Chapter 14
The Production of Solar Photovoltaic Power and Its Landscape Dimension

The Case of Andalusia (Spain)

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Abstract Solar photovoltaic power development has had various effects on the landscape, especially in rural areas, where the contrasts with other land uses are more striking. Landscape criteria are not normally taken into account in the planning and the design of these installations, and measures must therefore be taken to control and manage photovoltaic development in order to ensure that the quality of the landscape is preserved or even improved. In this case, one of the most effective landscape management tool is the integration of these installations into the landscape. In this chapter, we analyse the landscape features of these installations, and systematize their impacts on the landscape. We also offer various landscape integration proposals, as a kind of Good Practice Guide. Our case study focuses on the Andalusia region of southern Spain, where there has been very rapid development of photovoltaic power energy in recent years. We believe this is a representative case and that the results can be extrapolated to other areas in which a similar process is taking place.

Keywords Renewable energies landscapes • Solar photovoltaic plants • Landscape integration • Landscape impact • Andalusia

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14.1 Introduction

Solar photovoltaic energy installations and, in particular, photovoltaic power plants have grown so quickly in Spain that it has been very difficult to assess their impact on the landscape, especially in regions such as Andalusia, in which development has not been restricted by climatic or legislative limitations (de la Hoz et al. 2013). This development is often at odds with the quality of landscapes and has frequently resulted in important impacts, due to the lack of landscape and territorial planning considerations during this expansion process. The deployment of photovoltaic energy plants has taken place above all in rural locations outside protected areas, in ordinary landscapes used by local people on an everyday basis. It is therefore necessary to strike a balance between photovoltaic power and landscape, by applying measures that combine the development of environmentally friendly sources of energy and the defence of the landscape values of the territory. Landscape integration, as an instrument of landscape management, offers an effective means of diminishing the negative effects of these new installations and promoting their scenic potential.

Within this context, the main goal of this chapter is to explore the existing connection between photovoltaic power plants and landscape, analysing the perceptible dimension of these installations and their effects on the landscape. In this way we will be establishing a series of landscape integration guidelines which together form a Good Practice Guide, as to the best way to incorporate these elements into the landscape, in order to maintain or improve its quality. We use the definition of landscape set out in the European Landscape Convention, namely, any part of the territory, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors (Council of Europe 2000). In this sense, this chapter seeks to analyse the factors and elements that affect our perception of photovoltaic plants, systematising the modifications they make to the landscape and its character. We also analyse public perception and evaluations regarding these plants and propose ways to advance in the landscape integration of these new components of landscape. In the methodology we propose there are five variables: location and site of the installations, density, overall design, design of the component parts and internal organisation of these components. These variables in turn give rise to three methodological phases: identification of the landscape features of photovoltaic plants, analysis of their impacts and proposals for landscape integration.

As a case study, we will be analysing the region of Andalusia (Spain). In this region, the proliferation of photovoltaic plants has been particularly intensive during the first decade of this century and has affected a wide variety of landscapes. It is, therefore, a representative case study for the analysis of this issue, and the results can be extrapolated to other areas in which a similar process is taking place. The information used in this chapter is the result of a detailed analysis of the existing photovoltaic plants in Andalusia in 2009 – a total of 88 installations – and of the assessment of their effects on the landscape, as gauged by the research team and by the results of a survey of the nearby population.

This chapter has been structured into four sections. In the first section, we examine the energy potential of Andalusia and the development of photovoltaic power in the region so far. In the second part, we explore the landscape characteristics of Andalusian photovoltaic plants, and in the third we classify the impacts of these installations on the landscape. Finally, the last part seeks to identify the best landscape integration measures to ensure that the plants blend in as much as possible with their surrounding landscape.

14.2 Theoretical Background

The study of the relationships between photovoltaic power and the environment is a recent area of research, and its landscape dimension has hardly been tackled. Most research in this field has focused on the environmental repercussions of photovoltaic energy. One of the first studies of the environmental impact of solar technologies, including photovoltaic energy, was by Tsousos et al. (2005). Many others such as Aguado-Monsonet (1998), Pehnt (2006), Pacca et al. (2007), or Stoppato (2008) have tried to establish the environmental costs of the production process of photovoltaic technologies and materials, by applying LCA (life cycle assessment) methods. The environmental benefits of photovoltaic power have also been the subject of several studies, such as Scognamiglio and Rostvik (2012) – on sustainable buildings – or El Bassam and Maegaard (2004), on rural installations. On this question, Larcher et al. (2013) highlight the potential of photovoltaic power for rural development. Finally, other studies in the field of architecture such as those by Roberts and Guariento (2009), Martín and Fernández (2007), and Martín (2011) analysed the various means of integrating photovoltaic devices into the structure of buildings, and some of the solutions they propose (materials, shapes, colours) can also be applied to the components of photovoltaic plants.

Most research into renewable energies and landscape has centred on wind power (Nadaï and van der Horst 2010), and little research has yet been done on the landscape aspects of photovoltaic power, with some exceptions including Chiabrando et al. (2009) and Mérida et al. (2010), who researched the landscape impacts of photovoltaic plants, and Minichino (2013), who suggested that landscape design should become a criterion in photovoltaic energy policy. For its part, public perception of photovoltaic power has only been tackled in a few specific papers (Poize 2013; Mérida and Lobón 2012) and is hardly mentioned in studies of the general perception of renewable energies, above all wind power, such as those by West et al. (2010), Wüstenhagen et al. (2007) or Zoellner et al. (2008). Papers on social perception of renewables in Spain such as those by Frolova (2010), Frolova and Pérez (2011) and Frolova et al. (2013) have also focussed on wind energy. At a regional level, the expansion of photovoltaic power in Andalusia and its consequences have been researched by Prados (2010a) and by Mérida and Lobón (2012), whereas Prados (2010b) analysed the sectoral planning of this source of energy, within the framework of the various types of renewable energy. Initial research into the creation of new energy landscapes dominated by renewable energies in Spain has been done by Mérida et al. (2009), who focussed on the spatial combination of different energy installations, and by De Andrés and Iranzo (2011), who analysed their impact source by source, although the latter paper did not consider photovoltaic installations.

