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Integration of Public Perception in the Assessment of Licensed Solar Farms: A Case Study in Greece

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Abstract: The increasing adoption of solar power plants requires the consideration of different aspects involved in the transformation of landscape. In this view, recent studies encourage public engagement and landscape integration strategies in the decision-making process to ensure an accepted and inclusive energy transition. However, there is limited knowledge on how to include landscape considerations in the planning processes, specifically on public perception and values. This work aims to assess five licensed solar farms in the region of Central Macedonia (Greece) based on the opinion of the inhabitants. The paper presents the results of an online and onsite questionnaire administered in different villages around the study area in October 2022. The survey utilized the potential benefits and impacts, as well as siting criteria and spatial configuration strategies, taken from literature to describe public perception and preferences. The methodology consists of three phases: investigation of public perception on solar farms; operationalization of the results to make them spatially explicit; overall suitability of the areas and mitigation strategies. The results illustrate the prioritization of the perceived impacts and benefits of photovoltaic installations and highlight the different levels of suitability of the areas and possible mitigation measures. The proposed approach is complementary to the planning processes taking into account societal considerations.

Keywords: solar energy landscapes; public perception; solar siting; landscape integration; site assessment

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1. Introduction

Solar Power Plants (SPPs) play a key role in addressing the challenges related to climate change mitigation. The deployment of Renewable Energy Technologies (RETs) entails massive transformations of the landscape [1], increasingly causing local opposition, despite the overwhelming percentage of 88% of people supporting renewable energy in Europe [2]. The growing attention to the relationship between RET facilities and landscape has generated the definition of a new type of landscape, namely, Renewable Energy Landscape (REL) [3,4]. Specifically, there is a call for a wider consideration of landscape [5] that includes not only the physical patterns but also user interpretations and experiences in the environment (e.g., [6–8]). Indeed, despite being a valuable solution in terms of economic and environmental benefits [9], the drastic increase in SPPs has led, in some cases, to landscape saturation in Mediterranean countries, posing questions of how to include landscape in discussions of meeting energy targets [8].

Land use competitions and ecological impacts have been gaining attention in the research discourse, suggesting going beyond technical and economic aspects in energy planning procedures by introducing sustainability concerns [10] and landscape-inclusive strategies [11]. Indeed, recent studies highlight the need to include societal considerations in the processes of REL planning [12–14]. Several factors can be included: economic, for example, related to land use loss [15], generation of profit [16], and transmission lines [9]; environmental, such as wildlife habitat disturbance [17,18] or runoff generation and erosion [19]; and landscape-related, such as those linked to visual impact [20] and aesthetic impact [21,22]. However, there is limited knowledge on how to include landscape considerations, specifically those linked to public perception and values. Indeed, most of the studies focusing on social issues of renewable energy infrastructures refer to wind power, while very few focus on solar energy [7,23,24].

These considerations can be particularly important in the contexts of landscape saturation and local resistance against the deployment of SPPs [14,25–28]. In this regard, the "Not-In-My-Backyard" (NIMBY) explanation of opposition has been overcome and considered too simplistic [29], calling for attention towards the social and landscape dimensions of REL [30,31]. Embracing the definition of "landscape" provided in Article 1 of the European Landscape Convention [32] as "an area as perceived by people; whose character is the result of the action and interaction of natural and/or human factors", we define as landscape-related the considerations linked to photovoltaic installations' physical appearance and public perception. In line with this definition, several recent studies have advanced landscape-based approaches. The concept of landscape integration is widely known for photovoltaic applications in buildings, namely, Building Integrated Photovoltaic (BIPV) [33]. An extension of this concept has recently been proposed for on-ground photovoltaic applications, known as Landscape Integrated Photovoltaic (LIPV) [6,34]. Accordingly, the study by Oudes et al. [8] advances a typology of multifunctional SPPs, illustrating several spatial configurations. The shift from monofunctional to multifunctional SPPs can change their physical appearance, such as their materials and infrastructure [35]. For example, photovoltaic (PV) panels can be lifted to enable agricultural cultivation [36,37]. Another example of spatial configuration is leaving space for nature in between rows or beneath panels [8]. These considerations influence societal aspects, as they support the production of locally produced renewable energy while delivering other functions, such as agricultural production [38], protection of flora and fauna [39], or preservation of cultural heritage [40]. Furthermore, recent studies have considered public perception and social acceptance of solar systems (e.g., [41–44]). Bevk and Golobič [7] evaluated the landscape features of solar farms based on field visits and focus groups with citizens. Salak et al. [45] and Spielhofer et al. [46] compared the acceptance of different densities of energy infrastructures in different types of landscapes. Various configurations of SPPs were evaluated using the Q methodology by Lu et al. [47] and Naspetti et al. [48]. However, these studies do not suggest procedures for the inclusion of such considerations in energy planning processes. Indeed, there is a gap in how to include public opinion in planning processes.

Terms such as public engagement, participation, and social acceptance are increasingly being considered in SPP projects, addressing local opposition [49–51]. These topics are particularly relevant in decision-making processes to promote inclusive and transparent transition [52]. Specifically, a shift is envisioned from information sharing to the involvement of all stakeholders in open discussions and to the capacity to coordinate their interests [53]. Societal considerations are normally discussed among stakeholders during processes of planning or evaluating energy landscapes in relation to their site suitability, distinguishing between suitable and unsuitable areas (e.g., [10,54,55]). In general, suitable locations are those in which negative impacts are low and technical conditions are favorable [56]. For example, Oudes and Stremke [10] and Clarke et al. [55] defined a list of criteria (e.g., environmental, cultural, technical, and visual) to identify suitable areas. However, this approach reduces the number of suitable sites [57] and raises ethical questions concerning the balanced distribution of solar farms within communities (e.g., [13,58]). In this regard, a recent study [59] proposed the introduction of qualitative criteria for the spatial configuration of PV arrays in planning tools. Thus, the suitability of an area can also be associated with the level of landscape integration required, linking spatial planning with innovative design solutions. Design solutions may include the dual use of land strategies (e.g., [36,60]): parameters improving the relationship with the landscape [8], and the architectural configuration of PV arrays [56]. Such solutions may reduce the land use efficiency of the system (MWh/kWp/m^2) but would provide several co-benefits. The process to design landscape-integrated photovoltaic landscapes encompasses three different scales: planning (site selection; scale), landscape design (pattern), and architectural design (design of the system) [6]. Such insights were considered in this study to support local participatory planning and assessment of licensed solar farms.

The purpose of this research was therefore to propose a framework to include landscape considerations in the assessment of SPPs that were granted a license for production, considering both landscape integration purposes and public perception. The study proposes spatially explicit public considerations as an additional layer that can be overlapped with other societal factors, aiming to connect appropriate locations with integration requirements. Specifically, two main objectives were set. The first was to investigate the public perception of SPPs in the study area. The second was to include the opinion of the respondents in the assessment of the solar farms. This was achieved by answering the following questions:

1. What are the perceived benefits and impacts of the SPPs?
2. What are the spatial and design features influencing public opinion?
3. How to consider public opinion in the assessment of the SPPs?

To answer these questions, we interviewed inhabitants with a questionnaire reflecting on the perception of the impacts and benefits of the SPPs through site selection and design strategy criteria. The results of the questionnaire were further operationalized to be spatially explicit and to be included in the planning processes.

In Section 2, the theoretical framework is outlined, which was employed to collect the literature used to develop the questionnaire. In Section 3 (Materials and Method), the survey procedure is explained, including the design of the questionnaire, the participants involved, and the analysis of the results and their operationalization. The results of the survey and the assessment of the SPPs are presented in Section 4. In Section 5, a discussion reflects on the potentialities and limitations of the procedure, as well as in relation to other studies. In Section 6, conclusions are drawn on how to include landscape considerations in the assessment of licensed solar farms.

