Coupling rural development with the development of Energy Communities: A participatory study in Vega de Valcarce, Spain

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Abstract

This study followed an integrated approach to foster the development of a local Energy Community (ECs) in Vega de Valcarce, a rural town 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 organizational and legal forms. To provide socially accepted, technically optimal and feasible options for the implementation of the EC at Vega de Valcarce, we apply a participatory Multi-Criteria Analysis supported by the results of a mixed-integer linear programming for energy system optimization. We provide insights into the objectives of local stakeholders and their preferences, technical scenarios for viable EC options, and feasible governance models for ECs under current Spanish law. We summarize the encountered challenges implementing an EC and conclude with recommendations to overcome these in the Spanish context. While contributing to the understanding of the roll-out of ECs in Spain and Europe, our research also provides an approach to connect rural development with the energy transition.

Keywords: renewable energy communities, energy transition, rural development, participatory Multi-Criteria Analysis, energy system optimization, governance models

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Highlights

- Researches the practical set-up of an Energy Community (EC) in rural Spain
- Applies an integrated approach using participatory and modeling-based methods
- Restrictions on the radius and on peak installations limit the feasibility of ECs
- Legal, advisory, financial support targeted at the local level is needed

1. Introduction

Spain's solar power capacity continues to rise, however, less than 10% of this installed capacity is subject to self-consumption and net-metering [1]. With the recently passed Royal decree (RD) 244/2019 [2], this self-consumption and net-metering rate is likely to increase, easing the very 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 at placing 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 open and voluntary participation of natural persons, small-medium enterprises and local authorities aiming at social and environmental rather than economic benefits through the generation, supply or provision of energy services [5]. Therefore, ECs are a means to 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 local and rural economies and re-attract population to areas suffering from rural depopulation, which particularly applies to the rural Spanish context [6].

Despite the existing political will to foster the energy transition, there have been challenges to connect rural development with the transition to renewable energy [7] and to roll-out ECs across the EU [8]. Lode et al. [9] showed that the number of energy cooperatives, as a prominent form for ECs, are low in most areas of Spain which were related to a lower performance on socio-economic indicators constituting the social progress index in the EU. The emergence of ECs are affected by many factors, such as the history of energy cooperatives of the region, the availability of practical and financial support for local authorities and communities [10]. Heras-Saizarbitoria et al. [11] have also stressed that Spain has no history of ECs and that contextual and managerial insights into the practical implementation of ECs are missing. Blasch et al. [8] summarized four understudied areas of ECs, namely factors composing an enabling institutional background for ECs, processes, and mechanisms of learning, new (community) business models and their viability, and the verification of the claimed benefits. To address the research gap, we conduct a case study on the participatory development of an EC to foster rural development in Vega de Valcarce, Spain. We apply an integrated participatory assessment method called Multi-Actor Multi-Criteria Analysis (MAMCA) [12] coupled with a tool for energy system optimization. We highlight the encountered practical institutional and participatory challenges for ECs and introduce the possible community business models for the Spanish context. Our findings are specifically interesting for policy makers, practitioners in the energy transition, and for (rural) communities in Spain and Europe.

2. Method

2.1. Fostering the energy transition in rural Spain, a case study

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 Castille and León in the Northwest of Spain, close to the Galician border. The municipality of Vega de Valcarce consists of 23 villages, the largest being Vega with around 200 residents [13]. Like many rural villages in Spain, Vega is faced with an aging and declining population as younger inhabitants are leaving to cities for better job opportunities [14] and its geographic location is distant from urban centers and services [15]. As a result, the accessibility to educational, public health, and social engagement services of rural communities is becoming increasingly challenging. Figure 1 shows the declining population of Vega since 2002 [16]. While faced with a multiplicity of demographic and economic challenges, Vega has, in contrast, a high potential for renewable energy sources (RES) deployment. Since the case of most rural areas in Spain is similar to the one in Vega, finding ways 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.