In addition authors studying landscape integration have traditionally focussed on installations on farm buildings located in rural areas (Ayuga 2001; Hernández et al. 2006; Rogge et al. 2008; Tassinari et al. 2007; Mérida and Lobón 2011; Riesco 2000; Sovinski 2009). However, many of their results can also be applied to photovoltaic plants.

As can be seen, the study of the relationship between photovoltaic energy and landscape is still at an early stage, and a lot of work remains to be done to improve our understanding, both in the analysis of the perceptive dimension of the installations and in their public perception and evaluation. We must also explore the landscape integration of photovoltaic installations and the new landscapes they are helping to form. This paper seeks to achieve these goals and to help us understand these relationships better.

14.3 Andalusia, Its Territory and Photovoltaic Energy Development

Andalusia is very well suited for the development of various renewable energies, and in particular the different forms of solar energy, such as photovoltaic power. As a result, renewable energy sources have been developed quickly and widely across the region and now account for 35.6 % of electricity generation (Agencia Andaluza de la Energía 2012).

Photovoltaic energy is ideally suited to the Andalusian climate. The region enjoys more sunshine than many other parts of Spain and indeed Europe. The sun shines for over 3,000 h a year in a large part of Andalusia, with the Mediterranean coast and the Guadalquivir valley receiving the greatest amounts. The intensity of solar radiation is also high – over 4 kWh/m^2 in the whole region (AEMET 2005).

In addition, a substantial part of the land is located on level or slightly undulating ground, especially in the Guadalquivir river valley. The region covers a large area, 84,000 km^2, with a population density that is average for Europe, but is concentrated in certain areas, such as the coast and the main metropolitan areas. There is therefore abundant available space in inland rural areas in the region, facilitating the setting up of this type of extensive installation due to the low price of the land and the higher returns offered by photovoltaic energy compared to traditional agricultural uses.

From a technological point of view, the region has a wide, high-voltage electricity distribution network that stretches over 9,000 km. Andalusia also has a significant industrial sector specialising in the field of renewable energies. Last but not least, in the first decade of this century, Andalusia, and Spain in general, made a commitment to encourage the development of renewable energies, introducing various laws and regulations offering substantial economic support to allow the sector to expand. However, with the onset of the economic crisis, in the last few years, this official support has been reduced drastically, slowing down the development of this energy sector. Despite the current circumstances, the official plans for the sector, namely, the Renewable Energies Plan 2011–2012 (Ministerio de Industria, Turismo y Comercio 2011) or the Andalusian Energy Sustainability Plan 2007–2013 (Agencia Andaluza de la Energía 2007), still somewhat paradoxically assert the enduring public commitment to the promotion of renewable energies.

Within this context, the production of photovoltaic power in Andalusia has undergone a rapid evolution. Whereas according to the Andalusian Energy Agency, the installed power in 2007 was 64.13 MW, by the end of 2012, it had reached 840.13 MW, a thirteenfold increase in only 6 years. Growth has not been constant over this period, with an initial period of spectacular increase to 663.28 MW in 2008. Since then, installed power has grown at a more moderate pace, with practically no growth at all in 2009 (665.91 MW) and slightly more sustained increases in 2010 (733.20 MW), 2011 (783.39 MW), 2012 (840.13 MW) and 2014 (883), in line with the changes in the regulations.

As a result of this whole process, photovoltaic power is now the second renewable energy source in Andalusia, after wind power. Of the total amount of electricity produced by renewable sources at the end Of the total amount of renewable installed power at the end of 2013 (6.016 MW), photovoltaic power accounted for 14.4 % and wind power 52.5 %.

In Spain as a whole, Andalusia is the second Autonomous Region in terms of installed photovoltaic power, after Castilla-La Mancha (ASIF 2011), and within Andalusia, most of the installed power is centred in the provinces of Seville and Cordoba, which together account for 46 % of the total (Table 14.1).

So far, photovoltaic power plants account for most of the installed power and the proportion of rooftop installations is noticeably lower, at 21.3 %, although this percentage has been gradually increasing in recent years and is expected to continue growing. There are significant variations from one province to the next, with the highest percentage of rooftop installations in Cadiz (34.8 %) and the lowest in Cordoba (12.4 %).

Table 14.1 Installed photovoltaic power (MW) in Andalusia by province (31/12/2014)

Province	MW	%
Almeria	84.67	9.58
Cadiz	73.54	8.32
Cordoba	195.06	22.08
Granada	96.47	10.92
Huelva	73.37	8.30
Jaen	91.83	10.39
Malaga	52.78	5.97
Seville	215.61	24.40
Total Andalusia	883.33	100.00

Source: Andalusian Energy Agency

The photovoltaic plants we have analysed (virtually all those currently existing) are mostly situated in the provinces of Seville (27.2 %) and Granada (19.3 %), while most of the land occupied by these installations (64.5 %) is concentrated in the provinces of Seville, Granada and Cordoba.

14.4 Landscape Features of Photovoltaic Plants

The photovoltaic plants so far installed in Andalusia are scattered across the territory and occupy a relatively small area. For these reasons, more than new types of landscape, in those places where they are relatively frequent, they should be considered as components of the landscape and in those where there are relatively few, as special landscape features. Only in those situations in which the plants are installed in association with other renewable energy facilities, such as thermo-solar or wind energy, occupying a significant area (several km^2) and laid out practically adjacently with only small spaces in between can we talk about a specific type of landscape, a renewables landscape (Mérida et al. 2009).

