Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 122 (2017) 529–534

Energy Procedia

www.elsevier.com/locate/procedia

CISBAT 2017 International Conference – Future Buildings & Districts – Energy Efficiency from Nano to Urban Scale, CISBAT 2017 6-8 September 2017, Lausanne, Switzerland

Social indicators to localize renewable energy sources considering their visual impacts

Giacomo Chiesa[a]*

[a]*Politecnico di Torino, Department of Architecture and Design, Viale Mattioli 39, Torino 10125, Italy*

Abstract

In historical and consolidated contexts, the influence of visual factors and landscape perception may limit the possible integration of renewable energy systems (RES) and retrofitting actions. However, in several cases, these restrictions do not take into account the real visibility of a landmark or landscape excellence, causing constraints and limitations in zones where the visual effect is non-existent or limited. The paper will introduce, using 3-D GIS mutual-visibility analyses and social network geo-referred information, an indicator of visibility to define the expected impact of an RES. This methodology may help designers and administrations when re-defining the effect of such technologies on the preservation of the local visual impact of landmarks and points of interest without exceeding in restriction.

Peer-review under responsibility of the scientific committee of the CISBAT 2017 International Conference – Future Buildings & Districts – Energy Efficiency from Nano to Urban Scale

Keywords: 3d-GIS; renewable energy localization; landscape preservation; visual impact; social network

1. Introduction

The European Union, as underlined in the objectives of the programme Horizon 2020 [1], has a great interest in reducing energy consumption and GHG emissions, given climate challenges and the need for sustainable energy alternatives. The promotion of renewable energy sources is defined in the EU according to the Directive 2009/28/EC. Furthermore, according the 2010/31/CE EPBD recast Directive, Renewable Energy Sources (RES) constitute an important requirement for nZEBs, even if defined and implemented differently in each country. [2].

* Corresponding author. Tel.: +39 0110904371; fax: +39 0110906419.
E-mail address: giacomo.chiesa@polito.it

1876-6102
Peer-review under responsibility of the scientific committee of the CISBAT 2017 International Conference – Future Buildings & Districts – Energy Efficiency from Nano to Urban Scale
10.1016/j.egypro.2017.07.315

According to D'Agostino [3], solar thermal, geothermal, passive solar, passive cooling, heat recovery (with the exclusion of Sweden-SE), and PV (SE excluded) are considered RE generation sources in EU Member States (MS). Furthermore, wind power, micro-combined heat and power units such as biomass, biogas and biofuel (except for Denmark) are included. [3]. Nevertheless, only a few MS have specific targets for renewables, ranging from 25% (Cyprus) to 60% (Germany), with an average of 50% [2]. Furthermore, an analysis of the balance between on-site generation and consumption is reported in [4].

The preservation of the environment and of the landscape, together with energy production by renewable sources are generally considered parts of the same typologies of intervention. Nevertheless, possible contradictions may arise when the need for sustainable development and environment preservation thanks to renewable energy production conflicts with the preservation of the visual value of a landscape –such as Regional Landscape Plans, e.g. [5], even from a juridical and constitutional point of view [6]. Furthermore, since the promulgation of the European Landscape Convention, the entire territory is considered as landscape when it is perceived by populations. Several RE technologies, especially the ones devoted to nearby or external production, have, in fact, a huge effect on the landscape as they introduce visible modifications such as changes in the skyline (e.g. wind turbines), in traditional agricultural practices (e.g. production of rape seed) or in soil usage (e.g. large PV fields). Furthermore, other impacts on landscape preservation may arise from urban regeneration and retrofit interventions in historical contexts (e.g. traditional architectural environments such as mountain settlements with extensive stonework) or other environmental/economic indicators [7]. These transformations affect the cultural, economic and social perception of the local landscape as it acts on landscape shapes, colourations and recognisability, or the specific preservation of areas of high historical and cultural value, e.g. archaeological locations or UNESCO World Heritage sites [see also 8]. Some National or Regional regulations may limit interventions to preserve the visual and historical integrity of the landscape by asking for different levels of authorization (in Italy see dlgs 42/2004, D.P.C.M. 12 December 2005, dpr 31/2017). However, methods to help quantify the perceived landscape value are limited, thus increasing constraints on RES.

