategic Environmental Assessment logic. Besides the quantification of the landscape impact, the model construction implied the creation of an extended database of landscape features and of their visibility area, which can be used as a template for designers as shown in the following paragraphs, or as an aid in Environmental Impact Assessment procedures[‡].

3. From Landscape Analysis to Landscape Design

3.1. Analysis of the territory and cartographic transposition of themes

The complex process that leads to the landscape design stage requires an adequate knowledge of the territorial and landscape features. Once identified, this information must be communicated with appropriate tools [9]. The first aspect investigated at this stage of the research was the graphic representation of those

[†] "Wind Exclusion Areas" (WEA).
[‡] compulsory for new wind farm construction.

thematic features that are closely related to the design of wind farms. Several maps have been produced at a cartographic scale of 1:25.000 and 1:10.000. The maps produced aim to show in detail the landscape features considered in the previous paragraphs, whose distinctive characters are the centre of the detailed scale project.

The maps are divided into the following themes:

- Ecological system: this map aims to give information about the main characters that define the ecosystemic relationships of that place.
- Anthropic system: focuses on landscape transformation caused by anthropic activities. This map is important to understand the relationships that could be compromised by the introduction of a new element in the landscape.
- Geomorphological system: the characteristics of the geological processes that concurred to create the present landscape aspects.
- Wind speed and producibility: presence and exploitability of the wind resource at 75m above sea level.
- Administrative constraints and land use plans: National, regional and local constraints related to heritage, landscape and environment.

3.2. The Landscape Design

The project developed on two levels:

- The "*Perceptual Project*"[10] acts on a territorial scale considering turbines as a new landmark;
- The "*Ground project*" [11] analyses the transformations of the landscape on the specific site, giving a landscape value to the technical infrastructures.

In the first level, the focus is on designing new areas to be capable of establishing beneficial relationships with pre-existing landmarks[12]. The basic assumption is that any attempt to hide the turbines is useless and inappropriate. It appears much more convenient to follow an approach that aims to clearly define the "sensitivity" of the site specific landscape and thus to determine the limits of the transformation that can be "imposed" to the site. Within some peculiar landscapes, whose elements require an aesthetic autonomy, the visual impact of the turbines should be avoided. However, the approach proposed tries to create a new landscape in which the wind farm assumes a prominent role.

The nearby town of Berceto and the planned wind farm have been considered as two poles of a new landscape system. The plant appears as a semicircle facing the city centre, thus building a visual relationship with the context. In this way the turbines become the edge of the local landscape, whose continuity is ensured by the orography and delimited on the other side by the town centre, specular to the wind farm.

The second level, the "Ground project", addresses specific details like: the design of paths, the construction materials etc. Walls have been considered as a design theme, structural elements that modernise the dry stone walls once used to create the terraces that shape the local landscape. These elements are scattered along the entire area of the wind farm and become, according to the functional needs, benches or shelters to protect from wind, sun and rain. The landscape design is thought as "*inseparable from particular ways of seeing and acting. In this sense, landscape is an ongoing medium of exchange, a medium that is embedded and evolved within the imaginative and material practices of different societies and different times*"[13].

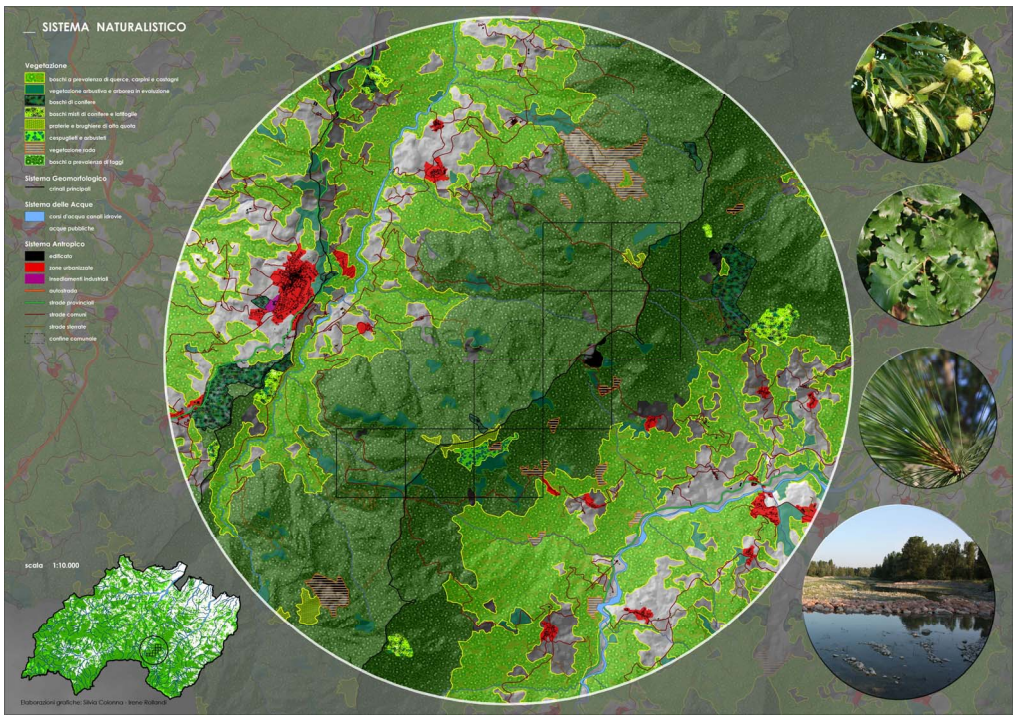

Fig. 3 Cartographic representation of landscape features: The ecological system. Scale 1:10000

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