Renewable Energy 216 (2023) 119030

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

Energy communities in rural areas: The participatory case study of Vega de Valcarce, Spain

Maria Luisa Lode [a,b,**], Alex Felice [b], Ander Martinez Alonso [b], Jayesh De Silva [c], Maria E. Angulo [c], Jens Lowitzsch [d,e], Thierry Coosemans [b], Luis Ramirez Camargo [b,f,*]

[a] *Mobilise Research Group, Department of Business Technology and Operations (BUTO), Vrije Universiteit Brussel, Pleinlaan 2, Brussels, 1050, Belgium*
[b] *Electric Vehicle and Energy Research Group (EVERGI), Department of Electrical Engineering and Energy Technology (ETEC), Vrije Universiteit Brussel, Brussels, Pleinlaan 2, Brussels, 1050, Belgium*
[c] *ReViEVAL (NGO), Castilla y Léon, Spain*
[d] *Kelso Institute Europe, Kreuzbergstraße 76, 10965, Berlin, Germany*
[e] *Faculty of Business Administration and Economics, European University Viadrina, Große Scharrnstrasse 59, 15230, Frankfurt (Oder), Germany*
[f] *Copernicus Institute of Sustainable Development - Utrecht University, Princetonlaan 8a, 3584 CB, Utrecht, the Netherlands*

ARTICLE INFO

Keywords:
Renewable energy communities
Energy transition
Rural development
Participatory multi-criteria analysis
Energy system optimisation
Governance models

ABSTRACT

This study follows a multi-disciplinary approach to implementing an Energy Community (ECs) in Vega de Valcarce, a rural community in Spain. ECs are entities that encompass collective actions of citizens and other actors towards the open, democratic governance of renewable energy sources; ECs can take various technical and organisational forms. This study developed and evaluated socially accepted, technically optimal and feasible options for the implementation of the EC at Vega de Valcarce. We conducted a participatory multi-criteria analysis incorporating the results of mixed-integer linear programming for energy system optimisation and regulatory analysis of ECs under Spanish law. Our study showed that the main objectives of local stakeholders are the reduction of the energy bill and emissions. The limited liability company fulfilled legal and regulatory restrictions the best by implementing a bigger-sized EC. We summarise the key challenges of implementing an EC in a rural context, mainly legal and financial, and conclude with recommendations on how to overcome these. While contributing to understanding the roll-out of ECs in Spain and Europe, our research aims to provide a structured approach for the uptake of renewable energy in rural areas.

1. Introduction

Spain's solar power capacity continues to increase, but only a fraction of this installed capacity was subject to self-consumption and net metering [1]. With the recently passed Royal decree (RD) 244/2019 [2], this self-consumption and the net-metering rate is increasing due to the end of the restrictive rule on self-consumption and prosumerism in Spain before 2019 [3]. Therefore, it is a step towards the implementation of the European Clean Energy Package (CEP) for all Europeans [4], in particular of the recast of the Renewable Energy Directive (REDII) and the Internal Electricity Market Directive (IEMD) [4,5]. The CEP aims to place a stronger focus on energy end-consumers, energy efficiency and self-consumption, building the ground for the new legal entity of Energy Communities (ECs) in the European Union (EU). ECs are based on the open and voluntary participation of natural persons, small-medium enterprises and local authorities in the generation, supply or provision of energy services aiming at social and environmental rather than economic benefits [5]. Therefore, ECs increase local consumption and production of renewable energy and engage energy end-consumers to become an active part of the energy market. ECs may also be an instrument to strengthen and revitalize local and rural economies, which is specifically needed in the context of rural Spain [6].

Despite the existing political will to foster the energy transition and ECs, there have been challenges to connect rural development with the energy transition [7] and the roll-out ECs across the EU [8]. While ECs present a valuable option to strengthen the local economy through the attraction of both financial as well as human capital, rural areas struggle

* Corresponding author. Copernicus Institute of Sustainable Development - Utrecht University, Princetonlaan 8a, 3584 CB, Utrecht, the Netherlands.
** Corresponding author. Mobilise research group, Department of Business Technology and Operations (BUTO), Vrije Universiteit Brussel, Pleinlaan 2, Brussels, 1050, Belgium.
E-mail addresses: maria.luisa.lode@vub.be (M.L. Lode), l.e.ramirezcamargo@uu.nl (L. Ramirez Camargo).

https://doi.org/10.1016/j.renene.2023.119030
Received 14 October 2022; Received in revised form 9 July 2023; Accepted 11 July 2023
Available online 14 July 2023
0960-1481/

Abbreviations

AHP	Analytic Hierarchy Process
BES	Battery energy storage
CEC	Citizen Energy Community
CEP	Clean Energy Package
CSOP	Consumer Stock Ownership Plan
DSO	Distribution system operator
ECs	Energy Communities
EU	European Union
LP	Limited Partners
LLC	Limited liability company
IEMD	Internal Electricity Market Directive
MAMCA	Multi-Actor Multi-Criteria Analysis
MCA	Multi-Criteria Analyses
MILP	Mixed integer linear program
PV	Photovoltaic
REC	Renewable Energy Community
RES	Renewable Energy Sources
RD	Royal decree
SCR	Self-consumption ratio
SME	Small Medium Enterprises
SMART	Simple Multi-attribute Rating Technique
SSR	Self-sufficiency ratio

with localizing the proclaimed benefits of the energy transitions leading to the fact that mainly external players benefit from the rural energy transition [9]. Focusing on the rural context and giving practical insights into how such benefits could be localized remains understudied [10].

Generally, it was shown that the diffusion of ECs is affected by various factors, such as the history of energy cooperatives in the region and the availability of practical and financial support for local authorities and communities [11]. Heras-Saizarbitoria et al. [12] have also stressed that Spain has no strong history of cooperative models and that contextual and managerial insight into the practical implementation of ECs are missing, this also affects currently low numbers for ECs in Spain, despite its high renewable energy sources (RES) potential [1]. Sorman et al. [13] stressed that progressing towards a fairer rural energy transition, stakeholders need to be included in the transition processes and decision-making. However, participation and decision-making power are less common for rural energy decisions.

Furthermore, Blasch et al. [8] highlight four understudied areas of ECs as leading challenges for the implementation of ECs, namely what an enabling institutional background for ECs, mechanisms of learning, new (community) business models and their viability can look like, and how the claimed benefits can be verified. To build on these gaps, we research which EC schemes are technically and legally feasible, as well as socially accepted in the rural Spanish context and how the development of ECs could be fostered in a participatory way.

2. Research approach

2.1. Multi-Actor Multi-Criteria Analysis

Multi-Criteria Analyses (MCA) are increasingly applied for the evaluation of renewable energy projects and mostly consist of similar steps, namely, problem definition, definition of alternative solutions to the problem, evaluation criteria, and an evaluation analysis [14–16]. Therefore, they are considered a suitable methodology to complex sustainability problems [17]. One advantage of MCAs, in contrast to traditional cost-benefit analyses, is that they allow to include quantitative as well as qualitative criteria in evaluation processes including non-monetary benefits of alternative solutions to a specified problem [18]. However, MCAs often lack of an open and transparent evaluation process making it difficult to be understood and followed by the public [19]. Participatory MCAs aim to address this by involving and engaging affected and affecting stakeholders in the evaluation process. The involvement of stakeholders at an early stage of the project development phase is considered to affect the acceptance and the distribution of shared benefits of the solution [20,21].

For this reason, participatory MCAs were also applied in the context of renewable energy, as well as for ECs [22–24]. It was shown that applying participatory MCAs allow to systematically engage stakeholders in the design and evaluation of different types of ECs. ECs can take up different legal forms, can be implemented by different types of stakeholder groups and that they are highly dependent from the context they are employed in Lode et al. [23].

