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EXPLORING THE CRITERIA FOR "SMART PRACTICES" IN RENEWABLE ENERGY PROJECTS: THE PROVINCE OF JAEN (SPAIN) AS A CASE STUDY

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Abstract

The transition to a future sustainable energy requires the implementation of renewable energy projects. However, to ensure their success, these initiatives must go beyond simply installing clean technologies and adopt smart practices that transcend technical challenges. This work aims to advance the conceptual framework of "smart practices" and analyses their application in renewable energy projects in the province of Jaen. Semi-structured interviews with environmental technicians from the Provincial Council of Jaen were used to identify projects aligned with the criteria proposed by Frantál et al. (2018). The research results suggest the need to consider projects beyond the technological advancement they represent and take into account the context in which an energy installation is planned, and how perception and social acceptance play a fundamental role as a guarantee of success.

Key words: Smart practices; renewable energies; energy transition; solar photovoltaic plant; wind farm; biomass power plant; province of Jaen.

EXPLORANDO LOS CRITERIOS DE "PRÁCTICAS INTELIGENTES" EN PROYECTOS DE ENERGÍAS RENOVABLES: ESTUDIO DE CASO EN LA PROVINCIA DE JAÉN (ESPAÑA)

Resumen

La transición hacia un futuro energético sostenible exige la implementación de proyectos de energía renovable. Sin embargo, para garantizar su éxito, estas iniciativas deben ir más allá de la simple instalación de tecnologías limpias y adoptar prácticas inteligentes que transciendan los desafíos técnicos. Este trabajo tiene como objetivo avanzar en el marco conceptual de las "prácticas inteligentes" y analizar su aplicación en proyectos de energía renovable en la provincia de Jaén. Se realizaron unas entrevistas semiestructuradas a técnicos de medio ambiente de la Diputación Provincial de Jaén para identificar proyectos que se ajustasen a los criterios propuestos por Frantál et al. (2018). Los resultados de la investigación sugieren la necesidad de contemplar los proyectos más allá del avance-innovación tecnológica que supongan y consideren el contexto sobre el que se proyecta una instalación energética, y cómo la percepción y la aceptación social juega un papel fundamental como garantía de éxito.

Palabras clave: Prácticas inteligentes; energías renovables; transición energética; planta solar fotovoltaica; parque eólico; central de biomasa; provincia de Jaén.

BERRIZTAGARRI ENERGIETIKOAREN "PRAKTIKA UKABEAK" KRITERIOAK AZTERGAI: JAEN PROBINTZIA (ESPAINIA) IKUSI KASU GISA

Laburpena

Etorkizun energetiko iraunkorrerantz mugitzeko, energia berriztagarriko proiektuak inplementatu behar dira. Hala ere, arrakasta ziurtatzeko, ekimen hauek teknologia garbiak instalatzearen gainetik "praktika ukabeak" hartu behar dituzte, erronka teknikoen gainetik aurrera egin dezaten. Lan honek "praktika ukabeen" marko kontzeptualaren aurrerapena eta energia berriztagarriko proiektuetan beren aplikazioa aztertzea du helburu Jaen probintzian. Jaen Foru Diputazioaren ingurumen teknikariek elkarrizketa eremukoak burutu zituzten Frantál et al. (2018) proposatutako kriterioekin bat datozen proiektuak identifikatzeko. Ikerketaren emaitzek proiektuak teknologia aurrerapenaren aurrera suposatzen duten inguruneaz harago kontuan hartzea beharrezkoa dela iruditu dute, eta nola instalazio energetiko baten gainean proiektatutako kontestua, eta nola ikusmena eta onartze soziala jokatzeko papera oinarri gisa duten arrakasta bermatzeko.

Gako-hitzak: Praktika ukabeak; energia berriztagarriak; energia trantsizioa; eguzki-instalazio fotovoltaikoa; eoliko parkea; biomasa zentrala; Jaen probintzia.

1. Introduction

In a world increasingly conscious of the urgency to reduce carbon emissions and combat climate change, renewable energy projects have become a fundamental pillar in the transition to a sustainable future(Visintainer Lerman et al., 2021). However, mere implementation of renewable technologies is not sufficient to ensure lasting positive impact. The success of these projects hinges on the adoption of smart practices that holistically tackle technical, financial, and social challenges (Faller, 2016).

Given the current climate urgency and the need to meet increasingly ambitious energy objectives, there is a push to advance smart energy systems in the energy transition process, where the implementation of smart practices is expected to address many potential social and technical challenges (Skjølsvold, Ryghaug, & Berker, 2015). However, the approach to smart practices has traditionally been limited to technical (engineering) or economic disciplines, emphasizing technological capabilities, potential, and economic profitability (Skjølsvold, Ryghaug, & Berker, 2015). In recent years, social sciences have made progress in studying energy transition and smart practices, with a more holistic understanding of how installations fit into their context and are perceived by other users, as well as in formulating new strategies that could increase the chances of technology adoption and success (Rochlin, 2014).

This research seeks to advance the conceptual understanding of ‘smart practices’ within the context of renewable energy and the energy transition. For this purpose, semi-structured interviews were conducted with environmental technicians from the Provincial Council of Jaen based on three open questions: i) “Which renewable energy projects do you consider most representative of ‘smart practices’ in the province?”; ii) “What criteria do you consider when defining a project as a ‘smart practice’?”; iii) “What are the peculiarities of these projects?”. These questions were used to identify those projects executed in the province that, according to the interviewees’ criteria, could be classified as “smart”. Upon the selected projects, criteria established by Frantál et al. (2018) for considering a practice “smart” will be applied to validate the adequacy of these general criteria to different contexts and technologies. In the last phase of interviews, the three technicians collectively reflected on the question: “What weaknesses do renewable energy projects present in the expansion of the energy transition in the province of Jaen?”.