This paper analyses different innovative strategies to quantify the visual perception of a landscape-recognised object in order to introduce an indicator of visibility to be used with local maps of geo-climatic and energy applicability of RES indicators such as [9,10] while suggesting new strategies for RES diffusion in accordance with proper landscape preservation.

2. Objective and methodology

Models and methods to define the local potential of a PV system, a wind farm or a different RES are well-known and consolidated among both researchers and professionals. For example for PV, there is the PVGIS interactive map [11], or the use of GIS, such as GRASS-GIS, combining Digital Surface Models (DSM) and possibly other data such as turbidity levels or roof area definitions [12]. However, methods and tools which are able to define perceived landscape values are less widespread and consolidated – see for example [13,14]. A wide-ranging debate on this topic is taking place [15], which underlines a new approach that is adding to a rigid descriptivism (prescriptive morphological approach) a more flexible and experimental vision of planning in order to describe contemporary transformations [16]. Several devoted city plans are present around the world to safeguard local landscape scenic value and integrity [17] – e.g. district height limitations in New York, since 1916; Plan des hauteurs in Paris, 2010; backdrop preservation in Denver, 2009; skyline and visual cones in London [15].

The principal aim of this paper is to describe a series of methods to define the visual and perceived impact of a landscape landmark according to a performance approach which is able to, at least partially, overcome the solely prescriptive morphological approach. This approach is based on an activities→needs→requirements←(indicators)←performances feed-back flowchart [18]. The proposed methodology, thanks to the use of GIS instruments, helps to quantify local landscape quality in order to suggest flexible and verifiable restrictions with a view to landscape preservation. Three main families of needs are defined: the first refers to specific RES technology (e.g. for PV panels, environmental, functional and operational requirements such as the quantity of solar exposition and intensity, dimensions and connections, maintenance and use), the second to visual landscape preservation especially for historical and touristic sites, and the third to perceived landscape value. In accordance with this paper's aims, the last two families will be explored considering local or focused regional planning uses (a maximum visibility radius of 5000m is considered even if some studies refer to even 9000m). The use of DSM bases together with social georeferred data in a 3d-GIS environment allow us to create territorial layers which evaluate landscape visual integrity (see [15,16]) and social perception of a landmark thanks to its identification in social networks (as Flickr, Facebook, Twitter). The use of shapefiles derived from social network data in landscape landmark definition was described by the author in [16] and for site design in [19]. These analyses can be overlapped with RES applicability analyses (e.g. the already mentioned PV analases based on comparable shapefiles) to define a planning constraint map based on optimal RES positioning (see Fig. 1).

3. Visibility performance analyses

The method here proposed is illustrated in Figure 1. For each family of indicators a map is generated, even if for specific variables technical constraints can be included (e.g. for solar average. yearly exposure or a minimum value below which PV panels are not economically feasible) . Furthermore, each analysis is weighted to define an optimized map for RES localization.

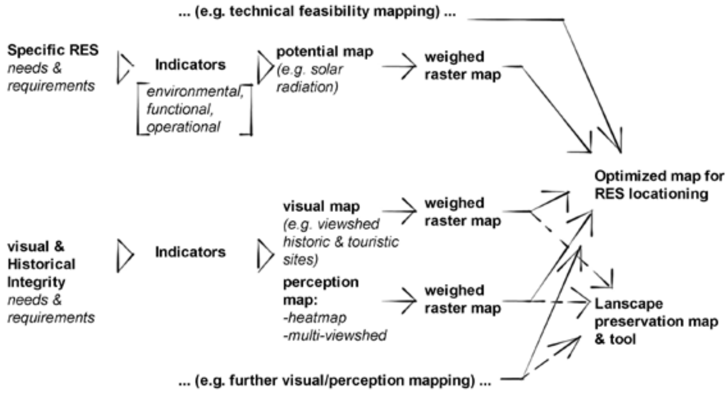

Fig. 1. Flowchart of the proposed method to optimize RES localization according to specific RES needs and requirements and visual/historical needs for landscape integrity preservation.