2. Framework

Several studies have focused on the relationship between the social perception of the impacts and benefits of SPPs and the degree of citizens' acceptance [7,14,50,51,61,62]. Most of the time, the concerns involve the environment, tourism, local landscape, and agricultural land use impacts. Societal considerations—including economic-, nature-, and landscape-related considerations—become urgent topics during planning and design processes and may play an important role in tackling local resistance. In this view, land use is a core topic in the energy transition discourse, as PV arrays require suitable space, land conversion, and management practices [63]. However, as outlined above, site selection is not the only parameter for the promotion of socially accepted solar landscapes. Design strategies can change the conventional way of implementing SPPs, defining new landscape and architectural components and mitigating the impacts of ground-mounted PV arrays on land use. This section analyzes the literature, linking spatial strategies, including spatial configuration and site selection, with societal considerations of SPPs. When embracing a landscape-based approach [6,8], the considerations to plan and design SPPs can be divided into three main categories: nature, landscape, and socioeconomic.

Environmental impacts, in general, tend to dominate expert debates around the siting of energy facilities [7]. However, it is not clear what local communities envisage as environmental considerations and if they play an important role in accepting a REL. This aspect includes issues related to biodiversity, land, soil, water, air, and climate [64]. Significant environmental impacts are associated with the ecological value of sites. Therefore, damaged areas, such as brownfields or landfills, as well as arid areas, could be considered optimal sites [6]. Environmentally sensitive areas, such as sites for nature or biodiversity conservation and sites of landscape importance, should be avoided or preserved [10,55]. Spatial configurations preserving ecological features, such as habitats, should leave space for vegetation, such as flower meadows, protect existing vegetation, or make fences permeable [8].

Landscape is becoming a key topic in the energy debate. Landscape considerations include natural assets, as well as cultural heritage, and they are related to the perception of landscape by users. In this view, place attachment is a factor affecting the acceptance of solar farms, causing perceived threats to specific locations and scenic features with which the local communities feel connected [61]. Landscape considerations include esthetic ones (color, fractality, and glare of the panels), visual impact (based on objective or subjective parameters) [22], and the character of an area. Cultural heritage sites, as well as very visible and natural areas [65,66], should be avoided or preserved. Landscape considerations are linked to physical appearance, for example, following landscape patterns and improving the user experience [6,8]. For instance, modifications to conventional patterns through sub patches and the porosity of PV arrays can limit the visual impact. Moreover, preserving existing landscape features or restoring past ones may be a landscape-inclusive strategy [8].

Socioeconomic aspects are associated with renewable energy production benefits: job opportunities, land rental, ownership of facilities, community funds, shepherd electricity, local assets and facilities, provision of local services, and country interests [9,16]. However, the entity of such benefits depends on the promoters and the type of economic model developed. Local development is perceived as an advantage in relation to renewable energy technologies, as solar farms are often located in disadvantaged rural areas. RELs have the potential to foster economies in rural territories (especially in fragile and subsidized agricultural systems), as well as in urban areas through energy communities, for example, by creating employment opportunities, social cohesion, and an increase in self-esteem [61,67]. Economic aspects are generally considered through land use energy intensity and total energy delivered parameters [6]. However, combining electricity production with other profitable land use functions may provide further profit [8].

3. Materials and Method

This study was conducted within the framework of the H2020 PEARLS project, which aims to increase public engagement on the behalf of a sustainable renewable energy system through collaboration among both academic and nonacademic partners from different Mediterranean countries, namely, Israel, Italy, Greece, Portugal, and Spain. This section provides a brief description of the methods employed to assess people's perception of licensed solar farms in the region of Central Macedonia in Greece and to integrate the results into planning tools.

3.1. Questionnaire Design

The goal of the questionnaire was to assess inhabitants' perception of SPPs and their level of acceptance. Considering the dual aspects of landscape perception (physical transformations and sensation), the survey aimed to investigate the determinants of physical changes, as well as social ones. Moreover, considering that the acceptance of PV panels may depend on their location (i.e., spatial strategies), as well as their design, both aspects were included. The first draft of the questionnaire was developed together with other colleagues of the PEARLS project, who were assessing inhabitants' perception of wind farms on Paros Island (Greece), to establish a common structure. This first draft was based on previous studies [68] and on the literature analysis of existing methods [3,45,54,69], and we aimed at overcoming the drawbacks of other interview formats or to adapt questions discussed among experts for citizens. The questionnaire was further tailored to the Central Macedonia case study with the contribution of local experts, who brought an insider perspective as engineering consultants and residents of the region. The questionnaire was composed of an introductory part, including a presentation of the project, an information sheet and consent form, and four sections structured as follows: (1) demographic data and knowledge on Renewable Energy Sources (RES); (2) perceived impacts of SPP and siting preferences; (3) perception of innovative design solutions; (4) perceived social benefits of

SPP and position on the case study. Most of the questions were closed-ended, and only a few were open-ended (Appendix A).

In the first section, participants were asked to provide information about their gender (Q1.1), their range of age (Q1.2), their level of education (Q1.3), and their employment status (Q1.4). Participants then indicated their relationship with the area by defining how often they spent their time there (Q1.5). Their knowledge on RES was asked for in (Q1.6) and on photovoltaic energy production in (Q1.7). Finally, participants were asked to express their level of concern about environmental issues (Q1.8). In the second section, participants had to provide their opinion on ground-based photovoltaic installation site suitability. First, they had to indicate how often they notice PV panels in the landscape (Q2.1). Then, participants assessed a selection of relevant ecological impacts (i.e., wildlife habitat disturbance [17], landscape disturbance [14,22,62,70], visual impact [20,62,71], environmental impacts [17,72], disturbance to archaeological sites [73,74], decrease in property values [14,62], lack of transparency in the procedure [14,75], and place attachment [76,77]) in (Q2.2). The potential impacts were collected from established studies in the literature [6,14,64] and reduced to a manageable number according to the case study with the support of local experts. The importance of appropriate site selection was addressed in (Q2.3), as well as the prioritization of the siting criteria (i.e., agricultural value [6], pastureland value [6], integration with existing infrastructures/buildings [6], distance from archeological sites [10,54,55], distance from urban areas [6,54], visibility from recreative areas and touristic routes [78], visibility from the streets [59], and distance from protected areas [54,55]) in (Q2.4). Siting criteria were collected from studies in the literature [8,54,55] and reduced to a manageable number with the support of local experts. In the third section, participants were asked to express their perception of innovative design solutions of SPPs through visual stimuli by evaluating images representing ground-based photovoltaic installations. The innovative solutions were selected from studies in the literature that focused on LIPV, such as from the work of Scognamiglio [6]. They included landscape design strategies focused on the macro-layout (D1, D2, D3, and D4), architecture design strategies (D5), and multifunctionality (D6, D7, D8, and D9). The architecture design included only one image, as expressing architectural opinions on PV panels can be difficult with images, especially for nonexperts. In the last section, information about the perceived benefits was collected focusing on the advantages of PV plants in the area (Q4.1), beneficiaries of PV plants (Q4.2), and position on licensed SPPs (Q4.3) and life cycle (Q4.4). To conclude, participants were given the opportunity to express additional thoughts.

3.2. Area of Study

Greece's mainland, as a Mediterranean country, includes large areas with solar exposure particularly suitable for the exploitation of solar energy [79,80]. The two oil crises in the 1970s and the increased costs of electricity played a key role in the growth of license requests for the realization of medium- and large-scale on-ground PV plants within rural areas. In this rapid growth of SPPs, frameworks to consider sustainability and landscape issues were missing in the assessment of potential solar plants.

The evaluation process of solar farms consists of three phases and is listed by the Regulatory Authority for Energy as follows. The first phase, known as the Producer's Certificate, was introduced by Law 4685/2020 and constitutes a "permit of expediency". This certificate is granted if the following conditions related to the feasibility of developing a project with the specific technical characteristics are met:

1. Existence of sufficient energy space (nonsaturation of the grid distribution), no overlapping of the proposed project with another licensed one, and the SPPs' size space is to be occupied by the project and the distance between the production units.
2. Verification that the proposed project does not fall within exclusion zones defined by the Greek Special Framework for Spatial Planning and Sustainable Development for RES.

3. Additionally, the criteria taken into consideration are the financial sufficiency of the implementing body and the energy efficiency of the project.