The perceptive dimension of a photovoltaic plant depends primarily on its typological characteristics and the visual relationships it establishes with its environment. A landscape analysis of photovoltaic plants must therefore take several variables into account: their location and site, their density, the design of the installation as a whole, the specific design of the various devices and components, and the internal layout of these components. We will now analyse these factors for the case of photovoltaic installations in Andalusia (Fig. 14.1).

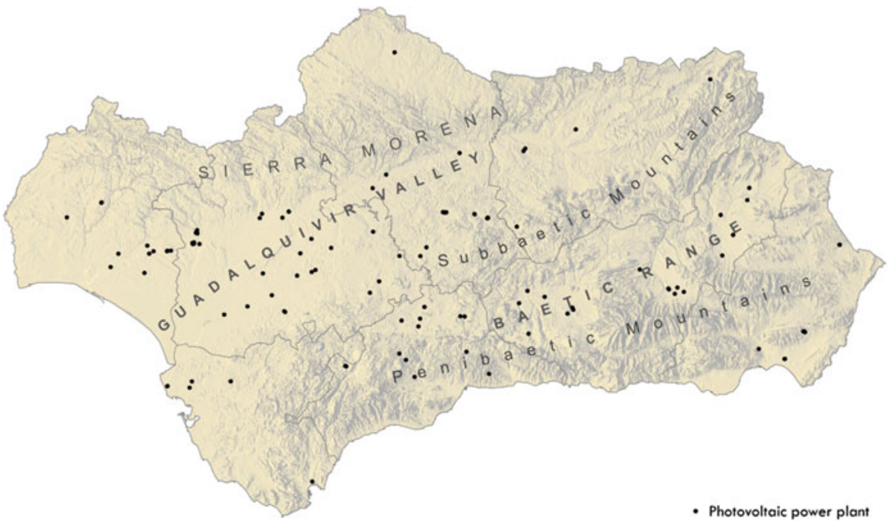

Fig. 14.1 Photovoltaic power plants in Andalusia (2009) (Source: Mérida and Lobón 2012)

14.4.1 Location and Site

The photovoltaic power plants in Andalusia are spatially centred around the Guadalquivir valley and in the fertile plains and the plateaus between the mountains of the Betic mountain ranges. In general, there are very few plants in mountain terrains, due to both topographic reasons and to the lack of infrastructure (electrical and other types) in these areas. They are also relatively scarce in coastal areas, although in this case, this is due to competition from other productive activities such as tourism and intensive agriculture. In the same way, they are practically non-existent in peri-urban and metropolitan areas. In any case, there is one essential location criterion: proximity to the main electricity distribution networks.

On a more detailed scale, the installations we analysed were most frequently located on two types of physiographic unit: hillocks and hills, in 42 % of the cases, and plains (fluvial, plateaus, intra-mountain basins, etc.) in 41 %. There are relatively few sites on very sloping hillsides (4.5 %), peaks (2.3 %), foothills (6.8 %) and valley floors (3.4 %). Normally, the land on which they were installed had previously been used in agriculture (70 % of the cases), mainly tree plantations and olive groves, which provided lower returns than photovoltaic energy. It is precisely because of their frequent location on agricultural land and their original modest dimensions that photovoltaic power plants are often referred to as 'solar farms'.

The rapid proliferation of photovoltaic plants has made their effective control in territorial planning difficult, and they now appear in practically any type of landscape. Only protected areas have remained unaffected by this phenomenon, while the expansion in ordinary landscapes, by contrast, has occurred in a disorganised, uncontrolled way with no landscape management.

14.4.2 Density

In general terms, the density of photovoltaic power plants in terms of the area they occupy as a proportion of the whole territory of Andalusia is not very high (they cover a total area of 1,000 ha in a territory measuring 87,500 km^2), even in their preferred locations. They can occasionally reach higher densities in specific areas and municipalities, where various photovoltaic power plants are grouped together within one single panoramic view. In any case, the visual prominence of these installations, often in stark contrast with traditional land uses in the rural areas where they are located, makes them seem more densely deployed than they actually are.

14.4.3 Overall Design of Photovoltaic Power Plants

The overall design of photovoltaic power plants encompasses various different factors, such as the occupied space, their exterior morphology, their internal composition, the changes made to the terrain, the conservation of pre-existing features or the characteristics of perimeter fencing. As regards occupied space, if they are compared to the other energy installations, especially conventional energy plants, photovoltaic power plants are relatively large installations, each occupying an average of 13.81 ha in Andalusia. However, this average value is not considered to be significant, due to the fact that large installations, 7 % of those analysed, account for almost 35 % of the occupied space, a reflection of the current tendency towards large-scale plants, in which plants of tens and even hundreds of hectares are increasingly frequent, whereas the first solar farms normally only covered 1 or 2 ha. This trend is closely linked with the gradual reduction of public subsidies and with big companies entering the sector.

As regards the exterior morphology, most plants have a rectangular floor plan for both technological and operational reasons. The fact that they are often sited on previously farmed fields also explains the predominance of regular shapes. Internally the photovoltaic power plants tend to be fragmented into sectors, both for technical reasons (access for maintenance purposes) and due to regulatory factors because, for a time, the legal fragmentation of a single complex into smaller independent installations enabled developers easier access to subsidies.

In general, these installations do not entail significant modifications of the terrain because they are not required and would increase the cost of the investment, although, in some cases, an unsuitable site selection means that earth has to be moved and terraces, slopes and retaining walls have to be built. This happens above all on hillsides or on the top of hills.

In general terms, the overall design of the plants does not usually take into account the conservation, exploitation or reuse of pre-existing features (both natural and artificial), although, in some cases, some of the original most distinctive trees are preserved. Some old agricultural buildings occasionally remain within photovoltaic plants, although they normally have no specific use and lie abandoned in ruins.

Most photovoltaic power plants use perimeter fencing to protect the installation. Some use transparent fencing, generally made of metal mesh, while others have solid walls made of concrete and, occasionally, of masonry.

