Sustainable energy communities.
Feasibility for today or long term? Case Analysis

Ramon Balaguer Vich
ramon.balaguer.vich@gmail.com

Instituto Superior Técnico, Universidade de Lisboa, Portugal

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1. Introduction

For a few years, the European Union launched the so-called European Green Pact, an ambitious package of measures to reduce the effects of climate change in the coming years.

In this way, in 2016, the European Commission updated the EU's energy policy framework to promote a clean and fair energy transition for the future and to become the first economy with neutral emissions on the horizon of 2050 [1]. To achieve this objective, objectives have been established for different terms, varying according to the country.

By 2020, a 20% reduction in greenhouse gas emissions relative to 1990 levels has been set as targets; a 20% contribution from renewable energy sources; and a 20% improvement in energy efficiency.

The medium-term objectives for the year 2030 establish at least a 40% reduction in greenhouse gas emissions; 32% of the energy from renewable sources; and at least 32.5% improvement in energy efficiency.

Finally, and although no clear and measurable objectives have been defined, the European Union aspires to be climate neutral by 2050.

These measures will promote the so-called local energy communities. This is a figure that the European Union has defined in the framework of the new policies against climate change and that is expected to contribute to the implementation of technologies for the production and consumption of energy from renewable sources.

The objective of this work is to study the feasibility of implementing an energy community in the short and long term. To do this, the concept of the energy community is first analyzed and the situation has evolved over the last few years in different territories and with different measures and incentives applied. Also, those success cases and their characteristics have been studied.

Then, the knowledge obtained is applied to see if the creation of a sustainable energy community (SEC) is viable and if it would be an economic and environmental benefit for citizens. Different scenarios in which you could work are simulated and the keys to their realization are analyzed, as well as the problems that it should face.

2. Energy communities review. Approaches and practice

2.1. Concept and main important aspects

In the Clean Energy Package for All Europeans, two related terms are defined that can be included in the concept of Sustainable Energy Community.

First, there is the concept of 'Renewable Energy Community'. It is established as a legal entity based on open and voluntary participation that is controlled by members who are close to renewable energy projects. Its main objective is to provide community, economic or social benefits for its members or for the local areas where it operates (figure 1).

Second, there is the term 'Community of citizen energy'. The definition of this community based on voluntary and open participation includes the main objective of providing community environmental, economic or social benefits to its members or local areas. It can participate in the generation, including from renewable sources, distribution, supply, consumption, aggregation, energy storage, energy efficiency services or charging services for electric vehicles or provide other energy services to its members or shareholders.

Figure 1 presents a space in which the different combinations of technical and social aspects are combined to form the community.

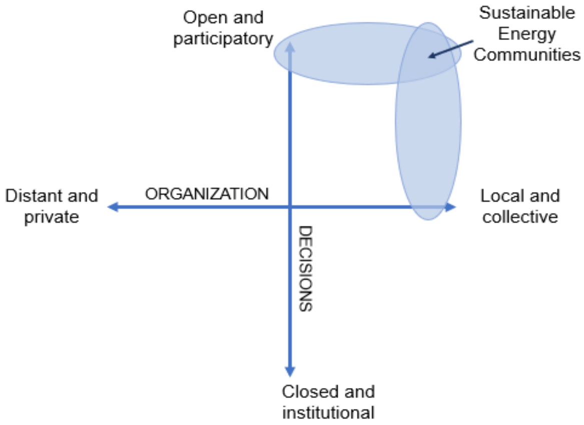

Figure 1: Community renewable energy in relation to project decisions and organization dimensions. Source: [2]

The definition for a SEC could be a voluntary group of people who have the common goal to provide benefits related to the production, distribution or consumption of renewable energy. The SEC's cover those projects that have these objectives, regardless of how it works as a legal entity.

2.2. Options and Approaches

The SEC definition is not unique and there are many typologies in which it can be presented. First, a sustainable energy community is characterized by the activities that are carried out in it. It can focus from the most common tasks, such as the generation and consumption of electricity or district heating, to some of those that have emerged in recent years, such as sustainable mobility through the sharing of electric vehicles.

Secondly, the community exploits different types of technologies for energy production and consumption. Not all of them are suitable for installation in each territory due to the limitations that exist there, and it must be studied very well which ones are best adapted to the situation of each community.