Since ECs are socio-technical configurations, apart from a technical analysis, also social aspects should be considered in their design and implementation. However, a structured approach of involving stakeholder input from the initiation phase of a project until the implementation is still lacking and there is no standardization of participation for the set-up of ECs [25].

To build on this, we apply an integrated participatory MCA called Multi-Actor Multi-Criteria Analysis (MAMCA) [26] supported by a mixed integer linear program (MILP) for the evaluation of EC schemes. MAMCA allows the integration of different sets of both quantitative and qualitative criteria for affected and affecting stakeholder groups in the decision-making and engagement processes surrounding complex sustainability problems [26]. MAMCA was proposed as a tool for Transition Management and applied for the development of ECs in Belgium, the Netherlands, Spain, and Greece [23]. In this research, we included inputs from social (stakeholder objectives), techno-economic (energy system optimisation), and regulatory (governance models) spheres, making this study highly interdisciplinary. Therefore, we chose to apply MAMCA as the guiding framework for the transition process towards an EC at Vega.

We conduct MAMCA incorporating both qualitative and quantitative methods in a participatory way and followed the steps as shown in Fig. 1.

First, the regulatory and technical options for ECs in Vega were screened, resulting in the definition of four feasible EC options, in addition to the current situation. This screening was based on a regulatory, organisational, and technical pre-analysis to define four options that are legally, organisationally, and technically feasible at Vega. Second, a survey was developed to assess which stakeholders are considered to be affected or are affecting the implementation of an EC, and which are the objectives of the responding stakeholders.

The survey was sent out and opened to the public in September 2021 (building on the version available in Lode et al. [23]; see Appendix A1). In the survey, the respondents were asked to select the most important criteria for their energy supply from a compiled list of criteria resulting from a literature review and adaptation to the local context in collaboration. Since the citizens were not yet introduced to the concept of ECs, a brief explanation of ECs was given at the beginning of the survey. Additionally, the respondents were asked about perceived challenges towards the energy transition, and, following the snowball method [28], about stakeholders and how they perceive to be affected by the transition. A list of the selected criteria was compiled per identified stakeholder group (consumer, prosumer, commercial consumers, and the municipality). Each stakeholder group could therefore have a unique set of criteria reflecting their priorities. The criteria are the basis for the evaluation of the technical scenarios.

To communicate the findings on the technical and governance options for an EC, four stakeholder groups (the total number of participants

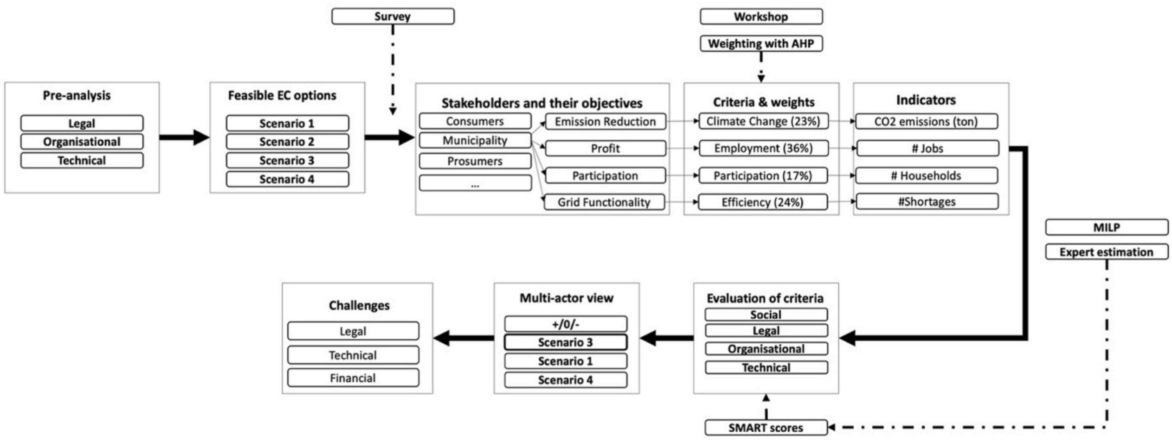

Fig. 1. Input and output of the MAMCA methodology adapted from [27].

was 30, the consumer group was divided into two groups due to their higher number) and the non-profit and research institutions were invited to a two-day community event. The identified stakeholders were invited and the pre-liminary list of objectives were confirmed and weighted. To start the participatory exercise (weighting and evaluation), the results of the survey (the set of criteria per stakeholder group) were presented and discussed. Before the stakeholders were asked to evaluate the impact of the technical scenarios on their selected criteria, the stakeholders were introduced to the optimisation results of the technical scenarios and the governance options.

The weighting is based on the importance the stakeholders attribute to the respective objectives using the Analytic Hierarchy Process (AHP). During this pairwise comparison, each selected criterion is compared to the other selected criteria resulting in a weighted list [29]. The evaluation of the EC options was conducted using the objectives of the stakeholders as criteria. The energy system modelling tool and regulatory analysis were used to estimate the performance of the indicators within the different EC options. With this input, the stakeholders evaluated the shown technical scenarios based on how they see the scenarios impacting their criteria, for which the Simple Multi-attribute Rating Technique (SMART) was used [30]. Using SMART, stakeholders were asked to attribute a score between 0 and 10 for the estimated impact on their criteria in the different scenarios. A score equal to 5 means no impact on their stated criteria in a selected scenario, a score higher than 5 is a positive impact, and lower than 5 is a negative one. Using the MAMCA software on provided laptops and tablets allowed the direct input and visualisation of the results [31]. This resulted in a multi-actor view with the performance evaluation results for each stakeholder group. Based on this overview, the different technical scenarios and governance options were discussed. Lastly, the technical, organisational, regulatory, and financial challenges for the implementation of the EC options were summarised.

Since we incorporate different scientific as well as participatory inputs, Table 1 shows a differentiation of the participatory and scientific activities within each step of MAMCA.

2.2. Energy system optimisation

For the different EC configurations, a MILP that minimizes energy provision costs [32] was used to determine the optimal system configuration and techno-economic indicators for each scenario.

In the proposed MILP the energy provision costs are defined as the sum of all investments, which are affected by the lifetime of the system and a capital discount rate, and operational costs incurred to supply a particular demand. The energy provision cost is also the objective function to be minimised in the optimisation model, defined by:

Table 1
Overall research approach.

Stakeholder process	Scientific activities	MAMCA step
Discussion with local partners	Technical, regulatory, and organisational screening of feasible EC options	Feasible EC options
Distribution with the support of the municipality	Survey, analysis of stakeholders and their objectives	Identification of stakeholders and their objectives
Communal workshop and discussion of objectives	Weighting of objectives according to their importance (AHP)	Weighting of objectives
Discussion with energy community experts on performance of qualitative objectives	MILP and expert evaluation of the objectives within each EC option	Scientific evaluation
Stakeholders share their perception on the evaluation	Evaluation scores by participants (SMART)	Participatory evaluation
Discussion of overall results, challenges, general attitudes	Bridging scientific results and the opinions of the participants	Multi-actor-view

$$\frac{EAC + C_{op}}{D}$$

Where EAC is the equivalent annual cost of investment, defined as:

$$EAC = \sum_a \frac{Cap_a \cdot C_a \cdot d}{1 - (1 + d)^{-L_a}}$$

With Cap_a being the installed capacity, C_a the installation cost and L_a is the lifetime of the asset a. d representing the discount rate. The operational costs C_{op} is defined as the sum of the $OPEX$ of all the assets and the cost of the electricity imported from the grid P_t^{imp}:

$$C_{op} = OPEX + \sum_t \left(P_t^{imp} \cdot C_t^{grid}\right) \cdot \Delta t$$