14.4.4 Design of the Components

The main components of photovoltaic installations are photovoltaic panels, which consist of modules which in turn are made up of cells. These photovoltaic panels are installed on top of support structures, which can be stationary or mobile, and follow the course of the sun, on one or two axes. These support structures can be laid out in rows or independently of each other. Normally, these independent structures have a tracking mechanism and are known as trackers. In Andalusian photovoltaic power plants, fixed row structures are more common, featuring in 58 % of the installations.

The modules on photovoltaic panels are made of different materials, of which monocrystalline, multicrystalline and amorphous silicon, in this order, are most commonly used. Apart from these solar sensors, photovoltaic plants also have other components of great importance for the landscape, such as transformers, electricity transmission towers and cables, road networks (both the network providing access to the installation and the internal network) and large information or advertising panels.

14.4.5 Internal Layout of the Components

The distribution of the structures depends on the typology used. The installation of continuous rows is laid out symmetrically in alternate regular strips. In the installation of free-standing solar trackers, the only common theme is the geometrical layout, within a regular frame, similar to that used in fruit farms. Auxiliary technical installations also have internal organisation standards. In general, regular layouts are usual, although in some cases these installations are laid out irregularly in groups (Fig. 14.2).

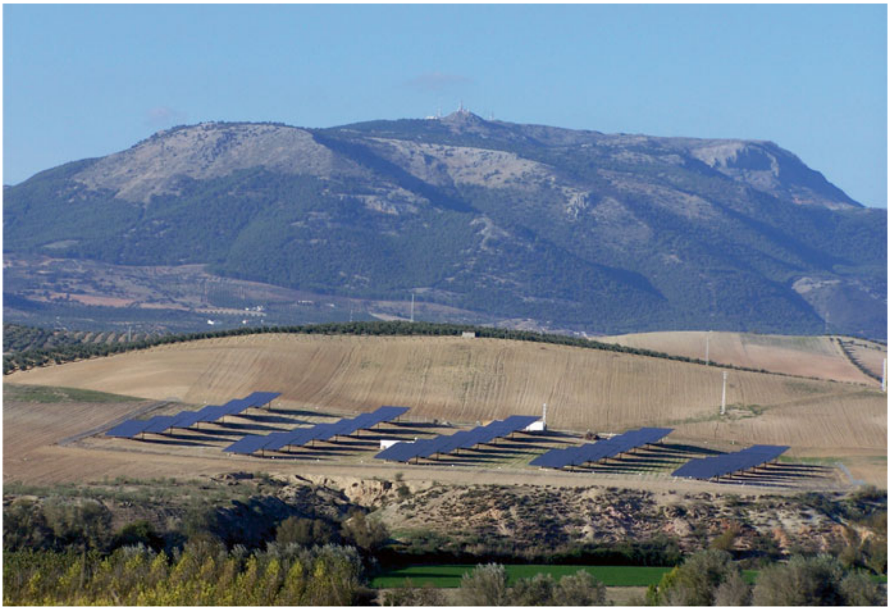

Fig. 14.2 Trackers in photovoltaic power plant (Fuensanta, Granada province)

14.5 Effects of Photovoltaic Plants on Landscapes

14.5.1 General Principles

The effects of photovoltaic plants on landscapes are the result of two characteristics of these installations: their outward appearance and the meanings they incorporate into the landscape. These characteristics correspond to the different stages of the perception process: sensation and perception (Matlin and Foley 1996). The *physiognomy* of photovoltaic plants is manifested in the presence of specific geometries, compositions, textures and colours and, especially, in the reflection or brightness of their most characteristic components.

These installations also have specific associated *meanings*: first of all, and as with other renewable energy plants, that relating to the clean, renewable and natural energy they produce. They also transmit messages relating to their productive nature (industrial activity, as a sign of progress and prosperity or as a sign of the denaturalisation of rural spaces) and their innovative nature, resulting from their recent origin and expansion, which links them (positively or negatively) with the idea of modernity.

The impacts on the landscape are produced in two ways (Gómez Orea 1999): the influence on the spaces occupied by these installations (intrinsic landscape) and the alteration of the visual conditions of the territory (extrinsic landscape). This impact on the landscape is normally regarded as negative in environmental impact reports, even though these installations, like other energy or transport infrastructures, have certain aspects which, if valued, could help to enhance landscapes and bring about a positive impact. In any case their effects on the landscape are synergistic, cumulative and reversible, an especially important feature.

The effects of photovoltaic plants on landscapes result from the factors which affect their landscape characterisation, as explained in the following sections.

14.5.2 Location and Site as Impact Factors

Depending on their productive nature, the typological singularity of their components and their density, photovoltaic power plants produce more landscape impacts on rural areas than on others more subject to human action, altering the identity and the landscape meaning of these areas. The rural space in Andalusia has valuable natural and agricultural landscapes, and even though many of them are inherently dynamic, in general, they have only undergone minimum transformation and they have no large industrial areas and have not experienced intensive urban development processes. Some of these landscapes are considered as part of local or regional identity, as is the case of olive groves, fluvial landscapes, traditional irrigated land, extensive cultivated areas and mountain landscapes. However, it is in these rural areas rather than in more economically dynamic spaces that most photovoltaic plants are normally installed.

Within rural areas, in principle, the impact is perceived as being less significant on agricultural terrains, where human presence has already modified the land surface, introducing regular shapes, human constructions and other more recent installations, such as greenhouses. In natural spaces, however, the contrast is usually much greater, leading to clear conflicts with the existing landscape character. In these areas, the impact on the landscape may also come in the form of significant topographic alterations.

The location of photovoltaic plants in open areas, their often large dimensions and the reflection from their panels make them visible from many places. The viewsheds they create are generally very large, over 10,000 ha in practically half of the cases we analysed. In addition, their position next to transport networks (almost two third are situated in the vicinity of highways and major roads) increases the number of potential observers, in other words, their visual effect. On other occasions, the impact is produced because of the intrusion of photovoltaic plants on views with a high scenic value (Fig. 14.3).