3.1. Mutual geometrical visibility

A recognized instrument to perform geometrical visibility analysis is the tool "viewshed" implemented in the 3d-analysis toolbox of ArcMap. This instrument allows us to define mutual visibility between one/multiple point(s) and a target. The analysis is performed on DEM (digital elevation model), DSM (digital surface model) and DTM (digital terrain model) and returns a true/false raster layer. If multiple original points are considered it is possible to obtain a combined analysis derived from the sum of single visible/not visible results. The parameters which are able to define the viewshed analysis are: *Offset*, which refers to the height of the observer (assumed as 1.6); *azimuth1* and *2*, which define the horizontal angles of observation (0° = North); *vert1* and *2*, which are the vertical angles of observation (generally assumed as 90°, -90°); and *radius1* and *2*, which report the analysis depth (radius 1 can be set as 0). Viewshed analysis can be performed for one or multiple points of interests (e.g. landmarks) while taking into consideration mutual visibility (e.g. from a recognized panorama, or to an historical landmark) in order to define a map of visibility. Some applications in landscape preservation studies were reported and used [17,20].

3.2. Social geo-referred impact

Social perception of a landscape is generally analysed using surveys (questionnaires, interviews, mental maps) and visual media (e.g. videos or photographs). These tools are effective, but are difficult to be datizated or geo-referred in order to be quantified and used. The method introduced in this paper will use a different approach based on 3d-geographic analyses. Thanks to the plug-in Mosquito it is possible to surf several social networks and collect datapoints respondent to specific indicators in the Grasshopper platform for Rhinoceros® (see also [19]). A series of examples has been provided using Flickr, which was chosen because of its photographic nature, using only those data which have a geotag. Results were automatically filtered for location in order to exclude fake points. The derived database is commutated in a list of coordinates to be reported in a shape file (e.g. using the XYtoPoint plug-in QGis) – see Figure 2. Two main indicators were here introduced to define visual perception for landscape constraints: spatial intensity (heatmap) of collected pictures and multiple visibility analyses (multi-viewshed) performed according to the defined observation points. As illustrated in Figure 3, spatial intensity refers to the creation of a raster map of concentration in GIS according to the distribution of the photographic observation points (georeferred vector shapefile of picture points). The methodology used is well-known and based on the plug-in heatmap for QGis. It is possible to define a minimal threshold by using the raster calculation tool. Similar procedures are present in other GIS software. On the other hand, the definition of a multi-visibility analysis based on a cumulative viewshed analysis performed on the considered set of observation points requires a new process.

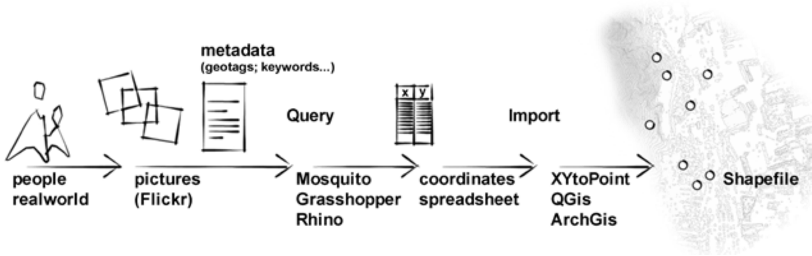

Fig. 2. The used procedure to create a shapefile based on defined viewpoints of interest by people.

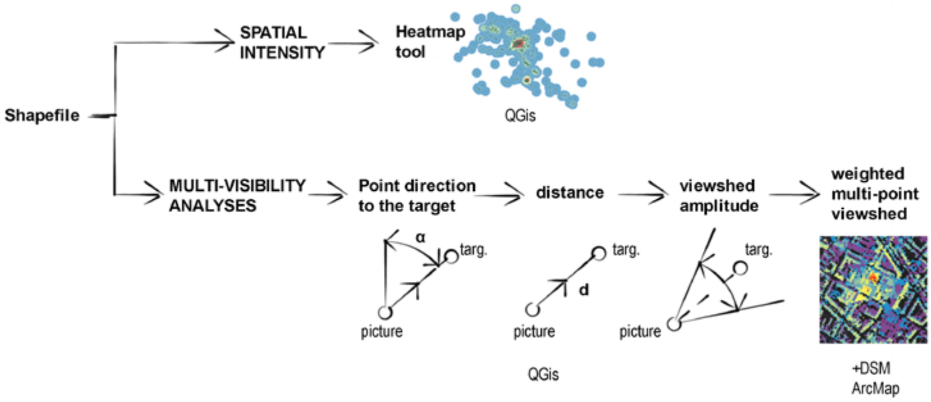

Fig. 3. (a) The proposed methodology for defining the two visual perception indicators.

