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PATRIMONIO Y REHABILITACIÓN

HERITAGE AND REHABILITATION / PATRIMONIO Y REHABILITACIÓN

TOWARDS A METHODOLOGY FOR THE ASSESSMENT OF VISUAL IMPACT CAUSED BY RENEWABLE ENERGY FACILITIES ON THE LANDSCAPE IN CULTURAL HERITAGE SITES

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Abstract: Renewable energy facilities have led to conflicts due to the visual impact they generate due to their profusion, their dispersed nature and their location, usually in places of maximum visibility.
The relevant aspects concerning heritage (cultural or local values) are not consider by existing methodologies when assessing the generated visual impact in spite of their importance for minor heritage. This paper presents the first results of the research being developed within the recognized research group "Intervention in the heritage and sustainable architecture" from the University of Alcala, for the accomplishment of a methodology of valuation of the visual impact caused by renewable energy facilities on the landscape in cultural heritage sites. The preliminary outline of the methodology is presented, based on previously published studies of the settings of the Uclés Monumental Complex, the Segóbriga Archaeological Park and the Santiago's Way on its way through *Alto del Perdón* in Navarre.

Keywords: Visual impact; Landscape; Cultural heritage; Setting; Renewable energies.

1. Introduction

This paper is presented as part of the results of the research I am developing as FPI-MINECO fellow in a research project of the National Plan for R&D. The profusion, dispersed nature and location of Renewable energy (RE) facilities frequently led to conflicts due to the visual impact they generate in the landscape, usually in places of maximum visibility. With the Charter of Krakow and the European Landscape Convention, landscape becomes conceived as heritage and, therefore, susceptible of being protected. Therefore, there is currently dichotomy between the increase in the proportion of clean energy needed for the sustainability of the planet and social awareness of the visual impact generated by these facilities on heritage.
In the first fifteen years of the present century, several research were carried out on the visual impact generated by wind farms and solar plants in the landscape (Bishop, 2002, Hurtado et al., 2004, Bishop and Miller, 2007, Ladenburg, 2009, Torres-Sibille et al., 2009, Tsoutsos et al., 2009, Rodrigues et al., 2010, Chiabrando et al., 2011, Molina-Ruiz et al., 2011, Sullivan et al., 2012, Depellegrin et al., 2014, Kokologos et al., 2014, Minelli et al., 2014, Mirasgedis et al., 2014, Manchado, 2015). None of them addresses the visual impact generated on the landscape in cultural heritage sites. Nor is this type of study required in Environmental Impact Assessment (EIA), although some studies report that some constructions in the setting of cultural heritage sites affect their contextualization and enjoyment (Masser, 2006), and others demand a better integration between landscape and heritage in the EIA and the inclusion of local heritage values in the process (Lambrick et al., 2005, Jones, 2010, Diego and Chías, 2016a). The present research starts from the premise that the existing methodologies do not adapt to the characteristics of these landscapes. The aim of this study is to present the preliminary outline of a methodology for assessing the visual impact caused by the ER facilities, wind and solar, on the landscape in cultural heritage sites.

2. Methods

The research was developed in several stages. Firstly, a bibliographic review was carried out on the state of the art of the assessing of visual impact generated by renewable energy facilities (wind and solar), and the evolution of the landscape concept since the endings of the s. XVIII with Humboldt to the present day and the conception of cultural patrimony. The searcher engines used were "academic google", "dialnet", "Teseo" and "Elsevier". The keywords were "visual impact", "landscape", "landscape impact", among others and their analogues in Spanish. The analysis of several case studies was carried out: the ER facilities that were constructed and planned to be built in the setting of the Uclés Monumental Complex, the Segóbriga Archaeological Park and the Santiago's Way on its way through *Alto del Perdón* in Navarre. (Diego and Chías, 2016a, Diego and Chías, 2016b). On one hand, these cases were useful to verify that the methods available in the EIA for assessing the visual impact of these facilities were not valid. On the other hand, people's perception of these facilities and their impacts was collected and analysed. From here a new methodology is being developed, based in perceptive parameters, both qualitative and quantitative, introducing as newness cultural parameters to evaluate the visual impact caused by the ER facilities in the landscape in the setting of cultural heritage sites. A preliminary outline is presented below, which will evolve in function of the results that would be obtained.