The second phase constitutes the Environmental Impact Assessment procedure (as it has been put into force by the Environmental Impact Assessment (EIA) Directive (2011/92/EU as amended by 2014/52/EU and put in force in Greek legislation), which is mandatory to obtain the SPPs license. During the environmental licensing procedure, an EIA study for the SPP is implemented and submitted to the relevant licensing authority. Public consultation takes place, as well as actions to collect a significant number of approvals from different services (e.g., forestry, archaeological services, Ministry of Environment). If the EIA is approved and the environmental permit granted, then one can move to the third phase. Phase 3 entails the Final Connection Offer. This is a critical stage for the licensing of RES projects, as the electrical grids are saturated in many areas and there is no possibility of connecting new RES projects. In any case, the cost of connecting the station to the system/network, which the investor undertakes, may act as a deterrent for the implementation of the project, since—given the congestion of the network—significant investments are usually required to connect the station (e.g., construction of a substation, an additional line).

Among licensed projects in Greece's mainland, five areas in the region of Central Macedonia (Table 1), on the border between the Municipality of Kilkis and Paonia, have been selected, namely, Agroktima Vafiochorioy, Kotyli, Hersotopi, Kokartza, and Neo Sirakio (Figure 1). These areas are located in a rural environment characterized by small villages and two larger settlements, Kilkis (22,914 inhabitants) and Polykastro (12,000 inhabitants).

Table 1. Information about the selected areas (authors' elaboration from source: https://geo.rae.gr/, accessed on 4 July 2022).

ID	Location	Municipality	Company	Max. Power (mW)	Area (km^2)	Status of License
1	Agroktima Vafiochorioy	Kilkis, Paionia	Envalue Hellas SP1, single-member, private company (IKE)	754.71	5.80	This company had a Producer's Certificate, but they recently withdrew their application from the evaluation process
2	Kotyli		Idea Fos S.A.	248.96	3.19	EIA license
3	Hersotopi		Isida energeiaki S.A.	181.73	1.99	Producer's Certificate
4	Kokartza		Iliako power VII, single-member, private company (IKE)	432.60	5.05	Producer's Certificate
5	Neo Sirakio		Idea Fos S.A.	460.24	4.78	EIA license

3.3. Participants

A survey was administered both through in-person questionnaires and online through a Google Form shared with potentially interested people. On the 7th and 11th of October 2022, two days of onsite surveys were conducted visiting most of the settlements within a buffer zone of 3 km around the area selected for the case study. On Friday the 7 of October 2022, the villages of Chorigi, Kato Apostoli, Mesi Apostoli, Paleo Ginekokastro, and Neo Ginekokastro were visited, collecting 27 answers. On Tuesday the 11th of October 2022, the villages of Aspros, Axiochori, and Vafiochori and the city of Polykastro were visited, collecting 35 answers. Two collaborators from Consortis approached local inhabitants, presented the purpose of the questionnaire, resolved consequential doubts of respondents, and arranged meetings with local authorities to collect more information on the communities. Most of the people were met without any appointment in public places, such as local coffee shops, restaurants, commercial activities, parks, and schools. The online campaign started immediately after the onsite survey and was closed in February 2023. Participants were selected through the following criteria: age (above 18 years old) and connection with the area. Indeed, both the online and onsite surveys accepted respondents living or working in the area and asked them to identify the specific village. Considering both the onsite (62 answers) and online campaign (24 answers), 86 participants answered the questionnaire. The percentage of respondents for each village is shown in Figure 1. The group of respondents included representative of:

- Both sexes: 58 males and 28 females;
- Different age gaps: 3 between 18 and 24 years old; 11 between 25 and 34; 12 between 35 and 44; 24 between 45 and 54; 16 between 55 and 64; 13 between 65 and 74; and 7 above 75;
- Various employment statuses: 42 employed, 14 self-employed, 7 entrepreneurs, 1 unemployed, and 22 retired.

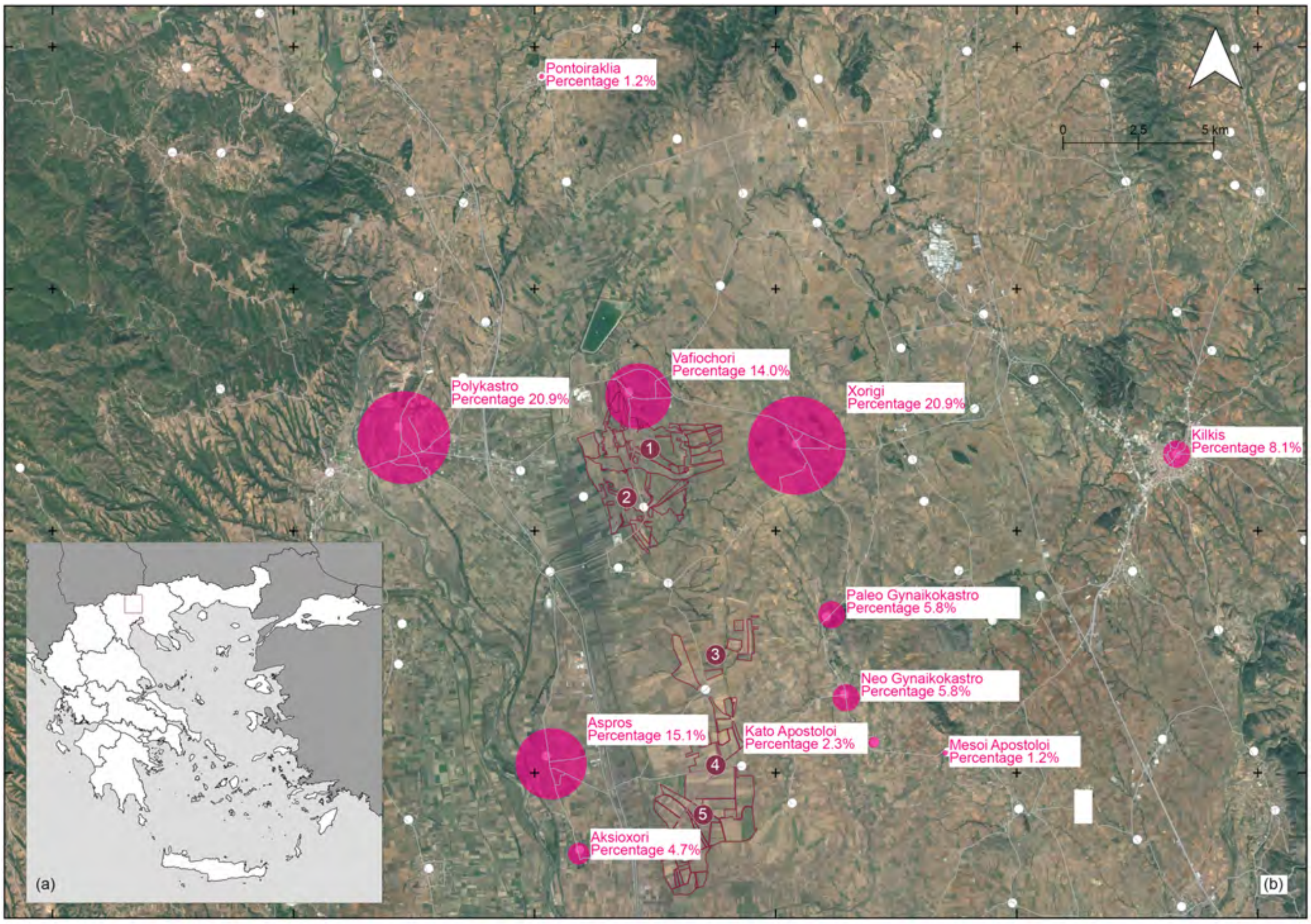

Figure 1. Case study: (**a**) location in Greece; (**b**) selected Solar Power Plants (SPPs) in the region of Kilkis and surrounding villages associated with the percentage of respondents, (1) SPP in Agroktima Vafiochorioy, (2) SPP in Kotyli, (3) SPP in Hersotopi, (4) SPP in Kokartza and (5) SPP in Neo Sirakio.

The survey took an average of 10 min to complete and was previously tested among collaborators of local colleagues to test both the time and clarity of the questions. Onsite and online disseminations were combined to reach a socially representative sample of respondents providing a wide range of diverse opinions. Since in the smallest villages only a few people were available to answer the questionnaire, an online campaign aimed to reach people that were not available in person (e.g., because they were at work or studying in another village or city).