The results and conclusions of this study aim to offer valuable insights for planning and designing future energy projects in the province. These projects, conceived from the principles of “smart practices” and grounded in an understanding of the context in which they are situated, are intended to have a greater likelihood of success, thus contributing to accelerating the necessary energy transition to meet agreed-upon climate objectives. Additionally, the findings of this research contribute to the body of literature aimed at advancing the dynamism of renewable energy projects by promoting smart practices. Specifically, they add to the body of geographical studies that, from a social perspective, seek new understandings and theorizations of the energy transition.

In recent years, the literature on “smart practices” in renewable energy and energy transition has significantly expanded, underscoring the importance of furthering such studies for a more sustainable development based on decarbonizing the economy and replacing fossil fuels with renewable energy sources. However, most existing studies on “smart practices” tend to adopt a more technical or technological approach, analyzing strategies and/or technologies to efficiently and safely integrate renewable energies into the electrical grid. This includes demand management systems, energy storage, and microgrids. Notable studies also examine the economic aspects, assessing the opportunities and challenges of applying circular economy principles in the renewable energy sector, such as recycling, reuse, and remanufacturing of materials.

On the other hand, there is a relative scarcity of applied studies that delve into the criteria of “smart practices” from a social perspective, aiming to identify those that ensure a higher degree of public acceptance of renewable energy projects. Nonetheless, there are examples such as the studies by Ugwoke et al. (2021) or Mustafa et al. (2022) conducted in rural areas, which indicate that involving communities, transparency, participation, and fair distribution of benefits are key criteria that every project should meet to ensure its success and widespread acceptance.

The present work is structured as follows: firstly, a theoretical-conceptual framework is established to enhance understanding of the concept of “smart practices,” and the methodological framework is described, outlining the different phases in which the interviews were conducted. Subsequently, the results are presented, with an analysis conducted for each of the projects selected by the technicians. The analysis structure is consistent across all cases, comprising: i) technical data sheet, ii) description and characterization, iii) identification of criteria as smart practices. Following this initial descriptive phase, a reflective exercise based on the interviews is carried out, elucidating the criteria by which the technicians consider the selected case studies as intelligent, and consequently, outlining the challenges posed by the energy transition in the province. Finally, the discussion and conclusions of this research are presented.

2. Theoretical-conceptual framework

Alongside the development of renewables as an economic activity, companies have sought to refine and improve these practices with the aim of understanding the factors of success and indicators of a “good practice” that add final value to renewable energy projects (Harrison & Lock, 2017). Nevertheless, the criteria for defining a practice as ‘good’ are not universally applicable across all projects or territories. The distinctive attributes of a project, the specific features of its location, the resident population, and their relationship with the space and project render each practice unique and challenging to replicate (Vesely, 2011), necessitating a detailed analysis of each practice and its characteristics.

Various authors have sought to define universally when and why a renewable energy project can be regarded as a ‘good’ practice (Overman & Boyd, 1994; Bretschneider, Marc-Aurele, & Wu, 2004; Myers, Smith, & Martin, 2004; Zaring, 2006; Frantál et al., 2018), broadly concurring on concepts such as continuous learning, feedback, and reflection on what works and why, or why not. Ultimately, emphasis is placed on the functionality, progress, and innovation of a project. Now, the multiplicity of approaches to the concept, in a methodological attempt to formulate a set of necessary and sufficient conditions to identify a true “good practice”, have caused the traditional understanding of “good practice” to be questioned and to have mutated in the face of new methodological approaches that seek more objective criteria that can be extrapolated to other contexts.

The field of business and economic management has extensively explored the concept of “best practices”. Production theory in economics seeks to understand the relationships between inputs and outputs that allow identifying the best example in which inputs are transformed into products (Vilcapoma, 1995). Building on this theory and in relation to “best practices”, authors such as Bretschneider, Marc-Aurele, and Wu (2004) or Osborne (2008) propose the use of the term “best practice” instead of “good practice” as a concept that is not only based on continuous learning, feedback, or functionality but also seeks examples of applied innovation and success, which can translate into greater applicability to other practices. “Best practices” are defined as those practices that appear to be better than any other alternative (Bretschneider, Marc-Aurele, & Wu, 2004).

However, the conceptualization of “best practices” has not been exempt from controversy. Bardach (2004) argued that the term is misleading because we rarely are sure of having truly identified the best example from all the options that could solve the problem we are facing or the goal we are trying to achieve. Conducting such exhaustive research that truly considers all options becomes nearly impossible, resulting in simply identifying a “good practice”.

Since the development of a practice is linked to a context, and its consideration as “good” in one environment may not be so in another, Bardach (1998) began working with the term “smart practice”. This term suggests the presence of an innovative or noteworthy idea within a particular practice, that merits attention. It is precisely this “intelligence” that the researcher should seek, study, verbalize, and evaluate its applicability in the context of the destination site. Therefore, “smart practices” emerge as a flexible concept that seeks to identify those generic objectives that could be applicable to any context, allowing those who apply them the freedom to adapt them to new circumstances (Frantál et al., 2018).

3. Methodology

We employed a sequential methodological approach characterized by two stages of data collection, processing, and analysis. Through semi-structured interviews with experts, we identified renewable energy projects that, according to their expertise as technicians, could be considered representative examples of “smart practices” in the province. Subsequently, we proceeded with an exercise of characterizing these projects based on the categorization established by Frantál et al. (2018) for the study of smart practice cases.