3. Preparation of data

To carry out the methodology, it is necessary to prepare all the data. This includes delimiting the Visual Influence Area (VIA) and preparing the required digital models.

3.1 *Delimitation of Visual Influence Area (VIA)*

Firstly, the VIA of the ER facility must be delimited to be able to subsequently select the digital models within that area. This area will depend on three fundamental factors: the orography of the place, the type of installation and the size of it. For solar facilities, there are hardly any tables of visual influence depending on the distance. However, for wind farms there are several studies classifying different distances to which these facilities are visible per their size. Bishop (Bishop, 2002) set boundary distances to which wind turbines of up to 78 m high produce visual impact, establishing 8.5 km as the severe impact limit, 10 km the moderate impact limit and more than 10 km the slight impact limit. Sinclair (University of Newcastle, 2002) adapted the Thomas matrix for wind turbines up to 100 m high, stating that for wind turbines of 90-100 m high the visual impact limits are: up to 4 km high impact, up to 8 km medium-high impact, up to 18 km medium impact, up to 23 km light-medium impact and up to 30 km light impact. Vissering (Vissering, 2011) suggested a 40 km VIA for modern 2 MW wind turbines, as these can be seen in good weather conditions at distances of 24 to 32 km. Sullivan (Sullivan et al., 2012) proposed a visibility limits matrix for wind facilities with wind turbines between 90 and 120 m high in slightly rugged regions, delimiting a VIA of 48 km, in which the casual visibility limit is 32 km and the visual dominance limit is16 km. Manchado (Manchado et al., 2015) extrapolated the matrix of Bishop to obtain the visual impact limits of wind turbines up to 140 m high, establishing that up to 8 km distances the impact is severe, up to 16 km is medium and for distances greater than 16 km the impact is slight. With these data, a table of Visual Influence Areas was developed according to the height of the installation (table 1), both wind and solar concentrators. The photovoltaic facilities, being superficial, have an VIA smaller than the wind installations or the solar towers, reason why the smaller area presented below will be taken like VIA for them.

Table 1. Areas of Visual Influence depending on the height of the facility (wind turbine or solar tower)

Height of the facility (m)	VIA (Km)
41-48	16
53-57	19
72-78	24
90-100	30
100-140	48

3.2 *Preparation of digital elevation models*

A digital cartography of the study area needs to be prepare to carry out the visibility analyses of the ER facility and then, the analysis with GIS tools such as ArcGIS will be carry out. The digital cartography used is Digital Elevation Models (DEM). These can be obtained through LIDAR data or also by modifying Digital Terrain Models (DTM) adding Digital Surface Models (DSM) which includes the heights of various element typologies. Although the use of LIDAR data is faster, using DTM was preferred to be able to elaborate own cartography of the study areas. To obtain the different DTM included in the VIA of the facilities, the BTN25 cartographic products into the VIA are downloaded from the National Geographic Information Centre (NGIC) to convert them into an DTM using ArcGIS. The result is the basis that will be used to add all MDS wanted, in this case, vegetation, buildings and facilities. To obtain the DSM of vegetation, the Spanish Forest Map MFE50 will be used as a data source. To obtain the DSM of the buildings and facilities, the layer of buildings and the various layers of the facilities of the BTN25 will be used as a data source. Once the necessary data is obtained to elaborate the different DSM, the height to each of the layers is assigned and the different DSM added to the DTM to obtain the DEM that will be used for the later analyses.
Since the focus of this research is the visual impact on the landscape in the cultural heritage sites, it is desirable to get all protected areas of the study area, as well as the rest of the cultural heritage sites, if any, and all areas of potential observer concentration (ZCPO), both the active attitude of the observer, such as the viewpoints or scenic routes (tourist routes, picturesque roads ...), and passive attitude, such as visual corridors (highways, roads ...) or the rest of ZCPO, among which the populations stand out for their high permanent concentration of observers. Each of these elements will be cartography for later use in the methodology.

4. Development of the methodology

The methodology for assessing the visual impact of renewable energy installations on the landscape in cultural heritage sites will be developed in several phases: activity analysis or convergent visibility, analysis of visual quality, analysis of visual fragility, weighting of the result through surveys and calculation of the total impact.