3.4. Questionnaire Data Analysis

The content of the survey analysis was drawn from the literature review and document analysis. The survey was mostly based on Likert scale questions but also included an open-ended question (Q.4.4), a multiple choice question (Q.4.1), a ranking scale question (Q.2.4), and two matrices based on a series of Likert scale questions (Q.2.2 and Q.3.1). Moreover, several questions offered the respondent the opportunity to add comments or further explain their answer. The feedback obtained from the open-ended question and from the comments were not sufficient to be subjected to a statistical description but was useful to enrich the interpretation of the other answers. To visualize the results of the close-ended questions, in most cases, the percentage of each answer was calculated and used to build bar or pie charts. In the case of the matrixes and of the ranking scale question, two different data visualization approaches were used. For both approaches, the percentage of the grade for each option was calculated. The first approach exploits the stacked bar to visualize the results, allowing to see the percentage or the number of the single rates for each option. According to the other approach, the weighted average percentage of each option was calculated. The ranking scale question had eight alternatives to grade, in order of importance, from 1 to 8. A decreasing positive value, from 4 to 1, is associated with the four highest grades and a decreasing negative value, from −1 to −4, is associated with the last four values. The calculation of the weighted average percentage made it possible to visualize results as a bar chart, where the options are scaled according to the answer of the respondents. This allows to rapidly distinguish the answer with the highest rate from the answer with the lowest rate. Similar visualization solutions were applied to the two matrices: using the percentage to build a stacked bar and the weighted average percentage to build a bar chart. The only variable is the number of available answers for each question of the matrixes. For the first matrix (Q.2.2), respondents had five possible answers for each question: two negative, two positive, and one neutral. In this case, the weighted average is based on a scale from −2 to 2 (from negative to positive and 0 for neutral). For the second matrix (Q.3.1), respondents had three possible answers: one negative, one positive, and one neutral. In this case the weighted average is based on a scale from −1 to 1 (from negative to positive and 0 for neutral). For the multiple choice question, the results are visualized using a bar chart showing the integer number of respondents choosing each option.

3.5. Operationalization of Public Perception

The opinion of the inhabitants was further operationalized to gather useful information for further inclusion in the energy planning tools. Specifically, the concerns of the residents related to site selection were made spatially explicit. The procedure for the operationalization consisted of four steps (Figure 2).

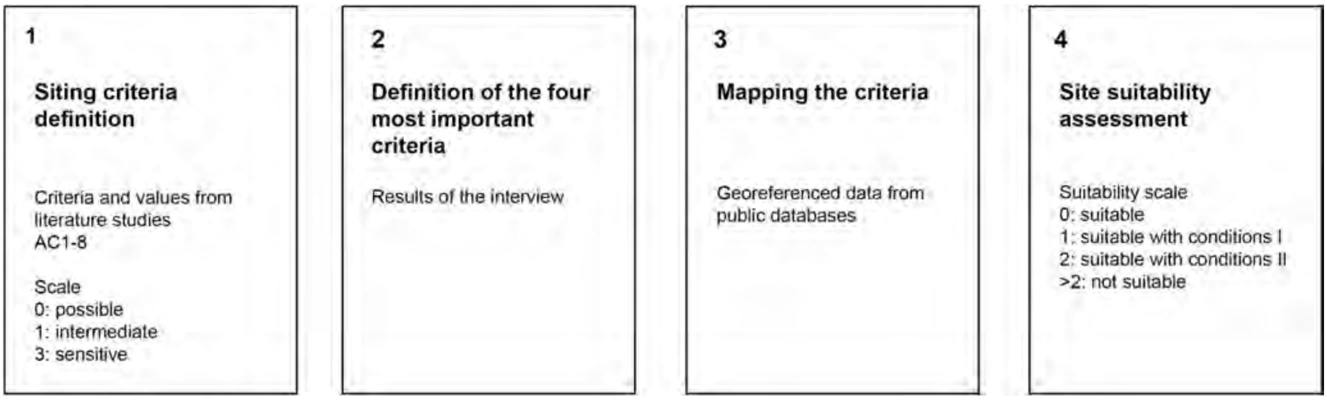

Figure 2. Workflow of the public perception operationalization.

The first step was the definition of the siting criteria according to the values derived from studies in the literature. Starting from a long list of more than forty sustainability criteria collected from studies, such as [3,55], eight criteria were selected for the case study (i.e., agricultural values, distance from protected areas, pastureland value, distance from urban areas, integration with existing infrastructures, distance from archeological sites, visibility from the streets, and visibility from touristic routes). The criteria excluded technical constraints, such as terrain suitability and access to power grid, considering environmental, social, and economic issues. The second step was the selection of the four most significant criteria as perceived by the respondents from the answers of Q2.4. These were then made spatially explicit using georeferenced data derived from public databases, as reported in Table 2. Each policy aspect was scored on a 3-point scale as being "possible", "intermediate", or "sensitive", underlying the level of mitigation action required.

Table 2. Georeferenced data used to assess Siting Criteria (SC).

Name	Description	Use	Source
Natura 2000 areas	Areas of communitarian interest, protected for biodiversity conservation	SC8	Natura 2000 Network
Agricultural areas	Arable land, permanent crop, and heterogeneous agricultural areas	SC1	Corine Land Cover
Pasture land	Grassland for livestock	SC2	Corine Land Cover
Urban areas	Continuous and discontinuous urban fabric	SC5	Corine Land Cover

Finally, the last step is the assessment of the site by defining suitability degrees within the area. The scores of the areas are derived from the sum of the scores assigned in step three, considering the same weight for each criterion. The result is a map of suitability levels of the solar farms as perceived by the inhabitants, identifying areas that are suitable for solar siting, areas that are suitable under mitigating circumstances, and areas that are not suitable. The resulting map can be taken into consideration in the landscape impact assessment process of the licensed solar farms in the region of Kilkis.

4. Results

The case study enables us to examine the perceptions of residents concerning potential solar power plants located in their vicinity. Such perceptions are linked with the degree of acceptance, the conflicts and trade-offs that might arise, and the diverging points of view. According to several studies focusing on public perception, SPPs are highly visible features of the landscape. However, a clear trend among the respondents regarding the frequency with which they notice panels in the landscape could not be detected. This could be related to the fact that some of them do not often leave the urban settlements, as well as their sensibility towards the surrounding landscape. This section presents the results of the questionnaire (Section 4.1) and their interpretation according to the three dimensions of SPPs (Section 4.2). The operationalization of the results to make them spatially explicit is outlined in Section 4.3 together with the assessment of the licensed areas for PV deployment.

4.1. Results of the Questionnaire

This subsection presents some considerations based on the visualization of the questionnaire results. Considering the area object of investigation and the focus of the questionnaire, most of the respondents declared that they spend time around the area where new PV plants could be installed at least sometimes (66%) and only a few never (14%) or rarely (20%), as shown in Figure 3a. Most of the interviewees considered their knowledge concerning renewable energy (Figure 3b) to be good (42%), as well as (47%) on photovoltaic energy (Figure 3c). Moreover, most people (83%) admitted to being at least quite a bit concerned about environmental issues (Figure 3d). All respondents were used to seeing photovoltaic panels at least sometimes (Figure 3e). This result was confirmed during the two days in the field: roof PV plants are very common in some of the villages and small ground PV plants are spread around the area. Most of the respondents were positive (60%) or neutral (27%) regarding the installation of new PV plants in the area (Figure 3f), while only a few declared being negative (11%).