Where C_t^{grid} is the price of electricity per kWh at every hour t. The technologies that were considered as options to meet the demand of the proposed scenarios are PV systems, batteries for electricity storage and the distribution grid. Hence the power balance of the system is given by:

$$d_t + P_t^{ch} - P_t^{PV} - P_t^{disch} - P_t^{imp} + P_t^{ex} = 0$$

With d_t being the electricity demand, P_t^{ch} and P_t^{disch} the charging and discharging power of the battery energy storage (BES), P_t^{PV} is the power production of a photovoltaic (PV) system and P_t^{ex} is the exported power to the grid. The optimisation problem is solved for an entire year of operation in hourly temporal resolution assuming a perfect forecast of supply from variable RES and electricity demand. Other outputs of the model include the optimal sizes and generation profiles of each considered technology as well as total investment costs of the entire system, self-sufficiency ratio (SSR), and self-consumption ratio (SCR) indicators which are defined by the following equations:

$$SSR = 100 \cdot \frac{\sum_t \left(P_t^{PV} - P_t^{ex}\right)}{\sum_t P_t^{PV}}$$

$$SCR = 100 \cdot \frac{\sum_t \left(P_t^{PV} - P_t^{ex}\right)}{\sum_t d_t}$$

The hourly generation profile of the PV installations considered in the case study was estimated using PVLIB for Python [27] and ERA5-land temperature, wind speed and solar radiation data as proposed by Ramirez Camargo and Schmidt [33] and assuming a configuration (inclination and orientation) that would maximize the yearly output of the installation.

The electricity demand data, input for the assessment, was reconstructed from monthly metering values and local profiles provided by the municipality of Vega in accordance with the procedure conceived by the Spanish Government [2]. Additional information from average monthly and annual consumption data, as well as demand and reference values provided by the Spanish distribution system operator (DSO) [34], were used to recreate realistic profiles (Appendix A2).

The used profiles include the town hall building, lighting infrastructure, the school, and Vega's commercial and residential buildings. The community is introduced as a single consumer. Hence exchange of surplus energy inside the community boundaries is free of charge. Moreover, the capital expenditures used in the optimisation for the PV plant and the battery storage system are 1,015 €/kWp and 700 €/kWh, respectively. These values are based on quotes from local providers. Additionally, local electricity tariffs and taxes on energy are implemented in the model based on real electricity bills from 2020. Any remuneration for injecting surplus electricity is ignored, which makes this analysis conservative. Based on the results of the MILP we also calculate savings per unit of energy and payback time and assessed economic viability while assuming the members of the community would receive a return on investment of 10%.

3. Rural energy transition at Vega de Valcarce: A case study

We conduct the participatory case study in Vega de Valcarce, Spain because of our focus on the rural context. By choosing this case study, we provide further insights into how the benefits of the energy transition (e.g. supply chain benefits, shared ownership, communal benefits) can be practically localised and distributed in a participatory manner [7].

Vega de Valcarce (from here on Vega to differentiate from the municipality with the same name) is a rural town located in the autonomous region of Castilla y León in the Northwest of Spain. The municipality of Vega de Valcarce consists of 23 villages, the largest being Vega with around 200 residents [35]. Like many rural villages in Spain, Vega is faced with an ageing and declining population as younger inhabitants are leaving for cities for better job opportunities [36], and its geographic location is distant from urban centres and services [37]. As a result, the accessibility to educational, public health, and social engagement services in rural communities is becoming increasingly challenging. While faced with a multiplicity of demographic and economic challenges, Vega has, in contrast, a high potential for RES deployment. Since the case of most rural areas in Spain is like the one in Vega, finding approaches to foster the deployment of renewable energies there in a replicable way can have a large impact on achieving an energy transition to renewables for the country.

As seen in the barriers for energy cooperatives, as a primary example for ECs, local stakeholders such as citizens, municipalities, and small-medium enterprises are interested in rural energy transitions, however, they struggle with their implementation [12]. Aligning with this trend, a local non-profit association at Vega considered ECs as an opportunity for the revitalisation of rural communities and collaborated with the municipality of Vega to jointly develop and implement a local EC.

Due to the need for external support on socio-economic, technical, legislative, and regulatory aspects, the collaboration was then joined by two H2020 projects, namely RENAISSANCE and SCORE. RENAISSANCE aimed to test participatory and energy system modelling tools, MAMCA and Renergise, at Vega [38]. SCORE aimed to support the development and diffusion of (co-)ownership models for RES [39]. The present study resulted from this collaboration with the goal of facilitating the development of a local EC at Vega by connecting different tools and expertise with local practitioners and knowledge.

3.1. Possible EC options for Vega

3.1.1. Governance options

Vega is subject to the European legislation on ECs and has, therefore, limited governance options to implement a local ECs. The CEP acknowledges two forms of ECs, namely "Renewable Energy Communities" (RECs) and "Citizen Energy Communities" (CECs) [4,5]. In this regard, the differences between the REDII and IEMD pertain mainly to the governance model. While CECs are open to all types of entities, members or shareholders of RECs are limited to physical persons and local authorities, including municipalities and small medium enterprises (SMEs). Despite a similar definition (see Article 2 pt. 11 IEMD and Article 2 pt. 16 REDII) there are three key differences for CECs: (i) no requirement of geographic proximity for controlling shareholders, (ii) the absence of the requisite to be autonomous, i.e., independent of single members or shareholders and (iii) a restriction for enterprises among the controlling shareholders or members to small and micro size firms. Both types of ECs enjoy the right to share energy/electricity produced by the production units of the energy community within that community, including over the public grid if it owns two metering points, anchored, and defined in the IEMD. See the comparison of CEC and REC in Table 2 building on Frieden et al. [40].

Within the Spanish context, we have identified five organisational models that, in principle, could fulfil the purpose of CECs and/or RECs: a partnership, a limited partnership, a limited liability company (LLC), a cooperative, and a Consumer Stock Ownership Plan (CSOP) as a trustee scheme [41].

This legislative framework is the basis for analysing the different EC options for Vega.

3.1.2. Considered technical scenarios

The municipality, the local non-profit organisation, the research institutions, and local RES project developers assessed jointly possible technical options. A total of five different scenarios of ECs were considered, they are shown in Table 3. These range from the case where the municipality decides to act on its own and invests in a system that is optimal for its own demand, which includes the town hall and the lighting infrastructure of Vega, to a large energy community that includes the municipality, the local school building, 100 residential consumers and five commercial consumers.

4. Results

4.1. Governance options

A comparison of the five models emphasizing their main characteristics is provided in building on [42]; see Table 4. The first two

Table 2
Comparison of CEC and REC.

Criteria	Renewable Energy Communities (RECs) Arts. 2 (16), 22 REDII	Citizen Energy Communities (CECs) Arts. 2 (11), 16 IEMD
Primary Purpose	*"Environmental, economic or social community benefits for its shareholders/members or for local areas where it operates, rather than financial profits";*	
Energy Eligibility	**Renewable Energy** Natural persons; SMEs; local authorities incl. municipalities;	Electricity Any entity;
Membership	*"open and voluntary participation of the members based on principles of non-discrimination"*	
Ownership and Control	● Effectively controlled by shareholders or members that are in the proximity of the renewable energy project; ● **Is autonomous** (no individual shareholder may own more than 33% of the stock).	● Effectively controlled by shareholders or members; ● Limitation for firms included in shareholders controlling entity to those of small/micro size (not medium); ● Shareholders engaged in large-scale commercial activity for which energy constitutes the primary area of activity excluded from control.
Advantages to qualify as REC or CEC	● "Enabling framework" to promote and facilitate the development of RECs; ● "Equal footing" principle considers size and ownership structure of RECs vis-à-vis commercial projects;	● Level playing field; ● Although elements of support to integrate RES are present no specific advantages to increase CECs competitiveness vis-a-vis commercial projects foreseen;
Energy Sharing	Right to share energy/electricity produced by the production units owned by an energy community within that community including over the public grid if it owns two metering points.	