As described in Sec. 3.1, the viewshed analysis is based on specific parameters. For this analysis offset, vert1, vert2 and radius1 are fixed to respectively 1.6, 90, -90, 0. However, azimuth1, azimuth2 and radius2 need to be set for each point individually by introducing an automatic procedure. Considering the aim of this indicator, each viewshed has to be performed in the direction of the target point (landmark, point of interest…) which is chosen as the keyword in the social network survey. Furthermore, the distance between the observation point and the target has to be considered in order to establish the portion of the view which is encompassed by the landmark (azimuths), define the corresponding depth of the view (radius2), and exclude or weigh points that are too far away to define precise visibility constraints (e.g. 5000 m). The direction of the target point is calculated assuming that the viewshed analysis is performed without considering earth curvature because of the limited distance of the view. For each point *A*, a virtual point *A'* (χ_t; γ_A) is created, where χ_t is the *target* longitude, while γ_A is the point *A* latitude. The distance *d*, between *target* point and point *A*, and the distance *d'*, between *target* point and point *A'*, are calculated. Finally, the orientation angle α from *A* to the *target* point considering North as 0° is defined according to the following expression (1). Furthermore, according to *d*, the two azimuths (1 and 2) are calculated respectively by subtracting and adding half of the angular view (portion) defined as reported in Table 1 for the relative focal length, which is fixed as a function of *d* according to photographic assumption. Radius 2 is calculated following expression 2. When all the parameters are defined for each datapoint in the observation point shapefile it is possible to perform a cumulative viewshed analysis in ArcMap and further classify the results.

$$\alpha = \begin{cases} 270 - \arcsin(d/d')\cdot(180/\pi) \Rightarrow long_A > long_t \wedge lat_A > lat_t \\ 270 + \arcsin(d/d')\cdot(180/\pi) \Rightarrow long_A > long_t \wedge lat_A < lat_t \\ 90 - \arcsin(d/d')\cdot(180/\pi) \Rightarrow long_A < long_t \wedge lat_A < lat_t \\ 90 + \arcsin(d/d')\cdot(180/\pi) \Rightarrow long_A < long_t \wedge lat_A > lat_t \end{cases} \tag{1}$$

$$radius2 = \{100 \Rightarrow d < 50; d \cdot 2 \Rightarrow 50 \le d < 3500; 7000 \Rightarrow d > 3500\} \tag{2}$$

Table 1. The chosen focal length [mm] and corresponding angular view (for a reference film dimension of 24x36mm).

Distance *d*	Focal length	Angular view [°]	Distance *d*	Focal length	Angular view [°]
< 50	21mm	91.74	< 2500 [16]	80mm	30.28
< 250	35mm	63.47	< 5000	200mm	12.35
< 1200 [20]	50mm	46.82	> 5000	300mm	8.25

3.3. Sample applications coupled with solar access

Figure 4(a) shows the results of a viewshed analysis performed on 4-panorama points localized in the recognized historical and preserved site of the Sacra di San Michele, one of the major landmarks in the Piedmont Region in Italy. The points were chosen by geo-localizing the existing spherical google streetview points in this location. Figure 4(b) reports yearly solar radiation exposure analysis (Area Solar Radiation tool in ArchMap). Figure 4(c) overlap the results assuming that panorama preservation in these points is a priority (viewshed ≥1 → landscape constraint). Solar-based RES technologies may be considered only in those locations where panorama visibility is False (radius2 = 2500) and solar exposure ≥ 50% of the maximum value (or different threshold) - see Fig. 4(c).