Other perspectives for the SEC to consider are those of location, size, and possibility of access to the electrical grid. It is important to know the place where the community wants to be implanted, the magnitude of the objectives to be covered and what are the points that will limit the project.

Finally, it is also necessary to define the social, economic and organizational aspects. Who directs the project and who provides the financing are some of the aspects that make this a collective, open and participatory project in which all members of the community can have their voice.

Table 1 tries to present the possible categorizations that a SEC may have from different perspectives. The combination of its elements endows the community with a definition that will differ from the others.

Table 1: SEC's categorization from different perspectives. Source: [3] and [4]

Perspective	**Categorization**
Activities	Generation Supply Consumption and energy sharing Collective purchasing Distribution (electricity and heating networks) Energy services Electro-mobility Financial services
Energy technologies	Wind Solar Small hydro Bioenergy Heat pumps District heating networks Electric vehicles
Scale	Large: city, region Medium: neighbourhood Small: household/buildings
Grid connection	Grid connected Off-grid
Initiatives	Led by citizens Led by private enterprises Led by government
Location	Developed countries – urban and rural Developing countries – urban and rural
Organisational structure	Cooperative Association Partnership Development trust Private company

2.3. Review of publications and cases

2.3.1. Germany

Thanks to the promotion of energy communities, mainly through the facilitation of procedures for the creation of new cooperatives and the implementation for a few years of Feed-in Tariff (FIT), in 2017 approximately 46% of all the capacity of Renewable energy in Germany was owned by individuals and farmers [5].

2.3.2. Portugal

Portugal is among the countries of the European Union with the highest proportion of renewable energy in consumption. To do this, it has established guaranteed Feed-ins tariff of up to 15 years and has promoted investment in projects up to 40% [6]. Despite this, the country currently only has one energy community in a cooperative regime, Coopernico. To reverse the situation, last year, the term Renewable Energy Communities was inculcated in the legislation and through its promotion that it is an important and complementary system of the national electrical system.

2.3.3. Spain

Although it one of the countries that has experienced a greater increase in the use of renewable energy, it is also one of those with the lowest number of SECs 60% of the installed power in renewables is owned by five large companies.

A deficit electricity system that eliminated the FITs, a complicated bureaucracy and the application of fees to small producers, has meant that recently, no community projects have emerged. The legal changes made in 2018 and the future definition of the Energy Communities as a legal entity, make it foresee that their creation in the coming years can start [7].

2.3.4. Denmark

Following the oil crisis, the first local wind turbine cooperatives in Europe began to develop in the late 1970s to address the country's energy dependence and climate change. Tax incentives and the FIT system meant that in 1996 there were some 2,100 wind turbine cooperatives in Denmark, and in 2001 their participation in wind turbines was 86% [8].

In 1999, the market was liberalized and aid to renewable energy was reduced. As a result, between 2004 and 2008, virtually no new wind turbines were installed. Again, in 2008, the aid system was reformed, including other technologies such as photovoltaics and has led to new growth in renewable energy projects in Denmark.

2.3.5. Comparison

Table 2 shows the approximate number of energy cooperatives each country currently owns and some of the key factors that can explain the differences between them.

Table 2: Comparison between countries

Country	DE	PT	ES	DK
Renewable electricity	38%	52%	35%	62%
Renewable energy	16%	30%	17%	36%
Emissions related to 1990	70%	119%	120%	71%
Nº of energy cooperatives	1070	7	29	150
GDP per capita, in €	47616	23.403	30.324	61.391

As shown in Table 2, the differences between the two southern countries and the two northern countries in terms of SEC's are quite marked.

2.4. Challenges for Energy Communities

Table 3 gives the categorization of the problems that energy communities must face

Table 3: Issues facing energy communities

Categorization	**Issues**
Technological	Matching demand with supply Energy efficiency Storage Local flexibility and grid's impact
Socio-economic	Energy autonomy and security of supply Initial costs and financing Economic incentives Community engagement Willingness of people to pay
Environmental	Environmental awareness and climate change Emission levels Waste generation and management Space available for installation
Institutional	Motivation and continuity on the project Energy democracy Installation's ownership Long-term goals Institutional design Roles and responsibilities of people in the community

3. Case analysis

3.1. General aspects

The selected case study to analyse the implementation of an energy community is that of Son Espanyol, a small neighbourhood located on the outskirts of Palma de Mallorca, in Spain.