3.1. Interview Development

Semi-structured interviews were selected as they provide a balance between flexibility and uniformity, ensuring interpretations align with the study's objectives (Díaz-Bravo et al., 2013). This approach is increasingly prevalent in studies focusing on energy transitions and renewable energy systems (Belmonte et al., 2007; Pérez Pérez, 2016; Lobo & Parajón Chavez, 2017; Stuhldreher & Morales Olmos, 2018). In these cases, conducted with social agents, they seek an approach to the issue through a citizen perspective, aiming to obtain the meanings that informants attribute to the topics in question (Díaz-Bravo et al., 2013). Building on this methodological contextualization, the present study is characterized by conducting interviews with experts in the field, rather than with the general public as done in the aforementioned previous works. The initial phase aims to understand and characterize "smart practices" in the energy transition process from a technical perspective. With this intention, the main environmental technician from the Provincial Council of Jaen, responsible for the development of renewable energy projects in the province, was contacted. One specialist was selected for each of the three renewable energy sources chosen for this research: wind, photovoltaic solar, and biomass. In selecting renewable energy technologies, two criteria were considered: i) these technologies had a significant weight in the provincial electricity generation structure; ii) the technologies had significant technical potential for medium-term development and expansion. Previous technical studies related to this issue carried out for the province were consulted for this purpose (Ruiz-Arias et al., 2012; Osorio-Aravena et al., 2022).

The three interviews were conducted in person in April 2022 at the Provincial Council of Jaen's facilities. After an initial contextualization about the concept and categorization of "smart practices", the interview process unfolded in two phases:

1. Firstly, three generic questions were asked to extract information about the concept of "smart practices" from an expert perspective, aiming to identify the considerations for a project to be considered as such and what lessons can be drawn for the future energy development of the region: "Which renewable energy projects do you consider most representative of 'smart practices' in the province?", "What criteria do you consider when evaluating a project as a 'smart practice'?", "What are the peculiarities of these projects?". A semi-structured and generic interview format was chosen to be adaptable to different renewable energy technologies existing in the regions, as there is only one wind energy case in the province of Jaen.

2. Secondly, once the experts identified the renewable energy projects, they deemed most representative in the province as "smart practices", a characterization activity was conducted with them. Based on the criteria established in a European study executed by Frantál et al. (2018) and in the form of a questionnaire, a form was completed for each of the selected projects (Table 1). This exercise subsequently allowed for contrasting whether the projects selected by the technicians as good

examples of energy development complied with the indicators established by researchers in the field.

Table 1. Support criteria for identifying “smart practices”

Criteria	Description
Rural Area	Located in a rural area
Visual Impact	Reduces visual impact
Local Benefits	Provides economic benefits for the local population/community
Border Periphery	Located in a border or peripheral area
Low Population Density	Located in areas with low population density
Pilot Project	Represents a pilot or experimental project
Local Demand	Meets local energy demand
Decentralization	Provides spatial decentralization of impacts
Land Use Synergy	Allows co-use of land
Environmental Synergy	Environmentally compatible, using local sources
No Land Use Conflict	Located on land with no other (significant) use
Technological Innovation	Represents technological improvement or innovation
Small Scale	Small size of installation and/or a reduced number of units
New Landmark	Creates a new visual landmark
Co-benefits	Provides by products and/or co-benefits
Reversibility	Easy removal of technology, thus restoring the area
Educational Function	Serves for demonstration and public education
Regulation Function	Provides some ecosystem regulation function
Heritage Synergy	Compatible with cultural heritage objects
Degraded Land	Utilizes environmentally degraded land (abandoned industrial areas)
Infrastructure Synergy	Utilizes existing infrastructure / Located in areas already used for energy production
Improves Stigmatized Spaces	Improves the image of stigmatized space

Source: Frantál et al. (2018)

The intention behind applying these criteria to installations of different renewable technologies is to understand how renewable energy projects integrate into the territory and adapt to political, technical, and social systems. The aim is to extract lessons from this analysis to guide future projects, identifying in a more pragmatic way what strengths ensure the success of a project and/or what weaknesses may condition its execution and operation (conflicts among stakeholders, public opposition, poor management, etc.). Therefore, ultimately, after the individualized interviews and having identified which criteria of “smart practices” the selected and analyzed energy projects meet, an exercise is carried out. Inspired by the expert panel of the Delphi method, the three technicians interviewed were brought together for a joint debate based on the question “From your own experience and the criteria outlined in the table, what do you consider to be the weaknesses of renewable energy projects regarding the expansion of the energy transition in the province of Jaen?”

3.2. Limitations

Since the intention of this research is to understand the technical perspective of the energy transition in the province of Jaen, only the main responsible person in the execution of projects in the province was contacted for each of the three selected technologies. However, this study does not aim for representativeness of the results but seeks to make an initial approach to practical understanding of the transition, which will be expanded in future studies with interviews and surveys of other stakeholders in the study area.

Regarding the analyzed projects, for the case of wind energy and biomass, there are few operational parks and plants in the province, with only one wind park. Therefore, the number of smart practices to be selected in photovoltaic solar projects was limited to 4, to maintain equity in the study. Nevertheless, it was decided to work with the three technologies, as they represent the energy reality of the province, and their potential for future development is significant as indicated by technicians and confirmed by studies such as Osorio-Aravena et al. (2022). Additionally, understanding the context and characteristics of these projects can serve as a learning experience for the planning of future projects.