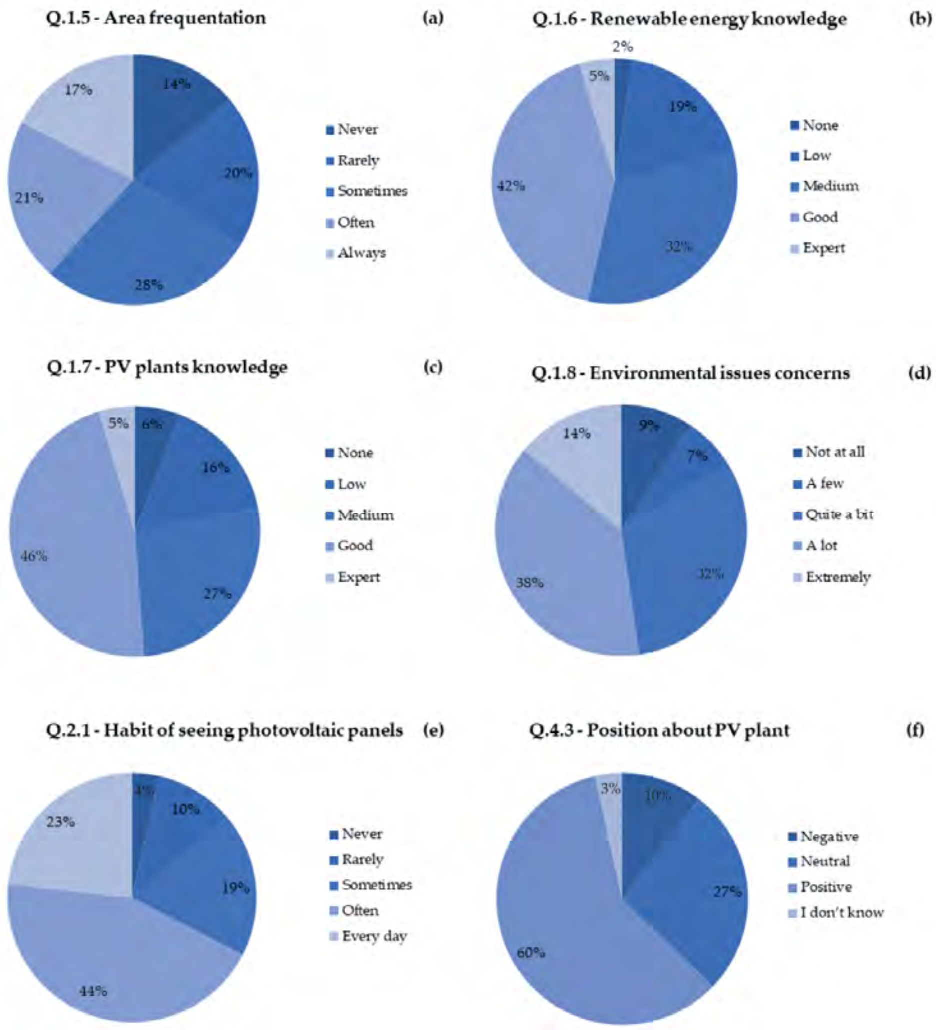

Figure 3. Results of the questionnaire concerning the following topics: (**a**) frequentation of the area object of analysis; (**b**) knowledge on renewable energy; (**c**) knowledge on Photovoltaic (PV) plants; (**d**) concerns about environmental issues; (**e**) habits of seeing photovoltaic panels in the area; (**f**) position of local inhabitants on licensed PV plants in the area.

According to the weighted average level of agreement among the respondents to a list of factors potentially causing negative reactions among local inhabitants, place attachment, environmental impacts, and landscape disturbance were the main factors that may cause oppositions to the licensed PV plants (Figure 4a). Most of the respondents (74 participants, 92%) considered the "appropriate site" selection process important (Figure 4b). Considering site selection, each criterion was mentioned at least once as the most important factor for the site selection. Agricultural value (mean rank: 1.9), distance from protected areas (mean rank: 1.7), and pastureland value (mean rank: 1.1) emerge as the three most important criteria to consider when siting a PV farm (Figure 4c). The section on alternative design solutions highlighted that the respondents considered the following as the most suitable options for the area: adoption of shape and slope of the ground, respect for the proportion of other elements in the landscape in the dimensioning of the plants, and recall of the shape of the landscape in the design of single panels (Figure 4d,e). Most of the respondents perceived as benefits of the new PV plants the economical revenues for the landowners (Figure 4f), and investors were considered the main beneficiaries of the PV plants (Figure 4g).

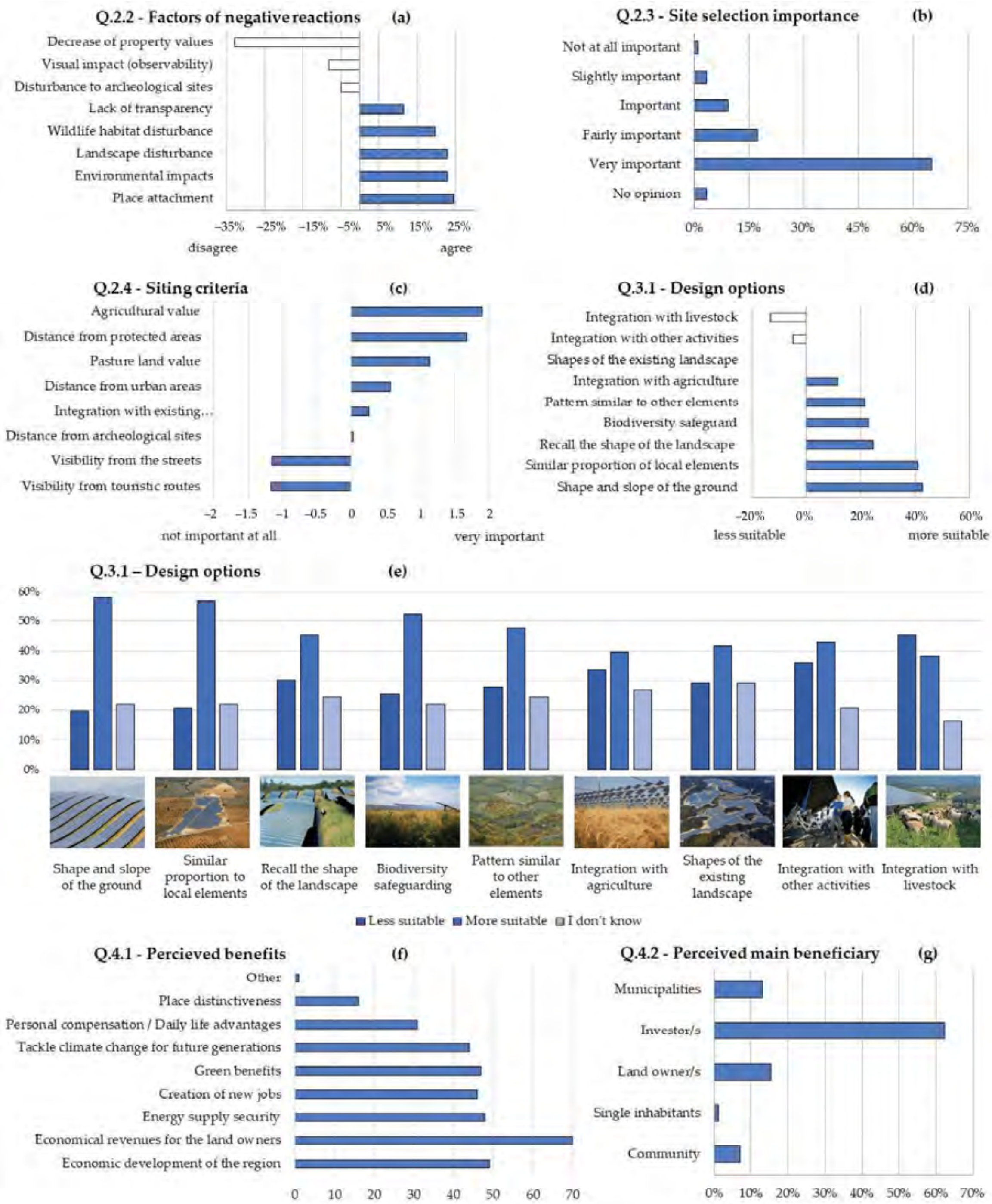

Figure 4. Results of the questionnaire concerning the following topics: (**a**) factor causing negative reactions among local communities; (**b**) importance of ground PV plant site selection; (**c**) ranking of ground PV plant siting criteria; (**d**) ranking of ground PV plant alternative design options; (**e**) percentage of different answers for each design option; (**f**) perceived benefits of licensed ground PV plants in the area; (**g**) perceived main beneficiary of the licensed PV plants in the area.