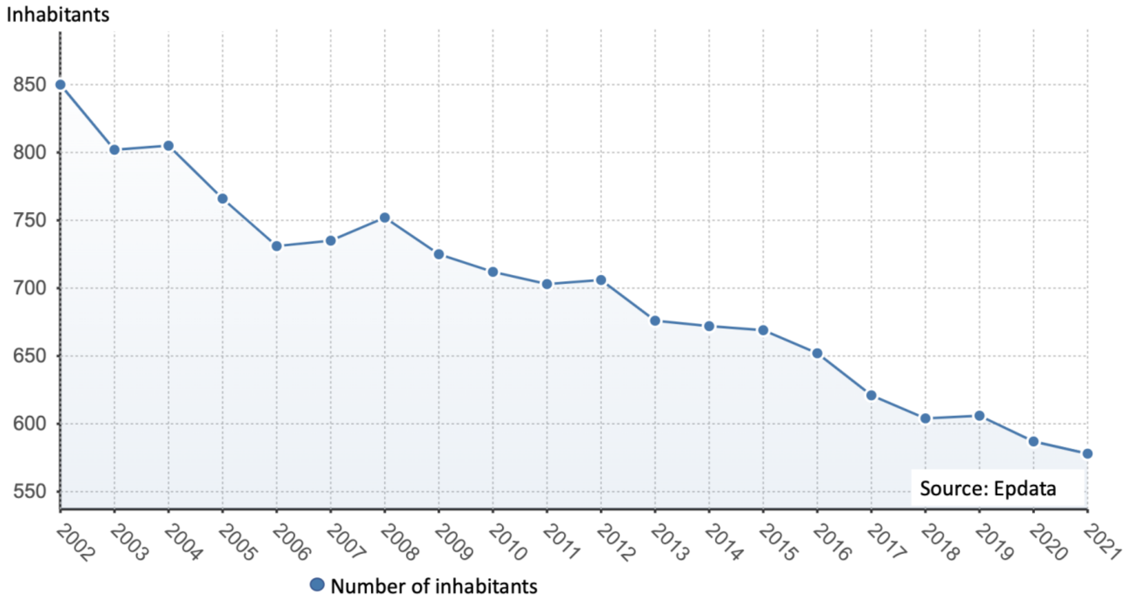

Figure 1: Evolution of population of Vega 2002-2021

ReViEVAL, a non-profit association, with the aim of facilitating the revitalisation of rural communities, collaborates with the municipality of Vega to develop a local EC [17]. 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 modeling tools, MAMCA and Renergise, at Vega [18]. SCORE aimed to support the development and diffusion of (co-)ownership models for RES [19]. The present study resulted from this collaboration with the goal to facilitate the development of a local EC at Vega through connecting different tools, and expertise with local practitioners and knowledge. Through MAMCA, the different tools and inputs were included in a systematic manner.

2.2. Multi-Actor Multi-Criteria Analysis

MAMCA is a participatory method to conduct a participatory Multi-Criteria Analysis which allows to integrate both quantitative and qualitative criteria for decision-making and engagement purposes surrounding complex sustainability problems [12]. MAMCA was proposed as a tool for Transition Management and applied for the development of an EC in Belgium, the Netherlands, Spain, and Greece [20,21]. MAMCA provides the framework for the transition process towards an EC at Vega, it is an example for a methodology applied for action research in which researchers work together with practitioners [22].

The methodology is composed of six main (non-subsequent) steps: 1. Development of potential solutions, 2. Stakeholder identification and engagement, 3. Assessment of the objectives, 4. Evaluation of the solutions, 5. Participatory discussion of the solutions and result of the evaluation, and 6. Monitoring and re-evaluation.

How the steps were implemented, and which tools and data were included in each step are explained in the following. To develop potential solutions for the set-up of an EC at Vega, various aspects were considered. Important considerations included technical scenarios and possible governance models respecting the legislative and regulatory constraints under Spanish law.

2.2.1. Technical scenarios

Multiple scenarios for the constitution of the EC were co-created between the municipality, ReViEVAL, the research institutions and local RES project developers. A total of five different scenarios of REC are considered as shown in Table 1. These were initially assessed using a techno-economic optimization model. The model is a mixed-integer linear program that optimizes the size of the PVs plant and a battery storage system that gives the minimum final cost (investment + operation) for various compositions of users inside the community. A detailed description of the optimization model can be found in [23]. The community is introduced as a single consumer, hence exchange of surplus energy inside the community boundaries is free of charge. The capital expenditures used in the optimization for the PV plant and the battery storage system are 1,015 €/kWp and 700 €/kWh respectively. These values are based on quotes of local providers. Additionally, local electricity tariffs and taxes on energy are implemented in the model based on real electricity bills. Any remuneration for injecting surplus electricity is ignored, which makes this analysis conservative. A maximum size of 100 kWp PV to be installed in the School Building was set to comply with legislation and to follow recommendations of local project developers for the most appropriate site in Vega to develop such a system. Further, current transposition for ECs imposes a 500m geographic radius for consumption from individual generation systems [2].

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) [24], were used in order to recreate realistic profiles (Appendix A for the methodology). The profiles include the town hall building, the school, commercial and residential buildings of Vega.