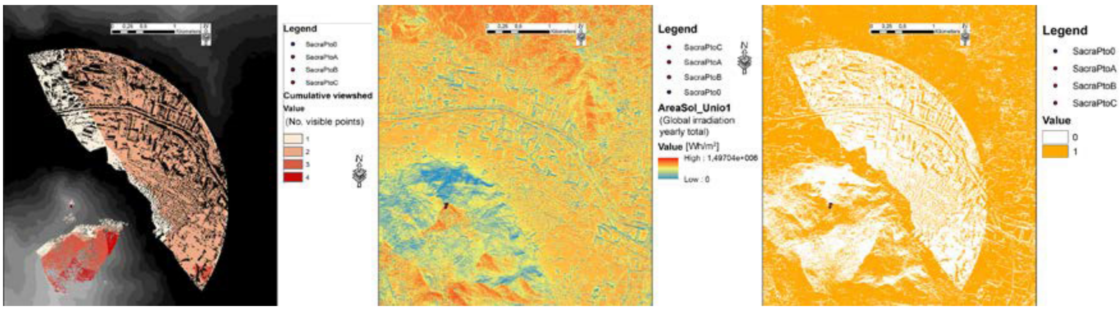

Fig. 4. (a) 4-point overlapped viewshed analysis (offset 1.6; azimuth 0°/360°; vert 90°/-90°; radius 0/2500); (b) yearly solar radiation exposure; (c) overlapped results for PV localization (visibility = *null*; sol. exp. <50% of maximum value = *null*). Analyses based on the dataset DSM 2009-

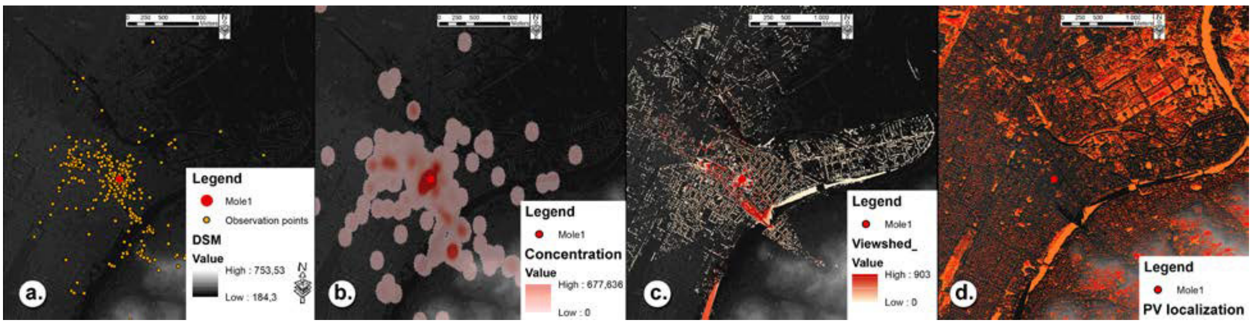

Fig. 5. (a) Geo-referred observation points; (b) heatmap of concentration – observation points; (c) cumulative viewshed performed according to Sec. 3.2; (d) overlapped results for PV localization. Analyses based on the dataset DSM 2009-2011 Piemonte ICE of the Regione Piemonte.

Figure 5 refers to a different type of landmark: the Mole Antonelliana, a symbol of the City of Turin, Italy. This second analysis focuses on the perceived visibility of an historical and touristic landmark to be preserved. In Fig. 5(a) the results of a social network datization are presented and geolocalized. Furthermore, in Fig. 5(b), a heatmap of concentration of these points is reported using a radius of 100m. In Fig. 5(c) a cumulative viewshed analysis is performed for all considered observation points according to the parameters defined in Sec. 3.2. Finally, all those layers are overlapped with the local yearly solar exposure raster following the procedure described in Fig. 1 and assuming that solar potential has a weight of 0.5, spatial intensity of 0.2, and a cumulative viewshed weight of 0.3. Fig. 5(d) shows the final optimized map of PV applicability.