4. Case Study

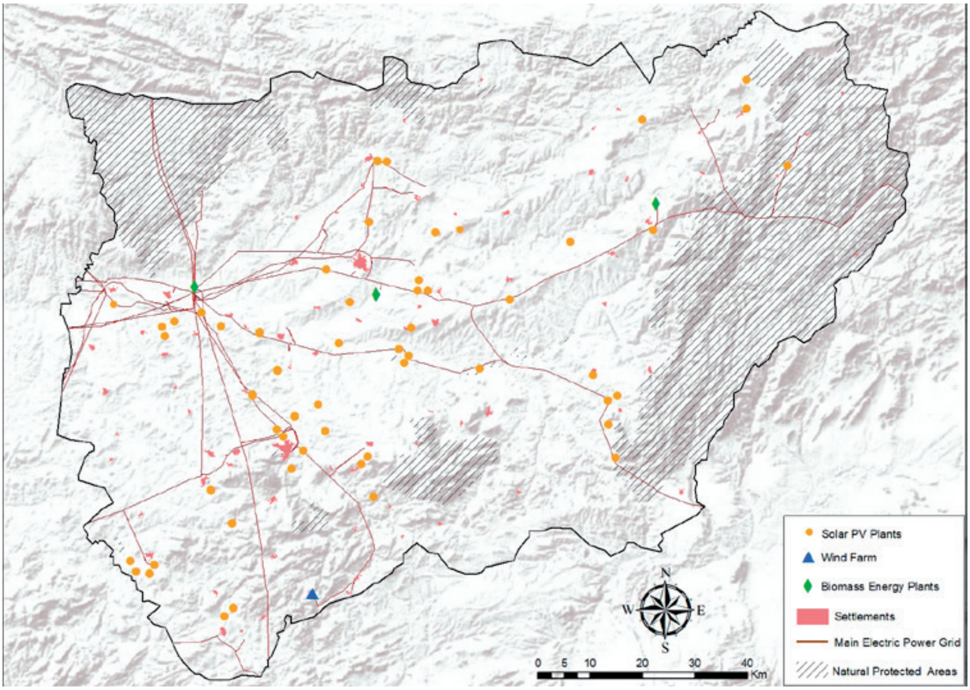
The province of Jaen, located in the northeast of the autonomous community of Andalusia, Spain, consists of 97 municipalities, which are administratively grouped into ten subregions. It has an area of 13,484 km2 (15.5% of the total area of Andalusia) and a population of 620,242 inhabitants (National Institute of Statistics 2023). The province has 304,175 hectares of protected natural spaces and 550,000 hectares of olive groves, which form the basis of the local economy (Herrador Lindes & Martín Mesa 2020). In fact, the province produces 50% of Spanish olive oil and 20% of all the oil produced in the world (Esencia de Olivo 2021).

4.1. Current context of electricity generation in the province of Jaen

In 2023, the province of Jaen had an installed capacity of 564.7 MW of renewable energy technology, accounting for 4.8% of the total for Andalusia as a whole, with a gross electricity production of 607 GWh (Andalusian Energy Agency 2023). Its renewable electricity generation park consists of a single wind farm with an installed capacity of 15.2 MW, 3 biomass-powered plants (16 MW, 15 MW, and 6 MW), and more than 50 photovoltaic plants with a total of 299.2 MW installed (Figure 1). Most of them have an installed capacity ranging from 2 to 10 MW, with the largest solar PV plant recently installed with a capacity of 200 MW. Renewable electricity produced in the province of Jaen barely covers 30% of all electricity consumed in the province (Andalusian Energy Agency 2023). The province lacks electricity generation plants based on fossil fuels or hydroelectric power (Andalusian Energy Agency

2023). This implies a situation of external energy dependence (importation of resources and electricity) to meet its energy needs. Consequently, the great potential of renewable energies in this region could provide a perfect solution for the province to self-supply electricity within the framework of the energy transition (Osorio-Aravena et al. 2022).

Figure 1. Spatial location of existing renewable energy plants in the province of Jaen



Source: Datos Espaciales de Referencia de Andalucía (DERA). Source: own elaboration.

5. Results

In this section, we present the results extracted from the surveys carried out with technicians from the Provincial Council of Jaen, showcasing those examples identified as smart practices by the technicians based on the questions posed in the interview model (for the case of wind energy, the work is done on the only existing wind farm in the province). For each of the three studied technologies, a technical data sheet on the installations to be analyzed is shown first. Next, a transcription of the most relevant information extracted during the entire interview process for each selected case study is provided, and finally, the completed data sheet with those criteria for identifying smart practices that the technicians consider these projects meet is presented.

5.1. Wind Energy: Sierra del Trigo Wind Farm

Table 2. Technical data sheet of Sierra del Trigo Wind Farm.

Location: Noalejo (37º30'55.08"N 3º44'18.856"W),
Property: Olivento SL
Project cost (estimated amount): 10 mill
Technology and size: Gamesa Eólica G47/660 (47 m diameter; 660 kW power each turbine). 23 turbines.
Total installed power: 15 MW
Installation year: 2002

Source: own Source: own elaboration

Experimental project that represented a technological improvement in the province as it was the first wind farm installed. Its location spans part of the municipal terms of Noalejo, Campillo de Arenas, and Valdepeñas de Jaen. Although bordering, its location did not pose a problem in its planning or subsequent construction due to the economic benefit associated with the wind turbines, as for 20 years, the owners of the land encompassed by the park benefit from economic compensation. This economic incentive, along with the temporary employment generated during construction, mostly from neighboring towns, distorts the technical location and favors public acceptance even though all electricity generated by the park is fed into the grid. Although the project was not located in areas already designated for energy production, it led to improvements in nearby road and electrical infrastructures, benefiting the wind farm and serving as a social co-benefit of the project.

Built in the heart of the mountain range, it became a new visual landmark in the landscape and caused an impact considered negative by environmental groups due to its verticality, size, and bird mortality associated with such installations. In response, technicians and engineers suggested the possibility of painting the wind turbines and towers in blue and earth tones to make them visually less conspicuous, but this camouflage measure posed a risk to birds, so if painted, it should be done in bright colors that would be noticeable to wildlife, but that would increase the visual impact of the installation. Its construction was not planned from a perspective of spatial impact de-concentration, as the wind turbines are concentrated in a nearby space (while safeguarding safety distances), in addition to being a large-scale project due to the size of the installation. However, all renewable energy projects are subject to environmental impact assessment (EIA), making them compatible with the environment. Furthermore, the direct land occupation in these types of installations is relatively small, allowing for shared land use, such as grazing, hunting, and farming, avoiding conflicts of land use, while this characteristic allows for easy reversibility, being able to restore the area to its previous state. Alongside the EIA, the project includes archaeological studies to ensure compatibility with any existing cultural heritage sites.