Table 1: Overview of scenarios of Vega

Scenario	Number	Involved consumers	Total consumption
Reference	0	Municipality (townhall)	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 (5) consumers	303,933 kWh/year
Large Community	4	Municipality and school (townhall and school building), residential (100) and commercial (5) consumers	443,034 kWh/year

2.2.2. Governance models

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, local authorities including municipalities and 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 as long as it owns two metering points, anchored and defined in the IEMD. See the comparison of CEC and REC in Table 2 building on [25].

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	· **<u>Renewable Energy</u>**	· Electricity
Eligibility	· Natural persons, · SMEs, · Local authorities, incl. municipalities;	Any entity;
Member-ship	*„open and voluntary participation of the members based on principles of non-discrimination"*	
Owner-ship and Control	● Effectively controlled by shareholders or members **<u>that are located in the proximity of the RE project</u>**; ● **<u>Is autonomous</u>** (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 and 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 takes into account 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 as long as it owns two metering points.	

The legislative framework is considered our starting point for analyzing which governance models are possible under current Spanish law.

2.2.3. Stakeholder Identification and assessment of their criteria

For the participatory evaluation of the potential EC solutions, a survey prior to a community event was sent out and open to the public during September 2021 (see survey in Appendix B). The distribution of the survey was supported by the municipality of Vega. 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 literature review, and adaptation to the local context in collaboration with ReViEVAL. Further, they were asked about perceived challenges towards the energy transition, and stakeholders they see affected by the transition (for details on the applied snowball method see [26]). A list of the selected criteria was compiled per stakeholder group (consumer, prosumer, commercial consumers, and the municipality). The criteria are the basis for the evaluation of the technical scenarios.

2.2.4. Participatory evaluation and adaptation of the EC options

To communicate the findings on the technical and governance models, the mentioned four stakeholder groups (total number of participants around 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. During this event, RENAISSANCE together with ReViEVAL presented the technical models and conducted the participatory exercises with the participants. SCORE presented the findings on the suitable governance models. To start the participatory exercise, the results of the survey were presented and discussed. Then, using the MAMCA software [27], the stakeholder groups weighted their selected and confirmed criteria according to their importance (application of Analytic Hierarchy Process (AHP)). Before the evaluation exercise, the stakeholders were presented the optimization results, organizational and legal options, and the potential impacts on the weighted criteria. With this input, the stakeholders started the weighting exercise (application of the Simple Multi-attribute Rating Technique (SMART)). This resulted in a multi-actor view on the solutions with the performance evaluation results for each stakeholder group. Based on this overview, the different technical solutions and governance models were discussed.

3. Results

3.1. Technical scenarios

The results of the optimization model indicate that increasing self-consumption within the community is the best solution for an electricity bill reduction, which is between 30 to 40 % for all the scenarios except the 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. In addition to energy bill savings to the consumers, the EC members receive a 10% return of investment. The payback period for the initial investment was between 9 and 10 years for all the community scenarios except the 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 battery energy storage (BES). Due to the very high capital cost of BES, storage was not financially viable in any of the scenarios. Table 3 summarizes the key economic analysis for the different community scenarios. Note that the assumptions were based on retail tariffs of 2020 (including a corporation tax rate of 25%), 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 to the grid is assumed to have an economic value of zero.

Table 3: Economic results for the energy community scenarios for Vega

	Scenario	**Average unit cost without EC**	**PV production**	**PV system capacity**	**Cost of the PV plant**	**Self-consumption ratio**	**PV electricity consumed within the EC**	**Injected to the grid as a % of total energy generated**	**Required tariff by REC to meet 10% economic rate of return**	**Saving per unit of energy**
		€/MWh	kWh/ year	(kWp)	€	(%)	(kWh/ year)	(%)	(€/ MWh)	(€/ MWh)
0	Municipality	33	9,828	7.3	7,399	56	5,460	44%	154	(21)
1	Municipality + School	140	27,627	20.5	20,799	78	21,504	22%	110	30
2	Municipality + School + 10 Residential buildings + 5 Commercial buildings	141	82,139	60.9	61,839	83	68,456	17%	103	38

3	Municipality + School + 50 Residential buildings + 2 Commercial buildings	142	102,891	76.3	77,462	84	86,107	16%	103	39
4	Municipality + School + 100 Residential buildings + 2 Commercial buildings	144	134,820	100.0	101,500	91	122,489	9%	95	49

3.2. Governance Models

Within the Spanish context, we have identified five organizational 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 [28].

The first two 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 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 the further analysis. Under the remaining three incorporated options, the limited liability company and the cooperative are conventionally known while trusteed schemes like the CSOP are less common [28] .