Table 3
Overview of technical scenarios of Vega.

Scenario	Number	Involved consumers	Total consumption
Reference	0	Municipality (townhall and street lighting)	61,541 kWh/year
Public buildings	1	Municipality and school (townhall and school building)	107,646 kWh/year
Small community	2	Municipality and school (townhall and school building), residential (10) and commercial (5) consumers	249,886 kWh/year
Medium-sized community	3	Municipality and school (townhall and school building), residential (50) and commercial (2) consumers	303,933 kWh/year
Large Community	4	Municipality and school (townhall and school building), residential (100) and commercial (2) consumers	443,034 kWh/year

partnerships raise the issue of whether they qualify under the Spanish legal framework as ECs since European law requires a separate and distinct legal personality. Furthermore, the former would imply the personal unlimited liability of individuals for the overall project. In the latter, citizens becoming limited partners would have no influence on decision-making and imply limited control rights conflicting with the desire to actively involve the local population. Therefore, independently of the question of the missing legal personality, we regard both as not suitable and will not include them in further analysis. Under the remaining three incorporated options, the limited liability company and the cooperative are conventionally known while trustee schemes like the CSOP are less common [41].

The cooperative model is defined by the cooperative principle of "one member, one vote" regardless of the number of shares held [43]. They usually follow economic or social community benefits for their members contributing and have more leeway in defining operational priorities. Compensation for cooperative managers, which as a rule, also need to be members of the cooperative, is usually capped, and profits from operations are allocated under agreed-upon terms. However, with respect to the heterogeneity of co-investors in ECs, when partnering with municipalities, the necessity of representation of their officials on management and supervisory bodies has been reported as an obstacle [42] as all members of cooperatives are elected by and from the members' general assembly. Furthermore, partnering with businesses or other more commercially oriented entities is difficult because these partners usually expect voting rights to be allocated proportionally to shareholding. As the local project in Vega involves both the municipality and several local small enterprises, the cooperative approach was not found to be optimal for the reasons mentioned.

To mitigate the problems of cooperatives concerning a heterogeneous constituency, trustee schemes like CSOPs can be employed. Unlike in cooperatives, voting rights are proportional to shareholding rendering such models also attractive for (local) commercial investors while at the same time compensating possible imbalances between the members by ensuring that consumer shareholdings are consolidated through the trusteeship. In CSOPs, the shareholding of individual participants in the operating company is indirect and mediated via a trusteeship (physical person or an entity). Apart from making consumers' voting behaviour predictable, the representation by a trustee still ensures meaningful participation in decision-making. Which decisions are retained by the consumer shareholders and which once are delegated to the trustee is stipulated in the fiduciary agreement drafted and agreed on during the inception phase. Normally, day-to-day decision-making is left to the trustee (jointly with the other shareholders) while strategic decisions like a capital increase or a change in the objective of operations would be subject to a consumer vote which then is represented accordingly on the board of the operating company. However, a downside of trustee models is the extra costs associated with the trusteeship. While these additional costs in medium or large projects can be offset by reduced transaction costs, CSOPs are not suited for small or micro projects unless the costs of the trusteeship can be backed by several independent small projects.

Consequently, the option left for Vega for implementing an EC is setting up a closely held LLC, which under Spanish law can be set up under the rules for *"Sociedad de responsabilidad limitada en régimen de formación sucesiva"* (SLFS = limited liability company under successive formation), a qualification of the conventional *"Sociedad de responsabilidad limitada"* (SRL = limited liability company). The legal basis for this concept is the revised text of the Law on capital companies amended by the Law on support for entrepreneurs and their internationalisation of 14/2013 [44]. This concept foresees the possibility of derogative incorporation without a minimum social capital conditional on: (a) the transfer of 20% of yearly profits to a legal reserve; (b) no distribution of dividends if net assets remain below 60% of the required minimum capital of a conventional LLC (i.e., 60% below EUR 3,000); and (c) that the yearly remuneration of partners and administrators cannot be more than 20% of yearly net assets.

Under this concept, the REC governance model required by the REDII must be enshrined in the statutes from the outset with provisions that it cannot be altered without a ¾ majority of the votes to ensure compliance over time. Combined with restricted rules for sale between shareholders or to outsiders, the 33% and 51% shareholding limits for RECs, ensuring that no one member of the REC controls a disproportionate amount of decision-making power, can be guaranteed. The results of the regulatory analysis were explained during the MAMCA workshop, the LLC was shown as the most suitable governance option to implement a REC at Vega.

Table 4
Comparison of the five governance options.

	Partnerships	Limited partnership	LLC	Cooperatives	CSOPs
Voting rights	Direct, often proportional to shares	Only for general partners (GPs), direct, proportional to shares)/not for limited partners (LPs)	Direct, proportional to shares	Direct, one member, one vote	Conveyed through trustee/representative
Rights of information	Given	Limited for LPs	Given	Given	Given/but may be delegated
Compatibility with strategic commercial investors	Not practised	Given	Less common	Unusual	Given
Compatibility with municipal investments	Not possible	Possible, but not common	Given	Limited	Given
Personal liability	Unlimited	For LPs limited to investment/for GPs personal, unlimited	Limited to investment	Usually limited to investment	Limited to investment
Changes in participants	Possible, no registration	Limited/costly unless trustee relationship	Limited/conditional on agreement of shareholders	Possible, easy/according to statutes	Possible, easy/according to statutes
Start-up costs	Low	Medium	Low	Low	Medium

4.2. Technical scenarios

Table 5 summarises the key economic analysis for the different community scenarios. These indicate that increasing self-consumption within the community is the best solution for an electricity bill reduction, which is between 30 and 40% for all the scenarios except reference one (scenario 0). The more heterogeneous the members of the EC, the higher the increased community self-consumption resulting in higher energy bill savings. The payback period for the initial investment was between 9 and 10 years for all the community scenarios except reference one (scenario 0). Increasing the number of members that have different consumption patterns during the day improves the business case because the generation from solar PV cannot be controlled without BES. Due to BES' very high capital cost, storage was not financially viable in any of the scenarios. Note that the assumptions were based on the retail tariffs of 2020, which are significantly lower than current Spanish tariffs that are expected to continue to rise. This means the potential energy bill savings could now be significantly higher and the payback time considerably shorter than what is listed below for all scenarios. Further, the electricity injected into the grid is assumed to have an economic value of zero.

4.3. Stakeholder preferences

The survey received 52 complete responses, of which 38 agreed to provide socio-demographic information, see a summary on the demographics in Fig. 2.

The respondents stressed the problem of depopulation in rural Spain and lack of knowledge as barriers to the energy transition. During the workshop, the selected objectives were first confirmed among the participants because not all survey respondents were also participating in the workshop, and then they were weighted. The selection and weights showed that reduction of the energy bill and reduction of emissions are the most important for most of the stakeholder groups. But also, social inclusion, local job creation, and the replicability of the EC were selected to be important. See Fig. 3 for the summary of selected objectives and respective weights for each stakeholder group.