The reason for this choice is that the Balearic archipelago depends to a large extent on the electrical contribution made from the Iberian Peninsula through the cables that connect Mallorca and Valencia. During 2019, almost 28% of the electricity consumed was supplied by continental Spain. These data already indicate a high energy dependence on the islands. Of the remaining 72% of electricity generated on the islands, only about 6% of the energy generated comes from renewable sources, the majority produced by photovoltaic parks and renewable waste [9].

3.2. Son Espanyol neighbourhood

Son Espanyol is a peripheral and dispersed neighbourhood of the Balearic capital that still retains a certain rural character. It is one of those with the least population, although in recent years it has experienced slight growth. Its population density is low, approximately 1,5 people per hectare.

According to 2010 data, the neighbourhood has about 232 homes and the average number of people residing in each home is 2,8 [10].

In this study, the homes belonging to the Son Espanyol water community will be analysed. It is a group that was formed in 1984 and that groups 200 households. The approximate area occupied by these two hundred houses and some that do not belong to the community is approximately 1,95 km^2.

3.3. Study of current energy demand

3.3.1. Energy consumption

The average consumption of a single-family house located in the Mediterranean climate zone is 1,255 toe per year (14.596 kWh). Most of it is used for heating and represents 63,3% of total consumption [11]. To fulfil this function, firewood burning is widely used in the area.

On the other hand, concerning kitchen services and water heating, many houses in the area have boilers and kitchens that work with LPG. Also, there is a regulation applicable to new construction homes or those that are going to be rehabilitated that requires a minimum solar contribution for water heating.

3.3.2. Electric consumption

To define the neighbourhood's electrical load curve, historical electricity consumption studies have been used for the climate zone and a sample of electric bills for 11 houses has been collected.

To describe the monthly average consumption of houses, an average curve has been defined between the theoretical annual consumption data per house and the collected bills. During the central winter and summer months, it is when the community has consumption peaks.

To study the variation in consumption during each day of the week and since the variation is minimal, the theoretical values provided by the Atlas of Spanish electricity are used.

Finally, and to define the hourly consumption, the data from the Atlas have also been used.

Once the behaviour of the load curve has been defined during each hour and day of the year, the annual profile of the 200 houses is drawn in Figure 2 using the Homer Energy software.

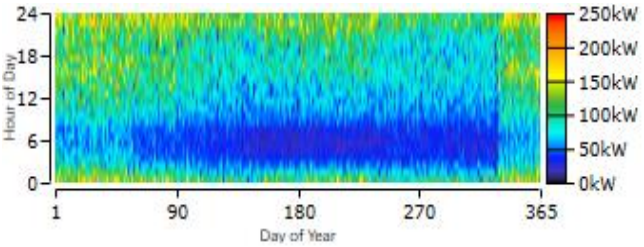

Figure 2: Electricity consumption of the 200 houses for each hour and day of the year. Source: Homer Energy

Thus, the total consumption of the community in a year is approximately 741.918 kWh.

3.4. Study and modelling of the solar resource

The production of electricity using solar panels is one of the energy resources with the most potential for the area, its installation could be carried out on the roofs of houses or on multiple lands that are not used now.

To carry out the study and modelling of the photovoltaic installation, the irradiation and hourly air temperature data have first been obtained through the PVGIS platform. In addition, and to counteract the angle of solar incidence and obtain higher performance, it will be considered that all the panels will be oriented to the south and inclined at an optimal angle of 35º. In Figure 3, the average global irradiation during one day of each month for this optimal angle is given.

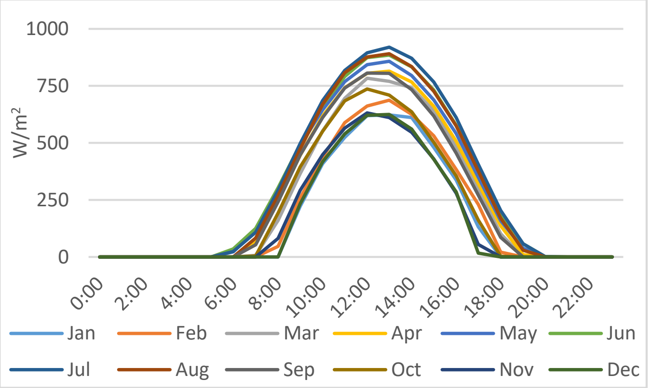

Figure 3: Average global irradiation during a day of each month, for an angle of 35º. Data Source: [12]

Table 4 contains the solar panels characteristics introduced into the Homer Energy software.