The co-operative model is defined by the co-operative principle of "one member, one vote" regardless of the number of shares held [29]. They usually follow economic or social community benefits for their members contributing and have more leeway in defining operational priorities. Compensation for co-operative 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 [30] 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 is not feasible for the reasons mentioned.

To mitigate the problems of cooperatives concerning a heterogeneous constituency, trusteed 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 trusteed models are 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.

Consequently, we are left with the option of 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 internationalization of 14/2013 [31]. 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 SRL (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 ECs ensuring that no one member of the EC controls a disproportionate amount of decision-making power, can be guaranteed.

A comparison of the five discussed models emphasizing their main characteristics is provided by Table 4 building on [30].

Table 4: Comparison of the five discussed models for the EC at Vega

	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

3.3. Social insights from the survey and MAMCA

The survey received 52 complete responses. Most of the respondents were female between the age of 35-55 and had mainly economic and environmental objectives concerning their energy supply. They also mentioned the problem of depopulation in rural Spain and lack of knowledge as barriers to the energy transition. The main result of the survey was lists of objectives per stakeholder group. During the workshop the selected objectives were first confirmed among the participants because not all survey respondents were also participating in the workshop, 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 Appendix C

1. Criteria selection and weighting per stakeholder group, Figure C 1: Criteria selection and weights for the prosumer groupFigure C 1- C5).

Figure 2 shows the evaluation results from the MAMCA analysis resulting from the weighting exercise of objectives and the results from the techno-economic models. 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 bigger the EC, the better the performance.

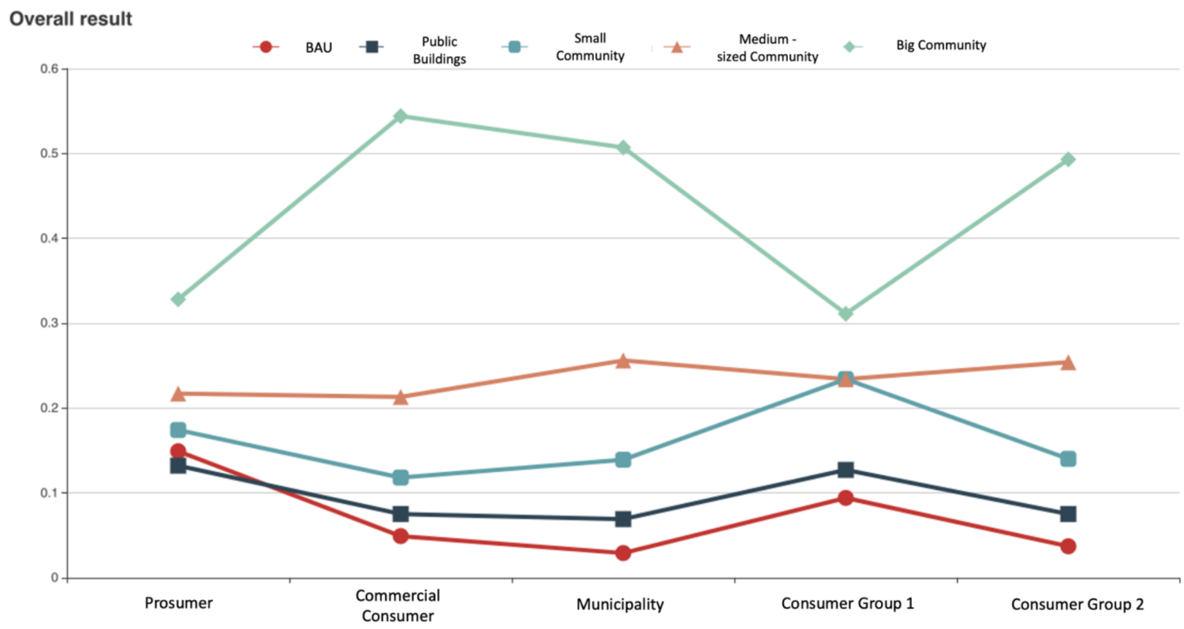

Figure 2: Multi-Actor view on scenarios for Vega

Building on the findings of the technical and governance analysis, Vega could opt 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 can also fulfil the REC requirements if no member owns more than 33% of the shares of the EC.

While the results are a clear indication for the profitability of a REC, and a means to make citizens part of the rural energy transition, the practical implementation of the envisioned REC was accompanied by regulatory and practical challenges.

4. Challenges encountered and recommendations

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 Vega case study, this has led to significant challenges during the implementation phase. The following sections summarize the encountered key challenges and provide recommendations to overcome them.