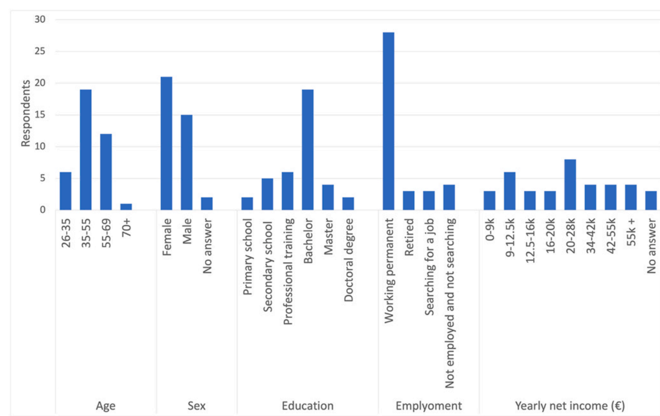

Fig. 2. Demographics of survey respondents.

Fig. 4 shows the evaluation results from the MAMCA analysis resulting from the objectives' weighting exercise and the techno-economic models' results. It shows that the big community performs best on the mentioned objectives of all stakeholders. As the techno-economic performance improves with an increasing number of EC members, and the workshop participants were mainly driven by economic and environmental motives, the more heterogeneous and more significant the EC, the better the performance.

Building on the technical and regulatory analysis findings, opting for a community with as many members and as heterogeneous as possible under an LLC scheme. As the community members fulfil the proximity criteria (500m of geographic radius between the generation and consumption of energy), the community also fulfils the REC requirements if no member owns more than 33% of the shares of the EC.

While the results are a clear indication of the profitability of a REC,

Table 5
Economic results for the energy community scenarios for Vega.
The average electricity cost with REC includes 10% rate of return for the REC members.

Scenario	Average electricity cost without REC	PV production	PV system capacity	Cost of the PV plant	Self-consumption ratio	Self-sufficiency ratio	Average electricity cost with REC	Saving per unit of electricity
	€/MWh	kWh/a	(kWp)	€	(%)	(%)	(€/MWh)	(€/MWh)
0	133	9,828	7.3	7,399	56	9	154	−21
1	140	27,627	20.5	20,799	78	20	110	30
2	141	82,139	60.9	61,839	83	27	103	38
3	142	102,891	76.3	77,462	84	28	103	39
4	144	134,820	100.0	101,500	91	28	95	49

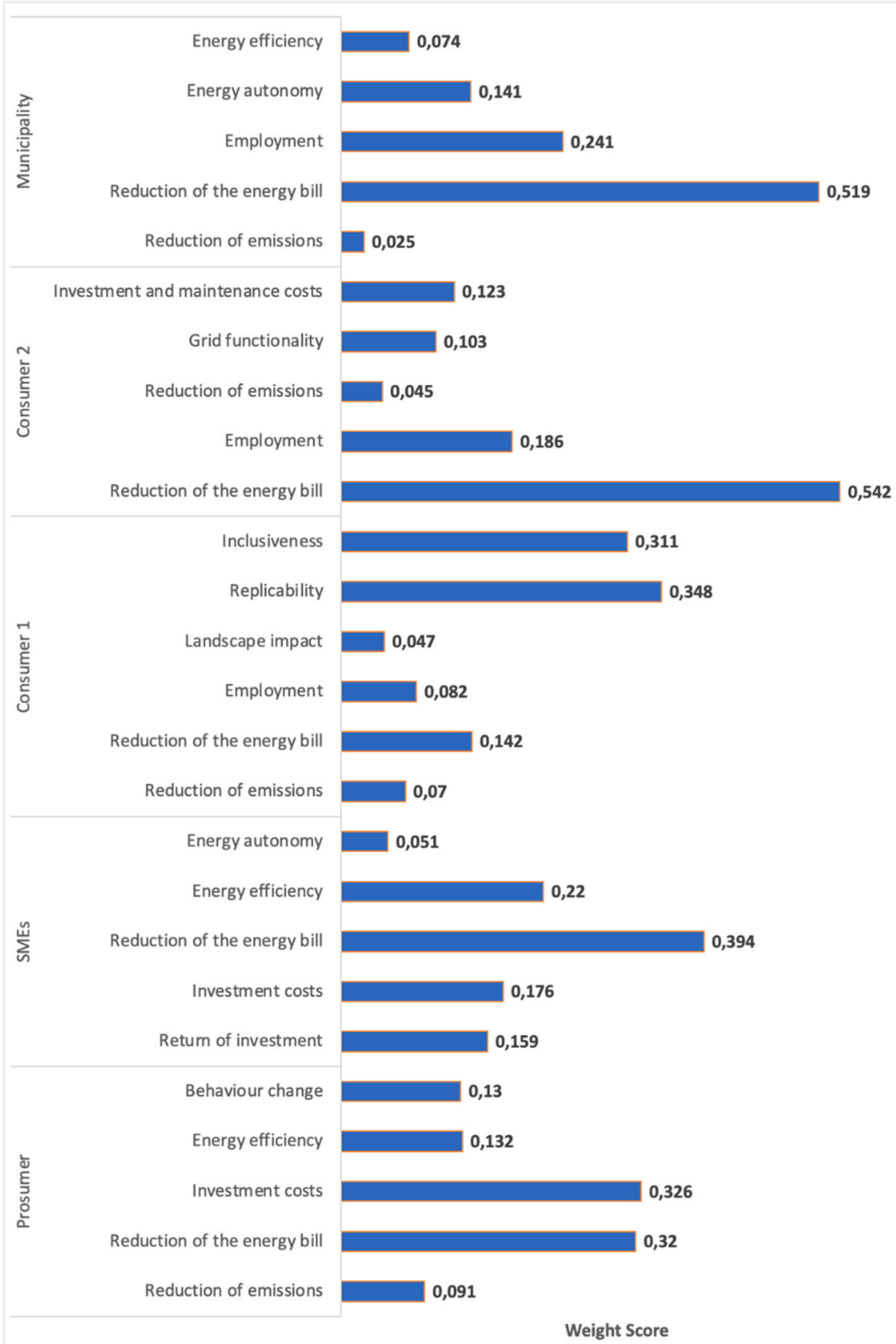

Fig. 3. Criteria selection and weights for all stakeholder groups.

and a means to make citizens part of the rural energy transition, the practical implementation of the envisioned REC is accompanied by regulatory and practical challenges.

5. Challenges and recommendations

There is potential for replication of ECs, as proposed for Vega, in rural areas in Spain and other European countries. Still, the process must be simplified, and the identified challenges for implementation must be addressed. Although there has been progress on the transposition of the REDII, the transposition to Spanish national law has included further restrictions that are not included in REDII. In the case study, this has led to significant challenges during the implementation phase. The following sections explain the key challenges encountered and provide recommendations to overcome them (see summary in Table 6).

5.1. Challenges for rural areas

In the context of rural development through the energy transition, three main benefits for rural areas were studied in the literature, namely, the supply chain benefits (e.g., local employment and labour), shared ownership and investment in RES assets, and community benefits (local capacity, community building, empowerment) [7]. However, [7] also highlight that empirical evidence for these benefits is understudied, and [9] stressed that rural communities struggle with the internalisation and localisation of such benefits.

Our research showed that the implementation and maintenance of an EC at Vega would require labour and create employment for the

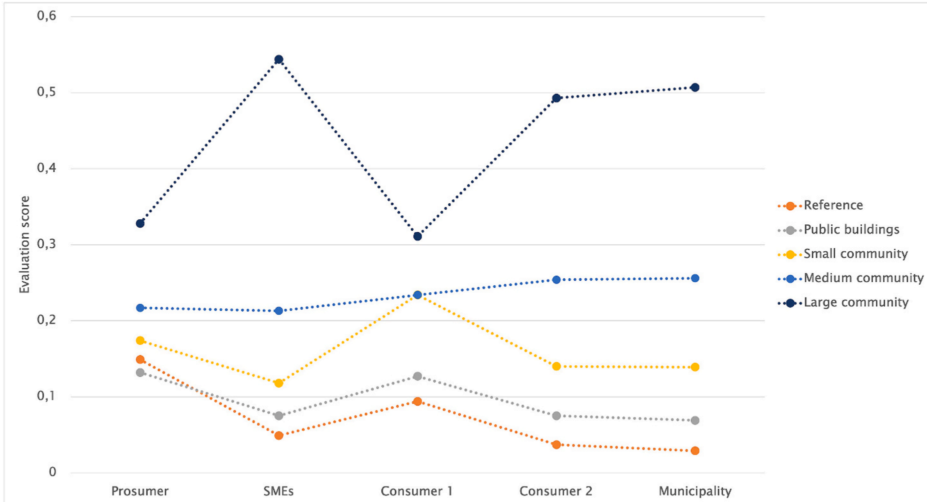

Fig. 4. Multi-actor view on scenarios for Vega.