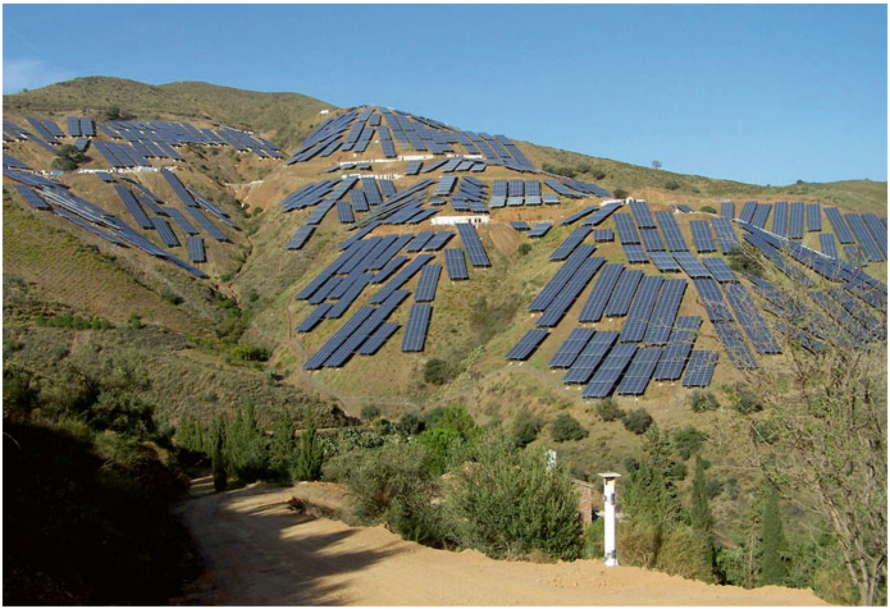

Fig. 14.3 Landscape impact of photovoltaic power plant in mountain area (Moclinejo, Málaga province)

14.5.3 Density and Landscape Impact

The landscape impact of a high density of installations lies in their synergistic character: the overall effect is higher than the sum of the individual impacts. The impacts on the landscape are higher when photovoltaic power plants are arranged in a scattered way on the land, generating discontinuity and areas with gaps which are rendered useless. Nevertheless, the concentration of photovoltaic power plants in specific areas, apart from grouping impacts together, can also lead to the creation of a new specialised landscape, particularly if they coincide spatially with other renewable energy sources (Mérida et al. 2009) and, above all, if quality is central to their designs. A process of this nature is taking place in the El Marquesado area in the province of Granada, where the density of photovoltaic and other renewable energy sources is relatively high, although they have yet to be treated together as part of a territorial whole.

14.5.4 Impact of the Overall Design of Photovoltaic Power Plants

Photovoltaic plants cover a large area compared to other sources of energy, especially conventional ones. In addition to the total dimensions, the impact on the landscape can also result from the contrast between the size and external morphology of the photovoltaic installation and the size and external morphology of the pre-existing plots of land. If the plots are of varying sizes and shapes, the impact of a photovoltaic installation could be reduced by adapting the shape and size of the plant to those of the plots of land (Fig. 14.4).

In terms of composition, the fragmentation of the installation or its division into sectors produces a significant impact on the landscape, due to the introduction of orthogonal axes or strips corresponding to the gaps, unusual geometries in rural areas, and to the colour contrast between these discontinuities and the areas occupied by photovoltaic panels.

Topographic alterations also have a very important impact on the landscape as a result of the introduction of geometrical shapes and lines, the use of nontraditional materials in retaining walls or the higher reflectivity of bare rocks. The positioning of the structures can cause important effects on the landscape, particularly if the rows of panels are installed perpendicular to the contour lines. Semantically, the alteration of the relief causes serious impacts due to the lack of landscape coherence and legibility (Kaplan and Kaplan 1989). This same effect on the nature of landscapes occurs with the abandonment of old traditional buildings that are enclosed within photovoltaic plants, which in functional terms also represent a waste of resources that could have been given a new use in designs of a higher quality.

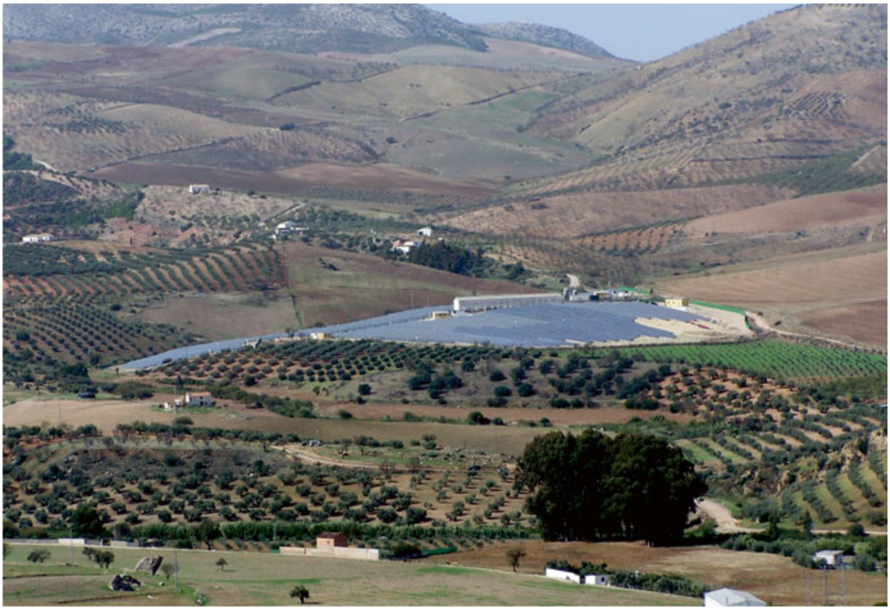

Fig. 14.4 Photovoltaic power plant adapted to plots of land (Ardales, Málaga province)

Finally, on some occasions, the fencing around the plants can also produce impacts on the landscape, sometimes to a greater extent than the installation itself, particularly if hard morphologies and opaque materials with high albedo, such as concrete, are used.