Table 4: Solar panels characteristics

Capital	1.200 € / kWp
Cost maintenance	12 € / yr · kWp
Efficiency	18%
Temp coefficient	-0,4% / ºC
Derating factor	88%
Lifetime	25 yr

3.5. Study and modelling of the wind resource

Although Son Espanyol is not located in an area with a large wind resource, the implementation of small wind turbines for electricity production has been studied during the winter months, when photovoltaic production decreases and consumption increases.

From the PVGIS, wind speed data has been obtained for each hour and day of the year at a height of 10 m. Together, with the roughness coefficient of the area, which is 0,3 m, it has been possible to extrapolate the speed to a height of 25m, as is given in Figure 4. This is a typical height value for the type of wind turbines that are planned to be installed.

Several models have been studied to decide which one best suit the environment. The different power curves of each wind turbine have been obtained and, together with the speed, its annual production and the cost per kilowatt-hour generated have been calculated. The model chosen for the job has been the Lely Aircon 10.

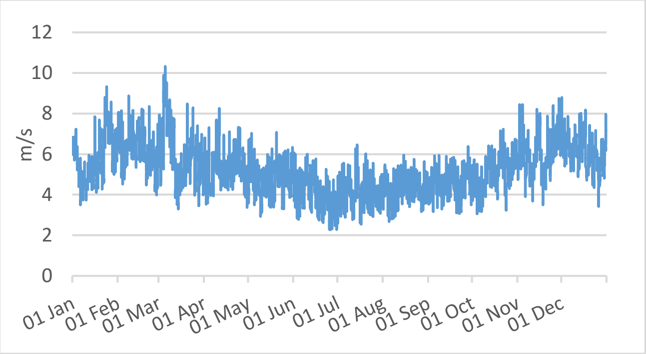

Figure 4: Hourly wind speed at a height of 25 m

Table 5 contains the wind turbine characteristics introduced into the Homer Energy software, in addition to the power curve.

Table 5: Wind turbine characteristics. Data source: [13]

Capital	30.000 €
Cost maintenance	400 € / yr
Capacity	10 kW
Hub height	25 m
Lifetime	20 yrs

3.6. Modelling of the batteries

The possible installation of batteries has been modelled to store the excess energy production that would generate the photovoltaic panels during the central hours of the day to be able to consume them at night. Also, the battery system would provide greater stability to the community's electrical system.

It has been decided to analyse the installation of lithium-ion batteries. It is the predominant option for residential use given its low maintenance cost, which has no memory effect, its high energy density and its good efficiency. Its characteristics are those shown in the Table 6.

Table 6: Characteristics of the lithium-ion batteries. Data source: [14]

Capital	711 € / kWh
Cost maintenance	10 € / yr · kWh
Efficiency	90%
Lifecycles	3000 cycles
Lifetime	15 yr

3.7. Modelling of converter

Due to the installation of photovoltaic panels or battery type energy storage systems, it is necessary to install a direct current to alternating current converter. On the one hand, the panel system and the battery bank operate on direct current; and on the other, the houses and the wind turbines do it in alternating. Table 7 contains the converter system characteristics introduced into the software.

Table 7: Characteristics of the converter system

Capital	200 € / kW
Cost maintenance	4 € / yr · kW
Efficiency	95%
Lifetime	15 yr

3.8. Current grants to avail

These are the subsidies that could be received if the energy community project were developed [15]:

- For the installation of a photovoltaic system, a 50% subsidy is established on the value of the installation's admissible investment. The maximum allowed investment value is 1 € / Wp and the first 50 kWp are subsidized.

- For investments in new installations of small wind farms, a subsidy of 50% is established on the value of the eligible investment. The maximum admissible investment value is 5 € / W and the first 10 kW of power are subsidized.

- Finally, for those projects that incorporate lithium-ion accumulation systems, a 50% subsidy is established on the value of the investment. The maximum admissible investment value is 600 € / kWh of accumulation and the first 12 kWh are subsidized.