4.2. Public Perception of PV Impacts and Benefits

Although environmental considerations are a common concern affecting local resistance, many respondents of the questionnaire acknowledge the environmental benefits of photovoltaic installations. Wildlife disturbance is considered one of the main factors causing negative reactions for on-ground PV systems, as well as other environmental issues related to ecosystems, soil, and water. The respondents with a negative position on the licensed PV areas considered both wildlife disturbance and other environmental impacts factors affecting negative reactions. Landscape is often mentioned as a negative outcome of energy transition, both for solar power plants and wind farms. For example, solar panels are considered negative for heritage conservation. In line with this issue, some respondents of the questionnaire mentioned distance from archaeological sites as one of the most important factors for site suitability. Moreover, landscape disturbance is considered one of the main issues causing negative reactions towards the SPPs. All respondents with a negative position on the licensed PV areas consider landscape disturbance a factor affecting negative reactions. However, it is not clear which type of landscape the respondents refer to.

In this view, the adoption of a landscape charter might be a valuable asset to acknowledge and preserve the local context. The licensed PV sites are in rural areas considered remote and peripheral and mainly devoted to agriculture. Several respondents mentioned that they rent or have sold their property for solar power generation, or they mentioned that they would like to use their land for this purpose, as they see it as a more convenient investment than agriculture. Therefore, such areas may be considered in need of alternative strategies for local development. Indeed, the envisioned model includes both companies and private individuals, but it is subject to an insecure position due to political instability and grid saturation. According to the results, socioeconomic benefits, such as economic revenues for landowners, economic development of the region, and creation of new jobs, were the most considered by the respondents.

4.3. SPPs Assessment According to Public Perception

The information gathered from the citizens can inform the assessment of the licensed PV plants and highlight areas considered highly fragile according to the people, which could require mitigation measures. Specifically, the results of the site-selection criteria prioritization (Q2.4) were operationalized to inform the site suitability of the planned solar farms. According to the respondents, the four most important criteria to be considered for site selection are agricultural value, pastureland value, distance from protected areas, and distance from urban areas.

The four criteria were made spatially explicit considering a three-point scale. The selected thresholds of the suitable and unsuitable areas for each siting criteria are presented in Table 3. The resulting maps are presented in Figure 5.

Table 3. Thresholds of the siting criteria.

Site Criteria	Mean Grade Received	Sensitive		Intermediate		Possible	
Agricultural value	1	2	High value cultivation	1	Wood crops	0	Other
Distance from protected areas	2	2	Protected area	1	Buffer 0–500 m	0	>500 m
Pastureland value	3	2	High value pasture	1	Pastureland	0	Other
Distance from urban areas	4	2	Urban areas	1	Buffer 0–500 m	0	>500 m

Considering the sensitive areas that are unsuitable and, subsequently, excluded, this would lead to a substantial reduction in the available surface area. Thus, embracing a landscape-integration approach, the areas were divided between “nonsuitable”, “suitable under condition”, and “suitable”. The conditions represent mitigation actions, such as modifications to the physical appearance of the solar farm. Overlapping the four criteria, the scores of each area were summed. Specifically, to support this process, a suitability scale was created defining the thresholds for the levels of suitability, considering the possibility that some siting criteria can overlap. Specifically, summing the points assigned to each siting criteria, according to Table 3, a sum of zero points represents suitable locations, of one point suitable locations with conditions, of two points suitable locations with restricted conditions, and more than two points nonsuitable locations. The result is a map showing the levels of suitability for solar site selection as perceived by the inhabitants (Figure 6).

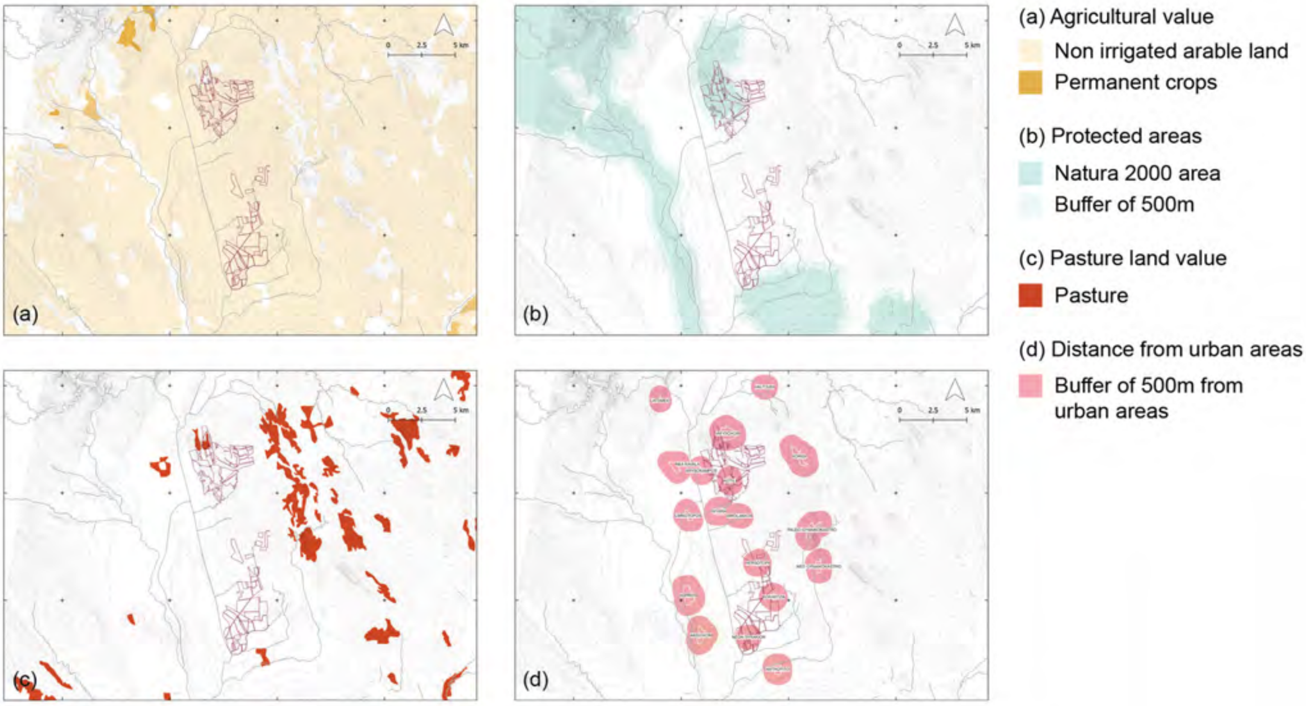

Figure 5. The most critical siting criteria according to the respondents, in ranking order: (**a**) agricultural value; (**b**) protected areas; (**c**) pastureland value; (**d**) distance from urban areas.

Figure 6. Map of the levels of suitability of the licensed SPPs according to the siting preferences of the inhabitants.

Each licensed PV farm in the region of Kilkis was assessed according to the perceived impacts and to the values assigned to the siting criteria. For example, the area named Agroktima Vafiochori is only partially suitable considering the answers of the inhabitants. Indeed, the selected area includes protected areas and areas within 500 m from an urban core, which are considered sensitive by the respondents. Figure 7 shows the classification of the suitability levels derived from the procedure. Moreover, we present a selection of innovative design solutions to consider for the mitigation of the perceived impacts by linking the design strategies included in the questionnaire to the impacts of the SPPs (Table 4).

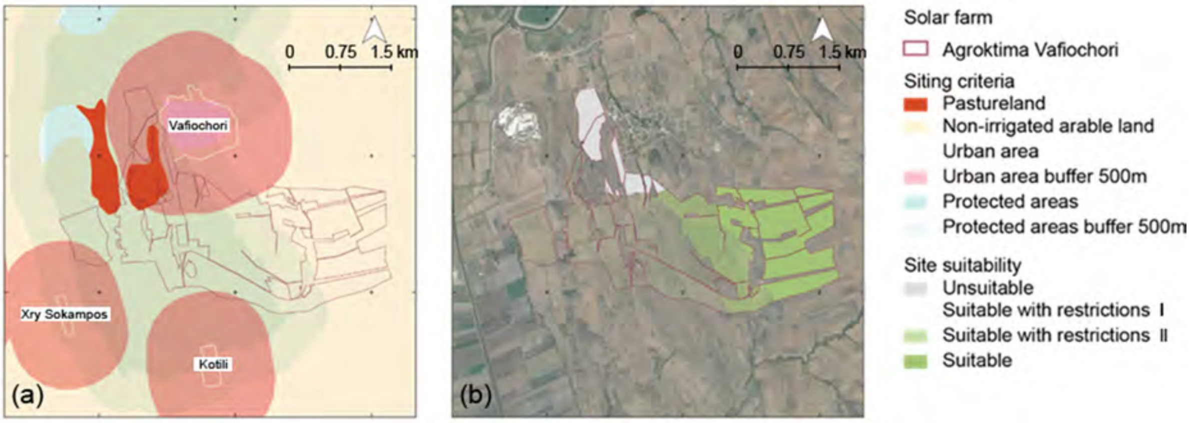

Figure 7. Spatialization of the results in the solar farm Agroktima Vafiochori: (**a**) most critical siting criteria; (**b**) suitability levels according to the opinion of the inhabitants.