4.1 *Activity analysis or convergent visibility through visual basins*

The convergent activity or visibility is the visibility that exists from outside the study area towards the study area itself. It calculates the points from which the installation under study is visible, obtaining a map with these points. For the present investigation, will be calculated both the convergent visibility of the ER installation and that of the cultural heritage site on which the visual impact caused by it is evaluated.
Using the "observer points" tool of ArcGIS we will obtain a map of visual basins in which will appear the points from which the ER installation and the cultural heritage place are seen, each one separately and both at the same time. The part of the map that interests us is that layer that contains the points from which both constructions are seen at the same time. This layer will be superimposed on the cartography previously obtained with the DEM.
All protected areas of the study area will overlap to this new map together with the rest of cultural heritage sites, if any, and all ZCPO, including populations and active and passive ZCPO. The result is a map of all the ZCPO from which both constructions are visible.
Finally, a map of visual basins will be made from each ZCPO from which both constructions are visible to find out what other items (betterments and attenuations) are visible from each ZCPO. This will be used in the field work when checking in situ in each ZCPO the visible betterments and attenuations of the landscape.

4.2 *Visual quality analysis*

The next step is calculating the visual quality of the landscape in the cultural heritage site from each ZCPO. The visual quality will be measured in terms of the intrinsic importance of the cultural heritage site, the cultural or acquired importance and possible betterments or attenuations.

4.2.1 *Intrinsic importance of cultural heritage site*

Based on the scale of evaluation developed by Grijota (Grijota Chousa, 2012), the valuation of the intrinsic importance (I_i) of the cultural heritage site will be done according to the international, national, regional or local value. Table 2 is an adaptation of the scale.

Table 2. Intrinsic importance of cultural heritage site

Cultural Heritage Class	Description	I_i
International value	Elements declared by UNESCO as World Heritage. Tourist routes of international value. Elements of global popularity such as museums or isolated architectural pieces.	12
National value	Immovables of cultural interest declared in the framework of Law 16/1985, of June 25, of the Spanish Historical Heritage (sets, monuments ...). Picturesque roads or tourist routes of national interest.	9
Regional value	Immovables of cultural interest declared in the autonomic frame. Picturesque roads or tourist routes of regional interest.	6
Local value	Corners or viewpoints of local interest, such as hermitages, parks, etc.	3

Although the application to the case studies is still in process, we estimate that they will have an I_i = 12.

4.2.2 *Cultural or acquired importance of the cultural heritage site*

The intrinsic importance of the cultural heritage site will be weighed through the appearances of the own heritage in literature and art, the importance in the popular culture of the area and through surveys in each ZCPO that is a population (especially valuable for heritage local, which is considered with the least intrinsic value and is the least protected). This will allow us to obtain the cultural or acquired importance of the cultural heritage site. The weighting will be done through "Eq. 1". Each variable of cultural importance can acquire values between 0 and 3 points depending on the degree of importance of the place cultural heritage, as shown in table 3.

$$I_c = I_i + I_{cal} + I_{caa} + I_{cpz} + I_{ce} \qquad (1)$$

Where:
I_c: cultural or acquired importance.
I_i: intrinsic importance of the cultural heritage site.
I_{cal}: cultural importance by the appearances in the literature of the cultural heritage site.
I_{caa}: cultural importance by the appearances in the art of cultural heritage site.
I_{cpz}: cultural importance in the popular culture of the area.
I_{ce}: cultural importance according to the surveys carried out in the ZCPO that are populations.

Table 3. Acquired importance of the cultural heritage site.

Degree acquired importance	Description	Cultural importance of each variable (I_{cal}, I_{caa}, I_{cpz}, I_{cezcpo})
Null importance	a) There are no appearances in literature. b) There are no appearances in art. c) It does not have importance in the popular culture of the zone. d) Surveys give a score of zero points to the importance in the popular culture of the area's cultural heritage site.	0
Medium importance	a) There is some appearance in the literature. b) There is some appearance in art. c) It has medium importance in the popular culture of the area. d) Surveys give a score of one to the importance in the popular culture of the area cultural heritage site.	1
High importance	a) There are at least two occurrences in the literature. b) There are at least two appearances in the art. c) It has high importance in the popular culture of the area. d) Surveys give a score of two to the importance in the popular culture of the area's cultural heritage site.	2
Very high importance	a) There are more than two appearances in the literature. b) There are more than two appearances in art. c) It is very important in the popular culture of the area. d) Surveys give a score of three to the importance in the popular culture of the area cultural heritage site.	3

In the case studies, we estimate that the Roman city of Segóbriga and the Santiago's Way will have a cultural importance of 3 in each item and Uclés of 2.