4. Assessment of application and feasibility

To simulate the operation of the energy community of Son Espanyol, different possible scenarios have been considered, as shown in Table 8. To do this, the purchase and sale prices of electricity to the grid have been varied, the maximum power to be installed has been limited and it has been considered whether or not the project could benefit from the subsidies in those scenarios that present a more unfavourable situation and where it may have a higher incidence.

Table 8: Characteristics of the simulated scenarios

Scenario	Sale price [€/kWh]	Purchase price [€/kWh]	Grants	Additional characteristics
1	0,04	0,10	No	-
2	0,08	0,10	No	-
3	0,04	0,20	No	-
4	0,08	0,20	No	-
5	0,08	0,10	No	Limitation of power
6	0,08	0,20	No	Limitation of power
7	0,04	0,10	Yes	-
8	0,04	0,20	Yes	-

4.1. Scenario 1

The optimal system architecture for this scenario, shown in Table 9, is the installation of photovoltaic panels and the respective converter system to meet the demands of the houses during the production hours of the panels and that offers economic savings in the long term to the population since they are decreasing their consumption from the grid.

Table 9: Optimized architecture

	PV	WT	Converter	Battery
Capacity	145 kW	-	92,9 kW	-
Energy out	241.315 kWh	-	226.353 kWh	-

4.2. Scenario 2

The installation of the maximum possible photovoltaic power is proposed, as can be seen in the Table 10. Solar production costs are estimated at 0,0585 € / kWh and the surplus sales cost is 0,08 € / kWh. In this way, all the energy generated by the system provides a net positive benefit for the community and is interested in producing the highest possible levels.

Table 10: Optimized architecture

	PV	WT	Converter	Battery
Capacity	1.657 kW	-	1.035 kW	-
Energy out	2.751.993 kWh	-	2.569.572 kWh	-

4.3. Scenario 3

In this scenario, the installation of the wind turbines is profitable, since its production cost is 0,126 € / kWh and would generate savings compared to the 20 cents paid to the grid. The result, given in Table 11, is that the optimal installation is that of 16 wind turbines and a photovoltaic system, to cover the maximum of electrical demand, without seeking the production of surpluses.

Table 11: Optimized architecture

	PV	WT	Converter	Battery
Capacity	121 kW	160 kW	75,9 kW	-
Energy out	200.792 kWh	361.666 kWh	187.705 kWh	-

4.4. Scenario 4

The optimal architecture of this scenario shown in Table 12, is a mixture of that offered in the simulations of scenarios 2 and 3. On the one hand, since the cost of solar production is less than the purchase of surpluses, it is recommended to produce maximum electricity using photovoltaic panels to sell it. On the other hand, wind production costs are lower than the purchase price to the grid and the installation of wind turbines is profitable to achieve savings on bills.

Table 12: Optimized architecture

	PV	WT	Converter	Battery
Capacity	1.659 kW	170 kW	1.035 kW	-
Energy out	2.754.920 kWh	384.271 kWh	2.571.707 kWh	-

4.5. Scenario 5

This scenario has the same characteristics as the second, but the power of the solar system that can be installed has been limited. Power on the order of megawatts is more representative of an electric company than a sustainable energy community. This limitation has been stipulated with the total energy value that the two hundred houses would need in a year and that for the future, with the use of the grid as a macro battery or with the improvement of storage systems, it can reach that the community self-consume everything it needs.

Considering the losses produced in the converter system and the losses produced by temperature variations in the photovoltaic system and wind turbines, the optimal result obtained is the installation of a photovoltaic system as indicated in Table 13.

Table 13: Optimized architecture

	PV	WT	Converter	Battery
Capacity	473 kW	-	316 kW	-
Energy out	786.019 kWh	-	742.033 kWh	

4.6. Scenario 6

As in the previous scenario, annual energy production has been limited to the community's annual demand.

The optimal architecture obtained, given in Table 14, is the same as before; with a photovoltaic system and its corresponding converter system. Unlike the previous scenario, the installation of wind turbines is profitable in this scenario, but having established annual production limits, the technology that can generate that amount of energy at a lower cost has been chosen.