14.5.5 Design of the Components and Their Impact

To a large extent, the landscape impacts of photovoltaic power plants are due to the visual importance and the semantic singularity of their components, industrial and futuristic-looking devices that contrast sharply with neighbouring traditional rural uses of land, affecting the character of landscapes and making their perception difficult, even more so if they are deployed intensively over a short period of time.

The landscape impact of the components starts with the photovoltaic structures themselves. Photovoltaic panels have an intense brightness due to the fact that a great part of the solar energy they receive is reflected (around 80 %), making them visible from a great distance. The materials used react differently in chromatic terms. In general, monocrystalline silicon modules show a homogeneous colour somewhere between blue and grey, multicrystalline silicon modules produce an intense bluish colour and a heterogeneous texture and amorphous silicon modules have a homogeneous appearance and a dark colour. The dividing lines between the modules also influence the image of the panels as do the frames. The structures supporting the panels are also of great visual importance, especially in free-standing structures, which create a vertical axis, raising the panels off the ground and making the supporting mast visible, as well as interrupting the sheetlike continuity of the panels. The negative impact is greater in treeless, essentially horizontal landscapes, such as cereal-growing areas. In the case of panels aligned in rows, this interruption of continuity is less noticeable, although the alternate strips between the rows are visible, especially from the sides of the plants. If structures have a tracking system, the impact is higher because the position and orientation of the panels are constantly changing throughout the day, a movement which, although slow, undoubtedly has an impact on the landscape.

The rest of the components of photovoltaic power plants stand out less than the module structures although, in some cases, they are also clearly noticeable. The transformers, for instance, are visible because of their size and colour and also because they reinforce the industrial, urbanised perception of the landscape. Paths and access roads can cause some impact depending on their design, the modifications to the land they entail or the particular road surface used, while both transmission towers and information and advertising panels stand out in the landscape, above all, because of their vertical typology and their location in a prominent position.

14.5.6 Internal Organisation of Components and Their Impact

The way the components of a photovoltaic installation are grouped together is of outstanding visual importance, especially from the middle and long distance, from which the design of the components is less noticeable. In plants with continuous rows of modules, this impact occurs when the alternating strips of structures and unoccupied land are visible, and is greater when the rows are positioned perpendicular to the natural contour lines, if different orientations are mixed within the same installation or if similar alignments do not exist in the surrounding landscape as a form of reference. This impact is very significant in natural areas where concepts of order and symmetry do not apply.

In the installations with free-standing solar trackers, the landscape impact of the layout pattern depends on the contrast it produces with the existing pattern in the landscape. This means that the use of geometrical patterns is unsuitable in areas with an irregular layout pattern, such as pasture land, whose character and coherence would be affected. On the contrary, the impact is noticeably reduced if there are regular layouts in the surrounding area and if the alignments follow those in the vicinity.

The internal organisation of auxiliary technical installations can also produce important landscape effects, especially in installations with fixed row structures in which the support structures are lower. In principle, the impact of regular layouts is higher, as in the case of row structures, they can interrupt the sheetlike continuity of the panels. Nevertheless, if distribution patterns coincide with those of existing isolated buildings, impacts would be reduced.

The research team has systematised the factors and components involved in the perception of photovoltaic plants, and this needs to be complemented with an analysis of the social valuation of these installations, in line with the premises set out in the European Landscape Convention, as a means of moving on from the potential impact to the real impact as perceived by local people. We have therefore made a survey of public opinion, which we will now go on to describe.

14.5.7 Impact of Photovoltaic Plants and Their Public Perception

We complemented our assessment of the impacts of photovoltaic plants on the landscape with an analysis of public perception of these impacts. In order to gauge the level of public concern in Andalusia, a survey of inhabitants of areas near photovoltaic plants was carried out during 2009, involving a total of 82 personal interviews distributed in 4 populated areas of different provinces. Our target group was also divided by age group and sex from the population of over 16 years of age from each town or village, according to the quota sampling technique. From the analysis of the results, we deduced that photovoltaic installations are viewed positively (63.4 %), and that 58.5 % of those interviewed consider them to be beneficial for their area, because of the economic, employment and environmental benefits they bring, although they also put forward mistaken arguments in favour, such as better electricity supply and cheaper electricity for local residents. This acceptance of photovoltaic plants confirms the findings of Europe-wide reports on solar energy in general (European Union 2007). Likewise, most of the interviewees considered that solar energy in all its various forms has a great future. Nonetheless, this support fell to 35 % and opposition rose to 45.1 %, when they were asked about possible proliferation of photovoltaic plants or an increase in their size. Those opposing such changes cited landscape protection as the main reason for their opposition. These results imply that people prefer photovoltaic plants as special features in the landscape rather than as components of the landscape or as a type of landscape.

Aesthetically speaking, however, a large majority of those interviewed (56 %) found the plants unattractive, although a significant minority (29 %) considered them aesthetically appealing. They associated their image with that of other landscape components such as water, greenhouses, warehouse roofs or industrial units. The impact is perceived both on the views and on the contents of the landscape.

The weighted evaluation of the landscape in the area where the interviewees live offers a high average score (7.62 points out of 10), but this drops to 5.46 if photovoltaic plants are included. This initial approximation would suggest therefore that according to the people interviewed, the loss of landscape quality produced by photovoltaic plants could be estimated at around 20 %. This negative opinion of the impact of these plants on the landscape is reinforced by the fact that the survey respondents stated that they would prefer them to be installed in poorly visible sites (65.6 %) and that given the choice they prefer (48.7 %) the installations on the roofs of buildings, although in one of the villages, those interviewed also opposed roof installations due to their possible impact on their urban landscape.