4.2.3 *Intrinsic importance of each ZCPO*

For each ZCPO, the intrinsic importance of each APOC according to the rating scale, developed by Grijota, by the international, national, regional or local importance of each ZCPO, in accordance with the table 4, will be added to the value of the cultural importance of the cultural heritage site.

Table 4. Intrinsic importance of each ZCPO (Grijota Chousa, 2012)

Class of ZCPO	Importance of ZCPO	Description	I_{zcpo}
Viewpoint	International value	Elements declared by UNESCO as a World Heritage and Biosphere Reserves, and other particular elements of global popularity, such as museums or isolated architectural pieces, Biosphere Reserves. Tourist routes of international interest.	12
	National value	Protected natural areas declared within the framework of Law 42/2007, of 13 December, on Natural Heritage and Bio-diversity. Immovables of cultural interest declared in the framework of Law 16/1985, of June 25, of the Spanish Historical Heritage (sets, monuments ...). Picturesque roads or tourist routes of national interest.	9
	Regional value	Protected areas declared within the autonomic framework. Red Natura 2000. Immovables of cultural interest declared within the autonomic framework. Picturesque roads or tourist routes of regional interest.	6
	Local value	Corners or viewpoints of local interest, such as hermitages, parks, etc.	3
Visual corridors (except scenic routes)	Category 1	Highways.	4
	Category 2	National highways (Law 25/1988, of July 29, of Roads), autonomic roads and general rail lines, including AVE and conventional FFCC.	3
	Category 3	Local roads.	2
	Category 4	Tracks and rural roads.	1
Rest of ZCPO	Category 1	Urban nucleus with more than 10.000 inhabitants	8
	Category 2	Towns with 1,000 - 10,000 inhabitants.	6
	Category 3	Towns with less than 1,000 inhabitants.	4
	Category 4	Rest of points of the field of study.	2

4.2.4 *Betterments from cultural heritage place from each ZCPO*

For each ZCPO, there will be added the possible betterments (P) that exist in the views from each ZCPO to the cultural heritage site. Betterments refer to the existence of landscape resources (RP) of natural origin (a rocky escarpment, a lagoon, etc.) or of anthropic origin (a castle, a hermitage, a sculpture, etc.). Based on the table developed by Grijota, a rating scale is proposed in table 5 as a function of the number of RP and the distance from the RP to the ZCPO.

Table 5. Valuation of betterments: presence of landscape resources (RP)

Distance between RP and ZCPO	Betterment in each scenic plane	Total betterment (P_t)
Foreground (0-100 m)	$P_{p1} = \Sigma$ [nº RP x (+1,00)]	$P_t = P_{p1} + P_{p2} + P_{p3}$
Intermediate plane	$P_{p2} = \Sigma$ [nº RP x (+0,50)]	
Backdrop	$P_{p3} = \Sigma$ [nº RP x (+0,25)]	

4.2.5 *Attenuations of the cultural heritage site from each ZCPO*

Also for each ZCPO, will be subtracted the possible attenuations (A) of visual quality arising due to the presence of discordant elements (ED) in the landscape or of the existence of obstacles, noises or odours in the visual from the ZCPO to the cultural heritage site. EDs are little or no integrated elements (such as a road or a facility) which reduce visual quality to the landscape perceived from that area. Arating scale for these attenuations is proposed in table 6 based on the table developed by Grijota.

Table 6. Assessment of visual quality attenuations

Attenuation variable	Partial attenuation	Total attenuation (A_t)
Existence of obstacles	A_{ob} = -1	$A_t = A_{ob} + A_{ru} + A_{ol} + A_{p1} + A_{p2} + A_{p3}$
Existence of noise	A_{ru} = -1	
Existence of bad odours	A_{ol} = -1	
ED in the foreground (0-100	A_{p1} = Σ [nº RP x (-1,00)]	
ED in intermediate plane	A_{p2} = Σ [nº RP x (-0,50)]	
ED on backdrop	A_{p3} = Σ [nº RP x (-0,25)]	

4.2.6 *Total cultural importance (I_{ct}) of the cultural heritage site from each ZCPO*

The total cultural importance (I_{ct}) of the cultural heritage site from each ZCPO will be obtained by adding the previous parameters of visual quality and entering the data in table 7.

