Renewable Energy 36 (2011) 754–763

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

A GIS-based interactive web decision support system for planning wind farms in Tuscany (Italy)

Riccardo Mari [a], Lorenzo Bottai [a], Caterina Busillo [a], Francesca Calastrini [b], Bernardo Gozzini [b], Giovanni Gualtieri [b,*]

[a] Laboratory of Monitoring and Environmental Modelling for the sustainable development (LAMMA), Via Madonna del Piano 10, 50019 Sesto Fiorentino, Italy
[b] Research National Council-Institute for biometeorology (CNR-IBIMET), Via Caproni 8, 50145 Firenze, Italy

ARTICLE INFO

Article history:
Received 30 April 2010
Accepted 10 July 2010
Available online 2 August 2010

Keywords:
Wind resource assessment
Wind energy policy
GIS
Decision support system
Interactive web system
Tuscany region

ABSTRACT

In the framework of regional renewable energy policies, starting from 2008 the Tuscany Regional Authority promoted the "WIND-GIS" project aimed at assessing the large-scale wind potential of Tuscany region, Italy. This goal was achieved by developing an integrated Geographic Information System (GIS) based decision support system (DSS), compliant with Directive 2007/2/EC of European Commission (EC), which was designed to help public operators in the preliminary location of sites eligible for wind harness. To make the system an actually operative tool, it was conceived as a web-oriented interactive system that the public operators may freely access. The DSS was developed by using the MapServer open-source web-GIS application. Furthermore, the "p.mapper" front-end application developed in JavaScript and PHP/Mapscript was used, which enables a user-friendly interface to MapServer to be performed.

System's wind resource data are estimated by the 2-km resolution application over Tuscany of a meteorological model chain through a 4-year period (January 2004–December 2007) with a 1-h time-step. Wind estimations at 75 m were taken into account in order to be addressed to large-scale wind turbines according to the Tuscany Energy Plan objectives of 300 MW installed power derived from wind within 2012. Furthermore, to overcome the problems posed by all groups involved with initially opposing positions in the location for new wind farms (e.g., investors vs. environmentalist groups), the DSS also encompasses a number of layers such as landscape, ecological and archaeological constrained areas.

This paper presents the description of the DSS, as well as the application results in terms of maps of wind resource and energy yield once a 2-MW wind turbine has been set as a sample.

The developed DSS is currently in use by the Tuscany Regional Authority for planning the regional wind energy strategy.

1. Introduction

The selection of final location for the construction of wind farms must often be negotiated among the groups involved in the planning process, where the different groups may have conflicting interest: for example, investors and power utilities will look for economically more attractive locations, while other agents, such as environmentalist groups, might consider some of these places as unacceptable from an environmental impact standpoint. This conflict of interests can delay, and even block, the realisation of new wind farms. As a matter of fact, wind farm planning is subject to multi-criteria decision-making processes under uncertainty with conflicting technological, economic, environmental and social aspects. Therefore, the selection of suitable geographical locations should be performed by means of a multi-criteria planning tool attempting to consider jointly most of the economic, technical, environmental and social implications of the planning problem [1].

To pursue such a goal, in the present work an integrated Geographic Information System (GIS) based decision support system (DSS) was developed to help public operators in the preliminary step of selecting consensual locations for new wind farms from initially opposing positions and make these processes faster and more effective, obtaining acceptable solutions for all the groups [1]. Successful completion of this preliminary phase is always accompanied by a local impact study involving a detailed field analysis of any landscape or environmental impacts the

* Corresponding author. Tel.: +39 055 4483027; fax: +39 055 444083.
E-mail address: gualtieri@lamma.rete.toscana.it (G. Gualtieri).

0960-1481/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.renene.2010.07.005

Table 1
Summary of wind energy application features implemented in WIND-GIS.

Item	Parameter	Value
Wind estimations	Processed time period	01/01/2004-31/12/2007
	Time step	1 h
	Processed data sample	35064
	Valid data	99.50%
	Height	75 m a.g.l.
Prognostic model	Name	WRF
	Spatial resolution	10 Km
	No. processed gridded points	525 (25 × 21)
Diagnostic model	Name	CALMET
	Spatial resolution	2 Km
	No. processed gridded points	12840 (120 × 107)
Wind turbine characteristics	Name	Typical 2000 KW
	Number of blades	3
	Cut-in wind speed	4 m/s
	Cut-off wind speed	25 m/s
	Rated wind speed	15 m/s
	Hub height	78 m
	Rotor diameter	80 m
	Swept area	5027 m^2
	Rated power	2000 KW

Table 2
List of layers imported in WIND-GIS as sorted by thematic category.