Table 3. Criteria for identifying smart practices applied to the Sierra del Trigo Wind Farm.

Smart practices criteria (Frantál et al., 2018)	Sierra del Trigo Wind Farm
Located in a rural area	x
Visual impact	x
Provides local economic benefit	
Border or peripheral location	x
Location in an area of low population density	x
Represents pilot or experimental project	x
Meets local energy demand	
Spatial deconcentration of impacts	
Allows co-use of land	x
Environmentally compatible	x
Generates land use conflict	
It represents a technological improvement or innovation	x
Small scale installation	
It represents a new visual milestone in the landscape	x
Provides by-products or co-benefit	x
Easy reversibility, restoring the previous area	x
It has an educational function	x
Provides some environmental regulation function	
It is compatible with cultural heritage objects	x
Uses environmentally degraded land	
Utilizes existing infrastructure / Located in areas already used for energy production	x
Improves the image of environmentally stigmatized lands	

Source: own elaboration

5.2. Biomass plants

In the province of Jaen, there are currently three operational biomass plants located in the municipalities of Villanueva del Arzobispo, Linares, and Andújar. These three plants were deemed and chosen by the technician as exemplars of intelligent practices. Given their highly similar characteristics, a joint analysis of these facilities is undertaken.

Table. 4. Technical data sheet of biomass plants in the province of Jaen.

La Loma biomass plant (case study 1)
Location: Villanueva del Arzobispo (38° 12’ 42.591”N, 2° 56’ 51.0756”W)
Property: ENCE
Project cost (estimated amount): 45 million
Technology and size: combustion/rankine cycle
Total installed power: 16MW
Installation year: 2003
Baeza Station – Linares biomass plant (case study 2)
Location: Linares (38° 3’ 8.0568”N, 3° 35’ 40.8516”W)
Ownership: Sacyr Industrial SL
Project cost (estimated amount): 50mill
Technology and size: combustion/rankine cycle
Total installed power: 16MW
Installation year: 2007
Aldebarán Energía biomass plant (case study 3)
Location: Andújar (38° 3’ 12.783”N, 3° 59’ 34.6374”W)
Property: Aldebarán Energía
Project cost (estimated amount): 20 million
Technology and size: combustion/rankine cycle
Total installed power: 7 MW
Installation year: 2009

Source: own elaboration

Located on the outskirts of urban areas, their integration into previously existing industrial zones serves a triple purpose: to reduce transportation costs of raw materials by proximity to rural areas, to benefit from existing road and electrical infrastructures, and to minimize visual impact as much as possible. While these plants do not represent a new landmark in the landscape as they are situated in already industrialized areas, the scale of their boilers, reaching up to 40 meters in height, is not devoid of visual impact, as is the case in Villanueva del Arzobispo, where they are fully visible from the urban core.

Covering an area ranging from 5 to 10 hectares, the plants were built with the purpose of generating large volumes of electricity, which is entirely fed into the grid. Therefore, the facilities, in addition to being large in size, are spatially concentrated, preventing co-land use.

Despite their magnitude, which might suggest environmental incompatibility , these plants establish synergy with the surrounding environment and its resources. The Villanueva del Arzobispo plant helps to eliminate waste produced during oil production, generating clean electricity (for every ton of olive pomace, around 18 tons of CO_2 emissions are avoided). Additionally, the steam generated during combustion is condensed to be used as water, which is reused in the electricity generation process. The plants in Linares and Andújar use olive pruning as their main fuel, preventing it from being burned by landowners and thus reducing CO2 emissions. It is estimated that each plant purchases the pruning from around 23,000 nearby hectares, which amounts to about 35 tons of biomass. They also purchase forest biomass, facilitating the cleaning and maintenance of forests and mountains, thereby contributing to the proper development of hunting and pastoral activities carried out in these areas.

Due to the commercial/industrial nature of the plants, they directly meet the energy demand of the surrounding municipalities. However, as a result of their construction and operation, electrical grids have been reinforced, road infrastructures have been improved, and ashes are obtained and used as fertilizers in agriculture, while farmers receive compensation for the purchase of their prunings.

Ultimately, none of the three plants has stimulated public participation in the planning, construction, and operation processes of the facilities. Only in the Andújar plant did the mayor negotiate with the energy company to hire local labor for the construction of the plant, while the facilities in Linares are used by the University of Jaen as a teaching and learning center for the Master’s program in renewable energies.

Table 5. Criteria for identifying smart practices applied to biomass plants in the province of Jaen.

Smart practices criteria (Frantál et al., 2018)	La Loma biomass plant	Biomass plant Linares Station - Baeza	Aldebarán Biomass Plant
Located in a rural area	X	x	x
Visual impact	X	x	x
Provides local economic benefit		x	x
Border or peripheral location			
Location in an area of low population density			
Represents pilot or experimental project			
Meets local energy demand			
Spatial deconcentration of impacts			
Allows co-use of land			
Environmentally compatible	X	x	x
Generates land use conflict			
It represents a technological improvement or innovation	X	x	x
Small scale installation			
It represents a new visual milestone in the landscape			
Provides by-products or co-benefit	X	x	x
Easy reversibility, restoring the previous area			

It has an educational function		x	
Provides some environmental regulation function			
It is compatible with cultural heritage objects	X	x	x
Uses environmentally degraded land			
Utilizes existing infrastructure / Located in areas already used for energy production	X	x	x
Improves the image of environmentally stigmatized lands			

Source: own elaboration

5.4. Photovoltaic Solar Energy

According to the specialized technician in photovoltaic solar projects in the province of Jaen, a distinction was made between projects located on rooftops and projects on land.