Table 7. Qualitative value of the total cultural Importance from each ZCPO (I_{ct})

$I_c + I_{zcpo} + P_t + A_t$	Qualitative value	Total cultural importance (I_{ct})
>20	Very high	3
16-20	High	2,5
10-15	Medium	2
5-9	Low	1,5
1-4	Very low	1

4.3 *Analysis of visual fragility*

Then the analysis of visual fragility of the landscape in the setting of the cultural heritage site will be carried out based on the visibility and accessibility of the RE facility from each ZCPO and the distance between the installation and each ZCPO.

4.3.1 *Visibility of the RE facility of each ZCPO*

The visibility of the RE facility will be based on its magnitude (number of wind turbines or surface of the solar plant), visual incidence and visual contrast, visual dominance and spatial dominance of the facility with respect to the landscape setting of the cultural heritage site, from each ZCPO.
The magnitude (M_i) of the RE facility will be assess according to table 8. Table 8 is based on the table developed by Hurtado in the Spanish method (Hurtado et al., 2004) and in the field work on case studies of wind farms and solar plants of the present research.

Table 8. Magnitude (M_i) of the RE facility

Nº towers or wind turbines	M_i	Solar plant surface (Ha)	M_i
1-3	1,0	<3	1,0
4-10	1,3	3-10	1,3
11-20	1,5	10-20	1,5
21-30	1,8	20-50	1,8
>30	2,0	>50	2,0

All data relating to solar installations are my own. It is one of the innovations of the thesis. Wind turbine data are adaptations of other studies to the criteria of the present investigation.

The visual incidence (I_v) will be assessed from "Eq. 2" proposed by Grijota (Grijota Chousa, 2012) following the experimental studies by Shang and Bishop (Shang and Bishop, 2000) on the visual incidence angle.

$$I_v = (n + \text{sen}\ \alpha) \cdot (n + \text{sen}\ \beta) \qquad (2)$$

Where:

α: is the vertical visual incidence angle from which the observer perceives the RE installation. It is calculated on the vertical projection between the ER installation, taking the highest and lowest point of the same, and the observer, considering the point closest to the project in case the ZCPO is linear or superficial.

β: is the horizontal visual incidence angle from which the observer perceives the RE installation. It is calculated on the horizontal projection between the RE installation and the observer, considering the point closest to the project in case the ZCPO is linear or superficial.

n: is the number of quadrants. It is equal to zero if the angle is less than 90 °, and will be equal to one or greater of one for the case where the angle is greater than 90 °.

For the case where the angle is greater than 90°, the value of I_{vh} will be equal to the sum of the sine of the angle of visual incidence in the incomplete quadrant plus the number of complete quadrants (n). For the case where the angle is less than 90°, the value of I_{vh} will be equal to the sum of the sine of the angle of visual incidence, being in this case n = 0.
For the evaluation of visual contrast, visual dominance and spatial dominance, table 9 will be considered (adaptation from the Visual Contrast Rating (VCR) method developed by Smardon. The visual contrast will result from adding each of the different contrasts. The total visual contrast will result from the sum of visual contrast, visual dominance and spatial dominance. The result will then be taken to table 10 to obtain the qualitative contrast value (C_t).

Table 9. Adaptation of the table *Visual Contrast Rating* (Smardon et al., 1979) to the present investigation