Table 14: Optimized architecture

	PV	WT	Converter	Battery
Capacity	473 kW	-	316 kW	-
Energy out	786.019 kWh	-	742.033 kWh	-

4.7. Scenario 7

In this seventh simulation, with characteristics like those of scenario 1, the receipt of public subsidies such as those mentioned in Chapter 3.8. is proposed.

Unlike the first scenario, in this the installation of the first wind turbine is profitable. Also, the reduction that involves the initial investment in the photovoltaic system, makes it recommended to install a slightly higher power. The objective, again, is to obtain savings on the electric bill and not the generation of surpluses. Table 15 shows the optimized architecture in this scenario.

Table 15: Optimized architecture

	PV	WT	Converter	Battery
Capacity	166 kW	10 kW	105 kW	-
Energy out	275.249 kWh	22.604 kWh	257.923 kWh	-

4.8. Scenario 8

In the last scenario proposed, with characteristics like those of scenario 3, the reception of public subsidies for the initial investment is assumed again. The optimal architecture given in Table 16 is that of an installation of photovoltaic panels and 16 wind turbines since both have production costs below the grid purchase price.

The important thing about this scenario is that it is the only one in which an storage system of lithium-ion batteries with the help of subsidies is profitable. Still, help is only for the first 12 kWh and future receipt for replacement is not guaranteed. Due to this reason and because its useful life would be approximately 8 years, with an autonomy of less than half an hour, this option has been ruled out.

Table 16: Optimized architecture

	PV	WT	Converter	Battery
Capacity	152 kW	160 kW	96,1 kW	-
Energy out	253.042 kWh	361.666 kWh	236.776 kWh	-

5. Results discussion

5.1. Results

Once the simulations have been carried out, it is time to compare the results obtained for each scenario.

With the variation in electricity prices, so do the installed powers and, therefore, the energy produced and self-consumption, as shown in Table 17.

As for sales, the increase that occurs between the scenarios with a sale price of 8 cents and those of 4 cents, indicates the moment in which the community goes from making their investment profitable through savings on the invoice to do it by obtaining profits from the sale of electricity.

Table 17: Results of energy self-consumption and interaction with grid per year

Scenario	Self-consumption [kWh]	Grid purchases [kWh]	Sells [kWh]	Losses [kWh]
1	201.855	540.063	24.498	11.913
2	309.017	432.901	2.260.554	135.241
3	441.438	300.480	107.933	9.879
4	493.447	248.471	2.462.530	135.353
5	282.636	459.282	459.396	39.054
6	282.636	459.282	459.396	39.054
7	234.295	507.623	46.232	13.575
8	449.513	292.405	148.929	12.462

The costs that the community must face each year are analysed in Table 18 according to what is explained in Chapter 3. As the installed powers increase, the money that must be spent at the end of the year on maintenance also increases.

On the other hand, the income received from the sale of electricity also increases. If the difference between annual costs and income is analysed, it is observed that the fact that the surpluses are sold at 0,04 € / kWh or 0,08 € / kWh has important relevance. The scenario in which the community must pay a greater amount of money is the third, where the installed power in wind turbines is high and the sale price of electricity is low. On the other hand, in scenarios where the sale price of surpluses is higher, maintenance costs are assimilated by the benefits produced by these sales.

Table 18: Maintenance costs and benefits from sales per year

Scenario	System costs [€]	Energy sales benefits [€]	Difference [€]
1	2.116	980	-1.136
2	24.025	180.844	156.819
3	8.155	4.317	-3.838
4	30.846	197.002	166.156
5	6.942	36.752	29.810
6	6.942	36.752	29.810
7	2.810	1.849	-961
8	8.613	5.957	-2.656

Analysing the impact that the implementation of the project would have on the location and the results of the environmental impact given in Table 19, there are notable differences between the scenarios. As mentioned in Chapter 1.1, by 2030, emission reduction targets of 40% and a renewable energy share of 32% have been established.

Although all the scenarios have a renewable energy penetration above 32%, part of the energy is sold to the grid and that means that in terms of self-consumed energy, the first and seventh scenarios are slightly below.

Regarding the reduction of emissions compared to the current system, considering the emission factor data from the island's electricity grid, the results range between 27% and 66%. Given that the European Commission marks a reduction compared to 1990, they are not comparable values, even so, the results can be on the right track.