4.1. Legislative and regulatory challenges

Under the current legislation [2], ECs can only share the energy they generate within its community for free. They cannot receive any financial compensation for that electricity by selling the electricity to its members. As a result, energy bill savings enjoyed by the members of the EC cannot be distributed fairly across the different members. To exemplify this problem, we stipulate two EC members, A and B. A consumes 80% and B consumes 20% of the electricity from the REC's generation. If they both invested equal funds in the EC, 50% each, the collective self-consumption benefits will now be disproportionately allocated to member A at the cost of member B. As a result, member B could be negatively affected by joining an EC. Given that current legislation requires members to be able to join and leave the EC at will, this creates risk to long term success of ECs. If enough members leave an EC, its energy generating assets could end up becoming stranded assets leaving members' investment 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 [32] 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 the electricity which will enable 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 [2,32,33]. The current grants made available under RD 477/2021 [34] are only subsidizing 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 RECs must be already formed and therefore RECs that are in the process of being set up are not eligible for any funding. This further increases burdens on citizens, municipalities, and small enterprises to set-up RECs, although they are claimed to be at the core of a just energy transition. 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.

4.2. Technical

Accurate half hourly energy consumption data is necessary to ensure commercial viability of EC projects in Spain as 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 roll out of smart meters within the community of Vega, it was difficult to access accurate energy consumption data for even the municipality buildings or near impossible to access half hourly consumption data. The utilities that have 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 useful to have a point of contact making available smart meter data accessible to consumers, so that historic consumption data is readily available at 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.

4.3. Financial

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 an EC which their commercial counterparts do not need to adhere to. For example, ECs can only have local consumers and investors, they cannot be large investors, the systems have to 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 not on a 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 a more 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 100kW capacity limit. This will help a REC to compete with commercial competitors more fairly and could contribute to make feasible the deployment of complementary RES, such as wind and PV systems , that might not be installed under these restrictions [35]

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.

5. 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 both the technical 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. Considering the current legal framework, the limited liability company is the most suitable organizational form for a renewable energy community at Vega, because of the low start-up costs and taking the limited number of members into consideration. 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. To engage and inform more participants, we suggest organizing more educational and engaging community events. 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 of 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. 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.

More generally, this study has shed a light on the understudied aspects of the actual setting-up and implementation of energy communities, such as the needed regulatory considerations, community learning mechanisms, and the possibility of viable technical scenarios.

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Appendices

Appendix A

1. Data processing methodology

To recreate the energy scenarios for Vega de Valcarce's Energy Community different types of data input belonging to different types of profiles have been collected: municipality (composed by townhall and school), local commerces and households.

1.1. Municipality final profiles methodology

Two different procedures were applied due to the availability of two different types of samples from the data measured in the electricity meters, which were provided in either monthly or hourly values.

In total, the data from 13 different electricity meters was collected, assumptions based on the size of the profiles, addresses and identifications determined that 10 of them with data starting from December 2018 belong to the town hall, and the other 3 with data starting from November 2017 belong to the school. Regarding the type of samples, 2 of the town hall electricity meters were discarded due to an empty profile, then 4 out of 13 - including the school electricity meters, were provided in monthly values meanwhile the rest were provided in hourly values.

- Final profiles out of hourly electricity measurements

For the cases where hourly measurements of the load profile were available, the profiles were reformatted into the required template for the techno-economic model. As previously mentioned, this methodology applied to 7 out of 13 electricity meters.

- Final profiles out of monthly electricity measurements

However, for the cases where only monthly measurements were available, a different procedure was followed. The data of these electricity meters have been processed according to the indications of the Spanish Government given by the Boletin Oficial del Estado 2020-17282 dated on the 18th December 2020 [36]. The final profiles were recreated and scaled up based on these measurements. After following through the procedure described in the cited document, the initial profiles were obtained. The final profiles were recreated based on a given standard initial profile that depends on the tariff/power contracted, for this case: P2.0TD, the Electric System Demand and Reference values provided by the Spanish DSO - Red Electrica de España, and the monthly measurements.

As per the Electric System Demand and System reference, values are calculated on a yearly basis. Yearly data from 2020 was chosen to calculate the profiles that would apply to a wider yearly range later. Therefore, based on a registered 5% decrease of the electric consumption for the year 2020 due to the Covid-19 pandemic, a factor of 1.05 was applied to the profile [37].

1.2. Local household and commerce profiles methodology

To recreate realistic scenarios of power consumption, standard local profiles for residential and commercial use in the area of Vega de Valcarce were recreated. The average consumption at the different consumption ranges (R1-R2-R3) and average contracted power of 20 households and 20 commerces in the area were collected as shown in Table A 1.