5.4.1. Photovoltaic Solar Energy on Rooftops

Table 6. Technical data sheet of two examples of rooftop solar photovoltaic systems in the province of Jaen.

"IFEJA" Solar PV Installation (case study 1)
Location: Roof of the Activa Jaen building. "IFEJA" Provincial Fairs and Congress Center (37° 46' 36.7212"N, 3° 45' 24.2022"W)
Property: Provincial Council of Jaen
Project cost (estimated amount): 650,000 euros
Technology and size: Small. High efficiency photovoltaic solar technology. Sunpower modules.
Total installed power: 85.14 kW
Installation year: 2007
"Juan Carlos I Public School" Solar PV Installation (case study 2)
Location: Torredelcampo (37° 46' 0.4038"N, 3° 53' 50.8776"W)
Property: Provincial Council of Jaen.
Project cost (estimated amount): 35,000 euros
Technology and size: Small. Photovoltaic solar technology.
Total installed power: 3.3 kW
Installation year: 2007 – 2009

Source: own elaboration

These two photovoltaic solar installations located within the urban area do not entail visual impact as they visually integrate into the urban landscape. By using existing infrastructures, in this case public buildings, as installation supports, they represent an improvement for both these buildings and the electrical grid they feed into. Moreover, their location does not imply land use conflicts and allows for easy reversibility, as the area can be restored quickly, with their small size being a characteristic that also facilitates this.

Both installations represent examples of innovation and technological improvement. While the IFEJA installation served as a pilot project, being the first installation in the province to use high-efficiency modules, the project at the Juan Carlos I public school marked the beginning of an initiative by the Jaen Provincial Council to promote renewable energy usage and awareness. This initiative involves installing solar panels in schools across the province and creating a monitoring classroom in each school for educational purposes.

In common, they are also characterized by not generating local economic benefit or co-benefits beyond the production of clean energy and the educational aspect. They only generate direct economic benefit for the property owner, in this case providing revenue to the municipal coffers as the owner of the buildings, in addition to creating employment opportunities for maintenance, monitoring, and insurance companies. However, the general public does not receive any benefits or experience any direct or indirect impacts; all the energy is fed into the grid, and these projects did not stimulate public participation in their planning and development either.

Table 7. Criteria for identifying smart practices applied to photovoltaic solar energy on rooftops in the province of Jaen.

Smart practice criteria (Frantál et al., 2018)	Solar PV IFEJA	Solar FV Juan Carlos I Public School
Located in a rural area		
Visual impact		
Provides local economic Benefit		
Border or peripheral location		
Location in an area of low population density		
Represents pilot or experimental project	x	x
Meets local energy demand		
Spatial deconcentration of impacts		
Allows co-use of land		
Environmentally compatible	x	x
Generates land use conflict		
It represents a technological improvement or innovation	x	x
Small scale installation	x	x
It represents a new visual milestone in the landscape		
Provides by-products or co-benefit		
Easy reversibility, restoring the previous area	x	x
It has an educational function		x
Provides some environmental regulation function		
It is compatible with cultural heritage objects	x	x

Uses environmentally degraded land		
Utilizes existing infrastructure / Located in areas already used for energy production	x	x
Improves the image of environmentally stigmatized lands		

Source: own elaboration

5.4.2. Ground-Mounted Solar Photovoltaic Energy

Table 8. Technical data sheet of two examples of ground-mounted solar photovoltaic solar plants in the province of Jaen.

Solar PV Installation "Los Villares Soccer Field" (case study 1)
Location: located in the parking lot of the municipal soccer field (37° 41' 2.5872"N, 3° 49' 24.5058"W)
Property: Los Villares City Council.
Project cost (estimated amount): 665,000 euros
Technology and size: Small. Photovoltaic solar technology.
Total installed power: 95 kW
Installation year: 2006
Solar PV Installation ""Los Olivares Solar Farm" (case study 2)
Location: Jaen (37° 47' 51.666"N, 3° 47' 47.3886"W)
Ownership: Solar Jiennense SL and Bergé Generación.
Project cost (estimated amount): 34 million
Technology and size: Large. 72 subgenerators made up of 46 branches in parallel with 12 modules of 220 Wp each in series. 4 subgenerators formed 40 parallel branches of 12 series branches each. 17 hectares occupied (largest in the province).
Total installed power: 7.6 MW
Installation year: 2008

Source: own elaboration

Although ground-mounted, these installations seamleddly integrate into urban and industrial spaces, such as parking lots or areas adjacent to industrial estates. This results in a visual integration of these infrastructures with urbanized landscapes, avoiding or mitigating visual impact and the introduction of a new landmark in the landscape.

Specifically, the Los Olivares Solar Farm is situated on land classified by the General Urban Organization Plan (GUOP/PGOU[1]) as non-buildable, which not only expedited its construction but also did not generate any land use conflicts, while enhancing the value of a space that initially had no established use. On the other hand, the installation in Los Villares was designed on the ground of a parking lot so that its elevated construction could serve as a cover for the parked cars.

1 PGOU: Spanish acronyms for Plan General de Ordenación Urbana, or General Urban Organization Plan.

Both ground-mounted installations coincide with the two previous case studies on rooftop installations in the absence of local benefit and citizen participation in the projects. Similarly, only the municipalities, as owners of the land, and the construction and maintenance companies, which are entirely external, derive benefits. The energy is fed into the grid, with society benefiting to some extent from improved access roads around the installations and reinforcement of the electrical grid.