There is, therefore, an important imbalance between the positive public perception of the economic and productive benefits of photovoltaic plants and the negative perception of their effects on the landscape. The perceived negative consequences on the landscape do not however prevent an overall positive rating. To some extent these negative consequences are considered an inherent part of energy development, and some interviewees even cited a widely held principle in rural communities, namely, the freedom of the owner to use the land for whatever purpose he/she deems fit.

The fact that there are seemingly contradictory opinions must be seen as an opportunity rather than as a problem: there is a positive opinion about the general nature of the installations that can be extended to their location and their outward appearance. The introduction of quality designs would make it possible to compensate for this imbalance, which means that landscape integration measures are of great importance.

14.6 Planning Tools: Landscape Integration Proposals

The landscape integration of photovoltaic power plants is a very useful tool for the territorial planning of this productive sector. On the one hand, it reduces the possible landscape repercussions of these installations, and on the other, it can give the photovoltaic power plant an added value – landscape quality – as a result of design quality and careful selection of the best site. Landscape integration can be defined as a territorial intervention procedure that aims to guide and shape landscape transformations in order to adapt them to the type of landscape taken as a reference (Mérida and Lobón 2011). Depending on its quality, the reference landscape can be both the present and the pre-existing one or any other proposed in the landscape quality objectives. In this section, on the basis of our analysis of the situation in Andalusia, we provide some possible guidelines about landscape integration that could be applied in the case of these installations. These are based on the landscape integration strategies and techniques (Ayuga 2001; Busquets and Cortina 2009; Mérida and Lobón 2011), the landscape impact principles and the results of the interviews we carried out.

14.6.1 Proposals for Location and Site

The landscape integration criteria relating to location depend on the scale being used. At a subregional level, different types of landscape and landscape components can be proposed in which or around which the installation of photovoltaic power plants does not alter the essence of the landscape. Many of them can even be used to increase the value of their landscape, contributing, in some cases, to the reuse of impoverished spaces and, in others, to the improvement of landscapes of a higher quality. For this reason the landscapes listed below could be highly suitable locations for these installations, because of both their common features (colour, morphology, size, type) and their shared or close meaning to that of photovoltaic power plants: transformation, infrastructure, innovation or singularity. In Andalusia there are many such landscapes and landscape components, including: areas with large numbers of greenhouses, industrial landscapes, mining spaces, peri-urban areas, water landscapes (even on floating structures), energy landscapes (both conventional and renewable) and transport infrastructures, such as roads, railways, airports and ports. In these cases, the photovoltaic installations could be placed on top of these infrastructures (e.g. acoustic screens, top of fake tunnels, dykes in ports, etc.), near transport and other networks or in the large empty spaces confined within transport infrastructures.

As regards the site, a suitable site for photovoltaic installations must take into account different criteria, such as the selection of flat or plateau terrains, with reduced viewsheds, low visual impact on populated or busy areas and far away from high-quality views and from exceptional elements in the landscape, especially those of a cultural nature. We also recommend that plants be sited on unproductive land as this new function would give the landscape more coherence or purpose. It is also necessary to take into account the relationship between local people and their landscape, ruling out as possible sites the most highly valued spaces or those in greatest demand for other social and economic functions.

14.6.2 Proposals for the Overall Design of Installations

The size of photovoltaic power plants must be regarded both in general terms, preferring small and middle-sized plants to large ones and, in relative proportions, adapting their size to the dimensions of nearby farms. Likewise, their external morphology must fit in with the characteristic shapes of the farms around them, be they linear or en masse, geometrical or irregular. The internal composition must seek homogeneity, reducing the gap strips to a minimum and avoiding the combination of different types of solar sensors.

In order to attain an acceptable level of landscape integration, another crucial criterion is adaptation to the relief. On sloping terrain the structures must be positioned parallel to the contour lines, ensuring integration on the horizontal plane, the plane of human sight. Changes to the ground surface (artificial slopes, embankments, etc.) should be avoided and, if this is not possible, specific corrective measures must be applied. In addition, the general design must try to preserve pre-existing elements – both natural and artificial and especially traditional constructions – giving them a new function. Finally, the type of perimeter fencing should be chosen carefully, preferably opting for transparent fencing materials with low visual impact and preserving the existing lines of traditional boundaries in their design.

14.6.3 Proposals for the Design of Components

An essential aim of landscape integration of photovoltaic power plants must be to insert the modules and panels, their main components, into the landscape more effectively. This does not necessarily mean hiding them; indeed their prominent position in the landscape can be maintained if the right measures are taken. In the case of photovoltaic modules, it is important to disguise the dividing lines between the cells by adapting their colour to match that of the cells. The shape of the modules can also be improved by exploring new possibilities which go beyond the omnipresent four-sided figures, as has happened, for example, in urban design with 'photovoltaic trees'. It would also be advisable to use larger modules (if the size of panels does not increase), as they would create a continuous surface on the panel similar to other landscape components (water sheets, greenhouses, industrial roofs), thereby integrating the modules more easily. The visual impact of module profiles must also be reduced by colour treatments or by using other materials.

In order to improve the landscape integration of modules, more suitable colours must be found. Amongst the most commonly used materials, monocrystalline silicon gives the best results for the landscape, due to its greyish tones, similar to those of other landscape components. Photovoltaic modules could also use other colours that are not currently used in photovoltaic power plants but are appearing, little by little, in architectural integration of this energy source. For this reason extending their use to photovoltaic power plants could be an important future challenge; the problem is that they are more expensive and less efficient. In any case, their obvious benefits for the landscape (and therefore for society) could bring added value to the installation, in terms of increased quality and prestige.