The repercussion that SEC would have in Son Espanyol has been measured in a simplified way, calculating the area necessary for the PV panels, considering an average value of 9 m^2 / kWp. Also, the noise pollution generated by wind turbine has been analysed. According to the manufacturer's data, the noise levels it produces are around 60 dB and if it is more than 60 m away, these values are below 40 dB, a value that does not affect health and people's rest.

Table 19 shows the environmental impact results calculated.

Table 19: Environmental impact results

Scenario	Renewable penetration	Emissions reduction	Surface panels	Acoustic impact
1	32,5%	27,2%	1305 m^2	No
2	370,9%	41,7%	14913 m^2	No
3	75,8%	59,5%	1089 m^2	Yes
4	423,1%	66,5%	14931 m^2	Yes
5	105,9%	38,1%	4257 m^2	No
6	105,9%	38,1%	4257 m^2	No
7	40,1%	31,6%	1494 m^2	Yes
8	82,9%	60,6%	1368 m^2	Yes

Both the second and third scenarios require a higher initial capital, due to the great power installed in the photovoltaic panels. Although installed power has been limited, in scenarios five and six, the initial investment is also high and is like scenarios three and eight in which 16 wind turbines are installed.

In those scenarios in which the purchase price is 20 cents per kilowatt-hour, the savings generated at the end of the year are much higher. Regarding the 25-year net present value, the factor that seems to condition it increase the most is the savings generated by self-consumption. In Table 20 its possible to see how the variation of the initial investment and sale price to the grid determines the payback period.

Table 20: Economic results for each scenario

Scenario	Initial capital [€]	Average annual savings [€]	Net present value [€]	Discounted payback [yr]
1	192.945	20.186	68.441	15,47
2	2.195.528	30.902	371.004	19,37
3	640.275	88.288	469.555	9,77
4	2.707.643	98.689	866.618	15,48
5	631.066	28.264	163.277	17,28
6	631.066	56.527	561.623	9,33
7	199.996	23.430	103.950	12,07
8	632.010	89.903	515.686	9,22

If the initial investment is made in equal parts among the 200 community members, the money that each must disburse ranges between 965 € in the first scenario and 13.538 € in the fourth. Considering that the average income of neighbours is around 29.866 € / yr, the initial investment would represent around 3,2% and 45,3% respectively.

Finally, the average annual savings each household would have on their electricity bill and the payments they should make in terms of community expenses are shown in Table 21. Expenses are the difference between the costs of maintaining the system and the income from the sale of electricity to the grid.

Table 21: Initial investment and annual savings compared to the current system for each house

Scenario	Initial capital per house [€]	Average annual savings per house [€]	Average annual costs per house [€]
1	965	101	-5,7
2	10.978	155	784,1
3	3.201	441	-19,2
4	13.538	493	830,8
5	3.155	141	149,0
6	3.155	283	149,0
7	1.000	117	-4,8
8	3.160	450	-13,3

5.2. Feasibility

All the optimal architectures obtained for each scenario are economically viable and what varies is the benefits obtained, the payback and the area required for the installation.

Technologically, none of the proposed architectures has complications, since the systems contemplated are mature technologies. But, a large installation of panels and turbines implies the need for free land for their placement. In the current pumping system that the water community has, the association has a small parcel of property. This purchase option is not viable since the prices of the square meter are high. The most viable option is to rent land for the installation of the system, where prices currently vary from 0,09 / m^2 to 0,12 € / m^2 for periods of 25 years.

Table 22: Calculation of land rent, loans and how it affects to the NPV

Scenario	Annual land rent [€]	Monthly payments [€]	Total payment [€]	NPV - Interests - Rent land [€]
1	137	3.637	218.202	39.759
2	1.566	41.382	2.482.923	44.463
3	114	12.068	724.087	382.884
4	1.568	51.035	3.062.074	472.993
5	447	11.895	713.673	69.496
6	447	11.895	713.673	467.842
7	157	3.770	226.175	73.849
8	144	11.912	714.740	429.365

The cost of renting the land decreases the net present value (NPV) and delays recovery. Also, it has been calculated in Table 22 how it affects economic viability if a loan were requested to pay the initial investment. This type of loan has a nominal interest of 4,95% and has been calculated for 5 years, the maximum period in which the eight scenarios would continue to offer a positive net present value.