Table 9. Criteria for identifying smart practices applied to solar photovoltaic energy on rooftops in the province of Jaen.

Smart practice criteria (Frantál et al., 2018)	Solar FV Los Villares soccer field	Los Olivares Solar Garden
Located in a rural area		x
Visual impact		x
Provides local economic benefit		
Border or peripheral location		
Location in an area of low population density		
Represents pilot or experimental project	x	
Meets local energy demand		
Spatial deconcentration of impacts		
Allows co-use of land	x	
Environmentally compatible	x	x
Generates land use conflict		
It represents a technological improvement or innovation	x	x
Small scale installation	x	
It represents a new visual milestone in the landscape		x
Provides by-products or co-benefit		
Easy reversibility, restoring the previous area	x	x
It has an educational function		x
Provides some environmental regulation function		
It is compatible with cultural heritage objects	x	x
Uses environmentally degraded land		
Utilizes existing infrastructure / Located in areas already used for energy production	x	x
Improves the image of environmentally stigmatized lands		

Source: own elaboration

5.5. Considerations of smart practices in the province of Jaen

After characterizing renewable energy projects considered “smart practices” by environmental technicians from the Provincial Council of Jaen, and having conducted an exercise to identify which of these characteristics coincide with the pre-established criteria by Frantál et al. (2018)

for a renewable energy practice to be considered “smart,” the following considerations can be drawn.

Firstly, regardless of the type of technology, the peculiarities of the installations, or their location, renewable energy practices in Jaen are considered “smart” by the technicians due to the innovation and novelty that their construction represented in the province. In other words, the interviewed experts understand these projects as the ultimate exponent of energy development and progress, being pioneers and sometimes experimental in renewable energy development, both locally and regionally. Therefore, the label “smart” from their perspective, is linked to criteria of innovation and progress, with little consideration for socio-environmental factors beyond those established by law.

This idea is reaffirmed by the fact that none of these projects have taken into account the citizen perspective or environmental values beyond the mandatory Environmental Impact Assessment for their construction. Additionally, at the social level, none of the projects have involved citizens in the planning and development processes, and although some of these projects have an educational connection, their outreach to the population is limited to the university/educational sphere. Consequently, technicians point out that this lack of connection between the installations and the local population may negatively affect the society’s perception of these technologies, located in their territory and landscapes, and mostly characterized by their large size, occupying extensive land, and altering the landscape.

Environmentally, although all projects comply with regulations and parameters set by the Environmental Impact Assessment (EIA) and the Guadalquivir River Basin Authority, applying the criteria of Frantál et al. (2018) reveals that these projects do not consider other environmental parameters that could enhance their value and acceptance. For example, their installation on environmentally degraded or stigmatized land. In the province of Jaen, it is observed that project locations prioritize industrial areas or areas near other installations due to the problem of limited electrical grid capacity, which complicates the evacuation of generated electricity. These aspects are positively emphasized by the interviewees, as they prevent widespread spatial dispersion of installations, thereby mitigating impacts on natural landscapes. Furthermore, this approach helps to avoid land use conflicts and to reuse existing infrastructures, which are often improved and reinforced.

However, for the peculiar case of biomass plants in the province of Jaen, this aspect does not always have a positive connotation. These plants seek proximity to the resource, so their integration into olive oil mills or factories, from which they obtain raw materials, sometimes results in proximity to population centers, generating tensions and citizen rejection due to noise, odor, or health concerns, as currently experienced in the municipality of Villanueva del Arzobispo.

In the various cases analyzed, it is observed, and technicians point out, that location is a key factor and a challenge in the province. Key, because location is essential to minimize the impact on potential land use and to avoid, to the extent possible, social opposition movements, as was the case in the municipality of Torredonjimeno, where over 600 signatures were collected locally and over 300 signatures were collected via the Change.org platform against the construction of a biomass plant planned 150 meters from the urban center. And a challenge, because the main problem in the province is the absence of unused land or land with suitable conditions for the construction of such projects without interfering with other potential land uses. Referring to the land use map (CORINE Land Use), the first thing that stands out is that out of the province's 1,349,600 hectares of land, 304,175 hectares are protected natural areas and 550,000 hectares are olive groves, meaning that 22.64% of the territory would be exempt from consideration for the construction of large energy projects. Consequently, only about 33% of the province's land would not be dominated by these two major land uses, a figure that is reduced when considering other uses such as urban, already built-up areas, rivers, or bodies of water. Additionally, the province of Jaen faces the handicap of having a quite rugged terrain. The slope of the land is a significant factor as it affects the profitability and productive capacity of any economic activity carried out on these lands. From a slope of 20% upwards, the territory does not allow for any other form of exploitation other than grazing or natural protection, as human accessibility and transportation are reduced, and technical investment would need to be increased to avoid erosion and soil movements, which would reduce the economic profitability of a project (Jaen Provincial Council 2001). Approximately 35% of the province's land has a slope greater than 20%. However, according to the interviewed experts, the province of Jaen faces two major challenges regarding the development of future renewable energy projects: i) the limitations of connection to a scarce grid unable to support the electrical discharge of large installations; ii) citizen awareness, but above all, their involvement in the different phases of the projects.

Regarding the second point, the technicians indicate that the Provincial Council has been conducting informative talks in those municipalities that have requested them in recent years. They have also organized training courses to help the population understand the proper functioning and socio-economic implications of self-consumption systems (biomass and photovoltaic), conducted educational workshops in schools, and encouraged local administrations to require the hiring of local labor for the construction of projects in their municipalities. In this way, they believe that stigmas associated with a lack of transparency and understanding by the local population and interest groups, who often perceive renewable energies as a business from which only companies and the administration profit, can be avoided.