Category	Layers
Wind data: CALMET points	Years 2004–2007
	Year 2007
	Year 2006
	Year 2005
	Year 2004
Wind power maps	Mean Wind Speed (m/s)
	Full Load Hours (h/y)
	Annual Energy Production (MWh/y)
Exclusion layers	Archaeological Constraints
	Landscape Constraint
	Parks, reserves and natural areas
Background	Municipality Borders
	Province Borders
	Cartography (1:250,000)

project is likely to generate [2]. The GIS platform is well suited for locating wind farms thanks to its capability to manage and analyse multidisciplinary data, perform "what if" scenarios which can be used to evaluate the effects of different planning policies, model impacts of proposed and operational sites, and suggest modifications to minimise them [3]. The GIS has been applied to other DSSs, such as in the evaluation of national wind energy classification [4], regional renewable energy potential [5,6], harness of local renewable resources [7], selection of power technology in rural electrification [8], and selection of potential locations for new wind farms [1,3]. It was also used to analyse wind energy scenario policies, both resulting from different adopted constraint criteria [2,9] and addressed to investigate nation-wide long-term incentive programs [10].

To make the current system an actually operative tool, it was conceived as a web-oriented interactive DSS public operators may freely access. This feature can be reckoned as an added value of the developed system and remarked to point out its originality.

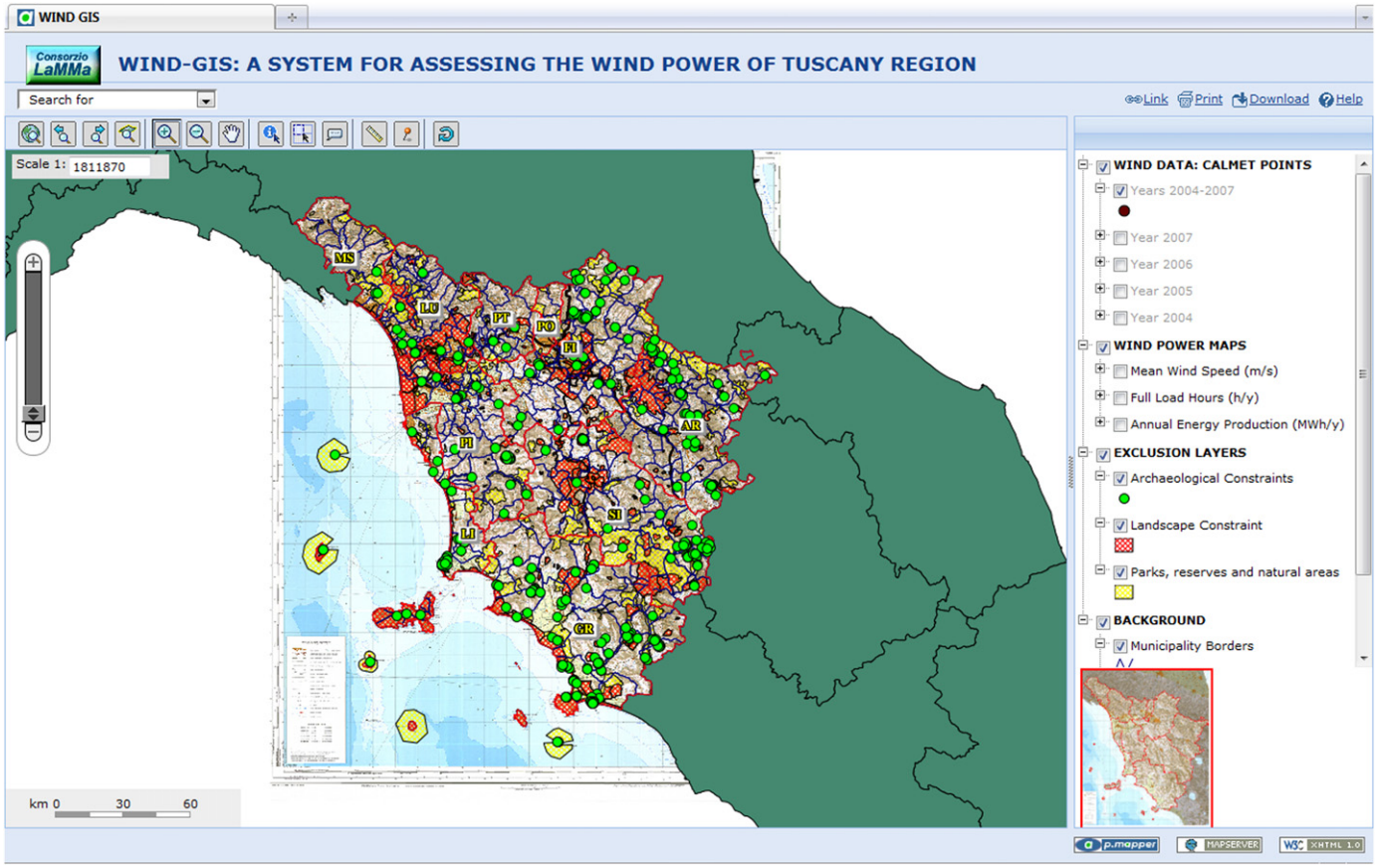

Fig. 1. Web layout of the developed "WIND-GIS" interactive wind resource mapping system over Tuscany region (Italy).