Table 6
Challenges and recommendations for EC implementation in Vega.

Section	Challenge	Recommendations
Rural	Third-party support and financing needed	Implementing local governance and re-investment schemes, more importance should lie on the initiation phase and supporting local actors and collaborations
Technical	Lack of granular consumption and generation data, restrictive net billing concept limits EC seize	Point of contact to make smart meter data accessible
Regulatory	Complexity of governance and business models, lack of specified support and governance models	Provision of regulatory and legal support, facilitation of sandboxing agreements, provision of specified funding at each project step
Financial	Restrictive measures for ECs (500m geographic limit and 100 kW-capacity limit) and ECs are forced to comply with same rules as large scale energy providers	Easing of geographic and capacity limit

installation of the energy supply system and the setting up of the community (short term), as well as for maintenance and administration (long term). Yet, already at the project's initiation phase, the community communicated a lack of support for and capacity to assess and overcome legal, financial, and administrative challenges. This exemplifies rural communities' realities, making them more likely to rely on expertise and investment from external third-party and commercial entities [7,9].

Therefore, mechanisms that allow capturing and direct benefits to local communities are specifically needed in the rural context [10].

In line with the findings of Phimister and Roberts [45] who showed that local governance and re-investment plans of revenues have a great positive impact on local (income) benefits, the trustee scheme of CSOPs was found most suitable for Vega. Moreover, in contrast to more conventional investment plans, the CSOP scheme also allows lower-income households to buy into community RE assets.

The community engagement and decision-making processes, which were supported by the structured approach of MAMCA showed that community benefits such as community building, education, behaviour change, and inclusion do play a role in community engagement in ECs. Usually, such benefits are not included in the evaluation of renewable energy projects, especially if commercial, large-scale entities are initiating and implementing them [9]. Structured engagement approaches, which make community benefits explicit, as well as allow for direct decision-making and participation, can positively influence procedural considerations of EC implementations which is a key aspect for localising benefits to the rural community [46].

5.2. Technical challenges

Accurate quarter-hourly energy consumption data is necessary to ensure the commercial viability of EC projects in Spain, as the energy that is not consumed by the EC members receives limited economic value under Spanish legislation. Article 14 of RD244/2019 [2] specifies a net billing concept whereby the economic value of the excess hourly energy may never exceed the economic value of the hourly energy consumed from the grid in the billing period. Therefore, to maximize community self-consumption it is paramount that the generation system is sized, and the generation profile is matched to the consumption profile of the members within the REC to minimize electricity injected to the grid.

Despite the comprehensive rollout of smart meters within the community of Vega, it was not easy to access accurate energy consumption data for the municipality buildings. The utilities with access to the data have little incentive to respond to the consumer. The DSO who collects this data was not reachable to the consumer, and for the researchers, the acquisition of individual data of potential EC members would have required individual data-sharing agreements with every single one of them.

It would be helpful to have a point of contact making available smart meter data accessible to consumers so that historical consumption data is readily available at a granular level. This would guarantee transparency of their consumption, and the EC can build generation systems optimized to generate and match their member's consumption profile avoiding excess generation.

5.3. Regulatory challenges

Under the current legislation [2], ECs can only share the energy they generate within their community for free. They cannot receive any financial compensation for that electricity by selling it to its members. As a result, energy bill savings enjoyed by the members of the EC cannot be distributed fairly across the different members. Given that current legislation requires members to be able to join and leave the EC at will, this creates a risk to the long-term success of ECs. If enough members leave an EC, its energy-generating assets could become stranded assets leaving members' investments in ECs at risk. Findings from the MAMCA analysis showed that reducing energy bills was the most important objective for the potential community members in Vega.

Under RD23/2020 [47], regulatory sandboxing is allowed under certain conditions for small research and development projects. This sandboxing could be used to relax restrictions and allow the selling of electricity, enabling equitable value sharing, an essential part of developing successful and energy-just business models.

Another challenge is the missing legal frameworks and pathways to set up viable ECs in Spain. The complexity of business and governance models that could fulfil the purpose of ECs in Spain requires energy and legal professionals to navigate through regulatory and legislative barriers found in the RDs 244/2019, 23/2020 and 960/2020 [2,47,48]. The current grants made available under RD 477/2021 [49] are only subsidising the hardware for REC projects and do not provide funding for advice on legislative and regulatory challenges or how to set up the legal entities required for RECs. To qualify for the funding, the REC must be successfully founded, and therefore, initiatives that aim to implement a REC are not eligible for any funding.

This further increases regulatory burdens on citizens, municipalities, and small enterprises to set up RECs, although ECs are aimed at lowering the market entry for these actors. Spanish funding and support need to be more targeted to setting up business models for RECs and advising on the legal complexity surrounding REC legislation.

5.4. Financial challenges

Under the European Directive REDII, members of an EC are treated as final consumers who can leave an EC at a moment's notice to switch to another energy supplier.

While this might be fair and appropriate for commercial ventures, the REDII places many restrictions on a REC to which their commercial counterparts do not need to adhere. For example, RECs can only have local consumers and investors, they cannot be large investors, and the systems must be renewable. In addition, under the Spanish transposition, the legislation places further restrictions such as a 500m geographic limit for consumers consuming from individual systems and an individual system not being able to exceed a maximum capacity of 100 kW. Essentially, the legislation is proposing that a REC must compete with the commercial sector but provides no levelled playing field.

This places an unfair risk on the RECs' local investors and consumers. If a significant number of consumers leave the REC, then the investors may be left with a stranded asset. Effectively small and local REC investors are being asked to finance long-term investments with no guaranteed revenue streams.

To create an equal playing field, it may be advisable that the Spanish legislation relaxes the 500m diameter geographic rule for selecting potential consumers to an individual system owned by the REC and the 100-kW capacity limit. This will help a REC to compete with commercial competitors more fairly and could contribute to making feasible the deployment of complementary RES, such as wind and PV systems, that might not be installed under these restrictions [50]. In addition, it could help to provide RECs with further financial, technical, and legal support to minimize or hedge the risk to the remaining members investing in a REC so that these legal entities are better protected from short-term fluctuations in the energy markets.

6. Conclusion

The present study has combined a participatory multi-criteria analysis with energy system modelling to design and develop a socially accepted renewable energy community in Vega de Valcarce, Spain. Following the technical, regulatory, and participatory results, the renewable energy community option with the most and more heterogeneous participants and generation assets performs best on the main objectives of the participating stakeholders. The weighted objectives of the stakeholders show that cost-related objectives (e.g., investment costs and reduction of the energy bill (operating costs)) are considered as most important among the participating stakeholders. Despite that, objectives differ across the different participants, but the qualitative benefits of the larger EC schemes (education, employment) also improve with the size of the EC and the involved members. The relating results from the MILP show that except for the reference scenario, the creation of any community brings economic benefits. These benefits increase with the size of the community because the inclusion of more consumer with heterogenous consumption profiles increase self-consumption of the PV system, which means that larger capacities become more beneficial. High self-consumption values would be possible with the introduction of BES, but due to its high upfront investment costs the gains are not sufficient to justify the investment. Considering the current legal framework, the limited liability company is the most suitable organisational form for a renewable energy community at Vega because of the low start-up costs and considering the limited number of members. Despite the successful community event and participatory workshop on renewable energy communities, Vega is faced with legal, technical, and financial obstacles towards the practical implementation of the renewable energy community under possibly fast-changing legislative conditions. We suggest organising more educational and engaging community events to engage and inform more participants. Concerning the legal framework, we recommend easing some restrictions for energy communities, such as the geographic limitation of 500m of self-consumption. Further, investment uncertainties, especially in municipalities, should be reduced to ensure that citizens and small-medium enterprises are really at the core of the rural energy transition.