4. Conclusions, further developments and limitations of the study

The presented study is the result of preliminary elaborations on the theme and will be implemented in future with the development of an RES site potential tool which is able to include visual landscape constraints. The proposed methodology includes perceived value datization and may help to better define the influence of landscape preservation constraints in a built-up environment and help to optimize landscape regulations in order to avoid over-limitation. Further analyses are under development to refine a scoring system for the visibility layer in order to find a possible connection with economic indicators related to visual landscape preservation and local energy production. The presented methodology on the social perception index is principally based on shared data from social networks, limiting its implications to the cases in which a large amount of data is available to guarantee a sufficient amplitude of the database and the possibility to nullify the effect of potential fakes. However, it could be possible in future to implement this analysis, in both local and focused regional planning actions, by using different datization sources (e.g. smartphone data).

Acknowledgements

This research was co-funded by the RTDgrant 59_ATEN_RSG16CHG directed by the author. Furthermore, dr. Luigi La Riccia (Politecnico di Torino, Dept. DIST) is thankfully acknowledged for urban planning suggestions.

References

[1] Horizon 2020 Online manual, last access 2016/08/10
[2] D'Agostino D, Zagheri P, Cuniberti B, Paci D, Bertoldi P. Synthesis Report on the National Plans for Nearly Zero Energy Buildings (nZEBs), Publications Office of the European Union 2016. See http://publications.jrc.ec.europa.eu/repository/handle/JRC97408, viewed Feb 2017
[3] D'Agostino D. Assessment of the progress towards the establishment of definitions of Nearly Zero Energy Buildings (nZEBs) in European Member states. Journal of Building Engineering 2015; 1:20-32.
[4] Sartori I, Napolitano A, Voss K. Net Zero Energy Buildings: a consistent definition framework. Energy Build. 2012; 48:220-232.
[5] Piedmont Region, Piano Paesaggistico Regionale, D.G.R. No. 20-1442, 18 May 2015.
[6] Ferraro L. Costituzione, tutela del paesaggio e fonti di energia rinnovabili. In Il Governo dell'energia dopo Fukushima, Università di Napoli Federico II, 7-8 giugno 2012, 21pp.
[7] Fregonara E, et al. Environmental Technology, Materials Science, Architectural Design, and Real Estate Market Evaluation: A Multidisciplinary Approach for Energy-Efficient Buildings. J. Urban Technol. 2013;20(4):57-80.
[8] Unesco, Recommendation on the Historic Urban Lanscape, 10 November 2011.
[9] Chiesa G, Grosso M. Geo-climatic applicability of natural ventilative cooling in the Mediterranean area. Energy Build. 2015;107:376-391.
[10] Chiesa G. Geo-climatic applicability of evaporative and ventilative cooling in China. Int. J. Vent. 2016;15(3-4):205-219.
[11] http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php, viewed April 2017
[12] Bottaccioli L et al. Distributed software infrastructure for evaluating the integration of photovoltaic systems in urban districts. In: 5th International Conference on Smart Cities and Green ICT Systems (SMARTGREENS 2016), Rome, Italy, 23-25 April, 2016;357-362
[13] Girardin F et al. Digital footprinting: uncovering tourists with user-generated content. IEEE Pervasive computing 2008;7(4):36-43.
[14] Chiesa G, La Riccia L. Dalla rappresentazione alle rappresentazioni di paesaggi e territori. Planum 2013:27(2).
[15] La Riccia L. Landscape Planning at the Local Level. Berlin: Springer; 2017.
[16] Chiesa G, La Riccia L. Tools and methods for evaluating and designing the perceived landscape. 3D-GIS, viewshed analysis, big data. In: Pagani R, Chiesa G, editors. Urban Data. Tools and methods towards the algorithmic city. Milan: FrancoAngeli; 2016. p. 159-198.
[17] Kriken JL. City Building. Nine Planning Principles for the twenty-first century. New York: Princeton architectural press; 2010.
[18] Chiesa G, Grosso M. An environmental technological approach to architectural programming for school facilities. In Sayigh A, editor. Mediterranean Green Building & Renewable Energy. Cham: Springer; 2017:701-716.
[19] Chiesa G. Paradigmi ed ere digitali. Torino: Accademia University Press; 2015.
[20] Nijhuis S, van Lammeren R, van der Hoeven F, editors. Exploring the visual landscape. Amsterdam: IOS press; 2011.