Projects with a high initial investment are not convenient. They force them to apply for a loan and that reduces profitability. On the other hand, these are the scenarios with the highest installed power and need to rent larger plots.

Finally, one of the aspects that can most affect the feasibility of the project is that in general, people in Spain have less financial capacity than in other countries, the population density is lower and it could be that Spanish people do not have the same sensitivity due to environmental problems [16].

5.3. Factors

Analysing the results of the eight simulations, it has been shown that there are three factors with great relevance for the viability of an energy community.

First, there is the purchase price to the grid. If the community is connected to the network and relies on self-consumption to obtain savings by reducing purchases, the project's sensitivity to price is high. For the community of Son Espanyol, the cost of electricity production is 0,126 € / kWh in the case of wind turbines and 0,585 € / kWh in solar panels. For any of these technologies to stop being profitable, the electric price should be below.

The second factor analysed is that of the sale price of the surplus produced. It is a factor more related to those projects that seek to obtain benefits from the sale of electricity. In the case of the community of Son Espanyol, the fact of seeking this objective can lead to the installation of the maximum photovoltaic power, which implies a large initial investment and generates a risk if the sale price varies, due to the small margins that exist.

The third factor that has been varied in the simulations is that of public subsidies, which only include maximum power and capacity to subsidize. In the case of the proposed energy community in Son Espanyol, with a much higher installed capacity, the only influence it has is a slight reduction in the initial investment and a reduction in the payback. As contemplated in the National Energy and Climate Plans of different countries, in the coming years the subsidies will probably cover greater powers, this factor will be more influential for the viability of larger communities.

Finally, and although its value has not varied in the simulations due to its low volatility, there are some additional factors. The first is the legal framework that affects the project and that facilitates or complicates its creation.

Another factor is the state of maturity in which the technologies to be exploited are located. Both wind turbines, photovoltaic panels, and the converter system are mature technologies that have improved their efficiencies and decreased their prices in recent years and are likely to continue to do so slightly. In contrast, the battery system is not currently a profitable technology for all communities and homes, but it is expected that in the coming years it will evolve and may have an important role in energy storage.

6. Conclusions

In this work, the viability of the constitution of a sustainable energy community in a neighbourhood of Mallorca, in Spain has been analyzed. The different types of existing communities have been discussed, success cases have been explained and different scenarios have been proposed for the case analysis.

The challenges posed by each territory, the country's legislative framework and the activities to be carried out, allow considering a great diversity of energy communities.

Different countries have proposed energy plans that include the promotion of sustainable energy communities and, for the moment, measures have been taken to facilitate procedures and help financially with subsidies. Although this is an important step, most of these measures only affect small communities and not cases like the one analyzed, a neighbourhood of 200 households.

In the case analyzed, it has been shown how the implementation of a mature technology such as photovoltaic panels and basing the objectives on self-consumption, is profitable and adapts very well to the characteristics of the place. Although factors such as the price of buying and selling electricity fluctuate or the subsidies disappear, the project is profitable since its photovoltaic production cost is around 0,0595 € / kWh.

On the other hand, for the installation of wind turbines, the potential of wind energy in the area is not great enough to be profitable in all the proposed scenarios. For this to happen, the purchase price of electricity must be higher than the production price, 0,126 € / kWh and currently, some of the neighbours are below. However, in other places with higher wind speeds, its installation is highly recommended as it eliminates the dependence on photovoltaic energy during production hours.

For less mature technologies, the analysis of the installation of a lithium-ion battery system is not recommended for communities that have a grid connection, due to its high cost, its short lifetime and that the government only subsidizes the first 12 kWh.

In the future and with the evolution of some technologies, the diversity of energy communities will increase even more. That is why public administrations should have an important role to motivate citizens who are already aware of the environment, but who still do not dare to invest in this type of project.

Defining community activity, technology and how the capital investment will be carried out are some aspects that mark the first steps of an energy community. With a greater citizen-institution relationship, this should be facilitated if energy self-production is to be promoted, one of the basic pillars to fulfil the objectives of the plan against climate change.

It is for all this mentioned that the main contribution of this thesis has been to make visible that the implementation of an sustainable energy community in southern Europe, where historically citizens have been more reluctant to get involved, is viable despite the fact that the scenarios can be uncertain and changeable.

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