Client Profile	Consumption R1 (kWh)	Consumption R2 (kWh)	Consumption R3 (kWh)	Power Contracted P1 (kW)
Household	65	59	107	3,3
Commerce	473	403	707	6,3

Table A 1: Average consumption and contracted power

Then, data was scaled up based on the typical monthly consumption data of the province where Vega de Valcarce is located. This profile was created by merging the profiles from Galicia and Castilla y Leon – as Vega de Valcarce is at the border between both Spanish provinces. Data from 2019 was used for this calculation, trying to avoid any distortion coming from the effects of Covid-19 pandemic [24]. Following the previously described methodology, hourly data for a year-long time series were fitted into a final profile.

Appendix B

1. Survey

Q1 **Welcome to this short survey about Renewable Energy Communities!**

Vega de Valcarce has partnered with the University of Brussels and its research group MOBI in a project titled RENAISSANCE to support the development of a Renewable Energy Community in Vega de Valcarce.

Its primary objective is to provide environmental, economic and social benefits to its community rather than financial profit. We would like to make it very clear that this project has nothing to do with the plan to build a wind farm in the vicinity of Vega de Valcarce. Our proposal would involve the generation of renewable energy by the community and for the community in a truly cooperative manner.

As a first step, we would like to get inputs from community members on what you would see as the most relevant objectives concerning the energy you consume. We, therefore, invite you to support us in filling out this survey. The survey will take about 5 minutes to complete. The results from the survey will be shared at the forthcoming workshop being organised in Vega on Thursday 30th September and Friday 1st October, where we hope to see you.

Thank you in advance for your support!

Q2 In addition to your opinion, we will collect some personal information such as age, education, employment condition linked to your email address, to be able to contact you for follow up, if needed. We securely store this data until the end of the research period. We respect your trust and privacy, therefore we will never share this data with any third parties. Your personal data will be processed in accordance with the principles of the General Data Protection Regulation (GDPR), in force since the 25th of May 2018. If you have further questions on how your data is processed you can always contact the Data Protection Officer by emailing dpo@vub.be

Have you read the text and agree to take part in the survey?

o I have read it and agree (1)

o I disagree (2)

Skip To: End of Survey If In addition to your opinion, we will collect some personal information such as age, education, em... = I disagree

Q3 Please indicate from which perspective you fill out the survey (which role do you have in the energy system:

- a consumer (residential household)
- a consumer (small medium enterprise)
- a consumer that both consumes and generates energy
- cooperative representative
- cooperative member
- energy retailer
- the distribution system operator
- the municipality

- an energy advisor
- Other? Please specify clearly
  ____

Q4 Please rank (drag and drop) which aspects affect your decision to join an energy community initiative most (from 1 being most influential to 5 being least influential).
If you use the paper version, please write down the numbers

______ Environment (e.g., emissions)
______ Economy (e.g., savings, costs)
______ Technical (e.g., guaranteed energy supply and production)
______ Social (e.g., shared benefits, collaboration)
______ Institutional/Legal (e.g., availability of support)

Q5 *What are the most relevant objectives for you concerning your energy supply and production*?

	Not relevant	Relevant	Really relevant	Not Applicable/ I do not understand it
Emissions reductions (less fossil fuel emissions)	o	o	o	o
Landscape impacts (e.g., change of build environment, noise)	o	o	o	o
Return on investment (costs are proportional to the financial gains)	o	o	o	o
Affordable investment and maintenance costs (installation, management and maintenance are within a reasonable price range)	o	o	o	o

Lower energy bill (reducing the overall energy expenses)	o	o	o	o
Replicability (the same system, products, business models can be upscaled)	o	o	o	o
Innovation (pioneering in new techniques and systems)	o	o	o	o
Employment (creation of additional jobs)	o	o	o	o
Commercial validation of products and services (being able to offer your own energy-related products and services)	o	o	o	o
(Green) image building (product/service is perceived as more sustainable and green)	o	o	o	o
Improve energy efficiency (e.g. reduce energy consumption by better management and more efficient equipment)	o	o	o	o

Grid stability, continuity and reliability (avoiding power outages and electricity failures)	o	o	o	o
Security (GDPR protection and protection against cyber attacks, or other rogue actions)	o	o	o	o
Energy autonomy (to have access to energy even when the main grid has an outage)	o	o	o	o
Inclusiveness (incorporating social costs and a contribution for the socially weak for a just transition)	o	o	o	o
Behaviour change (adopting a more sustainable and efficient use of energy in all aspects of our daily life)	o	o	o	o
Education (more knowledge about sustainable energy and consumption)	o	o	o	o

Available support (in form of available funds, information bureaus, facilitating policies and laws)	o	o	o	o

Q6 Do you want to add other objectives that were not mentioned above?

____

Q7 Do you have any remarks on the questions?