This work provides a participatory methodology to evaluate different energy community options considering local conditions and objectives. Due to the large potential for replication in the context of rural Spain, this may be of special interest to communities that want to transition to a low-carbon energy system and re-attract local capital and population. The proposed approach exemplifies how rural communities can internalise benefits related to the energy transitions, such as the creation of local, qualified jobs, shared ownership and re-investment in local infrastructure, as well as another community benefit such as energy education, community building and social inclusion. However, a large diffusion of ECs would require a considerable simplification of the process of setting up energy communities. This study has highlighted regulatory considerations, community learning mechanisms, and possible viable technical scenarios for setting up and simplifying energy community implementation.

Source of support

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreements No. 824342 (RENAISSANCE) and 784960 (SCORE).

CRediT authorship contribution statement

Maria Luisa Lode: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Visualization, Writing – original draft, Writing – review & editing. **Alex Felice:** Methodology, Validation, Formal analysis, Investigation, Data curation, Software, Writing – original draft, Writing – review & editing. **Ander Martinez Alonso:** Formal analysis, Investigation, Data curation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. **Jayesh De Silva:** Formal analysis, Data curation, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing. **Maria E. Angulo:** Conceptualization, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Jens Lowitzsch:** Formal analysis, Resources, Project administration, Funding acquisition, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Thierry Coosemans:** Resources, Project administration, Funding acquisition. **Luis Ramirez**

Camargo: Conceptualization, Methodology, Validation, Formal analysis, Data curation, Investigation, Supervision, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreements No. 824342 (RENAISSANCE) and 784960 (SCORE). Moreover, we would like to thank all respondents and participants of this research as well as the Municipality of Vega de Valcarce for the support with the organization of the event and the continuous support to the project.

Appendix A. Survey (A1) and electricity demand data (A2)

Supplementary data related to this article can be found at https://doi.org/10.1016/j.renene.2023.119030.