As regards the support structures, these are generally better integrated into the landscape when installed in rows rather than in groups of free-standing trackers, due to the fact that they more easily resemble other landscape features, such as water, industrial warehouses or greenhouses. By contrast, the landscape integration of free-standing solar trackers is more complicated because of their vertical structure and their scattered nature, although they can integrate better into industrial and similar areas and into rural areas that have isolated landscape components that are similar in shape (tree crops) or meaning (wind turbines).

Morphologically, it is important to design support structures that are innovative and have a design quality that goes beyond mere functionality. The incorporation of new landscape-friendly shapes would give the installation an image of quality, and of concern about design and about the environment, and this would benefit the company. Nevertheless, up until now, aesthetic criteria have not been taken into consideration in their design, and four-sided shapes predominate.

Both support structures and panels are more easily integrated the smaller they are. It would be advisable to establish size limits, even if this meant that more structures had to be installed: horizontal developments are preferable to vertical ones, in that they are parallel to the human plane of vision. Changing their colour to fit in with the existing tones in the environment would also be a good integration strategy.

In the case of auxiliary constructions, the best designs would be primarily horizontal with appropriate colour and texture, in order to assimilate them into the surrounding environment or nearby landscape references. Electricity transmission towers are difficult to integrate and therefore must be placed in areas of little visual importance. Information panels are equally difficult to integrate: their size and number must therefore be regulated and they must not be sited in sensitive landscape areas. The background colour of the panels should blend in with the colours in the surrounding environment.

In order to improve the landscape integration of access and internal road networks, particular attention must be paid to their design, especially in mountain areas, reducing steep profiles and topographic alterations. The surface of these roads must blend in with the area in terms of colour and texture.

14.6.4 Proposals for the Internal Organisation of Components

Successful landscape integration of photovoltaic power plants also depends on the correct internal distribution of their component parts. If panels are arranged in continuous rows, these must be organised in a rectangular way, with the minimum possible gap between them. They should also be aligned with any other pre-existing lines in the landscape, parallel to the contour lines on sloping land, and with the minimum gap required for technical reasons. As far as is possible, the gap strips should only be visible from places with few potential observers. Free-standing solar trackers, for their part, must be grouped together to form a homogeneous mass of panels. They must be laid out in a similar way to existing landscape features such as olive groves, fruit orchards or *dehesa* grazing land. Any auxiliary technical installations should where possible be grouped together in less visible places. In any case these elements must be laid out in such a way as to reproduce the distribution pattern in the surrounding landscape.

14.6.5 Implementation of Measures to Correct Landscape Impact

Corrective measures are specific actions in the landscape that seek to mitigate impacts that have already been caused by the unsuccessful integration of the plant into the landscape, due either to its location or its design. These measures are usually of limited effectiveness, due to the dimensions of the photovoltaic power plant and to their very nature, in that they must be exposed to the sun and cannot therefore be hidden from view. Corrective measures can however be very useful for adapting certain parts of the photovoltaic power plant into the landscape, for example, the artificial slopes and embankments sometimes created during installation. They can also be used to improve the landscape integration of perimeter fencing, internal roads and the free spaces between them. Their effectiveness on support structures is more limited, as less can be done for technical reasons. On the other hand, corrective measures in the landscape can be useful if they are also applied in the surrounding areas, such as in the spaces between the viewpoints and the installation (e.g. by maintaining pre-existing tree alignments).

Of the various corrective measures, visual screens made of trees are probably the most suitable for installations with free-standing solar trackers and for those situated at a higher level than the viewpoints. They can also help mask perimeter fencings. In treeless areas, by contrast, planting trees can intensify the presence of these installations on the landscape.

Visual screens can also be of a topographical nature, involving some earthmoving, or be constructed. In this sense, the use of walls can be appropriate in areas in which walls are a feature of the landscape, in which case similar materials and designs must be used. Platforms built for other infrastructures nearby, such as roads, canals, etc., can also be used.

Other corrective measures apart from visual screens can also be introduced. These include the placing of transition features (visual or semantic) in the spaces between the viewpoint and the plant or between components of the plant of different kinds. Finally, other possible corrective measures include modifying the textures and colour of specific components of the installation using plant textures for bare lands, stone and ceramic coverings or colour treatment.

Corrective measures may be applied to the plant as a whole or to its perimeter, although they are more effective if they focus on certain specific components or on one or more of its sides. Given that the landscape identity of these installations is provided by photovoltaic modules and panels, components that are more easily adaptable to the landscape but at the same time more difficult to hide, it makes more sense to apply these corrective measures to the sides and back of the installation, where most of the problems arise.

14.7 Conclusions

In the recent development of photovoltaic plants in Andalusia, landscape criteria have played no part in their territorial implementation and design, so that in most cases these plants are perceived as impacts on the landscape. The landscape treatment of these installations would not only reduce their possible impact but would also help improve and enrich the quality of landscapes. Our analysis of the experience of Andalusia has enabled us to reflect on the causes and intensity of this effect on landscapes and on how impacts may be mitigated and indeed reversed by drawing up landscape integration proposals applicable to both current and future installations in Andalusia and elsewhere.

The social benefits arising from the adoption of this good landscape practice can lead to other kinds of benefits, such as the political rewards earned from the positive image of photovoltaic power amongst the general public. Investors can also benefit from the incorporation of certain landscape integration measures which increase the added value of the installations: promoting the image and reputation of the companies, attracting the attention of visitors or developing patents and technologies relating specifically to landscape. This also shows the increasing importance of making landscapes and landscape integration a part of the Corporate Social Responsibility (CSR) of large companies.

In any case, the development of photovoltaic plants is still at an early stage, in which productive efficiency seems to be more important for investors than other considerations (such as landscape criteria). However, as has happened with other infrastructures such as transport, photovoltaic energy development is expected to lead to increased demands for improving the quality of the installations and an ordered, sustainable process of territorial deployment. In this sense, landscape integration may help bring about a more positive reappraisal of photovoltaic plants in which they can be viewed as potential landscape resources.

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