____

Q8 Would you like Vega de Valcarce to contribute to the energy transition?

- Yes
- No. Please explain why:

  ____

- I do not know

Q9 What are/ can be challenges for you and Vega de Valcarce to contribute to the energy transition?

____

Q10 Would you be willing to participate in a workshop on the topic of community energy?

- Yes
- No

Display This Question:

If Would you be willing to participate in a workshop on the topic of community energy? = Yes

Q11 If you want to stay updated and/or invited to the workshop, please provide us your email address:

____

Q12 What is your age?

- 18-25
- 26-35
- 35-55
- 55-69
- 70+
- Prefer not to tell

Q13 What is the highest level of education you have received?

- Primary school
- Secondary school
- Professional training
- University degree (Bachelor)
- University degree (Master)
- Doctoral degree
- Prefere not to tell

Q14 In which range lies your monthly net income ?

- 0 - 9 000 Euros
- 9 000- 12 500 Euros
- 12 500-16 000 Euros
- 16 000 - 20 000 Euros
- 20 000 - 28 000 Euros
- 28000 – 42 000 Euros
- 34 000 – 42 000 Euros
- 42 000 – 55 000 Euros
- More than 55 000
- Prefer not to tell

Q15 Which statement best describes your current employment status?

- Working (paid permanent employee)
- Working (self-employed)
- Not working (retired)
- Not working (searching for a job)
- Not working (not searching for a job)
- Prefer not to answer

Q16 How do you identify?

- Male
- Female
- Other

- Prefer not to say

Appendix C

1. Criteria selection and weighting per stakeholder group

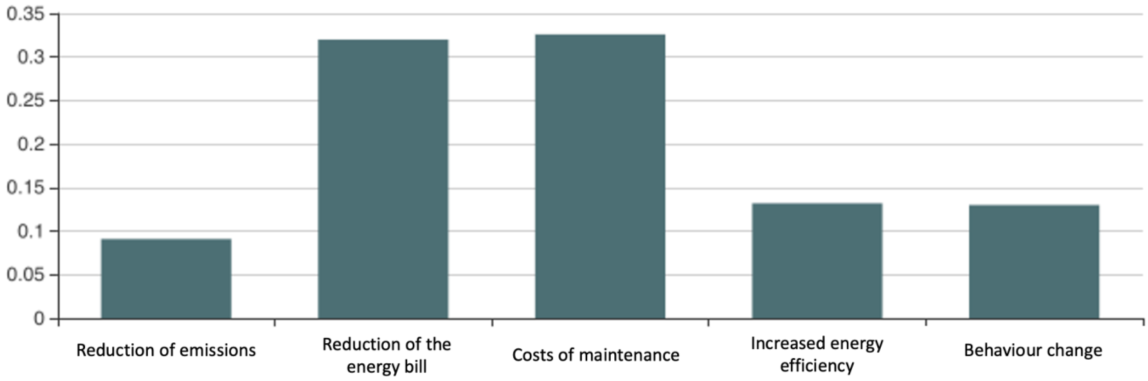

Figure C 1: Criteria selection and weights for the prosumer group

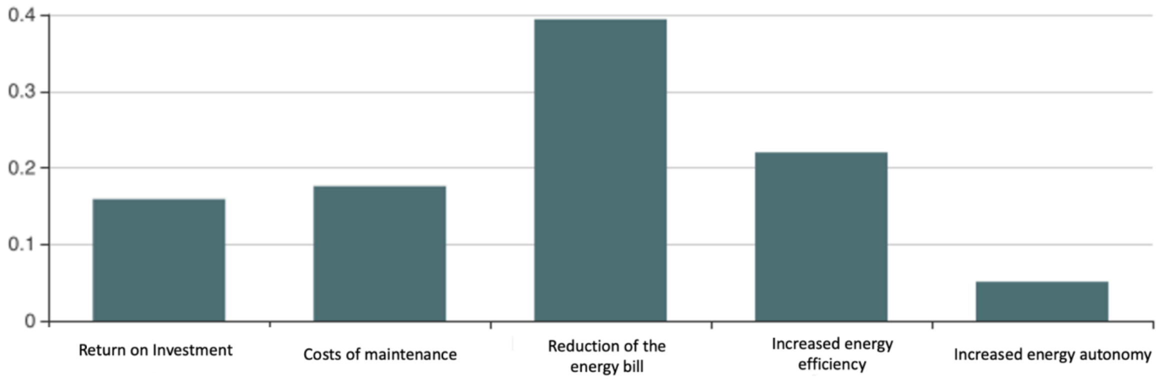

Figure C 2: Criteria selection and weights for the consumer group (SMEs)