Finally, regarding the utilization of biomass and biomass plants, the technician considers that society, and more specifically citizen collaboration, represents an additional challenge to the aforementioned points. In this regard, the Provincial Council has conducted several studies throughout the province to propose biomass plants that use olive pruning as the main bioenergy resource. In this process, communication with farmers was essential, as they and their work in the fields would provide the primary feedstock for the energy plant.

However, this is where the provincial administration has encountered a challenge that has not yet been overcome: the lack of involvement of farmers. The collaboration proposed with this social sector is voluntary, as they would not be paid for the residues, but in return, these residues would be treated and managed on the farm by the biomass plant for their use, which would save the farmer work and money compared to other methods of disposing of this organic matter. This free collaboration is not understood or accepted by farmers, who see it as opportunism by the administration and demand economic compensation in return. Accepting this condition would actually make the project economically unviable for investors, while if collaboration from the majority of farmers in the project area is not achieved, the project cannot be executed because large volumes of waste are needed to ensure economic profitability.

6. Discussion and Conclusions

Taking Frantál et al.'s work (2018) as a starting point, which suggests advancing the conceptual framework through the analysis of "smart practices" in new case studies, this research aimed to investigate the characteristics by which a renewable energy project could be considered "smart" in the province of Jaen through a series of semi-structured interviews conducted by three environmental technicians from the Provincial Council.

The results of the previous analyses are intended to be useful in the development of plans and policies that promote an intelligent implementation of renewable energy technologies in the territory and, thus, accelerate the necessary energy transition to meet climate goals.

During the interviews with technicians, experts, and connoisseurs of the main energy projects in the province of Jaen, it stands out how from their perspective, any renewable energy project that is finally executed and put into operation should be considered at least an example of "good practice". This idea is based on the fact that for a project to be executed, it must go through a lengthy process of studies and administrative approvals that ultimately validate its construction. Therefore, they do not conceive that bad practices are carried out when projects have undergone environmental impact assessments, heritage conservation, and potential studies, as well as approval from the various competent authorities.

When the exercise of identifying the criteria of "smart practices" established by Frantál et al. (2018) was carried out with them in the selected projects, it was shown that very few parameters met these projects. However, for the technicians, these projects should be considered "smart" because they meet a requirement they deem fundamental: representing a technological improvement and an step forward fot the province in achieving the energy transition. In this sense, studies like Mathiesen et al. (2015) highlight the need for technical improvements and advances to build intelligent energy systems that provide coherent solutions to potential energy problems. However, proposing smart projects only from a technical perspective can lead to an imbalance between the multiple dimensions that give solidity to current energy systems (policies, economy, society, environment...) (Miller 2013).

This paradigm is reflected in recent studies such as Liñán and Frolova (2024), where the perception of biogas plants in Andalusia differs between technicians, who consider the analyzed cases as examples of smart practices of the circular economy by reusing waste as fuel for energy production, compared to certain social groups that showed a position of rejection or reluctance to these energy plants.

Along these lines, in this research, we observed as “smart practices” the case of the biomass plant in Villanueva del Arzobispo, which represented a technical innovation and an advancement for the province in electricity generation from biomass, but is currently the subject of controversy and citizen rejection by a local population alleging poor air quality and atmospheric pollution problems due to the combustion of the plant, which is located very close to the municipality (López 2019). This type of protest follows the pattern of the controversial effects of other plants considered technically as “smart practices” (Liñán and Frolova 2024). Therefore, the outcomes of innovation could be threatened by the distrust and lack of social acceptance among local communities toward renewable energy plants, with citizens acting as a significant barrier to the success of energy transition policies (Bragolusi and Righettini 2022). Thus, studies like Segreto et al. (2020) conclude that trust in key actors remains an important factor in local acceptance, demonstrating that, to promote acceptance of renewable energy projects, the public must trust local authorities and developers. This trust must be built through a transparent process from planning to development and operation of the plant. Furthermore, the provision of quality information and allowing the public to participate and express their concerns in the planning process is an institutional factor in the local acceptance of renewable energy projects. In the analysis of the case studies presented in this work, it is reflected how the search for criteria that allow practices to be classified as good development examples will depend to some extent on the particular context in which a project is located (Bardach 2004). Therefore, for controversial cases such as the one mentioned above in the province of Jaen, it is essential to consider as a criterion the distance of the facilities from urban centers and citizen opinion. This citizen opinion, also consulted in the study by Rodríguez-Segura et al. (2023), depends a lot on the degree of proximity of the facilities to the population center, the visibility of the infrastructure/emissions, or the location of the project in cultivated land. However, these concerns decrease when the project generates a benefit for them, either economically or by meeting energy demand.

In conclusion, the concept of “smart practices” is neither static nor universal. While a general framework can be established, its interpretation depends on the specific conditions of the practice and the perspective from which it is evaluated. Thus, while for the agents responsible for projecting, planning, and executing a renewable energy project, the focus of success is on progress, technological innovation, modernization, and progress towards decarbonization of the economy, for the population, projects must meet two fundamental requirements: positively impacting the municipality and its residents and maintaining a certain distance from urban centers. These contrasting perspectives illustrate two approaches to energy transition in the province of Jaen, underscoring the importance of fostering dialogue between technicians and citizens to develop more integrated energy policy instruments. Energy projects, in addition to meeting the most technical objectives (production, environmental protection, socioeconomic restructuring, spatial development), should have as a principle to positively impact other sectors, such as the economic, landscape, or social. To achieve this, projects must be designed in a way that minimizes possible negative consequences for the local landscape or society, and their design must consider the context on which they are projected, as "copying" a smart practice from a particular place in a new context does not necessarily lead to success, as it will depend on how it is perceived by different actor groups.

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