<table>
<tr><th colspan="4">Visual contrast (C_v)</th><th colspan="4">Visual dominance (D_v)</th><th colspan="5">Spatial dominance (D_e)</th></tr>
<tr><td rowspan="4">Colour contrast</td><td>High</td><td>9</td><td rowspan="4"></td><td rowspan="5">RE facility in confined setting</td><td rowspan="5">Dominant</td><td rowspan="5">12</td><td rowspan="5"></td><td colspan="2"></td><td rowspan="5">2-3x Prominent</td><td rowspan="5">Dominant</td><td rowspan="5">6</td></tr>
<tr><td>Med.</td><td>6</td><td rowspan="6">Composition</td><td rowspan="6">Prominent
Significant
Inconspicuous</td></tr>
<tr><td>Low</td><td>3</td></tr>
<tr><td>Null</td><td>0</td></tr>
<tr><td rowspan="4">Shape Contrast</td><td>High</td><td>6</td><td rowspan="4"></td></tr>
<tr><td>Med.</td><td>4</td><td rowspan="5">Some or all of the RE facility in unconfined setting</td><td rowspan="5">Co-Dominant</td><td rowspan="5">8</td><td rowspan="5"></td><td rowspan="5">1x Prominent
o
2x Significant</td><td rowspan="5">Co-Dominant</td><td rowspan="5">4</td></tr>
<tr><td>Low</td><td>2</td></tr>
<tr><td>Null</td><td>0</td><td rowspan="6">Position</td><td rowspan="6">Prominent
Significant
Inconspicuous</td></tr>
<tr><td rowspan="4">Line Contrast</td><td>High</td><td>3</td><td rowspan="4"></td></tr>
<tr><td>Med.</td><td>2</td></tr>
<tr><td>Low</td><td>1</td><td rowspan="5">RE facility significant regarding the setting</td><td rowspan="5">Subordinate</td><td rowspan="5">4</td><td rowspan="5"></td><td rowspan="5">1x Significant</td><td rowspan="5">Subordinate</td><td rowspan="5">2</td></tr>
<tr><td>Null</td><td>0</td></tr>
<tr><td rowspan="4">Texture Contrast</td><td>High</td><td>3</td><td rowspan="4"></td></tr>
<tr><td>Med.</td><td>2</td><td rowspan="6">Backdrop</td><td rowspan="6">Prominent
Significant
Inconspicuous</td></tr>
<tr><td>Low</td><td>1</td></tr>
<tr><td>Null</td><td>0</td><td rowspan="5">RE facility small regarding the setting</td><td rowspan="5">Insignificant</td><td rowspan="5">0</td><td rowspan="5"></td><td rowspan="5">All inconspicuous</td><td rowspan="5">Insignificant</td><td rowspan="5">0</td></tr>
<tr><td rowspan="4">Scale Contrast</td><td>High</td><td>6</td><td rowspan="4"></td></tr>
<tr><td>Med.</td><td>4</td></tr>
<tr><td>Low</td><td>2</td></tr>
<tr><td>Null</td><td>0</td><td colspan="2"></td></tr>
<tr><td colspan="3">Σ Contrastes = C_v =</td><td></td><td colspan="3">D_v =</td><td></td><td colspan="4">D_e =</td><td></td></tr>
</table>

Table 10. Qualitative value of total contrast (C_t)

$C_v + D_v + D_e$	Contrast level	Total Contrast (C_t)
36-45	Severe	2,0
27-35	Strong	1,5
18-26	Moderate	1,0
9-17	Weak	0,5
0-8	Negligible	0,1

4.3.2 *Accessibility of each ZCPO*

The accessibility (A_{cc}) of each ZCPO will be considered according to a scale of assessment by type of ZCPO or type of population (for the case of populations) according to table 11 based on the studies of Grijota (Grijota Chousa, 2012) and the coefficient "e" of Hurtado (Hurtado et al., 2004).

Table 11. Accessibility of each ZCPO (own elaboration)

Type of ZCPO	Subtype	Accessibility (A_{cc})
Viewpoints and scenic routes	-	2,00
Towns	>10.000 hab.	2,00
	>5.000 hab.	1,90
	>300 hab.	1,70
	100-299 hab.	1,50
	50-99 hab.	1,30
	20-49 hab.	1,20
	5-19 hab.	1,10
	1-5 hab.	1,05
	0 hab.	1,00
Visual corridors	-	1,00

4.3.3 *Distance between each ZCPO and RE facility*

The distance (D) between the RE facility and each ZCPO will be evaluated according to a distance matrix (table 12) extrapolated from the Sinclair-Thomas Matrix (University of Newcastle, 2002: 21), in the case of the wind turbines and solar towers, and by means of a matrix of own elaboration based on the work of field, for the solar plants.