Table 4. Landscape-integration strategies to mitigate impacts and address societal considerations (E: environmental; L: landscape; S: socioeconomic).

Strategies			Societal Considerations	Impact Mitigated
Landscape design (PV landscape pattern)	L1	Porosity	L E	Environmental impacts
	L3	Low/high tilt angle	L	Landscape disturbance
	L4	Dual use of land: agrivoltaic	L S	Decrease in property value, landscape disturbance
		Dual use of land: recreational activities	L	Place attachment
	L5	Dimension of the patch	L	Landscape disturbance
	L6	Orientation of the stripes of the modules	L E	Landscape disturbance
Architecture design (system design)	D1	Land cover underneath	E	Wildlife habitat disturbance, environmental impacts
	D2	Azimuth and tilt angles	L	Landscape disturbance

5. Discussion

The results suggest that there is a good level of acceptance of the solar power plants. Although solar installations seem to be noticeable features in the landscape causing concerns about the landscape and environmental impacts, several benefits are recognized with the deployment of this method of renewable energy production. As other studies have already mentioned (e.g., [7,61,81–83]), these results should highlight that oppositions are not explained by the NIMBY attitude. In the following subsections, public responses, interactions with the citizens and the inclusion of the opinion in the assessment of licensed SPPs are discussed.

5.1. Public Perception and Preferences

The results indicate that more attention should be given to landscape when developing solar power plants, as landscape disturbance is perceived as one of the main impacts. Moreover, the integration with other uses, such as residential areas or landscape issues, such as protected areas, should be guaranteed in planning new RELs. Priority should therefore be given to the areas that are considered suitable. If not possible, in other areas, the physical appearance of SPPs should mitigate or reduce the impacts, for example, by adapting the height or density of the panels. These types of strategies may have different economic implications on the deployment of solar farms: while they reduce energy efficiency, they could provide several (long-term) co-benefits (e.g., food production, biodiversity enhancement), which are not normally assessed from an economic perspective.

The results facilitate our understanding of landscape developments driven by RES, providing crucial information for decision making. Specifically, the results of the questionnaire help to understand the perceived impacts and factors of PV plant acceptance. The survey seeks to define types of landscapes perceived as sensitive for the inhabitants. Moreover, introducing pictures of SPPs types within the questions facilitates the understanding of potential landscape transformations. The images represent several characteristics that could contribute to the deployment of landscape-inclusive installations, such as PV patterns in the landscape or design of the systems [5,6]. However, the pictures did not represent the diversity of the landscapes. The reasons for this are a lack of sound site exploration and proper knowledge of the area showing the diversity within the rural area, and lack of time for survey preparation. Hence, the results of the survey are not able to provide a clear link between site selection and strategies of landscape-integration design. This issue could be solved by addressing situational factors with individual characteristics using other methods, such as simulations of different densities of REL within different types of landscapes, such as in the works of Salak et al. [45] and Spielhofer et al. [46], or by asking specific information on the area through open-ended questions. In this regard, the question on additional thoughts was not very successful, as respondents did not have further comments. This issue might also be related to the fact that respondents who were stopped in the streets without an appointment were not keen to spend much time on the questionnaire. Choice experiment responses can be viewed as passive rather than active actions, but the language barrier was the main issue in trying to gather further information. The results may be affected by the sample of the respondents, whose representativeness could not be confirmed, so it would be encouraged to engage with more surveys. Indeed, a wider size sample of respondents would help to generalize the findings and trace specific trends. To increase the number of respondents, other dissemination strategies should be taken into consideration, as involving civil servants to engage more participants.

Some aspects related to solar power plant preferences and choices, such as efficiency and lifecycle, were not asked of the participants because of the difficulties in evaluation by nonexperts. To provide an overview on public preferences on these matters, we suggest organizing public meetings and workshops with focus groups to introduce the topics prior to spreading the questionnaire. Alternatively, two questionnaires could be disseminated: a basic version for citizens and an upgraded version for experts and relevant stakeholders.

5.2. Stakeholders Interactions

Because of the limited time and interactions with representatives from the municipalities, the questionnaire was only distributed to people in the villages. Most of the participants in this study were not prepared to inform judgements on solar power plants and express opinions or criteria for site suitability and impacts. For more inclusive results, other inhabitants, such as civil servants and entrepreneurs working in other areas, should participate. A closer collaboration with the municipalities could help to reach more respondents. Moreover, local experts could support the design of the questionnaire by better directing the questions and making them more specific to the context. For example, some types of questions were considered too difficult by some respondents because of a lack of knowledge and capacity to spatialize and visualize the questions. This limitation could be overcome by experimenting with other types of interactions with the citizens; for example, co-visioning [84] or q-sorting [47,48] could be valid alternatives.

5.3. Similarities and Differences with Other Approaches

Participatory methods are widely used in planning practices, but the inclusion of public opinion in energy planning processes has only recently gained research attention [85,86]. In energy planning, they have been divided into information, consultation, involvement, collaboration, and empowerment [53]. Spatial representation of qualitative considerations can be used to inform one of these participation levels. For example, Oudes and Stremke defined energy targets [10] by making a list of sites through a questionnaire. Spyridonidou et al. [54] and Loukogeorgaki et al. [69] assessed suitable sites for RES deployment through questionnaires. This study sought to translate the qualitative results from the survey into quantitative scenarios to assess planned PV plants. These processes require degrees of interpretation by the authors, but they are useful to produce a result that can be easily integrated or superimposed on existing planning tools. As the outcomes of the questionnaire directly affected choices, more specific and elaborated questionnaires may be beneficial for future projects, created in collaboration with administration servants from municipalities and regions. Moreover, the procedure is a tool for active participation and can contribute to creating awareness on the issues and on the occurring landscape transformations. The results of this method can support the creation of a long-term vision with the contribution of the inhabitants and to link it to design practices, to pursue the vision for the area. Recent literature called for improvements in the siting and design of renewable energy technologies [52], including participatory processes that are transparent and inclusive [12]. The presented study supports these processes providing information for decision makers, including siting and landscape integration design insight. Decision-makers can use the insight by setting fragile areas and quality criteria according to the inhabitants' preferences and drive clear and transparent procedures. These criteria can be set at different policy and governance levels, from regional to local normative criteria. Moreover, the procedure can be replicated to initiate conversations between citizens and policy makers on considerations, spatialization, configuration of renewable energy technologies installations, as a base for quality participatory processes [53]. The results suggest that inhabitants perceive benefits of SPPs mostly in relation to the possibility of local development rather than the enhancement of spatial qualities of the landscape. However, matching location with spatial configurations supports long term vision and likeliness to receive population support [8].

5.4. Implications in Decision-Making Processes

Recent literature has called for the improvement of current decision-making procedures related to sustainable energy planning [87]. Participatory processes are expected to shift from information sharing towards transparent and inclusive processes [12,52,53]. The presented procedure, understanding public perception on perceived benefits and impacts and its spatialization, supports these processes and provides advantages for decision makers and inhabitants. Decision makers can use the results or the procedure to set different levels of suitability areas and qualitative criteria for SPPs in permit regulation procedures [40,59,68]. Such criteria can be set on different governance local levels, from the legislative regional ones to the normative municipal ones [10,59]. In future studies, the results could be further refined using functions such as fuzzy quantifiers to create criteria in the georeferenced system incorporating uncertainty [88,89]. Moreover, suitable areas can be the result of techniques comparing and weighting sustainable siting criteria with public perception, such as through analytic hierarchy process or other multicriteria decision-making techniques [54,90].