References

[1] M. Schmela, EU Market Outlook for Solar Power (No. 2022–2026), SolarPower Europe, Brussels, 2022.
[2] Ministerio para la Transición Ecológica, Real Decreto 244/2019, de 5 de abril, por el que se regulan las condiciones administrativas, técnicas y económicas del autoconsumo de energía eléctrica, 2019.
[3] C. Gallego-Castillo, M. Heleno, M. Victoria, Self-consumption for energy communities in Spain: a regional analysis under the new legal framework, Energy Pol. 150 (2021), 112144, https://doi.org/10.1016/j.enpol.2021.112144.
[4] European Commission, Communication from the commission to the European parliament, in: The European Economic and Social Committee of the Regions and the European Bank: A Clean Planet for All A European Strategic Long-Term Vision for a Prosperous, Modern, Competitive and Climate Neutral Economy, the European Council, the Council, 2019.
[5] European Commission, Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the Promotion of the Use of Energy from Renewable Sources, vol. 61, Off. J. Eur. Union, 2018.
[6] V. Pinilla, L.A. Sáez, Rural depopulation in Spain: genesis of a problem and innovative policies, Proc. Áreas Escasamente Pobladas Sur Eur. 23 (2016).
[7] L.T. Clausen, D. Rudolph, Renewable energy for sustainable rural development: synergies and mismatches, Energy Pol. 138 (2020), 111289, https://doi.org/10.1016/j.enpol.2020.111289.
[8] J. Blasch, N.M. van der Grijp, D. Petrovics, J. Palm, N. Bocken, S.J. Darby, J. Barnes, P. Hansen, T. Kamin, U. Golob, M. Andor, S. Sommer, A. Nicita, M. Musolino, M. Mlinarič, New clean energy communities in polycentric settings: four avenues for future research, Energy Res. Social Sci. 82 (2021), 102276, https://doi.org/10.1016/j.erss.2021.102276.
[9] K. O'Sullivan, O. Golubchikov, A. Mehmood, Uneven energy transitions: understanding continued energy peripheralization in rural communities, Energy Pol. 138 (2020), 111288, https://doi.org/10.1016/j.enpol.2020.111288.
[10] Naumann, M., Rudolph, D., Conceptualizing rural energy transitions: Energizing rural studies, ruralizing energy research. J. Rural Stud. 73, 97–104. https://doi.org/10.1016/j.jrurstud.2019.12.011.
[11] M.L. Lode, G. te Boveldt, T. Coosemans, L. Ramirez Camargo, A transition perspective on Energy Communities: a systematic literature review and research agenda, Renew. Sustain. Energy Rev. (2022).
[12] I. Heras-Saizarbitoria, L. Sáez, E. Allur, J. Morandeira, The emergence of renewable energy cooperatives in Spain: a review, Renew. Sustain. Energy Rev. 94 (2018) 1036–1043, https://doi.org/10.1016/j.rser.2018.06.049.
[13] A.H. Sorman, X. García-Muros, C. Pizarro-Irizar, M. González-Eguino, Lost (and found) in Transition: Expert stakeholder insights on low-carbon energy transitions in Spain, Energy Res. Social Sci. 64 (2020) 101414, https://doi.org/10.1016/j.erss.2019.101414.
[14] R.A. Estévez, V. Espinoza, R.D. Ponce Oliva, F. Vásquez-Lavín, S. Gelcich, Multi-criteria decision analysis for renewable energies: research trends, gaps and the challenge of improving participation, Sustainability 13 (2021) 3515, https://doi.org/10.3390/su13063515.
[15] R. Kc, J. Föhr, T. Ranta, Public perception on the sustainable energy transition in rural Finland: a multi-criteria approach, Circ. Econ. Sustain. (2022), https://doi.org/10.1007/s43615-022-00206-5.
[16] I. Siksnelyte-Butkiene, D. Streimikiene, T. Balezentis, Addressing sustainability issues in transition to carbon-neutral sustainable society with multi-criteria analysis, Energy 254 (2022), 124218, https://doi.org/10.1016/j.energy.2022.124218.
[17] I.B. Huang, J. Keisler, I. Linkov, Multi-criteria decision analysis in environmental sciences: ten years of applications and trends, Sci. Total Environ. 409 (2011) 3578–3594, https://doi.org/10.1016/j.scitotenv.2011.06.022.
[18] G. te Boveldt, I. Keseru, C. Macharis, When monetarisation and ranking are not appropriate. A novel stakeholder-based appraisal method, Transp. Res. Part Policy Pract. 156 (2022) 192–205, https://doi.org/10.1016/j.tra.2021.12.004.
[19] M. Dean, Chapter six - multi-criteria analysis, in: N. Mouter (Ed.), Advances in Transport Policy and Planning, Standard Transport Appraisal Methods, Academic Press, 2020, pp. 165–224, https://doi.org/10.1016/bs.atpp.2020.07.001.
[20] F. Ribeiro, P. Ferreira, M. Araújo, Evaluating future scenarios for the power generation sector using a Multi-Criteria Decision Analysis (MCDA) tool: the Portuguese case, Energy 52 (2013) 126–136, https://doi.org/10.1016/j.energy.2012.12.036.
[21] R. Wüstenhagen, M. Wolsink, M.J. Bürer, Social acceptance of renewable energy innovation: an introduction to the concept, Energy Pol. 35 (2007) 2683–2691, https://doi.org/10.1016/j.enpol.2006.12.001.
[22] E. Dal Cin, G. Carraro, G. Volpato, A. Lazzaretto, P. Danieli, A multi-criteria approach to optimize the design-operation of Energy Communities considering economic-environmental objectives and demand side management, Energy Convers. Manag. 263 (2022), 115677, https://doi.org/10.1016/j.enconman.2022.115677.
[23] M.L. Lode, S. Heuninckx, G. te Boveldt, C. Macharis, T. Coosemans, Successful co-development of energy communities: a comparative study of seven pilots across the European Union, Energy Res. Social Sci. (2022).
[24] M. Schaefer, L. Schmitt Olabisi, K. Arola, C.M. Poitra, E. Matz, M. Seigel, C. Schelly, A. Adesanya, D. Bessette, Understanding socio-technological systems change through an indigenous community-based participatory framework, Sustainability 13 (2021) 2257, https://doi.org/10.3390/su13042257.
[25] V.Z. Gjorgievski, S. Cundeva, G.E. Georghiou, Social arrangements, technical designs and impacts of energy communities: a review, Renew. Energy 169 (2021) 1138–1156, https://doi.org/10.1016/j.renene.2021.01.078.
[26] C. Macharis, L. Turcksin, K. Lebeau, Multi actor multi criteria analysis (MAMCA) as a tool to support sustainable decisions: state of use, Decis. Support Syst. 54 (2012) 610–620, https://doi.org/10.1016/j.dss.2012.08.008.
[27] R.W. Andrews, J.S. Stein, C. Hansen, D. Riley, Introduction to the open source PV LIB for python Photovoltaic system modelling package, in: 2014 IEEE 40th Photovoltaic Specialist Conference (PVSC). Presented at the 2014 IEEE 40th Photovoltaic Specialists Conference (PVSC), IEEE, Denver, CO, USA, 2014, pp. 170–174, https://doi.org/10.1109/PVSC.2014.6925501.
[28] C. Costa, P.R. Cunha, Who are the players? Finding and characterizing stakeholders in social networks, in: Presented at the 43rd Hawaii International Conference on System Sciences, 2010, https://doi.org/10.1109/HICSS.2010.443.
[29] T.L. Saaty, Decision making with the analytic hierarchy process, Int. J. Serv. Sci. 1 (2008) 83, https://doi.org/10.1504/IJSSCI.2008.017590.
[30] D. Von Winterfeldt, W. Edwards, Decision Analysis and Behavioral Research, Cambridge University Press, Cambridge, MA, 1993.
[31] H. Huang, P. Lebeau, C. Macharis, The multi-actor multi-criteria analysis (MAMCA): new software and new visualizations, in: J.M. Moreno-Jiménez, I. Linden, F. Dargam, U. Jayawickrama (Eds.), Decision Support Systems X: Cognitive Decision Support Systems and Technologies, Lecture Notes in Business Information Processing, Springer International Publishing, Cham, 2020, pp. 43–56, https://doi.org/10.1007/978-3-030-46224-6_4.
[32] A. Felice, L. Rakocevic, L. Peeters, M. Messagie, T. Coosemans, L. Ramirez Camargo, Renewable energy communities: do they have a business case in Flanders? Appl. Energy 322 (2022), 119419 https://doi.org/10.1016/j.apenergy.2022.119419.
[33] L. Ramirez Camargo, J. Schmidt, Simulation of multi-annual time series of solar photovoltaic power: Is the ERA5-land reanalysis the next big step? Sustain. Energy Technol. Assess. 42 (2020) 100829, https://doi.org/10.1016/j.seta.2020.100829.
[34] Red Electrica de España, REData - todate | red Eléctrica de España [WWW Document]. https://www.ree.es/en/datos/todate, 2022 accessed 2.January.22.
[35] INEbase, Alteraciones de los municipios, 2022 [WWW Document]. INE, https://www.ine.es/intercensal/intercensal.do?search=1&cmbTipoBusq=0&textoMunicipio=Vega%20de%20Valcarce. accessed 11.January0.21.
[36] A.A.L. Soriano, A.C. Aliaga, M.I. Vidal-Sánchez, Depopulation in Spain and violation of occupational rights, J. Occup. Sci. 28 (2021) 71–80, https://doi.org/10.1080/14427591.2021.1896331.
[37] M. Alloza, V. González-Díez, E. Moral-Benito, P. Tello-Casas, Access to Services in Rural Spain Documentos Ocasionales, vol. 43, 2021.
[38] RENAISSANCE H2020, Renewable integration and sustainability in energy communities [WWW Document], Renaiss. H2020, https://www.renaissance-h2020.eu/, 2019. accessed July.13.20.
[39] SCORE H2020, Supporting consumer ownership in renewable energies [WWW Document], SCORE H2020, https://www.score-h2020.eu/, 2022. accessed 2. January.22.
[40] D. Frieden, A. Tuerk, J. Roberts, S. D'Herbemont, A.F. Gubina, B. Komel, Overview of emerging regulatory frameworks on collective self-consumption and energy communities in Europe, in: 2019 16th International Conference on the European Energy Market (EEM), 2019, pp. 1–6, https://doi.org/10.1109/EEM.2019.8916222. Presented at the 2019 16th International Conference on the European Energy Market (EEM).
[41] J. Lowitzsch, Consumer Stock ownership plans (CSOPs)—the prototype business model for renewable energy communities, Energies 13 (2019) 118, https://doi.org/10.3390/en13010118.

[42] F. Hanke, J. Lowitzsch, Empowering vulnerable consumers to join renewable energy communities—towards an inclusive design of the clean energy package, Energies 13 (2020) 1615, https://doi.org/10.3390/en13071615.
[43] International Labour Office, Promotion of Cooperatives (No. ILC89- Report V (1)), Report (V) 1, International Labour Office, Geneva, 2001.
[44] Jefatura del Estado, Ley 14/2013, de 27 de septiembre, de apoyo a los emprendedores y su internacionalización, 2013.
[45] E. Phimister, D. Roberts, The role of ownership in determining the rural economic benefits of on-shore wind farms, J. Agric. Econ. 63 (2012) 331–360, https://doi.org/10.1111/j.1477-9552.2012.00336.x.
[46] M.L. Lode, G. te Boveldt, L. Ramirez Camargo, T. Coosemans, Energy justice through participatory multi-criteria analysis? Practical insights from three energy communities in south America, SSRN Electron. J. (2022), https://doi.org/10.2139/ssrn.4309405.
[47] Jefatura del Estado, Real Decreto-ley 23/2020, de 23 de junio, por el que se aprueban medidas en materia de energía y en otros ámbitos para la reactivación económica, 2020.
[48] Ministerio para la Transición Ecológica y el Reto Demográfico, Real Decreto 960/2020, de 3 de noviembre, por el que se regula el régimen económico de energías renovables para instalaciones de producción de energía eléctrica, 2020.
[49] Ministerio para la Transición Ecológica y el Reto Demográfico, Real Decreto 477/2021, de 29 de junio, por el que se aprueba la concesión directa a las comunidades autónomas, 2021.
[50] C.E. Hoicka, J. Lowitzsch, M.C. Brisbois, A. Kumar, L. Ramirez Camargo, Implementing a just renewable energy transition: policy advice for transposing the new European rules for renewable energy communities, Energy Pol. 156 (2021), 112435, https://doi.org/10.1016/j.enpol.2021.112435.