Table 12. Diego-Chias matrix of qualitative distance classes (D) between ZCPO and RE facility (own elaboration)

Impact level	Qualitative class (D)	Towers or wind turbines height (m)							Solar plant surface (Ha)				
		41-45	52-57	70-78	90-100	100-140	140-182	182-206	<3	3-10	10-20	20-50	>50
		Range distances (km)							Range distances (km)				
High	**2,00**	0-2	0-2,5	0-3	0-4	0-5,5	0-7	0-8	0-0,3	0-0,5	0-1	0-2,5	0-3
Med-High	**1,50**	2-4	2,5-5	3-6	4-8	5,5-	7-14	8-16	0,3-0,5	0,5-0,9	1-1,8	2,5-4,5	3-5
Medium	**1,00**	4-6	5-8	6-10	8-13	11-18	14-23	16-26	0,5-0,7	0,9-1,3	1,8-2,6	4,5-6,5	5-7
Low-Med	**0,75**	6-9	8-11	10-14	13-18	18-25	23-32	26-37	0,7-0,9	1,3-1,7	2,6-3,4	6,5-8,5	7-9
Low	**0,50**	9-13	11-15	14-18	18-23	25-32	32-41	37-47	0,9-1,1	1,7-2,2	3,4-4,4	8,5-11	9-12
Almost nil	**0,25**	13-16	15-19	18-23	23-30	32-42	41-54	47-61	1,1-1,4	2,2-2,8	4,4-5,6	11-14	12-15
Null	**0,1**	>16	>19	>23	>30	>42	>54	>61	>1,4	>2,8	>5,6	>14	>15

4.4 *Partial visual impact from each ZCPO*

The partial visual impact from each ZCPO will be the visual impact that there is in the landscape in the setting of the cultural heritage site, from each ZCPO, due to the RE facility. It will be calculated by the following equation (Eq. 3) which contains all the above parameters:

$I_{vp} = I_{ct} \cdot M_i \cdot I_v \cdot C_t \cdot A_{cc} \cdot D$ (3)

4.5 *Partial visual impact of each ZCPO weighted according to the survey*

Once the partial visual impact has been calculated for each ZCPO, the result is weighted through a survey of the population in each ZCPO population. On the survey will be used the picture side by side method, already used by Shang and Bishop (Shang and Bishop, 2000), among others, in which one is the image of the original view of the landscape and the other is a photomontage of that view with the future facility. The answer to the question about the impact caused will be evaluated by a Likert scale with the values in table 13, considering that the impact is low, moderate or high. With this value, the parameter E will be multiplied to the value of I_{vp}, resulting from "Eq. 3 ", obtaining the weighted partial visual impact pursuant to the survey (I_{vpe}) as indicated in" Ec. 4".

Table 13. Weighting parameter according to survey (E)

Impact level	Total contrast (C_t)
High	1,5
Moderate	1,0
Low	0,5

$I_{vpe} = I_{vp} \cdot E$ (4)

4.6 *Total visual impact of the RE facility on the landscape in the cultural heritage site*

The total visual impact (I_{vt}) of the RE facility on the landscape in the setting of the cultural heritage site will be calculated by performing the average of the partial visual impacts from each ZCPO following "Eq. 5". With the result of "Eq. 5 ", we will introduce the value in table 14 to obtain the qualitative value of the total visual impact, adapted to the Spanish environmental impact assessment standard, which distinguishes compatible, moderate, severe and critical impacts.

$I_{vt} = \Sigma I_{vpe} / n^o ZCPO$ (5)

Table 14. Qualitative value of the total visual impact of the RE facility

Value of I_{vt}	Impact level
>10	Crítical
(5-10]	Severe
(1,5-5]	Moderate
(0-1,5]	Compatible

5. Discussion and conclusions

The methodology presented in this paper is the initial version of a methodology for assessing the visual impact of RE facilities in the landscape in the setting of cultural heritage sites. The final aim is to obtain a methodology of general application that serves both wind and solar installations, including photovoltaic and concentrators or solar towers. This is new since both kinds of installations are not usually included.

The total visual impact has been modulated according to the classes that typifies the law of environmental impact assessment in Spain. The novelty, and one of the contributions of this methodology, lies into the possibility that the intrinsic importance that cultural heritage sites have for their own recognition can be increased by the different parameters of cultural or acquired importance, by the intrinsic importance of each ZCPO from which it is visible and by the betterments in the landscape. This aspect is essential in the research because it aims to improve the valuation of local and regional heritage against the possible impacts caused by this type of facilities, taking into account public opinion through surveys, the importance in popular culture of the area and the different appearances in literature and art of the heritage.

In addition, this research has great potential and can be broad in scope: it might be introduced into the EIA as a methodology for studying the visual impacts of RE facilities on heritage and landscape; it might also reduce costs for energy companies by using it at the project stage to discern whether the site of the facilities is suitable for a heritage site; and might serve small town councils as a tool to contrast studies that present them with the impacts that these facilities have on their landscape.

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