Currently, landscape considerations are scarcely considered: participatory procedures are voluntary, and suitable areas are based on land use considerations [55,56]. Loukogeorgaki et al. [69] proposed a similar procedure for the incorporation of public perception in eligible marine areas for wind farms. For solar installations, Spyridonidou [54] included people's opinions by asking siting criteria information at the national level; Oudes and Stemke [10] declared that the questionnaire did not provide spatially explicit information at the regional level. This study incorporates the landscape perception of citizens at the local level, defining which areas are considered more sensitive for its residents. The proposed approach is complementary to the planning processes taking into account societal considerations (e.g., environmental, economic). Contributing to shaping energy landscapes is an important condition to empower citizens in the energy transition [53]. Thus, defining sensitive areas according to the inhabitants can improve social acceptance and limit the cases of local resistance. Despite these benefits, some trade-offs emerge. This process requires resources (time) and a certain level of interpretation. However, once developed for a certain area, the results can be re-used to assess and evaluate several SPPs applications.

6. Conclusions

This study on public perception of solar power plants presents a methodology that can support transparent and inclusive decision-making processes. The study contributes to the understanding of community perception in renewable energy projects. The main findings are as follows:

1. There is general support for systems based on solar energy production. However, respondents highlight concerns of the environmental impacts of photovoltaic installations. Economic aspects are mainly considered as positive benefits in relation to the possible revenues and development for regions and inhabitants. Landscape is considered in negative terms by the participants who consider landscape disturbance and place attachment one of the main effects that might cause negative reactions. Moreover, the landscape generated by the deployment of renewable energy sources is generally not associated with positive benefits for the communities involved. However, this could change by shifting to multifunctional photovoltaic installations with attention to their spatial and temporal qualifications.
2. A possible connection between the visual and contextual characteristics of solar power plants can be established in relation to land use. Participants might prefer solar infrastructures shaped according to the landscape and the people by changing the density, height, and patterns of the panels. Moreover, the respondents highlight that agricultural and pasture value and distance from urban and protected areas are important criteria for the site selection. Finding suitable sites in accordance with visual and contextual public perception can facilitate social acceptance.
3. This research proposes a methodological approach to include the opinion of the inhabitants in the energy planning tools. Siting criteria considered important by the participants were made spatially explicit and compared with the areas that received a license for energy production. Different degrees of suitability for photovoltaic implementation were assigned to the areas considered sensitive by the respondents.

The quantitative nature of the procedure allows for its execution with a larger number of participants. In this regard, the effect of the demographic sample interviewed was not tested, as the sample was small. Thus, the study cannot directly formulate recommendations for policy makers or landscape planners but values and a procedure to include visual and contextual considerations in impact assessment processes. Acknowledging the size of the sample as a potential limitation, the present investigation could be extended by focusing on the involvement of a larger number of residents in the whole region. Future research could also include visual simulations of suitable photovoltaic installations in the area to better link local landscape with solar farm spatial configurations. As energy transition is calling for a deeper consideration of landscape, this methodology represents an opportunity to adapt the shape and location of solar power plants to public perception. Methods such as this are needed to support the debate on the acceptance of renewables and can be adapted to other types of renewable energy installations and to other locations.

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Appendix A

This section contains the questions of the questionnaire.

Section 1—General Information
Q.1.1 What is your gender?
(Please check ☒ one choice only)
☐ Male
☐ Female
☐ Other
☐ I prefer not to answer

Q.1.2 What is your age?
(Please check ☒ one choice only)
☐ 18–24
☐ 25–34
☐ 35–44
☐ 45–54
☐ 55–64
☐ 65–74
☐ Above 75

Q.1.3 What is your highest level of education?
(Please check ☒ one choice only)
☐ Compulsory education
☐ Bachelor's degree or equivalent
☐ Master's degree or equivalent
☐ Doctoral degree or equivalent
☐ Other

Q.1.4 What is your current employment status? Please also define your current work field (i.e., agriculture, industry, commerce).
(Please check ☒ one choice only)
☐ Employed____
☐ Self-employed worker___________________________________
☐ Entrepreneur____
☐ Unemployed____
☐ Retired____
☐ Other (please define)____

Q.1.5 How often do you spend your time around the areas where the PV plants might be installed?
(Please check ☒ one choice only)
☐ Never (e.g., I do not know where this place is)
☐ Rarely (e.g., I barely know where this place is)
☐ Sometimes (e.g., I buy some products in the nearby)
☐ Often (e.g., I spend my free time in the nearby)
☐ Always (e.g., I live/work in the nearby area)

Q.1.6 How would you consider your knowledge on renewable energy production?
(Please check ☒ one choice only)
☐ None
☐ Low
☐ Medium
☐ Good
☐ Expert

Q.1.7 How would you consider your knowledge on photovoltaic energy production?
(Please check ☒ one choice only)
☐ None
☐ Low
☐ Medium
☐ Good
☐ Expert

Q.1.8 Are you concerned about environmental issues?
(Please check ☒ one choice only)
☐ Not at all
☐ A few
☐ Quite a bit
☐ A lot
☐ Extremely

Section 2—Public perception of PV plants and site selection
Q.2.1 How often do you notice photovoltaic panels in the landscape around you?
(Please check ☒ one choice only)
☐ Never
☐ Rarely
☐ Sometimes
☐ Often
☐ Every day

Q.2.2 Considering the licensed PV plants in the area, to what extent do you agree or disagree that the following factors might cause negative reactions among the community?

	Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**I Don't Know**
Wildlife habitat disturbance						
Landscape disturbance (integration in the context)						
Visual impact (observability)						
Environmental impacts (soil, ecosystems, water usage)						
Disturbance to archeological sites						
Decrease of property values						
Lack of transparency in the procedure						
Place attachment						
Other (please define)						

Q.2.3 How important do you consider the "appropriate site" selection of PV farms for community acceptance?
(Please check ☒ one choice only)
☐ Not at all important
☐ Slightly important
☐ Fairly important
☐ Important
☐ Very important
☐ No opinion

Q.2.4 Please, grade in order of importance the criteria for selecting a site for PV plant installation.
☐ AC1. Agricultural value
☐ AC2. Pasture land value
☐ AC3. Integration with existing infrastructures/buildings
☐ AC4. Distance from archeological sites
☐ AC5. Distance from urban areas
☐ AC6. Visibility from recreative areas and touristic routes
☐ AC7. Visibility from the streets
☐ AC8. Distance from protected areas

Section 3—Public perception of PV plants and PV plant design
Q.3.1 Define if you consider each of the following PV plants solutions more or less suitable than a traditional one for the area.
(Please, give an answer to each row)

		More Suitable	**Less Suitable**	**I Don't Know**
macro-layout following the shapes of the existing landscape				
macro-layout following the shape and slope of the ground				

		More Suitable	Less Suitable	I Don't Know
low-density layout following a pattern similar to other elements of the landscape				
dimension of the area with similar proportion to the local elements of the landscape				
micro-layout that recalls the shape landscape				
integration of agriculture and PV plants				
integration of livestock and PV plants				
ground coverage allowing biodiversity safeguarding/enhancing				
integration of recreational activities and PV plants				

Section 4—Perceived social benefits of PV plants
Q.4.1 Do you think the PV plants in the area can bring any of the following advantages? (Please check ☒ all that apply)

☐ Economic development of the region
☐ Economical revenues for the land owners
☐ Energy supply security
☐ Creation of new jobs
☐ Green benefits
☐ Tackle climate change for future generations
☐ Personal compensation/Daily life advantages
☐ Place distinctiveness
☐ Other:________________

Q.4.2 Who do you think benefits the most from the PV plant? And why
(Please check ☒ one choice only)
☐ Municipalities (name)____
☐ Investor/s____
☐ Land owner/s ____
☐ Single inhabitants ____
☐ Community____
☐ Other ____

Q.4.3 What is your position about the PV farms in the area?
(Please check ☒ one choice only)
☐ Negative
☐ Neutral
☐ Positive
☐ I don't know

Q.4.4 What do you think should happen to solar parks after their lifetime?

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