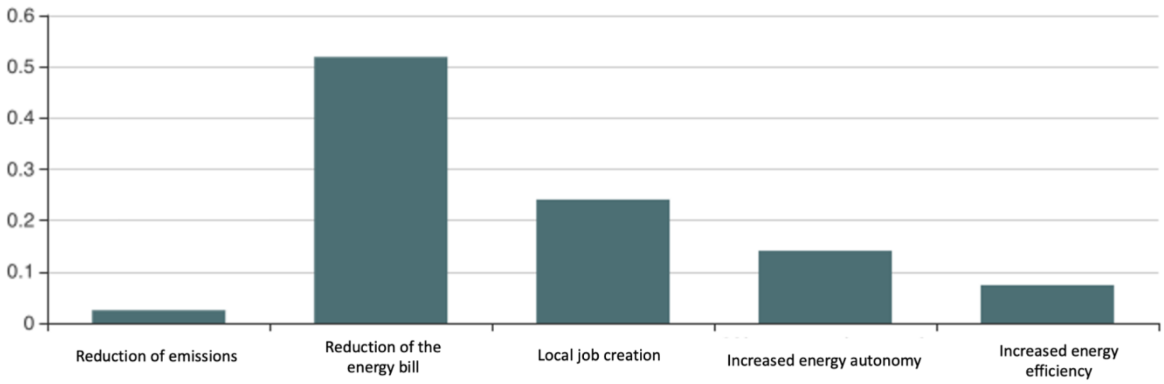

Figure C 3: Criteria selection and weights for the municipality

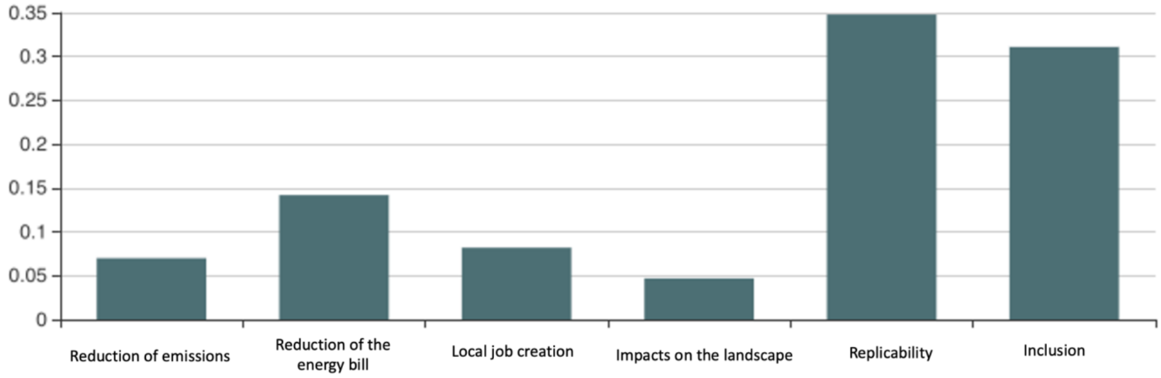

Figure C 4: Criteria selection and weights for the first consumer group

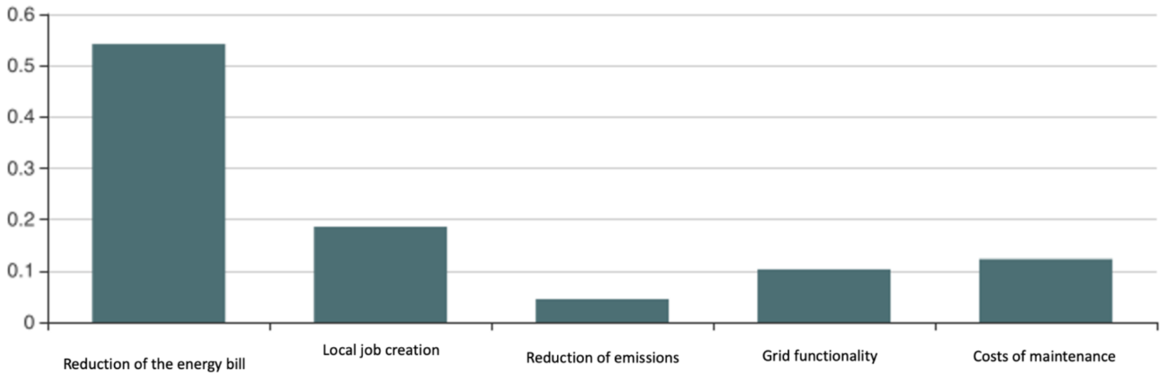

Figure C 5: Criteria selection and weights for the first consumer group